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Indian Society of Heating,
Refrigerating and Air-conditioning
Engineers

ISHRAE Databook 2017

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FORWARD

The HVAC industry is growing at a considerable rate due to technological developments and to meet the consumer expectations. The growing trend of smart buildings and homes, development of energy efficient systems, regulated by MEPS, and higher market penetration supported by green technologies are some of the factors contributing towards the growth of the HVAC market in the coming years. India is no exception and the growth is expected to be higher than the rest of the world, as 70 % of the buildings are yet to be built backed by the robust GDP growth. The Indian HVAC market is around 4 Bn $ which is 3 % of the world market. In last few years the technology gap between the developed countries and India has reduced and will be at par with the developed world in the coming years.

The HVAC industry which was limited to the metros has now penetrated to the tier two and three cities and the small towns.

ISHRAE, as a part of its objective to disseminate knowledge, has taken initiatives to publish Guide books, standards, and Data books to address various HVAC requirements specifically in the Indian context. This HVAC DATA book is one of the many initiatives undertaken. This is the third edition and has incorporated the up-dated Indian weather data, emerging refrigerants and other developments.

This data book will be of immense help to the upcoming designers, contractors and engineers in the HVAC field.

The data book is outcome of the dedication and passion of the ISHRAE ITC sub-committee chaired by R S Kulkarni. The other members who contributed are R P Paranjpe, Shantanoo Laghate and G M Lele

Jitendra Bhambure

Chair ISHRAE Technical Committee

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PREFACE

ISHRAE Bangalore Chapter brought out the first HVAC Handbook in 1996, for use, as a reference for HVAC professionals. This brought together, all the data necessary to conduct Heat Load Calculations.

In the year 2014, Bangalore ISHRAE Chapter, undertook to make this Handbook more comprehensive, with a lot of additional data, in the I-P System. In this revision, information has been added to make this Handbook relevant, and in line with the latest trends, especially the efficiency standards for HVAC Equipment, VRF / VRV systems and green building norms .

As ISHRAE is now publishing a number of other Handbooks, some of the repetetions, with the Refrigeration and Ventilation Handbook have been deleted, to make the Databook more suitable for HVAC alone.

In this Databook, the weather Data is udated as per latest ISHRAE Indian weather Data Handbook.

The I-P System is retained in this version also.

An addition of the CLTD Method of Heat Load Calculation has been made, to make available more precise Heat Load Calculations, linked to Indian weather data.

We hope to make Heat load Calculations less cumbersome and more precise, so that all ISHRAE members can use it.

Based on the feedback received earlier, links to Psychrometric Calculator are incorporated.

This effort could not have been possible without the guidance and contributions from Mr. R. P. Paranjpey, Mr. Shantanoo Laghate and Mr. Govind Lele.

I must thank them profusely.

Chairman HVAC Databook Committee.

ISHRAE TECHNICAL COMMITTEE

ISHRAE Technical Committee (ITC) is a standing committee of the society with members drawn from various sectors of the HVAC&R industry in the country. The ITC acts as a catalyst to drive technical development which is needed to sustain ISHRAE's image as a technical society. The primary responsibilities of the committee are:

- To act as the driver to implement technical projects by ISHRAE.
- To identify and prioritize potential technical development work to be undertaken by ISHRAE.
- To form guidelines for submission, review and approval of technical projects to be undertaken by the society - at HQ or Chapter levels.
- To approve technical projects to be undertaken.
- To allocate budgets for technical projects.
- To nominate technical sub-committees for implementation of specific projects approved by ISHRAE.
- To set timelines for approved projects.
- To review the progress of implementation of ISHRAE projects.
- To prepare guidelines (including copyright issues) for:
    - speakers and formats for presentation of papers and workshops at national level programs.
    - preparing soft copy formats of technical work.
    - acceptance and uploading of e-learning modules from external and internal sources on ISHRAE website.
- To liaise with external agencies e.g. BEE and partner Societies/Associations viz. RAMA, REHVA, CAR and ASHRAE to promote the objectives of respective MOUs with respect to technical work.
- To send timely reports to the Board on status of technical development work.
- In carrying out its mandate, the ITC works closely with the ISHRAE Institute of Excellence (IIE) and the ISHRAE Publications Committee and seeks support from external institutions as and when deemed necessary.

The ITC has the following members at present

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It is also expressed by the committe that while specifying Insulating Materials, due considerations should be given to the “Smoke Generation”. References to ISO-5659-2 (1994), NFPA 270, ASTMD5424 and BS-6853:1999 should be made.

HVAC Engineers’ Databook Committee.

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Section-2 **Air Distribution, Ducts, Design and Materials**

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Section-4 **Refrigerant Piping**

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SECTION - 1

DESIGN DATA, PSYCHROMETRICS, IAQ AND COMFORT

INTRODUCTION

ISO 16813:2006 is one of the ISO Building Environment Standards. It establishes the general principles of Building Environment Design. It takes into account the need to provide a healthy indoor environment for the occupant, as well as the need to protect the environment for future generations and promote collaboration among the various parties involved in Building Environmental Design for sustainability.

The Building Environmental Design Standard aims to:

- provide the constraints concerning sustainability issues from the initial stage of the design process, with building and plant life cycle to be considered together, with Owning and Operating costs from the beginning of the design process;

- assess the proposed design with rational criteria for indoor Air Quality, Thermal Comfort, Acoustical Comfort, Visual Comfort, Energy Efficiency and HVAC System Controls at every stage of the design process;

- iterate decisions and evaluations of the design throughout the design process.

ASHRAE is an international technical society for all individuals and organizations interested in HVAC. The society, allows exchange of HVAC knowledge and experiences for the benefit of the field's practitioners and the public. The most recognized standards for HVAC design are based on ASHRAE data.

The Indian Society of Heating, Refrigerating and Air-conditioning Engineers (ISHRAE) was established to promote the HVAC industry in India. ISHRAE is an associate of ASHRAE. ISHRAE was founded at Delhi in 1981 and a Chapter was started in Bangalore in 1989. Between 1989 & 1993, ISHRAE Chapters were formed in all major cities in India and also in the Middle East.

Within the construction sector, it is the job of the Building Services Engineer to design and oversee the installation and maintenance of the essential services such as Gas, Electricity, Water, Heating, Cooling and Lighting, as well as many others. These all help to make buildings comfortable and healthy places to live and work in.

The starting point in carrying out an estimate both for Cooling and Heating depends on the exterior climate and interior specified conditions. However, before taking up the Heat Load Calculation, it is necessary to find fresh air requirements for each area in detail, as pressurization is an important consideration.

Section 1 of the Databook covers the Outdoor Design Data, recommended Indoor Design Data and related topics which can be used by a designer as reference, while estimating the Heat Load Calculation for Buildings.

An Excel Calculator based on the CLTD method is also included in this Databook, to enable all ISHRAE members to use the programe for manual Heat Load Calculations.

Heat Load Estimation

Estimating the Heat Load requirement for the space to be conditioned, is the starting point in any ACR project. In order to make a simple Heat Load Estimate for Cooling & Dehumidifying (refer 1.95), relevant parameters pertaining to the location & application are required. Chapter 1 has several such data sheets which may be used to cull out such information.

The relevant Data sheets for CLTD Heat Load Calculator, are seperately added as an Annexure.

Outside/Ambient/Climatic Conditions

The Climatic Conditions or Outside Weather Conditions, vary from place to place (based on the location i.e. Latitude & Altitude), Season (viz. summer, monsoon, winter), Month to Month and, also based on the Time of the day. Tables I-T-1 to I-T-4 detail the data as published by the latest ISHRAE Technical Committee on weather Data.

Inside Design Conditions

Generally, the Inside Temperature & Humidity conditions are based on the Indoor Comfort zone falling in the envelope recommended in the ASHRAE standard 55 (refer Fig 1-F-4). However, for certain Industrial / Commercial / Food processing applications, the Product / Production needs will require Indoor Conditions favorable to the Product for higher productivity or longevity. Recommended Inside Design Conditions for Industrial & other Commercial Applications are given in Tables I-T-5,6,I-T-70,71,& I-T-72.

Other Heat Transmission Factors

Once the Ambient and Inside Design Conditions are selected, the Thermal Resistance of the Material used in the Building Envelope, the activity inside the Conditioned Area; and quantity of Outside Air coming in /or being taken in, have a major role in determining the Heat Load. The details of Solar Heat Gain through Glass and Building Materials is enumerated in the Tables I-T-8,to I-T-13 & I-T-15 to I-T- 20.

The activity inside the conditioned area will define the heat input from the occupants / people inside, equipment or appliances, inside the area being conditioned. The Tables I-T-24 to I-T-32 have data on Heat Loads due to the activity inside the conditioned areas.

Outside air coming in through doors / openings, as infiltration, and outside air being introduced into the conditioned area, mechanically, to meet the ventilation requirements /exhaust requirements as per the Standards / Practices also contribute to Head Load. Tables I-T-53, 54, 57, 60, 64, 67, 70, 84 give the data related to ventilation requirements which can be used for estimation.

Bypass factors & ADP

The performance of the Cooling and Dehumidification Coils will be based on the Heat Transfer, Fluid Flow Characteristics and the Material & instruction of the coils. Tables I T-25 & 26 give details of bypass Factors at Coils and I-T-39 to I-T-41 give the ADP values at various conditions which may be used to determine the Dehumidified and Total Air quantity, in the table I-T-100.

Psychrometric Charts and Formulae

Copy of the Psychrometric Charts related to Normal temperature and low temperature conditions, as well as psychrometric formulae are give from pages 1.93 to 1.97, for ready reference.

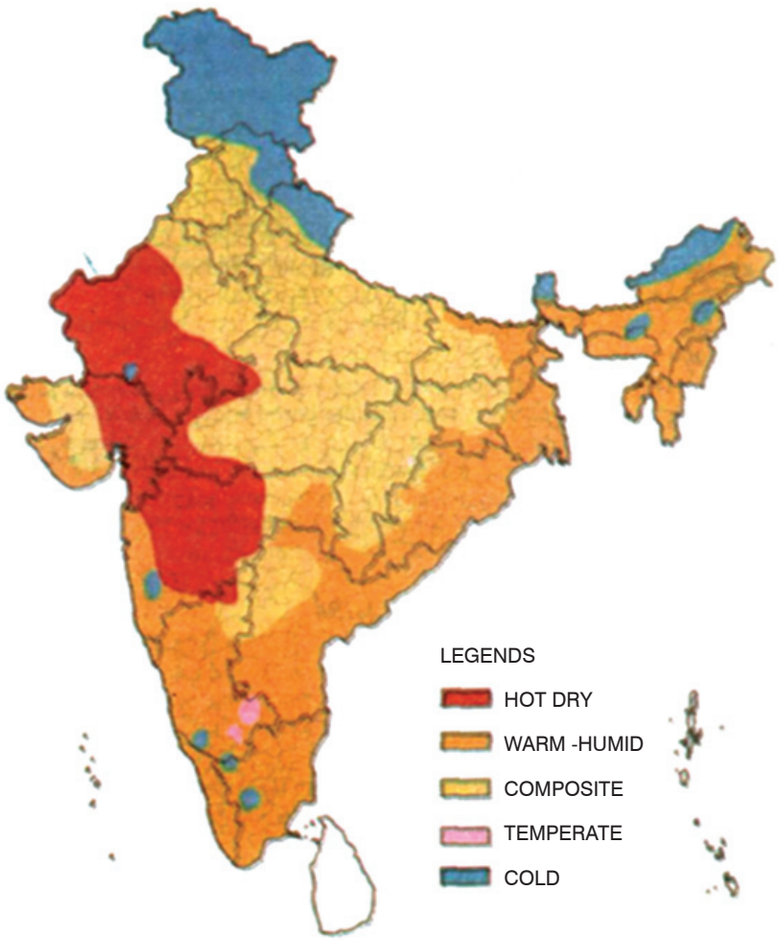


Figure 1.1 : Climate Zone Map of India

Source : ECBC-2007

Table 1.1 : Classification of Climate

Sl. No.	Climate Zone	Mean Monthly Max. Temperature (°F)	Mean Monthly Relative Humidity Percentage
1	2	3	4
1	Hot Dry	Above 86	Below 55
2	Warm Humid	Above 86	Above 55
3	Temperate	Above 77	Above 75
4	Cold	Between 77-86	Below 75
5	Composite	Below 77	All Values

Each Climatic Zone does not have the same climate for the whole year. It has a particular season for more than six months, and may experience other seasons for the remaining period. A Climatic Zone that does not have any season for more than six months may be called as Composite Zone.

Source: NBC-2005

Table 1.2 : Design Ambient Dry Bulb Temperature & Coincident Wet Bulb Temperature ^{0}F

City or STN Name	Longitude	Latitude	Elevation In M	Cooling DB/MCWB of						Cooling WB/ MCDB of						Heating DB / MCWB of			
				0.40%		1.00%		2.00%		0.40%		1%		2%		99.60%		99%	
				DB	MCWB	DB	MCWB	DB	MCWB	WB	MCDB	WB	MCDB	WB	MCDB	DB	MCWB	DB	MCWB
Ahmedabad	72° 37'	23° 4'	55	107.6	69.5	106.2	73.2	104.4	74.0	83.8	93.0	82.8	92.3	81.9	88.3	52.5	48.5	54.5	49.6
Akola	77° 1'	20° 42'	282	109.2	73.3	107.6	72.1	105.8	73.0	81.1	94.8	79.7	99.8	78.3	95.9	55.2	48.7	57.4	51.9
Allahabad	81° 43'	25° 27'	98	109.8	75.4	108.0	76.3	105.8	73.3	86.9	92.8	85.3	91.6	84.2	91.9	46.9	41.6	49.5	47.7
Amritsar	74° 52'	31° 37'	234	107.2	75.1	104.9	82.3	102.6	71.5	86.5	93.2	85.3	91.9	84.2	92.5	39.7	37.5	41.7	39.3
Aurangabad	75° 24'	19° 51'	579	104.7	78.7	102.2	72.4	100.4	73.6	79.9	89.5	78.8	92.9	78.1	88.4	50.4	47.9	52.5	48.4
Barmer	71° 22'	25° 45'	194	109.4	75.0	107.4	73.2	105.4	76.0	84.0	96.8	82.4	95.1	81.0	90.6	49.1	46.0	50.9	43.3
Belgaum	74° 37'	15° 51'	747	98.6	66.1	97.3	66.1	95.4	69.4	75.9	83.2	74.8	81.4	73.9	80.2	54.3	51.8	57.2	54.6
Bangalore	77° 34'	12° 58'	921	94.5	70.1	93.0	68.8	91.2	69.3	75.2	84.7	74.1	84.8	73.2	81.1	59.0	58.0	60.3	58.8
Bhagalpur	86° 56'	25° 13'	49	104.0	84.5	101.5	79.8	99.3	80.4	87.1	96.1	85.6	97.3	84.7	94.4	53.1	50.8	54.5	52.5
Bhopal-Bairagarh	77° 20'	23° 16'	523	107.4	79.8	105.6	75.3	102.9	72.0	81.0	105.4	79.3	90.2	78.3	90.2	49.6	43.1	51.4	47.3
Bhubaneshwar	85° 49'	20° 15'	46	101.5	83.9	99.5	83.2	97.9	83.0	85.5	95.9	84.7	95.7	84.0	93.3	56.7	54.4	58.8	56.3
Bhuj	69° 40'	23° 15'	80	105.3	70.9	103.1	73.0	100.9	78.2	84.2	97.0	83.3	96.5	82.4	93.8	49.8	44.7	51.6	49.1
Bikaner	73° 18'	28° 0'	224	112.3	72.0	109.6	70.9	107.2	74.2	83.5	93.5	82.8	93.0	82.0	91.4	39.6	38.2	42.8	39.1
Chennai-Minambakkam	80° 10'	13° 0'	16	103.6	80.5	100.2	76.5	97.9	78.2	84.2	91.6	83.5	91.6	82.4	91.1	68.7	67.4	69.8	68.1
Chitradurga	76° 25'	14° 13'	733	97.3	68.8	96.1	68.9	94.6	70.1	76.3	93.0	75.4	80.1	74.7	82.8	61.2	56.4	62.6	57.9
Dehradun	78° 1'	30° 19'	682	97.5	66.1	95.9	68.3	93.9	73.6	80.6	86.8	79.9	84.6	79.2	86.6	42.8	41.4	44.2	42.6
Dibrugarh	95° 1'	27° 28'	111	93.7	81.4	92.1	81.2	90.3	80.4	82.9	91.9	82.0	90.6	81.3	88.2	46.4	45.6	48.7	47.9
Gorakhpur	83° 22'	26° 45'	77	103.5	76.3	101.7	79.4	99.3	78.1	85.5	91.5	84.6	91.1	84.0	90.0	47.3	45.1	50.4	47.8
Guwahati	91° 34'	26° 6'	54	94.3	78.9	92.1	80.0	90.5	81.4	83.5	88.4	82.2	89.4	81.7	88.3	49.1	48.2	52.2	51.6
Gwalior	78° 15'	26° 13'	207	110.5	74.0	107.8	72.8	105.6	75.7	82.0	96.5	81.3	92.9	80.4	91.1	40.8	38.2	42.6	40.1
Hissar	75° 43'	29° 10'	221	112.3	78.2	110.5	74.7	108.7	73.9	86.2	93.3	85.3	93.7	84.4	92.7	44.1	44.0	46.2	45.1
Hyderabad-AP	78° 28'	17° 27'	545	102.9	71.9	100.6	72.8	99.1	72.5	78.1	92.9	77.2	88.0	76.3	86.8	56.8	52.8	59.2	55.4
Imphal	93° 54'	24° 46'	781	88.2	74.6	86.7	74.9	85.6	73.8	77.0	85.1	76.5	84.6	75.7	83.5	37.8	37.0	39.7	38.9
Indore	75° 48'	22° 43'	567	104.4	70.3	103.1	68.3	101.3	65.5	77.5	88.6	77.0	85.9	76.3	85.9	49.1	45.7	50.7	46.0
Jabalpur	79° 56'	23° 12'	393	105.3	72.0	103.6	72.0	101.5	72.0	80.1	94.0	79.5	92.0	78.8	89.1	47.7	46.7	49.5	46.7
Jagdalpur	82° 1'	19° 4'	553	101.5	70.9	100.0	74.6	97.5	70.9	78.8	91.1	77.9	89.9	77.4	87.1	47.1	45.6	49.8	47.4
Jaipur-Sanganer	75° 48'	26° 49'	390	107.6	71.1	106.2	72.3	104.4	72.6	81.9	89.6	81.0	91.3	80.1	89.4	45.3	40.3	47.5	42.5
Jaisalmer	70° 55'	26° 53'	231	110.3	74.0	108.5	77.1	106.3	76.7	84.7	98.2	83.1	99.6	82.2	98.8	48.2	36.0	50.9	41.4
Jamnagar	70° 1'	22° 28'	20	97.7	76.2	96.4	77.6	95.0	76.3	81.9	89.9	81.1	91.3	80.6	90.4	48.6	45.7	51.1	48.8
Jodhpur	73° 1'	26° 17'	224	108.9	69.0	106.7	72.3	104.7	72.8	82.8	93.3	81.3	92.2	80.2	89.5	50.4	44.9	52.0	46.8
Jorhat	94° 10'	26° 43'	90	93.9	82.8	92.7	81.7	91.0	81.5	83.5	91.9	82.6	90.5	82.0	90.1	48.6	47.5	50.0	49.0
Kodaikanal	77° 47'	10° 23'	2343	71.6	56.8	70.3	60.7	69.4	57.6	64.4	68.9	63.5	67.6	62.6	66.8	44.8	40.5	46.4	42.9
Kolkata Dum Dum	88° 26'	22° 38'	6	99.5	87.4	97.9	81.6	96.4	80.5	87.6	98.2	86.0	94.6	84.7	92.5	53.8	50.9	55.8	53.2
Kota	75° 50'	25° 8'	274	110.5	76.2	108.7	71.9	106.3	73.7	81.3	91.8	80.8	94.9	79.7	93.0	50.0	44.5	51.8	45.5
Kurnool	78° 4'	15° 48'	281	107.1	72.1	105.4	73.5	103.5	73.7	78.6	92.9	77.9	90.8	77.4	91.3	62.4	60.6	64.0	61.0
Lucknow-Amausi	80° 52'	26° 45'	128	106.3	70.8	104.0	73.3	102.0	71.6	85.8	92.2	84.6	90.6	83.7	91.1	44.6	43.2	48.0	45.9
Mangalore	74° 31'	12° 31'	22	94.3	75.4	93.6	73.7	92.7	73.4	80.2	88.2	79.7	89.4	79.2	88.1	68.2	64.4	69.6	66.6
Mumbai-SantaCruz	72° 50'	19° 7'	14	95.2	73.9	93.6	72.7	92.3	73.5	82.2	88.6	81.7	87.1	81.1	87.4	59.7	56.3	62.1	58.1
Nagpur-Sonegaon	79° 3'	21° 6'	310	109.2	76.2	107.6	79.0	105.8	76.0	82.2	100.5	80.4	89.6	79.5	88.9	53.2	49.2	55.8	52.1
Nellore	79° 58'	14° 26'	20	104.5	80.4	102.4	80.5	99.9	79.0	84.0	95.6	83.1	96.8	82.2	91.8	67.8	65.4	68.9	65.1
New Delhi Safdarjung	77° 11	28° 34'	216	107.8	70.8	105.4	72.6	102.7	74.8	84.0	92.2	82.9	89.0	82.2	89.1	43.0	41.7	44.8	43.7
Panjim	73° 49'	15° 28'	60	93.6	71.1	92.5	77.2	91.8	77.5	82.2	90.1	81.7	87.8	81.1	86.9	67.1	64.1	68.2	65.1
Patna	85° 10'	25° 16'	53	105.8	72.3	104.2	73.3	101.7	74.4	83.8	90.1	83.3	89.3	82.8	88.7	46.8	45.8	48.4	46.5
Port Blair	92° 72'	11° 67'	79	90.5	80.1	89.8	78.6	88.5	78.2	80.4	86.9	79.9	86.0	79.5	85.8	71.4	68.4	72.9	69.7
Pune	73° 50'	18° 31'	559	100.8	71.6	99.0	66.5	97.5	66.4	77.4	87.6	76.6	86.0	75.9	85.2	48.2	46.6	50.2	48.6
Raipur	81° 39'	21° 13'	298	109.8	73.3	107.6	72.7	105.6	74.1	80.6	88.2	80.1	87.5	79.5	87.0	51.1	47.6	53.6	48.4
Rajkot	70° 46'	22° 17'	138	106.5	71.4	104.9	66.3	103.1	67.7	81.9	89.1	81.1	88.4	80.4	87.3	53.4	45.0	56.5	46.7
Ramagundam	79° 25	18° 46'	156	110.1	79.5	108.1	80.7	105.6	77.8	82.8	99.5	81.7	94.2	80.8	95.2	55.2	53.4	57.4	54.8
Ranchi	85° 19'	23° 22'	655	102.2	71.0	99.0	70.1	96.8	71.2	78.3	86.6	77.4	86.6	76.8	84.5	48.2	45.6	50.5	48.1
Ratnagiri	73° 19'	16° 58'	67	92.8	71.9	91.8	69.8	90.5	72.8	81.1	86.2	80.6	86.1	79.9	85.5	63.9	57.4	66.7	62.8
Raxaul	84° 31'	26° 34'	1350	97.7	79.5	95.9	78.9	93.9	78.2	83.7	89.1	82.9	91.1	82.4	90.0	45.1	44.8	46.9	46.2
Saharanpur	77° 52'	29° 51'	274	101.7	74.5	99.3	74.5	97.9	74.7	82.8	91.0	82.2	90.5	81.5	90.8	34.5	34.0	36.5	35.7
Shillong	91° 52'	25° 34'	1500	76.6	67.0	74.5	67.4	72.9	65.1	69.1	73.8	68.2	72.6	67.6	71.9	32.5	32.5	33.1	33.1
Sholapur	75° 54'	17° 40'	479	105.4	75.8	103.3	74.2	101.3	73.4	80.4	92.8	79.5	86.2	78.6	89.2	59.7	51.7	61.5	53.7
Srinagar	74° 83'	34° 08'	1587	90.3	69.4	88.7	70.6	86.5	68.7	74.5	85.6	73.2	83.3	72.0	82.2	28.4	27.5	30.0	28.6
Surat	72° 49'	21° 12'	12	100.6	77.3	97.9	74.7	95.4	74.6	82.2	89.5	81.7	88.0	81.3	87.6	59.7	54.3	61.5	55.4
Tezpur	92° 46'	26° 37'	79	93.4	82.7	91.8	80.6	90.5	82.7	84.6	90.8	83.5	90.0	82.6	88.5	51.6	50.8	53.1	52.2
Thiruvananthapuram	76° 56'	8° 28'	64	91.8	81.4	90.9	79.2	90.1	78.2	81.9	88.8	81.1	88.2	80.6	87.6	73.0	71.7	73.8	72.2
Tiruchirapalli	78° 43'	10° 46'	88	101.1	78.5	100.2	79.8	98.6	77.1	81.7	92.0	81.0	88.7	80.6	95.2	68.0	65.8	69.1	67.4
Varanasi	82° 52'	25° 27'	85	107.4	78.3	105.3	69.0	102.6	69.1	86.5	93.7	85.3	94.4	84.2	92.0	43.3	40.8	47.8	45.1
Veraval	70° 22'	20° 53'	8	94.8	70.5	92.5	77.2	91.0	79.1	84.6	89.0	83.8	88.9	83.1	87.7	60.6	50.1	62.6	52.9
Visakhapatnam	83° 13'	17° 43'	3	96.8	81.4	95.7	78.7	94.6	80.2	84.0	91.7	83.3	90.6	82.9	91.0	59.7	57.5	63.1	61.2

Table 1.3 : Monthwise Maximum, Minimum Temperatures and Daily Range

City Or Station Name	Longitude	Latitude	Elevation
Ahmedabad	**72° 37'**	**23° 4'**	**180.4**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	84.56	60.62	23.94
Feb	91.76	68	23.76
Mar	103.82	77.9	25.92
Apr	107.24	80.06	27.18
May	109.76	86.18	23.58
Jun	107.96	84.02	23.94
Jul	98.06	83.48	14.58
Aug	93.02	78.8	14.22
Sep	99.68	71.06	28.62
Oct	100.94	82.76	18.18
Nov	98.6	70.88	27.72
Dec	92.3	59.18	33.12

City Or Station Name	Longitude	Latitude	Elevation
Akola	**77° 1'**	**20° 42'**	**282.0**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	89.96	57.56	32.4
Feb	101.48	65.12	36.36
Mar	105.08	72.14	32.94
Apr	111.2	83.48	27.72
May	110.66	85.82	24.84
Jun	113	84.02	28.98
Jul	96.98	77.72	19.26
Aug	91.4	71.96	19.44
Sep	98.6	77	21.6
Oct	98.06	69.44	28.62
Nov	90.32	66.02	24.3
Dec	90.68	59.9	30.78

City Or Station Name	Longitude	Latitude	Elevation
Allahabad	**81° 43'**	**25° 27'**	**98**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	79.16	55.94	23.22
Feb	92.66	65.66	27
Mar	100.94	68.9	32.04
Apr	111.56	81.5	30.06
May	113	84.38	28.62
Jun	113	86	27
Jul	103.1	88.16	14.94
Aug	92.48	81.32	11.16
Sep	96.08	81.68	14.4
Oct	96.26	78.26	18
Nov	86.72	69.44	17.28
Dec	79.88	55.4	24.48

Table 1.3 : Monthwise Maximum, Minimum Temperatures and Daily Range (Cont.)

City Or Station Name	Longitude	Latitude	Elevation
Amritsar	**74° 52'**	**31° 37'**	**234**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	74.66	40.28	34.38
Feb	77.18	54.5	22.68
Mar	94.82	61.88	32.94
Apr	101.48	65.48	36
May	108.86	68.36	40.5
Jun	111.74	78.62	33.12
Jul	98.6	83.48	15.12
Aug	99.86	81.68	18.18
Sep	99.68	72.86	26.82
Oct	95.36	67.82	27.54
Nov	82.04	59.18	22.86
Dec	75.2	46.58	28.62

City Or Station Name	Longitude	Latitude	Elevation
Aurangabad	**75° 24'**	**19° 51'**	**579**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	90.68	56.84	33.84
Feb	91.76	56.12	35.64
Mar	100.4	81.68	18.72
Apr	103.28	79.7	23.58
May	107.96	83.84	24.12
Jun	106.7	85.1	21.6
Jul	93.02	75.92	17.1
Aug	87.8	69.98	17.82
Sep	88.88	72.5	16.38
Oct	93.74	66.92	26.82
Nov	91.04	61.52	29.52
Dec	85.64	52.7	32.94

City Or Station Name	Longitude	Latitude	Elevation
Barmer	**71° 22'**	**25° 45'**	**194**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	83.84	52.34	31.5
Feb	91.04	58.1	32.94
Mar	98.96	68.18	30.78
Apr	110.3	80.96	29.34
May	113.54	90.5	23.04
Jun	111.74	82.94	28.8
Jul	106.34	82.04	24.3
Aug	100.22	81.14	19.08
Sep	102.56	81.86	20.7
Oct	104.36	84.38	19.98
Nov	94.28	69.62	24.66
Dec	86	64.4	21.6

Table 1.3 : Monthwise Maximum, Minimum Temperatures and Daily Range (Cont.)

City Or Station Name	Longitude	Latitude	Elevation
Belgaum	**74° 37'**	**15° 51'**	**747**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	87.8	57.02	30.78
Feb	95.36	59.36	36
Mar	99.14	69.98	29.16
Apr	101.48	70.16	31.32
May	100.94	73.94	27
Jun	93.2	69.98	23.22
Jul	82.4	70.52	11.88
Aug	83.12	70.7	12.42
Sep	87.08	67.1	19.98
Oct	87.8	67.82	19.98
Nov	87.08	67.28	19.8
Dec	86	55.4	30.6

City Or Station Name	Longitude	Latitude	Elevation
Bangalore	**77° 34'**	**12° 58'**	**921**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	88.34	59.72	28.62
Feb	89.42	68.72	20.7
Mar	94.28	70.34	23.94
Apr	98.78	77	21.78
May	95.72	72.14	23.58
Jun	91.76	72.68	19.08
Jul	88.16	68.18	19.98
Aug	86.9	69.44	17.46
Sep	86.18	69.08	17.1
Oct	84.92	65.66	19.26
Nov	83.48	67.64	15.84
Dec	82.4	63.14	19.26

City Or Station Name	Longitude	Latitude	Elevation
Bhagalpur	**86° 56'**	**25° 13'**	**49**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	86.18	55.76	30.42
Feb	90.68	62.42	28.26
Mar	102.02	75.2	26.82
Apr	105.08	78.08	27
May	110.12	84.92	25.2
Jun	108.68	81.32	27.36
Jul	98.06	81.86	16.2
Aug	98.6	83.3	15.3
Sep	99.68	81.86	17.82
Oct	100.22	82.22	18
Nov	96.98	67.64	29.34
Dec	89.06	59.18	29.88

Table 1.3 : Monthwise Maximum, Minimum Temperatures and Daily Range (Cont.)

City Or Station Name	Longitude	Latitude	Elevation
Bhopal-Bairagarh	**77° 20'**	**23° 16'**	**523**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	82.76	56.84	25.92
Feb	92.48	71.42	21.06
Mar	102.2	68.72	33.48
Apr	106.34	79.52	26.82
May	111.02	84.56	26.46
Jun	108.5	86.72	21.78
Jul	100.76	77.54	23.22
Aug	90.68	77	13.68
Sep	91.4	73.58	17.82
Oct	95.54	68.36	27.18
Nov	87.8	68.72	19.08
Dec	87.08	56.48	30.6

City Or Station Name	Longitude	Latitude	Elevation
Bhubaneshwar	**85° 49'**	**20° 15'**	**46**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	94.46	65.66	28.8
Feb	95.9	70.34	25.56
Mar	99.5	74.12	25.38
Apr	102.2	82.04	20.16
May	104.72	77.18	27.54
Jun	106.7	84.92	21.78
Jul	97.34	82.94	14.4
Aug	91.94	80.42	11.52
Sep	95	80.6	14.4
Oct	92.3	78.08	14.22
Nov	89.06	66.92	22.14
Dec	86	64.4	21.6

City Or Station Name	Longitude	Latitude	Elevation
Bhuj	**69° 40'**	**23° 15'**	**80**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	86.36	55.76	30.6
Feb	96.98	65.12	31.86
Mar	105.98	64.58	41.4
Apr	105.98	75.56	30.42
May	107.6	77.36	30.24
Jun	104	80.96	23.04
Jul	102.02	82.22	19.8
Aug	95.9	79.7	16.2
Sep	102.02	75.02	27
Oct	102.02	80.42	21.6
Nov	98.96	74.48	24.48
Dec	89.06	54.14	34.92

Table 1.3 : Monthwise Maximum, Minimum Temperatures and Daily Range (Cont.)

City Or Station Name	Longitude	Latitude	Elevation
Bikaner	**73° 18'**	**28° 0'**	**224**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	82.76	42.62	40.14
Feb	90.68	58.28	32.4
Mar	98.6	63.68	34.92
Apr	110.48	72.32	38.16
May	115.88	81.5	34.38
Jun	112.28	84.92	27.36
Jul	106.88	88.7	18.18
Aug	104.18	80.78	23.4
Sep	103.82	80.24	23.58
Oct	99.86	68.72	31.14
Nov	103.28	55.04	48.24
Dec	83.3	47.66	35.64

City Or Station Name	Longitude	Latitude	Elevation
Chennai-Minambakkam	**80° 10'**	**13° 0'**	**16**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	86.54	70.16	16.38
Feb	95.18	75.38	19.8
Mar	97.7	77.54	20.16
Apr	100.58	83.3	17.28
May	110.12	87.62	22.5
Jun	105.44	85.64	19.8
Jul	99.86	79.7	20.16
Aug	97.88	81.32	16.56
Sep	97.7	78.8	18.9
Oct	94.1	79.16	14.94
Nov	91.22	77.72	13.5
Dec	86.36	74.84	11.52

City Or Station Name	Longitude	Latitude	Elevation
Chitradurga	**76° 25'**	**14° 13'**	**733**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	89.96	67.82	22.14
Feb	93.56	69.08	24.48
Mar	98.06	74.66	23.4
Apr	100.4	75.74	24.66
May	98.42	78.26	20.16
Jun	91.4	68	23.4
Jul	89.96	71.06	18.9
Aug	83.66	70.52	13.14
Sep	89.42	68.9	20.52
Oct	88.88	64.76	24.12
Nov	84.92	69.62	15.3
Dec	86.18	64.76	21.42

Table 1.3 : Monthwise Maximum, Minimum Temperatures and Daily Range (Cont.)

City Or Station Name	Longitude	Latitude	Elevation
Dehradun	**78° 1'**	**30° 19'**	**682**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	72.68	42.44	30.24
Feb	79.52	51.98	27.54
Mar	85.82	65.12	20.7
Apr	97.16	70.34	26.82
May	100.58	74.66	25.92
Jun	96.8	75.38	21.42
Jul	92.84	78.8	14.04
Aug	89.06	74.48	14.58
Sep	90.86	68	22.86
Oct	88.16	63.5	24.66
Nov	81.5	56.3	25.2
Dec	75.92	46.4	29.52

City Or Station Name	Longitude	Latitude	Elevation
Dibrugarh	**95° 1'**	**27° 28'**	**111**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	76.64	50.72	25.92
Feb	78.8	54.68	24.12
Mar	85.1	62.24	22.86
Apr	91.04	64.58	26.46
May	93.92	73.76	20.16
Jun	98.06	78.98	19.08
Jul	92.66	73.94	18.72
Aug	99.32	76.46	22.86
Sep	94.64	78.62	16.02
Oct	89.6	70.52	19.08
Nov	86.72	62.24	24.48
Dec	78.62	50	28.62

City Or Station Name	Longitude	Latitude	Elevation
Gorakhpur	**83° 22'**	**26° 45'**	**77**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	76.64	13.8	62.84
Feb	82.94	15.1	67.84
Mar	95.72	22.7	73.02
Apr	104.36	24.5	79.86
May	106.7	27.3	79.4
Jun	100.22	29.5	70.72
Jul	95.9	27	68.9
Aug	94.28	27.8	66.48
Sep	93.56	27	66.56
Oct	93.56	24.5	69.06
Nov	92.12	20.1	72.02
Dec	82.4	15.2	67.2

Table 1.3 : Monthwise Maximum, Minimum Temperatures and Daily Range (Cont.)

City Or Station Name	Longitude	Latitude	Elevation
Guwahati	**91° 34'**	**26° 6'**	**54**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	79.16	56.84	22.32
Feb	81.5	53.24	28.26
Mar	91.04	69.62	21.42
Apr	99.32	70.52	28.8
May	97.16	71.6	25.56
Jun	95.9	80.96	14.94
Jul	92.84	78.8	14.04
Aug	94.64	77.18	17.46
Sep	90.68	78.44	12.24
Oct	89.96	74.66	15.3
Nov	85.28	64.22	21.06
Dec	79.52	58.64	20.88

City Or Station Name	Longitude	Latitude	Elevation
Gwalior	**78° 15'**	**26° 13'**	**207**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	79.88	44.96	34.92
Feb	91.22	52.52	38.7
Mar	101.12	64.04	37.08
Apr	109.76	74.48	35.28
May	112.64	88.16	24.48
Jun	113.9	90.32	23.58
Jul	104	84.02	19.98
Aug	99.5	80.06	19.44
Sep	101.84	80.24	21.6
Oct	102.2	64.76	37.44
Nov	94.46	58.46	36
Dec	81.68	45.32	36.36

City Or Station Name	Longitude	Latitude	Elevation
Hissar	**75° 43'**	**29° 10'**	**221**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	75.38	49.46	25.92
Feb	81.5	57.2	24.3
Mar	98.06	66.56	31.5
Apr	112.82	84.2	28.62
May	112.82	90.14	22.68
Jun	115.52	91.94	23.58
Jul	110.66	89.42	21.24
Aug	100.22	82.4	17.82
Sep	98.96	84.56	14.4
Oct	100.04	80.24	19.8
Nov	94.82	62.6	32.22
Dec	83.3	57.38	25.92

Table 1.3 : Monthwise Maximum, Minimum Temperatures and Daily Range (Cont.)

City Or Station Name	Longitude	Latitude	Elevation
Hyderabad-AP	**78° 28'**	**17° 27'**	**545**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	90.32	63.14	27.18
Feb	96.8	68	28.8
Mar	102.38	70.34	32.04
Apr	106.34	85.28	21.06
May	107.06	84.02	23.04
Jun	105.26	74.84	30.42
Jul	95.36	76.82	18.54
Aug	90.32	75.38	14.94
Sep	90.68	72.5	18.18
Oct	88.52	68.36	20.16
Nov	86.54	66.02	20.52
Dec	86.72	62.96	23.76

City Or Station Name	Longitude	Latitude	Elevation
Imphal	**93° 54'**	**24° 46'**	**781**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	80.924	38.48	42.444
Feb	83.84	48.92	34.92
Mar	89.672	54.32	35.352
Apr	69.908	60.44	9.468
May	73.472	62.42	11.052
Jun	86.756	73.4	13.356
Jul	65.372	73.4	-8.028
Aug	58.892	73.4	-14.508
Sep	64.724	69.62	-4.896
Oct	68.288	64.76	3.528
Nov	68.936	57.02	11.916
Dec	74.768	42.98	31.788

City Or Station Name	Longitude	Latitude	Elevation
Indore	**75° 48'**	**22° 43'**	**567**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	85.46	53.96	31.5
Feb	92.3	57.74	34.56
Mar	100.76	61.88	38.88
Apr	105.8	75.92	29.88
May	107.24	76.1	31.14
Jun	104.72	80.78	23.94
Jul	93.2	72.86	20.34
Aug	87.98	73.04	14.94
Sep	95.36	69.8	25.56
Oct	93.56	66.2	27.36
Nov	89.6	58.28	31.32
Dec	84.74	48.38	36.36

Table 1.3 : Monthwise Maximum, Minimum Temperatures and Daily Range (Cont.)

City Or Station Name	Longitude	Latitude	Elevation
Jabalpur	**79° 56'**	**23° 12'**	**393**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	84.2	48.56	35.64
Feb	96.8	60.26	36.54
Mar	99.68	66.92	32.76
Apr	107.6	74.3	33.3
May	107.24	73.76	33.48
Jun	108.86	84.92	23.94
Jul	92.84	77.72	15.12
Aug	90.86	75.02	15.84
Sep	95.18	75.92	19.26
Oct	90.32	68	22.32
Nov	89.24	63.5	25.74
Dec	82.22	48.74	33.48

City Or Station Name	Longitude	Latitude	Elevation
Jagdalpur	**82° 1'**	**19° 4'**	**553**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	85.82	51.62	34.2
Feb	95.9	51.44	44.46
Mar	100.22	68	32.22
Apr	105.62	69.8	35.82
May	103.46	72.86	30.6
Jun	97.52	72.32	25.2
Jul	91.4	72.86	18.54
Aug	87.08	73.94	13.14
Sep	89.96	72.32	17.64
Oct	88.7	70.88	17.82
Nov	86.9	55.04	31.86
Dec	86.72	55.22	31.5

City Or Station Name	Longitude	Latitude	Elevation
Jaipur-Sanganer	**75° 48'**	**26° 49'**	**390**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	77.54	43.52	34.02
Feb	86.54	58.1	28.44
Mar	99.68	70.7	28.98
Apr	108.68	81.14	27.54
May	110.48	86.18	24.3
Jun	109.4	89.78	19.62
Jul	101.84	81.68	20.16
Aug	93.92	82.94	10.98
Sep	98.96	76.46	22.5
Oct	98.6	75.74	22.86
Nov	92.48	63.32	29.16
Dec	85.28	56.84	28.44

Table 1.3 : Monthwise Maximum, Minimum Temperatures and Daily Range (Cont.)

City Or Station Name	Longitude	Latitude	Elevation
Jaisalmer	**70° 55'**	**26° 53'**	**231**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	83.12	55.4	27.72
Feb	92.84	69.44	23.4
Mar	98.42	73.22	25.2
Apr	112.1	84.02	28.08
May	112.1	80.96	31.14
Jun	111.92	82.76	29.16
Jul	108.32	88.34	19.98
Aug	104	88.34	15.66
Sep	103.28	79.34	23.94
Oct	104.54	82.4	22.14
Nov	92.3	73.4	18.9
Dec	84.02	63.86	20.16

City Or Station Name	Longitude	Latitude	Elevation
Jamnagar	**70° 1'**	**22° 28'**	**20**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	89.96	52.34	37.62
Feb	94.46	55.94	38.52
Mar	102.02	69.8	32.22
Apr	99.68	72.5	27.18
May	100.22	73.94	26.28
Jun	98.24	81.14	17.1
Jul	98.06	80.42	17.64
Aug	90.68	77.36	13.32
Sep	97.16	75.92	21.24
Oct	96.98	70.88	26.1
Nov	91.4	61.16	30.24
Dec	89.06	60.8	28.26

City Or Station Name	Longitude	Latitude	Elevation
Jodhpur	**73° 1'**	**26° 17'**	**224**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	86	52.52	33.48
Feb	93.56	71.42	22.14
Mar	103.1	77.18	25.92
Apr	111.74	80.6	31.14
May	111.38	85.46	25.92
Jun	116.24	90.32	25.92
Jul	103.64	91.22	12.42
Aug	95.72	78.98	16.74
Sep	104.36	75.2	29.16
Oct	108.5	75.02	33.48
Nov	94.82	67.1	27.72
Dec	90.14	61.16	28.98

Table 1.3 : Monthwise Maximum, Minimum Temperatures and Daily Range (Cont.)

City Or Station Name	Longitude	Latitude	Elevation
Jorhat	**94° 10'**	**26° 43'**	**90**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	75.38	51.26	24.12
Feb	80.24	55.22	25.02
Mar	91.76	57.92	33.84
Apr	91.4	70.52	20.88
May	94.46	77.9	16.56
Jun	96.08	79.7	16.38
Jul	99.68	75.56	24.12
Aug	94.82	77.54	17.28
Sep	95	78.8	16.2
Oct	89.78	70.16	19.62
Nov	85.28	62.78	22.5
Dec	78.62	56.12	22.5

City Or Station Name	Longitude	Latitude	Elevation
Kodaikanal	**77° 47'**	**10° 23'**	**2343**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	71.6	46.94	24.66
Feb	71.78	50.54	21.24
Mar	74.66	53.78	20.88
Apr	74.3	54.68	19.62
May	74.3	57.38	16.92
Jun	69.62	51.26	18.36
Jul	67.28	53.24	14.04
Aug	67.64	52.34	15.3
Sep	70.7	51.26	19.44
Oct	68	49.28	18.72
Nov	68.18	52.88	15.3
Dec	71.6	46.76	24.84

City Or Station Name	Longitude	Latitude	Elevation
Kolkata Dum Dum	**88° 26'**	**22° 38'**	**6**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	86	60.26	25.74
Feb	93.38	65.12	28.26
Mar	102.56	76.46	26.1
Apr	103.64	70.52	33.12
May	100.58	81.32	19.26
Jun	96.8	83.84	12.96
Jul	97.16	82.58	14.58
Aug	96.08	81.14	14.94
Sep	94.1	80.6	13.5
Oct	92.84	78.26	14.58
Nov	88.52	67.46	21.06
Dec	82.4	63.5	18.9

Table 1.3 : Monthwise Maximum, Minimum Temperatures and Daily Range (Cont.)

City Or Station Name	Longitude	Latitude	Elevation
Kota	**75° 50'**	**25° 8'**	**274**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	83.48	58.28	25.2
Feb	90.14	63.32	26.82
Mar	101.66	71.06	30.6
Apr	107.96	82.22	25.74
May	114.08	92.48	21.6
Jun	112.46	91.58	20.88
Jul	98.78	83.12	15.66
Aug	98.96	79.52	19.44
Sep	97.16	78.08	19.08
Oct	96.08	75.2	20.88
Nov	87.8	65.66	22.14
Dec	80.96	55.04	25.92

City Or Station Name	Longitude	Latitude	Elevation
Kurnool	**78° 4'**	**15° 48'**	**281**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	93.74	66.2	27.54
Feb	96.08	68.18	27.9
Mar	103.46	79.34	24.12
Apr	108.5	85.1	23.4
May	109.4	87.8	21.6
Jun	105.8	86	19.8
Jul	98.06	79.7	18.36
Aug	96.08	77	19.08
Sep	94.1	77	17.1
Oct	94.28	78.62	15.66
Nov	92.66	72.68	19.98
Dec	90.5	69.98	20.52

City Or Station Name	Longitude	Latitude	Elevation
Lucknow-Amausi	**80° 52'**	**26° 45'**	**128**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	80.6	54.86	25.74
Feb	89.6	59.18	30.42
Mar	98.24	70.88	27.36
Apr	107.6	76.64	30.96
May	110.12	86.18	23.94
Jun	105.44	80.96	24.48
Jul	100.58	81.14	19.44
Aug	92.66	82.76	9.9
Sep	95.72	76.46	19.26
Oct	92.66	72.68	19.98
Nov	88.88	66.38	22.5
Dec	79.16	55.22	23.94

Table 1.3 : Monthwise Maximum, Minimum Temperatures and Daily Range (Cont.)

City Or Station Name	Longitude	Latitude	Elevation
Mangalore	**74° 31'**	**12° 31'**	**22**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	95.54	69.62	25.92
Feb	94.82	72.14	22.68
Mar	94.82	76.46	18.36
Apr	95.36	77.72	17.64
May	97.52	76.1	21.42
Jun	93.74	76.82	16.92
Jul	87.98	74.66	13.32
Aug	87.62	75.02	12.6
Sep	87.62	74.12	13.5
Oct	93.56	73.76	19.8
Nov	93.2	73.4	19.8
Dec	94.1	71.96	22.14

City Or Station Name	Longitude	Latitude	Elevation
Bombay SantaCruz	**72° 50'**	**19° 7'**	**14**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	94.1	69.08	25.02
Feb	99.68	75.2	24.48
Mar	96.98	73.94	23.04
Apr	94.1	80.6	13.5
May	95.36	81.86	13.5
Jun	93.02	79.16	13.86
Jul	91.22	83.3	7.92
Aug	88.7	77.72	10.98
Sep	90.68	75.56	15.12
Oct	97.52	77.36	20.16
Nov	95.72	69.62	26.1
Dec	95.18	66.38	28.8

City Or Station Name	Longitude	Latitude	Elevation
Nagpur-Sonegaon	**79° 3'**	**21° 6'**	**310**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	89.42	60.26	29.16
Feb	91.94	71.42	20.52
Mar	100.4	71.78	28.62
Apr	105.62	82.94	22.68
May	111.92	84.92	27
Jun	113	92.12	20.88
Jul	98.42	81.68	16.74
Aug	92.3	78.26	14.04
Sep	93.02	74.66	18.36
Oct	91.04	75.56	15.48
Nov	87.8	69.44	18.36
Dec	86.18	53.78	32.4

Table 1.3 : Monthwise Maximum, Minimum Temperatures and Daily Range (Cont.)

City Or Station Name	Longitude	Latitude	Elevation
Nellore	**79° 58'**	**14° 26'**	**20**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	92.48	65.48	27
Feb	96.8	71.24	25.56
Mar	102.2	80.6	21.6
Apr	104.36	83.66	20.7
May	108.68	85.1	23.58
Jun	104.72	68	36.72
Jul	99.68	82.94	16.74
Aug	97.88	84.74	13.14
Sep	98.42	78.44	19.98
Oct	94.82	79.16	15.66
Nov	87.26	77.18	10.08
Dec	83.3	76.46	6.84

City Or Station Name	Longitude	Latitude	Elevation
New Delhi - Safdarjung	**77° 11**	**28° 34'**	**216**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	79.34	49.64	29.7
Feb	81.14	56.48	24.66
Mar	97.52	72.68	24.84
Apr	108.68	73.22	35.46
May	111.2	83.3	27.9
Jun	108.68	87.8	20.88
Jul	102.2	83.84	18.36
Aug	98.96	85.46	13.5
Sep	98.6	77.72	20.88
Oct	97.7	70.7	27
Nov	94.64	66.2	28.44
Dec	85.28	50	35.28

City Or Station Name	Longitude	Latitude	Elevation
Panjim	**73° 49'**	**15° 28'**	**60**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	95.36	68.54	26.82
Feb	95.54	73.76	21.78
Mar	95.18	70.88	24.3
Apr	93.2	75.74	17.46
May	93.38	79.16	14.22
Jun	91.76	74.84	16.92
Jul	87.26	76.28	10.98
Aug	85.46	77.18	8.28
Sep	89.06	76.46	12.6
Oct	92.84	78.44	14.4
Nov	95.72	75.38	20.34
Dec	95.54	71.6	23.94

Table 1.3 : Monthwise Maximum, Minimum Temperatures and Daily Range (Cont.)

City Or Station Name	Longitude	Latitude	Elevation
Patna	**85° 10'**	**25° 16'**	**53**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	78.44	54.32	24.12
Feb	86.36	54.14	32.22
Mar	103.82	67.28	36.54
Apr	106.88	74.3	32.58
May	109.4	79.52	29.88
Jun	108.32	81.5	26.82
Jul	100.76	82.94	17.82
Aug	97.16	76.46	20.7
Sep	93.56	81.32	12.24
Oct	92.12	76.64	15.48
Nov	84.92	64.04	20.88
Dec	82.04	50.18	31.86

City Or Station Name	Longitude	Latitude	Elevation
Port Blair	**92° 72'**	**11° 67'**	**79**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	85.82	75.02	10.8
Feb	87.44	73.94	13.5
Mar	90.68	74.3	16.38
Apr	92.66	79.88	12.78
May	91.76	83.48	8.28
Jun	89.06	77	12.06
Jul	86.54	77.18	9.36
Aug	87.08	79.16	7.92
Sep	86.36	77	9.36
Oct	86.18	75.92	10.26
Nov	86.72	79.52	7.2
Dec	87.62	77.72	9.9

City Or Station Name	Longitude	Latitude	Elevation
Pune	**73° 50'**	**18° 31'**	**559**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	88.7	55.22	33.48
Feb	92.48	53.24	39.24
Mar	101.12	58.28	42.84
Apr	102.92	66.02	36.9
May	105.8	68.9	36.9
Jun	102.74	72.68	30.06
Jul	88.7	73.04	15.66
Aug	85.28	70.52	14.76
Sep	87.26	70.52	16.74
Oct	91.76	68	23.76
Nov	88.16	56.12	32.04
Dec	85.64	55.04	30.6

Table 1.3 : Monthwise Maximum, Minimum Temperatures and Daily Range (Cont.)

City Or Station Name	Longitude	Latitude	Elevation
Raipur	**81° 39'**	**21° 13'**	**298**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	87.8	51.08	36.72
Feb	91.22	62.6	28.62
Mar	105.26	67.64	37.62
Apr	107.24	79.52	27.72
May	111.74	80.96	30.78
Jun	113.18	88.88	24.3
Jul	91.76	76.64	15.12
Aug	92.3	75.74	16.56
Sep	95.54	78.08	17.46
Oct	93.56	68.9	24.66
Nov	88.16	65.84	22.32
Dec	84.92	62.6	22.32

City Or Station Name	Longitude	Latitude	Elevation
Rajkot	**70° 46'**	**22° 17'**	**138**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	93.56	62.6	30.96
Feb	96.62	70.34	26.28
Mar	108.5	77.18	31.32
Apr	107.6	77.36	30.24
May	107.78	82.04	25.74
Jun	107.06	81.5	25.56
Jul	97.88	79.16	18.72
Aug	95.36	73.22	22.14
Sep	99.5	74.84	24.66
Oct	101.66	73.94	27.72
Nov	99.32	73.76	25.56
Dec	93.74	62.96	30.78

City Or Station Name	Longitude	Latitude	Elevation
Ramagundam	**79° 25**	**18° 46'**	**156**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	93.92	60.62	33.3
Feb	98.6	61.34	37.26
Mar	103.46	77	26.46
Apr	107.96	77	30.96
May	113.9	85.82	28.08
Jun	112.46	90.32	22.14
Jul	95.36	75.2	20.16
Aug	94.82	77.72	17.1
Sep	96.8	76.46	20.34
Oct	95	64.4	30.6
Nov	91.04	64.94	26.1
Dec	87.44	56.12	31.32

Table 1.3 : Monthwise Maximum, Minimum Temperatures and Daily Range (Cont.)

City Or Station Name	Longitude	Latitude	Elevation
Ranchi	**85° 19'**	**23° 22'**	**655**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	78.08	55.76	22.32
Feb	85.1	59.72	25.38
Mar	95.36	71.24	24.12
Apr	103.64	70.88	32.76
May	106.88	80.96	25.92
Jun	102.56	78.08	24.48
Jul	95	76.28	18.72
Aug	86.18	73.4	12.78
Sep	87.26	69.26	18
Oct	87.8	70.52	17.28
Nov	85.28	62.6	22.68
Dec	78.44	47.84	30.6

City Or Station Name	Longitude	Latitude	Elevation
Ratnagiri	**73° 19'**	**16° 58'**	**67**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	93.92	72.5	21.42
Feb	98.78	67.46	31.32
Mar	93.02	71.96	21.06
Apr	96.44	79.7	16.74
May	90.5	81.5	9
Jun	90.68	77	13.68
Jul	86.9	79.52	7.38
Aug	84.74	77.9	6.84
Sep	88.52	76.28	12.24
Oct	92.48	72.5	19.98
Nov	94.82	73.22	21.6
Dec	92.84	69.08	23.76

City Or Station Name	Longitude	Latitude	Elevation
Raxaul	**84° 31'**	**26° 34'**	**1350**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	79.16	52.88	26.28
Feb	85.28	52.52	32.76
Mar	91.04	52.7	38.34
Apr	99.32	62.78	36.54
May	102.56	78.62	23.94
Jun	102.56	78.62	23.94
Jul	94.46	79.88	14.58
Aug	94.28	78.44	15.84
Sep	93.92	76.82	17.1
Oct	89.6	68.72	20.88
Nov	87.44	58.64	28.8
Dec	81.5	52.88	28.62

Table 1.3 : Monthwise Maximum, Minimum Temperatures and Daily Range (Cont.)

City Or Station Name	Longitude	Latitude	Elevation
Saharanpur	**77° 52'**	**29° 51'**	**274**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	76.28	37.04	39.24
Feb	85.1	46.58	38.52
Mar	91.04	52.88	38.16
Apr	104.9	61.52	43.38
May	104.54	63.5	41.04
Jun	106.7	69.98	36.72
Jul	104.18	80.6	23.58
Aug	95	77.36	17.64
Sep	94.28	73.04	21.24
Oct	92.3	53.6	38.7
Nov	85.64	41	44.64
Dec	82.04	35.96	46.08

City Or Station Name	Longitude	Latitude	Elevation
Shillong	**91° 52'**	**25° 34'**	**1500**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	63.5	34.88	28.62
Feb	64.22	32.9	31.32
Mar	73.76	48.56	25.2
Apr	73.76	50	23.76
May	77.36	53.78	23.58
Jun	77.72	54.68	23.04
Jul	77.9	60.98	16.92
Aug	80.6	60.44	20.16
Sep	75.56	59.72	15.84
Oct	77.54	51.62	25.92
Nov	69.44	41.18	28.26
Dec	68	32.18	35.82

City Or Station Name	Longitude	Latitude	Elevation
Sholapur	**75° 54'**	**17° 40'**	**479**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	94.82	68.36	26.46
Feb	96.98	73.76	23.22
Mar	104.9	78.44	26.46
Apr	108.5	86	22.5
May	106.7	85.64	21.06
Jun	109.58	86.54	23.04
Jul	94.28	74.3	19.98
Aug	93.92	73.4	20.52
Sep	92.12	74.84	17.28
Oct	93.92	72.32	21.6
Nov	92.48	72.5	19.98
Dec	90.86	64.04	26.82

Table 1.3 : Monthwise Maximum, Minimum Temperatures and Daily Range (Cont.)

City Or Station Name	Longitude	Latitude	Elevation
Srinagar	**74° 83'**	**34° 08'**	**1587**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	51.26	38.84	12.42
Feb	56.66	31.28	25.38
Mar	70.88	46.4	24.48
Apr	81.5	52.52	28.98
May	89.24	56.3	32.94
Jun	95.18	63.5	31.68
Jul	93.38	70.88	22.5
Aug	90.86	68.72	22.14
Sep	90.14	61.7	28.44
Oct	78.98	51.62	27.36
Nov	71.24	39.92	31.32
Dec	57.02	27.14	29.88

City Or Station Name	Longitude	Latitude	Elevation
Surat	**72° 49'**	**21° 12'**	**12**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	92.48	62.6	29.88
Feb	96.26	66.2	30.06
Mar	108.5	77.54	30.96
Apr	99.86	74.66	25.2
May	103.64	78.44	25.2
Jun	95	82.4	12.6
Jul	92.48	80.42	12.06
Aug	89.24	81.32	7.92
Sep	91.4	77	14.4
Oct	96.62	76.1	20.52
Nov	94.64	76.28	18.36
Dec	91.4	65.3	26.1

City Or Station Name	Longitude	Latitude	Elevation
Tezpur	**92° 46'**	**26° 37'**	**79**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	80.6	52.34	28.26
Feb	82.76	57.92	24.84
Mar	88.88	64.76	24.12
Apr	92.12	64.58	27.54
May	93.2	76.1	17.1
Jun	95.36	78.44	16.92
Jul	95	79.16	15.84
Aug	95.18	80.96	14.22
Sep	91.4	76.64	14.76
Oct	91.22	66.92	24.3
Nov	86.54	64.04	22.5
Dec	80.06	56.48	23.58

Table 1.3 : Monthwise Maximum, Minimum Temperatures and Daily Range (Cont.)

City Or Station Name	Longitude	Latitude	Elevation
Thiruvananthapuram	**76° 56'**	**8° 28'**	**64**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	91.4	76.82	14.58
Feb	90.32	76.1	14.22
Mar	94.1	75.2	18.9
Apr	95.36	81.14	14.22
May	93.2	79.52	13.68
Jun	89.6	80.06	9.54
Jul	87.62	78.44	9.18
Aug	87.08	76.1	10.98
Sep	89.78	76.64	13.14
Oct	87.98	76.1	11.88
Nov	89.24	74.84	14.4
Dec	91.22	77	14.22

City Or Station Name	Longitude	Latitude	Elevation
Tiruchirapalli	**78° 43'**	**10° 46'**	**88**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	89.6	68.9	20.7
Feb	96.98	70.7	26.28
Mar	98.96	81.32	17.64
Apr	104.18	82.58	21.6
May	101.48	75.74	25.74
Jun	101.12	79.16	21.96
Jul	99.86	80.06	19.8
Aug	101.3	79.34	21.96
Sep	97.16	74.84	22.32
Oct	95.54	76.64	18.9
Nov	93.38	75.02	18.36
Dec	92.12	73.22	18.9

City Or Station Name	Longitude	Latitude	Elevation
Varanasi	**82° 52'**	**25° 27'**	**85**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	78.26	59.72	18.54
Feb	88.34	61.34	27
Mar	103.1	72.5	30.6
Apr	116.6	69.8	46.8
May	111.92	81.68	30.24
Jun	108.14	82.76	25.38
Jul	99.32	85.1	14.22
Aug	94.64	82.4	12.24
Sep	94.64	78.8	15.84
Oct	89.96	75.92	14.04
Nov	91.4	62.6	28.8
Dec	81.32	57.2	24.12

Table 1.3 : Monthwise Maximum, Minimum Temperatures and Daily Range (Cont.)

City Or Station Name	Longitude	Latitude	Elevation
Veraval	**70° 22'**	**20° 53'**	**8**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	95.9	75.2	20.7
Feb	91.04	69.8	21.24
Mar	98.6	70.52	28.08
Apr	104.36	78.98	25.38
May	93.2	79.88	13.32
Jun	98.24	79.88	18.36
Jul	88.7	82.94	5.76
Aug	90.86	80.06	10.8
Sep	95.54	80.42	15.12
Oct	99.5	75.02	24.48
Nov	98.06	75.92	22.14
Dec	91.22	69.44	21.78

City Or Station Name	Longitude	Latitude	Elevation
Visakhapatnam	**83° 13'**	**17° 43'**	**3**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	92.84	57.2	35.64
Feb	89.06	71.78	17.28
Mar	98.78	72.68	26.1
Apr	98.6	79.52	19.08
May	97.88	77.36	20.52
Jun	99.14	80.96	18.18
Jul	96.08	83.48	12.6
Aug	96.44	80.78	15.66
Sep	96.08	78.26	17.82
Oct	93.02	73.04	19.98
Nov	90.32	75.2	15.12
Dec	85.46	74.12	11.34

Table 1.4 : Typical Inside Design Conditions - Industrial

(Listed conditions are only typical; final design conditions are established by customer requirement)

INDUSTRY	PROCESS	DRY BULB (F)	RH (%)
ABRASIVE	Manufacture	75-80	45-50
	Dough Mixer	75-80	40-50
	Fermenting	75-82	70-75
	Proof Box	92-96	80-85
	Bread Cooler	70-80	80-85
	Cold Room	40-45	
	Make-up Rm	78-82	65-70
	Cake Mixing	95-105	-
	Crackers & Biscuits	60-65	50
	Wrapping	60-65	60-65
	Storage		
	Dried Ingredients	70	55-65
	Fresh Ingredients	30-45	80-85
	Flour	70-75	50-65
	Shortening	45-70	55-60
	Sugar	80	35
	Water	32-35	-
	Wax Paper	70-50	40-50
BREWERY	Storage		
	Hops	30-32	55-60
	Grain	80	60
	Liquid Yeast	32-34	75
	Lager	32-35	75
	Ale	40-45	75
	Fermenting Cellar	-	-
	Lager	40-45	75
	Ale	55	75
	Racking Cellar	32-35	75
CANDY CHOCOLATE	Candy Centres	80-85	40-50
	Hand Dipping Rm.	60-65	50-55
	Enrobing Rm	75-80	55-60
	Enrobing		
	Loading End	80	50
	Enrober	90	13
	Stringing	70	40-50
	Tunnel	40-45	DP-40
	Packing	65	55
	Pan Speciality Rm	70-75	45
	General Storage	65-70	40-50
CANDY HARD	Mfg.	75-80	30-40
	Mixing Cooling	75-80	40-45
	Tunnel	55	DP -55
	Packing	65-75	4045
	Storage	65-75	45-50
	Drying - Jellies, Gums	120-150	15
	Cold Room	-	-
	Marshmallow	75-80	45-50
CHEWING GUM	Mfg.	77	33
	Rolling	68	63
	Stripping	72	53
	Breaking	74	47
	Wrapping	74	58
CERAMICS	Refractory	110-150	50-90
	Molding Room	80	60-70
	Clay Storage	60-80	35-65
	Decal & Decorating	75-80	45-50
CEREAL	Packing	75-80	45-50

INDUSTRY	PROCESS	DRY BULB (F)	RH (%)
COSMETICS	Mfg.	65-70	-
DISTILLING	Storage		
	Grain	60	35-40
	Liquid Yeast	32-34	-
	Mfg.	60-75	45-60
	Aging	65-72	50-60
ELECTRICAL PRODUCTS	Electronic & X-Ray Coils		
	Winding	72	15
	Tube Assembly	68	40
	Electrical Inst.		
	Mfg. & Lab	70	50-55
	Thermostat Assembly & Calibration	76	50-55
	Humidistat Assembly & Calibration	76	50-55
	Close Tolerance Assembly	72	40-45
	Meter Assembly Test	74-76	60-63
	Switch gear	73	50
	Fuse & Cut -Out	73	50
	Assembly	73	50
	Cap Winding	73	50
	Paper Storage	73	50
	Conductor Wrapping	75	65-70
	Lightning Arrestor	68	20-40
	Circuit Breaker	76	30-60
	Assembly & Test		
	Rectifiers	74	30-40
	Process Selenium & Copper Oxide Plates		
FURS	Drying	110	-
	Shock Treatment	18-20	-
	Storage	40-50	55-65
GLASS	Cutting	75	<65%
	Vinyl Lam. Rm.	55	15
LEATHER	Drying		
	Veg. Tanned	70	75
	Chrome Tanned	120	75
	Storage	50-60	40-60
LENSES OPTICAL	Fusing	75	<65%
	Grinding	80	50
MATCHES	Mfg.	72-74	50
	Drying	70-75	40
	Storage	60-62	50
PAINT	Point Spraying	60-90	80
TEA	Packaging	65	65

Table 1.5 : Typical Inside Design Conditions - Industrial

(Listed conditions are only typical; final design conditions are established by customer requirement)

INDUSTRY	PROCESS	DRY BULB (F)	RH (%)
PHARMACEUTICALS	Powder Storage		
	Before Mfg	70-80	30-35
	After Mfg	75-80	15-35
	Milling Room	80	35
	Tablet Compressing	70-80	40
	Tablet Coating	80	35
	Effervescent		
	Tablet & Powder	90	15
	Hypodermic Tablet	75-80	30
	Colloids	70	30-50
	Cough Syrup	80	40
	Glandular Prod.	78-80	5-10
	Ampule Mfg.	80	35
	Gelatin Capsule	78	40-50
	Capsule Storage	75	35-40
	Microanalysis	Comfort	
	Biological Mfg.	80	35
	Liver Extract	70-80	20-30
	Serums	Comfort	
	Animal Rm	Comfort	
PHOTO MATERIAL	Drying		
	Cutting & Packing		
	Storage Film Base, Film paper Coated	70-75	40-65
	Safety Film	60-80	45-50
	Nitrate Film	40-50	40-50
PLASTIC	Mfg. Thermo Setting Compounds	80	25-30
	Cellophane	75-80	45-65
PLYWOOD	Hot Press Resin	90	25-30
	Cold Press	90	15-25
PRECISION MACHINING	Spectrographic Anal.	Comfort	35-40
	Gear Matching & Assembly	75-80	
	Storage		
	Gasket	100	50
	Cement & Glue	65	40
	Machine	Comfort	
	Gaging, Assembly		
	Adjusting Precision		
	Parts		
	Honing	75-80	3545
PRINTING	Multicolour Litho		
	Press room	75-80	46-48
	Stock room	73-80	49-51
	Sheet & Web Print	Comfort	
	Storage, Folding Etc	Comfort	
REFRIGERATION EQUIPMENT	Valve Mfg.	75	40
	Compressor Assembly	70-76	30-45
	Refrigerator Assembly	Comfort	
	Testing	65-82	47
RUBBER DIPPED GOODS	Mfg.	90	-
	Cementing	80	25-30
	Surgical Articles	75-90	25-30
	Storage Before Mfg.	60-75	40-50
	Lab. (ASTM Std.)	73.4	50

Source : Carrier Handbook

INDUSTRY	PROCESS	DRY BULB (F)	RH (%)
TEXTILES	Cotton		
	Opening & Packing	70-75	55-70
	Carding	83-87	50-55
	Drawing & Roving	80	65-60
	Ring Spinning		
	Conventional	80-85	60-70
	Long Draft	80-85	-
	Frame Spinning	80-85	55-60
	Spooling Warping	78-80	60-65
	Weaving	78-80	70-85
	Cloth Room	75	65-70
	Combing	75	55-65
	Linen		
	Carding, Spinning	75-80	62
	Weaving	80	80
	Woolens		
	Pickers	80-85	60
	Carding	80-85	65-70
	Spinning	80-85	50-60
	Dressing	75-80	50-60
	Weaving		
	Light Goods	80-85	55-70
	Heavy	80-85	60-65
	Drawing	75	50-60
	Worsteds		
	Carding, Combing & Gilling	80-85	60-70
	Storage	70-85	75-80
	Drawing	80-85	50-70
	Cap Spinning	80-85	50-65
	Spooling, Winding	75-80	55-60
	Weaving	80	50-60
	Finishing	75-80	60
	Silk		
	Prep. & Dressing	80	60-65
	Weaving & Spinning	80	65-70
	Throwing	80	60
	Rayon		
	Spinning	80-90	50-60
	Throwing	80	55-60
	Weaving	-	-
	Regenerated	80	50-60
	Acetate	80	55-60
	Spun Rayon	80	80
	Picking	75-80	50-60
	Carding, Roving	-	-
	Drawing	80-90	50-60
	Knitting		
	Viscose or Cuprammonium Synthetic Fiber	80-85	65
	Prep. & Weaving		
	Viscose	80	60
	Celanese	80	70
	Nylon	80	50-60
TOBACCO	Cigar and Cigarette		
	Mfg.	70-75	55-65
	Softening	90	85-88
	Stemming & Stripping	75-80	75
	Storage & Prep.	78	70
	Conditioning	75	75
	Packing & Shipping	75	60

Table 1.6 : Corrections in Outdoor Design Temperatures for Time of Day

(For Cooling Load Estimates)

DAILY RANGE OF TEMPERATURES (F)	DRY BULB OR WET BULB	SUN TIME									
		AM			PM						
		8	10	12	2	3	4	6	8	10	12
10	DRY BULB	-9	-7	-5	-1	0	-1	-2	-5	-8	-9
	WET BULB	-2	-2	-1	0	0	0	-1	-1	-2	-2
15	DRY BULB	-12	-9	-5	-1	0	-1	-2	-6	-10	-14
	WET BULB	-3	-2	-1	0	0	0	-1	-1	-3	-4
20	DRY BULB	-14	-10	-5	-1	0	-1	-3	-7	-11	-16
	WET BULB	-4	-3	-1	0	0	0	-1	-2	-3	-4
25	DRY BULB	-16	-10	-5	-1	0	-1	-3	-8	-13	-18
	WET BULB	-4	-3	-1	0	0	0	-1	-2	-3	-5
30	DRY BULB	-18	-12	-6	-1	0	-1	-4	-10	-15	-21
	WET BULB	-5	-3	-1	0	0	0	-1	-3	-4	-6
35	DRY BULB	-21	-14	7	-1	0	-1	-6	-12	-18	-24
	WET BULB	-6	-4	2	0	0	0	-1	-3	-5	-7
40	DRY BULB	-24	-16	8	1	0	-1	-7	-14	-21	-28
	WET BULB	-7	-4	-2	0	0	0	-2	-4	-6	-9
45	DRY BULB	-26	-17	-8	2	0	2	-8	-16	-24	-31
	WET BULB	-7	-5	-2	0	0	1	-2	-4	-8	-10

The daily Range of Dry Bulb Temperature is the difference between the hightest and lowest Dry Bulb Temperature during a 24 hour period on a typical Design Day.

Equation: Outdoor Design Temperature at any time=Outdoor design temperature from Table 1-T-2 + correction from above table.

Table 1.7 : Corrections in Outdoor Design Temperatures for Month of Year

(For Cooling Load Estimates)

YEARLY RANGE OF TEMPERATURE (F)	DRY OR WET BULB	TIME OF YEAR								
		MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPT.	OCT.	NOV.
120	DRY BULB	-39	-22	-11	-4	0	0	-9	-24	-44
	WET BULB	-23	-12	-5	2	0	0	-4	-13	-27
115	DRY BULB	-33	-22	-11	-4	0	0	-8	-20	-36
	WET BULB	-18	-11	-5	2	0	0	-4	-10	-21
110	DRY BULB	-30	-20	-11	-4	0	0	-6	-17	-31
	WET BULB	-15	-10	-5	2	0	0	-3	-8	-16
105	DRY BULB	-30	-20	-11	-4	0	0	-6	-17	-29
	WET BULB	-15	-10	-5	-2	0	0	-3	-8	-14
100	DRY BULB	-29	-19	-10	-3	0	0	-6	-16	-27
	WET BULB	-14	-10	-5	-2	0	0	-3	-8	-14
95	DRY BULB	-29	-19	-10	-3	0	0	-6	-16	-27
	WET BULB	-14	-10	-5	-2	0	0	-3	-8	-14
90	DRY BULB	-29	-19	-10	-3	0	0	-6	-16	-26
	WET BULB	-14	-10	-5	-2	0	0	-3	-8	-14
85	DRY BULB	-29	-19	-9	-3	0	0	-5	-16	-25
	WET BULB	-14	-10	-5	-2	0	0	-3	-8	-14
80	DRY BULB	-24	-16	-8	-3	0	0	-4	-12	-20
	WET BULB	-13	-9	-4	-2	0	0	-2	-6	-11
75	DRY BULB	-14	-9	-4	-1	0	0	-3	-7	-15
	WET BULB	_7	-5	-2	0	0	0	-2	-4	-8
70	DRY BULB	-13	-9	-4	-1	0	0	-2	-7	-14
	WET BULB	-6	-4	-2	0	0	0	-1	-4	-6
65	DRY BULB	-11	-8	-4	-1	0	0	-2	-6	-12
	WET BULB	-6	-4	-2	0	0	0	-1	-3	-6
60	DRY BULB	-9	-7	3	1	0	0	-2	-5	-10
	WET BULB	-4	-3	-2	0	0	0	-1	-3	-5
55	DRY BULB	-6	-5	-3	-1	0	0	-2	-4	-8
	WET BULB	-3	-3	-2	0	0	0	-1	-2	-4
50	DRY BULB	-5	-4	-3	-1	0	0	-2	-4	-7
	WET BULB	-3	-2	-1	0	0	0	-1	-2	-3

* Yearly Range of Temperature is the difference between the Summer and Winter normal Design Dry Bulb Temperatures (Table 1.2).
Equation: Outdoor Design Temperature = Outdoor Design Temperature from Table 1.2 + correction from above table.

Source : Carrier Handbook

Table 1.8 : Overall Factors for Solar Heat Gain through Glass with or Without Shading Devlces

Outdoor Wind Velocity, 5 mph - Angle of Incidence, 30°, Shading Device fully covering Window

TYPE OF GLASS	GLASS FACTOR NO SHADE	INSIDE VENETIAN BLIND 45⁰ HORZ. OR VERTICAL OR ROLLER SHADE			Outside Venetian Blind 45⁰ Hon. Slits		OUTSIDE SHADING 17⁰ HORIZONTAL SLATS SCREEN		OUTSIDE AWNING SIDES AND TOP	
		Light Colour	Medium Colour	Dark Colour	Light Colour	Light On Outside Dark on Inside	Medium Colour	Dark Colour	Light Colour	Med. Or Dark
ORDINARY GLASS	1.00	0.56	0.65	0.75	0.15	0.13	0.22	0.15	0.20	0.25
REGULAR PLATE (1/4 inch)	0.94	0.56	0.65	0.74	0.14	0.12	0.21	0.14	0.19	0.24
HEAT ABSORBING GLASS										
40 to 48% Absorbing	0.80	0.56	0.62	0.72	0.12	0.11	0.18	0.12	0.16	0.20
48 to 56% Absorbing	0.73	0.53	0.59	0.62	0.11	0.10	0.16	0.11	0.15	0.18
56 to 70% Absorbing	0.62	0.51	0.54	0.56	0.10	0.10	0.14	0.10	0.12	0.16
DOUBLE PANE										
Ordinary Glass	0.90	0.54	0.61	0.67	0.14	0.12	0.20	0.14	0.18	0.22
Regular Plate	0.80	0.52	0.59	0.65	012	0.11	0.18	0.12	0.16	0.20
48 To 56% Absorbing Outside Ordinary Glass Inside	0.52	0.36	0.39	0.43	0.10	0.10	0.11	0.10	0.10	0.13
48 To 56% Absorbing Outside Regular Plate Inside	0.50	0.36	0.39	0.43	0.10	0.10	0.11	0.10	0.10	0.12
TRIPLE PANE										
Ordinary Glass	0.83	0.48	0.56	0.64	0.12	0.11	0.18	0.12	0.16	0.20
Regular Plate	0.69	0.47	0.52	0.57	0.10	0.10	0.15	0.10	0.14	0.17
PAINTED GLASS										
Light Colour	0.28									
Medium Colour	0.39									
Dark Colour	0.50									
STAINED GLASS										
Amber Colour	0.70									
Dark Red	0.56									
Dark Blue	0.60									
Dark Green	0.32									
Grey - Green	0.46									
Light Opalescent	0.43									
Dark Opalescent	0.37									

Table 1.9 : Transmission Coefficient U for Windows, Skylights, Doors & Glass Block Walls (Btu / (hr) (sq. ft.) (Deg. F Temp Diff)

GLASS										
AIR SPACE THICKNESS (IN.)	VERTICAL GLASS							HORIZONTAL GLASS		
	SINGLE	DOUBLE			TRIPLE			Single		Double (1/4")	
		1/4	1/2	3/4 - 4	1/4	1/2	3/4 - 4	Summer	Winter	Summer	Winter
Without Storm Windows	1.13	0.61	0.55	0.53	0.41	0.36	0.34	0.86	1.40	0.50	0.70
With Storm Windows	0.54							0.43	0.64		

Source : Carrier Handbook

Table 1.10 : Solar Heat Gain through Ordinary Glass Btu / (Hr.) (Sq. Ft. Sash Area)

10° 10°

10° NORTH LATITUDE		AM						SUN TIME				PM			10° SOUTH LATITUDE	
TIME OF YEAR	EXPOSURE	6	7	8	9	10	11	NOON	1	2	3	4	5	6	EXPOSURE	TIME OF YEAR
	NORTH	19	44	50	45	44	43	41	43	44	45	50	44	2	SOUTH	
	NORTH EAST	55	131	153	140	106	65	28	14	14	13	11	8	2	SOUTH EAST	
JUNE 21	EAST	54	134	155	139	98	41	14	14	14	13	11	8	2	EAST	DEC 22
	SOUTH EAST	18	49	55	43	25	14	14	14	14	13	11	8	2	NORTH EAST	
	SOUTH	2	8	11	13	14	14	14	14	14	13	11	8	2	NORTH	
	SOUTH WEST	2	8	8	13	14	14	14	14	25	43	55	49	18	NORTH WEST	
	WEST	2	8	8	13	14	14	14	41	98	139	155	134	54	WEST	
	NORTH WEST	2	8	8	13	14	18	28	65	106	140	153	131	55	SOUTH WEST	
	HORIZONTAL	4	44	107	166	205	233	243	233	205	166	107	44	4	HORIZONTAL	
	NORTH	5	34	39	35	33	31	30	31	33	35	39	34	5	SOUTH	
	NORTH EAST	42	127	148	133	109	56	22	14	14	13	11	7	1	SOUTH EAST	
JULY 21	EAST	50	135	158	142	98	43	14	14	14	13	11	7	1	EAST	JAN 21
& MAY 21	SOUTH EAST	26	57	66	56	32	14	14	14	14	13	11	7	1	NORTH EAST	&
	SOUTH	1	7	11	13	14	14	14	14	14	13	11	7	1	NORTH	NOV 21
	SOUTH WEST	1	7	11	13	14	14	14	14	32	56	66	57	26	NORTH WEST	
	WEST	1	7	11	13	14	14	14	43	98	142	158	135	50	WEST	
	NORTH WEST	1	7	11	13	14	14	22	56	109	133	148	127	42	SOUTH WEST	
	HORIZONTAL	3	42	107	166	210	236	247	236	210	166	107	42	3	HORIZONTAL	
	NORTH	1	15	16	15	15	14	14	14	15	15	16	15	1	SOUTH	
	NORTH EAST	17	113	103	111	80	34	14	14	14	13	11	7	1	SOUTH EAST	
	EAST	25	138	163	149	104	46	14	14	14	13	11	7	1	EAST	
	SOUTH EAST	18	79	94	85	60	27	14	14	14	13	11	7	1	NORTH EAST	
AUG 24	SOUTH	1	7	11	13	14	14	14	14	14	13	11	7	1	NORTH	FEB 20
&	SOUTH WEST	1	7	11	13	14	14	14	27	60	85	94	79	18	NORTH WEST	&
APR 20	WEST	1	7	11 _,	13	14	14	14	46	80	149	163	138	25	WEST	OCT 23
	NORTH WEST	1	7	11	13	14	14	14	34	15	111	130	113	17	SOUTH WEST	
	HORIZONTAL	2	38	105	167	213	242	250	242	213	167	105	38	2	HORIZONTAL	
	NORTH	1	6	11	13	14	14	14	14	14	13	11	6	1	SOUTH	
	NORTH EAST	1	89	103	80	45	17	14	14	14	13	11	6	1	SOUTH EAST	
SEPT 22 &	EAST	1	103	164	151	106	47	14	14	14	13	11	6	1	EAST	
MAR 22	SOUTH EAST	1	97	127	122	94	56	21	14	14	13	11	6	1	NORTH EAST	MAR 22 &
	SOUTH	1	6	13	19	24	27	28	27	24	19	13	6	1	NORTH	SEPT 22
	SOUTH WEST	1	6	11	13	14	14	21	56	94	122	127	9	1	NORTH WEST	
	WEST	1	6	11	13	14	14	14	47	106	151	164	130	1	WEST	
	NORTH WEST	1	6	11	13	14	14	14	17	45	80	103	89	1	SOUTH WEST	
	HORIZONTAL	1	31	97	160	207	235	247	235	207	160	97	31	1	HORIZONTAL	
	NORTH	0	5	10	13	14	14	14	14	14	13	10	5	00	SOUTH	
	NORTH EAST	0	58	66	44	28	14	14	14	14	13	10	5	0	SOUTH EAST	
	EAST	0	118	155	145	100	40	14	14	14	13	10	5	0	EAST	
	SOUTH EAST	0	103	147	149	123	81	46	18	14	13	10	5	0	NORTH EAST	
OCT 23 &	SOUTH	0	18	40	55	65	71	73	71	65	55	40	18	0	NORTH	APR 20 &
FEB 20	SOUTH WEST	0	5	10	13	14	18	46	81	123	149	147	103	0	NORTH WEST	AUG 24
	WEST	0	5	10	13	14	14	14	40	100	145	155	118	0	WEST	
	NORTH WEST	0	5	10	13	14	14	14	14	28	44	66	58	0	SOUTH WEST	
	HORIZONTAL	0	22	85	139	193	220	230	220	193	139	85	22	0	HORIZONTAL	
	NORTH	0	4	9	12	13	14	14	14	13	12	9	4	0	SOUTH	
	NORTH EAST	0	27	37	17	13	14	14	14	13	12	9	4	0	SOUTH EAST	
	EAST	0	99	143	132	93	39	14	14	13	12	9	4	0	EAST	
	SOUTH EAST	0	99	153	161	146	109	70	31	17	12	9	4	0	NORTH EAST	
	SOUTH	0	35	65	91	96	104	106	104	96	91	65	35	0	NORTH	
NOV 21 &	SOUTH WEST	0	4	9	12	17	31	70	109	146	161	153	99	0	NORTH WEST	MAY 21 &
JAN 21	WEST	0	4	9	12	13	14	14	39	93	132	143	99	0	WEST	JUL 23
	NORTH WEST	0	4	9	12	13	14	14	14	13	17	37	27	0	SOUTH WEST	
	HORIZONTAL	0	17	62	131	175	202	210	202	175	131	62	17	0	HORIZONTAL	
	NORTH	0	4	9	12	13	14	14	14	13	12	9	4	0	SOUTH	
	NORTH EAST	0	15	28	17	13	14	14	14	13	12	9	4	0	SOUTH EAST	
	EAST	0	86	137	130	91	42	14	14	13	12	9	4	0	EAST	
	SOUTH EAST	0	99	154	163	149	121	79	36	23	12	7	4	0	NORTH EAST	
DEC 22	SOUTH	0	50	74	94	109	116	120	116	109	94	74	50	0	NORTH	JUNE 21
	SOUTH WEST	0	4	9	12	23	36	79	121	149	163	154	99	0	NORTH WEST	
	WEST	0	4	9	12	13	14	14	42	91	130	137	86	0	WEST	
	NORTH WEST	0	4	9	12	13	14	14	14	13	17	28	15	0	SOUTH WEST	
	HORIZONTAL	0	14	66	120	167	193	202	193	167	120	66	14	0	HORIZONTAL	

Solar Gain Correction	Steel Sash or No Sash x 1/0.85 or 1.17	Haze -15% (Max)	Altitude +0.7% Per 10000 ft.	Dew Point Decrease From 67 F +7% Per 10 F	Dew Point Increase From 67 F - 7% Per 10 F	South Lat. Dec Or Jan +7%

Table 1.11 : Solar Heat Gain through Ordinary Glass Btu / (Hr.) (Sq. Ft. Sash Area)

20° 20°

10° NORTH LATITUDE		AM						SUN TIME				PM			10° SOUTH LATITUDE	
TIME OF YEAR	EXPOSURE	6	7	8	9	10	11	NOON	1	2	3	4	5	6	EXPOSURE	TIME OF YEAR
	North	28	41	33	25	19	17	15	17	19	25	33	41	28	South	
	North East	81	154	144	122	83	38	15	14	14	14	12	9	3	South East	
	East	81	148	160	143	96	41	14	14	14	14	12	9	3	East	
	South East	28	62	73	66	44	21	14	14	14	14	12	9	3	North East	
JUNE 21	South	3	9	12	14	14	14	14	14	14	14	12	9	3	North	DEC 22
	South West	3	9	12	14	14	14	14	21	44	66	73	62	28	North West	
	West	3	9	12	14	14	14	14	41	96	143	160	148	81	West	
	North West	3	9	12	14	14	14	14	38	83	122	144	154	81	South West	
	Horizontal	11	60	121	176	216	232	250	232	216	176	121	60	11	Horizontal	
	North	20	28	23	17	15	14	14	14	15	17	23	28	20	South	
	North East	71	132	138	111	73	31	14	14	14	13	12	8	3	South East	
	East	75	148	163	145	99	46	14	14	14	13	12	8	3	East	
	South East	31	70	85	79	57	29	14	14	14	13	12	8	3	North East	
JULY 23 & MAY 21	South	3	8	12	13	14	14	14	14	14	13	12	8	3	North	JAN 21 & NOV 21
	South West	3	8	12	13	14	14	14	29	57	79	85	70	31	North West	
	West	3	8	12	13	14	14	14	46	99	145	163	148	75	West	
	North West	3	8	12	13	14	14	14	31	73	111	138	132	71	South West	
	Horizontal	8	55	118	175	216	240	251	240	216	175	118	55	8	Horizontal	
	North	6	10	11	13	14	14	14	14	14	13	11	10	6	South	
	North East	45	111	118	89	50	18	14	14	14	13	11	7	2	South East	
	East	53	142	165	149	106	51	14	14	14	13	11	7	2	East	
	South East	29	89	113	108	98	55	20	14	14	13	11	7	2	North East	
AUG 24 & APR 20	South	2	7	11	14	20	24	26	24	20	14	11	7	2	North	FEB 20 & OCT 23
	South West	2	7	11	13	14	14	20	55	98	108	113	89	29	North West	
	West	2	7	11	13	14	14	14	51	106	149	165	142	50	West	
	North West	2	7	11	13	14	14	14	18	50	89	118	111	45	South West	
	Horizontal	5	48	107	167	210	235	247	235	210	167	107	48	5	Horizontal	
	North	0	6	11	13	14	14	14	14	14	13	11	6	0	South	
	North East	0	83	87	59	22	14	14	14	14	13	11	6	0	South East	
	East	0	130	163	149	104	45	14	14	14	13	11	6	0	East	
	South East	0	99	136	140	120	84	41	14	14	13	11	6	0	North East	
SEPT 22 & MAR 22	South	0	8	22	38	52	63	65	63	52	38	22	8	0	North	MAR 22 & SEPT 22
	South West	0	6	11	13	14	15	41	84	120	140	136	99	0	North West	
	West	0	6	11	13	14	14	14	45	104	149	163	130	0	West	
	North West	0	6	11	13	14	14	14	14	22	59	87	83	0	South West	
	Horizontal	0	30	93	153	198	225	233	225	198	153	93	30	0	Horizontal	
	North	0	4	9	12	13	14	14	14	13	12	9	4	0	South	
	North East	0	44	52	29	13	14	14	14	13	12	9	4	0	South East	
	East	0	99	147	141	100	49	14	49	13	12	9	4	0	East	
	South East	0	91	146	146	149	119	74	119	13	12	9	4	0	North East	
OCT 23 & FEB 20	South	0	21	50	76	96	106	111	106	93	76	50	21	0	North	APR 20 & AUG 24
	South West	0	4	9	12	13	27	74	119	149	160	146	91	0	North West	
	West	0	4	9	12	13	14	14	49	100	141	147	99	0	West	
	North West	0	4	9	12	13	14	14	14	13	29	52	44	0	South West	
	Horizontal	0	18	68	127	171	196	208	196	171	127	68	18	0	Horizontal	
	North	0	3	8	11	13	13	13	13	13	11	8	3	0	South	
	North East	0	24	26	14	13	13	13	13	13	11	8	3	0	South East	
	East	0	71	128	127	91	43	13	13	13	11	8	3	0	East	
	South East	0	73	144	164	158	135	91	46	16	11	8	3	0	North East	
NOV 21 & JAN 21	South	0	28	69	100	123	136	141	136	123	100	69	28	0	North	MAY 21 & JUL 23
	South West	0	3	8	11	16	46	91	135	158		144	73	0	North West	
	West	0	3	8	11	12	13	13	43	91	64	128	71	0	West	
	North West	0	3	8	11	12	13	13	13	13	127	26	24	0	South West	
	Horizontal	0	5	48	101	146	172	180	172	146	14	48	5	0	Horizontal	
	North		2	7	11	12	13	13	13	12	101	7	2	0	South	
	North East		14	18	12	12	13	13	13	12	11	7	2	0	South East	
	East		56	118	121	82	34	13	13	12	11	7	2	0	East	
	South East		59	139	167	159	134	97	60	20	11	7	25	0	North East	
DEC 22	South		25	74	111	132	146	149	146	132	111	74	25	0	North	JUNE 21
	South West		2	7	11	20	30	97	134	159	167	139	59	0	North West	
	West		2	7	11	12	13	13	34	85	121	118	56	0	West	
	North West		2	7	11	12	13	13	13	12	12	18	14	0	South West	
	Horizontal		4	36	93	135	161	107	161	135	92	36	4	0	Horizontal	

Solar Gain Correction	Steel Sash or No Sash x 1/0.85 or 1.17	Haze -15% (Max)	Altitude +0.7% Per 10000 ft.	Dew Point Decrease From 67 F +7% Per 10 F	Dew Point Increase From 67 F - 7% Per 10 F	South Lat. Dec Or Jan +7%

Source : Carrier Handbook

Table 1.12 : Solar Heat Gain through Ordinary Glass Btu / (Hr.) (Sq. Ft. Sash Area)

30° 30°

10° NORTH LATITUDE		AM						SUN TIME				PM			10° SOUTH LATITUDE	
TIME OF YEAR	EXPOSURE	6	7	8	9	10	11	NOON	1	2	3	4	5	6	EXPOSURE	TIME OF YEAR
	North	33	29	18	14	14	14	140	14	14	14	18	29	33	South	
	North East	105	139	130	97	55	19	140	14	14	14	12	10	5	South East	
	East	108	156	161	143	98	44	140	14	14	14	12	10	5	East	
	South East	42	75	90	90	73	44	17	14	14	14	12	10	5	North East	
JUNE 21	South	5	10	12	14	15	19 H	21	19	15	14	12	10	5	North	DEC 22
	South West	5	10	12	14	14	14	17	44	73	90	90	75	42	North West	
	West	5	10	12	14	14	14	14	44	98	143	161	156	108	West	
	North West	5	10	12	14	14	14	14	19	55	97	130	139	105	South West	
	Horizontal	19	61	131	180	217	240	250	240	217	180	131	61	19	Horizontal	
	North	22	20	14	13	14	14	14	14	14	13	14	20	22	South	
	North East	93	131	123	89	46	14	14	14	14	13	12	9	4	South East	
	East	100	155	164	145	99	44	14	14	14	13	12	9	4	East	
	South East	42	82	100	100	83	53	22	14	14	13	14	20	22	North East	
JULY 23 & MAY 21	South	4	9	12	14	20	27	30	27	20	14	12	9	4	North	JAN 21 & NOV 21
	South West	4	9	12	13	14	14	14	53	83	100	100	82	42	North West	
	West	4	9	12	13	14	14	14	44	99	145	164	55	100	West	
	North West	4	9	12	13	14	14	14	16	46	89	123	131	93	South West	
	Horizontal	15	66	123	176	214	236	246	239	2I4	176	123	66	15	Horizontal	
	North	6	8	11	13	13	14	14	14	1 3	13	11	8	6	SOUTH	
	North East	55	108	100	27	14	14	14	14	13	13	11	8	2	South East	
	East	66	147	165	102	46	46 1	14	14	13	13	11	8	2	East	
	South East	37	98	127	112	82	82	39	15	13	13	11	8	2	North East	
AUG 24 & APR 20	South	2	8	13	47	58	58	63	58	47	21	13	8	2	North	FEB 20 & OCT 23
	South West	2	8	11	13	15	15	39	82	112	129	127	98	37	North West	
	West	2	8	11	13	14	14	14	46	102	148	165	147	66	West	
	North West	2	8	11	13	14	14	14	14	27	66	100	108	55	South West	
	Horizontal	6	47	107	200	225	225	235	225	200	161	107	47	6	Horizontal	
	North	0	5	10	12	13	14	14	14	13	12	10	5	0	South	
	North East	0	74	90	40	15	14	14	14	13	12	10	5	0	South East	
	East	0	124	158	144	103	48	14	14	13	12	10	5	0	East	
	South East	0	98	131	152	141	113	67	25	13	12	10	5	0	North East	
SEPT 22 & MAR 22	South	0	9	18	60	82	98	105	98	82	60	18	9	0	North	MAR 22 & SEPT 22
	South West	0	5	10	12	13	25	67	113	141	152	131	98	0	North West	
	West	0	5	10	12	13	14	14	48	104	144	158	124	0	West	
	North West	0	5	10	12	13	14	14	14	15	40	90	74	0	South West	
	Horizontal	0	25	81	135	179	202	212	202	179	135	81	25	0	Horizontal	
	North	0	3	8	11	12	13	14	13	12	11	8	3	0	South	
	North East	0	33	39	18	12	13	14	13	12	11	8	3	0	South East	
	East	0	79	135	132	94	43	14	13	12	11	8	3	0	East	
	South East	0	73	142	163	159	136	92	47	15	11	8	3	0	North East	
OCT 23 & FEB 20	South	0	18	57	92	121	139	145	139	121	92	57	18	0	North	APR 20 & AUG 24
	South West	0	3	8	11	15	47	92	136	159	163	142	73	0	North West	
	West	0	3	8	11	12	13	14	43	94	132	135	79	0	West	
	North West	0	3	8	11	12	13	14	13	12	18	39	33	0	South West	
	Horizontal	0	6	49	100	143	171	179	171	143	100	49	6	0	Horizontal	
	North	0	1	6	9	11	12	12	12	11	9	6	1	0	South	
	North East	0	8	16	9	11	12	12	12	11	9	6	1	0	South East	
	East	0	27	109	116	83	35	12	12	11	9	6	1	0	East	
	South East	0	28	127	161	162	143	104	64	23	9	6	1	0	North East	
NOV 21 & FEB 20	South	0	10	68	109	137	154	159	154	137	109	68	10	0	North	MAY 21 & JUL 23
	South West	0	1	6	9	23	64	104	143	162	161	127	28	0	North West	
	West	0	1	6	9	11	12	12	35	83	116	109	27	0	West	
	North West	0	1	6	9	11	12	12	12	11	9	16	8	0	South West	
	Horizontal	0	2	27	71	109	136	145	136	109	71	27	2	0	Horizontal	
	North	0	0	4	9	11	12	12	12	11	9	4	0	0	South	
	North East	0	0	10	9	11	12	12	12	11	9	4	0	0	South East	
	East	0	0	92	105	80	32	12	12	11	9	4	0	0	East	
	South East	0	0	114	157	162	143	108	72	28	9	4	0	0	North East	
DEC 22	South	0	0	64	113	142	159	163	159	142	113	64	0	0	North	JUNE 21
	South West	0	0	4	9	28	12	108	143	162	157	114	0	0	North West	
	West	0	0	4	9	11	12	12	32	80	105	92	0	0	West	
	North West	0	0	4	9	11	12	12	12	11	9	10	0	0	South West	
	Horizontal	0	0	19	60	97	122	131	122	97	60	19	0	0	Horizontal	

Solar Gain Correction	Steel Sash or No Sash x 1/0.85 or 1.17	Haze -15% (Max)	Altitude +0.7% Per 10000 ft.	Dew Point Decrease From 67 F +7% Per 10 F	Dew Point Increase From 67 F - 7% Per 10 F	South Lat. Dec Or Jan +7%

Table 1.13 : Total Solar Radiation (Direct plus Diffused) Incident on Various Surfaces of building in Btu/ Sqft / day for Summer and Winter Seasons

ORIENTATION	SEASON	Latitude					
		9°N	13°N	17°N	21°N	25°N	29°N
1	2	3	4	6	6	7	8
North	Summer	1494	1251	2102	1775	2173	1927
	Winter	873	859	840	825	802	765
North East	Summer	2836	2717	3144	3092	3294	3189
	Winter	1240	1158	1068	1001	912	835
East	Summer	3344	3361	3475	3598	3703	3794
	Winter	2800	2673	2525	2409	2211	2055
South East	Summer	2492	2660	2393	2629	2586	2735
	Winter	3936	3980	3980	3995	3892	3818
South	Summer	1009	1185	1035	1117	1112	1350
	Winter	4674	4847	4958	5059	4942	5981
South West	Summer	2492	2660	2393	2629	2586	2735
	Winter	3936	3980	3980	3995	3892	3818
West	Summer	3341	3361	3475	3598	3703	3794
	Winter	2800	2673	2525	2409	2211	2055
North West	Summer	2836	2717	3144	3092	3294	3189
	Winter	1240	1158	1068	1001	912	835
Horizontal	Summer	8107	8139	8379	8553	8817	8863
	Winter	6409	6040	5615	5231	4748	4281

Source NBC 2005

Table 1.14 : Solar Altitudes (to the Nearest Degree) for Indian Latitudes

Period of Year	22nd June						21st March And 23rd September						22ND December					
Hours Of Day (Sun Or Solar	7.00	8.00	9.00	10.00	11.00	12.00	7.00	8.00	9.00	10.00	11.00	12.00	7.00	8.00	9.00	10.00	11.00	12.00
Latitude	17	16	15	14	13	-	17	16	15	14	13	-	17	16	15	14	13	-
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
10°N	18	31	45	58	70	77	15	30	44	59	72	80	9	23	33	46	53	57
13°N	19	32	46	60	72	80	15	29	44	58	70	77	8	21	33	43	51	54
16°N	20	33	47	61	74	83	14	29	43	56	68	74	7	19	11	41	48	51
19°N	21	34	48	62	75	86	14	28	42	55	66	71	5	18	29	48	45	48
22°N	22	35	49	62	75	89	14	28	41	53	64	68	4	16	27	36	42	45
25°N	23	36	49	63	76	88	13	27	40	52	61	65	3	14	25	34	39	42
28°N	23	36	49	63	76	86	13	26	39	50	59	62	1	13	23	31	37	39
31°N	24	37	50	62	75	82	13	25	37	48	56	56	-	11	21	28	34	36
34°N	25	37	49	62	73	79	12	25	36	46	53	56	-	9	18	26	31	33

Source NBC 2005

Table 1.15 : U-Factors for Various Fenestration Products in Btu/h-ft - F

Product Typo		Glass Only		Vertical Installation									
Frame Type				Operable (Including Sliding And Swinging Glass Doors)					Fixed				
ID	Glazing Type	Center Of Glass	Edge Of Glass	Aluminum Without Thermal Break	Aluminum With Thermal Break	Rein-forced Vinyl / Alumi-num Clad Wood	Wood/ Vinyl	Insulated Fibre Glass with Break	Aluminum Without Thermal Break	Aluminum With Thermal Break	Rein-forced Vinyl/ Alumi-num Clad Wood	Wood/ Vinyl	Insulated Fiber Glass Vinyl
	Single Glazing												
1	1/8 in. glass	1.04	1.04	1.23	1.07	0.93	0.91	0.85	1.12	1.07	0.98	0.98	1.04
2	1/4 in. acrylic/polycarbonate	0.88	0.88	1.10	0.94	0.81	0.80	0.74	0.98	0.92	0.84	0.84	0.88
3	1/8 in. acrylic/polycarbonate	0.96	0.96	1.17	1.01	0.87	0.86	0.79	1.05	0.99	0.91	0.91	0.96
	Double Glazing												
4	1/4 in. air space	0.55	0.64	0.81	0.64	0.57	0.55	0.50	0.68	0.62	0.56	0.56	0.55
5	1/2 in. air space	0.48	0.59	0.76 .	0.58	0.52	0.50	0.45	0.62	0.56	0.50	0.50	0.48
6	1/4 in. argon space	0.51	0.61	0.78	0.61	0.54	0.52	0.47	0.65	0.59	0.53	0.52	0.51
7	1/2 in. argon space	0.45	0.57	0.73	0.56	0.50	0.48	0.43	0.60	0.53	0.48	0.47	0.45
	Double Glazing e=0.60 on surface 2 or 3												
8	1/4 in air space	0.52	0.62	0.79	0.61	0.55	0.53	0.48	0.66	0.59	0.54	0.53	0.52
9	1/2 in. air space	0.44	0.56	0.72	0.55	0.49	0.48	0.43	0.59	0.53	0.47	0.47	0.44
10	1/4 in. argon space	0.47	0.58	0.75	0.57	0.51	0.50	0.45	0.61	0.55	0.49	0.49	0.47
11	1/2 in. argon space	0.41	0.54	0.70	0.53	0.47	0.45	0.41	0.56	0.50	0.44	0.44	0.41
	Double Glazing e=0.40 on surface 2 or 3												
12	1/4 in. air space	0.49	0.60	0.76	0.59	0.53	0,51	0.46	0.63	0.57	0.51	0.51	0.49
13	1/2 in. air space	0.40	0.54	0.69	0.52	0.47	0.45	0,40	0.55	0.49	0.44	0.43	0.40
14	1/4 in. argon space	0.43	0.56	0.72	0.54	0.49	0.47	0,42	0.58	0.52	0.46	0.46	0.43
15	1/2 in. argon space	0.36	0.51	0.66	0.49	0.44	0.42	0.37	0.52	0.46	0.40	0.40	0.36
	Double Glazing e=0.20 on surface 2 or 3												
16	1/4 in. air space	0.45	0.57	0.73	0.56	0.50	0.48	0.43	0.60	0.53	0.48	0.47	0.45
17	1/2 in. air space	0.35	0.50	0.65	0.48	0.43	0.41	0.37	0.51	0.45	0.39	0.39	0.35
18	1/4 in. argon space	0.38	0.52	0.68	0.51	0.45	0.43	0.39	0.54	0.47	0.42	0.42	0.38
19	1/2 in. argon space	0.30	0.46	0.61	0.45	0.39	0.38	0.33	0.47	0.41	0.35	0.35	0.30
	Double Glazing e=0.10 on surface 2 or 3												
20	1/4 in. air space	0.42	0.55	0.71	0.54	0.48	0.46	0.41	0.57	0.51	0.45	0.45	0.42
21	1/2 in. air space	0.32	0.48	0.63	0.46	0.41	0.39	0.34	0.49	0.42	0.37	0.37	0.32
22	1/4 in. argon space	0.35	0.50	0.65	0.48	0.43	0.41	0.37	0.51	0.45	0.39	0.39	0.35
23	1/2 in. argon space	0.27	0.44	0.59	0.42	0.37	0.36	0.31	0.44	0.38	0.33	0.32	0.27
	Double Glazing e=0.05 on surface 2 or 3												
24	1/4 in. air space	0.41	0.54	0.70	0.53	0.47	0.45	0.41	0.56	0.50	0.44	0.44	0.41
25	1/2 in. air space	0.30	0.46	0.61	0.45	0.39	0.38	0.33	0.47	0.41	0.35	0.35	0.30
26	1/4 in. argon space	0.33	0.48	0.64	0.47	0.42	0.40	0.35	0.49	0.43	0.38	0.37	0.33
27	1/2 in. argon space	0.25	0.42	0.57	0.41	0.36	0.34	0.30	0.43	0.36	0.31	0.31	0.25
	Triple Glazing												
28	1/4 in. air space	0.38	0.52	0.67	0.49	0.43	0.43	0.38	0.53	0.47	0.42	0.42	0.38
29	1/2 in. air space	0.31	0.47	0.61	0.44	0.38	0.38	0.34	0.47	0.41	0.36	0.36	031
30	1/4 in. argon space	0.34	0.49	0.63	0.46	0.41	0.40	0.36	0.50	0.44	0.38	0.38	0.34
31	1/2 in. argon space	0.29	0.45	0.59	0.42	0.37	0.36	0.32	0.45	0.40	0.34	0.34	0.29
	Triple Glazing e=0.20 on surface 2 or 3, 4 or 5												
32	1/4 in. air space	0.33	0.48	0.62	0.45	0.40	0.39	0.35	0.49	0.43	0.37	0.37	033
33	1/2 in. air space	0.25	0.42	0.56	0.39	0.34	0.33	0.29	0.42	0.36	0.31	0.31	0.25
34	1/4 in. argon space	0.28	0.45	0.58	0.41	0.36	0.36	0.31	0.45	0.39	0.33	0.33	0.28
35	1/2 in. argon space	0.22	0.40	0.54	0.37	0.32	0.31	0.27	0.39	0.33	0.28	0.28	0.22
	Triple Glazing e=0.20 on surface 2 or 3, & 4 or 5												
36	1/4 in air space	0.29	0.45	0.59	0.42	0.37	0.36	0.32	0.45	0.40	0.34	0.34	0.29
37	1/2 in. air space	0.20	0.39	0.52	0.35	0.31	0.30	0.26	0.38	0.32	0.26	0.26	0.20
38	1/4 in. argon space	0.23	0.41	0.54	0.37	0.33	0.32	0.28	0.40	0.34	0.29	0.29	0.23
39	1/2 in. argon space	0.17	0.36	0.49	0.33	0.28	0.28	0.24	0.35	0.29	0.24	0.24	0.17
	Triple Glazing e=0.10 on surface 2 or 3, & 4 or 5												
40	1/4 in. air space	0.27	0.44	0.58	0.40	0.36	0.35	0.31	0.44	0.38	0.32	0.32	0.27
41	1/2 in. air space	0.18	0.37	0.50	0.34	0.29	0.28	0.25	0.36	0.30	0.25	0.25	0.18
42	1/4 IN. argon space	0.21	0.39	0.53	0.36	0.31	0.31	0.27	0.38	0.33	0.27	0.27	0.21
43	1/2 in. argon space	0.14	0.34	0.47	0.30	0.26	0.26	0.22	0.32	0.27	0.21	0.21	0.14
	Quadruple Glazing e=0.10 on surface 2 or 3, 4 or 5												
44	1/4 in air space	0.22	0.40	0.54	0.37	0.32	0.31	0.27	0.39	0.33	0.28	0.28	0.22
45	1/2 in. air space	0.15	0.35	0.48	0.31	0.27	0.26	0.23	0.33	0.27	0.22	0.22	0.15
46	1/4 in. argon space	0.17	0.36	0.49	0.33	0.28	0.28	0.24	0.35	0.39	0.24	0.24	0.17
47	1/2 in. argon space	0.12	0.32	0.45	0.29	0.25	0.24	0.20	0.31	0.25	0.20	0.20	0.12
48	1/4 in. Krypton spaces	0.12	0.32	0.45.	0.29	0.25	0.24	0.20	0.31	0.25	.0,20	0.20	0.12

Note: 1. All Heat Transmission Coefficients in this Table include Film Resistances and are based on winter condition of 0^0F Outdoor Air Temperature and 70^0F Indoor Air Temperature, with 15 mph Outdoor Air Velocity and zero Solar Fux. With the exception of single glazing, small changes in Indoor and Outdoor Temperatures will not significantly affect overall U-factors. Coefficients are for vertical position, except skylight values, which are for 20^0 from horizontal with Heat follow-up.

2. A Glazing layer surfaces are numbered form Outdoor to Indoor, Double, Triple and Quadruple, refer to the number fof glazing panels. All data are based on 1/8 in. glass unless otherwise specified. Thermal Conductivites area 0.53 Btu/h-ft-^{0}f for glass and 0.11 Btu/h-ft-^{0}f Acrylic and Polycarbonate.

3. Standard spacers are metal. Edge of glass effects are assumed to extend over the 2 1/2in. band around perimeter of each glazing unit.

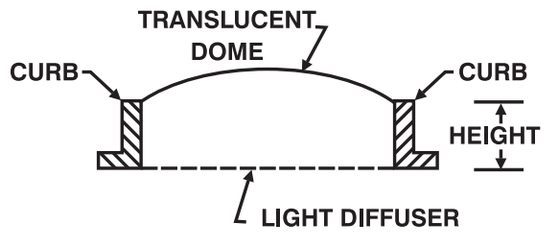
Table 1.16 : U-Factors for Various Fenestration Products in Btu/h-ft - F

Vertical Installation							Sloped Installation							
Garden Windows		Curtain Wall			Glass Only (Skylight)		Manufactured Skylight				Site Assembled Sloped/overhead Glazing			
Aluminum Without Thermal Break	Wood/ Vinyl	Aluminum Without Thermal Break	Aluminum With Thermal Break	Structural Glazlng	Center Of Glass	Edge of Glass	Aluminum Without Thermal Break	Aluminum With Thermal Break	Reinforced Vinyl/ Aluminium Clad Wood	Wood/ Vinyl	Aluminum Without Thermal Break	Aluminum With Thermal Break	Struc- tural Glazing	ID
2.50	2.10	1.21	1.10	1,10	1.19	1.19	1,77	1.70	1.61	1,42	1.35	1.34	1.25	1
2.24	1.84	1.06	0.96	0.96	1.03	1.03	1.60	1.54	1.45	1,31	1.20	1.20	1.10	2
2.37	1.97	1.13	1.03	1.03	1.11	1.11	1.68	1.62	1.53	1.39	1.27	1.27	1.18	3
1.72	1.32	0.77	0.67	0.63	0.58	0.66	1.10	0.96	0.92	0.84	0.80	0.83	0.66	4
1.62	1.22	0.71	0.61	0.57	0.57	0.65	1.09	0.95	0.91	0.84	0.79	0.82	0.65	5
1.66	1.26	0.74	0.63	0.59	0.53	0.63	1.05	0.91	0.87	0.80	0.76	0.80	0.62	6
1.57	1.17	0.68	0.58	0.54	0.53	0.63	1.05	0.91	0.87	0.80	0.76	0.80	0.62	7
1.68	1.28	0.74	0.64	0.60	0.54	0.63	1.06	0.92	0.88	0.81	0.77	0.80	0.63	8
1.56	1.16	0.68	0.57	0.53	0.53	0.63	1.05	0.91	0.87	0.80	0.76	0.80	0,62	9
1.60	1.20	0.70	0.60	0.56	0.49	0.60	1.01	0.87	0.83	0.76	0.72	0.77	0,58	10
1.51	1.11	0.65	0.55	0.51	0.49	0.60	1.01	0.87	0.83	0.76	0.72	0.77	0.58	11
1.63	1.23	0.72	0.62	0.58	0.51	0.61	1.03	0.89	0.85	0.78	0.74	0.78	0,60	12
1.50	1.10	0.64	0.54	0.50	0.50	0.61	1.02	0.88	0.84	0.77	0.73	0.78	0.59	13
1.54	1.14	0.67	0.56	0.52	0.44	0.56	0.96	0.83	0.78	0.72	0.68	0.74	0.54	14
1.44	1.04	0.61	0.50	0.46	0.46	0.58	0.98	0.85	0.80	0.74	0.70	0.75	0.56	15
1.57	1.17	0.68	0.58	0.54	0.46	0.58	0.98	0.85	0.80	0.74	0.70	0.75	0.56	16
1.43	1.03	0.60	0.50	0.45	0.46	0.58	0.98	0.85	0.80	0.74	0.70	0.75	0.56	17
1.47	1.07	0.62	0.52	0.48	0.39	0.53	0.91	0.78	0.74	0.68	0.64	0.70	0.50	18
1.35	0.95	0.55	0.45	0.41	0.40	0.54	0.92	0.79	0.75	0.68	0.64	0.71	0.51	19
1.53	1.13	0.66	0.56	0.51	0.44	0.56	0.96	0.83	0.78	0.72	0.68	0.74	0.54	20
1.38	0.98	0.57	0.47	0.43	0.44	0.56	0.96	0.83	0.78	0.72	0.68	0.74	0.54	21
1.43	1.03	0.60	0.50	0.45	0.36	0.51	0.88	0.75	0.71	0.65	0.61	0.68	0.47	22
1.30	0.90	0.53	0.43	0.38	0.38	0.52	0.90	0.77	0.73	0.67	0.63	0.69	0.49	23
1.51	1.11	0.65	0.55	0.51	0.42	0.55	0.94	0.81	0.76	0.70	0.66	0.72	0.52	24
1.35	0.95	0.55	0.45	0.41	0.43	0.56	0.95	0.82	0.77	0.71	0.67	0.73	0.53	25
1.40	1.00	0.58	0.48	0.44	0.34	0.49	0.86	0.73	0.69	0.63	0.59	0.66	0.45	26
1.27	0.87	0.51	0.41	0.37	0.36	0.51	0.88	0.75	0.71	0.65	0.61	0.68	0.47	27
		0.61	0.51	0.46	0.39	0.53	0.90	0.75	0.71	0.64	0.62	0.69	0.48	28
		0.55	0.45	0.40	0.36	0.51	0,87	0.72	0,68	0,61	0.60	0.67	0.45	29
		0.58	0.48	0.43	0.35	0.50	0,86	0,71	0.67	0.60	0.59	0.66	0.44	30
		0.53	0.43	0.38	0.33	0.48	0.84	0.69	0.65	0.59	0.57	0.65	0.42	31
		0.57	0.47	0.42	0.34	0.49	0.85	0.70	0.66	0.59	0.58	0.65	0.43	32
		0.50	0.40	0.35	0.31	0.47	0.82	0.67	0.63	0.57	0.56	0.63	0.41	33
		0.53	0.43	0.37	0.28	0.45	0.80	0.64	0.60	0.54	0.53	0.61	0.38	34
		0.47	0.37	0.32	0.27	0.44	0.79	0.63	0.59	0.53	0.52	0.60	0.37	35
		0.53	0.43	0.38	0.29	0.45	0.81	0.65	0.61	0.55	0.54	0.62	0.36	36
		0.46	0.36	0.30	0.27	0.44	0.79	0.63	0.59	0.53	0.52	0.60	0.37	37
		0.48	0.38	0.33	0.24	0.42	0.76	0.60	0.57	0.50	0.49	0.58	0.35	38
		0.43	0.33	0.28	0.22	0.40	0.74	0.58	0.55	0.49	0.48	0.57	0.33	39
		0.52	0.42	0.37	0.27	0.44	0.79	0.63	0.59	0.53	0.52	0.60	0.37	40
		0.44	0.34	0.29	0.25	0.42	0.77	0.61	0.57	0.51	0.50 '	0.59	0.36	41
		0.46	0.36	0.31	0.21	0.39	0.73	0.57	0.54	0.48	0.47	0.56	0.32	42
		0.40	0.30	0.25	0.20	0.39	0.72	0.56	0.53	0.47	0.46	0.55	0.31	043
		0.47	0.37	0.32	0.22	0.40	0.74	0.58	0.55	0.49	0.48	0.57	0.33	44
		0.41	0.31	0.26	0.19	0.38	0.71	0.55	0.52	0.46	0.45	0.54	0.30	45
		0.43	0.33	0.28	0.18	0.37	0.70	0.54	0.51	0.45	0.44	0.54.	0.29	46
		0.39	0.29	0.23	0.16	0.35	0.68	0.52	0.49	0.43	0.42	0.52	0.28	47
		0.39	0.29	0.23	.0.13	0.33	0.65	0.49	0.46	0.40	0.40	0.50	0.25	48

4. Use U=0.6 Btu (h-ft2 °F) for glass block with mortar but without reinforcing or framing.
5. Use of this table should be limited to that of an estimating tool for the early phases of design.

SOURCE: ASHRAE 2013-F

Table 1.16a : Solar Heat Gain Co-efficient for Domed Horizontal Skylights



Dome	Light Diffuser (Translucent)	Curb		Solar Heat Gain Coefficient	Visible Transmittance
		Height In	Width To Height Ratio		
Clear T = 0.86	Yes T=0.58	0 9 12	5 2.5	0.53 0.50 0.44	0.56 0.58 0.59
Clear T = 0.86	None	0 9 12	5 2.5	0.86 0.77 0.70	0.91 0.91 0.91
Translucent T - 0.52	None	0 9 12	5 2.5	0.50 0.40 030	046 0:32 0.25
Translucent T-0.27	None	0 9 12	5 2.5	0.30 0.26 0.24	0.25 0.21 0.18

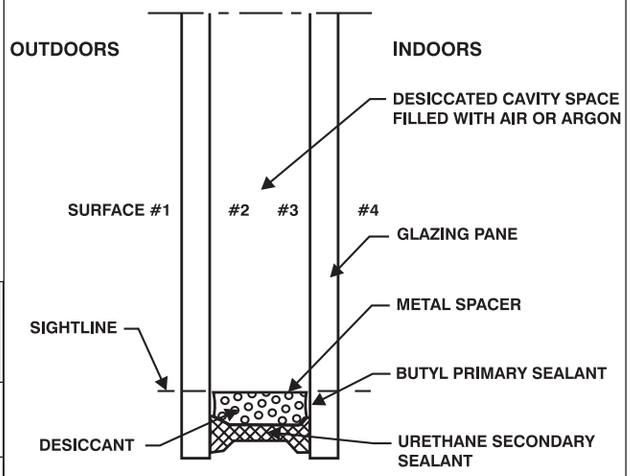


Figure 1.2 : Double Glazing Unit Construction Detail

Table 1.17 : Design U-Factors of Swinging Doors In Btu/H-Ft² °F

Door Type (Rough Opening=38x82in)	No Glazing	Single Glazing	Double Glazing With 1/2 In. Air Space	Double Insulated Fiber Glass Vinyl glazing With E=0.10 1/2 In. Argon
Slab Doors				
Wood Slab In Wood Frame	0.46			
6% Glazing (22 X 8 In.)	-	0.48	0.46	0.44
25% Glazing (22 X 36 In.)	-	0.58	0.46	0.42
45% Glazing (22x64 In.)	-	0.69	0.46	0.39
More Than 50% Glazing	1 - T - 15			
Insulated Steel Slab With Wood Edge	0.16			
6% Glazing (22 X 8 In.)	-	0.21	0.19	0.18
25% Glazing (22 X 36 In.)	-	0.39	0.26	0.23
Lift (Jln/Ing (22x64 In.)		0.58	0.35	0.26
More Than 50% Glazing	1 - T - 15			
Foam insulated Steel Slab With Metal edge in Steel Frame	0.37			
6% Glazing (22 X 8 In.)	-	0.44	0.41	0.39
25% Glazing (22 X 36 In.)	-	0.55	0.48	0.44
45% Glazing (22 X 64 In.)	-	0.71	£.56	0.48
More Than 50% Glazing	1 - T - 15			
Cardboard Honeycomb Slab With Metal Edge In Steel Frame	0.61			
Stile And Rail Doors				
Sliding Glass Doors / French Doors	1 - T - 15			
Site Assembled Stile And Rail Doors				
Aluminum In Aluminum Frame	-	1.32	0.93	0.79
Aluminum In Aluminum Frame With Thermal Break	-	1.13	0.74	0.63

Notes:
*Thermally broken sill (add 0.03 Btu/h-Ft2 -0F For non-thermally broken sill)
*Non-thermally broken sill
Normally U-Factors are through centre of insulated panel before consideration of thermal bridges around edges of door sections and because of frame.

Source: ASHRAE 2013-F

Table 1.18 : Design U-Factors for Revolving Doors in Btu/h-ft² -°F

Type	Size (Width x Height)	U FACTOR
3 Wings	8x7 ft.	0.79
	10x8 ft.	0.80
4 Wings	7x6.5 ft	0.63
	7x7.5 ft.	0.64
Open*	82x84 in.	1.32

* U-factor of open door is determined using NFRC technical document 100-91. It has not been updated to current rating methodology in NFRC technical document 100-2004.

Table 1.19 : - Design U-Factors for Double Skin Steel Emergency Exit Doors in Btu/h - ft² - °F

Core Insulation		Rough Opening Size	
Thickness, in.	Type	3 ft x 6 ft 8 in.	6 ft x 6 ft 8 in.
1 3/8'	Honeycomb kraft paper	0.57	0.52
	Mineral wool, steel ribs	0.44	0.36
	Polyurethane foam	0.34	0.28
1 3/4"	Honeycomb kraft paper	0.57	0.54
	Mineral wool, steel ribs	0.41	0.33
	Polyurethane foam	0.31	0.26
1 3/8"	Honeycomb kraft paper	0.60	0.55
	MIneral wool, steel ribs	0.47	0.39
	Polyurethane foam	0.37	0.31
1 3/4"	Honeycomb kraft paper	0.60	0.57
	Mineral wool, steel ribs	0.44	0.37
	Polyurethane foam	0.34	0.30

Table 1.20 : Thermal Resistance R - Building and insulating Materials (Deg. F per Btu) / (hr) (Sq. ft)

MATERIAL	DESCRIPTION	THICK-NESS (IN.)	DENSITY (IB PER CU. FT)	WEIGHT (IB PER CU. FT)	RESISTANCE R	
					PER INCH THICK-NESS 1/K	FOR LISTED THICK-NESS 1/K
BUILDING MATERIALS						
BUILDING BOARD BOARDS PANELS SHEATHING ETC.						
	Asbestos - Cement Board		120	-	0.25	-
	Asbestos - Cement Board	1/8	120	125	-	0.03
	Gypsum Or Plaster Board	3/8	50	1.58	-	0.32
	Gypsum Or Plaster Board	1/2	60	2.08	-	0.45
	Plywood		34	.	1.25	-
	Plywood	'/4	34	0.71	-	0.31
	Plywood	3/8	34	1.06	-	0.47
	Plywood	1/2	34	1.42	-	0.63
	Plywood Or Wood Panels	3/4	26	2.13	2.38	0.94
	Wood Fiber Board, Laminated Or Homogeneous		31	-	2.00	-
	Wood Fiber, Hardboard Type		65	-	0.72	-
	Wood Fiber, Hardboard Type	1/4	65	1.35	-	0.18
	Wood Firber Or Pine Sheathing	25/22	32	2.08	-	0.98
	Wood Firber Or Pine Sheathing	15/8	32	4.34	-	2.03
BUILDING PAPER	Vapor Permeable Felt		-	-	-	0.06
	Vapor Seal, 2 Layers Mopped 15 Inb Felt		-	-	-	0.12
	Vapor Seal, Plastic Film		-	-	-	NEGI
WOODS	Maple, Oak And Similar Hardwoods		45	-	0.91	-
	Fir, Pine And Similar Softwoods		32	-	1.25	-
MASONRY UNITS		4	120	40	-	0.80
	Brick, Common	4	130	43	-	0.44
	Brick Face					
	Clay Tile, Hollow:					
	1 Cell Deep	3	60	15	-	0.80
	1 Cell Deep	4	48	18	-	1.11
	2 Cells Deep	6	50	25	-	1.52
	2 Cells Deep	8	45	30	-	1.85
	2 Cells Deep	10	42	35	-	2.22
	3 Cells Deep	12	40	40	-	2.50
	Concrete Blocks, Three Oval Core	3	76	19	-	0.40
	Sand And Gravel Aggregate	4	69	23	-	0.71
		6	64	32	-	0.91
		8	64	43	-	1.11
		12	83	63	-	1.28
	Cinder Aggregate	3	68	17	-	0.86
		4	00	20	-	1.11
		8	54	27	-	1.50
		8	T>«	37	-	1.72
		12	53	53	-	1.89
		3	60	15	-	1.27
	Lightweight Aggregate	4	52	17	-	1.50
	(Expanded Shale, Clay, Slate Or Slag; Pumice)	8	48	32	-	2.00
		12	43	43	-	2.27
	Gypsum Partition Tile					
	3" X 12" X 30" Solid	3	45	11	-	1.26
	3" X 12" X 30" 4 Cell	34	35	9	-	1.35
	3" X 12" X 30" 3 Cell		38	13	-	1.67
	Limestone Or Sand		150	-	0.08	-

Table 1.20 : Thermal Resistance R - Building and insulating Materials (Deg. F per Btu) / (hr) (Sq. ft) (Contd.)

MATERIAL	DESCRIPTION	THICKNESS (IN.)	DENSITY (IB PER CU. FT)	WEIGHT (IB PER CU. FT)	RESISTANCE R	
					PER INCH THICKNESS 1/K	FOR LISTED THICKNESS 1/K
BUILDING MATERIALS (Contd...)						
MASONRY MATERIALS CONCRETE	Cement Mortar		116	-	0.20	-
	Gypsum-Fiber Concrete 87 1/2% gypsum		-	-		
	12 1/2% Wood Chips		51	-	0.60	-
	Lightweight Aggregates		120	-	0.19	-
	Including Expanded		100	-	0.28	-
	Shale, Clay or Slate		80	-	0.40	-
	Expanded Slag; Cinders		60	-	0.59	-
	Pumice; Fertile; Vermiculite		40	-	0.86	-
	Auto claved Cellular Concrete		30	-	1.11	-
			20	-	1.43	-
	Sand & Gravel or Stone Aggregate (Oven Dried)		140	-	0.11	-
	Sand and Gravel or Stone Aggregate (Not Dried)		140	-	0.08	-
	Stucco		116	-	0.20	-
PLASTERING MATERIALS	Cement Plaster, Sand Aggregate		116		0.20	-
	Sand Aggregate	1/2	116	4.8	-	0.10
	Sand Aggregate	3/4	16	7.2	-	0.15
	Gypsum Plaster					
	Lightweight Aggregate	1/2	45	1.88	-	0.32
	Lightweight Aggregate	5/8	45	2.34	-	0.39
	Lightweight Aggregate on Metal Lath	3/4	45	2.80	-	0.47
	Fertile Aggregate		45	-	0.67	-
	Sand Aggregate		105	-	0.18	-
	Sand Aggregate	1/2	196	4.4	-	0.09
	Sand Aggregate	5/8	105	5.5	-	0.11
	Sand Aggregate on Metal Lath	3/4	105	6.6	-	0.13
	Sand Aggregate on Wood Lath		105	-	-	0.40
	Vermiculite Aggregate		45	-	0.59	-
ROOFING	Asbestos - Cement Shingles		120	-	-	0.21
	Asphalt Roll Roofing		70	-	-	0.15
	Asphalt Shingles		70	-	-	0.44
	Built-up Roofing	3/8	70	2.2	-	0.33
	Slate	1/2	201	8.4	-	0.05
	Sheet Metal		-	-	Negi	-
	Wood Shingles		40	-	-	0.94
SIDING MATERIALS (On Flat Surface)	Singles					
	Wood 16", 7 1/2 Exposure		-	-	-	0.87
	Wood Double, 16' 12" Exposure		-	-	-	1.19
	Wood, Plus Insul Backer Board 5/16"		-	-	-	1.40
	Siding					
	Asbestos - Cement 1/4" Lapped		-	-	-	0.21
	Asphalt Roll Siding		-	-	-	0.15
	Asphalt Insul Siding 1/2" Board		-	-	-	1.45
	Wood, Drop 1"x8"		-	-	-	0.79
	Wood, Bevel, 1/2" x 8" lapped		-	-	-	0.81
	Wood, Bevel, 3/4" x 10" lapped		-	-	-	1.05
	Wood, Bevel, 3/4x10" lapped		-		-	0.59
	Structural Glass		-	-	-	0.10
FLOORING MATERIAL	Asphalt Tile	1/8	120	1.25	-	0.04
	Carpet and Fibrous Pad		-	-	-	2.08
	Carpet and Rubber Pad		-	-	-	1.23
	Ceramic Tile	1	-	-	-	0.08
	Cork Tile		25	-	2.22	-
	Cork Tile	1/8	25	0.26	-	0.28
	Felt, Flooring		-	-	-	0.06
	Floor Tile	1/8	-	-	-	0.05
	Linoleum	1/8	80	0.83	-	0.08
	Plywood Subfloor	5/8	34	1.77	-	0.78
	Rubber or Plastic Tile	1/8	110	1.15	-	0.02
	Terrazzo	1	140	11.7	-	0.08
	Wood Subfloor	25/32	32	2.08	-	0.98
	Wood, Hardwood Finish	3/4	45	2.81	-	0.68

Table 1.20 : Thermal Resistance R - Building and insulating Materials (Deg. F per Btu) / (hr) (Sq. ft) (Contd.)

MATERIAL	DESCRIPTION	THICK-NESS (IN.)	DENSITY (IB PER CU. FT)	WEIGHT (IB PER CU. FT)	RESISTANCE R	
					PER INCH THICK-NESS 1/K	FOR LISTED THICK-NESS 1/K
INSULATING MATERIALS						
BLANKET AND BATT	Cotton Fiber		0.8 - 2.0	-	3.85	-
	Mineral Wool, Fibrous Form Processed from Rock, Slug or Glass		1.5 - 4.0	-	3.70	-
	Wood Fiber		3.2 - 3.6	-	4.00	-
	Wood Fiber, Multilayer Stitched Expanded		1.5 - 2.0	-	3.70	-
BOARD AND SLABS	Glass Fiber		9.5	-	4.00	-
	Wood or Cone Fiber					
	Acoustical Tile	1/2	224	0.93	-	1.19
	Acoustical Tile	3/4	22.4	1.40	-	1.78
	Interior Finish (Tile, Lath, Plank)		15.0	-	2.86	-
	Interior Finish (Tile, Lath, Plank)	1/2	15.0	0.62	-	1.43
	Roof Deck Slab					
	Sheathing (Impreg or Coated)		20.0	-	2.63	-
	Sheathing (Impreg or Coated)	1/2	20.0	0.83	-	1.32
	Sheathing (Impreg or Coated)	25/32	20.0	1.31	-	2.06
	Cellular Glass		9.0	-	2.50	-
	Cork Board (without added binder)		6.5-8.0	-	3.70	-
	Hog Hair (with Asphalt binder)		8.5	-	3.00	-
	Plastic (Foamed)		1.62	-	3.45	-
	Wood Shredded (Cemented in Preformed Slabs)		22.0	-	1.82	-
LOOSE FILL	Macerated Paper or Pulp Products		2.5 - 3.5	-	3.57	-
	Wood Fiber : Redwood, Hemlock, or Fir		2.0 - 3.5	-	3.33	-
	Mineral Wool (Glass, Slag or Rock)		2.0 - 5.0	-	3.33	-
	Sawdust or Shavings		8.0 - 15.0	-	2.22	-
	Vermiculite (Expanded)		7.0	-	2.08	-
ROOF INSULA-TION	All Types (Also refer table 6-T-5 for detailed list)					
	Preformed, for use above deck					
	Approximately	1/2	15.6	0.7	-	1.39
	Approximately	1	15.6	1.3	-	2.78
	Approximately	1 1/2	15.6	1.9	-	4.17
	Approximately	2	15.6	2.6	-	5.26
	Approximately	21/2	15.6	3.2	-	6.67
	Approximately	3	15.6	3.9	-	8.33
AIR SPACES	**POSITION** **HEAT FLOW**					
	Horizontal Up (Winter)	3/4 - 4	-	-	-	0.85
	Horizontal Up (Summer)	3/4 - 4	-	-	-	0.78
	Horizontal Down (Winter)	3/4	-	-	-	1.02
	Horizontal Down (Winter)	1 1/2	-	-	-	1.15
	Horizontal Down (Winter)	4	-	-	-	1.23
	Horizontal Down (Winter)	8	-	-	-	1.25
	Horizontal Down (Winter)	3/4	-	-	-	0.85
	Horizontal Down (Winter)	1 1/2	-	-	-	0.93
	Horizontal Down (Winter)	4	-	-	-	0.99
	Sloping 45° Up (Winter)	3/4 - 4	-	-	-	0.90
	Sloping 45° Up (Winter)	3/4 - 4	-	-	-	0.89
	Vertical Horz. (Winter)	3/4 - 4	-	-	-	0.97
	Vertical Horz. (Summer)	3/4 - 4	-	-	-	0.86
AIR FILM AT Still Air	POSITION HEAT FLOW					
	Horizontal up					
	Sloping 45° up					
	Vertical Horizontal					
	Sloping 45° Down					
	Horizontal Down					
15 Mph Wind	Any Position (For Winter) Any Direction		-	-	-	0.17
7 1/2 Mph Wind	Any Position (For Summer) Any Direction		-	-	-	0.25

Table 1.21 : Equivalent Temperature Difference (Deg. F)
For Dark Colored+ Sunlit and Shaded Walls*

Based on Dark Colored Walls; 95°F DB Outdoor Design Temp. Constant 80°F DB Room Temp
20°F Daily Range; 24 Hour Operation; 40° and N Lat.

Exposure	Weight of Wall (lb / sq.ft)	SUN TIME																							
		AM							PM													AM				
		6	7	8	9	10	II	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5
North East	20	5	15	22	23	24	19	14	13	12	13	14	14	14	12	10	8	6	4	2	0	-2	-3	4	-2
	60	-1	-2	-2	5	24	22	20	15	10	11	12	13	14	13	12	11	10	8	6	4	2	1	0	-1
	100	4	3	4	4	4	10	16	15	14	12	10	11	12	12	12	11	10	9	8	7	6	6	5	5
	140	5	5	6	6	6	6	6	10	14	16	14	12	10	10	10	10	10	10	10	9	9	8	7	7
East	20	1	17	30	33	36	35	32	20	12	13	14	14	14	12	10	8	6	4	2	0	-1	-2	-3	-3
	60	-1	-1	0	21	30	31	31	19	14	13	12	13	14	13	12	11	10	8	5	4	3	1	1	0
	100	5	5	6	8	14	20	24	26	24	20	18	16	14	14	14	13	12	11	10	9	8	7	7	6
	140	11	10	10	9	8	9	10	15	18	19	18	17	16	14	12	13	14	14	14	13	13	12	12	12
South East	M	10	6	13	19	26	27	28	26	24	19	16	15	14	12	10	8	6	4	2	0	-1	-1	-2	-2
	60	1	1	0	13	20	24	28	26	25	21	18	15	14	13	12	11	10	8	6	5	4	3	3	2
	100	7	7	6	6	6	11	14	17	18	19	18	16	14	13	12	11	10	10	10	9	9	8	8	7
	140	9	8	8	8	8	7	6	11	14	15	16	18	16	15	14	13	12	12	12	11	11	10	10	9
South	20	-1	-2	-4	1	4	14	22	27	30	28	26	20	16	12	10	7	6	3	2	1	1	0	0	-1
	60	-1	-3	-4	-3	-2	7	12	20	24	25	26	23	20	15	12	10	8	6	4	2	1	1	0	-1
	100	4	4	2	2	2	3	4	8	12	15	16	18	18	15	14	11	10	9	8	8	7	6	6	5
	140	7	6	6	5	4	4	4	4	4	7	10	13	14	15	16	16	14	12	10	10	9	9	8	7
South West	20	-2	-4	4	-2	0	4	6	19	26	34	40	41	42	30	24	12	6	4	2	1	1	0	-1	-1
	60	2	1	0	0	0	1	2	8	12	24	32	35	36	35	34	20	10	7	6	5	4	4	3	3
	100	7	5	6	5	4	5	6	7	8	12	14	19	22	23	24	23	22	15	10	10	9	9	8	7
	140	8	8	8	8	8	7	6	6	6	7	8	9	10	15	18	19	20	13	8	8	8	8	8	8
West	20	-2	-3	4	-2	0	3	6	14	20	32	40	45	48	34	22	14	8	5	2	1	0	0	-1	-1
	60	2	1	0	0	0	2	4	7	10	19	26	34	40	41	36	28	16	10	6	5	4	3	3	2
	100	7	7	6	6	6	6	6	7	8	10	12	17	20	25	28	27	26	19	14	12	11	10	9	8
	140	12	11	10	9	8	8	8	9	10	10	10	11	12	14	16	21	22	23	22	20	18	16	15	13
North West	20	-3	4	4	-2	0	3	6	10	12	19	24	33	40	37	34	18	6	4	2	0	-1	-1	-2	-2
	60	-2	-3	4	-3	-2	0	2	6	8	10	12	21	30	31	32	21	12	8	6	4	3	1	0	-1
	100	5	4	4	4	4	4	4	4	4	5	6	9	12	17	20	21	22	14	8	7	7	6	6	5
	140	8	7	6	6	6	6	6	6	6	6	6	7	8	9	10	14	18	19	20	16	13	11	10	9
North (Shade)	20	-3	-3	4	-3	-2	1	4	8	10	12	14	13	12	10	8	6	4	2	0	0	-1	-1	-2	-2
	60	-3	-3	4	-3	-2	-1	0	3	6	8	10	11	12	12	12	10	8	6	4	2	1	0	-1	-2
	100	1	1	0	0	0	0	0	1	2	3	4	5	5	5	8	7	6	5	4	3	3	2	2	1
	140	1	1	0	0	0	0	0	0	0	1	2	3	4	5	6	7	8	7	6	4	3	2	2	1
		6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5
		AM							PM												AM				
		SUN TIME																							

Equation : Heat gain through walls, Btu / hr = (Area, Sq. Ft.) x (Equivalent temp diff.) x (Transmission Coefficient U)
* All values are for both insulated and uninsulated walls.
For other conditions, refer to table 1.23
For wall constructions less than 20 lb / sq. ft use listed values of 20 lb / sq. ft.

Table 1.22 : Equivalent Temperature Difference (Deg. F)
For Dark Colored, Sunlit and Shaded Roof*

Based on 95°F DB Outdoor Design Temp; Constant 80°F DB Room Temp
20°F Daily Range; 24 Hour Operation; 40° and N Lat.

CONDITION	Weight of Wall (lb/sq.ft)	SUN TIME																							
		AM							PM													AM				
		6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5
Exposed to Sun	10	-4	-6	-7	-5	1	7	15	24	32	38	43	46	45	41	35	28	22	16	10	7	3	1	-1	-3
	20	0	-1	-2	-1	2	9	16	23	30	36	41	43	43	40	35	30	25	20	15	12	8	6	4	2
	40	4	3	2	3	6	10	16	23	28	33	38	40	41	39	35	32	28	24	20	17	13	11	9	6
	60	9	8	6	7	8	11	16	22	27	31	35	38	39	38	36	34	31	28	25	22	18	16	13	11
	80	13	12	11	11	12	13	16	22	26	28	32	35	37	37	35	34	34	32	30	27	23	20	18	14
Covered with Water	20	-5	-2	0	2	4	10	16	19	22	20	18	16	14	12	10	6	2	1	1	-1	-2	-3	4	-5
	40	-3	-2	-1	-1	0	5	10	13	15	15	16	15	15	14	12	10	7	5	3	1	-1	-2	-3	-3
	60	-1	-2	-2	-2	-2	2	5	7	10	12	14	15	16	15	14	12	10	8	6	4	3	2	1	0
Sprayed	20	-4	-2	0	2	4	8	12	15	18	17	16	15	14	12	10	6	2	1	0	-1	-2	-2	-3	-3
	40	-2	-2	-1	-1	0	2	5	9	13	14	14	14	14	13	12	9	7	5	3	1	0	0	-1	-1
	60	-1	-2	-2	-2	-2	0	2	5	8	10	12	13	14	13	12	11	10	8	6	4	2	1	0	-1
Shaded	20	-5	-5	-4	-2	0	2	6	9	12	13	14	13	12	10	8	5	2	1	0	-1	-3	4	-5	-5
	40	-5	-5	-4	-3	-2	0	2	5	8	10	12	13	12	11	10	8	6	4	2	0	-1	-3	-4	-5
	60	-3	-3	-2	-2	-2	-1	0	2	4	6	8	9	10	10	10	9	8	6	4	2	1	0	-1	-2
		6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5
		AM							PM												AM				
		SUN TIME																							

Equation : Heat Gain through Roofs, Btu / hr = (Area, Sq. Ft.) x (Equivalent temp diff.) x (Transmission Coefficient U)
* With attic ventilated and ceiling insulated roofs, reduce equivalent temp diff. 25%
For peaked roofs, use the roof area projected on a horizontal plane.
For other conditions, refer to corrections in table below.

Table 1.23: Corrections to Equivalent Temperatures (Deg. F)

Outdoor Design for month at 3 PM Minus Room Temp. (Deg.F/)	DAILY RANGE (Deg.F)																
	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40
-30	-39	-40	-41	-42	-43	-44	-45	-46	-47	48	-49	-50	-51	-52	-53	-54	-55
-20	-29	-30	-31	-32	-33	-34	-35	-36	-37	-38	-39	-40	41	-42	-43	-44	-45
-10	-19	-20	-21	-22	-23	-24	-25	-26	-27	-28	-29	-30	-31	-32	-33	-34	-35
0	-9	-10	-11	-12	-13	-14	-15	-16	-17	-18	-19	-20	-21	-22	-23	-24	-25
5	-4	-5	-6	-7	-8	-9	-10	-11	-12	-13	-14	-15	-16	-17	-18	-19	-20
10	1	0	-1	-2	-3	-4	-5	-6	-7	-8	-9	-10	-11	-12	-13	-14	-15
15	6	5	4	3	2	1	0	-1	-2	-3	4	-5	-6	-7	-8	-9	-10
20	11	10	9	8	7	6	5	4	3	2	1	0	-1	-2	-3	-4	-5
25	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
30	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5
35	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10
40	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15

Source : Carrier Handbook

Table 1.24: Heat gain from people

DEGREE OF ACTIVITY	TYPICAL APPLICATION	Metabolic Rate (Adult Male Btu/hr)	Average-Adjusted Metabolic Rate* Btu/hr	ROOM DRY - BULB TEMPERATURE									
				82F		80F		78F		75F		70F	
				Btu/hr		Btu/hr		Btu/hr		Btu/hr		Btu/hr	
				Sensible	Latent	Sensible	Latent	Sensible	Latent	Sensible	Latent	Sensible	Latent
Seated at rest	Theater, Grade School	390	350	175	175	195	155	210	140	230	120	260	90
Seated, Very light work	High School	450	400	180	220	195	205	215	185	240	160	275	125
Office Worker	Offices, Hotels Apts. College	475	450	180	270	200	250	215	235	245	205	285	165
Standing, Walking Slowly	Dept. Retail or Variety Store	550											
Walking, Seated	Drug Store	550	500	180	320	200	300	220	280	255	245	290	210
Standing, Walking Slowly	Bank	550											
Sedentary work	Restaurant	500	220	190	360	220	330	240	310	280	270	320	230
Light Bench Work	Factory Light Work	800	750	190	560	220	530	245	505	295	455	365	385
Moderate dancing	Dance Hall	900	850	220	630	245	605	275	575	325	525	400	450
Walking 3 mph	Factory, fairly heavy work	1000	1000	270	730	300	700	330	670	380	620	460	540
Heavy work	Bowling Alley Factory	1500	1450	450	1000	465	985	485	965	525	925	605	845

Adjusted Metabolic Rate is the metabolic rate to be applied to a mixed group of people with a typical percent composition based on the following factors : Metabolic Rate, Adult Female = Metabolic Rate, Adult Male x 0.85. Metabolic Rate, Children = Metabolic Rate, Adult male x 0.75.

Restaurant - values for this application include 60 Btu per hr for Food per individual (30 Btu Sensible and 30 Btu Latent (Heat per hr.)
Bowling-Assume one person per alley, actually bowling and all others sitting, Metabolic Rate 400 Btu per hr. or standing, 550 Btu per hr.

Table 1.25 : Typical Bypass Factors
(For Finned Coils)

DEPTH OF COILS (ROWS)	WITHOUT SPRAYS		WITH SPRAYS*	
	8 ftns/In.	14 fins/to	8 flns/in.	14 fins/in
	300 - 700	300 - 700	300 - 700	300 - 700
2	0.42 - 0.55	0.22 - 0.38		
3	0.27 - 0.40	0.10 - 0.23		
4	0.19 - 0.30	0.05 - 0.14	0.12 - 0.22	0.03 - 0.10
5	0.12 - 0.23	0.02 - 0.09	0.08 - 0.14	0.01 - 0.08
6	0.08 - 0.18	0.01 - 0.06	0.06 - 0.11	0.01 - 0.05
8	0.03 - 0.08		0.02 - 0.05	

*The bypass factor with spray coils is decreased because the spray provides more surface for conditioning the air.

Table 1.26 : Typical Bypass Factors
(For Various Applications)

COIL BYPASS FACTOR	TYPE OF APPLICATION	EXAMPLE
0.30 to 0.50	A small total load or a load that is somewhat larger with a low sensible heat factor (high latent load)	Residence
0.20 to 0.30	Typical comfort application with a relatively small total load or a low sensible heat factor with a somewhat larger load	Residence, small retail shop, factory
0.10 to 0.20	Typical comfort application	Dept. Store, Bank, Factory
0.05 to 0.10	Applications with high internal sensible loads or requiring a large amount of outdoor air for ventilation	Dept. Store, restaurant, factory
0 to 0.10	All outdoor air applications	Hospital Operating Room, Factory

Source : Carrier Handbook

Table 1.27 : Recommended Rates of Radiant and Convectlve Heat Gain from Warewashing Equipment during idle (standby) or washing conditions

Appliance	Energy Rate Btu/h		Rate of H*at Gain, Btu/h					Usage Factor Fu	Radiation Factor Fr
			Unhooded				Hooded		
	RATED	Standby/ Washing	Sensible Radiant	Sensible Convective	Latent	Total	Sensible Radiant		
Dishwasher (conveyor type, chemical sanitizing	46800	5700/43600	0	4450	174940	17940	0	0.36	0
Dishwasher (conveyor type, hot water sanitizing) standby	46800	5700/N/A	0	4750	16970	21720	0	N/A	0
Dishwasher (door type, chemical sanitizing wash-ing)	18400	1200/13300	0	1980	2790	4770	0	0.26	0
Dishwasher (door type hot water sanitizing) washing	18400	1200/13300	0	1980	2790	4770	0	0.26	0
Dishwasher* (under counter type chemical sanitizing) standby	26600	1200/18700	0	2280	4170	6450	0	0.35	0.0
Dishwasher* (under counter type, hot water sanitizing) standby	26600	1700/19700	800	1040	3010	4850	800	0.27	0.34
Booster heater*	130000	0	500	0	0	0	500	0	N/A
Note : Heat load values are prorated for 30% washing and 70% standby.									

Table 1.28 : Recommended Heat Gain from Typical Medical Equipment

Equipment	Nameplate, W	Peak	Average
Anesthesia System	250	177	166
Blanket Warmer	500	504	221
Blood Pressure Meter	180	33	29
Blood Warmer	360	204	114
ECG / Resp.	1440	54	50
Electrosurgery	1000	147	109
Endoscope	1688	605	596
Harmonic Scalpel	230	60	59
Hysteroscopic Pump	180	35	34
Laser Sonics	1200	256	229
Optical Microscope	330	65	63
Pulse Oximeter	72	21	20
Stress Treadmill	N/A	198	173
Ultrasound System	1800	1063	1050
Vacuum Suction	621	337	302
X-Ray System	968		82
	1725	534	480
	2070		18

Source : ISHRAE Handbook

Table 1.29 : Recommended Heat Gain from Typical Laboratory Equipment

Equipment	Nameplate	Peak	Average
Analytical Balance	7	7	
Centrifuge	138	89	87
	288	136	132
	5500	1176	730
Electrochemical analyzer	50	45	44
	100	85	84
Flame Photometer	180	107	105
Fluorescent Microscope	150	144	143
	200	205	178
Function generator	56	29	29
Incubator	515	461	451
	600	479	264
	3125	1335	1222
Orbital Shaker	100	16	16
Oscilloscope	72	38	38
	345	99	97
Rotary Evaporator	75	74	73
	94	29	28
Spectronlcs	36	31	31
Spectrophotometer	575	106	104
	200	122	121
	N/A	127	125
Spectroflurometer	340	405	395
Thermocycler	1840	965	641
	N/A	233	198
Tissue Culture	475	132	46
	2346	1178	1146

Table 1.30 : Recommended Heat Gain from Typical Computer Equipment

Equipment	Description	Nameplate Power Consumption, W	Average Power Consumption, W
Desktop Computer[a]	Manufacturer A (model A); 2.8 GHz processor, 1 GB RAM	480	73
	Manufacturer A (model B); 2.6 GHz processor, 2 GB RAM	480	49
	Manufacturer B (model A); 3.0 GHz processor, 2 GB RAM	690	77
	Manufacturer B (model B); 3.0 GHz processor, 2 GB RAM	690	48
	Manufacturer A (model C); 2.5 GHz processor, 2GB RAM	1200	97
Laptop Computer[b]	Manufacturer 1; 2.0 GHz processor, 2 GB RAM, 17 in screen	130	36
	Manufacturer 1; 1.8 GHz processor, 1 GB RAM, 17 in screen	90	23
	Manufacturer 1; 2.0 GHz processor, 1 GB RAM, 14 in screen	90	31
	Manufacturer 2; 2 .13 GHz processor, 1 GB RAM, 14 in. screen tablet PC	90	29
	Manufacturer 2; 366 MHz processor, 130 MB RAM, 14 in. screen	70	22
	Manufacturer 3; 900 MHz processor, 256 MH RAM, 10.5 in. screen	50	12
Flat panel monitor[c]	Manufacturer X (model); 30 in. screen	383	90
	ManufactureR X (model); 22 in. screen	360	36
	Manufacturer Y (model); 19 in. screen	288	28
	Manufacturer Y (model); 1 7 in screen	240	27
	Manufacturer Y (model); 17 in. screen	240	29
	Manufacturer Y (model); 15 in. screen	240	19

[a]Power consumption for newer desktop computers in operational mode varies from 50 to 100 W, but a conservative value of about 65W may be used. Power consumption in sleep mode is negligible because of cooling fan. Approximately 90% ot load is by convection and 10% is by radiation. Actual power consumption is about 10 to15% of nameplate value.
[b]Power consumption of laptop computer is relatively small depending on processor speed and section size, it varies from about 15 to 40W.

Table 1.31 : Recommended Heat Gain from Typical Laser Printers and Copier

Equipment	Description	Nameplate Power consumption, W	Average Power Consumption, W
Laser Printer	Printing speed up to 10 pages per minute	430	137
Typical desktop	Printing speed up to 35 pages per minute	890	74
Small-office type[a]	Printing speed up to 19 pages per minute	508	88
	Printing speed up to 17 pages per minute	508	98
	Printing speed up to 19 pages per minute	635	110
	Printing speed up to 24 pages per minute	1344	130
Multifunction (copy, print, scan)b	Small, Desktop type	600 40	30 15
	Medium, desktop type	700	135
Scanner[b]	Small, desktop type	19	16
Copy machine[c]	Medium	1750	800 (idle 260 W)
		1440	550 (idle 135 W)
		1850	1060 (idle 305 W)
Fax machine	Medium, desktop type	936	90
	Small	40	20
Plotter	Manufacturer A	400	250
	Manufacturer B	456	140

Source : Hospital and Beak (2008)
[a]Various Laser Printers commercially and commonly used in personal offices were tested for power consumption in print mode which varied from 75 to 140 W, depending on model, print capacity and speed. Average power consumption of 11 W may be used, split between convection and radiation in approximately 70/30%.
[b]Small multi-function (copy scan print) systems use about 15 to 30 W; medium sized ones use about 135W. Power consumption in idle mode is negligible.

Nameplate values do not represent actual power consumption and should not be used. Small single -sheet scanners consume less than 20 W and do not contribute significantly to building cooling load.
[c]Power consumption for large machines in large Offices and Centers ranges from about 550 to 1100 W in copy mode. Consumption in idle mode varies from about 130 to 300W. Idle mode power consumption is mostly convective in Cooing Load Calculations.

Source : ASHRAE Handbook

Table 1.32: Recommended Heat Gain from Miscellaneous Office Equipment

Equipment	Maximum Input Rating, W	Recommended Rate of Heat Gain, W
Mail-processing equipment		
Folding Machine	125	80
Inserting Machine 1600 to 6800 pieces / hr	600 to 3300	390 to 2150
Labeling Machine 1500 to 30,000 pieces/hr	600 to 6600	390 to 4300
Postage Meter	230	150
Vending Machines		
Cigarette	72	72
Cold food / beverage	1150 to 1920	575 to 960
Hot Beverage	1,725	862
Snack	240 to 275	240 to 275
Other		
Bar Code Printer	440	370
Cash Registers	60	48
Check processing workstation 12 pockets	4800	2470
Coffee Maker, 10 cups	1500	1 050 W sens 1 540 Btu/h latent
Microfilm reader	85	85
Microfilm reader	520	520
Microfilm reader / printer	1150	1150
Microwave oven, 1 ft 3	600	400
Paper Shredder	250 to 3000	200 to 2420
Water Cooler, 32LPh	700	350

Table 1.34 : Recommended Load Factors for Various Types of Offices

Types of Use	Load Factor W/ft²	Description
100% Laptop, Light	0.25	167 ft²/ workstation, all laptop use, 1 printer, 10 speakers, misc.
Medium	0.33	125 ft2/workstation, all laptop use, 1 printer, 10 speakers, misc.
50% Laptop, Light	0.40	167 ft²/workstation, 50% laptop /50% desktop 1 printer per 10 speakers, misc.
Medium	0.50	125 ft²/workstation, all laptop use, 1 printer per 10 speakers, misc.
100% Desktop, Light medium	0.60 0.80	167 ft²/ workstation, all desktop use, 1 printer per 10 speakers, misc. 125 ft²/workstation, all desktop use, 1 printer per 10 speakers, misc.
100% Desktop, Two monitors	1.00	125 ft²/ workstation, all desktop use, 2 monitors, 1 printer per 10 speakers, misc.
100% Desktop, Heavy	1.50	85 ft²/ workstation, all desktop use, 2 monitors, 1 printer per 8 speakers, misc.
100% Desktop Full on	2.00	85 ft²/workstation, all desktop use, 2 monitors 1 printer per 8 speakers, misc., No diversity

Source : ASHRAE 2009

Table 1.33: Gain Load Estimates for Various Office Load Densities

Load Density*	Num-ber	Each W	Total W	Diver-sity	Load W
Light					
Computers	6	55	330	0.67	220
Monitors	6	55	330	0.67	220
Laser Printer - Small Desktop	1	130	130	0.33	43
Fax Machine	1	15	I 15	0.67	10
Total Area Load					**493**
Recommended Equipment Load Factor - 0.5 W/ft²					
Medium					
Computers	8	65	520	0.75	390
Monitors	8	70	560	0.75	420
Laser Printer - Small Desktop	1	215	215	0.5	108
Fax Machine	1	15	15	0.75	15
Total Area Load					**1525**
Recommended Equipment Load Factor - 1.0 W/ft²					
Medium / Heavy					
Computers	10	65	650	1	650
Monitors	10	70	700	1	700
Laser Printer - Small Desktop	1	320	320	0.5	160
Fax Machine	1	30	30	0.5	11
Total Area Load					**929**
Recommended Equipment Load Factor - 1.5 W/ft²					
Heavy					
Computer	12	75	900	1	900
Monitors	12	80	960	1	960
Laser Printer - Small Desktop	1	320	320	0.5	160
Fax Machine	1	30	30	0.5	15
Total Area Load					**2035**
Recommended Equipment Load Factor = 2.0 W/ft²					

Table 1.35: Minimum Nominal Full-Load Efficiency for V60H NEMA General Purpose Electric Motor* (Subtype 1) Rated 600 Volts or Less (Random Wound)*

Name Plater OR Brake Horse Power	Full Load Motor Efficiency Percent	Location of equipment with respect to Conditioned space or Air Stream		
		Motor In, Driven Ma-chine In HP x 2545 / Eff	Motor Out, Driven MacIne in HP x 2545	Motor In Driven Machine out HP x 2545 (1 - % Eff) Eff.
1/20	40	320	130	190
1/12	49	430	210	220
1/8	55	580	320	260
1/6	60	710	430	280
1/4	64	1000	640	360
1/	66	1290	850	440
1/2	70	1820	1280	540
3/4	72	2680	1930	750
1	79	3220	2540	680
1 1/4	80	4770	3820	950
2	80	6380	5100	1280
3	81	9450	7650	1800
5	82	15600	12800	2800
7 1/2	85	22500	19100	3400
10	85	30000	25500	4500
15	86	44500	38200	6300
20	87	58500	51000	7500
25	88	72400	63600	8800
30	89	85800	76400	9400
40	89	115000	102000	13000
50	89	143000	127000	16000
60	89	172000	153000	19000
75	90	212000	191000	21000
100	90	284000	255000	29000
125	90	354000	318000	36000
150	91	420000	382000	38000
200	91	560000	510000	50000
250	91	7000000	636000	64000

Table 1.36A : Minimum 50 Hz efficiency values defined in IEC/EN 60034-30-1:2014 (based on test methods specified in IEC 60034-2-1:2014)

Output kW	IE1				IE2				IE3				IE4			
	2 pole	4 pole	6 pole	8 pole	2 pole	4 pole	6 pole	8 pole	2 pole	4 pole	6 pole	8 pole	2 pole	4 pole	6 pole	8 pole
0.12	45.0	50.0	38.3	31.0	53.6	59.1	50.6	39.8	60.8	64.8	57.7	50.7	66.5	69.8	64.9	62.3
0.18	52.8	57.0	45.5	38.0	60.4	64.7	56.6	45.9	65.9	69.9	63.9	58.7	70.8	74.7	70.1	67.2
0.20	54.6	58.5	47.6	39.7	61.9	65.9	58.2	47.4	67.2	71.1	65.4	60.6	71.9	75.8	71.4	68.4
0.25	58.2	61.5	52.1	43.4	64.8	68.5	61.6	50.6	69.7	73.5	68.6	64.1	74.3	77.9	74.1	70.8
0.37	63.9	66.0	59.7	49.7	69.5	72.7	67.6	56.1	73.8	77.3	73.5	69.3	78.1	81.1	78.0	74.3
0.40	64.9	66.8	61.1	50.9	70.4	73.5	68.8	57.2	74.6	78.0	74.4	70.1	78.9	81.7	78.7	74.9
0.55	69.0	70.0	65.8	56.1	74.1	77.1	73.1	61.7	77.8	80.8	77.2	73.0	81.5	83.9	80.9	77.0
075	72.1	72.1	70.0	61.2	77.4	79.6	75.9	66.2	80.7	82.5	78.9	75.0	83.5	85.7	82.7	78.4
1.1	75.0	75.0	72.9	66.5	79.6	81.4	78.1	70.8	82.7	84.1	81.0	77.7	85.2	87.2	84.5	80.8
1.5	77.2	77.2	75.2	70.2	81.3	82.8	79.8	74.1	84.2	85.3	82.5	79.7	86.5	88.2	85.9	82.6
2.2	79.7	79.7	77.7	74.2	83.2	84.3	81.8	77.6	85.9	86.7	84.3	81.9	88.0	89.5	87.4	84.5
3	81.5	81.5	79.7	77.0	84.6	85.5	83.3	80.0	87.1	87.7	85.6	83.5	89.1	90.4	88.6	85.9
4	83.1	83.1	81.4	79.2	85.8	86.6	84.6	81.9	88.1	88.6	86.8	84.8	90.0	91.1	89.5	87.1
5.5	84.7	84.7	93.1	81.4	87.0	87.7	86.0	83.8	89.2	89.6	88.0	86.2	90.9	91.9	90.5	88.3
7.5	86.0	86.0	84.7	83.1	88.1	88.7	87.2	85.3	90.1	90.4	89.1	87.3	91.7	92.6	91.3	89.3
11	87.6	87.6	86.4	85.0	89.4	89.8	88.7	86.9	91.2	91.4	90.3	88.6	92.6	93.3	92.3	90.4
15	88.7	88.7	87.7	86.2	90.3	90.6	89.7	88.0	91.9	92.1	91.2	89.6	93.3	93.9	92.9	91.2
18.5	89.3	89.3	88.6	86.9	90.9	91.2	90.4	88.6	82.4	92.6	91.7	90.1	93.7	94.2	93.4	91.7
22	89.9	89.9	89.2	87.4	91.3	91.6	90.9	89.1	92.7	93.0	92.2	90.6	94.0	94.5	93.7	92.1
30	90.7	90.7	90.2	88.3	92.0	92.3	91.7	89.8	93.3	93.6	92.9	91.3	94.5	94.9	94.2	92.7
37	91.2	91.2	90.8	88.8	92.5	92.7	92.2	90.3	93.7	93.9	93.3	91.8	94.8	95.2	94.5	93.1
45	91.7	91.7	91.4	89.2	92.9	93.1	92.7	90.7	94.0	94.2	93.7	92.2	95.0	95.4	94.8	93.4
55	92.1	92.1	91.9	89.7	93.2	93.5	93.1	91.0	94.3	94.6	94.1	92.5	95.3	95.7	95.1	93.7
75	92.7	92.7	92.6	90.3	93.8	94.0	93.7	91.6	94.7	95.0	94.6	93.1	95.6	96.0	95.4	94.2
90	93.0	93.0	92.9	90.7	94.1	94.2	94.0	91.9	95.0	95.2	94.9	93.4	95.8	96.1	95.6	94.4
110	93.3	93.3	93.3	91.1	94.3	94.5	94.3	92.3	95.2	95.4	95.1	93.7	96.0	96.3	95.8	94.7
132	93.5	93.5	93.5	91.5	94.6	94.7	94.6	92.6	95.4	95.6	95.4	94.0	96.2	96.4	96.0	94.9
160	93.8	93.8	93.8	91.9	94.8	94.9	94.8	93.0	95.6	95.8	95.6	94.3	96.3	96.6	96.2	95.1
200	94.0	94.0	94.0	92.5	95.0	95.1	95.0	93.5	95.8	96.0	95.8	94.6	96.5	96.7	96.3	95.4
250	94.0	94.0	94.0	92.5	95.0	95.1	95.0	93.5	95.8	96.0	95.8	94.6	96.5	96.7	96.5	95.4
315	94.0	94.0	94.0	92.5	95.0	95.1	95.0	93.5	95.8	96.0	95.8	94.6	96.5	96.7	96.6	95.4
355	94.0	94.0	94.0	92.5	95.0	95.1	95.0	93.5	95.8	96.0	95.8	94.6	96.5	96.7	96.6	95.4
400	94.0	94.0	94.0	92.5	95.0	95.1	95.0	93.5	95.8	96.0	95.8	94.6	96.5	96.7	96.6	95.4
450	94.0	94.0	94.0	92.5	95.0	95.1	95.0	93.5	95.8	96.0	95.8	94.6	96.5	96.7	96.6	95.4
500-1000	94.0	94.0	94.0	92.5	95.0	95.1	95.0	93.5	95.8	96.0	95.8	94.6	96.5	96.7	96.6	95.4

The manufacturer's documentation must show how the efficiency values are determined. Efficiency values can only be compared if they are based on the same testing method.

What are the threshold levels of the motor efficiency classes?
Table 1.36A to the left shows the threshold levels of the motor efficiency classes for 2, 4, 6 and 8 pole motors between 0.12 and 1000 kW at 50 Hz.

How is the IE class marked?
The lowest efficiency value and the associated IE-code of the motor are shown on the rating plate.

How is IEC/EN 60034-30-1 compatible with other efficiency standards?
Differences still exist between the various standards. The IEC standard harmonizes the currently different requirements for induction motor efficiency levels around the world, making the comparison easier. Work to harmonize standards continues.

Table 2 : below shows a rough comparison between IEC/EN 60034-30-1 and main national MEPS schemes world wide.

IEC/EN 60034-30-1	EU MEPS	EISA US EEV Canada	Other, similar local regulations
IE4 Super-Premium efficiency			
IE3 Premium efficiency	IE3 Premium efficiency	Identical to NEMA Premium efficiency	Japan 2015 Australia/New Zealand 2015 Korea 2015 China 2016
IE2 High efficiency	IE2 High efficiency	Identical to NEMA Energy efficiency/ EPACT	Canada Mexico Australia New Zealand Brazil
IE1 Standard efficiency		Below standard efficiency	Costa Rica Israel Taiwan

The IEC/EN 60034-30-1 defines only the requirements for the efficiency classes and aims to create a basis for International consistency. It does not specify which motors must be supplied with which efficiency level. This is left to the respective regional legislation and EU Directive. Each country will be advised to adopt the minimum efficiency levels compatible with the EU Directive as a way to assure availability of the most efficient motors for users.

How does ABB apply the standard?
- ABB has calculated motor efficiency values under the efficiency testing standard (IEC 60034-2-1: 2014) according to the indirect method, with additional losses determined from measuring.
- ABB has a full range of IE2 and IE3 available from stock, and a broad range of IE4 motors.

For more information please visit :
www.abb.com/motors&generators

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Table 1.36B : Recommended Rates of Radiant Heat Gain from Hooded Gas Appliances during Idle (Ready-to-Cook) Conditions

Appliances	Energy Rate, Btu/h		Rate of Heat Gain, Btu/h		
	Rated	Standby	Sensible Radiant	Usage Factor F_{ru}	Radiant Factor F_r
Broiler Batch Type	95000	69200	8100	0.73	0.12
Broiler chain (conveyor)	132000	96700	13200	0.73	0.14
Broiler overfired (upright)	100000	87900	2500	0.88	0.03
Broiler underfired	96000	73900	9000	0.77	0.12
Fryer : Doughnut	44000	12400	2900	0.28	0.23
Fryer : open deep-fat 1 vat	80000	4700	1100	0.06	0.23
Fryer : pressure	80000	9000	800	0.11	0.09
Griddle : double sided 3ft. (clamshell down)	108200	8000	1800	0.07	0.23
Griddle : Double sided 3 ft. (clamshell up)	108200	14700	4900	0.14	0.33
Griddle : flat 3 ft.	90000	20400	3700	0.23	0.18
Oven : Combi: Combi mode	75700	6000	400	0.08	0.07
Oven : Combi: Convention mode	75700	5800	1000	0.08	0.17
Oven : Convention full size	44000	11900	1000	0.27	0.08
Oven : Conveyor (pizza)	170000	68300	7800	0.4	0.11
Oven : deck	105000	20500	3500	0.2	0.17
Oven : rack mini rotating	56300	4500	1100	0.08	0.24
Pasta Cooker	80000	23700	0	0.3	0
Range Top : Top off / oven on	25000	7400	2000	0.3	0.27
Range top : 3 burner on / oven off	120000	60100	7100	0.5	0.12
Range top : 6 burner on / oven off	120000	120800	11500	0.01	0.1
Range top : 6 burner on / oven on	145000	122900	13600	0.85	0.11
Range : wok	99000	87400	5200	0.88	0.06
Rethermalizer	90000	23300	11500	0.26	0.49
Rice Cooker	35000	500	300	0.01	0.60
Salamander	35000	33300	5300	0.95	0.16
Steam kettle : large (60 gal) simmer lid down	145000	5400	0	0.04	0
Steam kettle : large (10 gal) simmer lid down	52000	3300	300	0.06	0.09
Steam kettle : large (40 gal) simmer lid down	10000	4300	0	0.04	0
Steamer : Compartment atmospheric	260000	8300	0	0.32	0
Tilting skillet / braising pan	104000	10400	400	0.1	0.04
Source : Swiercyzna et al. (2008 - 2009)					

Table 1.37 : Recommended Rates of Radiant Heat Gain from Hooded Solid Fuel Appliances During Idle (Ready-to-Cook) Conditions

Appliance	Energy Rate, Btu/h	Rate of Heat Gain Btu/h		Usag* Factor F_u	Radiation Factor F_r
		Standby	Sensible		
Broiler: Solid fuel: Charcoal	40	42,000	6200	N/A	0.15
Broiler: Solid Fuel: wood (mesquite)*	40	49,600	7000	N/A	0.14

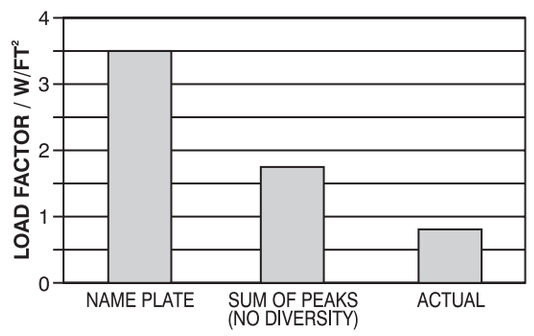


Figure 1.3 : Office Equipment Load Factor Comparison (Wilkins and Me Gaffin 1994)

Source : ASHRAE 2013 - F

NON-RESIDENTIAL COOLING AND HEATING LOAD CALCULATIONS

Table 1.38 : Lighting Power Densities Using Space-by-Space Method

Common Space Types*	LP0, W / ft²	Building - Specific Space Types*	LPD, W/ft²	Building - Specific Space Types*	LPD, W/ft²
Atrium				**Library**	
First 40 ft in height	0.03 per ft (height)	Service/repair (Automobile)		Card file and cataloging	0.72
Height above 40 ft	0.02 per ft (height)	Bank/office	1.38	Reading area	0.93
		Banking activity area		Stacks	1.71
		Convention center		Manufacturing	
Audience/seating area- permanent		Audience seating	0.82	Corridor/transition	0.41
For auditorium	0.79	Exhibit space	1.45	Detailed manufacturing	1.29
For performing arts theatre	2.43	Courthouse/police station/penitentiary		Equipment room	0.95
For motion picture theater	1.14	Courtroom	1.72	Extra high bay (>50 ft floor-to-celling height)	1.05
		Confinement cells	1.10	High bay (25 to 50 ft floor-to-celling height)	1.23
Classroom/lecture/training	1.24	Judge's chambers	1.17	Low bay (<25ft floor-to-celling height)	1.19
Conference/meeting/multipurpose	1.23	Penitentiary audience seating	0.43		
Corridor/transition	0.66	Penitentiary classroom	1.34		
		Penitentiary dining	1.07		
Dining area	0.65	Dormitory		Museum	
For bar lounge/leisure dining	1.31	Living quarter	0.38	General exhibition	1.05
For family dining	0.89	Fire stations		Restoration	1.02
Dressing/fitting room for		Engine room	0.56	Parking Garage	
Performing arts theatre	0.40	Sleeping quarters	0.25	Garage area	0.19
		Gymnasium/fitness center		Post Office	
Electrical/mechanical rooms	0.95	Fitness area	0.72	Sorting area	0.94
Food preparation	0.99	Gymnasium audience seating	0.43	Religious buildings	
		Playing area	1.20	Audience seating	1.53
Laboratory		Hospital		Fellowship hall	0.64
For classroom	1.28	Corridor/transition	0.89	Worship pulpit, cholr	1.53
For medical/industrial/research	1.81	Emergency	2.26	Retail	
		Exam/treatment	1.66	Dressing/fitting room	0.87
Lobby	0.90	Laundry/washing	0.60	Mail concourse	1.10
Lobby for elevator	0.64	Lounge/recreation	1.07	Sales area	1.68
Lobby for performing arts	2.00	Medical supply	1.27	Sports arena	
Theatre	0.52	Nursery	0.88	Audience seating	0.43
Lobby for motion picture theatre		Nurses' station	0.87	Court sports arena-class 4	0.72
	0.75	Operating room	1.89	Court sports arena-class 3	1.20
Locker room	0.73	Patient room	0.62	Court sports arena-class 2	1.92
Lounge/recreation		Pharmacy	1.14	Court sports arena-class 1	3.01
		Physical therapy	0.91	Ring sports arena	2.68
Office	1.11	Radiology/Imaging	1.32	Transportation	
Enclosed	0.98	Recovery	1.16	Alr/traln/bus-baggage area	0.76
Open plan		Hotel/highway lodging		Airport-concourse	0.36
	0.98	Hotel dining	0.82	Waiting area	0.54
Restrooms	1.68	Hotel guest rooms	1.11	Terminal-ticket counter	1.08
Sales area	0.69	Hotel lobby	1.06	Warehouse	
Stairway	0.63	Highway lodging dining	0.88	Fine material storage	0.95
Storage	1.59	Highway lodging guest rooms	0.75	Medium/bulky material storage	0.58
Workshop					

Table 1.39 Apparatus Dew points

90-80 F DB

ROOM CONDITIONS				EFFECTIVE SENSIBLE HEAT FACTOR AND APPARATUS DEWPOINT*									
DB (F)	RH (%)	WB (F)	W (gr/lb)										
90	20	62.7	42.0	ESHF	1.00	0.96	0.92	0.90	0.88	0.86	0.84	0.82	0.81
				ADP	43.5	41	39	37	35	32	29	24	22
	25	65.1	52.7	ESHF	1.00	0.96	0.92	0.88	0.84	0.82	0.80	0.78	0.75
				ADP	49.6	48	46	44	41	39	36	32	22
	30	67.3	63.6	ESHF	1.00	0.92	0.87	0.83	0.80	0.76	0.74	0.72	0.70
				ADP	54.5	52	50	48	46	42	38	34	24
	35	69.3	74.2	ESHF	1.00	0.92	0.85	0.81	0.76	0.73	0.71	0.69	0,96
				ADP	58.8	57	55	53	50	48	45	42	33
	40	71.2	84.8	ESHF	1.00	0.92	0.83	0.78	0.74	0.69	0.66	0.63	0.62
				ADP	62.4	61	59	57	55	52	46	44	40
	45	73.0	96.5	ESHF	1.00	092	0.82	0.78	0.70	0.66	0.62	0.60	0,58
				ADP	65.8	65	63	61	59	56	52	49	43
	50	74.9	106.4	ESHF	1.00	0.92	0.78	0.68	0.64	0.60	0.58	0.56	0.54
				ADP	68.9	68	66	63	61	58	56	53	47
	55	76.7	117.5	ESHF	1.00	0.92	0.76	0.68	0.64	0.57	0.54	0.52	0.50
				ADP	71.6	71	69	67	66	62	59	57	50
	60	78.4	128.4	ESHF	1.00	0.86	0.68	0.60	0.56	0.52	0.50	0.48	0.46
				ADP	74.2	73	71	69	67	64	62	59	50
	65	80.0	139.6	ESHF	1.00	0.75	0.68	0.62	0.55	0.50	0.47	1.45	043
				ADP	76.8	75	74	73	71	69	66	64	59
	70	81.6	151.0	ESHF	1.00	0.78	0.66	0.60	0.52	0.47	0.43	0.41	0.39
				ADP	79.0	78	77	76	74	72	69	66	58
85	20	59.6	35.8	ESHF	1.00	098	095	092	090	088	087	086	084
				ADP	39.4	38	36	34	32	30	28	26	22
	25	61.7	44.8	ESHF	1.00	0.98	0.93	0.90	0.86	0.84	0.82	0.80	0.78
				ADP	45.2	44	42	40	37	35	32	28	20
	30	63.7	54.1	ESHF	1.00	0.94	0.89	0.85	0.81	0.79	0.77	0.75	0.73
				ADP	50.2	48	46	44	40	38	35	31	22
	35	65.5	62.9	ESHF	1.00	0.92	0.86	0.82	0.78	0.74	0.72	0.70	0.69
				ADP	54.1	52	50	48	45	41	38	32	27
	40	67.4	71.7	ESHF	1.00	0.92	0.84	0.79	0.76	0.73	0.69	0.67	0.65
				ADP	57.9	56	54	52	50	48	44	40	32
	45	69.1	81.1	ESHF	1.00	0.92	0.83	0.77	0.72	0.68	0.64	0.62	0.61
				ADP	61.2	60	58	56	54	51	46	41	36
	50	70.8	90.1	ESHF	1.00	0.92	0.80	0.73	0.68	0.64	0.61	0.59	0.57
				ADP	64.2	63	61	59	57	54	51	48	39
	55	72.3	99.4	ESHF	1.00	0.92	0.83	0.73	0.67	0.60	0.57	0.56	0.54
				ADP	66.9	66	65	63	61	57	54	52	47
	60	73.9	108.8	ESHF	1.00	0.92	0.76	0.67	0.61	0.56	0.54	0.52	0.50
				ADP	69.5	69	67	65	63	60	58	55	49
	65	75.5	118.2	ESHF	1.00	0.88	0.69	0.61	0.56	0.53	0.50	0.48	0.47
				ADP	71.9	71	69	67	65	63	61	58	54
	70	77.0	127.6	ESHF	1.00	0.81	0.63	0.55	0.51	0.49	0.47	0.45	0.43
				ADP	74.0	73	71	69	67	66	64	62	55
82	35	63.3	57.0	ESHF	1.00	0.92	0.88	0.84	0.80	0.76	0.74	0.72	0.71
				ADP	51.6	49	48	46	43	39	36	31	27
	40	65.0	65.1	ESHF	1.00	0.90	0.87	0.82	0.78	0.74	0.74	0.69	067
				ADP	55.2	53	52	50	48	45	41	38	31

ROOM CONDITIONS				EFFECTIVE SENSIBLE HEAT FACTOR AND APPARATUS DEWPOINT*									
DB (F)	RH (%)	WB (F)	W (gr/lb)										
82	45	66.7	73.5	ESHF	1.00	0.91	0.87	0.80	0.75	0.72	0.68	0.65	0.63
				ADP	58.5	57	56	54	52	50	46	41	53
	50	68.3	81.9	ESHF	1.00	0.90	0.80	0.74	0.70	0.64	0.64	0.60	0.59
				ADP	615	60	58	56	54	50	47	42	37
	55	69.8	90.2	ESHF	1.00	0.90	0.83	0.74	0.68	0.64	0.61	0.58	0.56
				ADP	64.2	63	62	60	58	56	54	50	44
	60	71.3	96.5	ESHF	1.00	0.92	0.76	0.68	0.63	0.59	0.56	0.54	0.52
				ADP	66.7	66	64	62	60	58	55	52	44
	65	72.8	107.0	ESHF	1.00	0.86	0.71	0.63	0.58	0.54	0.52	0.51	0.49
				ADP	69.1	68	66	64	62	60	58	56	51
	70	74.2	115.5	ESHF	1.00	0.80	0.71	0.65	0.60	0.54	0.51	0.48	0.46
				ADP	71.2	70	69	68	67	65	63	60	56
81	35	62.5	85.2	ESHF	1.00	0.94	0.89	0.84	0.81	0.77	0.75	0.73	0.71
				ADP	50.8	49	47	45	43	39	36	32	21
	40	64.2	63.2	ESHF	1.00	0.94	0.87	0.82	0.78	0.75	0.72	0.69	0.67
				ADP	54.4	53	51	49	47	45	41	36	23
	45	65,9	71.2	ESHF	1.00	0.96	0.91	0.83	0.78	0.74	070	0.67	0.64
				ADP	57.8	57	56	54	52	50	47	43	38
	50	67.5	79.0	ESHF	1.00	0.90	0.84	0.80	0.74	0.70	066	0.62	0.60
				ADP	60.5	59	58	57	55	53	50	45	38
	55	69.0	87.4	ESHF	1.00	0.90	0.77	0.71	0.66	0.62	060	0.58	0.56
				ADP	63.2	62	60	58	56	53	51	47	35
	60	70.8	96.4	ESHF	1.00	0.92	0.77	0.68	0.63	059	056	0.54	0.53
				ADP	65.8	65	63	61	59	56	53	50	46
	65	71.9	103.7	ESHF	1.00	0.85	0.76	0.71	0.66	0.60	056	0.52	0.50
				ADP	68.2	67	66	65	64	62	60	56	52
	70	73.3	111.9	ESHF	1.00	0.80	0.71	0.61	0.55	0.52	048	0.47	0.46
				ADP	70.3	69	68	66	64	62	58	56	52
80	20	56.4	30.4	ESHF	1.00	0.98	0.95	0.93	0.91	0.89	0.88	0.87	0.86
				ADP	35.4	34	32	30	28	26	24	22	20
	25	58.3	38.0	ESHF	1.00	0.96	0.93	0.90	0.88	0.86	0.84	0.82	0.81
				ADP	40.9	39	37	35	33	31	28	24	21
	30	60.0	45.6	ESHF	1.00	0.96	0.91	0.88	0.85	0.83	0.80	0.78	0.76
				ADP	45.7	44	42	40	38	36	32	28	21
	35	61.8	53.5	ESHF	1.00	0.94	0.88	0.85	0.82	0.79	0.77	0.73	0.72
				ADP	49.8	48	46	44	42	40	37	29	24
	40	63.5	61.2	ESHF	1.00	0.94	0.90	0.84	0.80	0.76	0.73	0.70	0.68
				ADP	53.5	52	51	49	47	44	41	36	28
	45	65.1	68.9	ESHF	1.00	0.96	0.87	0.81	0.76	0.73	0.70	0.67	0.64
				ADP	56.8	56	54	52	50	48	45	41	31
	50	66.7	76.7	ESHF	1.00	0.89	0.80	074	0.70	0.66	0.64	0.62	0.61
				ADP	59.7	58	56	54	52	49	46	42	39
	55	68.2	84.6	ESHF	1.00	0.89	0.82	0.74	0.69	0.65	0.61	0.59	0.57
				ADP	62.3	61	60	58	56	54	50	47	40
	60	69.6	92.3	ESHF	1.00	0.91	0.83	0.72	0.66	0.62	0.59	0.57	0.54
				ADP	64.8	64	63	61	59	57	55	53	47
	65	71.1	100.4	ESHF	1.00	0.85	0.76	0.71	0.63	0.58	0.55	0.52	0.50
				ADP	67.2	65	65	64	62	60	58	54	47
	70	72.4	108.3	ESHF	1.00	0.78	0.71	0.65	0.61	0.55	0.52	0.49	0.47
				ADP	69.4	68	67	66	65	63	61	58	53

Table 1.40 Apparatus Dew points

79-72 F DB

ROOM CONDITIONS				EFFECTIVE SENSIBLE HEAT FACTOR AND APPARATUS DEWPOINT*									
DB (F)	RH (%)	WB (F)	W (gr/lb)										
79	35	61.0	51.5	ESHF	1.00	0.96	0.91	0.89	0.85	0.82	0.78	0.75	0.73
				ADP	48.9	48	46	45	43	41	37	32	26
	40	62.7	59.2	ESHF	1.00	0.97	0.90	0.84	0.80	0.76	0.74	0.71	0.69
				ADP	52.7	52	50	48	46	43	41	36	29
	45	64.3	66.7	ESHF	1.00	0.91	0.83	0.78	0.75	0.72	0.70	0.67	0.65
				ADP	55.9	54	52	50	48	46	44	39	32
	50	65.9	74.2	ESHF	1.00	0.89	0.80	0.75	0.71	0.69	0.66	0.63	0.61
				ADP	58.9	57	55	53	51	49	47	42	33
	55	67.4	81.9	ESHF	1.00	0.96	0.82	0.74	0.69	0.66	0.63	060	0.68
				ADP	61.4	61	59	57	5	53	51	47	41
	60	68.8	89.3	ESHF	1.00	0.90	0.76	0.69	0.64	0.61	0.57	0.55	0.54
				ADP	63.9	63	61	59	57	55	51	47	41
	65	70.2	97.0	ESHF	1.00	0.84	0.71	0.64	0.59	0.56	0.54	0.52	0.51
				ADP	66.3	65	63	61	59	57	55	51	48
	70	71.6	104.8	ESHF	1.00	0.81	371	0.65	0.58	0.54	0.52	050	0.48
				ADP	68.5	67	66	65	63	61	59	57	53
78	35	60.3	50.0	ESHF	1.00	0.96	0.87	0.83	0.83	0.79	0.77	0.75	0.73
				ADP	48.2	47	43	41	41	37	35	31	22
	40	61.9	57.3	ESHF	1.00	0.93	0.82	0.79	079	0.77	0.73	0.71	0.69
				ADP	51.7	50	46	44	44	42	38	34	25
	45	63.5	64.6	ESHF	1.00	0.95	0.81	0.76	0.76	0.74	0.70	0.68	0.66
				ADP	55.0	54	50	48	48	46	42	39	34
	50	65.0	71.9	ESHF	1.00	0.94	0.76	0.73	0.73	0.70	0.67	0.64	0.62
				ADP	57.9	57	53	51	51	49	47	42	36
	55	66.6	79.2	ESHF	1.00	0.96	0.75	0.70	0.70	0.65	0.62	0.60	0.59
				ADP	60.5	60	56	54	54	51	48	44	41
	60	67.9	86.4	ESHF	1.00	0.90	0.76	0.69	0.69	0.64	0.60	0.57	0.55
				ADP	63.0	62	60	58	58	56	53	49	42
	65	69.3	93.8	ESHF	1.00	085	0.71	0.67	0.67	0.62	0.58	0.54	0.52
				ADP	65.2	64	62	61	61	59	57	53	48
	70	70.6	101.2	ESHF	1.00	0.71	0.62	0.59	0.59	0.55	0.52	0.50	0.48
				ADP	67.5	65	63	62	62	60	58	55	48
77	35	59.6	48.3	ESHF	1.00	0.96	0.91	0.87	0.83	0.79	0.77	0.75	0.74
				ADP	47.3	46	44	42	40	36	33	28	24
	40	61.2	55.5	ESHF	1.00	0.96	0.89	0.84	0.81	0.78	0.76	0.73	0.70
				ADP	50.9	50	48	46	44	42	40	36	27
	45	62.7	62.4	ESHF	1.00	0.94	0.86	0.81	0.77	0.74	0.72	0.69	0.66
				ADP	54.1	53	51	49	47	45	43	39	29
	50	64.2	69.7	ESHF	1.00	0.94	0.84	0.77	0.73	0.70	0.68	0.65	0.63
				ADP	57	56	54	52	50	48	46	42	37
	55	65.6	76.6	ESHF	1.00	0.95	0.83	0.75	0.70	0.67	0.63	0.61	0.59
				ADP	59.6	59	57	55	53	51	48	44	37
	60	67.1	83.6	ESHF	1.00	0.89	0.82	0.77	0.73	0.67	0.62	0.58	0.56
				ADP	62.0	61	60	59	58	56	53	48	43
	65	68.5	90.8	ESHF	1.00	0.84	0.72	0.64	0.60	0.57	0.55	0.54	0.53
				ADP	64.4	63	61	59	57	55	53	51	48
	70	69.8	97.9	ESHF	1.00	0.79	0.66	0.60	0.55	053	0.51	0.50	0.49
				ADP	66.5	65	63	61	59	57	55	53	49

ROOM CONDITIONS				EFFECTIVE SENSIBLE HEAT FACTOR AND APPARATUS DEWPOINT*									
DB (F)	RH (%)	WB (F)	W (gr/lb)										
76	35	58.9	46.7	ESHF	1.00	0.96	0.91	0.87	0.84	0.81	0.79	0.77	0.74
				ADP	46.3	45	43	41	39	37	34	31	21
	40	60.4	53.7	ESHF	1,00	0,86	0,68	0.64	0.81	0.78	0.76	0.72	0.70
				ADP	49.9	49	47	46	43	41	39	32	22
	45	61.9	60,4	EBHF	1,00	0.84	0.86	0,61	0.77	0.74	0.71	0.69	0.67
				AOP	53.2	62	60	46	46	44	40	37	31
	50	63.4	67,4	ESHF	1.00	0,83	0.63	0.77	0,73	0.69	0.67	0.65	0.63
				ADP	56.2	55	53	51	49	46	43	40	32
	55	64.9	74.0	ESHF	1.00	0.94	0.82	0.75	0.70	0.67	0.65	0.62	0.60
				ADP	58.7	58	56	54	52	50	48	44	38
	60	66.2	80.9	ESHF	1.00	0.90	0.77	0.70	0.66	0.62	0.60	0.58	0.57
				ADP	61.1	60	58	56	54	52	49	46	43
	65	67.6	87.6	ESHF	1.00	0.84	0.72	0.65	0.61	0.58	0.56	0.54	0.53
				ADP	63.4	62	60	58	56	54	52	48	43
	70	68.9	94.6	ESHF	1.00	0.80	0.67	0.60	0.56	0.54	0.52	0.51	0.50
				ADP	65.5	64	62	60	58	56	54	52	49
75	20	53.2	25.7	ESHF	1.00	0.98	0.96	0.94	0.92	0.90	0.89		
				ADP	31.5	30	28	26	24	22	20		
	25	54.8	32.1	ESHF	1,00	0.85	0.92	0.80	0.88	0.86	0,84		
				ADP	36.9	34	32	30	28	25	21		
	30	56.5	38,5	ESHF	1.00	0.87	0.83	0,80	0.87	0.85	0.82	0.80	0.79
				ADP	41,4	40	36	36	34	32	28	24	20
	35	58.1	45.2	ESHF	1.00	0,86	0.81	0.67	0.84	0.80	0,78	0.76	0.75
				ADP	45.5	44	42	40	38	34	31	27	22
	40	59.6	51.8	ESHF	1.00	0.86	0.69	0.64	0.81	0079	0.76	0,73	0.71
				ADP	49.1	48	46	44	42	40	37	32	24
	45	61.1	58.2	ESHF	1.00	0.84	0,87	0.61	0.77	0,75	0.72	0.69	0.67
				ADP	52.2	51	48	47	45	43	40	35	21
	50	62.6	65.0	ESHF	1.00	0.82	0.64	0.76	0.74	0,71	0.69	0.66	0.64
				ADP	55.2	54	62	60	48	46	44	40	34
	55	64.0	71.5	ESHF	1.00	0.94	0.87	0.78	0.73	0.69	0.65	0.63	0.61
				ADP	57.8	57	56	54	52	50	47	44	39
	60	65.3	77.9	ESHF	1.00	0.80	0.77	0.71	0.66	0.63	0.61	0.59	0.58
				ADP	60.1	59	57	55	53	51	49	46	43
	65	66.7	64.6	ESHF	1.00	0.84	0.72	0.65	0.61	0.59	0.57	0.55	0.54
				ADP	62.4	61	59	57	55	53	51	48	48
	70	68.0	91.2	ESHF	1,00	0.80	0.73	0.68	0.61	0.57	0.54	0.52	0.51
				ADP	64.5	63	62	61	59	57	55	52	49
72	35	55.9	40.8	ESHF	1.00	0.98	0.93	0.89	0.86	0.83	0.81	0.79	0.77
				ADP	42.8	42	40	38	36	34	31	28	22
	40	57.3	46.7	ESHF	1.00	0.95	0.92	0.87	0.84	0.81	0.77	0.75	0.73
				ADP	46.3	45	44	42	40	38	34	30	23
	45	58.7	52.7	ESHF	1.00	0.94	0.87	0.82	0.79	0.76	0.74	0.71	0,69
				ADP	49.5	48	46	44	42	40	38	32	22
	50	60.1	58.8	ESHF	1.00	0.92	0.88	0.81	0.77	0.73	0.70	0.68	0.66
				ADP	52.4	51	50	48	46	43	40	37	30
	55	61.4	64.4	ESHF	1.00	0.93	0.83	0.77	0.72	0.68	0.66	0.64	0.63
				ADP	54.9	54	52	50	48	45	42	39	36
	60	62.7	70.2	ESHF	1.00	0.89	0.79	0,72	0.68	0,66	0.65	0,61	0.60
				ADP	57.3	56	54	52	50	46	48	42	38

Table 1.41 Apparatus Dew points

72-55 F DB

ROOM CONDITIONS				EFFECTIVE SENSIBLE HEAT FACTOR AND APPARATUS DEWPOINT*									
DB (F)	RH (%)	WB (F)	W (gr/lb)										
72	65	840	76.3	ESHF	1.00	0.84	0.73	0.67	0.63	0.61	0.59	0.58	
				ADP	59.5	58	56	54	52	50	48	47	
	70	65.2	82.3	ESHF	1.00	0.80	0.69	0.62	0.59	0.56	0.54	0.53	
				ADP	61.6	60	58	56	54	51	48	44	
70	20	49.9	21.6	ESHF	1.00	0.98	0.98	0.94	0.93				
				ADP	27.6	26	24	22	21				
	25	51.5	27.0	ESHF	1.00	0.97	0.94	0.92	0.90	0.88			
				ADP	33.7	31	29	27	25	22			
	30	53.0	32.8	ESHF	1.00	0.98	0.94	0.91	0.88	0.86	0.84	0.82	
				ADP	37.1	36	34	32	30	27	25	20	
	35	54.4	38.0	ESHF	1.00	0.97	0.93	0.89	0.86	0.84	0.82	0.80	0.78
				ADP	41.1	40	38	36	34	32	30	27	22
	40	55.8	43.5	ESHF	1.00	0.95	0.90	0.86	0.83	0.80	0.78	0.76	0.74
				ADP	44.5	43	41	39	37	35	32	29	22
	45	57.1	49.1	ESHF	1.00	0.93	0.87	0.82	0.79	0.77	0.75	0.73	071
				ADP	47.7	46	44	42	40	38	36	33	27
	50	58.5	54.8	ESHF	1.00	0.92	0.84	0.80	0.76	0.74	0.71	0.69	0,67
				ADP	50.5	49	47	45	43	41	38	35	25
	55	59.7	60.1	ESHF	1.00	0.93	0.83	0.77	0.73	0.71	0.68	0.66	0.64
				ADP	53.1	52	50	48	46	44	42	38	32
	60	60.9	65.5	ESHF	1.00	0.89	0.79	0.73	0.69	0.66	0.64	0.62	0.61
				ADP	55.4	54	52	50	48	46	43	40	36
	65	62.2	71.1	ESHF	1.00	0.93	0.78	071	0.66	0.63	0.61	0.59	0.58
				ADP	57.7	57	55	53	51	49	47	44	40
	70	63.4	76.9	ESHF	1.00	0.90	0.74	0.66	0.61	0.59	0.57	0.56	0,55
				ADP	59.8	59	57	55	53	51	49	47	45
	75	64.5	82.5	ESHF	1.00	0.88	0.70	0.62	0.57	0.55	053	0.52	0.51
				ADP	61.7	61	59	57	55	53	51	49	44
	80	65.7	88.0	ESHF	1.00	0.87	0.73	0.65	0.60	0.54	0.51	0.49	0.48
				ADP	63.5	63	62	61	60	58	56	53	49
	85	66.8	93.7	ESHF	1.00	0.71	0.56	0.52	0.50	0.48	0.47	0.46	0.45
				ADP	65.3	64	62	61	60	59	58	57	54
	90	67.9	99.3	ESHF	1.00	0.66	0.56	0.50	0.47	0.45	0.43	0.42	0.41
				ADP	66.9	66	65	64	63	62	61	60	56
	95	69.0	105.0	ESHF	1.00	0.60	0.47	0.42	0.39	0.38	0,37		
				ADP	68.5	68	67	66	65	64	62		

* The values shown in the gray areas indicate the lowest effective sensible heat factor possible without the use of reheat. This limiting condition is the lowest effective sensible heat factor line that intersects the saturation curve. Note that the room dewpoint is equal to the required apparatus dewpoint for an effective sensible heat factor of 1.0.

Source : Carrier Handbook

ROOM CONDITIONS				EFFECTIVE SENSIBLE HEAT FACTOR AND APPARATUS DEWPOINT*									
DB (F)	RH (%)	WB (F)	W (gr/lb)										
60	60	52.3	46.2	ESHF	1.00	0.94	0.89	0.81	0.77	0.74	0.72	0.70	0.68
				ADP	46.0	45	44	42	40	38	36	34	28
	65	53.3	50.0	ESHF	1.00	0.91	0.86	0.78	0.74	0.70	0.69	0.67	0.65
				ADP	48.1	47	46	44	42	40	39	36	31
	70	54.3	53.9	ESHF	1.00	0.89	0.83	0.74	0.70	0.67	0.65	0.63	0.62
				ADP	50.1	49	48	46	44	42	40	37	34
	75	55.3	57.8	ESHF	1.00	0.79	0.74	0.71	0.68	0.64	0.62	0.60	0.59
				ADP	52.0	50	49	48	47	45	43	40	37
	80	56.3	61.7	ESHF	1.00	0.85	0.76	0.70	0.66	0.61	0.59	0.57	0.56
				ADP	53.8	53	52	51	50	48	46	44	41
	85	57.2	65.5	ESHF	1.00	0.75	0.67	0.63	0.57	0.56	054	0.53	
				ADP	55.4	54	53	52	50	49	47	45	
	90	58.2	69.4	ESHF	1.00	0.72	0.62	0.57	0.54	0.52	0.50	0.49	
				ADP	57.0	56	55	54	53	52	50	47	
	95	59.1	73.5	ESHF	1.00	0.69	0.55	0.49	0.47	0.46	0.45		
				ADP	58.5	58	57	56	55	54	52		
55	60	47.9	38.4	ESHF	1.00	0.93	0.89	0.85	0.80	0.77	0.75	0.73	0.71
				ADP	41.3	40	39	38	36	34	32	29	23
	65	48.8	41.4	ESHF	1.00	0.91	0.86	0.83	0.78	0.74	0.72	0.70	0.68
				ADP	43.3	42	41	40	38	36	34	31	24
	70	49.7	44.6	ESHF	1.00	0.90	0.84	0.80	0.74	0.71	0.69	0.67	0.66
				ADP	45.2	44	43	42	40	38	36	33	31
	75	50.6	48.0	ESHF	1.00	0.89	0.82	0.74	0.69	0.66	0..65	0.64	0.63
				ADP	47.1	46	45	43	41	39	37	36	34
	80	51.5	51.2	ESHF	1.00	0.88	0.79	0.74	0.67	0.64	0.62	0.61	0.60
				ADP	48.8	48	47	46	44	42	40	39	37
	85	52.4	54.5	ESHF	1.00	0.77	0.70	0.66	0.63	0.60	0.58	0.57	
				ADP	50.4	49	48	47	46	44	42	40	
	90	53.2	57.7	ESHF	1.00	0.76	0.67	0.61	0.58	0.55	0.54	0.53	
				ADP	52.0	51	50	49	48	46	44	41	
	95	54.2	61.2	ESHF	1.00	0.69	0.58	0.54	0.51	0.49			
				ADP	53.6	53	52	51	50	48			
65	60	56.6	55.0	ESHF	1.00	0.95	0.84	0.77	0.73	0.70	0.68	0.66	0,65
				ADP	50.6	50	48	46	44	42	39	36	34
	65	57.7	59.7	ESHF	1.00	0.92	0.85	0.80	0.73	0.69	0.66	0.64	0.62
				ADP	52.9	52	51	50	48	46	44	41	37
	70	58.9	64.5	ESHF	1.00	0.89	0.80	0.76	0.69	0.65	0.62	0.60	0.58
				ADP	55.0	54	53	52	50	48	46	43	37
	75	59.9	69.2	ESHF	1.00	0.88	0.78	0.72	0.65	0.61	0.58	0.56	0.55
				ADP	56.9	56	55	54	52	50	48	45	41
	80	51.0	73.8	ESHF	1.00	0.75	0.68	0.63	0.60	0.58	0.55	0.53	0.52
				ADP	58.7	57	56	55	54	53	51	48	46
	85	62.0	78.6	ESHF	1.00	0.71	0.63	0.58	0.55	0.52	0.50	0.49	
				ADP	60.3	59	58	57	56	54	52	50	
	90	63.0	83.2	ESHF	1.00	0.70	0.58	0.53	0.50	0.48	0.46	0.45	
				ADP	61.9	61	60	59	58	57	55	53	
	95	64.0	88.0	ESHF	1.00	0.69	0.51	0.46	0.43	0.42	0.41		
				ADP	63.5	63	62	61	60	59	58		

Table 1.42 : Relative Density of Air at various temperatures (70°F = 1.00)

Temp (F)	Relative Density	Temp (F)	Relative Density	Temp (F)	Relative Density	Temp (F)	Relative Density	Temp (F)	Relative Density
-40	1.261	110	0.93	260	0.736	410	0.609	560	0.52
-30	1.233	120	0.914	270	0.726	420	0.603	570	0.515
-20	1.205	130	0.898	280	0.716	430	0.596	580	0.510
-10	1.178	140	0.883	290	0.707	440	0.589	590	0.505
0	1.152	150	0.869	300	0.697	450	0.582	600	0.500
10	1.128	160	0.855	310	0.688	460	0.576	650	0.477
20	1.104	170	0.841	320	0.680	470	0.570	700	0.457
30	1.082	180	0.828	330	0.671	480	0.565	750	0.438
40	1.06	190	0.815	340	0.622	490	0.559	800	0.421
50	1.039	200	0.803	350	0.654	500	0.553	850	0.404
60	1.019	210	0.791	360	0..646	510	0.547	900	0.390
70	1.000	220	0.779	370	0.638	520	0.541	950	0.376
80	0.982	230	0.768	380	0.631	530	0.535	1000	0.364
90	0.964	240	0.757	390	0.624	540	0.530	1050	0.352
100	0.946	250	0.747	400	0,616	650	0.525	1100	0.340

Table 1.43 : Relative Density of Air at various Altitudes

(Sea Level @70°F = 1.00)

Altitude Feet	Relative Density	Corresponding Barometric Pressure
Sea Level	1.00	29.92
200	0.996	29.70
400	0.985	29.49
600	0.978	29.28
800	0.971	29.06
1000	0.964	28.85
1200	0.957	28.65
1400	0.951	28.44
1600	0.944	28.33
1800	0.937	28.02
2000	0.930	27.82
2500	0.913	27.31
3000	0.896	26.81
3500	0.873	26.32
4000	0.864	25.84
5000	0.832	24.89
6000	0.799	23.98
7000	0.774	23.09
8000	0.739	22.12
9000	0.715	21.38
10000	0.687	20.54

Table 1.44 : Standard Atmosphere Data for Altitudes to 60,000 Ft.

Altitude	Temperature °F	Pressure	
		In Hg	psia
-1000	62.6	31.02	15.236
-500	60.8	30.47	14.966
0	59.0	29.921	14.696
500	57.2	29.38	14.430
1000	55.4	28.86	14.175
2000	51.9	27.82	13.664
3000	48.3	26.82	13.173
4000	44.7	25.82	12.682
5000	41.2	24.90	12.230
6000	37.6	23.98	11.778
7000	34.0	23.09	11.341
8000	30.5	22.22	10.914
9000	26.9	21.39	10.506
10000	23.4	20.58	10.108
15000	5.5	16.89	8.296
20000	-12.3	13.76	6.758
30000	-47.8	8.90	4.371
40000	-69.7	5.56	2.731
50000	-69.7	3.44	1.690
60000	-69.7	2.10	1.051

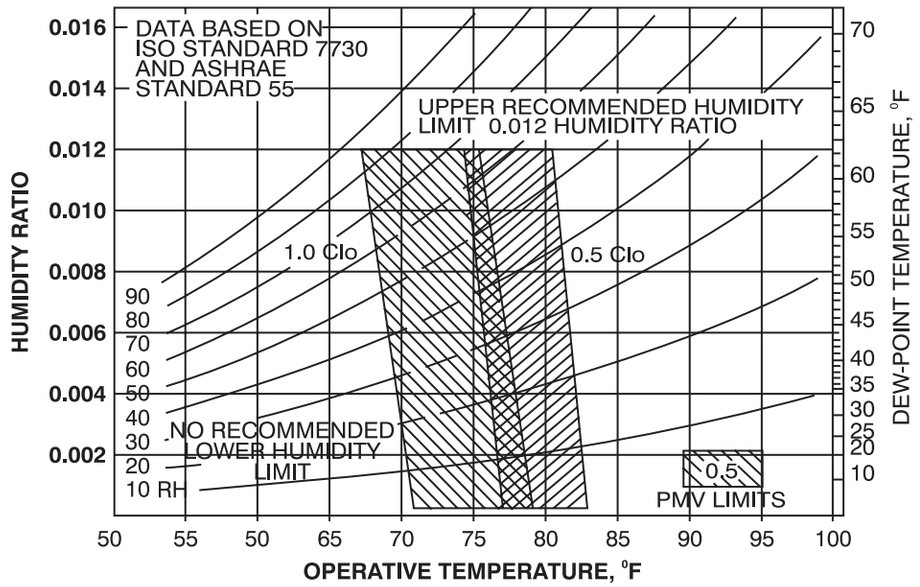
Table 1.45 : Dew Points in °F

Dry Bulb Temp °F	Relative Humidity Percent									
	10	20	30	40	50	60	70	80	90	100
68	14	26.6	35.6	42.8	48.2	53.6	57.2	60.8	64.4	68
71.6	15.8	28.4	39.2	46.4	51.8	57.2	60.8	64.4	68	71.6
75.2	17.6	32	42.8	50	55.4	60.8	64.4	68	71.6	75.2
78.8	19.4	33.8	44.6	51.8	59	64.4	68	71.6	75.2	78.8
82.4	21.2	37.4	48.2	55.4	62.6	68	71.6	75.2	78.8	82.4
86	24.8	41	51.8	59	64.4	69.8	75.2	78.8	82.4	86
89.6	26.6	42.8	53.6	62.6	68	73.4	78.8	82.4	86	89.6
93.2	28.4	46.4	57.2	66.2	71.6	77	82.4	86	89.6	93.2
96.8	32	48.2	60.8	68	75.2	80.6	86	89.6	93.2	96.8
100.4	33.8	51.8	64.4	71.6	78.8	84.2	89.6	93.2	96.8	100.4
104	37.4	55.4	66.2	75.2	82.4	87.8	93.2	96.8	100.4	104
107.6	39.2	57.2	69.8	78.8	86	91.4	96.8	100.4	104	107.6
111.2	42.8	60.8	71.6	80.6	87.8	95	100.4	104	107.6	111.2
114.8	46.4	64.4	75.2	84.2	91.4	98.6	104	107.6	111.2	114.8
118.4	48.2	66.2	78.8	87.8	95	100.2	105.8	111.2	114.8	118.4
122	57.8	69.8	82.4	91.4	98.6	104	109.4	114.8	118.4	122

Table 1.46 : Relative Humidity in percent

For various room temperatures and various differences between Wet and Dry-Bulb temperatures

Dry Bulb Temp°F	Relative Humidity In percent										
	0	2	4	6	8	10	12	14	16	18	20
50	100	87	74	62	50	39	28	17	7	0	0
52	100	88	75	63	52	41	30	20	10	0	0
54	100	88	76	65	54	43	33	23	14	5	0
56	100	88	77	66	55	45	35	26	17	8	0
58	100	88	77	67	57	47	38	28	20	11	3
60	100	89	78	68	58	49	40	31	22	14	6
62	100	89	79	69	60	50	41	33	25	17	9
64	100	90	79	70	61	52	43	35	27	20	12
66	100	90	80	71	62	53	45	37	29	22	15
68	100	90	81	72	63	55	47	39	' 31	24	17
70	100	90	81	72	64	56	48	40	33	26	20
72	100	91	82	73	65	57	49	42	35	28	22
74	100	91	82	74	66	58	51	44	37	30	24
76	100	91	83	74	67	59	52	45	38	32	26
78	100	91	83	75	67	60	53	46	40	34	28
80	100	91	83	76	68	61	54	47	41	35	29
82	100	92	81	76	69	62	55	49	43	37	31
84	100	92	84	77	70	63	56	50	44	38	32
86	100	92	85	77	70	63	57	51	45	39	34
88	100	92	85	78	71	64	58	52	46	41	35
90	100	92	85	78	71	65	59	53	47	42	37
92	100	92	85	78	72	65	59	54	48	43	38
94	100	93	86	79	72	66	60	54	49	44	39
96	100	93	86	79	73	67	61	55	50	45	40
98	100	93	86	79	73	67	61	56	51	46	41
100	100	93	86	80	74	68	62	57	52	47	42



[Acceptable ranges of Operative Temperature and Humidity with air speed ≤ 40 fpm for people wearing between 1.0 and 0.5 clothing during primarily sedentary activity (≤ 1.1 met)]

Figure 1.4: ASHRAE Summer and Winter Comfort Zones

Source : ASHRAE Fundamentals Standard 55 - 2013

Table 1.47: Equivalent Wind Chill Temperature of Cold Environments

	Actual Thermometer Reading (°F)											
Wind Speed (mph)	50	40	30	20	10	0	-10	-20	-30	-40	-SO	-60
	Equivalent Wind Chill Temperature (°F)											
0	50	40	30	20	10	0	-10	-20	-30	-10	-50	-60
5	48	37	27	16	6	-5	-15	-26	-36	-47	-57	-68
10	40	28	16	3	-9	-4	-34	-46	38	-17	-83	-95
15	36	22	9	-5	-18	-32	-45	-54	-72	-86	-99	-113
20	32	18	4	-11	-25	-39	-53	-68	-82	-96		
25	30	15	0	-15	-30	-44	-59	-74	-89	-104		
30	28	13	-3	-18	-33	-48	-64	-79	-94	-110		
35	27	11	-4	-20	-36	-51	-67	-83	-98	-114		
40	26	10	-6	-22	-38	-53	-69	-85	-101	-117		
	Little Danger			Increased danger of freezing within one minute of being exposed				Greater Danger : Flesh may freeze within 30 seconds				

Table 1.48: Desirable Wind Speeds (m/s) for Thermal Comfort Conditions

Dry Bulb Temperature	Relative Humidity (Percentage)						
	30	40	50	60	70	80	90
°C (1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
28	*	*	*	*	*	*	*
29	*	*	*	*	*	0.06	0.19
30	*	*	*	0.06	0.24	0.53	0.85
31	*	0.06	0.24	0.53	1.04	1.47	2.10
32	0.20	0.46	0.94	1.59	2.26	3.04	**
33	0.77	1.36	2.12	3.00	**	**	**
34	1.85	2.72	**	**	**	**	**
35	3.20	**	**	**	**	**	**

* None ** Higher than these acceptable in practice

Table 1.49: Minimum Wind Speed (m/s) for just Acceptable Warm Conditions

Dry Bulb Temperature	Relative Humidity (Percentage)						
	30	40	50	60	70	80	90
°C (1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
28	*	*	*	*	*	*	*
29	*	*	*	*	*	*	*
30	*	*	*	*	*	*	*
31	*	*	*	*	*	0.06	0.23
32	*	*	*	0.09	0.29	0.60	0.94
33	*	0.04	0.24	0.60	1.04	1.85	2.10
34	0.15	0.46	0.94	1.60	2.26	3.05	.*
35	0.68	1.36	2.10	3.05	**	**	**
36	1.72	2.70	**	**	**	**	**

* None ** Higher than these acceptable in practice

Source : NBC - 2005

Table 1.50: Garment Insulation Values

Garment Descriptiona	I_{clu} (Clo)[b]	Garment Description	I_{clu} (Clo)[b]
Underwear		**Suit Jackets and Vests (lined)**	
Men's Brief	0.04	Single - breasted (thin)	0.36
Panties	0.03	Single - breasted (thick)	0.44
Bra	0.01	Double - breasted (thin)	0.42
T-Shirt	0.08	Double - breasted (thick)	0.48
Full Slip	0.16	Sleeveless vest (thin)	0.10
Half Slip	0.14	Sleeveless vest (thick)	0.17
Long underwear top	0.20	**Sweaters**	
Long underwear bottoms	0.15	Sleeveless vest (thin)	0.10
Footwear		Sleeveless vest (thick)	0.17
Ankle - length athletic socks	0.02	Long-sleeved (thin)	0.25
Calf - length socks	0.03	Long-sleeved (thick)	0.36
Knee socks (thick)	0.06	**Dresses and skirts**	
Pantyhose / stockings	0.02	Sleeveless, Short Gown (thin)	018
Sandals/thongs	0.02	Sleeveless, long gown (thin)	0.20
Slippers (quilted, pile lined)	0.03	Short -sleeved hospital gown	0.31
Shoes	0.02	Skirt (thin)	0.14
Boots	0.10	Long - sleeved, long gown (thick)	0.46
Shirts and blouses		Long - sleeved, long gown (thick)	0.57
Sleeveless / scoop-neck blouse	0.12	Short - sleeved, long wrap robe (thick)	0.42
Short - sleeve, dress shirt	0.19	Long - sleeved, long wrap robe (thick)	0.69
Long - sleeve dress shirt	0.25	Long - sleeved, short wrap robe (thick)	0.48
Long - sleeve, flannel shirt	0.34	Short - sleeved, short robe (thin)	0.34
Short - sleeve, Knit sport shirt	0.17	Skirt (thick)	0.23
Long - sleeve sweat shirt	0.34	Sleeveless, scoop neck (thin)	0.23
Trousers and coveralls		Sleeveless, scoop neck (thick), i.e. jumper	0.27
Short shorts	0.06	Short sleeve shirt dress (thin)	0.29
Walking shorts	0.08	Long sleeve shirt dress (thin)	0.33
Straight trousers (thin)	0.15	Long sleeve shirt dress (thick)	0.47
Straight trousers (thick)	0.24		
Sweatpants	0.28		
Overalls	0.30		
Coveralls	0.49		

[a]"Thin" garments are Summer wear "thick" garments are Winter wear

[b]Clothing insulation value expressed in clo units- 1clo=0.88 $^{o}F\ ft^2\ h/Btu$

[c]Knee - length

Source : ASHRAE F-2013

Table 1.51 : Guidelines for Concentration Limits of Selected Air Contaminations of Indoor Origin

Contaminant	Concentration	ppm	Exposure time
Carbon dioxide*	1.8 g/cum	1000	Continuous
Carbon monoxide	55 mg/cum	50	8hrs
Chlordane	55 mg/cum	0.0003	Continuous
Ozone	100mg/cum	0.05	Continuous
Radon**	0.027/WL	-	Annual Average
Nitrogen dioxide	9 mg/cum.	5	Continuous
Sulphur dioxide	13 mg/cum.	5	
Total Suspended Particulates =100 μg/m/cum. 1 hr			

* Threshold value - 600 ppm (NIOSH)
** 3200 picocuries

Table 1.52 : Sources, Possible Concentrations, and Indoor to Outdoor Concentration Ratios of some Indoor Pollutants

Pollutant	Source of Indoor Pollution	Possible Indoor concentration	I/O concentration Ratio	Location
Carbon Monoxide	Combustion equipment engines, faulty heating systems	100 ppm	>>1	Skating rinks, offices, homes, cars, shops
Respirable Particles	Stoves, fireplaces, cigarettes, condensation of volatiles, aerosol sprays, resuspension, cooking	100 to 500ug/m^3	>>1	Homes, office, car, public facilities, bars, restaurants
Organic Vapours	Combustion, solvents, resin products, pesticides, aerosol sprays	NA	>1	Homes, restaurants, public facilities, offices, hospitals
Nitrogen dioxide	Combustion gas, stoves, water heaters, driers, cigarettes, engines	200 to1000 -g/m^3	>>1	Homes, staking rinks
Sulphur dioxide	Heating system	20 -g/m^3	<1	Removal inside
Total suspended particles without smoking	Combustion, resuspension, heating system	100 -g/m^3	1	Homes, offices, transportation, restaurants
Sulphate	Matches, gas stoves	5-g/m^3	>1	Removal inside
Formaldehyde	Insulation, product binders, particle board	0.05 to 1.0 ppm	>1	Homes, offices
Radon Progeny	Building Materials, ground water, soil	0.1 to 200 nCi/m^3	>>1	Homes, buildings
Asbestos	Fireproofing	<10 fiber/m^3	1	Homes, schools, offices
Mineral and Synthetic fibers	Products, cloth, rugs, wallboard	NA	-	Homes, schools, offices
Carbon dioxide	Combustion, humans, pets	3000 ppm	>>1	Homes, schools, offices
Viable Organisms	Humans, pets, rodents, insects, plants, fungi, humidifiers, air conditioners	NA	>1	Homes, hospitals, schools, offices, public places and facilities
Ozone	Electric arcing UV light sources	20ppb 200 ppb	<1 >1	Airplanes Offices

[a] Concentrations listed are only those reported indoors. Both higher and lower concentrations have been measured. NA averaging times are given. NA indicates it is not appropriate to list a concentration.

Table 1.53: Minimum Ventilation Rates In Breathing Zone for Air-conditioned Spaces

(This table is not valid in isolation; it must be used in conjunction with the accompanying notes)

Occupancy Category	People Outdoor Air Rate R_P		Area Outdoor Air Rate R_a		Notes	Default Values			Air Class
						Occupant Density (See note 4)	Combined outdoor Air Rate (See Note 5)		
	Cfm/ person	L/s person	Cfm/ft²	L/s m²		/1000 ft² or /100 m²	Cfm/ person	L/s person	
Correctional Facilities									
Cell	5	2.5	0.12	0.6		25	10	4.9	2
Day Room	5	2.5	0.06	0.3		30	7	3.5	1
Guard Stations	5	2.5	0.06	C.3		15	9	4.5	1
Booking / Waiting	7.5	3.8	0.06	0.3		50	9	4.4	2
Educational Facilities									
Day Care (Through age 4)	10	5	0.18	0.9		25	17	8.6	2
Day Care Sickroom	10	5	0.18	0.9		25	17	8.6	3
Classrooms (Ages 5-8)	10	5	0.12	0.6		25	15	7.4	1
Classroom (Ages 9 plus)	10	5	0.12	0.6		35	13	6.7	1
Lecture Classroom	7.5	3.8	0.06	0.3		65	8	4.3	1
Lecture Hall (fixed seats)	7.5	3.8	0.06	0.3		150	8	4.0	1
Art Classroom	10	5	0.18	0.9		20	19	9.5	2
Science Laboratories	10	5	0.18	0.9		25	17	8.6	2
University / College Laboratories	10	5	0.18	0.9		25	17	8.6	2
Wood / Metal shop	10	5	0.18	0.9	A	20	19	9.5	2
Computer Lab	10	5	0.12	0.6		25	15	7.4	1
Media Centre	10	5	0.12	0.6		25	15	7.4	1
Music / Theatre / Dance	10	5	0.12	0.3		35	12	5.9	1
Multiuse assembly	7.5	3.8	0.06	0.3		100	8	4.1	1
Food and Beverage Service									
Restaurant / Dining Rooms	7.5	3.8	0.18	0.9		70	10	5.1	2
Cafeteria / Fast food Dining	7.5	3.8	0.18	0.9		100	9	4.7	2
Bars, Cocktail Lounges	7.5	3.8	0.18	0.9		100	9	4.7	2
Kitchen (cooking)	7.5	3.8	0.12	0.6		20	14	7.0	2
General									
Breakrooms	5	2.5	0.06	0.3		25	7	3.5	1
Coffee Stations	5	2.5	0.06			20	8	4	1
Conference / Meeting	5	2.5	0.06	0.3		50	6	3.1	1
Corridors	-	-	0.06	0.3		-			1
Occupiable storage rooms for liquids or gels	5	2.5	0.12	0.6	B	2	65	32.5	2
Motels, Resorts, Dormitories									
Bedroom / Living Room	5	2.5	0.06	0.3		10	11	5.5	1
Barracks sleeping areas	5	2.5	0.06	0.3		20	8	4.0	1
Laundry Rooms, Central	5	2.5	0.12	0.6		10	17	8.5	2
Laundry Rooms within dwelling units	5	2.5	0.12	0.6		10	17	8.5	1
Lobbies / Prefunction	7.5	3.8	0.06	0.3		30	10	4.8	1
Multipurpose / Assembly	5	2.5	0.06	0.3		120	6	2.8	1

Source :ASHRAE 62.1,2013

Table 1.53: Minimum Ventilation Rates In Breathing Zone for Air-conditioned Spaces (Contd..)

(This table is not valid in isolation; it must be used in conjunction with the accompanying notes)

Occupancy Category	People Outdoor Air Rate RP		Area Outdoor Air Rate R,		Notes	Default Values			Air Class
						Occupant Density (See note 4)	Combined outdoor Air Rate (See Note 5)		
	Cfm/ person	L/s person	Cfm/ft²	L/s m²		/1000 ft² or /100 m²	Cfm/ person	L/s person	
Office Buildings									
Breakrooms	5	2.5	0.12	0.6		50	7	3.5	1
Main Entry Lobbies	5	2.5	0.06	0.3		10	11	5.5	1
Occupiable Storage rooms for dry materials	5	2.5	0.06	0.3		2	35	17.5	1
Office Space	5	2.5	0.06	0.3		5	17	8.5	1
Reception Areas	5	2.5	0.06	0.3		30	7	3.5	1
Telephone / Data Entry	5	2.5	0.06	0.3		60	6	3.0	1
Miscellaneous Spaces									
Bank Vaults / Safe Deposits	5	2.5	0.06	0.3		5	17	8.5	2
Banks or Bank Lobbies	7.5	3.8	0.06	0.3		15	12	6.0	1
Computer (not printing)	5	2.5	0.06	0.3		4	20	10.0	1
Freezer and Refrigerated Spaces (< 50°F)	10	5.0	0	0	E	0	0	0	2
General Manufacturing (excludes heavy industrial and processes using chemicals)	10	5.0	0.18	0.9		7	36	18	3
Pharmacy (prep. Area)	5	2.5	0.18	0.9		10	23	11.5	2
Photo Studio	5	2.5	0.12	06		10	17	8.5	1
Shipping / Receiving	10	5	0.12	0.6	B	2	70	35	2
Sorting, packing light assembly	7.5	3.8	0.12	0.6		7	25	12.5	2
Telephone Closets	-	-	0.00	0.0		-			1
Transportation Waiting	7.5	3.8	0.06	0.3		100	8	4.1	1
Warehouses	10	5	0.06	0.3	B	-			2
Public Assembly Spaces									
Auditorium Seating Area	5	2.5	0.06	0.3		150	5	2.7	1
Places of religious worship	5	2.5	0.06	0.3		120	6	2.8	1
Courtrooms	5	2.5	0.06	0.3		70	6	2.9	1
Legislative Chambers	5	2.5	0.06	0.3		50	6	3.1	1
Libraries	5	2.5	0.12	0.6		10	17	8.5	1
Lobbies	5	2.5	0.06	0.3		150	5	2.7	1
Museums (children's)	7.5	3.8	0.12	0.6		40	11	5.3	1
Museums / galleries	7.5	3.8	0.06	0.3		40	9	4.6	1
Residential									
Dwelling Unit	5	2.5	0.06	0.3	F, G	F			1
Common Corridors	-	-	0.06	0.3					1
Retail									
Sales (except as below)	7.5	3.8	0.12	0.6		15	16	7.8	2
Mall common areas	7.5	3.8	0.06	0.3		40	9	4.6	1
Barbershop	7.5	3.8	0.06	0.3		25	10	5.0	2
Beauty and Nail salons	20	10	0.12	0.6		25	25	12.4	2
Pet Shops (animal areas)	7.5	3.8	0.18	0.9		10	26	12.8	2
Supermarket	7.5	3.8	0.06	0.3		8	15	7.6	1
Coin operated Laundries	7.5	3.8	0.12	0.6		20	14	7.0	2

Source :ASHRAE 62.1,2013

Table 1.53 : Minimum Ventilation Rates In Breathing Zone for Air-conditioned Spaces (Contd..)

(This table is not valid in isolation; it must be used in conjunction with the accompanying notes)

Occupancy Category	People Outdoor Air Rate RP		Area Outdoor Air Rate R,		Notes	Default Values			Air Class
						Occupant Density (See note 4)	Combined outdoor Air Rate (See Note 5)		
	Cfm/ person	L/s person	Cfm/ft²	L/s m²		/1000 ft² or /100 m²	Cfm/ person	L/s person	
Sport and Entertainment									
Gym, Sports Arena (play area)	20	10	0.18	0.9	E	7	45	23	2
Spectator Areas	7.5	3.8	0.06	0.3		150	8	4.0	1
Swimming (pool & deck)	-	-	0.48	2.4	C	-	-	-	2
Disco / Dance Floors	20	10	0.06	0.3		100	21	10.3	2
Health Club / Aerobic rooms	20	10	0.06	0.3		40	22	10.8	2
Health Club / Weight Rooms	20	10	0.06	0.3		10	26	13.0	2
Bowling alley (seating)	10	5	0.12	0.6		40	13	6.5	1
Gambling Casinos	7.5	3.8	0.18	0.9		120	9	4.6	1
Game Arcades	7.5	3.8	0.18	0.9		20	17	8.3	1
Stages, Studios	10	5	0.06	0.3	D	70	11	5.4	1

General Notes for Table 1.53

1. **Related requirements:** The rates in this table are based on all other applicable requirements of this standard being met.
2. **Environmental Tobacco Smoke:** This table applies to ETS-free areas.
3. **Air density:** Volumetric airflow rates are based on an air density of 0.075 lb_{da}/ft^3 (1.2 kg_{da}/m^3), which correspond to dry air at a barometric pressure of 1 atm (101.3kPa) and an air temperature of 70^0F (21^0C). Rates may be adjusted for actual density but such adjustment is not required for compliance with this standard.
4. **Default occupant density:** The default occupant density shall be used when actual occupant density is not known.
5. **Default combined outdoor air rate (per person):** This rate is based on the default occupant density.
6. **Unlisted occupancies:** If the occupancy category for a proposed space or zone is not listed, the requirements for the listed occupancy category that is most similar in terms of occupant density, activities and building construction shall be used.

Item Specific Notes for Table 1.53

A) For High School and College libraries, use values shown for Public Assembly Spaces - Libraries.

B) Rate may not be sufficient when stored materials include those having potentially harmful emissions.

C) Rate does not allow for humidity control. Additional Ventilation or Dehumidification may be required to remove moisture. “Deck area” refers to the area surrounding the pool that would be expected to be wetted during normal pool use, i.e. when the pool are occupied. Deck area that is not expected to be wetted shall be designed as a space type (for example, “spectator area”)

D) Rate does not include special exhaust for stage effects, e.g., dry ice vapors, smoke.

E) When combustion equipment is intended to be used on the playing surface or in this space, additional dilution ventilation and / or source control shall be provided.

F) Default occupancy for dwelling units shall be two persons for studio and one-bedroom units, with one additional person for each additional bedroom.

G) Air from one residential dwelling shall not be recirculated or transferred to any other space outside of that dwelling.

Source :ASHRAE 62.1, 2013

Table 1.54 : Minimum Exhaust Rates

Occupancy Category	Exhaust Rate cfm / unit	Exhaust Rate cfm / sq.ft	Notes	Exhaust Rate L/s Unit	Exhaust Rate L/s m2	Air Class
Arenas	-	0.50	B	-	-	1
Art Classrooms	-	0.70		-	3.5	2
Auto repair rooms	-	1.50	A	-	7.5	2
Barber Shops	-	0.50		-	2.5	2
Beauty and nail salons	-	0.60		-	3.0	2
Cells with toilet	-	1.00		-	5.0	2
Copy printing room	-	0.50		-	2.5	2
Darkrooms	-	1.00		-	5.0	2
Educational science laboratories	-	1.00		-	5.0	2
Janiter closets, trash rooms, recycling	-	1.00		-	5.0	3
Kitchenettes	-	0.30		-	1.5	2
Kitchens - commercial	-	0.70		-	3.5	2
Locker / dressing rooms	-	0.25		-	1.25	2
Locker rooms	-	0.50		-	2.5	2
Paint spray booths	-	-	F	-	-	4
Parking garages	-	0.75	C	-	3.7	2
Pet shops (animal areas)	-	0.90		-	4.5	2
Refrigerating machinery rooms	-		F	-	-	3
Residential kitchens	50 / 100		G	25 / 50	-	2
Soiled laundry storage rooms	-	1.00	F	-	5.0	3
Storage rooms, Chemicals	-	1.50	F		7.5	4
Toilets - private	25 / 50	-	E, H	12.5 / 25	-	2
Toilets - public	50 / 70	-	D, H	25 / 35	-	2
Woodwork shop / classrooms	-	0.50		-	2.5	2

A. Stands where engines are run shall have exhaust systems that directly connect to the engine exhaust and prevent escape of fumes.

B. When combustion equipment is indended to be used on the playing surface additional dilution ventilation and/or source control shall be provided.

C. Exhaust not required if two or more sides comprise walls that are at least 50% open to the outside.

D. Rate is per water closet and/or urinal. Provide the higher rate where periods of heavy use are expected to occur e.g., toilets in theatres, schools and sports facilities. The lower rate may be used otherwise.

E. Rate is for a toilet room intended to be occupied by one person at a time. For continuous system operation during normal hours of use, the lower rate may be used. Otherwise use the higher rate.

F. See other applicable standards for exhaust rate.

G. For continuous systems operation, the lower rate may be used. Otherwise use the higher rate.

H. Please refer ASHRAE Standard 62.1 / 2013 for further details.

Source : ASHRAE 62.1, 2013

Guide for Using Table : 1.55

The substances listed in Table 1-T-55 are common air contaminants of concern in nonindustrial environments. The target concentrations that have been set or proposed by various national or international organizations concerned with health and comfort effects of outdoor and indoor air are listed for reference only. The table is not inclusive of all contaminants in indoor air, and achieving the target indoor concentrations for all of the listed substances does not ensure freedom from sensory irritation or from all adverse health effects for all occupants. In addition to indoor contaminant levels, the acceptability of indoor air also involves thermal conditions, indoor moisture levels as they impact microbial growth, and other indoor environmental factors. ASHRAE is not selecting or recommending default concentration.
Health or comfort effects and exposure periods that are the basis for the guideline levels are listed in the “comments” column. For design, the goal should be meeting the guideline levels continuously during occupancy because people spend a majority of their time indoors.
Users of this table should recognize that unlisted noxious contaminants can also cause unacceptable IAQ with regard to comfort (sensory irritation), odours, and health. When such contaminants are known or might reasonably be expected to be present, selection of an acceptable concentration and exposure may require reference to other guidelines or a review and evaluation of relevant toxicological and epidemiological literature. (Table 1-T-60 summarizes some of this literature).

Table 1.55 : Concentration of Interest for Selected Contaminants

Note: References numbers that are followed by (C) and (m) list lh<> concentration of Interest (c) and measurement methods (m).
Note: The user of any value in this table should take into account the purpose for which it was adopted and the means by which it was developed.

Contaminant	Sources	Concentrations of Interest	Comments	References
Carbon Monoxide (CO)	Leaking vented combustion appliances Unvented combustion appliances Parking garages Outdoor air	9 ppm (8 h)	Based on effects on people with coronary artery disease, with average exposure of eight hours. Sustained indoor concentrations exceeding outdoor concentrations may merit further investigation. Many Carbon monoxide measuring instruments have limited accuracy at low levels. Sources- burning of gasoline, natural gas, coal, oil, etc (Note: CO is unlikely to be the only contaminant of concern in parking garages or other spaces where vehicles operate) Health effects reduces ability of blood to bring oxygen to body cells and tissues; cells and tissues need oxygen to work. Carbon Monoxide may be particularly hazardous to people who have heart or circulatory problems and people who have damaged lungs or breathing passages.	For further details please refer ASHRAE STD. 62.1.2013
Formaldehyde (HCHO)	Pressed-wood products Furniture and furnishings	0.1 mg/m^3 (0.081 ppm) (30 min)	Based on irritation of sensitive people, 30 minute exposure (WHO)	
		27 ppb (8 h)	Established as a never - to - exceed guideline to avoid irritant effects in sensitive individuals. Does not protect against Formaldehyde's potential carcinogenicity (California Air Resources Board)	
		45 ppb (55 -g/m^3) (1 h) 73 ppb (9 ing/m^3) (8 h)	Acute and 8-hour non-cancer Reference Exposure Levels (RELs) developed based on current scientific database (Cal-EPA, OEHHA)	
			Health effects - Acute and chronic inhalation exposure to formaldehyde in humans can result in eye, nose, and throat irritation, respiratory symptoms, exacerbation of asthma, and sensitization. Human studies have reported an association between formaldehyde exposure and lung and nasopharyngeal cancer in 2004, the International Agency for Research on cancer (IARC) concluded that " formaldehyde is carcinogenic to humans (Group I), on the basis of sufficient evidence in humans and sufficient evidence in experimental animals"	
		16 ppb	FEMA Procurement Specification for Mobile Homes	

The US FPA has promulgated a guideline value of 4pCVL indoor concentration. This is not a regulatory value but an action level where mitigation is recommended if the value is exceeded in long-term tests. Conversion Factors[8-17]
Parts per million and mass per unit volume.
Measurements of Indoor airborne concentrations of substances are generally converted to standard conditions of 77°F (25OC) in Hg (101.325 kpa) pressure. Vapours or gases are often expressed in parts per million (ppm) by volume or in
mass per unit volume. Concentration in ppm by volume can be converted to mass per unit volume values as follows,
ppm*molecular weight/24. 450=mg/L
ppm*molecular weight/0.02445= μg/m3
ppm*molecular weight/24.45=mg/m3
ppm*molecular weight*28.3/24,450= mg/m3

Source : ASHRAE STD. 62.1 - 2013

Table 1.55 : Concentration of Interest for Selected Contaminants (contd...)

(Note: References numbers that are followed by (C) and (m) list the concentrations of Interest (c) and measurement methods (m). (Note: The user of any value in this table should take into account the purpose for which it was adopted and the means by which it was developed.

Contaminant	Sources	Concentrations of Interest	Comments	References
Particles (PM_{10})	Dust Smoke Deteriorating materials Outdoor air	50 - g/m^3	Based on protection against respiratory morbidity in the general population and avoiding exacerbation of asthma. Average exposure for one year, no carcinogens. Indoor concentration is normally lower, guideline level may lead to unacceptable deposition of dust.	For further details please refer ASHRAE STD. 62.1.2013
			Sources - burning of wood, diesel, and other fuels, Industrial Plants, Agriculture (ploughing, burning of fields) unpaved road. Health effects - nose and throat irritation, lung damage, bronchitis, early death. Environmental effects - Particulates are the main source of haze that reduce visibility.	
			Property damage - ashes, soot, smoke, and dust can dirty and discolour structures and other property, including clothes and furniture.	
Radon (Rn)	Soil gas	4 pCI/L[a]	Based on lung cancer, average exposure for one year.	
Sulfur Dioxide (SO_2)	Unvented space heaters (Kerosene) Outdoor air	80 g/m^3	Based on protection against respiratory morbidity in the general population and avoiding exacerbation of asthma. Average exposure for one year (WHO 50 μg/m^3 if with PM). Source - burning of coal and oil, expecially high - Sulphur Coal from the eastern United States: industrial processes (paper, metals). Health effects - breathing problems, may cause permanent damage to lungs. Environmental effects : SO_2 is a component of acid rain (acid aerosols), which can damage trees and lakes. Acid aerosols can also reduce visibility. Property damage - Acid aerosols can eat away stone used in buildings, statues, monuments etc.	
Total Volatile Organic Compounds (TVOCs)	New building materials and furnishings Consumable products Maintenance materials Outdoor air	Precise guidance on TVOC concentrations cannot be given	A variety of definitions of TVOC have been employed in the past, Reference B-27 contains a specific definition that reflects thinking on the subject. There is insufficient evidence that TVOC measurements can be used to predict health or comfort factors. In addition, odour and irritation responses of organic compounds are highly variable. Furthermore, no single method, currently in use, measures all organic compounds that may be of interest. Therefore, some investigations have reported the total of all measured VOC's as the Sum VOC in order to make explicit that the total of all VOC's are included. Some of the references included here use this method for presenting VOC measurement results. Setting target concentration for TVOC's is not recommended. Setting target concentration for specific VOC's of concern is preferred.	
Volatile Organic compounds (VOCs) (See Table B-3 for list of selected compounds)	New building materials and furnishings, Consumable products, Maintenance materials, Outdoor Air Parking Garages, Refueling stations	Must be determined for each individual compound (See Table B-3 for a list of selected compounds)	Individual Volatile Organic Compounds may be contaminants of concern in the application of the IAQ Procedure. Concentrations of concern range from less than 1 part per billion (ppb) for some very toxic compounds or for compounds having very low odor thresholds, up to concentrations several orders of magnitude higher. Not all compounds can be identified and toxicological data are incomplete for many compounds.	

The US FPA has promulgated a guideline value of ΔpCL/L indoor concentration. This is not a regulatory value but an action level where mitigation is recommended if the value is exceeded in long-term tests.
Conversion Factors for parts per million and mass per unit volume.
Measurements of Indoor airborne concentrations of substances are generally converted to standard conditions of 77^{0}F (25^{0C}) and 29.92 in Hg (101.325 kpa) pressure. Vapours or gases are often expressed in parts per million (ppm) by volume or in
mass per unit volume. Concentration in ppm by volume can be converted to mass per unit volume values as follows,
ppm*molecular weight/24.450=mg/L
ppm*molecular weight/0.02445= μg/m^3
ppm*molecular weight/24.45=mg/m^3
ppm*molecular weight*28.3/24,450= mg/m^3

Source : For further details please refer ASHRAE STD. 62.1 - 2013

Table 1.55 : Concentration of Interest for Selected Contaminants (Contd...)

Note: Reference numbers that are followed by (C) and (m) list the concentrations of Interest (c) and measurement methods (m). Note: The user of any value in this table should take into account the purpose for which it was adopted and the means by which it was developed.

Contaminant	Sources	Concentrations of Interest	Comments	References
Lead (Pb)	Paint, dust, outdoor air	1.5 -g/m^3	Based on adverse effects on neuropsychological functioning of children, average exposure for three months (WHO 0.5 -1 g/m^3 For 1 year). Sources - leaded gasoline (being phased out), paint (houses, cars), smelters (metal refineries), manufacture of lead storage batteries. Health effects : brain and other nervous system damage, children are at special risk. Some lead containing chemicals cause cancer in animals. Lead causes digestive and other health problems. Environmonlal effects of lead can harm wildlife.	For further details please refer ASHRAE STD. 62.1.2013
		100Mg/m:l	Based on providing protection against adverse respiratory effects, average exposure for one year.	
Nitrogen Dioxide (NO_2)	Leaking vented combustion appliances Unvented combustion appliances, Outdoor air, Parking garages		Sources - burning of gasoline, natural gas, coal etc. Cars are an important source of NO_2 outdoors, and cooking and water and space heating devices are important sources indoors. Health effects : lung damage, illnesses of breathing passages and lungs (respiratory system). Environmental effects : Nitrogen dioxide is a component of acid rain (acid aerosols) which can damage trees and lakes. Acid aerosols can reduce visibility. Property damage - Acid aerosols can eat away stone used on buildings, statues, monuments etc.	
		470 g/m_3	24-hour average to prevent high exposures during use of combustion appliances such as space-heating devices and gas stoves.	
Odors	Occupants, VOC sources, (including fungal sources such as mold), Cooking, Food Processing, Sewage, Waste facilities, etc.	Predicted (or measured) acceptability to 80% or more of occupants or visitors	C02 concentration can be used as a surrogate for occupant odors (odorous bioeffluents). For sources other than people, source control is recommended.	
Ozone (O_3)	Electrostatic appliances, Office Machines, Ozone generators, Outdoor air	100 g/m^3 (50 ppb)	Based on 25% increase in symptom exacerbation among adults or asthmatics (normal activity), eight-hour exposure (WHO); after continuous exposure (FDA). Ozone present at levels below the concentration of interest may contribute to the degradation of indoor air quality directly and by reacting with other contaminants in the indoor spaces. Ground - level ozone is the priciple component of smog. Sources - Outdoors, from chemical reaction of pollutants, VOC's and NO_x. Indoors, from photocopies, laser printers, ozone generators, electrostatic precipitators, and some other air cleaners. Health effects : breathing problems, reduced lung function, asthma, irritated eyes, stuffy nose, and reduced resistance to cold and other infections. May speed up aging of lung tissue. Environmental effects : Outdoors, ozone can damage plants and trees; smog can cause reduced visibility. Property damage : Indoors and outdoors, ozone damages natural and synthetic rubbers, plastics, fabrics etc.	
Particles ($PM_{2\,5}$)	Combustion products, Cooking, Candles, Incense, resuspension, Outdoor Air, Diesel exhaust, and Parking Garages	15 g/m^3		

Guide for using Table 1.56

Table 1-T-55 provides information that may be beneficial for designers who choose to comply with the Indoor Air Quality Procedure of this Standard. The VOCs included in the table were reported in published, peer-reviewed surveys conducted in office buildings and in new and existing residences in North America during the period 1990-2000. Only those VOCs for which exposure guidelines for the general population have been developed by cognizant authorities are listed in Table 1-T56.

Reference Exposure Levels (RELs) are guidelines for acute, 8-hour and chronic inhalation exposures developed by California Office of Health Hazard Assessment (OEHHAA). Minimum Risk Levels (MRLs) for hazardous substances are guidelines for acute, intermediate and chronic inhalation exposures developed by the Agency for Toxic Substances and Disease Registry (ATSDR). Factors for μg/m3 to ppb concentration conversions are shown.

The Table does not purport to represent (a) all possible chemicals found in nonindustrial indoor environments and (b) all concentration Guidelines, Standards, and Regulatory Limits. Published peer-reviewed surveys conducted in office buildings and in new and existing residences in North America since 2000 may identify several more compounds, for some of which guidelines may be available from the cognizant authorities described above.

Table 1.56 : Concentrations of Interest for Selected Volatile Organic Compounds

Compound	CAS Number	Chemical Class[a]	Conversion Factor; (μg/m^3) to (ppb)[b]	CA OEHHA REL		ATSDR MRL			
				Acute[c] (μg/m^3)	8-hr[d] (μg/m^3)	Chronic (μg/m^3)	Acute[f] (ppb)	intermediate[g] (ppb)	Chronic[h] (ppb)
Acetaldehyde	75-07-0	Ald	0.554	470	300	140			
Aerolein	107-02-8	Ald	0.436	2.5	0.7	0.35	3	0.4	
Acrylonitrile	107-13-1	Misc	0.460			5	100		
Benzene	71-43-2	Arom	0.313	1300		60	9	6	3
Bromomethane (Methyl bromide)	74-83-9	Halo	0.258				50	50	5
1, 3-Butadiene	106-99-0	Alke	0.452			20	6000		
2-Butanone	78-93-3	Ket	0.339	13,000			2000		
2-Butoxyethanol	111-76-2	Gly	0.207					3000	200
2-Butyl methyl ether (Methyl-t-butyl ether)	1634-044	Ethr	0.277			8000		700	700
Carbon disulfide	75-15-0	Misc	0.321	6200		800			300
Carbon tetrachloride	56-23-5	Halo	0.159	1900		40		30	30
Chlorobenzene	108-90-7	ClArom	0.217			1000			
Chloroform	67-66-3	Halo	0.205	150		300	100	50	20

a. Alc=alcohol; Ethr=ether; Gly=glycol ether; Ket=Ketone; Ald=aldehyde; Estr=acetates and other estors; Acid= carboxylic acid; Alka=alkene HC; Cycl= cyclic HC; Terp= terpene HC, Arom= aromatic HC; ClAro=chlorinated aromatic HC; Halo= halogenated alphatic HC; Misc=miscellaneous category.

b. Conversion factors from (μg/m^3) to (ppb)[b].

c. Exposure averaging time is 1 hour.

d. Designed to address continuous exposures for up to a lifetime. The exposure metric used is the annual average exposure.

e. Exposure to a chemical for a duration of 14 days or less, as specified in the toxicological profiles.

f. Exposure to a chemical for a duration of 15-364 days, as specified in the toxicological profiles.

g. Exposure to a chemical for 365 days or more, as specified in the toxicological profiles.

h. See also Tables B-1 and B-2 for additional guidance on formaldehyde.

Table 1.56 : Concentrations of Interest for Selected Volatile Organic Compounds (contd..)

Compound	CAS Number	Chemical Class[a]	Conversion Factor; $\mu g/m^3$ to (ppb)[b]	CA OEHHA REL [B-36]		ATSDR MRL[B-46]			
				Acute[c] ($\mu g/m^3$)	8-hr[d] ($\mu g/m^3$)	Chronic ($\mu g/m^3$)	Acute[f] (ppb)	intermediate[g] (ppb)	Chronic[h] (ppb)
1 ,4-Dichlorobenzene	106-46-7	ClAro	0.166			800	2000	200	10
1 ,2-Dichloroethane (Ethylene dichloride)	107-06-2	Halo	0.247						600
Dichloromethane (Methylene chloride)	75-09-2	Halo	0.288	14,000		400	600	300	300
1 ,4-Dioxane	123-91	Ethr	0.278	3000		3000	2000	1000	1000
Ethylbenzene	100-414	Arom	0.230			2000	10000	700	300
Ethylene glycol	107-21-1	Gly	0.394			400	788		
Formaldehyde	50-00-0	Ald	0.815	55	9	9	40	30	8
n-Hexane	110-54-3	Alka	0.284			7000	600		
Naphthalene	91-20-3	Arom	0.191			9			0.7
Phenol	108-95-2	Alc	0.260	5800		200			
2-Propanol (Isopropanol)	67-63-0	Alc	0.407	3200		7000			
2-Propanone (Acetone)	67-64-1	Ket	0.421				26,000	13,000	13,000
Styrene	100-42-5	Arom	0.235	21,000		900	2000		200
Tetrachloromethylene (Tetrachloromethyl-ene Perchl or omethylene)	127-18-4	Halo	0.147	20,000		35	200		40
Toluene	108-88-3	Arom	0.265	37,000		300	1000		80
1,1,1,-Trichloro-ethane (Methyl chloroform)	71-55-6	Halo	0.183	68,000		1000	2000	700	
Trichloroethene (Trichlorethylene)	79-01-6	Halo	0.186			600	2000	100	
Vinyl chloride	75-014	Halo	0.391	180000			500	30	
Xylene Isomers	1330-20-7	Arom	0.230	22,000		700	2000	600	50

a. Alc=alcohol; Ethr=ether; Gly=glycol ether; Ket=Ketone; Ald=aldehyde; Estr=acetates and other estors; Acid= carboxylic acid; Alka=alkene HC; Cycl= cyclic HC; Terp= terpene HC, Arom= aromatic HC; ClAro=chlorinated aromatic HC; Halo= halogenated alphatic HC; Misc=miscellaneous category.

b. Conversion factors from ($\mu g/m^3$) to (ppb)[b].

c. Exposure averaging time is 1 hour.

d. Designed to address continuous exposures for up to a lifetime. The exposure metric used is the annual average exposure.

e. Exposure to a chemical for a duration of 14 days or less, as specified in the toxicological profiles.

f. Exposure to a chemical for a duration 15-364 days, as specified in the toxicological profiles.

g. Exposure to a chemical for 365 days or more, as specified in the toxicological profiles.

h. See also Tables B-1 and B-2 for additional guidance on formaldehyde.

Table 1.57 : Recommended Values of Air changes (for ventilation only)

Sl. No.	Application	Air change per hour
1	2	3
1	Assembly rooms	4-8
2	Bakeries	20-30
3	Banks/building societies	4-8
4	Bathrooms	6-10
5	Bedrooms	2-4
6	Billiard rooms	6-8
7	Boiler rooms	15-30
8	Cafes and coffee bars	10-12
9	Canteens	8-12
10	Cellars	3-10
11	Churches	1-3
12	Cinemas and theatres	10-15
13	Club rooms	12 min
14	Compressor rooms	10-12
15	Conference rooms	8-12
16	Dairies	8-12
17	Dance halls	12 min
18	Dye works	20-30
19	Electroplating shops	10-12
20	Engine rooms	15-30
21	Entrance halls	3-5
22	Factories and workshops	8-10
23	Foundries	15-30
24	Garages	6-8
25	Glass houses	25-60
26	Gymnasium	6 Min
27	Hair dressing saloon	10-15
28	Hospitals - sterilizing	15-25
29	Hospital-wards	6-8
30	Hospital - domestic	15-20
31	Laboratories	6-15
32	Launderettes	10-15
33	Laundries	10-30
34	Lavatories	6-15
35	Lecture theatres	5-8
36	Libraries	3-5
37	Living rooms	3-6
38	Mushroom houses	6-10
39	Offices	6-10
40	Paint shops (not cellulose)	10-20
41	Photo and X-ray dark room	10-15
42	Public house bars	12 Min
43	Recording control rooms	15-25
44	Recording studios	10-12
45	Restaurants	8-12
46	Schoolrooms	5-7
47	Shops and supermarkets	8-15
48	Shower baths	15-20
49	Stores and warehouses	3-6
50	Squash courts	4 Min
51	Swimming pools	10-15
52	Toilets	6-10
53	Utility rooms	15-20
54	Welding shops	15-30
NOTE: The ventilation rates may be increased by 50 percent where heavy smoking occurs or if the room is below ground.		

Source : NBC - 2005

Table 1.58 : Maximum Permissible Wet Bulb Temperature for Given Dry Bulb Temperatures (Industrial Ventilation Application)

Dry Bulb Temperature °C	Maximum Wet Bulb Temperature °C
(1)	(2)
30	29.0
35	28.5
40	28.0
45	27.5
50	27.0

Note

1. These are limits beyond which the Industry should not allow the thermal conditions to go for more than 1h continuously. The limits are based on a series of tests conducted on Indian subjects, in psychrometric chamber and on other data on heat causalities in earlier studies conducted in Kolar gold fields and elsewhere.

2. Figures given in this table are not intended to convey that human efficiency at 50^{0}C will remain the same as at 30^{0}C provided appropriate wet bulb temperatures are maintained. Efficiency decreases with rise in the Dry Bulb temperature as well. Long exposures to temperature of 50^{0}C Dry Bulb / 27^{0}C Wet Bulb may prove dangerous.

3. Refrigeration or some other method of cooling is recommended in all cases where conditions would be worse than those shown in this table.

Table-1.59 : Maximum allowable contaminant concentrations in Ventilation Air Annual Average (Arithmetic Mean)

Contaminants	Annual Average (Arithmetic Mean) g/M^3	Short-Term Level (Not to exceed more than once a year) g/M^3	Averaging period (hr)
(1)	(2)	(3)	(4)
Suspended particulates	60	150	24
Sulphur Oxides	80	400	24
Carbon Monoxide	20000	30000	8
Photochemical Oxidant	100	500	1
Hydrocarbons (not including methanes)	1800	4000	3
Nitrogen oxide	200	500	24
Odour : Essentially objectionable	-	-	-

Source : NBC 2005

Table 1.60 : Temperature and Time Requirements For Killing Moths in Stored Clothing

Storage Temperature ^{0}F	All Eggs Dead After, Days	All Larvae Dead After, Days	All Adults Dead After, Days
0.4 to 5	1	2	1
5 to 10	2	21[a]	1
10 to 15	4	-	1
15 to 19	-	-	1
20 to 25	21	67	4
25 to 30	21	125[b]	7
30 to 35	-	283[c]	-

Table adapted from USDA publication AMS-57 (1955)

[a]50 to 95% of larvae may be killed in 2 days

[b]A few larvae survived this period

[c]Larvae survived this period

Table 1.61 : Refrigerating Effect (RE) Produced by Open Refrigerated Display Fixtures

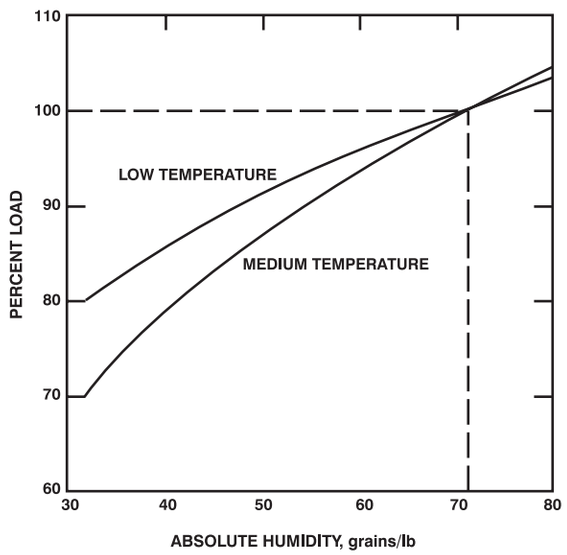


Figure 1.5 : Refrigerated Case Load Variation with Store Air Humidity

SUPERMARKETS

Display Fixture Types	RE on Building Per Unit Length of Fixture			
	Latent Heat Btu/h-ft	% Latent to Total RE	Sensible Heat Btu/h-ft	Total RE Btu/h-fc
Low temperature (frozen food)				
Single Deck	38	15	207	245
Single deck / double Island	70	15	400	270
2-deck	144	20	576	720
3-deck	322	20	1288	1610
3 or 5 deck	400	20	1600	2000
Ice Cream				
Single Deck	64	15	366	430
Single deck / double Island	70	15	400	470
Standard Temperature				
Meats				
Single Deck	52	15	298	350
Multideck	219	20	876	1095
Dairy Multideck produce	106	20	784	980
Produce				
Single Deck	36	15	204	240
Multideck	192	20	768	960

'There figures are general magnitude for fixtures adjusted for average desired product temperatures and apply to store ambient in front of display cases of 72 to 74^{0}F with 45% to 55% rh. Raising the dry bulb only 3 to 5^{0}F and the humidity to 5 to 10% can increase loads (heat removal) by 25% or more. Lower temperature and humidities, as in winter have an equally marked effect on lowering loads and heat removal from the space. Consult display case manufacturer's data for the particular equipment to be used.

Table 1.62 : Typical Recommended Design Criteria for Ventilation and Filtration for Office Buildings

Category	Ventilation and Exhaust				Minimum Filtration Efficiency MERV
	Combined outdoor Air (Default Value) cfm per person	Occupant Density per 1000ft2	Cfm/ft²	Cfm per unit	
Office Areas	17	5			6 to 8
Reception Areas	7	30			6 to 8
Entry	11	10			6 to 8
Lobbies					
Telephone/Data Entry	6	60			6 to 8
Cafeteria	9	100			6 to 8
Kitchen			0.7 (Exhaust)		NA
Toilets				0.7 (Exhaust)	NA
Storage			0.12		1 to 4
Notes : Based on ASHRAE Standard 62.1.2010 Table 6-1 and 6.4 for systems service multiple zones, apply multiple zone calculations procedure.					

Table 1.63 : Typical Recommended Indoor Temperature and Humidity in Office Buildings

Area	Indoor Design Conditions		
	Temperature ^{0}F Relative Humidity %		
	Winter	Summer	Comments
Offices, Conference Rooms, Common areas	70.0 to 74.0 20 to 30%	74.0 to 78.0 50 to 60%	
Cafeteria	70 to 73.5 20 to 30%	78.5 50%	
Kitchen	70 to 73.5	84 to 88	No Humidity Control usually not conditioned
Storage	64.0		No humidity Control
Mechanical Rooms	61.0		Usually not conditioned

Table 1.64 : Hotel Design Criteria

Category	Inside Design Conditions				Ventilation	Exhaust[d]	Filter Efficiency[e]	Noise RC Level
	Winter		Summer					
	Temperature	Relative Humidity[c]	Temperature	Relative Humidity				
Guest Rooms	74 to 76^{0}F	30 to 35%	74 to 78^{0}F	50 to 60%	30 to 60 cfm per room	20 to 50 cfm per room	6 to 8 MERV	25 to 35
Lobbies	68 to 74^{0}F	30 to 35%	74 to 78^{0}F	40 to 60%	15 cm cfm per person	-	8 MERV or better	35 to 35
Conference	68 to 74^{0}F	30 to 35%	74 to 78^{0}F	40 to 60%	20 cm cfm per person	-	8 MERV or better	25 to 35
Meeting Rooms Assembly Rooms	68 to 74^{0}F	30 to 35%	74to78^{0}F	40 to 60%	15 cm cfm per person	-	8 MERV or better	25 to 35
This table should be the only source for design criteria. Data contained here can be determined from volumes of the ASHRAE Handbook, Standards and Governing Local Codes.					[c]Minimum recommended humidity [d]Air exhaust from bath and toilets areas [e]Pre ASHRAE Standard 52.2 MERV - minimum efficiency reporting values			

Table 1.65 : General Design Criteria temperature RH and Air Movement

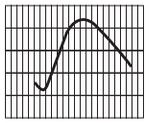
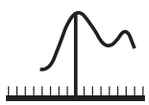
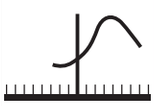
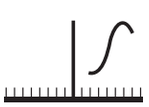
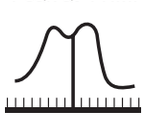
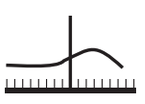
General Category	Specific Category	Inside Design Conditions		Air Movement	Circulation air changes per hour	Noise	Filteration Efficiencies (ASHRAE Standard 52.1)	Load Profile	Comments
		Winter	Summer						
Dining and Entertainment	Cafeteria and function Areas	70to74^{0}F 20 to 30% in RH	78.1 50% RH	50 fpm and 6 ft. above	12 to15	NC 40 to 50	35% or better	Peak at 1 to 2 P. M. 	Proven draft discomfort for patrons waiting in serving lines
	Restaurants	70 to 74^{0}F 20 to 30% in RH	74 to78^{0}F 55 to 60% RH	28 to 30fpm	8 to 12	NC 35 to 40	35% or better	Peak at 1 to 2 P. M. 	
	Bars	70 to74^{0}F 20 to 30% RH	74 to 78^{0}F 55 to 60% RH	30 fpm at 6 ft above floor	15 to 20	NC 35 to 50	Use charcoal for odor control with manual purge control for 100% outside air to exhaust +35% prefilters	Peak at 5 to 7 P.M. 	
	Nightclubs and Casinos	70 to 74^{0}F 20 to 30% RH	74 to 78^{0}F 55 to 60% RH	Below 2.5 fpm at 5 ft above floor	20 to 30	NC 35 to 45	Use charcoal for odor control with manual purge control for 100% outside air to exhaust +35% prefilters	Nightclubs peak at 8 P.M. to 2 A.M. Casinos Peak at 4 P.M. to 2A.M. Equipment used 24h/day	Provide good movement but prevent cold draft discomfort for patrons.
	Kitchens	70 to 74^{0}F	85 to 88^{0}F	30 to 50 fpm	12 to 15	NC 40 to 50	10 to 15%		Negative air Pressure required for odor control.
Office Building		70 to 74^{0}F 20 to 30% rh	85 to 88^{0}F 50 to 60%	25 to 45 fpm 0.75 to 2cfm/ft^2	4 to 10	NC 30 to 45^0	35 to 60% or better	Peak at 4 P.M. 	
Museum, Libraries and Archives	Average	68to72^{0}F 40 to 55% rh		Below 25 fpm	8 to 12	NC 35 to 40	35 to 60% or better	Peak at 3 P.M. 	
	Archival	Museum Libraries and Archives		Below 25 fpm	8 to 12	NC35	35% prefilters plus charcoal filters, 85 to 90% final filters	Peak at 3 P.M. 	

Table 1.65 : General Design Criteria[a,b] temperature RH and Air Movement (contd.)

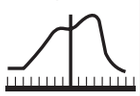
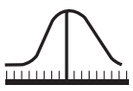
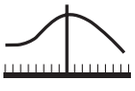
General Category	Specific Category	Inside Design Conditions		Air Movement	Circulation air changes per hour	Noise	Filteration Efficiencies (ASHRAE Standard 52.1)	Load Profile	Comments
		Winter	Summer						
Bowling Centres		70 to 74°F 20 to 30% rh	73 to 78°F 50 to 55%	50 fpm at 6 ft. above floor	10 to 15	NC 40 to 50	10 to 15%	Peak at 6 to 8pm. 	
Communication Centres	Telephone Terminal Rooms	72 to 78°F 40 to 50% rh	72 to 78°F 40 to 50% rh	50 fpm at 6ft. above floor	8 to 20	upto NC 60	83% or better	Varies with location and use	Constant temperature and humidity required
	Radio and Television Studios	72 to 78°F 40 to 50% rh	72 to 78°F 40 to 50% rh	50 fpm at 6ft. above floor	15 to 40	NC 15 to 25	35% or better	Varies widely due to changes in lighting and people	Constant temperature and humidity required
Transportation Centres	Airport Terminals	70 to 74°F 20 to 30% rh	70 to 74°F 50 to 60% rh	25 to 30 fpm at 6 ft. above floor	8 to 12	NC 35 to 50	35% or better and charcoal filters	Peak at 10 A.M. to 9 P.M. 	Positive air pressure required in terminal
	Ship Docks	70 to 74°F 20 to 30% rh	70 to 74°F 50 to 60% rh	25 to 30 fpm at 6 ft. above floor	8 to 12	NC 35 to 50	10 to 15%	Peak at 10 A.M. to 5 P.M. 	Positive air pressure required in waiting area
	Bus Terminals	70 to 74°F 20 to 30% rh	70 to 74°F 50 to 60% rh	25 to 30 fpm at 6 ft. above floor	8 to 12	NC 35 to 50	35% with exfiltration	Peak at 10 A.M. to 5 P.M. 	Positive air pressure required in terminal
	Garages	40 to 55°F	80 to 100°F	30 to 75 fpm	4 to 6	NC 35 to 50	10 to 15%	Peak at 10A.M. to 5 P.M. 	Negative air pressure required to remove combustion products. Positive air pressure in adjacent occupied spaces
Warehouses		Inside design temperatures for warehouse often depend on the material stored			1 to 4	to NC 75	10 to 35%	Peak at 10 A.M. to 3 P.M. 	

Table 1.66 : Design Criteria for Hotel Back - of - House Areas[a] T & RH

Category	Inside Design Conditions	Comments
Kitchen (General)	82^{0}F	Provide Spot Cooling
Kitchen (Pastry)	76^{0}F	
Kitchen (Chef's Office)	74 to 78^{0}F 50 to 60% rh (summer) 30 to 35% rh (winner)	Fully Air - Conditioned
Housekeeper's Office	74 to 78^{0}F 50 to 60% rh (summer) 30 to 35% rh (winter)	Fully Air - Conditioned
Telephone Equipment Room	Per Equipment criteria	Stand alone Air - Conditioner, Air - Conditioned all year
Wine Storage	Per food and beverage manager criteria	Air - conditioned all year
Laundry		Spot cooling as required at workstations
[a]Governing local codes must be followed for design of the HVAC		

Table 1.67 : Recommended Winter and Summer Design Dry-Bulb Temperatures for Various Spaces in Schools[a]

Space	Winter Design °F	Summer Design °F
Laboratories	72	78[d]
Auditoriums, Libraries, Administrative areas etc.	72	78
Classrooms		
Pre-K through 3rd	75	
4th through 12th	72	78
Shops	72	78
Lockers, Shower rooms	75[d]	78[d]
Toilets	72	c
Storage	65	c, d
Mechanical Rooms	60	c
Corridors	68	80[b]
a For spaces of high population density and where sensible heat factors are 0.75 or less. Lower dry-bulb temperature will result in generation of less latent heat, which may reduce the need for reheat and thus save energy. Therefore optimum Dry Bulb Temperatures should be the subject of detailed design analysis. b Frequently not air-conditioned. c Usually not air-conditioned. d Provide ventilation for odor control.		

Table 1.68 : Filter Efficiencies for Central Ventilation and Air-Conditioning Systems in General Hospitals[c]

Minimum Number of Filter Beds	Area Designation	Filter Efficiencies MERV[a]	
		Filter Bed	
		No. 1	No. 2
2	Orthopedic Operating Room Bone marrow Transplant Operating Room Organ Transplant Operating Room	7	HEPA[b]
2	General procedure operating rooms Delivery rooms Nurseries Intensive Care Units Patient Care Rooms Treatment Rooms Diagnostic and Related Areas	7	14
1	Laboratories Sterile Storage	13	
1	Food Preparation areas Laundries Administrative Areas Bulk Storage Soiled Holding Areas	7	
[a]MERV - minimum efficiency reporting value based on ASHRAE Standard S2-2-2007. [b]HEPA filters at air outlets. [c]For guidance on selection and placement of filters, see ASHRAE Standard 170.			

Table 1.69 : Design Parameters for Areas Affecting Patient Care in Hospitals and Outpatient Facilities

Space Function	Pressure Relationship to Adjacent Areas (n)	Minimum Outdoor Air-ACH	Minimum Total Air-ACH	All Room Air Exhausted Directly to Outdoors(j)	Air Recirculated by Means of Room Units(a)	Relative Humidity Rh % (k)	Design temperature (l),°F/°C
Surgery and Critical Care							
Operating Rooms (Classes B and C) (m) (n), (o)	Positive	4	20	N/R	No	20 to 60	68-75 / 20-24
Operating / surgical cycstoscopic rooms (m) (n), (o)	Positive	4	20	N/R	No	20 to 60	68-75 / 20-24
Delivery room (Caesarean) (m) (n), (o)	Positive	4	20	N/R	No	20 to 60	68-75 / 20-24
Substerile services area	N/R	2	6	N/R	No	N/R	N/R
Recovery room	N/R	2	6	N/R	No	20 to 60	70-75 / 21-24
Critical and intensive care	N/R	2	6	N/R	No	30 to 60	70-75 / 21-24
Intermediate care (s)	N/R	2	6	N/R	NR	Max. 60	70-75 / 21-24
Wound intensive care (burn unit)	N/R	2	6	N/R	No	40 to 60	70-75 / 21-24
New born intensive care	Positive	2	6	N/R	No	30 to 60	70-75 / 21-24
Treatment rooms (t)	N/R	2	6	N/R	N/R	20 to 60	70-75 / 21-24
Trauma Room (Crisis or Shock) (C)	Positive	3	15	N/R	No	20 to 60	70-75 / 21-24
Medical Anesthesia gas storage (r)	Negative	N/R	8	Yes	N/R	NR	N/R
Laser eye room	Positive	3	15	N/R	No	20 to 60	70-75 / 21-24
ER waiting rooms	Negative	2	12	Yes(q)	N/R	Max 65	70-75 / 21-24
Triage	Negative	2	12	Yes(q)	N/R	Max 60	70-75 / 21-24
ER De-contamination	Negative	2	12	Yes	No	N/R	N/R
Radiology waiting rooms	Negative	2	12	Yes [q), (w)	N/R	Max 60	70-75 / 21-24
Procedure Room (Class A Surgery) (o), (d)	Positive	3	15	N/R	No	20 to 60	70-75 / 21-24
Emergency Department Exam / Treatment Room (p)	N/R	2	6	N/R	N/R	Max. 60	70-75 / 21-24
Inpatient Nursing							
Patient room (s)	N/R	2	4 (y)	N/R	N/R	Max 60	70-75 / 21-24
Nourishment Area or Room	N/R	N/R	2	N/R	N/R	N/R	
Toilet room	Negative	N/R	10	Yes	No	N/R	N/R
Newborn nursery suite	N/R	2	6	N/R	No	30 to 60	N/R
Protective environment room (t)	Positive	2	12	N/R	No	Max 60	72-78 / 22-26
All rooms (u)	Negative	2	12	Yes	No	Max 60	70-75 / 21-24
Combination All / PE Room	Positive	2	12	Yes	No	Max 60	70-75 / 21-24
All Anterooms (u)	(e)	N/R	10	Yes	No	N/R	N/R
PE Anterooms (t)	(e)	N/R	10	N/R	No	N/R	N/R
Combination All / PE Anterooms	(e)	N/R	10	Yes	No	N/R	N/R
Labor / Delivery / Recovery / Postpartum (LDRP) (s)	N/R	2	6	N/R	N/R	Max 60	70-75 / 21-24
Labor / Delivery / Recovery (LDR) (s)	N/R	2	6	N/R	N/R	Max 60	70-75 / 21-24
Patient corridor	N/R	N/R	2	N/R	N/R	N/R	N/R
Nursing Facility							
Resident Room	N/R	2	2	N/R	N/R	N/R	70-75 / 21-24
Resident Gathering / Activity / Dining	N/R	4	4	N/R	N/R	N/R	70-75 / 21-24
Resident Unit Corridor	N/R	N/R	4	N/R	N/R	N/R	N/R
Physical Therapy	Negaitve	2	6	MD	N/R	N/R	70 75/21-24
Occupational Therapy	N/R	2	6	N/R	N/R	N/R	70-75/21-24
Bathing Room	Negative	N/R	10	Yes	No	N/R	70-75/21-24
Radiology (V)							
X-Ray (Diagnostic and Treatment)	N/R	2	6	N/R	N/R	Max. 60	72-78/22-26
X-Ray (Surgery / Critical Care and Catherization)	Positive	3	15	N/R	No	Max. 60	72-75/21-24
Darkroom (g)	Negative	2	10	Yes	No	N/R	N/R
Diagnostic And Treatment							
Bronchoscopy, Sputum collection and Pentamidine administration (n)	Negative	2	12	Yes	No	NR	68-73 / 20-23
Laboratory, general (v)	Negative	2	6	N/R	N/R	N/R	70-75 / 21-24
Laboratory, bacteriology (v)	Negative	2	6	Yes	N/R	N/R	70-75 / 21-24
Laboratory, biochemistry (v)	Negative	2	6	Yes	N/R	N/R	70-75 / 21-24
Laboratory, cytology (v)	Negative	2	6	Yes	N/R	N/R	70-75 / 21-24
Laboratory, glass washing	Negative	2	10	Yes	N/R	N/R	N/R
Laboratory, histology (v)	Negative	2	6	Yes	N/R	N/R	70-75 / 21-24
Laboratory, microbiology (v)	Negative	2	6	Yes	N/R	N/R	70-75 / 21-24
Laboratory, nuclear medicine (v)	Negative	2	6	Yes	N/R	N/R	70-75 / 21-24
Laboratory, pathology (v)	Negative	2	6	Yes	N/R	N/R	70-75 / 21-24
Laboratory, serology (v)	Negative	2	6	Yes	N/R	N/R	70-75 / 21-24
Laboratory, sterilizing (v)	Negative	2	10	Yes	N/R	N/R	70-75 / 21-24
Laboratory, media transfer (v)	Positive	2	4	N/R	N/R	N/R	70-75 / 21-24
Non-refrigerated body-holding rooms	Negative	N/R	10	Yes	No	N/R	70-75 / 21-24
Autopsy room	Negative	2	12	Yes	No	N/R	68-75 / 20-24
Pharmacy	Positive	2	4	N/R	N/R	N/R	N/R
Examination room	N/R	2	6	N/R	N/R	Max 60	70-75 / 21-24
Medication room	N/R	2	4	N/R	N/R	Max 60	70-75 / 21-24
Gastrointestinal endoscopy procedure room (x)	N/R	2	6	N/R	No	20-60	68-75 / 20-24
Endoscope cleaning	Negative	2	10	Yes	No	N/R	N/R
Treatment room	N/R	2	6	N/R	N/R	Max 60	70-75 / 21-24

Table 1.70 : Design Parameters for Areas Affecting Patient Care in Hospitals and Outpatient Facilities

Hydrotherapy	Negative	2	6	N/R	N/R	N/R	72-80 / 22-27
Physical Therapy	Negative	2	6	N/R	N/R	Max 65	72-80 / 22-27
Sterlizing							
Sterilizer Equipment Room	Negative	N/R	10	Yes	No	N/R	N/R
CENTRAL MEDICAL AND SURGICAL SUPPLY							
Soiled Or Decontamination Room	Negative	2	6	Yes	No	N/R	72-78 / 22-26
Clean Workroom	Positive	2	4	N/R	No	Max. 60	72-78/22-26
Sterile Storage	Positive	2	4	N/R	N/R	Max. 60	72-78 / 22-26
SERVICE							
Food Preparation Center (i)	N/R	2	10	NR	No	N/R	72-78 / 22-26
Warewashing	Negative	N/R	10	Yes	No	N/R	N/R
Dietary Storage	N/R	N/R	2	NR	No	N/R	72-78 / 22-26
Laundry, General	Negative	2	10	Yes	No	N/R	N/R
Soiled Linen Sorting And Storage	Negative	N/R	10	Yes	No	N/R	N/R
Clean Linen Storage	Positive	N/R	2	N/R	N/R	N/R	72-78 / 22-26
Linen And Trash Chute Room	Negative	N/R	10	Yes	No	N/R	N/R
Bedpad Room	Negative	N/R	10	Yes	No	N/R	N/R
Bathroom	Negative	N/R	10	Yes	No	N/R	72-78 / 22-26
Janitor's Closet	Negative	N/R	10	Yes	No	N/R	NR
SUPPORT SPACE							
Soiled Workroom or Soiled Holding	Negative	2	10	Yes	No	N/R	N/R
Clean Workroom or Clean Holding	Positive	2	4	N/R	N/R	N/R	N/R
Hazardous Material Storage	Positive	2	10	Yes	No	N/R	N/R

NOTES for Table 1-T-74

a. Except where indicated by a "No" in this column, recirculating room HVAC units (with heating or cooling coils) are acceptable for providing that portion of the minimum total air changes per hour that is permitted by Section 7.1 of ASHRAE STD 170-2013 (subparagraph [a][5]). Because of the cleaning difficulty and potential for buildup of contamination, recirculating room units shall not be used in areas marked "No." Recirculating devices with HEPA filters shall be permited in existing facilities as interim, supplemental environmental controls to meet requirements for the control of airborne infectious agents. The design of either portable or fixed systems should prevent stagnation and short circuiting of airflow. The design of such systems shall also allow for easy access for scheduled preventative maintenance and cleaning,

b. Pharmacy compounding areas may have additional air change, differential pressure, and filtering requirements beyond the minimum of this table depending on the type of pharmacy, the regulatory requirements which may include adoption of USP 797), the associated level of risk of the work (see USP [2013] in Informative Appendix B), and the equipment utilized in the spaces.

c. The term *trauma* room as used herein is a first-aid room and/or emergency room used for general initial treatment of accident victims. The operating room within the trauma center that is routinely used for emergency surgery is considered to be an operating room by this standard.

d. Pressure relationships need not be maintained when the room is unoccupied.

e. All air need not be exhausted if darkroom equipment has a scavenging exhaust duct attached and meets ventilation standards regarding NIOSH, OSHA, and local employee exposure limits. A nonrefrigerated body-holding room is applicable only to facilities that do not perform autopsies on-site and use the space for short periods while waiting for the body to be transferred,

f. Minimum total air changes per hour (ach) shall be that required to provide proper makeup air to kitchen exhaust systems as specified in ANSI/ASHRAE Standard 154.[4] In some cases, excess exfiltration or infiltration to or from exit corridors compromises the exit corridor restrictions of NFPA 90A,[5] the pressure requirements of NFPA 96,[6] or the maximum defined in the table. During operation, a reduction in the number of air changes to any extent required for odor control shall be permitted when the space is not in use.

g. In some areas with potential contamination and/or odor problems, exhaust air shall be discharged directly to the outdoors and not recirculated to other areas. Individual circumstances may require special consideration for air exhausted to the outdoors. To satisfy exhaust needs, constant replacement air from the outdoors is necessary when the system is in operation.

h. The RH ranges listed are the minimum and/or maximum allowable at any point within the design temperature range required for that space.
Systems shall be capable of maintaining the rooms within the range during normal operation. Lower or higher temperature shall be permitted when patients' comfort and/or medical conditions require those conditions,

i. National Institute for Occupational Safety and Health (NIOSH) criteria documents regarding occupational exposure to waste anesthetic gases and vapors, and control and /or occupational exposure to nitrous oxide[7] indicate a need for both local exhaust (scavenging) systems and general ventilation of the areas in which the respective gases are utilized. Refer to NFPA 99 for other requirements.[8]

j. If pressure-monitoring device alarms are installed, allowances shall be made to prevent nuisance alarms. Short-term excursions from required pressure relationship shall be allowed while doors are moving or temporarily open. Simple visual methods such as smoke trail, ball-in-tube, or flutterstrip shall be permitted for veification of airflow direction.

k. Surgeons or surgical procedures may require room temperatures, ventilation rates, humidity ranges, and/or air distribution methods that exceed the minimum indicated ranges.

l. Treatment rooms used for bronchoscipy shall be treated as bronchoscopy rooms. Treatment rooms used for procedures with nitrous oxide shall contain provisions for exhausting anesthetic waste gases.

m. In a recirculating ventilation system, HEPA filters shall be permited instead of exhausting the air from those spaces to the outdoors provided that the return air passes throught the HEPA filters before it is introduced into any other spaces The entire minimum total air changes per hour of recirculating airflow shall pass through HEPA filters. When these areas are open to larger, nonwaiting spaces, the exhaust air volume shall be calculated based on the seating area of the waiting area. (Note. The intent here is to not require the volume calculation to include a very large space [e.g., an atrium] just because a waiting area opens onto it).

n. See NFPA 99 for further requirements.[8]

o. For intermediate care, labor/delivery/recovery rooms, and labor/delivery/recovery/postparum rooms, four total ach shall be permitted when supplemental heating and/or cooling systems (radiant heating and cooling, baseboard heating, etc.) are used.

p. The protective environment airflow design specifications protect the patient from common environmental airborne infectious microbes (i.e., Aspergillus spores). Recirculation HEPA filters shall be permitted to increase the equivalent room air exchanges; however, the outdoor air changes are still required. Constant-volume airflow is required for consistent ventilation for the protected environment. The pressure relationship to adjacent areas shall remain unchanged if the PE room is utilized as a normal patient room. Rooms with reversible airflow provisions for the purpose of switching between protective environment and all functions shall not be permitted.

q. The All room described in this standard shall be used for isolating the airborne spread of infectious diseases, such as measles, varicella, or tuberculosis. Supplemental recirculating devices using HEPA filters shall be permitted in the All room to increase the equivalent room air exchanges; however, the minimum outdoor air changes of tables are still required. All rooms that are retrofitted from standard patient rooms, from which it is impractical to exhaust directly outdoors, may be recirculated with air from the All room, provided that air first passes through a HEPA filter. When the All room is not utilized for airborne infection isolation, the pressure relationship to adjacent areas, when measured with the door closed, shall remain unchanged and the minimum total air change rate shall be 6 ach. Switching controls for reversible airflow provisions shall not be permitted.

r When required, appropriate hoods and exhaust devices for the removal of noxious gases or chemical vapors shall be provided in accordance with NFPA 99.[8]

s. The requirement that all room air is exhausted directly outdoors applies only to radiology waiting rooms programmed to hold patients who are waiting for chest x-rays for diagnosis of respiratory disease.

t. If the planned space is designated in the organization's operational plan to be utilized for both bronchoscopy and gastrointestinal endoscopy, the design parameters for "bronchoscopy, sputum collection, and pentamidine administration" shall be used.

u. For single-bed patient rooms using Group D diffusers, a minimum of six total ach shall be provided and calculated based on the volume from finished floor to 6 ft (1.83 m) above the floor.

Source : ASHRAE std 170-2013

Table 1.71 : Comparison of Regulations and Guidelines Pertinent to Indoor Environments

(The user of any value in this table should take into account the purpose for which it was adopted and the meaning by which it was developed)

	Enforceable and/or Regulatory Levels			Non-enforced Guidelines and Reference Levels			
	NAAQS/EPA	OSHA	MAK	Canada	WHO/Europe	NIOSH	ACGIH
Carbon dioxide		5000 ppm	5000 ppm 10000ppm(1 h)	3500 ppm (L)		5000 ppm 30000 ppm (15 min)	5000ppm 30000 ppm (15 min)
Carbon monoxide[c]	9 ppms 35 ppm (1 h)[g]	50 ppm	30 ppm 60 ppm (30 min)	11 ppm (8h) 25 ppm (1 h)	90 ppm(15 mm) 50 ppm (30 mm) 25 ppm (1 h) 10 ppm(8h)	35 ppm 200 ppm (C)	25 ppm
Formaldehyde[h]		0.75 ppm 2 ppm(15 min)	0.3 ppm 1 ppm	0.1 ppm (L) 0.05 ppm (L)[b]	0.1mg/m^3 (0.081 ppm) (30 min)[p]	0.016 ppm 0.1 ppm (15 min)	0.3 ppm (C)
Lead	1.5 p/m	0.05 mg/m^3	0.1 mg/m^3 1 mg/m^3	Minimise exposure	0.5 g/m^3 '(1 yr)	0.050 mg/m^3	0.05 mg/m^3
Nitrogen dioxide	0.05 ppm (1 yr)	5 ppm (C)	5 ppm 10 ppm (5 min)	0.05 ppm 0.25 ppm (1 h)	0.1 ppm (1 h) 0.02 ppm (1 yr)	1 ppm (15 Mm)	3 ppm 5 ppm (15 min)
Ozone	0.12ppm(1h)9 0.08 ppm	0.1 ppm	J	0.12 ppm (1 h)	0.064 ppm (120 g/m^3) (8h)	0.1 pprn (C)	0.05 ppm[k] 0.08 ppm[l] 0.1 ppm[m] 0.2 ppm[n]
Particles[e] <2.5 m MMAD[d]	15 g/m^3 (1yr)[0] 35 g/m3 (24 h)[0]	5 mg/m3	1.5 mg/m^3 for<4 m	0.1 mg/m^3 (1 h) 0.040 mg/m^3 (L)			3 mg/m^3 (C)
Particles[e] <10 m MMAD[d]	150 g/m^3 (24 h)[0]		4 mg/m^3				10 mg/m^3 (C)
Radon				800 Bq/m^3(1yr)			
Sulfur dioxide	0.03 ppm (1 yr) 0.14 ppm (24 h)[g]	5 ppm	0.5 ppm 1 ppm	0 38 ppm (5min) 0.01 9 ppm	0 048 ppm (24 h) 0 012 ppm (1 yr)	2 ppm 5 ppm (15mm)	2 ppm 5 ppm (15 min)
Total Particles[c]		15 mg/m^3					

a. Numbers in brackets ( ) refers to either a ceiling or to averaging times of less than or greater than eight hours (min=minutes, h=hours, y=year, c=ceiling, L=long term. Where no time is specified, the averaging time is eight hours.

b. Target level is 0.05 ppm because of its potential carcinogenic effects. Total aldehydes limited to 1 ppm. Although epidemiological studies conducted to date provide little convincing evidence that formaldehyde is carcinogenic in human populations, because of this potential, indoor levels should be reduced as much as possible.

c. As one example regarding the use of values in this table, readers should consider the applicability of carbon monoxide concentrations. The concentrations considered acceptable for nonindustrial, as opposed to industrial exposure are substantially lower. These lower concentrations (in other words the ambient air quality standards, which are required to consider population at highest risk) are set to protect the most sensitive subpopulations, individuals with pre-existing heart conditions.

d. MMAD mass median aerodynamic diameter in microns (micrometers) less than 3.0 μm is considered respirable; less than 10 μm is considered inhalable.

e. Nuisance particles not otherwise classified (PNOC), not known to contain significant amounts of asbestos, lead, crystalline, silica, known carcinogens or other particles known to cause significant adverse health effects.

f. Refer US EPA guideline.

g. Not to be exceeded more than once per year.

h. The US Department of Housing and Urban Development adopted regulations concerning formaldehyde emissions from plywood and particleboard intended to limit the airborne concentration of formaldehyde in manufactured homes to 0.4 ppm (24 CFR Part 3280, HUD Manufactured Home Construction and Safety Standards). In addition, California Air Resources Board Regulations 93120 entitled “Airborne Toxic Control Measure to Reduce Formaldehyde Emission from Composite Wood products” has specific chamber-based requirements for composite wood products sold in California [B-47].

i. Never to be exceeded.

j. Carcinogen, no maximum values established.

k. TLV for heavy work.

l. TLV for moderate work.

m. TLV for light work.

n. TLV for heavy, moderate or light workloads (less than or equal to two hours).

o. 62FR38652 -38760, July 16,1997.

p. Epidemiological studies suggest a causal relationship between exposure to formaldehyde and nasopharyngeal cancer, although the conclusion is tempered by the small number of observed and expected cases. There are also epidemiological observations of an association between relatively high occupational exposures to formaldehyde and sinonasal cancer.

Table 1.72 : Pressure Relationships and Ventilation of Criteria Areas of Nursing Homes

Function Area	Pressure Relationship to Adjacent Areas	Minimum Air Changes of Outside Air per Hour Supplied to Room	Minimum total Air Changes per Hour Supplied to Room	All Air Exhausted Directly Outside	Air Recirculated within room Units
Patient Care					
Patient Room (Holding room)	*	2	6	Optional	Optional
Patient area corridor	*	Optional	2	Optional	Optional
Toilet room	Negative	Optional	10	Yes	No
Diagnostic and Treatment					
Examination room	*	2	6	Optional	Optional
Physical therapy room	Negative	2	6	Optional	Optional
Occupational therapy room	Negative	2	6	Optional	Optional
Soiled workroom or soiled holding room	Negative	2	10	Yes	No
Clean workroom or clean holding room	Positive	2	4	Optional	Optional
Sterilizing and Supply					
Sterilizer exhaust room	Negative	Optional	10	Yes	No
Linen and trash chute room	Negative	Optional	10	Yes	No
Laundry, general	*	2	10	Yes	No
Soiled linen sorting and storage	Negative	Optional	10	Yes	No
Clean linen storage	Positive	Optional	2	Yes	No
Service					
Food preparation center	*	2	10	Yes	Yes
Warewashing room	Negative	Optional	10	Yes	Yes
Dietary day storage	*	Optional	2	Yes	No
Janitor closet	Negative	Optional	10	Yes	No
Bathroom	Negative	Optional	10	Yes	No

*Continuous directional control not required

Source : ASHRAE Handbook

Table 1.73 : Recommended Dry-Bulb Temperatures for Common Laboratory Animals

Animal	Temperature ^{o}F
Mouse, Rat, Hamster, Gerbil, Guinea pig	64 to 79
Rabbit	61 to 72
Cat, Dog, Non - human primate	64 to 84
Farm animals and Poultry	61 to 81

Source : ILAR (1996)
Note : These ranges permit scientific personnel who use the facility to select optimum conditions (set points). The ranges do not represent acceptable fluctuation ranges.

Table 1.74 : Heat Generated by Laboratory Animals

Species	Weight lb	Heat Generation, Btu/h per Normally Active Animal		
		Sensible	Latent	Total
Mouse	0.046	1.11	0.54	1.65
Hamster	0.260	4.02	1.98	6.00
Rat	0.62	7.77	3.83	11.6
Guinea pig	0.90	10.2	5.03	15.2
Rabbit	5.41	39.2	19.3	58.5
Cat	6.61	45.6	22.5	68.1
Non - human primate	12.0	71.3	35.1	106.0
Dog	22.7	105.0	56.4	161.0
Dog	50.0	231.0	124.0	355.0

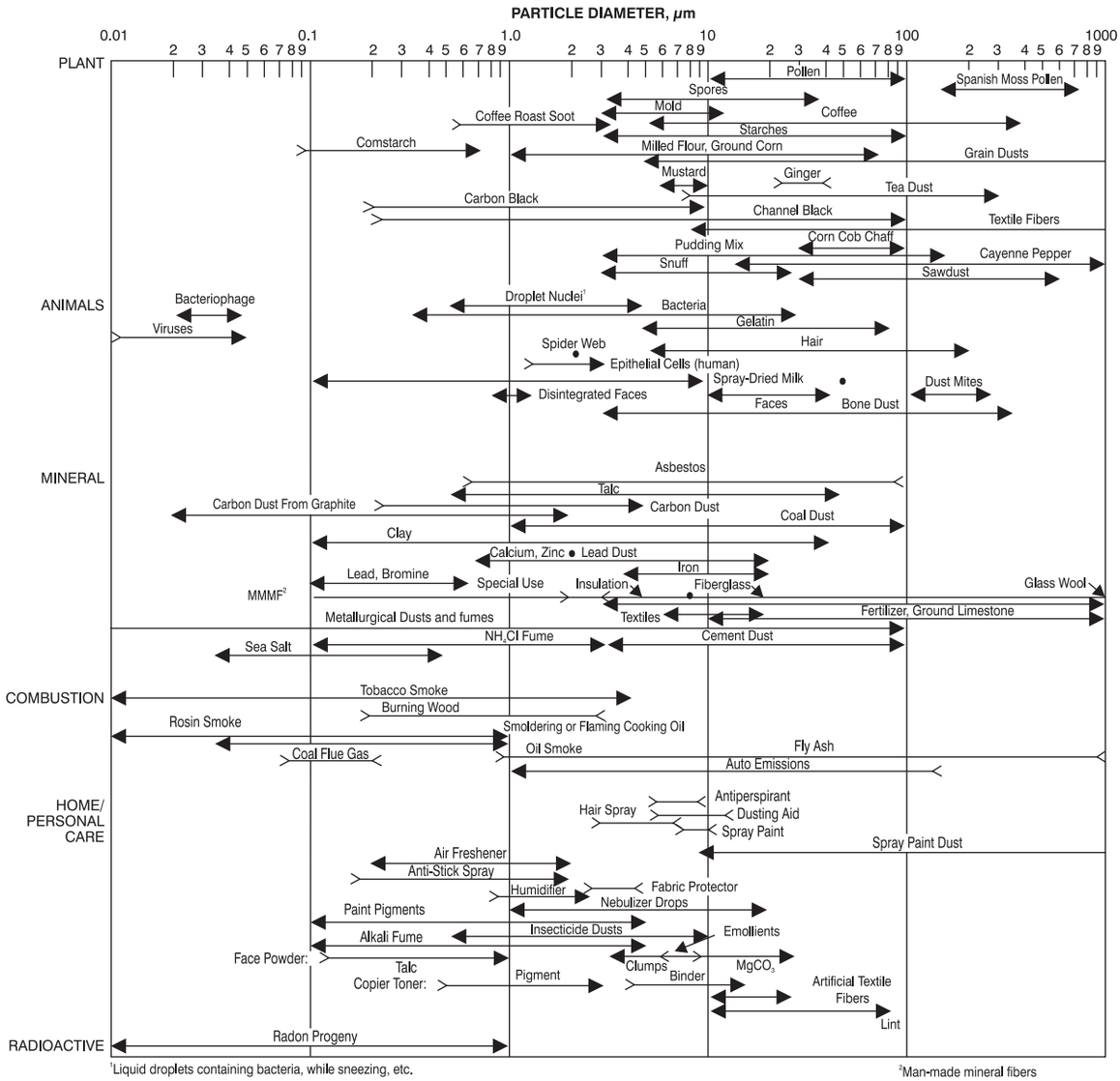


Figure 1.6 : Size of Indoor Particles

Source : ASHRAE F-2013

Engine Test Facilities

Table 1.75 : Exhaust Quantities for Test Cells

	Minimum Exhaust Rates per Square Foot of Floor Area	Air Changes per h[a]
	Cfm	
Engine Test cell operating	10	60
Cell idle	2	12
Trenches and pits	10	-
Accessory Testing	4	24
Control Rooms and Corridors	1	6

[a] Based on a cell height of 10 ft.
[b] For chassis dynamometer rooms, this quantity is usually set by test requirements.
[c] For large trenches, use 100 fpm across the cross-sectional area of the trench.

Source : ASHRAE F-2013

Table 1.76 : Typical Noise Levels in Test Cells

Type and Size of Engine	Sound level 3 ft. from Engine, dBA			
	63Hz	124Hz	5OOHz	2000Hz
Diesel				
Full load	105	107	98	99
Part load	70	84	56	49
Gasoline engine, 440 V in 3 phase at 5000 rpm				
Full load	107	108	104	104
Part load	75	-	-	-
Rotary engine, 100 hp				
Full load	99	90	83.5	86
Part load	79	78	75	72

Table 1.77 : Sample Diesel Locomotive Engine Emission Data[a]

Throttle Position (Notch)	Engine Speed (rpm)	Engine Power bhp	Engine Airflow[b] cfm	Fuel Rate lb/h	NO lb/h	CO lb/h	HC lb/h	$S0_2$ lb/h	Particulars lb/h
Four Stroke Cycle, with Head End Power (HEP)									
8. Freight	1050	3268	8816	1103	81	59	3.9	0.51	0.96
7. HEP	900	2771	7068	929	71	13	3.0	0.43	1.1
6. HEP	900	2254	5668	762	62	11	2.6	0.35	0.92
5. HEP	900	1777	4433	609	51	10	1.6	0.28	0.64
4. HEP	900	1023	2677	369	34	3.2	1.2	0.17	0.51
3. HEP	900	713	2055	266	22	2.3	0.94	0.12	0.49
2. HEP	900	431	1656	174	14	1.6	0.88	0.08	0.54
1. HEP	900	322	1651	144	13	1.6	0.92	0.07	0.65
HEP idle	900	185	1511	81	6.3	2.0	1.1	0.04	0.91
Standby	720	512	1441	189	16	1.9	0.81	0.09	0.65
High idle	450	34	466	23	1.9	0.49	0.40	0.01	0.13
Low idle	370	22	NA	17	1.1	0.70	0.35	0.01	0.10
Two Stroke Cycle, with Head End Power (HEP)									
8	903	3210	8880	1060	86	8.1	2.0	0.49	1.3
7	821	2540	7100	833	56	4.1	1.2	0.38	0.92
6	726	1700	5310	572	38	1.5	0.83	0.26	0.64
5	647	1390	4630	480	33	1.4	0.79	0.22	0.58
4	563	1060	3950	368	28	0.61	0.64	0.17	0.42
3	489	714	3410	254	24	0.42	0.51	0.12	0.30
2	337	370	2200	142	13	0.46	0.33	0.07	0.12
1	337	207	2270	91	7.7	0.34	0.25	0.04	0.07
High idle	339	14	2390	32	2.5	0.17	0.21	0.02	0.05
Low idle	201	10	1320	14	1.3	0.08	0.08	0.01	0.02
Auxiliary Engine / Alternative for Head End Power (HEP)									
N/A	1800	699	1930	275	17	7.3	0.09	0.13	0.37
N/A	1800	566	2190	226	17	1.1	0.78	0.19	N/A
N/A	1800	438	2010	179	13	0.53	0.67	0.08	0.26
N/A	1800	377	1900	157	10	0.39	0.65	0.07	0.23
N/A	1800	305	1810	135	8.4	0.39	0.56	0.06	0.23
N/A	1800	238	1710	114	6.5	0.40	0.57	0.05	0.20
N/A	1800	173	1640	95	4.8	0.41	0.55	0.04	0.18
N/A	1800	31	1480	55	2.2	0.46	0.60	0.03	0.16

[a]Data from SwRI (Southwest Research Institute) report 084976 (1992) intake corrected to standard air density 0.0751 lb/ft^2

Table 1.78 : Comparison of Construction Alternatives - Tall Buildings

Alternative 1	Alternative 2	Alternative 3
Central Fan Systems	Floor-by-Floor Fan Systems	Floor-by-Floor DX Systems
Central Chilled Water	Central Chilled Water	Central Cooling Tower
First Cost Considerations		
HVAC		
Fewer Units, field erected. More complex and expensive duct systems. More complex field-installed controls. Central Chilled-Water plant.	More units, factory-fabricated and assembled. Simpler ductwork. Field-installed control system. Central Chilled-Water plant.	More units, factory-fabricated and assembled. Simpler ductwork. Factory-installed control system. No central Chilled-Water plant; Cooling Tower only.
Building Management System		
Complex controls and interface with building management system (BMS) and smoke control system	Controls are relatively simple but field - installed. Interface with BMS and smoke control system less complex.	Unit controls provided by manufacturer. Interface with BMS and smoke control system simple.
Electrical		
Electrical loads concentrated in central location. Probably lowest electrical cost.	Minor cost premium for distributed fan motors. Probably higher electrical cost than alternative 1.	Additional cost for electrical distribution to local DX units. Highest electrical cost.
General Construction		
Additional gross floor space needed. No separate outside air or smoke exhaust shaft.	Additional cost of sound treatment of local floor-by-floor fan room. Need separate outdoor air and smoke exhaust shaft.	Additional cost of sound treatment of local floor-by-floor fan room. Need separate outdoor air and smoke exhaust shaft.
Construction Schedule		
General Complexity of Installation		
Central mechanical equipment room space and complex construction technology for both chiller plant and fan systems locations. Requires piping of a major chiller plant. Chiller plant location critical to construction schedule. Heavier slab construction at central mechanical equipment room. Extensive complex ductwork in central mechanical equipment room.	Chiller plant space is required, with need for more complex construction technology. Requires piping a major chiller plant. Chiller plant location critical to construction schedule. Heavier slab construction for chiller plant only. Limited ductwork, repetitive fan room arrangement on each floor.	Areas that contain complex construction technology are limited. No major chiller plant. Cooling Tower only. Chiller Plant is not required. Very limited special slab construction. Limited ductwork, repetitive fan room arrangement on each floor.
Owner Issues		
Marketing / Electric Metering		
Tenant lights and small power can be metered directly. Fan energy and Chiller Plant energy, as well as heating energy, operating costs are allocated unless heating is by electric resistance heat. Other common building operating costs are allocated.	Tenant lights, small power, and fan energy can be metered directly tor any floor with a single tenant. Multi - tenanted floors require allocation of fan energy only. Chiller plant energy, as well as heating energy, operating costs are allocated unless heating is by electric resistance heat. Other common building operative costs are allocated.	Tenant lights, small power, fan, and cooling energy can all be metered for any floor with a single tenant. Multi - tenanted floors require allocation of fan energy and cooling energy only. Heating energy operating cost must be allocated unless heating is by electric resistance heat. Other common building operating costs are allocated.
Operating Costs		
For normal operating day, operating costs for all floors occupied are lower than alternative 3. Approximately equal to altemative 2. Overtime operation requires the chiller plant to operate in the summer. With variable-speed fan control and headered supply and return fans, energy costs equal to altemative 2. Operation more cumbersome. Fan and chiller plant costs must be allocated.	For summer operative day, operating costs for all floors occupied are lower because of lower energy consumption than alternative 3. Approximately equal to alternative 1. Overtime operation requires chiller plant to operate in summer but is otherwise simple. Chiller plant cost must be allocated.	For the summer operating day, operating costs for all floors occupied are higher due to higher energy consumption than alternatives 1 or 2 because of less efficient DX compressors. Overtime operation simplest but probably higher in cost than alternatives 1 or 2. Single-floor tenant cost for cooling tower only must be allocated.
Equipment Issues		
Equipment Maintenance		
All equipment are installed in central mechanical equipment room with centralized maintenance.	Requires more maintenance than alternative 1 but less than alternative 3, because of larger number of units with filters, motors, fan drives, bearings, etc. Chiller is in central mechanical equipment room, allowing centralized maintenance.	Requires more maintenance than alternative 1 or 2 because of larger number of units with filters. Motors, fan drives, bearings, etc. plus compressor equipment on each floor.

Table 1.78 : Comparison of Construction Alternatives - Tall Buildings (Contd...)

Alternative 1	Alternative 2	Alternative 3
Equipment Redundancy and Flexibility		
Can operate in reduced mode in case of limited failure due to headered fan arrangement. Can handle changing cooling loads and / or uneven cooling loads on a floor-by-floor basis within limits. Can usually turn down system operation to supply air to a single floor.	If unit fails, floor is without air-conditioning. Cannot handle changing cooling loads or uneven cooling loads on a floor-to-floor basis without building in additional system capacity at design.	If unit fails, floor is without air-conditioning. Cannot handle changing cooling loads on a floor-to-floor basis without building in additional system capacity at design.
Equipment Life Expectancy		
Life expectancy of equipment is in excess of 25 years.	Life expectancy of equipment is in excess of 25 years.	Compressor life expectancy is probably approximately 10 years. Remainder of installation life expectancy is in excess of 25 years.
Architectural Issues		
Building Massing		
Central Fan rooms usually require two-storey MER. Chiller plant room usually requires two-story MER.	Local fan room fits within floor-to-floor height of the office floor. Chiller plant room usually requires two-storey MER	Local fan room fits within floor-to-floor height of the office floor. No central chiller plant room required.
Usable Area		
Takes the least area per office floor. Maximum usable area per office floor.	Takes a greater area per floor. Less usable area per office floor than alternative 1.	Takes a greater area per floor. Less usable area per office floor than alternative 1.
Gross Area Takes more gross building area than alternatives 2 to 3.	Takes more gross building area than alternative 3 but less than alternative 1.	Takes less gross building area than alternatives 1 or 2.

Table 1.79: Airborne Particle Concentration Limits from ISO Standard 14644-1

Class	0,1 μm	0.2 μm	0.3 μm	0.5 μm	1.0 μm	5.0 μm
	Particles per m3					
ISO 1	10	2				
ISO 2	100	24	10	4		
ISO 3	1000	237	102	35	8	
ISO 4	10,000	2370	1020	352	83	
ISO 5	100,000	23,700	10,000	3520	832	29
ISO 6	1,000,000	237,000	102,000	35,200	8320	293
ISO 7				352,000	83,200	2930
ISO 8				3,520,000	832,000	29,300
ISO 9				35,200,000	8,320,000	293,000

Note : Values shown are the concentration limits for particles equal to and larger than the sizes shown.
Formula, $Cn = 10^n \times (0.1/D)^{2.08}$ Concentration limits in particles /m3, N=ISO Class, and D= particle diameter in μm

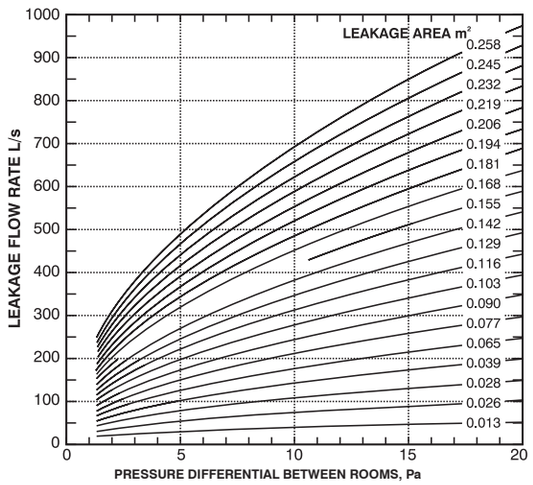


Figure 1.7 : Flow rate through leakage area under pressure differential

An air lock is a transitional space between adjacent rooms to prevent airborne cross contamination. Based on relative space pressure levels, air locks can be classified as follows:

- Cascading : Air lock pressure is between pressures in Clean Room and Corridor.

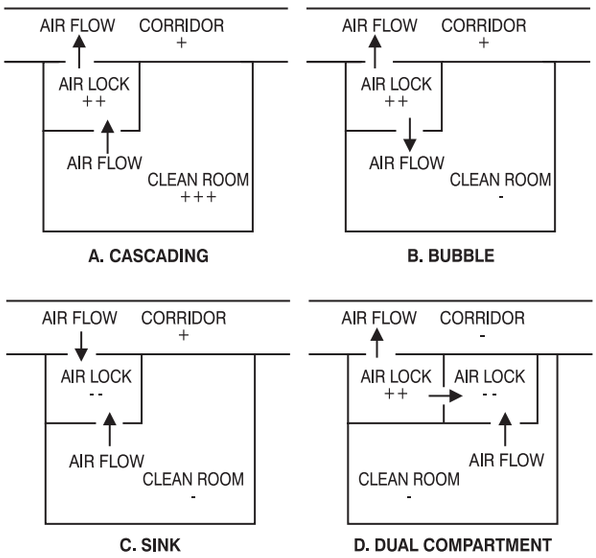


Figure 1.8 : Clean room air lock type

- Bubble : Air lock pressure is above pressures in Clean Room and Corridor
- Sink : Air lock pressure is below pressures in Clean Roorn and Corridor.
- Dual-compartment : A bubble and a sink air lock are connected.

Double-door air locks are often used at clean room entrances and exits. It is important that both doors are not open at the same time, to avoid cross contamination. A required time delay (RTD) needs to be specified between door openings, to minimize possible contamination during door opening. The RTD should be long enough for HEPA filtered clean supply air to partially or fully replace the entire air volume of the air lock room at least once before the second door is allowed to open. RTD operational procedures often use hard interlocks (I.e., the second door cannot be opened until after the required time delay) or soft interlocks, in which procedures are supplemented by lights or alarms.

Design Concerns for Pharmaceutical Clean rooms

The owner and designer must define the tolerable range of variable value (acceptance criterion) for each critical parameter. In that range, the product's safety, identity, strength, purity, and quality are not affected. The owner should define action alarm points at the limits of acceptance criteria, beyond which exposed product may be adulterated. The designer should select tighter (but achievable) target design values for critical parameters (in the range of acceptance criteria) along with appropriate values for warning alerts.

Facilities manufacturing penicillin or similar antibiotics, (e.g. cephalosporins) must be physically isolated from other manufacturing areas and served by a dedicated HVAC system. Other processes also require dedicated HVAC systems, including high-potency formula and formula that must have dedicated production facilities.

Facilities manufacturing aseptic/sterile products derived from chemical synthesis may have different requirements than those manufacturing biological or biotechnological products. The owner must define the inspecting agency's requirements.

Type of Clean room	Air Lock Type	Purpose of Air Lock	Relative Pressure Relationship
* Positive pressure * No Fumes or Bioagents * No Containment needed	Cascading	Prevent clean room being contaminated by dirty corridor air. Prevent clean room being contaminated from surrounding spaces through cracks.	Clean room +++ Air Lock ++ Corridor +
* Negative Pressure * Has Fumes or Bioagents * Containment needed	Bubble	Prevent clean room being contaminated by dirty corridor air.	Clean room (-) Air Lock ++ Corridor +
* Negative Pressure * Has Fumes or Bioagents * Containment needed	Sink	Prevent clean room being contaminated by dirty corridor air.	Clean room (-) Air Lock (- -) Corridor +
* Negative Pressure * Has toxic fumes or Hazardous bio agent contamination or has potent compound substances. * Containment needed * Personal protection needed	Dual compartment	Prevent clean room being contaminated by dirty corridor air.	Clean room (-) Air Lock ++ & (- -) Corridor (-)

Notes : 1) Excessive negative pressure in clean room is not recommended. If it is not surrounded by other clean spaces. untreated dirty air can infiltrate through cracks into clean room.
2) A clean room service corridor must often be designed with slightly positive or neutral pressure. Do not design for negative pressure unless a dual compartment lock is used.

Table 1.80 : Air changes per Hour Versus Vertical Airflow Velocities, Room Heights and Cleanliness Classes for HIGH BAY areas

ISO Class	Equivalent Federal Std. 209	Average Room Velocity, fpm	Air changes per Hour					
			8 ft. Celling	10 ft. Ceiling	20 ft. Ceiling	30 ft. Ceiling	40 ft. Ceiling	50 ft. Ceiling
2		85 to 100	638 to 750	510 to 500	255 to 300	170 to 200	128 to 150	85 to 100
3	Class 1	70 to 85	525 to 838	420to510	210 to 255	140 to 170	105 to 128	70 to 85
4	Class 10	60 to 70	450 to 525	360 to 420	180 to 210	120 to 140	90 to 105	60 to 79
5	Class 100	45 to 55	338 to 41 3	270 to 330	135 to 165	90 to 110	68 to 83	45 to 55
6	Class 1000	25 to 35	166 to 263	150 to 210	75 to 105	50 to 70	38 to 53	25 to 35
7	Class 10000	8 to 16	60 to 120	50 to 100	24 to 48	15 to 30	12 to 24	8 to 16
8	Class 100000	4 to 6	30 to 45	25 to 35	12 to 16	8 to 12	8 to 9	4 to 6
9	Class 1000000	2to3	15 to 23	12 to 18	6to9	4 to 6	3 to 5	2 to 3

Note : Large volumes of air in a high bay clean room use central recirculating fan systems and are commonly used with minimum heating and cooling capability. A separate injection air handler provides heating cooling and make - up air.

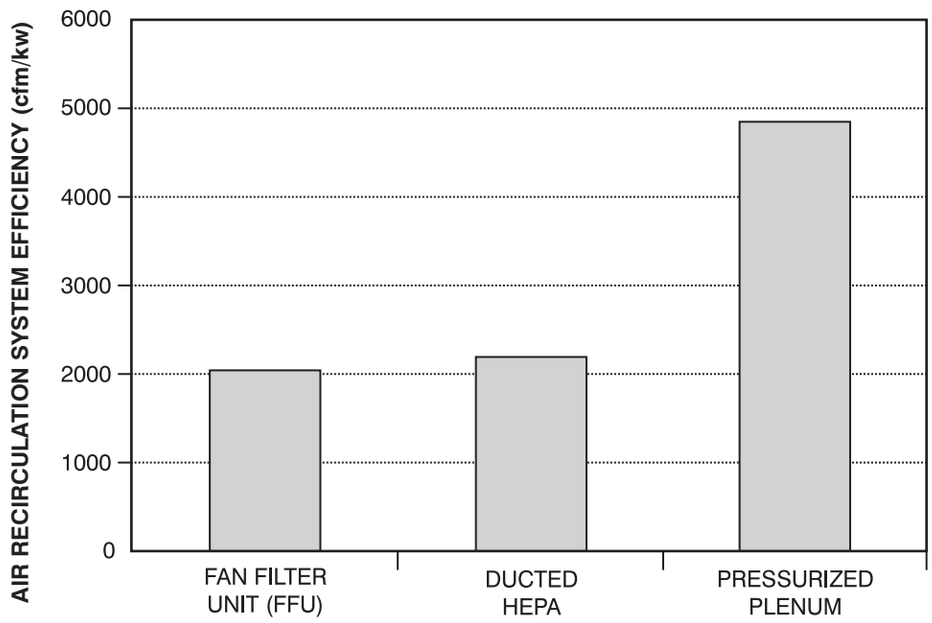


Figure 1.9 : Energy Efficiency of Air Recirculation System

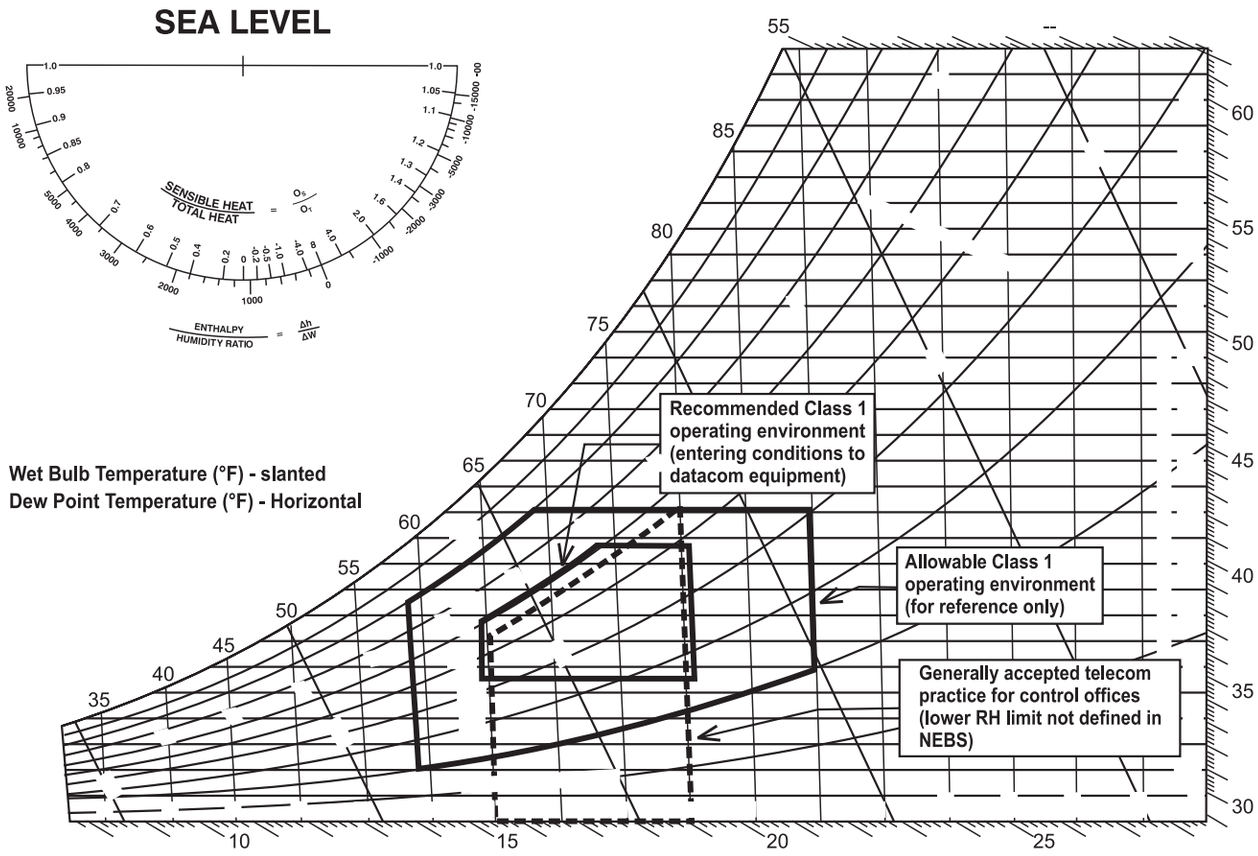


Figure 1.10 : Recommended Data Center Class 1, Class 2 and NEBS Operating ^{0}F

Table 1.81 : Class 1, Class 2 and Selected NEBS Design Conditions

Condition	Class 1 and 2		NEBS	
	Allowable Level	Recommended Level	Allowable Level	Recommended Level
Temperature control range[a]	59 to 90^{0}F (Class1) 50 to 90^{0}F (Class 2)	64.4 to 80.6^{0}F	41 to 104^{0}F	65 to 85^{0}F
Maximum temperature rate of change[a]	9^{0}F/h		(Cooling) 54^{0}F/h[c] (Warming) 173^{0}F/h[cd]	
Relative humidity control range[a]	20 to 80% 63^{0}F max. dew point (Class-1) 70^{0}F max. dew point (Class-2)	Dew Point 42 to 59^{0}F rh less than 60%	5 to 85% 82^{0}F max. dew point[c]	Max 55%[c]
Filtration quality	65% min. 30% (MERV 11, min MERV 8)[b]			Min. 85% (Min MERV 13)[b]

a. Inlet conditions recommended in ASHRAE (2008).
b. Percentage values per ASHRAE Standard 52.1 dust spot efficiency test. MERV values as per ASHRAE Standard 52.2, Telephone (2006), Telecordia (2001).
c. Generally accepted telecommunications practice. Telecommunications central offices are not generally humidified, but personnel are often grounded to reduce Electrostatic Discharge (ESD).

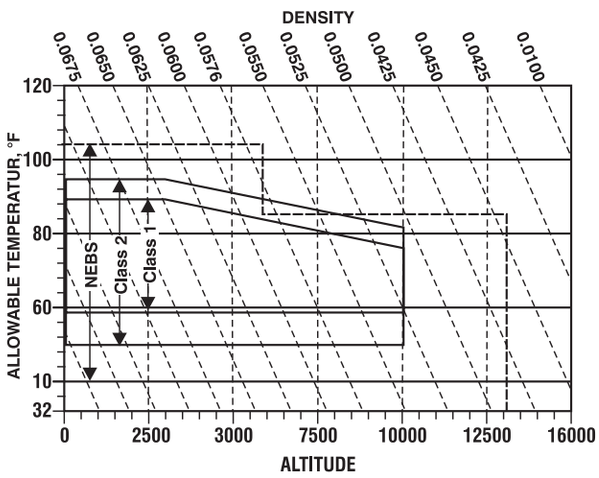


Figure 1.11 : Class 1, Class 2 and NEBS Allowable Temperature Range Versus Altitude

Temperature in many data centers tends to be warmer near the top of racks, particularly if warm rack exhaust air does not have a direct return path to the CRACs. This warmer air also affects the relative humidity, resulting in lower values at the top of the rack. The air temperature generally follows a horizontal line on the Psychometric Chart, where Absolute Humidity remains constant but Relative Humidity decreases.

Temperature Rate of Change

Some Datacom manufacturers have established criteria for allowable rates of environmental change to prevent shock to the data and communications equipment. These criteria need to be reviewed for all installed datacom equipment. A maximum inlet Temperature change of 9° F/h is recommended by ASHRAE (2008) for Classes 1 and 2. Humidity rate of change is typically most important for tape and storage products. Typical requirements for tape are a rate of change of less than 3.5° F/h and a relative humidity change of less than 5%/h (ASHRAE 2004).

In Telecommunication Central Offices, the NEBS requirements per Telcordia (2006) for testing new equipment is a rate change (cooling) of 54° F/h. However, in the event of an air-conditioning failure, the rate of temperature change can easily be significantly higher. Consequently, Telcordia (2201-2006) prescribes testing with a warming gradient of 173° F/h for 15 min. Manufacturers requirements should be reviewed and fulfilled to ensure that the system functions properly during normal operation and during start-up and shutdown.

Proceedings must be in place for response to an event that shuts down Critical Cooling Systems while Critical loads continue to operate, causing the space temperature to begin rising immediately. Procedures should also be in place governing how quickly elevated space temperatures can be returned to normal to avoid Thermal Shock Damage.

Datacom equipment usually tolerates a somewhat wider range of environmental conditions when not in use [see Table 2.1 in ASHRAE (2008)]. However, it may be desirable to provide uninterruptible cooling in the room to maintain operating limits and minimize thermal shock to the equipment.

Table 1.82 : Types of Air Filters and its Applications

Sl. No.	Type	Grade	Sub Grade	Level of Filtration	Filtering Application	Characteristics
1	Coarse	G	G 1,2,3,4	> 10 Micron	HVAC and Paint Filters. Filters leaves, textiles fibres, hair, pollen dust.	High flow volume, high face velocity, low filtration efficiency.
2	Fine Filters	F	5,6,7	1 to 10 Micron	HVAC pre or final filters. Filters pollen, spores, fine dust, mist particles causing spotting.	Lower volume air flow, lower face velocity, higher filtration efficiency.
3	Fine Filters	F	F 8, 9	1 to 10 Micron	HVAC pre or final filters. Filters Oil fumes, carbon black particles, tobacco fumes, welding fumes etc.	Lower volume, air flow, lower air velocity, higher filtration efficiency.
4	HEPA	H	H 10, 11, 12	< 1 Micron	Final filters HVAC cleans rooms, filters germs, bacteria, viruses, tobacco fumes, welding fumes etc.	Lower volume air flow, lower air velocity, higher filtration efficiency.
5	HEPA	H	H 13, 14	< 1 Micron 0-	Final filters HVAC cleans rooms, oil fumes, agglomeration of carbon black particles, tobacco fumes, welding fumes, radioactive particles etc.	Lower volume air flow, lower air velocity, higher filtration efficiency.
6	ULPA	U	U 15, 16	< 0.03 Micron	Final Filters HVAC for ultra clean rooms. Filters aerosols.	Much lower volume air flow, and face velocity, endless or gel seal gasketting.

Table 1.83 : Comparison of Standard of Filtration efficiency classification

Eurovent and ASHRAE Classification			
ASHRAE 52.2-1999 MERV	**ASHRAE 52.2-1999 Arrestance**	**ASHRAE 5.2-1999 Dust spot Efficiency**	**Eurovent Category**
1	< 65% >	> 20%	G1
2	65 - 70%	< 20%	G2
3	70 - 75%	< 20%	G3
4	≥ 75	> 20%	G4
5	80 - 85%	20-25	G4
6	> 90%	25-30%	G4
7	> 90%	30-35%	G4
8	> 90%	35-40%	G4
9	> 90%	40-45%	F5
10	> 95%	50-55%	F6
11	> 95%	60-65%	F7
12	> 95%	70-75%	F8
13	> 98%	80-90%	F8
14	> 98%	90-95%	F9
15	NA	>95%	
16	NA	NA	
17		≥ 99.97%	*IEST Type A
18		≥ 99.99	*IEST Type C
19		≥ 99.999	*IEST Type D (for clean room class 5.7)
20		≥ 99.999	*IES Type F (for clean room class 1 & 2)

* IEST : Institute of Environmental Sciences and Technology

Table 1.84 : The Beaufort Scale of Wind Force with Specifications and Velocity Equivalents

Beaufort Number	**General Description**	**Specifications**	**Limits of Velocity 20 ft above level ground**			
			m/sec.	**Km/hr**	**Mph**	**Knots**
0	Calm	Smoke rises vertically	Under 0.6	Under 1	Under 1	Under 1
1	Light air	Wind direction shown by smoke drift but not by vanes	0.6-1.7	1-6	1-3	1-3
2	Slight breeze	Wind felt on face; leaves rustle, ordinary vane moved by wind	1.8-3.3	7-12	4-7	4-6
3	Gentle breeze	Leaves and twigs in constant motion; wind extends light flange	3.4-5.2	13-18	8-11	7-10
4	Moderate breeze	Dust and loose paper, small branches are moved	5.3-7.4	19-26	12-16	10-14
5	Fresh breeze	Small trees and leaves begin to sway	7.5-9.8	27-35	17-22	15-19
6	Strong breeze	Large branches in motion; whistling in telegraph wires	9.9-12.4	36-44	23-27	19-24
7	Moderate gale	Whole trees in motion	12.5-15.2	45-55	28-34	24-30
8	Fresh gale	Twigs broken off trees; progress generally impeded	15.3-18.2	56-66	35-41	30-35
9	Strong gale	Slight structural damage occurs; chimney pots removed	18.3-21.5	67-77	42-48	36-42
10	Whole gale	Trees uprooted; considerable structural damage	21.6-25.4	78-90	49-56	42-49
11	Storm	Very rarely experienced; widespread damage	25.5-29.0	91-104	57-67	49-56
12	Hurricane		Above 29	Above 104	Above 67	Above 56

Table 1.85: Generation of Gaseous Contaminants by Building Materials

Contaminant	Emission Factor Averages μg/thm²					
	Acoustic Ceiling Panels	Carpets	Fiber Boards	Gypsum Boards	Paints on Gypsum Board	Particle Boards
4-Phenylcyclohexane (PCH)		8.4 (n.d.-85)				28 (n.d.-55)
Acetaldehyde		2.8 (n.d.-37)	9.0 (n.d.-32)			
Acetic acid			8.4(n.d-26)			
Acetone	12 (n.d-33)		35(n.d-67)	37(n.d-110)	35(n.d-120)	
Ethylene glycol			140(n.d-290)		19(n.d-190)	160(140-200)
Formaldehyde	5.8 (n.d-25)	3.6(n.d-41)	220(n.d-570)	6.8(n.d-19)		49(n.d-97)
Naphthalene		11(n.d-59)	30(n.d-82)			
Heptanes			21(n.d-53)			
Nominal	4.9(1.7-11)	11(n.d-68)		10(n.d-28)	3.7(n.d-24)	
Toluene			19(n.d-46)			
TVOC	32(3.2-150)	1900(270-9100	400(52-850)	15(n.d-61)	2500 (170-6200)	420(240-510)
Source: nd- non-detactable TVOC Concentration calculated						

Table 1.86 : Generation of Gaseous Contaminants by Building Materials

Contaminant	Emission Factor Averages μg/thm²					
	Plastic Laminates and Assemblies	Non-rubber based resilient flooring	Rubber-based Resilient flooring	Tackable wall panels	Thermal insulations	Wall based (Rubber-Based)
1 ,2,4 Trimthylbenzene			210(n.d-590)			
2-Butoxy-ethanol			1.6(n.d-24)			
Acetaldehyde						
Acetone	75(4.8-150)				12(1.8-21)	220(39-400)
Butyric acid						
Dodecane			1.3(n.d-20)			
Ethylene glycol		38(n.d-210)				
Femadhyde	13(n.d-29)	6.8(n.d-79)			5.9(0.35-14)	32(3.6-61)
Naphthalene		3.4(n.d-14)	5.6(n.d-28)	6.6(6.6)		
Batamol						100(n.d-200)
Norcemel		5.7(n.d-19)	1.4(n.d-11)		1.8(0.57.4)	
Octane						150(n.d-300)
Phenol	9.4(4.4-19)	35(n.d-310)				340(n.d-680)
Tolune		5.1(n.d-12)				
Unckcame						140(13-270)
TVOC	160(6.3.310)	680(100-2100)	15000 (1500-100000)	270(100-430)	7.50.57-26)	7100 (1200-13000)

Table 1.87 : Total Body Emission of Some Gaseous Contaminants by Humans

Contaminants	Typical Emission μg/h	Contaminants	Typical Emission μg/h
Acetaldehyde	35	Methane	1,716
Acetone	475	Methanol	6
Ammonia	15,600	Methylene chloride	88
Benzene	16	Propane	1.3
2-Byttabce (MEK)	9,700	Temacholcethane	1.4
Carbon Dioxide	32x10	Tetrachloroethane	1
Carbon Monoxide	10,000	Telene	23
Chloroform	3	1.1.1 Trichloroethane	42
Carbon	9.4	Vinyl chloride Monomer	0.4
Hydrogen Sulfide	15	Xylene	0.00

Table 1.88 : Filter Efficiencies

Standard 52.2 MERV	Intended Standard 52.1 Value	Arrestance Value	Example Range of Contamination Controlled	Example Application	Sample Air Cleaner Type (S)
HEPA Filters					
MERV 20	N/A		0.12 to 0.5 μm particles, virus (unattached), carbon dust, sea salt, radon progeny, combustion smoke	Clean room, pharmaceutical manufacturing and exhaust, radioactive material handling and exhaust, orthopedic and organ transplant surgery, carcinogenic materials, welding fumes	SULPA>99.999% 0.10 to μm IEST type F (ceiling panel)
MERV 19					ULPA >99.999%0.3 μm IEST type D (ceiling panel)
MERV 18					HEPA >99.999% 0.3 μm IEST type C (ceiling or up to 12 in. deep)
MERV 17					HEPA >99.97% 0.3 μm IEST type A (box style 6 to 12 in. deep)
E-I Range					
MERV 16	Intended to replace 70 to 98 % dust-spot efficiency filters	>99%	0.3 to 1.0 μm size range, bacteria, smoke (ETS), paint pigments, face powder, some virus, droplet nuclei, insecticide dusts, soldering fumes	Day surgery, general surgery, hospital general ventilation, turbo equipment compressors, welding/ soldering air cleaners, pre filters to HEPAs, LEED for existing (EB) and new (NC) commercial buildings, smoking lounges	Box-style wet - laid or lofted fiber glass, box-style synthetic media, minipleated synthetic or fiberglass paper, depths from 4 to 12 in. Pocket filters of fiberglass or synthetic media 12 to 36 in.
MERV 15		>99%			
MERV 14		>98%			
MERV 13		>97%			
E-2 Range					
MERV 12	Intended to replace 50 to 80 % dust-spot efficiency filters	>97%	1.0 to 3.0 μm size range: milled flour, lead dust, combustion soot, legionella, coal dust, some bacteria, process grinding dust	Food processing facilities, air separation plants, commercial buildings, better residential, industrial air cleaning, pre filtration to higher-efficiency filters, schools, gymnasiums.	Box-style wet - laid or lofted fiber glass, box-style synthetic media, minipleated synthetic or fiberglass paper, depths from 2 to 12 in. Pocket filters of fiberglass or synthetic media 12 to 36 in.
MERV 11		>95%			
MERV 10		>95%			
MERV 09		>90%			
E-3 Range					
MERV 08	Intended to replace 20 to 60 % dust-spot efficiency filters	>90%	3.0 to 10 μm size range : pollens, earth-origin dust, mold spores, cement dust, powdered milk, snuff, hair spray mist	General HVAC filtration, industrial equipment filtration, commercial properties and schools air control pre filter to high efficiency filters, paint booth intakes, electrical/phone equipment protection.	Wide range of pleated media, ring panels, cubes, pockets in synthetic or fiber glass, disposable panels, depths from 1 to 24 in.
MERV 07		>90%			
MERV 06		>85%			
MERV 05		>85%			
MERV 04	<20%	>70%	Arrestance method	Protection from blowing large particle dirt and debris, industrial environment air ventilation.	Initial separators.
MERV 03	<20%	>70%			
MERV 02	<20%	>65%			
MERV 01	<20%	>65%			

Note : MERV for non- HEPA/ULPA filters also includes test airflow rate, but it is not shown here because it is of no significance for the purpose of this table. N/A = not applicable.

Table 1.89 : Electrically Operated Unitary Air - Conditioners and Condensing Units-Minimum Efficiency Requirements

Equipment Type	Size Category	Heating Section Type	Subcategory or Rating Condition	Minimum Efficiency	Test Procedure
Air - conditioners, Air - cooled	<65,000 Btu/h[b]	All	Split system	13.0 SEER	AHRI 210/240
			Single Package	13.0 SEER (before 1/20/1 5) 14 SEER As of 1/1/2015	
Through the wall, Air - cooled	< 30,000 Btu/hb	All	Split system Single Package	12.0 SEER 12.0 SEER	
Small duct High velocity Air - cooled	<65,000 Btu/hb	All	Split System	11.0 SEER	
Air conditioners, Air - cooled	≥ 65.000 Btu/h and <1 35, 000 Btu/h	Electric resistance (or none)	Split System and Single Package	11.2EER 11.4IEER (before 1/1/2016) 12.9 IEER (as of 1/1/2016)	AHRI 340/360
		All other	Split System and Single Package	11.0 EER 11.2 IEER (before 1/1/2016 12.7 IEER (as of 1/1/2016	
	≥1 35,000 Btu/h and <240,000 Btu/h	Electric resistance (or none)	Split System and Single Package	11.0 EER 11. 2 IEER (before 1/1/2016 12.4 IEER (as of 1/1/2016	
		All other	Split System and Single Package	10.8 EER 11.0 IEER (before 1/1/2016) 12.2 IEER (as of 1/1/2016	
	≥ 240,000 Btu/h and <760,000 Btu/h	Electric resistance (or none)	Split System and Single Package	10.0 EER 10.1 IEER (before 1/1/201 6) 11.6 IEER as of 1/1/2016	
		All other	Split System and Single Package	9.8 EER 9.9 IEER (before 1/1/2016) 11.4 IEER (as of 1/1/2016	
	≥760,000 Btu/h	Electric resistance (or none)	Split System and Single Package	9.7 EER 9.8 IEER (before 1/1/2016) 11.2 IEER (as of 1/1/2016	
		All other	Split System and Single Package	9.5 EER 9.6 IEER (before 1/1/2016) 11.0 IEER (as of 1/1/2016	

Single-phase, air-cooled air-conditioners <65,000 Btu/h are regulated by NAECA

Table 1.89 : Electrically Operated Unitary Air - Conditioners and Condensing Units-Minimum Efficiency Requirements (contd.)

Equipment Type	Size Category	Heating Section Type	Subcategory or Rating Condition	Minimum Efficiency	Test Procedure[a]
Air - conditioners, Water - cooled	<65,000 Btu/h	All	Split system and Single Package	12.1 EER 12.3 IEER	AHRI 210/240
	≥ 65,000 Btu/h and <1 35,000 Btu/h	Electric resistance (or none)	Split System and Single Package	12.1 EER 12.3 IEER (before 1/1/2016) 13.9IEER (as of 1/1/2016)	
		All other	Split System and Single Package	11.9 EER 12.1 IEER (before 1/1/2016) 13.7 IEER (as of 1/1/2016)	AHRI 340/360
	≥1 35,000 Btu/h and <240,000 Btu/h	Electric resistance (or none)	Split System and Single Package	12. 5 EER 12.5 IEER (before 1/1/2016) 13.9 IEER (as of 1/1/2016)	
		All other	Split System and Single Package	12.3 EER 12.5 IEER (before 1/1/2016) 13.7 IEER (as of 1/1/2016)	
	≥ 240,000 Btu/h and <760,000 Btu/h	Electric resistance (or none)	Split System and Single Package	12.4 EER 12.6 IEER (before 1/1/2016) 13.6 IEER (as of 1/1/2016)	AHRI 340/360
		All other	Split System and Single Package	12.2 EER 12.4 IEER (before 1/1/2016) 13.4 IEER (as of 1/1/2016)	
	≥ 760,000 Btu/h	Electric resistance (or none)	Split System and Single Package	12.2 EER 12.4 IEER (before 1/1/2016) 13.5IEER (as of 1/1/2016)	AHRI 340/360
		All other	Split System and Single Package	12.0 EER 12.2 IEER (before 1/1/2016) 13.3 IEER (as of 1/1/2016)	

a. Single-phase, air-cooled air-conditioners <65,000 Btu/h are regulated by NAECA.

ANSI/ASHRAE/IES Standard 90-1-2013

Table 1.90 : Water - Chilling Packages - Efficiency Requirements [a,b,c,]

Equipment Type	Size Category	Units	Effective 1/1/2010		Effective 1/1/2015		Test Procedure
			Path A	Path B	Path A	Path B	
Air-cooled chillers	< 150 tons	EER (Btu/W)	≥9.562 FL	NA[d]	≥1 0.1 00 FL	≥ 9.700 FL	AHRI 550/590
			≥12.500 IPLV		≥13,700 IPLV	≥1 5.800 IPLV	
	≤ 150 tons		≥9.562 FL	NA[d]	≥10.100 FL	≥ 9.700 FL	
			≥12.750 IPLV		≥ 14.000 IPLV	≥ 16.001 IPLV	
Air - cooled without condenser electrically operated	All Capacities	EER (Btu/W)	Air - cooled chillers without condenser must be rated with matching condenser and comply with air - cooled chiller efficiency requirements				
Water cooled, electrically operated positive displacement	<75 tons	kW/ton	≤ 0.780 FL	≤ 0.800 FL	≤ 0.750 FL	≤ 0.780 FL	
			≤ 0.630 IPLV	≤ 0.600 IPLV	≤ 0.600 IPLV	≤ 0.500 IPLV	
	≥75 tons and < 150 tons		≤ 0.775 FL	≤ 0.790 FL	≤ 0.720 FL	≤ 0.750 FL	
			≤ 0.615 IPLV	≤ 0.586 IPLV	≤ 0.560 IPLV	≤ 0.490 IPLV	
	≥150 tons and <300 tons		≤ 0.680 FL	≤ 0.718 FL	≤0.660 FL	≤ 0.680 FL	
			≤ 0.581 IPLV	≤ 0.540 IPLV	≤ 0.540 IPLV	≤ 0.440 IPLV	
	≥300 tons and <600 tons		≤ 0.620 FL	≤ 0.639 FL	≤ 0.610 FL	≤ 0.625 FL	
			≤ 0.540 IPLV	≤ 0.490 IPLV	≤ 0.520 IPLV	≤0.410 IPLV	
	≥600 tons		≤ 0.620 FL	≤ 0.639 FL	≤ 0.560 FL	≤ 0.585 FL	
			≤ 0.540 IPLV	≤ 0.490 IPLV	≤ 0.500 IPLV	≤ 0.380 IPLV	
Water - cooled electrically operated centrifugal	< 150 tons	kW/ton	≤ 0.634 FL	≤ 0.639 FL	≤ 0.610 FL	≤ 0.695 FL	
			≤ 0.596 IPLV	≤ 0.450 IPLV	≤ 0.550 IPLV	≤0.440 IPLV	
	≥150 tons and < 300 tons		≤ 0.634 FL	≤ 0.639 FL	≤ 0.610 FL	≤ 0.635 FL	
			≤ 0.596 IPLV	≤ 0.450 IPLV	≤ 0.550 IPLV	≤ 0.400 IPLV	
	≥300 tons and <400 tons		≤ 0.576 FL	≤ 0.600 FL	≤ 0.560 FL	≤ 0.595 FL	
			≤ 0.549 IPLV	≤ 0.400 IPLV	≤ 0.520 IPLV	≤ 0.390 IPLV	
	≥400 tons and ≥600 tons		≤ 0.576 FL	≤ 0.600 FL	≤ 0.560 FL	≤ 0.585 FL	
			≤ 0.549 IPLV	≤ 0.400 IPLV	≤ 0.500 IPLV	≤ 0.380 IPLV	
	≤ 600 tons		≤ 0.570 FL	≤ 0.590 FL	≤ 0.560 FL	≤ 0.585 FL	
			≤ 0.539 IPLV	≤ 0.400IPLV	≤ 0.500IPLV	≤ 0.380 IPLV	
Air-cooled absorption, single effect	All capacities	COP	≥0.600 FL	NAd	≥0.600 FL	NAd	AHRI 560
Water cooled absorption, single effect	All capacities	COP	≥0.700 FL	NA"	≥0.700 FL	NAd	
Absorption double effect, indirect fired	All capacities	COP	> 1 .000 FL	NAd	≥ 1.000FL	NAd	
			> 1.050 IPLV		≥ 1.050 IPLV		
Absorption double effect, direct fired	All capacities	COP	> 1 .000 FL	NAd	≥ 1 .000 FL	NAd	
			> 1.000 IPLV		≥ 1.000 IPLV		

a. The requirements for air-cooled, water-cooled positive displacement and absorption chillers are at standard rating conditions defined in the reference test procedure.
b. Both the full-load and IPLV requirements must be met or exceeded to comply with this standard. When there is a Path B, compliance can be with either Path A or Path B for any application.
c. NA means the requirements are not applicable for Path B, and only Path A can be used for compliance.
d. FL is the full-load performance requirements, and IPLV is for the part-load performance requirements.

Table 1.91 : Electrically Operated Packaged Terminal Air - Conditioners, Single-Package Vertical Air - Conditioner, Room Air - Conditioners, and Room Air - Conditioner Heat Pumps - Minimum Efficiency Requirements

Equipment Type	Size Category (Input)	Subcategory or Rating Condition	Minimum Efficiency	Test Procedure[a]
PTAC (cooling mode) Standard size	All capacities	95° F db outdoor air	13.8-(0.300xCap/1000)c (before 1/1/2015) 14.0— (0.300xCap/1 000)c (as of 1/1/2015)	AHRI 310/380
PTAC (cooling mode) nonstandard size	All capacities	95° F db outdoor air	10.9— (0.21 3xcap/1 000)°	
SPVAC (Cooling mode)	<65,000 Btu/h ≥65,000 Btu/h and 135,000 Btu/h ≥1 35,000 Btu/h and <240,000 Btu/h	95" F db/75° F wb outdoor air 95° F db/75° F wb outdoor air 95° F db/75° F wb outdoor air	10.0 EER 10.0 EER 10.0 EER	AHRI 390
Room air - conditioners with louvered sides	<600 Btu/h ≥6000 Btu/h and <8000 Btu/h ≥8000 Btu/h and <14,000 Btu/h ≥ 14,000 Btu/h and <20,000 Btu/h ≥20,000 Btu/h		9.7 SEER 9.7 SEER 9.8 SEER 9.7 SEER 8.5 SEER	ANSI/AHAM RAC-1

a. Nonstandard size units must be factory labelled as follows, "MANUFACTURED FOR NONSTANDARD SIZE APPLICATIONS ONLY; NOT TO BE INSTALLED IN NEW STANDARD PROJECTS". Nonstandard size efficiency apply only to units being installed in existing sleeves having an external wall opening of less than 16 in. high or less than 42 in. wide and having a cross-sectional area less than 670 in^2.
b. "Cap" means the rated cooling capacity of the product in Btu/h. (If the unit's capacity is less than 7000 Btu/h in the calculation.) If the unit's capacity is greater than 15,000 Btu/h, use 15,000 Btu/h in the calculation.

Table 1.92 : Performance Requirements for the Heat Rejection Equipment

Equipment Type	Total System Heat Rejection Capacity at Rated Conditions	Subcategory or Rating Condition[h]	Performance Required[a,b,c,d,f,g]	Test Procedure*
Propeller or axial fan open-circuit cooling towers	All	95°F entering water 85°F leaving water 75°F entering wb	≥40.2 gpm/hp	CTI ATC-105and CTI STD-201
Centrifugal fan open-circuit cooling towers	All	95"F entering water 85°F leaving water 75°F entering wb	≥20.0 gpm/hp	CTI ATC-105AND CTISTD-201
Propeller or axial fan closed-circuit cooling towers	All	102°F entering water 90°F leaving water 75°F entering wb	≥14.0 gpm/hp	CTI ATC-105S and CTI STD-201
Centrifugal closed-circuit cooling towers	All	102"F entering water 90°F leaving water 75°F entering wb	≥7.0 gpm/hp	CTI ATC-105S and CTI STD-201
Propeller or axial fan evaporative condensers	All	R-507A test fluid 165°F entering gas temperature 105°F condensing temperature 75°F entering wb	≥1 57, 000 Btu/h hp	CTI ATC-106
Propeller or axial fan evaporative condensers	All	Ammonia test fluid 1 04°F entering gas temperature 96.3°F condensing temperature 75°F entering wb	≥134,000 Btu/h hp	CTI ATC-106
Centrifugal fan evaporative condensers	All	R-507A test fluid 165°F entering gas temperature 105°F condensing temperature 75°F entering wb	≥1 35,000 Btu/h hp	CTI ATC-106
Centrifugal fan evaporative condensers	All	Ammonia test fluid 140°F entering gas temperature 96.3°F condensing temperature 75°F entering wb	≥1 10,000 Btu/h hp	CTI ATC-106
Air - cooled condensers	All	125"F condensing temperature 190°F entering gas temperature 15°F sub-cooling 95°F entering db	≥176,000 Btu/h hp	AHRI 460

a. Nonstandard size units must be factory labelled as follows, "MANUFACTURED FOR NONSTANDARD SIZE APPLICATIONS ONLY; NOT TO BE INSTALLED IN NEW STANDARD PROJECTS". Nonstandard size efficiency apply only to units being installed in existing sleeves having an external wall opening of less than 16 in. high or less than 42 in. wide and having a cross-sectional area less than 670 in^2.
b. "Cap" means the rated cooling capacity of the product in Btu/h, if the unit's capacity is less than 7000 Btu/h in the calculation. If the unit's capacity is greater than 15,000 Btu/h, use 15,000 Btu/h in the calculation.

Table 1.93 : Heat Transfer Equipment

Equipment Type	Subcategory	Minimum Efficiency	Test procedures[b]
Liquid to-liquid heat exchangers	Plate type	Not Specified	AHRI 400

a. NR = No requirement

Table 1.93A : Electricity Operated Variable-Refrigerant-Flow Air-Conditioners Minimum Efficiency Requirements

Equipment Type	Size Category	Heating Section Type	Subcategory or Rating Condition	Minimum Efficiency	Test Procedures
VRF air conditioners, air - cooled	<65,000 Btu/h	All	VRF multisplit system	13.0 SEER	AHRI 1230
	≥65,000 Btu/h and <1 35,000 Btu/h	Electric resistance (or none)	VRF multisplit system	11.2EER 13.1 IEER	
	≥1 35,000 Btu/h and <240,000 Btu/h	Electric resistance (or none)	VRF multisplit system	11.0EER 12.9 IEER	
	≥240,000 Btu/h	Electric resistance (or none)	VRF multisplit system	10.0 EER 11.6IEER	
VRF air - cooled (cooling mode)	<65,000 Btu/h	All	VRF multispjit system	13.0 SEER	AHRI 1230
	≥65,000 Btu/h and <135,000 Btu/h	Electric resistance (or none)	VRF multisplit system	11.0 EER 12.3 IEER	
	≥65,000 Btu/h and <1 35,000 Btu/h	Electric resistance (or none)	VRF multisplit system with heat recovery	10.8 EER 12.1 IEER	
	≥135,000 Btu/h and <240,000 Btu/h	Electric resistance (or none)	VRF multisplit system	10.6 EER 11.8 IEER	
	≥1 35,000 Btu/h and <240,000 Btu/h	Electric resistance (or none)	VRF multisplit system with heat recovery	10.4 EER 11.6 IEER	
	≥240,000 Btu/h	Electric resistance (or none)	VRF multisplit system	9.5 EER 10.6 IEER	
	≥240,000 Btu/h	Electric resistance (or none)	VRF multisplit system with heat recovery	9.3 EER 10.4 IEER	
VRF water source (cooling mode)	<65,000 Btu/h	All	VRF multisplit systems 86°F entering water	12.0 EER	AHRI 1230
	<65,000 Btu/h	All	VRF multisplit systems with heat recovery 86°F entering water	11.8 EER	
	≥65,000 Btu/h and <135,000 Btu/h	All	VRF multisplit systems 86°F entering water	12.0 EER	
	≥65,000 Btu/h and <1 35,000 Btu/h	All	VRF multisplit systems with heat recovery 86°F entering water	11.8 EER	
	≥135,000 Btu/h	All	VRF multisplit systems 86°F entering water	10.0 EER	
	≥135, 000 Btu/h	All	VRF multisplit systems with heat recovery 86°F entering water	9.8 EER	
	≥135,000 Btu/h	All	VRF multisplit systems 59°F entering water	16.2 EER	
VRF ground source (cooling mode)	<1 35,000 Btu/h	All	VRF multisplit system 77°F entering water	13.4 EER	AHRI 1230
	<135,000 Btu/h	All	VRF multisplit system with heat recovery 77°F entering water	13.2 EER	
	≥135,000 Btu/h	All	VRF multisplit system 77°F entering water	11.0 EER	
	≥135,000 Btu/h	All	VRF multisplit system with heat recovery 77°F entering water	10.8 EER	

Table 1.94 : Air - Conditioners and Condensing Units Serving Computer Rooms

Equipment Type	Net Sensible Cooling Capacity[a]	Minimum SCOP-1 27, Efficiency Downflow Units / Upflow Units	Test Procedure
Air - Conditioners, air - cooled	<65,000 Btu/h	2.20/2.09	ANSI/ASHRAE 127
	≥65,000 Btu/h and < 240,000 Btu/h	2.10/1.99	
	≥240,000 Btu/h	1.90/1.79	
Air - Conditioners, water - cooled	<65,000 Btu/h	2.60/2.49	ANSI/ASHRAE 127
	≥65,000 Btu/h and < 240,000 Btu/h	2.50/2.39	
	≥240,000 Btu/h	2.40/2.29	
Air - Conditioners, water - cooled with fluid economizer	<65,000 Btu/h	2.55/2.44	ANSI/ASHRAE 127
	≥65,000 Btu/h and < 240,000 Btu/h	2.45/2.34	
	≥240,000 Btu/h	2.35/2.24	
Air - Conditioners, glycol cooled (rated at 40% propylene - glycol)	<65,000 Btu/h	2.50/2.39	ANSI/ASHRAE 127
	≥65,000 Btu/h and < 240,000 Btu/h	2.15/2.04	
	≥240,000 Btu/h	2.10/1.9'9	
Air - Conditioners, glycol cooled (rated at 40% propylene glycol) with fluid economizer	<65,000 Btu/h	2.45/2.34	ANSI/ASHRAE 127
	≥65,000 Btu/h and < 240,000 Btu/h	2.10/1.99	
	≥240,000 Btu/h	2.05/194	

a. Net sensible cooling capacity. The total gross cooling capacity less the latent cooling less the energy to the air movement. (Total Gross -Latent—Fan Power).

b. Sensible coefficient of performance (SCOP-127); A ratio calculated by dividing the net sensible cooling capacity in watts by the total power input in watts (excluding reheaters and humidifiers) at conditions defined in ASHRAE Standard 127. The net sensible cooling capacity minus the energy dissipated into the cooled space by the fan system.

Table 1.95 : Cooling and Dehumidifying Heat Load Estimate Form

Job Name :										
Floor :										
Space :						Ht. (Ft)				
Size :	287	sq ft	2870	Cu ft						
SOLAR GAIN CLASS				**HEAT GAIN**	CONDITION	DB (^{0}F)	WB (^{0}F)	% RH	DP (^{0}F)	GR/LB
Item	Area	Sun Gain	Factor	**Btu/hour**	OUTSIDE					
	(Sq ft)	(Btu/h.sq ft)			ROOM					
N - Glass					DIFFERENCE		xxxx	xxxx	xxxx	
NE - Glass										
E - Glass					**OUTSIDE AIR (VENTILATION)**					
SE - Glass					Fresh Air	CM/Person x No. of Person + .06 x Area Sq.ft.				
S - Glass					Fresh Air					
SW - Glass										
W - Glass										
NW - Glass					EFF.SENSIBLE HEAT FACTOR (ESHF) =					
Skylight					Indicated ADP =			^{0}F		
SOLAR & TRANS. GAIN WALLS & ROOF					Selected ADP =			^{0}F		
Item	Area	Eq. temp. diff.	Factor		Dehum. temp rise =			^{0}F		
	(Sq ft)	(^{0}F)	(Btu/h.sq ft)		DEHUMIDIFIED CFM =					
N - Wall										
NE - Wall					**AS PER REQD. AIR CHANGES**					
E - Wall					Min. Air Changes / hr =					
SE - Wall					Min. cfm reqd. =					
S - Wall										
SW - Wall										
W - Wall										
NW - Wall										
Room Sun										
Roof Shaded										
TRANS. GAIN EXCEPT WALLS & ROOF										
Item	Area	Eq. temp. diff.	Factor							
	(Sq ft)	(^{0}F)	(Btu/h.sq ft)							
All Glass										
Partition wall										
Ceiling										
Floor										
INTERNAL HEAT GAIN										
People		Nos x								
Light		W x								
Eq. Load		W x								
ROOM SENSIBLE HEAT (RSH)										
Supply duct heat gain +	Supply duct leak loss +	Heat gain from fan HP (%)								
	Safety factor (%)									
OUTSIDE & INFILTRATED AIR										
CFM	^{0}F	BF	FACTOR							
EFFECTIVE ROOM SENSIBLE HEAT (ERSH)										
LATENT HEAT										
People		Nos x								
OUTSIDE & INFILTRATED AIR										
CFM	^{0}F	BF	FACTOR							
ROOM LATENT HEAT (RLH)										
Supply duct leakage loss +	Safety factor %									
EFFECTIVE ROOM LATENT HEAT (ERLH)										
EFFECTIVE ROOM TOTAL HEAT (ERTH)										
OUTSIDE AIR HEAT (SENSIBLE)										
CFM	^{0}F	BF	FACTOR							
OUTSIDE AIR HEAT (LATENT)										
CFM	GR / LB	1 - BF	FACTOR							
HEAT SUB TOTAL										
Return duct heat gain & leak loss +	HP Pump +	Dehum & Pipe loss (%)								
GRAND TOTAL HEAT										

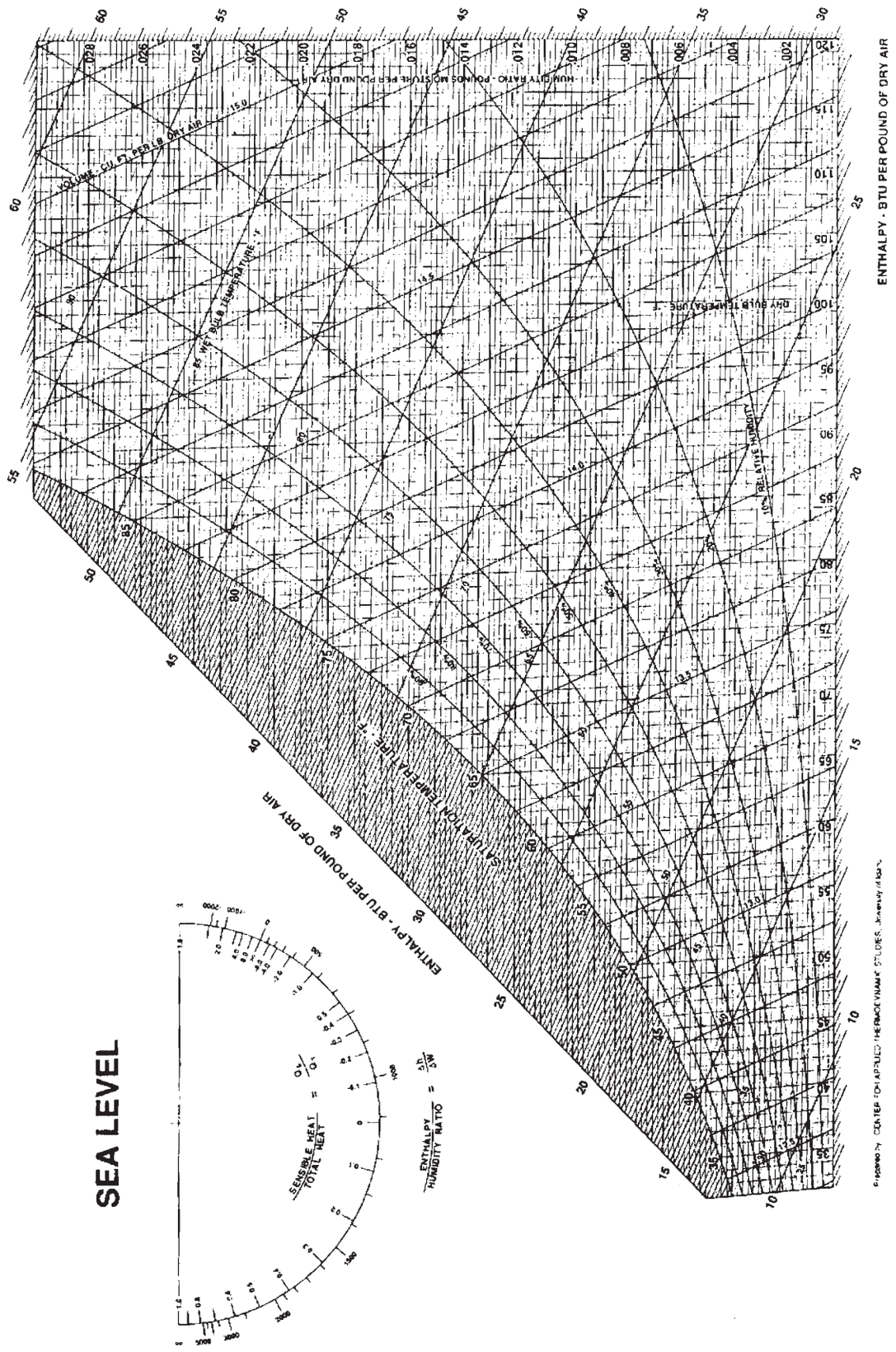


Figure 1.12 : Psychrometric Chart - Normal Temperature ^{0}F
Design pressure : 760 mm hg

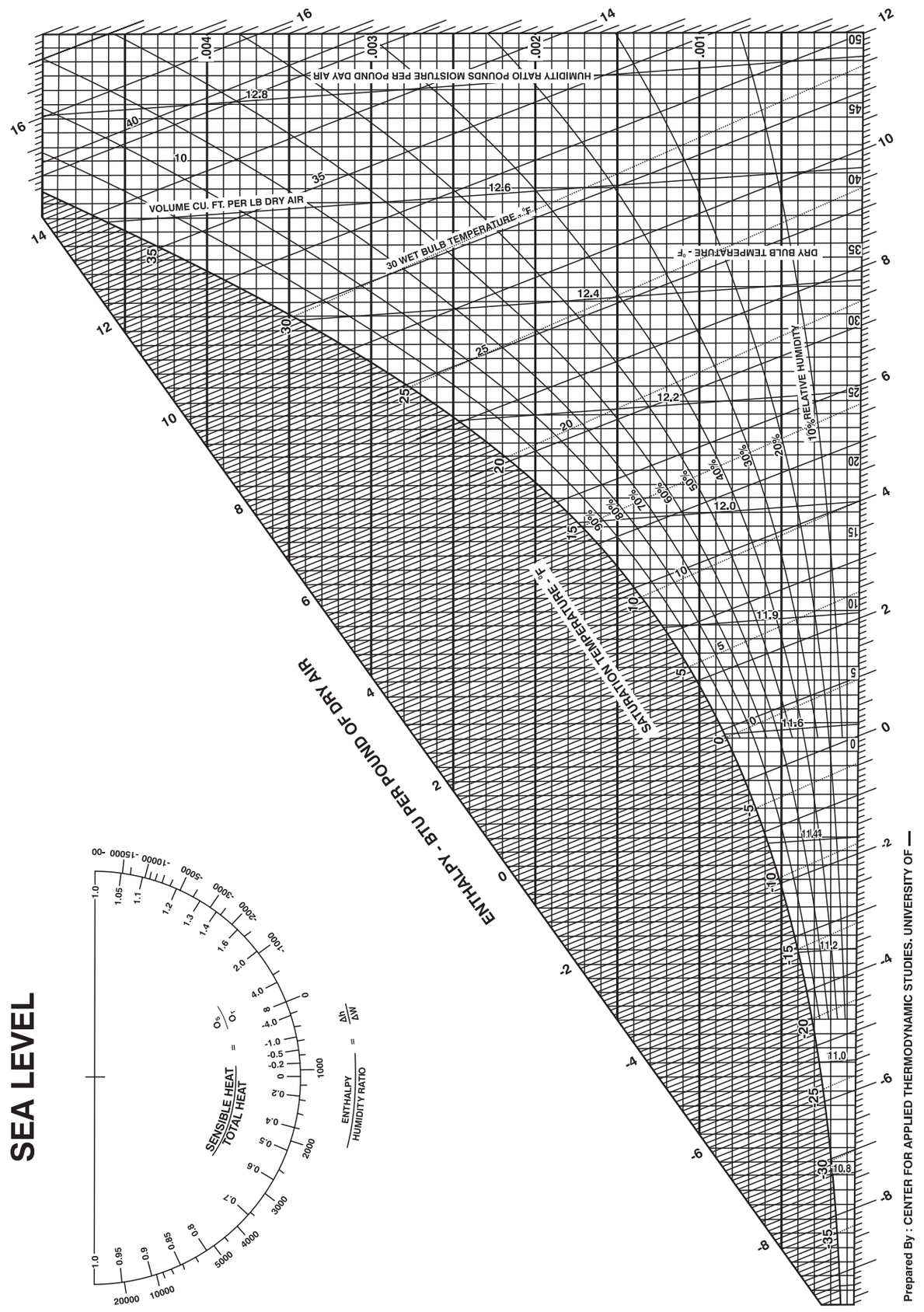


Figure 1.13 : Psychrometric Chart - Low Temperature ^{0}F
Design pressure : 760 mm hg

Psychrometric Formulae

A. AIR MIXING EQUATIONS (Outdoor and Return Air)

$$tm = \frac{(cfm_{oa} \times t_{oa}) + (cfm_{ra} \times h_{ra})}{cfm_{ga}} \quad (1)$$

$$hm = \frac{(cfmoa \times hoa) + (cfm_{ra} \times h_{ra})}{cfm_{sa}} \quad (2)$$

$$wm = \frac{(cfm_{oa} \times W_{oa}) + (cfm_{ra} \times h_{ra})}{cfm_{sa}} \quad (3)$$

B. COOLING LOAD EQUATIONS

$$ERSH = RSH + (BF)\,(OASH) + RSHS^* \quad (4)$$
$$ERLH = RLH + (BF)\,(OALH) + RLHS^* \quad (5)$$
$$ERTH = ERLH + ERSH \quad (6)$$

$$TSH = RSH + OASH + RSHS^* \quad (7)$$
$$TLH = RLH + OALH + RLHS^* \quad (8)$$
$$GTH = TSH + TLH + GTHS^* \quad (9)$$

$$RSH = 1.08 \times cfm_{sa} \times (t_{rm} - t_{sa}) \quad (10)$$
$$RLH = 0.68 \times cfm_{sa} \times (W_{rm} - W_{sa}) \quad (11)$$
$$RTH = 4.45 \times cfm_{sa} \times (h_{rm} - h_{sa}) \quad (12)$$
$$RTH = RSH + RLH \quad (13)$$

$$OASH = 1.08 \times Cfmoa \times (toa - trm) \quad (14)$$
$$OALH = 0.68 \times cfmoa \times (Woa - Wrm) \quad (15)$$
$$OATH = 4.45 \times cfmoa \times (hoa - hrm) \quad (16)$$

$$OATH = OASH + OALH \quad (17)$$
$$(BF)(OATH) = (BF)\,(OASH) + (BF)\,(OALH) \quad (18)$$

$$ERSH = 1.08 \times Cfm_{da} \times (t_{rm} - t_{adp})\,(1\text{-}BF) \quad (19)$$

$$ERLH = 0.68 \times Cfm_{da} \times (W_{rm} - W_{adp})\,(1\text{-}BF) \quad (20)$$

$$ERTH = 4.45 \times Cfm_{da} \times (h_{rm} - h_{adp})\,(1\text{-}BF) \quad (21)$$

$$TSH = 1.08 \times Cfm_{da} \times (t_{edp} - t_{idp})^{**} \quad (22)$$

$$TLH = 0.68 \times Cfm_{da} \times (W_{ea} - W_{la})^{**} \quad (23)$$

$$GTH = 4.45 \times x \times Cfm_{da} \times (hea - h!a)^{**} \quad (24)$$

C. SENSIBLE HEAT FACTOR EQUATIONS

$$RSHF = \frac{RSH}{RSH + RLH} = \frac{RSH}{RTH} \quad (25)$$

$$ESHF = \frac{ERSH}{RSH + ERLH} = \frac{ERSH}{RRTH} \quad (26)$$

$$GSHF = \frac{RSH}{TSH + TLH} = \frac{TSH}{GTH} \quad (26)$$

D. BYPASS FACTOR EQUATIONS

$$BF = \frac{t_{ldb} - t_{adp}}{t_{edp} - t_{adp}} : (1 - BF) = \frac{t_{edb} - t_{idp}}{t_{edb} - t_{adp}} \quad (28)$$

$$BF = \frac{W_{la} - W_{adp}}{W_{ea} - W_{adp}} : (1 - BF) = \frac{W_{ea} - W_{la}}{W_{ea} - W_{adp}} \quad (29)$$

$$BF = \frac{h_{la} - h_{adp}}{h_{ea} - h_{adp}} : (1 - BF) = \frac{h_{ea} - h_{la}}{h_{ea} - h_{adp}} \quad (30)$$

E. TEMPERATURE EQUATIONS AT APPARATUS

$$t_{edb}^{**} = \frac{(cfm_{oa} \times t_{oa}) + (cfm_{ra} \times t_{ra})}{cfm_{sa}\ \#} \quad (31)$$

$$tldb = t_{adp} + BF\,(t_{edb} - t_{adp}) \quad (32)$$

t_{edb}** and t_{lwb} correspond to the calculated values of h_{ea} and h_{la} on the psychrometric chart.

$$h_{ea}^{**} = \frac{(cfm_{oa} \times h_{oa}) + (cfm_{ra} \times h_{ra})}{cfm_{sa}\ \#} \quad (33)$$

$$h_{ldb} = ht_{adp} + BF\,(h_{ea} - h_{adp}) \quad (34)$$

F. TEMPERATURE EQUATIONS FOR SUPPLY AIR

$$tsa = trm - \frac{RSH}{1.08\,(cfm_{sa}\ \#)} \quad (35)$$

Psychrometric Formulae (Contd...)

G. AIR QUANTITY EQUATIONS

$$cfm_{da} = \frac{ERSH}{1.08 \times (1\text{-}BF)\ (t_{rm} - t_{adp})} \quad (36)$$

$$cfmda = \frac{ERLH}{0.68 \times (1\text{-}BF)\ (W_{rm} - W_{adp})} \quad (37)$$

$$cfm_{da} = \frac{ERTH}{4.45 \times (1\text{-}BF)\ (h_{rm} - h_{adp})} \quad (38)$$

$$cfm_{da} = \frac{TSH}{1.08 \times (1\text{-}BF)\ (t_{edp} - t_{ldp})} \quad (39)$$

$$cfm_{da} \ddagger = \frac{TLH}{0.68 \times (W_{ea} - W_{la})} \quad (40)$$

$$cfm_{da} \ddagger = \frac{GTH}{4.45 \times (h_{ea} - h_{la})} \quad (41)$$

$$cfm_{sa} \ddagger = \frac{RSH}{1.08 \times (t_{rm} - T_{sa})} \quad (42)$$

$$cfm_{sa} = \frac{RLH}{0.68 \times (W_{rm} - W_{sa})} \quad (43)$$

$$cfm_{da} = \frac{RTH}{4.45 \times (h_{rm} - h_{sa})} \quad (44)$$

$$cfm_{ba} = cfm_{sa} - cfm_{da} \quad (44)$$

Note : cfm_{da} will be less than cfm_{sa} only when air is physically bypassd around the conditioning apparatus.

$$cfm_{sa} = cfm_{oa} - cfm_{ra} \quad (45)$$

$1.08 = 0.244 \times \frac{60}{13.5}$

Where 0.244 = Specific heat of moist air at 70 F db and 50% rh, Btu / (deg F) (lb dry air).

60 = min./hr

13.5 = specific volume of moist air at 70 F db and 50% rh

$0.68 = \frac{60}{13.5} \times \frac{1076}{7000}$

Where 60 = min./hr

13.5 = Specific volume of moist air at 70 F db and 50% rh

1076 = average heat removal required to condense one pound of water vapor from the room air

7000 = grains per pound

$4.45 = \frac{60}{13.5}$

Where 60 = min./hr

13.5 = Specific volume of moist air at 70 F db and 50% rh

* RSHS, RLHS and GTHS are supplementary loads due to duct heat gain, duct leakage loss, fan and pump horsepower gains, etc. To simplify the various examples, these supplementary loads have not been used in the calculations. However, in actual practice, these supplementary loads should be used where appropriate.
Note : cfmda will be less than cfmsa only when air is physically bypassed around the conditioning apparatus.

‡ When no air is to be physically bypassed around the conditioning apparatus, $cfm_{da} = cfm_{sa}$.

** When t_m, Wm and hm are equal to the entering conditions at the cooling apparatus, they may be substituted for t_{edp} W_{ea} and h_{ea} respectively.

ABBREVIATIONS

Adp	Apparatus Dewpoint
BF	Bypass Factor
(BF) (OALH)	Bypassed Outdoor Air Latent Heat
(BF) (OASH)	Bypassed Outdoor Air Sensible Heat
But/hr	British Thermal Units per hour
Cfm	cubic feet per minute
db	Dry-Bulb Temperature
dp	Dewpoint
ERLH	Effective Room Latent Heat
ERSH	Effective Room Sensible Heat
ERTH	Effective Room Total Heat
ESHF	Effective Sensible Heat Factor
F	Fahrenheit degrees
fpm	feet per minute
gpm	gallons per minute
gr/lb	grains per pound
GSHF	Grand Sensible Heat Factor
GTHS	Grand Total Heat Supplement
OALH	Outdoor Air Latent Heat
OASH	Outdoor Air Sensible Heat
OATH	Outdoor Air Total Heat
rh	relative humidity
RLH	Room Latent Heat
RLHS	Room Latent Heat Supplement
RSH	Room Sensible Heat
RSHF	Room sensible heat supplement
RSHS	Room Latent Heat supplement
RTH	Room Total Heat
Sat Eff	saturation efficency of spray
SHF	Sensible Heat Factor
TLH	Total Latent Heat
TSH	Total Sensible Heat
w b	wet bulb

SYMBOLS

cfm_{ba}	Bypassed Air Quantity around Apparatus
cfm_{da}	Dehumidified Air Quantity
cfm_{oa}	Outdoor Air Quantity
cfm_{ra}	Return Air Quantity
cfm_{sa}	Supply Air Quantity
h	Specific Enthalpy
h_{adp}	Apparatus Dewpoint Enthalpy
h_{es}	Effective Surface Temperature Enthalpy
h_{ea}	Entering Air Enthalpy
h_{ia}	Leaving Air Enthalpy
h_{m}	Mixture of Outdoor and Return Air Enthalpy
h_{oa}	Outdoor Air Enthalpy
h_{ra}	Room Air Enthalpy
h_{sa}	Supply Air Enthalpy
t	Temperature
t_{adp}	Apparatus Dewpoint Temperature
t_{edb}	Entering Dry-Bulb Temperature
t_{es}	Effective Surface Temperature
t_{ew}	Entering Water Temperature
t_{ewb}	Entering Wet-Bulb Temperature
t_{ldb}	Leaving Dry-Bulb Temperature
t_{lwb}	Leaving Wet-Bulb Temperature
t_{m}	Mixture of Outdoor and Return Air Dry-Bulb Temperature
t_{oa}	Outdoor Air Dry-Bulb Temperature
t_{im}	Room Dry-Bulb Temperature
t_{sa}	Supply Air Dry-Bulb Temperature
W	Moisture Content or Specific Humidity
W_{adp}	Apparatus Dewpoint Moisture Content
W_{ea}	Entering Air Moisture Content
W_{es}	Effective Surface Temperature Moisture Content
W_{la}	Leaving Air Moisture Content
W_{m}	Mixture of Outdoor and Return Dry Moisture Content
W_{oa}	Outdoor Air Moisture Content
W_{m}	Room Moisture Content
W_{sa}	Supply Air Moisture Content

SECTION - 2

AIR DISTRIBUTION, DUCTS, DESIGN AND MATERIALS

INTRODUCTION

The three central functions - Heating, Ventilating, and Air-Conditioning are interrelated, especially, with the need to provide Thermal Comfort and acceptable Indoor Air Quality within reasonable installation, operation, and maintenance costs. HVAC systems can provide ventilation, reduce air - infiltration, and maintain pressure relationships between spaces. The means of air delivery and removal from spaces is known as Room Air Distribution.

HVAC systems use ventilation air ducts installed throughout a building to supply conditioned air to a room, through supply air duct; with terminal outlets vents, such as diffusers, grills, registers etc. The air from conditioned space is received through return air ducts with terminals such as grills etc.

Since the 1980s, manufacturers of HVAC equipment have been making an effort to make the systems they manufacture more efficient. This was originally driven by rising energy costs, and has more recently been driven by increased awareness of environmental issues.

Section 2 of this book deals in design elements of Air distribution, Ducts and related materials. Useful reference data/materials in this section, include those from ASHRAE, SMACNA, Bureau of Indian Standards, etc.

Air Handling Units

In the Commercial and Industrial Air - Conditioning application, cooling the space to be conditioned uniformly or without hot pockets, or discomfort, is a basic expectation of the customer. All air - conditioning systems have Air Handlers from where, the cooled / treated / dehumidified air is circulated and collected back from the conditioned area. Typical Air Handler consists of Filter, Cooling Coil & Fan sections, from where the air is ducted to the area to be conditioned. Tables 2-1 & Figs 2.1 to 2.5 illustrate Fan laws applicable to geometrically similar centrifugal fans.

Air Ducts

Depending on the heat load and air quantity requirement, size of the area to be conditioned and locations where air is to be distributed, and the number of air handling systems involved, layout design of supply air / return air ducting is made. Sizing of ducting has a bearing on the pressure drop, recommended supply air velocities and outlet velocities at components. Table 2-2 to 2-15 have data on velocities and recommended dimensions. Table 2-9 gives data for Equivalent Rectangular Duct dimensions for Circular Ducts. Table 2 -43 is a ready reference table to get duct surface area per unit length, for various sizes of ducts.

Materials for ducting

Materials used for ducting shall have properties which are user friendly such as non - shedding, rust resistant, least friction for flow, easily fabricated and giving a tight seal when installed. Tables 2-16 to 2 -27, 47 and 48 give properties of various materials used for ducting. Tables 2-50 to 2-67 give data related to other materials used for Reinforcement, Supports, Fastening etc.

Fabrication / Installation Methods

To get the best results out of the installed ducting, BIS and SMACNA have recommended methods of fabrication, joinery, reinforcement, flanges, etc which are illustrated in pages 22 to 37.

CLASSIFICATION OF DUCTS

Supply and return duct systems are classified with respect to the velocity and pressure of the air within the duct.

Velocity

There are two types of air transmission systems used for air conditioning applications. They are called conventional or Low Velocity and High Velocity Systems. The dividing line between these systems is rather nebulous but, for the purpose of this section, the following initial supply air velocities are offered as a guide.

1. Commercial Comfort Air - Conditioning
   a) Low velocity - upto 2500 fpm. Normally between 1200 and 2200 fpm.
   b) High Velocity - above 2500 fpm.
2. Factory Comfort Air - Conditioning / air cooling
   a) Low velocity - upto 2500 normally between 2200 and 2500 fpm.
   b) High velocity above 2500 to 5000 fpm.

Normally, Return Air Systems, for both low and high velocity supply air systems, are designed as low velocity systems. The velocity range for commercial and factory comfort application for return air is as follows :

1. Commercial Comfort Air - conditioning low velocity upto 2000 fpm. Normally between 1500 and 1800 fpm.
2. Factory comfort air - conditioning low velocity upto 2500 pm. Normally between 1800 and 2200 fpm.

Pressure

Air distribution systems are divided into three pressure categories - Low, Medium and High. These divisions have the same pressure ranges as Class I, II, III fans as indicated.

1. Low pressure - up to ¾ in wg, Class 1 Fan.
2. Medium pressure - bfrom 3 ¾ to 6 ¾ in. wg-Class II Fan.
3. High pressure - from 6 ¾ to 12 ¾ in. wg-Class III Fan.

These pressure ranges are Total Pressure, including the losses through the Air Handling Apparatus, Ductwork and the Terminal in the space.

Table 2.1: Fan Laws

(APPLICABLE FOR GEOMETRICALLY SIMILAR FANS)

Variable	Constant	No	Law	Formula
Speed	Air Density	1	Capacity varies as the speed	$\frac{Q_1}{Q_1} = \frac{N_1}{N_1}$
	Fan Size	2	Pressure varies as the square of the speed	$\frac{P_1}{P_2} = \left(\frac{N_1}{N_2}\right)^2$
	Distribution System	3	Horsepower varies as the cube of the speed	$\frac{HP_1}{HP_2} = \left(\frac{N_1}{N_2}\right)^3$
FAN SIZE	Air Density, Tip Speed	4	Capacity and Horsepower vary as the square of the Fan size	$\frac{Q_1}{Q_2} = \frac{Hp_1}{Hp_2} = \left(\frac{D_1}{D_2}\right)^2$
		5	Speed varies inversely as the Fan size	$\frac{N_1}{N_2} = \frac{D_2}{D_1}$
		6	Power varies with Pressure	
	Air Density . Speed	7	Capacity varies on the cube of the size	$\frac{Q_1}{Q_2} = \left(\frac{D_1}{D_2}\right)^3$
		8	Pressure varies on the cube of the size	$\frac{P_1}{P_2} = \left(\frac{D_1}{D_2}\right)^3$
		9	Horsepower varies at the fifth power of the size	$\frac{Hp_1}{Hp_1} = \left(\frac{D_1}{D_2}\right)^5$
Air Density	Pressure, Fan Size, Distribution System	10	Speed, capacity and Horse-power vary inversely as the square root of density	$\frac{N_1}{N_2} = \frac{Q_1}{Q_2}$ $= \frac{Hp_1}{Hp_2} = \left(\frac{W_2^{0.5}}{W_1}\right)$
	Capacity Fan Size Distribution System	11	Pressure and Horsepower vary as the density	$\frac{P_1}{P_2} = \frac{Hp_1}{Hp_2} = \frac{W_1}{W_2}$

Legend :
D = Fan Size (Wheel dia)
N = Rotational Speed
D = Gas Density
Q = Volume Flow Rate
P = Pressure
W = Power

1. Air Power

In IPS Unit

Air Power = p x Q / 6360

Where 'p' is in inches Wg & 'Q' is in cfm

$$\textbf{BHP} = \frac{\text{cfm x stpr}}{\text{6360 x fan efficiency}}$$

Example : For 1000 cfm, 2 inch static pressure, 60% fan static efficiency

$$\textbf{BHP} = \frac{1000 \times 2}{6360 \times 0.6} = 0.524$$

Note : If 'p' is the fan static pressure (pt) the result is air power.

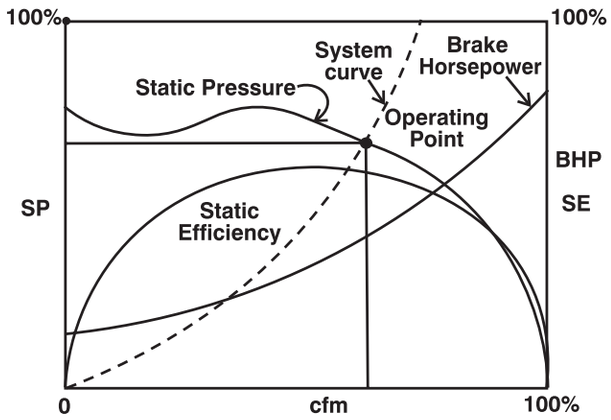


Figure 2.1 : Fan Law for Speed Curves

Ex. For 1000 cfm, 2" Sp. Pressure 60% for efficiency.

$$BHP : \frac{1000 \times 2}{6360 \times 0.6} = 0.524$$

HP = 1.15 * BHP

* Guidance Value

2. Fan Efficiency

Fan efficiency is the ratio of the Air Power to Mechanical Input Power and is usually expressed as a percentage:

Fan Total Efficiency n_t

$$= \frac{\text{air power (total)}}{\text{measured fan input power}} \times 100\%$$

Fan Static Efficiency n_s

$$= \frac{\text{air power (static)}}{\text{measured fan input power}} \times 100\%$$

3. Temperature Rise

SI Units

$$T = \frac{P_t}{n_t \times 1.23}$$

in I.P. Units

$$T = \frac{P_t}{n_t \times 2.7}$$

4. Sound power :

$Lw_2 = Lw_1 + \{50 \log (N_2 / N_1)\} + \{50 \log (D_2 / D_1)\} + \{22 \log (P_2 / P_1)\}$

Note : Fan Law for sizes are applicable only for "Geometrically similar" fans.

Fan Law for Speed Curves

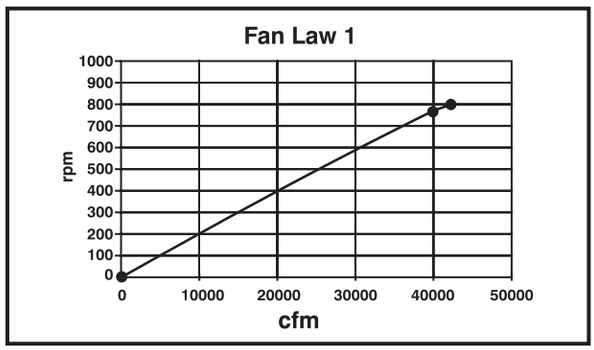


Figure 2.2. : Fan law - Air Flow

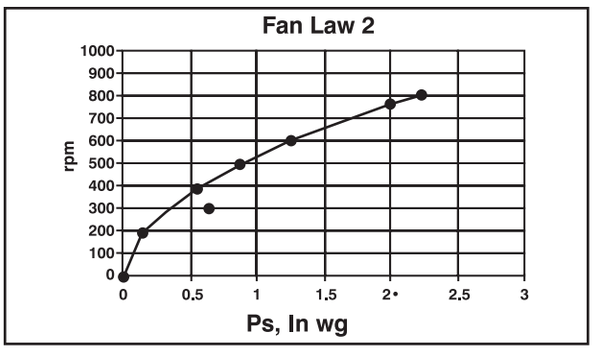


Figure 2.3 : Fan law - Pressure

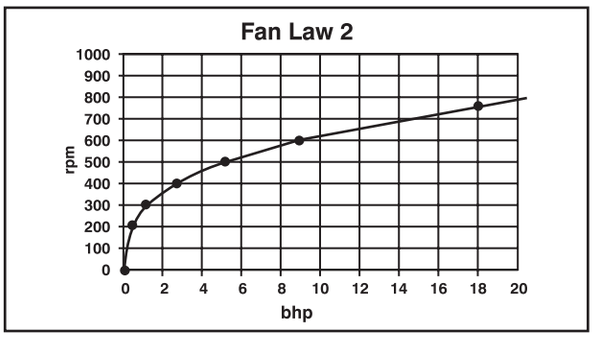


Figure 2.4 : Fan law - Brake Horsepower

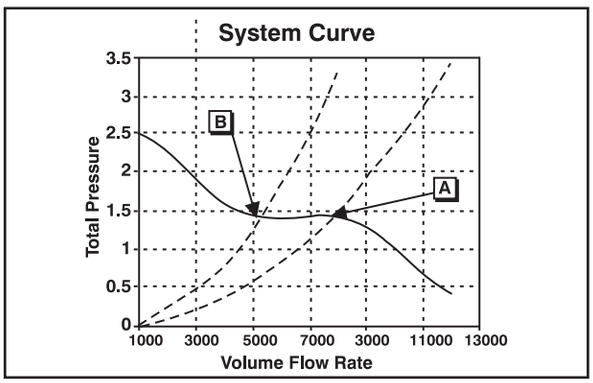


Figure 2.5 : Centrifugal Fan Performance Curves

Table 2.2 : Recommended Maximum Duct Velocities for Low Velocity Systems (FPM)

Application	Controlling Factor* Noise Generation Main Ducts	Controlling Factor - Duct Friction			
		Main Ducts		Branch Ducts	
		Supply	Return	Supply	Return
Residences	600	1000	800	600	600
Apartments, Hotel Bedrooms, Hospital Bedrooms	1000	1500	1300	1200	1000
Private Office, Directors Rooms, Libraries	1200	2000	1500	1600	1200
Theatres Auditoriums	800	1300	1100	1000	800
General Offices High Class Restaurants, High Class Stores, Banks	1500	2000	1500	1600	1200
Average Stores, Cafeterias	1800	2000	1500	1600	1200
Industrial	2500	3000	1800	2200	1500

Table 2.3 : Occupied Zone Room Air Velocities (3 ft. above floor level) in FPM

Room Air Velocity	REACTION	Recom-mended Application
0-16	Complaints about stagnant air	None
25	Ideal Design - Favourable	All Commercial applications
25-50	Probably favourable but 50 fpm is approaching max. tolerable velocity for seated persons	All Commercial applications
65	Unfavourable - light papers are blown off a desk	
75	Upper limit for people moving about slowly - favourable	Retail and Dept. Store
75-300	Some Factory air - conditioning installations - favourable	Factory air - conditioning. Higher Velocities for spot cooling

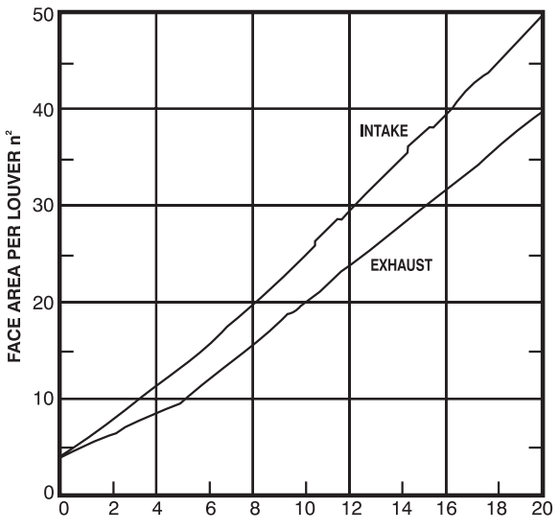
Table 2.5 : Typical Terminal Velocities

APPLICATION	TERMINAL VELOCITY (FPM)
Broadcast Studios	300-500
Residences	500-750
Apartments	500-750
Churches	500-750
Hotel Bedrooms	500-750
Legitimate Theatre	500-750
Private Offices Acoustically Treated	500-750
Private Offices, Not treated	1000-1250
Motion Picture Theaters	1000
General Offices	1000-1250
Dept. Stores, Upper Floors	1500
Dept. Stores, Main Floor	2000

Table. 2.4 : Typical Design Velocities For HVAC Components

Duct Element	Face Velocity, FPM
Louvers	
Intake	
7000 cfm and greater	400
Less than 7000 cfm	See Figure 2.6
Exhaust	
5000 cfm and greater	500
Less than 5000 cfm	See Figure 2.6
Filters	
Panel Filters	
Viscous Impingement	200 to 800
Dry type, extended surface	
Flat (Low Efficiency)	Duct Velocity
Pleated media (intermediate efficiency	Upto 750
HEPA	250
Renewable Media Filters	
Moving Curtain Viscous Impingement	500
Moving Curtain dry media	200
Electronic air cleaners Ionizing Type	150 to 350
Heating Coils	500 to 1000
Steam and hot water	200 min. 1500 max
Electric	
Open Wire	Refer to mfg. Sata
Finned Tubular	Refer to mfg. Data
Dehumidifying Coils	400 to 500
Air Washers	
Spray type	Refer to mfg. Data
Cell Type	Refer to mfg. Data
High Velocity Spray Type	1200 to 1800

Source : ASHRAE Handbook, 2009



Parameters used to Establish Figure	Intake Louver	Exhaust Louver
Minimum free % (49 in. square least section)	45	45
Water generation gzn (ft 0.25 h)	Negligible (less than 0.01)	NVA
Maximum static pressure drop (inches of water)	0.14	0.25

SOURCE : ASHRAE HANDBOOK 2009

Figure 2.6 : Criteria for Louver Sizing

Table 2.6 : Duct Roughness Factor

Duct Type Material	Absolute Roughness ξ ft.	
	Range	Roughness Category
Drawn tubing (Madison 1946)	0.0000015	Smooth 0.0000015
PVC plastic pipe (Swim 1982)	0.00003 to 0.00015	Medium smooth 0.00015
Commercial Steel or wrought iron (Moody 1944)	0.00015	Average 0.0003
Aluminium, round longitudinal seams, crimped slip joints, 3 ft. spacing (Hutchinson 1953)	0.00012 to 0.0002	
Friction Chart Glavanised steel, round, longitudinal seams, variable joints (Vanstone, drawband, welded, primarily beaded coupling) 4 ft. joint spacing (Griggs et al. 1987) Galvanized steel, spiral seams, 10 ft joint spacing (Jones 1979) Galvanised steel, spiral, seam with 1, 2 and 3 ribs, beaded couplings, 12 ft joint spacing (Griggs et al. 1987) Galvanised steel, rectangular, various types joints (Vanstone, drawband, welded, beaded coupling) 4ft spacing[a] (Griggs et al. 1987) Galvanised steel, rectangular, various types joints (Vanstone, drawband, welded, beaded coupling) 4 ft spacing (Griggs and Khodabakash - Sharifabad 1992)	0.0001 6 to 0.00032 0.0002 to 0.0004 0.0029 to 0.00038 0.00027 to 0.0005	
Wright Friction Chart Galvanised steel, round, longitudinal seams, 2.5 ft. joint spacing £ = 0.0005 ft.	Retained for historical purpose (See Wright (1945) for development of friction chart)	
Flexible duct, fabric and wire fully extended (Abushakara et al. 2004; Culp 2011) Galvanised steel L_1 spiral corrugated1" Beaded slip coupling, 10 ft spacing (Kulkarni et al. 2009) Fibrous glass duct, rigid (tentative) Fibrous glass duct liner, air side with facing material (Swim 1978)	0.0003 to 0.003 0.001 8 to 0.0030 - 0.005	Medium rough 0.003
Fibrous glass duct liner, air side spray coated (Swim 1978) Flexible duct, metallic, fully extended Concrete (Moody 1944)	0.015 0.004 to 0.007 0.001 to 0.01	Rough 0.01

[a]Griggs and Khodabakhush Sharifabad (1992) showed that r values for rectangular duct construction combine effects of surface condition joint spacing joint type and duct construction (cross breaks etc.) and that the r value range is listed as representative.
[b]Spiral seam, spacing was 4.65 in with two corrugations between seams. Corrugations were 0.75 in. wide by 0.23 in. (semicircle). Subject duct classified “tentatively medium rough” based on data available.

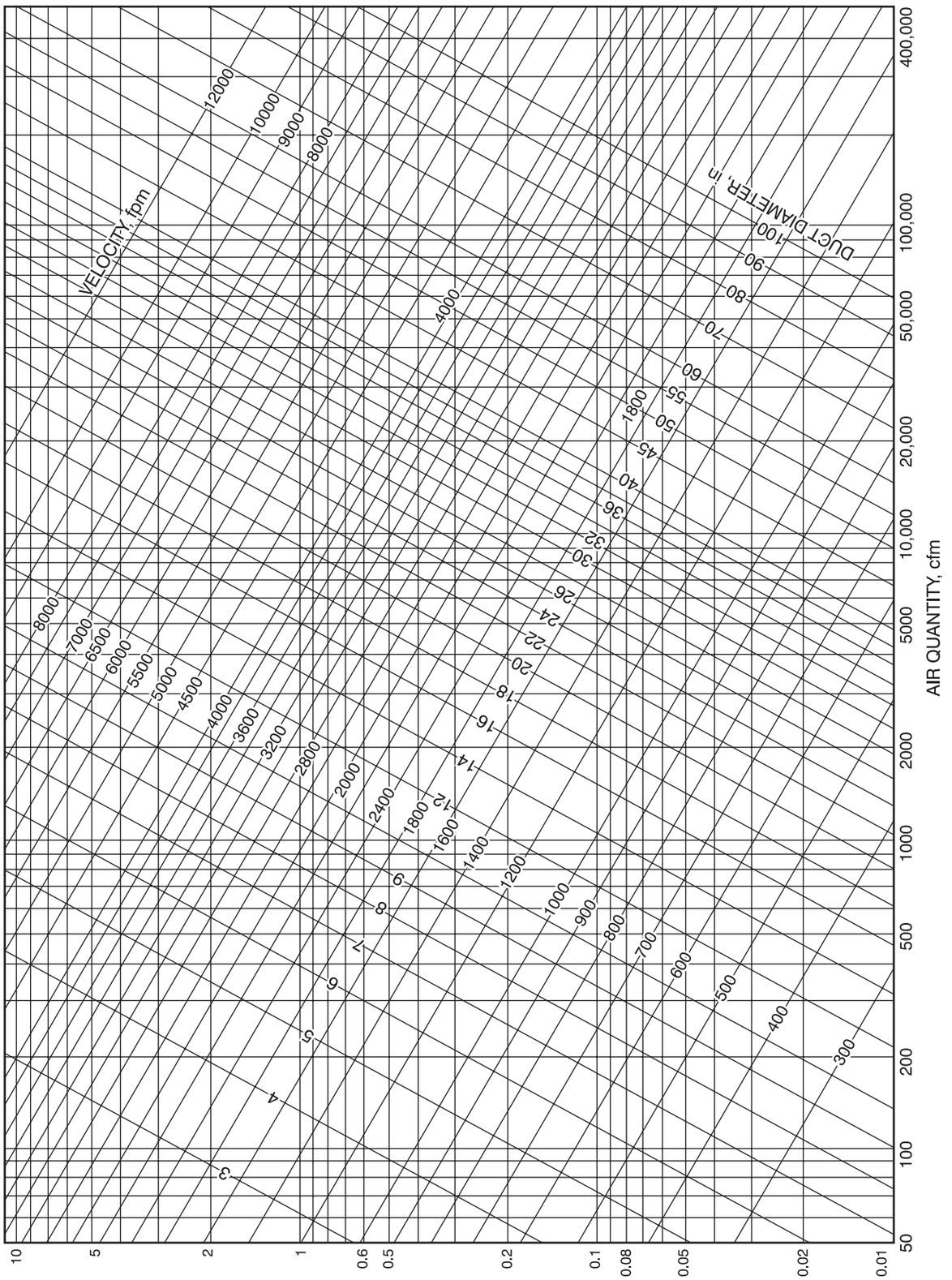


Figure 2.7 : Rigid Duct Design - Friction Chart
Friction chart for Round Duct, Air Density = 0.075 lb/ft3 and ξ =0 0.003 ft.

Source : ASHRAE Handbook 2013

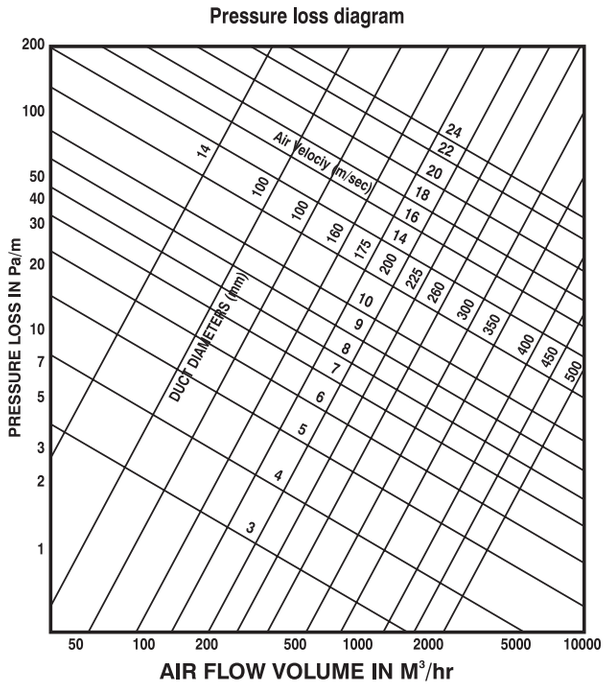


Figure 2.8 : Round Flexible Duct

Table 2.7 : Recommended Maximum System Leakage (Percentage)

Sl	Type of System	System Condition	Test Pressure[2] Inch of Water	Maximum System Leakage
1	Fractional Horsepower System, Small Exhaust / Return Systems, Residential Systems	During Construction, Operating	Operating Pressure 0.5	5% 5%
2	Single Zone Supply, Retum or Exhaust Systems	During Construction, Operating	Operating Pressure 2.0	5% 5%
3	Multizone Supply, Return or Exhaust System	During Construction, Operating	Operating Pressure 2.0	5% 5%
4	VAV and CAV Supply systems	During Construction, Operating	Operating Pressure 6.0	5% 5%
5	VAV3 and CAV1 Supply systems	During Construction, Operating	Operating Pressure Upstream box 4.0 Downstream box 1.0	5% 5% 5%
6	VAV and CAV Return Systems	During Construction, Operating	Operating Pressure Downstream box 1.0	5% 5% 5%
7	Chilled Beam Systems	During Construction, Operating	Operating Pressure 4.0	5% 5%
8	High pressure Induction Systems	During Construction, Operating	Operating Pressure 6.0	5% 5%
9	Supply and Return Ductwork located Outdoors	During Construction, Operating	Operating Pressure 3.0	2% 2%
10	Exhaust Ductwork located Outdoors	During Construction, Operating	Operating Pressure 3.0	2% 2%
11	Air-Handling Units	Site test by manufacturer	Specified design pressure	1%

Notes: 1) Test pressure should not exceed fluctuating pressure rating.
2) It is recommended that Duct pressure rating equal fan shutoff pressure if possibility of fan shutoff exists either in VAV systems or in systems with smoke fire damper control.
3) Assuming primary air damper is located at Duct inlet, if damper is at box, then box should be included in upstream leakage testing.

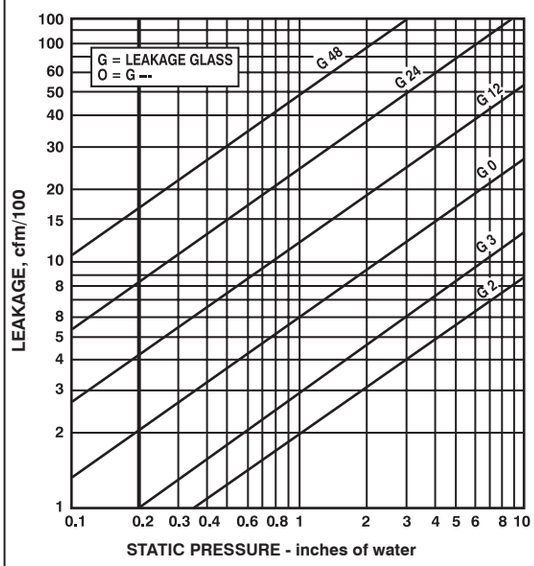


Figure 2.9 : Duct Leakage Classification

Source : ASHRAE Handbook 2009

Table 2.8 : Leakage as Percentage of Airflow[a,b]

Leakage Class	System cfm per ft² Duct Surface[c]	Static Pressure, inches of water						
		0.5	1	2	3	4	5	6
48	2	15	24	38	49	59	77	
	2.5	12	19	30	39	47	62	
	3	10	16	25	33	39	51	
	4	7.7	12	19	25	30	38	
	5	6.1	9.6	15	20	24	31	
24	2	7.7	12	19	25	30	38	
	2.5	6.1	9.6	15	20	24	31	
	3	5.1	8.0	13	16	20	26	
	4	3.8	6.0	9.4	12	15	19	
	5	3.1	4.8	7.5	9.8	12	15	
12	2	3.8	6.0	9.4	12	15	19	
	2.5	3.1	4.8	7.5	9.8	12	15	
	3	2.6	4.0	6.3	8.2	9.8	13	
	4	1.9	3.0	4.7	6.1	7.4	9.6	
	5	1.5	2.4	3.8	4.9	5.9	7.7	
6	2	1.9	3	4.7	6.1	7.4	9.6	
	2.5	1.5	2.4	3.8	4.9	5.9	7.7	
	3	1.3	2.0	3.1	4.1	4.9	6.4	
	4	1.0	1.5	2.4	3.1	3.7	4.8	
	5	0.8	1.2	1.9	2.4	3.0	3.8	
3	2	1.0	1.5	2.4	3.1	3.7	4.8	
	2.5	0.8	1.2	1.9	2.4	3.0	3.8	
	3	0.6	1.0	1.6	2.0	2.5	3.2	
	4	0.5	0.8	1.3	1.6	2.0	2.6	
	5	0.4	0.6	0.9	1.2	1.5	1.9	

Percentage applies to airflow entering a section of duct operating at an assumed pressure equal to average of upstream and downstream pressure. Ratios are typical of fan valumetric flow rate divided by total system surface. Portions of systems may vary from these averages.

HIGH ALTITUDE DUCT DESIGN

When any Air Distribution is designed to operate above 2000 Feet altitude, below 30°F, or above 120°F temperature, the Friction Loss obtained from Fig. 2.7, Page 2.6 must be corrected for the Air Density. Figure 2.10 presents the correction factors for Temperature and Altitude. The actual cfm is used to find the Friction Loss and this loss is multiplied by the Correction Factor or Factors from the Chart in Fig. 2.10 to obtain the actual friction loss.

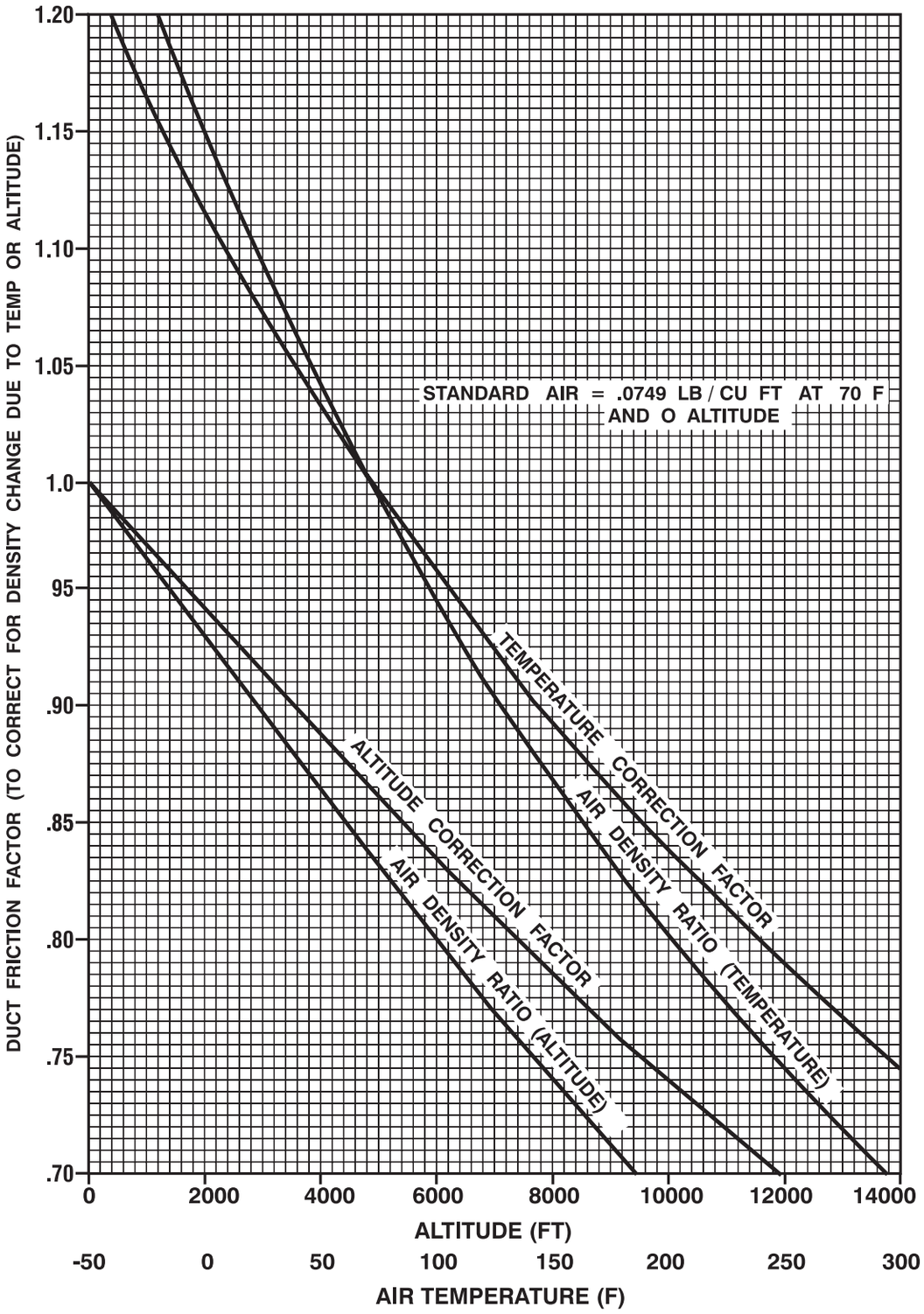


Figure 2.10 : AIR DENSITY CORRECTION FACTORS

Source : Carrier system design manual

Table 2.9 : Equivalent Rectangular Duct Dimensions

Circular Duct Diameter, in.	Length of One Side of Rectangular Duct a, in.																			
	4	5	6	7	8	9	10	12	14	16	18	20	22	24	26	28	30	32	34	36
Length of Adjacent Side of Rectangular Duct b, in.																				
5	5																			
5.5	6	5																		
6	8	6																		
6.5	9	7	6																	
7	11	8	7																	
7.5	13	10	8	7																
8	15	11	9	8																
8.5	17	13	10	9																
9	20	15	12	10	8															
9.5	22	17	13	11	9															
10	25	19	15	12	10	9														
10.5	29	21	16	14	12	10														
11	32	23	18	15	13	11	10													
11.5		26	20	17	14	12	11													
12		29	22	18	15	13	12													
12.5		32	24	20	17	15	13													
13		35	27	22	18	16	14	12												
13.5		38	29	24	20	17	15	13												
14			32	26	22	19	17	14												
14.5			35	28	24	20	18	15												
15			38	30	25	22	19	16	14											
16			45	36	30	25	22	18	15											
17				41	34	29	25	20	17	16										
18				47	39	33	29	23	19	17										
19				54	44	38	33	26	22	19	18									
20					50	43	37	29	24	21	19									
21					57	48	41	33	27	23	20									
22					64	54	46	36	30	26	23	20								
23						60	51	40	33	28	25	22								
24						66	57	44	36	31	27	24	22							
25							63	49	40	34	29	26	24							
26							69	54	44	37	32	28	26	24						
27							76	59	48	40	35	31	28	25						
28								64	52	43	38	33	30	27	26					
29								70	56	47	41	36	32	29	27					
30								76	61	51	44	39	35	31	29	28				
31								82	66	55	47	41	37	34	31	29				
32								89	71	59	51	44	40	36	33	31				
33								96	76	64	54	48	42	38	35	33	30			
34									82	68	58	51	45	41	37	35	32			
35									88	73	62	54	48	44	40	37	32	32		
36									95	78	67	58	51	46	42	39	36	34		
37									101	83	71	62	55	49	45	41	38	36	34	
38									108	89	76	66	58	52	47	44	40	38	36	
39										95	80	70	62	55	50	46	43	40	37	36
40										101	85	74	65	58	53	49	45	42	39	37
41										107	91	78	69	62	56	51	47	44	41	39
42										114	96	83	73	65	59	54	50	46	44	41
43										120	102	88	77	69	62	57	53	49	46	43
44											107	93	81	73	66	60	55	51	48	45
45											113	98	86	76	69	63	58	54	50	47
46											120	103	90	80	72	66	61	56	53	49
47											126	108	95	84	76	69	64	59	55	52
48											133	114	100	89	80	73	67	62	58	54
49											140	120	105	93	84	76	70	65	60	56
50											147	126	110	98	88	80	73	68	63	59
51												132	115	102	92	83	76	71	66	61
52												139	121	107	96	87	80	74	69	64
53												145	127	112	100	91	83	77	71	67
54												152	133	117	105	95	87	80	74	70
55													139	123	110	99	91	84	78	72
56													145	128	114	104	95	87	81	75
57													151	134	119	108	98	91	84	78
58													158	139	124	112	102	94	87	81
59													165	145	130	117	107	98	91	85
60													172	151	135	122	111	102	94	88

TABLE 2.10 : EQUIVALENT FLAT OVAL DUCT DIMENSIONS

Circular Duct Diameter, in.	Minor Axis a, in.													Circular Duct Diameter, in.	Minor Axis a, in.												
	3	4	5	6	7	8	9	10	11	12	14	16			8	9	18	11	12	14	16	18	20	22	24	
	Major Axis A, in														Major Axis A, in.											
5	8													19	46	-	34	-	28	23	21					
5.5	9	7												20	50	-	38	-	31	27	24	21				
6	11	9												21	58	-	43	-	34	28	25	23				
6.5	12	10	8											22	65	-	48	-	37	31	29	26				
7	15	12	10	8										23	71	-	52	-	42	34	30	27				
7.5	19	13	-	9										24	77	-	57	-	45	38	33	29	26			
8	22	15	11	-										25			63	-	50	41	36	32	29			
8.5		18	13	11	10									26			70	-	56	45	38	34	31			
9		20	14	12	-	10								27			76	-	59	49	41	37	34			
9.5		21	18	14	12	-								28					65	52	46	40	36			
10			19	15	13	11								29					72	58	49	43	39	35		
10.5			21	17	15	13	12							30					78	61	54	46	40	38		
11				19	16	14	-	12						31					81	67	57	49	44	39	37	
11.5				20	18	16	14	-						32						71	60	53	47	42	40	
12				23	20	17	15	13						33						77	66	56	51	46	41	
12.5				25	21	-	-	15	14					34							69	59	55	47	44	
13				28	23	19	17	16	-	14				35							76	65	58	50	46	
13.5				30	-	21	18	-	16	-				36							79	68	61	53	49	
14				33	-	22	20	18	17	15				37								71	64	57	52	
14.5				36	-	24	22	19	-	17				38								78	67	60	55	
15				39	-	27	23	21	19	18				40									77	69	62	
16				45	-	30	-	24	22	20	17			42										75	68	
17				52	-	35	-	27	24	21	19			44										82	74	
18				59	-	39	-	30	-	25	22	19														

SOURCE : ASHRAE HANDBOOK 2013

TABLE 2.11: UNSEALED LONGITUDINAL SEAM LEAKAGE, METAL DUCTS

Type of Duct /Seam	Leakage CFM per ft Seam Length	
	Range	Average
Rectangular		
Pittsburg Lock		
26 gauge	0.001 to 0.02	0.0168
22 gauge	0.001 to 0.002	0.0016
Button Punch snaplock		
26 gauge	0.03 to 0.1 5	0.0795
22 gauge	NA (1 test)	0.0032
Round		
Spiral (26 gauge)	NA (1 set)	0.015
Snaplock	0.04 to 0.1 4	0.11
Grooved	0.11 to 0.18	0.12
Leakage rate is at 1 in. of water static pressure		

SOURCE : ASHRAE HANDBOOK 2013

TABLE 2.12 : PERCENT SECTION AREA IN BRANCHES FOR MAINTAINING EQUAL FRICTION

CFM Capacity%	Duct Area %	CFM Capacity %	Duct Area %	CFM Capacity %	Duct Area %	CFM Capacity %	Duct Area %
1	2.0	26	33.5	51	59.0	76	81.0
2	3.5	27	34.5	52	60.0	77	82.0
3	5.5	28	35.5	53	61.0	78	83.0
4	7.0	29	36.5	54	62.0	79	84.0
5	9.0	30	37.5	55	63.0	80	84.5
6	10.5	31	39.0	56	64.0	81	85.5
7	11.5	32	40.0	57	65.0	82	86.0
8	13.0	33	41.0	57	65.5	83	87.0
9	14.5	34	42.0	59	66.5	84	87.5
10	16.5	35	43.0	60	67.5	85	88.5
11	17.5	36	44.0	61	68.0	86	89.5
12	18.5	37	45.0	62	69.0	87	90.0
13	19.5	38	46.0	63	70.0	88	90.5
14	20.5	39	47.0	64	71.0	89	91.5
15	21.5	40	48.0	65	71.5	90	92.0
16	23.0	41	49.0	66	72.5	91	93.0
17	24.0	42	50.0	67	73.5	92	94.0
18	25.0	43	51.0	68	74.5	93	94.5
19	26.0	44	52.0	69	75.5	94	95.0
20	27.0	45	53.0	70	76.5	95	96.0
21	28.0	46	54.0	71	77.0	96	96.5
22	29.5	47	55.0	72	78.0	97	97.5
23	30.5	48	56.0	73	79.0	98	98.0
24	31,5	49	57.0	74	80.0	99	99.0
25	32.5	50	58.0	75	80.5	100	100.0

Source : Carrier system design manual

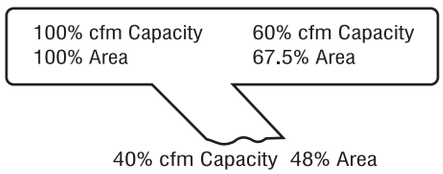


TABLE 2.13 : MAXIMUM DIFFERENCE BETWEEN SUPPLY AIR TEMPERATURE AND ROOM DEWPOINT WITHOUT CONDENSING MOISTURE ON DUCT (F)

Air Conditions Surrounding Duct		AIR VELOCITY IN STRAIGHT RUN OF DUCT (FPM)*											
		Painted	Bright Metal	Painted	Bright Metal	Painted	Bright Metal	Painted	Bright Metal	Painted	Bright Metal	Painted	Bright Metal
DB(F)	RH(%)	400 FPM		800 FPM		1200 FPM		1600 FPM		2000 FPM		3000 FPM	
74-100	45	20	15	15	9	11	8	8	5	7	4	5	3
	50	18	13	13	8	10	7	7	5	6	4	4	3
	55	15	11	11	7	8	6	6	4	5	3	4	2
	60	13	10	10	6	7	5	5	3	4	3	3	2
	70	9	7	7	4	5	4	4	2	3	2	2	2
	80	6	4	4	3	3	2	2	2	2	1	2	1
	85	4	3	3	2	2	2	2	1	2	1	1	1
Value of $\frac{f_2}{u} - 1$		.99	.66	.66	.42	.49	.31	.37	.24	.31	.20	.23	.15

For elbows and other fittings See Notes 4 and 7.

Equation ; $T_{dp} - T_{sa} = (T_{pm} - T_{dp}) \left\{ \frac{f_2}{u} - 1 \right\}$

Where T_{dp} = duct surface temp in ^{0}F. Assumed equal to room dewpoint
T_{sa} = supply air dry-bulb temp in duct
T_{rm} = room dry-bulb temp
U = overall heat transmission coefficient of duct (Btu/hr Sq. Ft. Deg. F)
f2= film heat transmission coefficient on outside of duct Btu/hr Sq.ft. Deg. F 1.65 for painted duct and 1.05 bright metal ducts

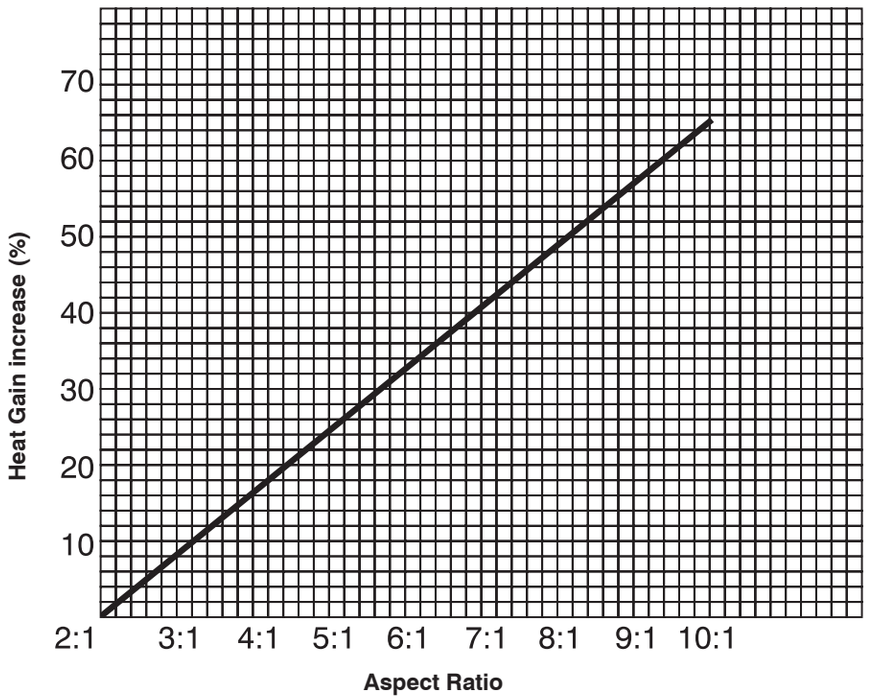
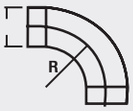
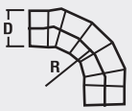
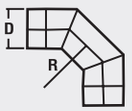
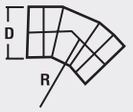


Figure 2.11: Duct Heat Gain VS Aspect Ratio

Source : Carrier system design manual

TABLE 2.14 : FRICTION OF ROUND ELBOWS

Elbow Diameter (in.)	90° Smooth  R/D = 1.5	90° 5-PIECE  R/D = 1.5	90° 3-PIECE  R/D = 1.5	45° 3-PIECE  R/D = 1.5	45° SMOOTH  R/D = 1.5
ADDITIONAL EQUIVALENT LENGTH OF STRAIGHT DUCT (FT)					
3	2.3	3	6	1.5	1.1
4	3	4	8	2	1.5
5	3.8	5	40	2.5	1.9
6	4.5	6	12	3	2.3
7	5.3	7	14	3.5	2.6
8	6	8	16	4	3
9	-	9	18	4.5	-
10	-	10	20	5	-
11	-	11	22	5.5	-
12	-	12	24	6	-
14	-	14	28	7	-
16	-	16	32	8	-
18	-	18	36	9	-
20	-	20	40	10	-
22	-	22	44	11	-
24	-	24	48	12	-

Source : Carrier System Design manual

TABLE 2.15 : FRICTION OF RECTANGULAR ELBOWS

Duct Dimensions (in.)		Radius Elbow No Vanes	Radius Elbow - with Vanes				Square Elbows	
								
W	D	Radius Ratio** R/D=1.25	R_t = 6" (Recommended)		R_t=3" (Acceptable)		Double Thickness Turning Vanes	Single Thickness Turning Vanes
ADDITIONAL EQUIVALENT LENGTH OF STRAIGHT DUCT (FT)								
			Vanes		Vanes			
96	48	31	45	2	43	3	40	60
	36	25	36	2	31	3	30	45
	30	22	31	2	38	2	25	37
	24	19	33	1	29	2	20	30
	20	16	28	1	25	2	17	25
72	48	28	44	2	41	3	35	60
	36	23	33	2	29	3	29	45
	30	21	28	2	33	2	25	37
	24	17	29	1	25	2	21	30
	20	15	23	1	19	2	18	25
	16	13	18	1	16	2	15	20
	12	12			15	1	11	15
60	48	27	41	2	39	3	33	60
	36	22	31	2	27	3	27	45
	30	19	25	2	31	2	23	37
	24	16	27	1	26	2	20	30
	20	14	22	1	21	2	17	25
	16	12	16	1	15	2	13	20
	12	10			14	1	10	15
48	96	45	35	3				
	48	26	35	2	34	3	29	60
	36	20	26	2	22	3	23	45
	30	18	23	2	28	2	21	37
	24	15	24	1	21	2	18	30
	20	14	19	1	17	2	15	25
	16	11	15	1	14	2	12	20
	12	9			13	1	10	15
	10	8			11	1	8	12
	8	8			9	1	7	10
42	42	23	28	2	26	3	24	53
	36	20	24	2	21	3	22	45
	30	17	21	2	26	2	20	37
	24	15	21	1	19	2	16	30
	20	13	18	1	16	2	14	25
	16	11	14	1	13	2	12	20
	12	9			13	1	9	15
	10	8			10	1	8	12
	8	7			8	1	6	10
36	72	34	27	3				
	36	19	22	2	19	3	20	45
	30	16	19	2	22	2	18	37
	24	14	20	1	22	2	15	30
	20	12	17	1	15	2	13	25
	16	10	13	1	12	2	11	20
	12	9			12	1	9	15
	10	8			9	1	8	12
	8	7			8	1	6	10
32	32	17	19	2	16	3	17	40
	30	16	18	2	21	2	17	37
	24	14	19	1	17	2	15	30
	20	12	16	1	14	2	12	25
	16	10	12	1	12	2	11	20
	12	8			12	1	8	15
	10	7			9	1	7	12
	8	6			8	1	6	10

Source : Carrier Systems Design Manual

TABLE 2.15 : FRICTION OF RECTANGULAR ELBOWS (CONTD...)

Duct Dimensions (in.)		Radius Elbow No Vanes	Radius Elbow - with Vanes				Square Elbows	
								
W	D	Radius Ratio** R/D=1.25	R_t = 6" (Recommended)		R_t=3" (Acceptable)		Double Thickness Turning Vanes	Single Thickness Turning Vanes
ADDITIONAL EQUIVALENT LENGTH OF STRAIGHT DUCT (FT)								
			Vanes		Vanes			
28	28	15	14	2	17	2	14	34
	24	13	17	1	15	2	13	30
	20	12	15	1	13	2	12	25
	16	10	11	1	11	2	10	20
	12	8			11	1	8	15
	10	7			9	1	7	12
	8	6			8	1	6	10
24	96	38	19	3			23	80
	72	32	17	3			21	72
	48	22	20	2	20	3	18	62
	24	13	16	1	14	2	12	30
	20	11	13	1	12	2	10	25
	16	10	11	1	10	2	9	20
	12	8			10	1	8	15
	10	7			8	1	7	12
	8	6			7	1	6	10
	6	5					4	8
20	80	32	16	3			19	66
	60	26	19	2			17	58
	40	22	15	2	14	3	14	49
	20	11	12	1	10	2	10	25
	16	9	9	1	9	2	8	20
	12	7			9	1	7	15
	10	6			8	1	6	12
	8	5			7	1	5	10
	6	4					4	8
16	64	26	9	3			14	48
	48	21	12	2	12	3	12	43
	32	15	11	2	9	3	11	38
	16	9	8	1	8	2	7	20
	12	7			8	1	6	15
	10	6			6	1	5	12
	8	5			6	1	5	10
	6	4					4	8
12	48	19	8	2	8	3	10	33
	36	16	7	2	7	3	9	30
	24	11	8	1	8	2	8	26
	12	7			7	1	5	15
	10	6			5	1	5	12
	8	5			5	1	4	10
	6	4					3	8
10	40	19	6	2	6	3	8	27
	30	13	6	2	8	2	7	24
	20	9	7	1	6	2	6	21
	10	5			5	1	4	12
	8	4			5	1	4	10
	6	4					3	8
8	32	13	5	2	4	3	6	21
	24	11	6	1	5	2	6	19
	16	8	4	1	5	2	5	16
	8	4			4	1	3	10
	6	3					3	8
6	24	10	4	1	4	2	4	15
	18	8	3	1	4	2	4	13
	12	6			4	1	3	11
	6	3					3	8

* Denotes Hard Bends as shown
- Hard Bend
** For other radius ratios, refer carrier Drg.
- Easy Bend
**For other sizes, refer carrier Drg.
Vanes must be located as illustrated in 2.13, to have minimum losses.

Source : Carrier System Design manual

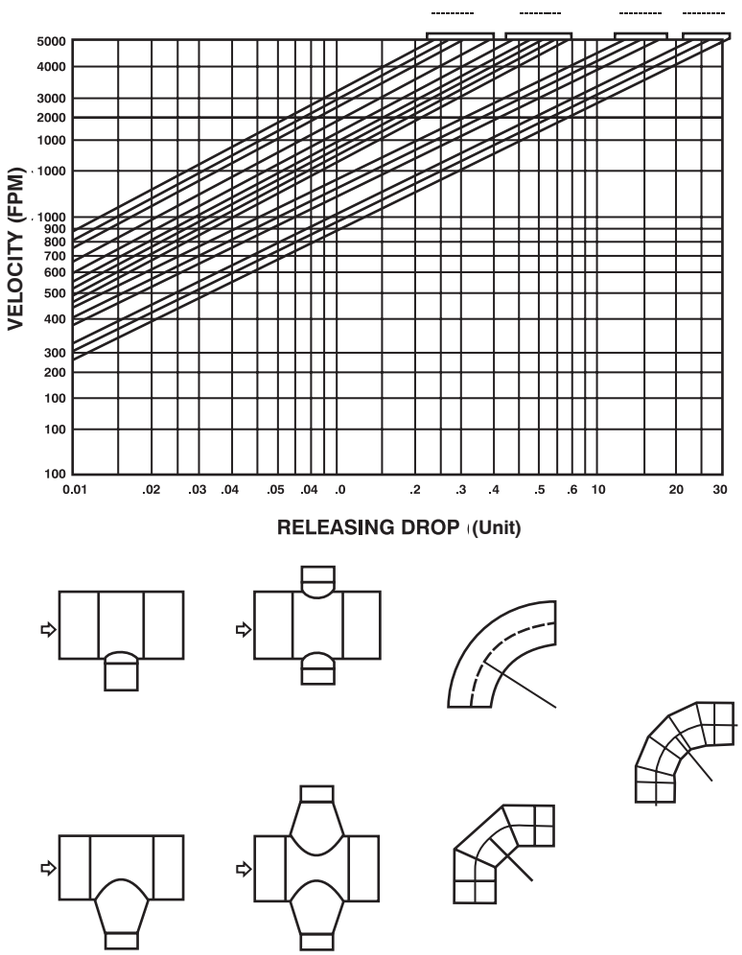


Figure 2.12: Losses for Round Fittings

NOTES : 1. Loss for tee or cross is a function of the velocity in the branch. This represents the loss in static pressure from the main up stream to the branch. Q_R is the ratio of air quantity of the branch to the main upstream.
2. Loss for 45° smooth elbow is equal to one half the loss for a 90° smooth elbow.
3. Loss for 45° 3 piece elbow is equal to one half the loss for a 90° 5 piece elbow.

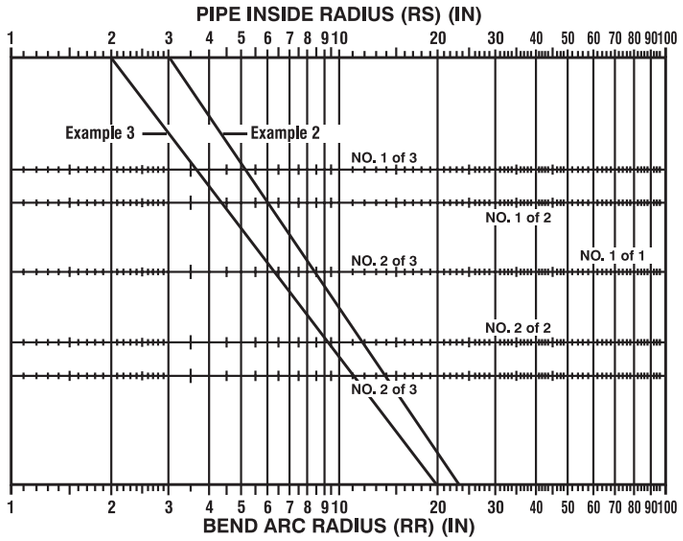


Figure 2.13 : Vane Location for Rectangular Elbow

Table 2.16 : Galvanized Sheet Thickness

Galvanized Sheet Gauge	Thickness in.		Nominal Weight, lb/ft²
	Nominal	Minimum	
30	0.0157	0.0127	0.656
28	0.0187	0.0157	0.781
26	0.0217	0.0187	0.906
24	0.0276	0.0236	1.156
22	0.0336	0.0296	1.406
20	0.0396	0.0356	1.656
18	0.0516	0.0466	2.156
16	0.0635	0.0575	2.656
14	0.0785	0.0705	3.281
13	0.0934	0.0854	3.906
12	0.1084	0.0994	4.531
11	0.1233	0.1143	5.156
10	0.1382	0.1292	5.781

1 lb / ft² = 4.887 kg / m²
Minimum thickness is based on hot-dip galvanized sheets in cut lengths and coils as per ASTM Standard.

Table 2.17 : Stainless Steel Sheet Thickness

Gauge	Thickness, in.		Nominal Weight, lb/ft²	
			Stainless Steel	
	Nominal	Minimum	380 Series	400 Series
28	0.0151	0.0131	0.634	0.622
26	0.0178	0.0148	0.748	0.733
24	0.235	0.0205	0.987	0.968
22	0.293	0.0253	1.231	1.207
20	0.0355	0.0315	1.491	1.463
18	0.0480	0.0430	2.016	1.978
16	0.0595	0.0535	2.499	2.451
14	0.0751	0.0681	3.154	3.094
13	0.0900	0.0820	3.780	3.708
12	0.1054	0.0964	4.427	4.342
11	0.1200	0.1100	5.040	4.944
10	0.1350	0.1230	5.670	5.562

Minimum thickness is based on thickness tolerance of hot-rolled sheets in cut lengths and cold-rolled sheets in cut lengths and coils as per ASTM Standard.

Table 2.18: Uncoated Steel Sheet Thickness

Manufacturers standard Gauge	Thickness, In.			Nominal Weight, lb/ft²
	Nominal	Minimum		
		Hot rolled	Cold rolled	
28	0.0149		0.0129	0.625
26	0.0179		0.0159	0.750
24	0.0239		0.0209	1.000
22	0.0299		0.0269	1.250
20	0.0359		0.0329	1,500
18	0.0478	0.0428	0.0438	2.000
16*	0.0598	0.0538	0.0548	2.500
14	0.0747	0.0677	0.0697	3.125
13	0.0897	0.0827	0.0847	3.750
12	0.1046	0.0966	0.0986	4.375
11	0.1196	0.1116	0.1136	5.000
10	0.1345	0.1265	0.1285	5.625

Note: Table is based on 48 in. width coil and short stocks, 60 in. coil has same tolerance except that 26 gauge is 0.007 in. for hot-rolled coils and sheets.
Minimum thickness is based on thickness tolerances of hot and cold rolled sheets in cut lengths and coils as per ASTM Standards.

Table 2.19 : Steel Angle Weight per Unit Length (Approximate)

Angle Size, Inches	Weight, lb/ft
3/4 x3/4 x 1/8	0.59
1 x 1 x 0.0466 (minimum)	0.36
1 x -1 x 0.0575 (minimum)	0.44
1x1x1/8	0.80
11/4x1 1/4 x 0.0466 (minimum)	0.45
11/4x1 1/4 x 0.0575 (minimum)	0.55
11/4x1 1/4 x 0.0854 (minimum)	0.65
11/4x1 1/4 x 1/8	1.01
11/2x1 1/2 x 0.0575 (minimum)	0.66
11/2x1 1/2 x 1/8	1.23
11/2x1 1/2 x 3/16	1.80
11/2x1 1/2 x 1/4	2.34
2 x 2 x 0.0575 (minimum)	0.89
2x2x1/8	1.65
2x2x3/16	2.44
2x2x1/4	3.19
21/2x21/2x3/16	3.07
21/2x2 1/2 x 1/4	4.10

Source : ASHRAE Handbook

Table 2.20: Pressure Classification for Ductwork

Type Duct	Static Pressure Class inches of water													
	+1/2	-1/2	+1	-1	+2	-2	+3	-3	+4	4	+6	-6	+10	-10
Rectangular	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Round						•				•		•	•	•
Flat Oval													•	•
Fiber glass duct board	•	•	•	•	•	•								
Flexible duct fabric and wire	•	•	•	•	•	•	•	•	•	•	•	•	•	•

Note: Same reinforcements as rectangular ducts, except reinforcement mechanically attached to ducts.

Columns with a dot indicate that construction standards are available for the pressure classes shown, fibreglass duct board must be UL Standard 181 listed. Flexible duct must be UL Standard 181 listed.

Table 2.21: Static Pressure in Ducts Classification

Duct Pressure Class		Operating Pressure
to. wg	Pa	
½	125	Up to ½ in.wg
1	250	Over ½ in. up to 1 in. wg
2	500	Over 1 in. up to 2 in. wg
3	750	Over 2 in. up to 3 in. wg
4	1000	Over 3 in. up to 4 in. wg
6	1500	Over 4 in. up to 6 in. wg
10	2500	Over 6 in. up to 10 in. wg

Table 2.22 : Recommended Return Inlet Face Velocities

Inlet Location	Velocity Across Gross Area, fpm
Above Occupied Zone	>800
In Occupied Zone, not near seats	600-800
In Occupied Zone, near seats	400-600
Door or Wall Louvers	200-300
Through undercut area of doors	200-300

ZINC COATING OF STEEL SHEETS (As per IS 277 - 2003)

Unless otherwise agreed to between the purchaser and the manufacturer, the zinc coating shall conform to the requirement of any one of the grades prescribed in Table 2-T-23.

The mass of coating referred to in this standard shall represent the total mass of zinc. Both sides inclusive.

Any other mass of coating, than those specified in Table 2.23 may be supplied if agreed to between the purchaser and the manufacturer.

The following are recommended grades of zinc coating for the various thickness of sheets.

Table 2.23 : Zinc Coating on Sheets

Sl. No.	Sheet Thickness in mm	Grade of Zinc Coating
1	2	3
i)	0.18 to 0.28 (both inclusive)	200 GSM
ii)	0.30 to 0.55 (both inclusive)	220 GSM
iii)	0.63 to 1 .0 (both inclusive)	275 GSM
iv)	Above 1.0 mm	350 GSM
GSM : Grains per square meter		

Notes :

1. The recommended thickness for roofing application is 0.63 mm and corresponding recommended grade of coating shall be minimum 275 (g/m2).
2. If agreed to between the manufacturer and the purchaser for thickness 0.18 mm to 0.28 mm (both inclusive) other coating grades 180 and 120 may be used.

In addition, X-Ray fluorescence method (on line / off line) can also be used for the same.

Table 2.24 : Mass of Coating (Total both sides)

Si. No.	Grade of Coating	Minimum Average Coating Triple Spot g/m^2	Minimum Coating Single Spot Test g/m^2
i)	600	600	510
ii)	450	450	380
iii)	350	350	300
iv)	275	275	235
v)	220	220	190
vi)	200	200	170
vii)	180	180	155
viii)	120	120	100
i)	100	100	90
ii)	80	80	75
* Minimum individual value obtained in triple spot test			

If agreed to between the purchaser and the manufacturer, the grade of coating 100 and 80 may be used for non-critical applications other than roofing. The mass of coating in such cases shall be as per table.

Note : For the above grade of coating, the mandrel diameter for bend test for adhesion of zinc coating shall be subject to mutual agreement between the purchaser and the manufacturer.

Table 2.25 : Classification by Internal Pressure of Duct and Pressure Range (IS 635-2006)

Classifications by Pressure	Normal Service Pressure, Pa		Limit Pressure, Pa	
	Positive Pressure, P_p	Negative Pressure, P_n	Positive Pressure	Negative Pressure
(1)	(2)	(3)	(4)	(5)
Low pressure duct	Pp $\leq$ + 500	- 500 < Pn	+ 1000	-750
Medium pressure duct	+500 <PP $\leq$ + 1000	- 500 >Pn>- 1000	+ 1500	-1500
High pressure duct	+ 1000 <PP $\leq$ + 2500	- 1 000 >Pn>- 2000	+ 3000	-2500
NOTE:- Normal service pressure means the internal pressure of duct at normal running				

TABLE 2.26 - TOLERANCE ON EXTERNAL DIAMETERS OF CIRCULAR DUCT, CIRCULAR SPIRAL DUCT AND SOCKET JOINT

Internal Diameter of Duct, mm	Dimensional Tolerances of Duct, mm		Tolerances on External Diameter of Socket Joint, mm	
(1)	Min (2)	Max (3)	Min (4)	Max (5)
63	0	+0.5	-1.2	-0.7
80				
100				
125				
160		+0.6	-1.3	
200		+0.7	-1.4	
250		+0.8	-1.5	
315		+0.9	-1.6	
355		+1	-1.7	
400			-1.8	
450		+1.1		
500				
560		+1.2	-1.9	
630				
710		+1.6	-2	
800				
900		+2	-2.1	
1000				
1120		+2.5	-2.2	
1250				
NOTE: Dimensional tolerances on cross-section of circular glass wool duct shall be ± 3 mm				

Table 2.27: Thickness of Sheet for Galvanized Steel Sheet Duct - (IS : 655 / 2006)

Classification of Duct by Pressure	Low Pressure Duct	Medium Pressure Duct and High Pressure Duct	Thickness of Sheet, Min mm
Long side of duct - L	$L \leq 450$	-	0.5
	$450 < L \leq 750$	-	0.6
	$750 < L \leq 1500$	$L \leq 450$	0.8
	$1500 < L \leq 2200$	$450 < L \leq 1200$	1.0
	$2200 < L$	$1200 < L$	1.2

Table 2.28: Thickness of Sheet for Stainless Steel Sheet Duct - (IS : 655 / 2006)

Classification of Duct by Pressure	Low Pressure Duct	Medium Pressure Duct and High Pressure Duct	Thickness of Sheet, Min mm
Long side of duct - L	$L \leq 750$	-	0.5
	$750 < L \leq 1500$	-	0.6
	$1\,500 < L \leq 2200$	$L \leq 450$	0.8
	$2200 < L$	$450 < L \leq 1200$	1.0
	-	$1200 < L$	1.2

Table 2.29: Thickness of Sheet for Rigid Polyvinyl Chloride Duct - (IS : 655 / 2006)

Classification of Duct by Pressure	Low Pressure Duct and Medium Pressure Duct, Pa	High Pressure Duct, Pa		Thickness of Sheet, Min mm
	$p \leq 1000$	**$1000 < p \leq 1500$**	**$1500 < p \leq 2000$**	
Long side of duct - L	$L \leq 500$	$L \leq 500$	-	3
	$500 < L \leq 1000$	-	$L \leq 500$	4
	$1\,000 < L \leq 2000$	$500 < L \leq 2000$	$500 < L \leq 2000$	5
	$2000 < L$	$2000 < L$	$2000 < L$	6

Table 2.30: Thickness of Sheet for Galvanized Steel Sheet Duct and Stainless Steel Sheet Duct Round - (IS : 655 / 2006)

Classification of Duct by Pressure	Low Pressure Duct	Medium Pressure Duct and High Pressure Duct	Thickness of Sheet, Min mm
Internal diameter of duct (d) mm	$d \leq 500$	-	0.5
	$500 < d \leq 630$	-	0.6
	-	$d \leq 450$	0.8
	-	$450 < d \leq 630$	1.0

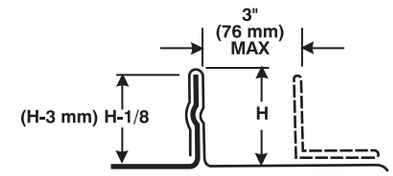
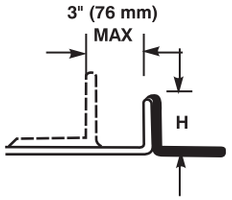
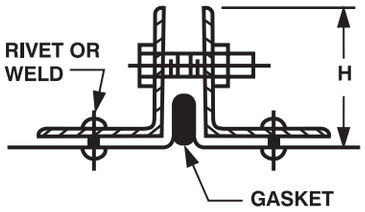
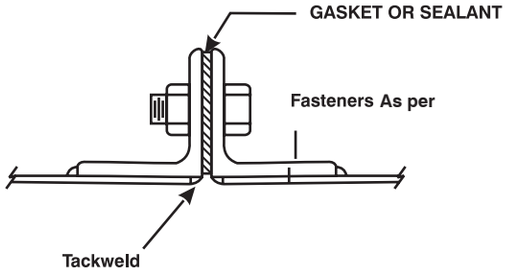
Table 2.31: Thickness of Sheet for Circular Spiral Galvanized Steel Sheet Duct - (IS : 655 / 2006)

Classification of Duct by Pressure	Low Pressure Duct	Medium Pressure Duct and High Pressure Duct	Thickness of Sheet, Min mm
Internal diameter of duct (d) mm	$d \leq 450$	$d \leq 200$	0.5
	$450 < d \leq 710$	$200 < d \leq 560$	0.6
	$710 < d \leq 1000$	$560 < d \leq 800$	0.8
	$1000 < d$	$800 < d \leq 1000$	1.0
	-	$1000 < d$	1.2

Table 2.32: Thickness of Sheet for Circular Spiral Stainless Steel Sheet duct (IS : 655 / 2006)

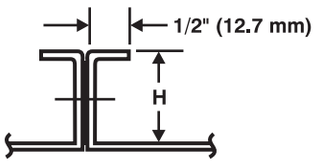
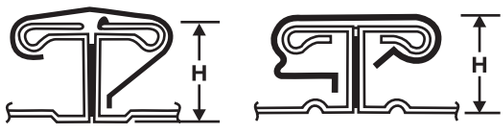
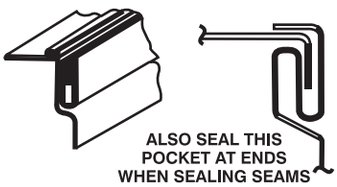
Classification of Duct by Pressure	Low Pressure Duct	Medium Pressure Duct and High Pressure Duct	Thickness of Sheet, Min mm
Internal diameter of duct (d) mm	$d \leq 560$	$d \leq 250$	0.5
	$560 < d \leq 800$	$250 < d \leq 560$	0.6
	$800 < d \leq 1000$	$560 < d \leq 800$	0.8
	$1000 < d$	$800 < d \leq 1000$	1.0
	-	$1000 < d$	1.2

Figure 2.14 : Rectangular Duct / Transverse Joints

 **STANDING SEAM** **ANGLE REINFORCED STANDING SEAM**	• Button punch or otherwise fasten within 2 in, of each corner and at 6 in, maximum intervals. • Seal and fold corners. • Stagger joints on adjacent sides if using standing seam on all four sides. • Hammer longitudinal seam at ends of standing seam.
 **WELDED FLANGE REINFORCED W.F.**	• Use 1/2 in, Minimum flange and end weld. • Flanges larger than 5/8 in, must be spot welded, bolted, riveted or screwed to prevent separation (2 in, from ends and at 8 in, maximum intervals). • On 24, 22 or 20 ga, brace or weld 1/4 x 4 in. rod in corners or provide hangers at every joint.
 **COMPANION ANGLES (CAULK OR GASKET)**	• 3/8 in. Minimum flange on duct angles must have welded corners. • Angles must be tack welded, bolted or screwed to the duct wall at 2 in, maximum from the ends and at 12 in, maximum intervals. • Bolt Schedule : - 5/16 minimum diameter at 6 in, Maximum spacing for 4 in. wg or lower. - 1/8 in, angle required at 4 in. maximum spacing, for 4 in. wg. - 4 in. maximum spacing at higher pressures.
 **COMPANION ANGLES**	• Hold duct back 1/8 in, from vertical face of the angle and tack weld to the flange along the edge of the duct. • Fasten angle to duct as per Fig. • For additional tightness place sealant between the angle and duct or seal the weld. • If the faces of the angles are flush, thick consistency sealant may be used in lieu of gasket. • Use gasket suitable for the specific service and fit it uniformly to avoid protruding into the duct.

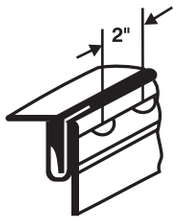
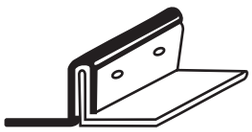
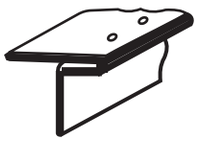
Source : SMACNA

Rectangular Duct / Transverse Joints (contd....)

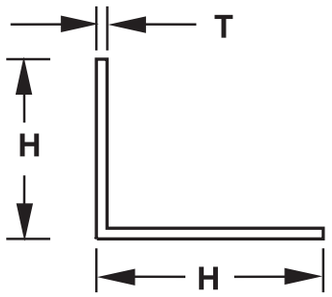
 **FLANGED (WITH GASKET)**	• Close corners with minimum 16 g corner pieces and 3/8 in. blots min. • Lock flanges together with 6 in. long clips located within 6 in. of each corner. • Clips spaced at 15 in. maximum for 3 in. wg pressure class or lower. • Clips spaced at 12 in. maximum for 4. 6 and 10 in. wg. • Gasket to be located to form an effective seal.
 **FLANGED (WITH GASKET)**	• Bolt, rivet 1 in. maximum from ends and at 6 in. maximum intervals. • Limited to 2 in. wg pressure class. • Gasket to be located to form an effective seal.
 **FLANGED (WITH GASKET)** **FLANGED (WITH GASKET)**	• Ratings may be adjusted with E2-rated bar stock or members. • Supplemental members may be attached to the duct wall on both sides of the joint. • Single members may be used if they are fastened through mating flanges. • Gasket to be located to form an effective seal.
 **SLIP-ON FLANGE**	• Consult manufacturers for ratings established by performance documented to functional criteria.
	• Pocket depth from 1/4 in. to 5/8 in. • Use on straight duct and fittings. • Upto ± 10 in. wg.

Source : SMACNA

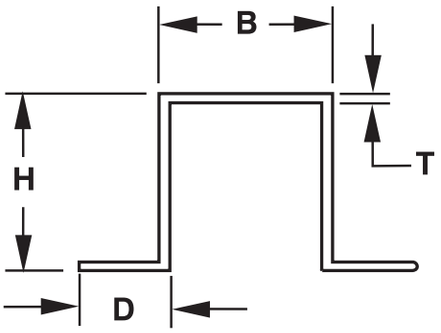
Rectangular Duct / Transverse Joints (contd....)

	• 5/8 in. pocket depth for 20, 22 and 24 g. • 1/2 in. pocket depth for 24 and 26 g. • Upto ± 4 in. wg. • Screws must be added at the ends of all ducts for 4 in. wg and separate works at the ends of 3 in. wg when the duct is over 48 in. width.
 **GROOVED SEAM** **ALSO CALLED FLAT LOCK AND PIPE LOCK**	• Upto ±10 in. wg.
 **STANDING SEAM**	• Upto ± 10 in. wg • 1 in. seam up to duct width of 42 in. • 1 1/2 in. seam for larger ducts. • May be used on duct interiors. • Fasten at 2 in. Maximum from ends and at 8 in. Maximum intervals.
 **SINGLE CORNER SEAM**	• Upto ± 10 in. wg. • Fasten as above standing seam.
 **FLANGED** **(WITH GASKET)**  **FLANGED** **(WITH GASKET)**	• Ratings may be adjusted with EL-rated bar stock or members. • Supplemental members may be attached to the duct wall on both sides of the joint. • Single members may be used if they are fastened through both mating flanges. • Gasket to be located to form an effective seal.

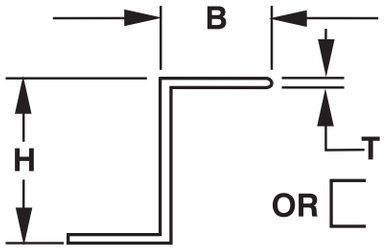
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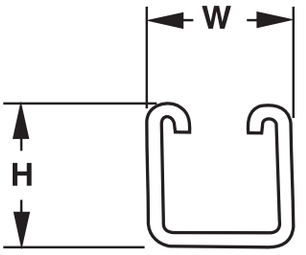
ANGLE



HAT SECTION



CHANNEL OR ZEE

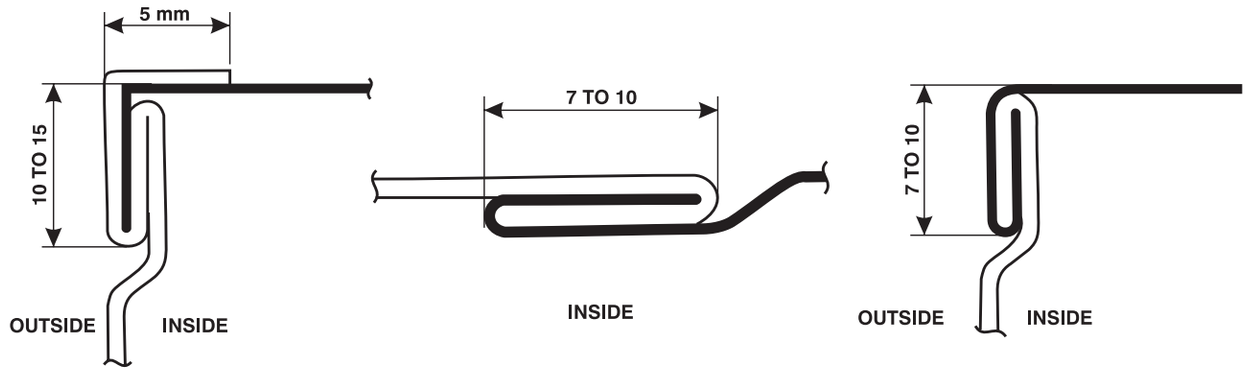


FRAMING CHANNEL

Note : Other structural shapes may be used for external reinforcements when equivalent effective stiffeners ratings (Ei) can be demonstrated.

Figure 2.15 : Rectangular External Reinforcement

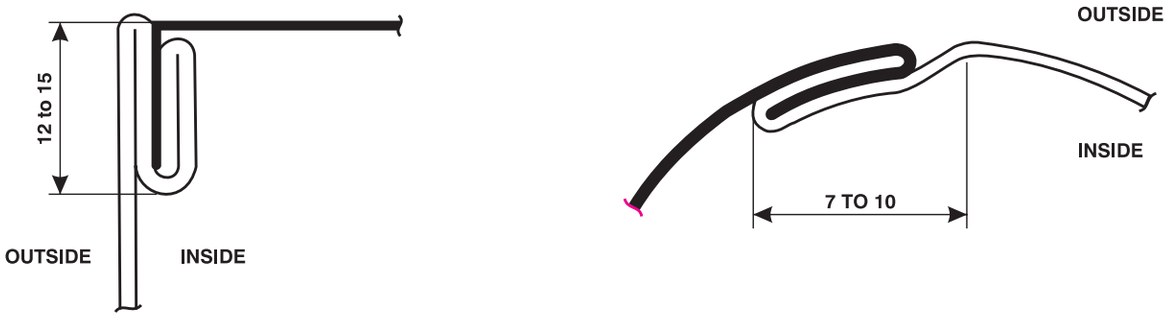
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a) PITTSBURG LOCK SEAM

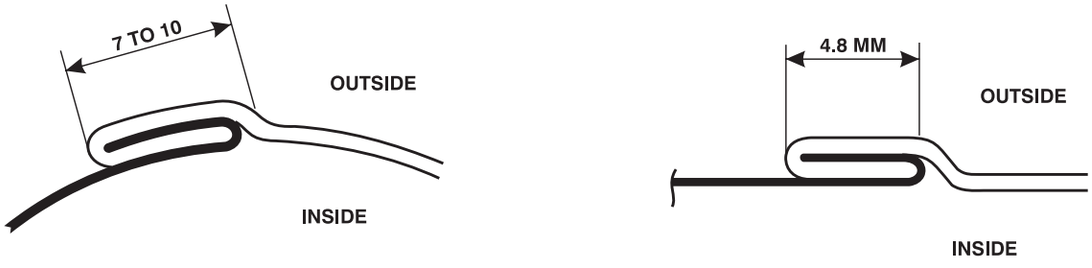
b) GROOVED LOCK SEAM

c) GROOVED CORNER LOCK SEAM



d) PITTSBURG PUNCH SNAP LOCK SEAM

e) GROOVED SEAM

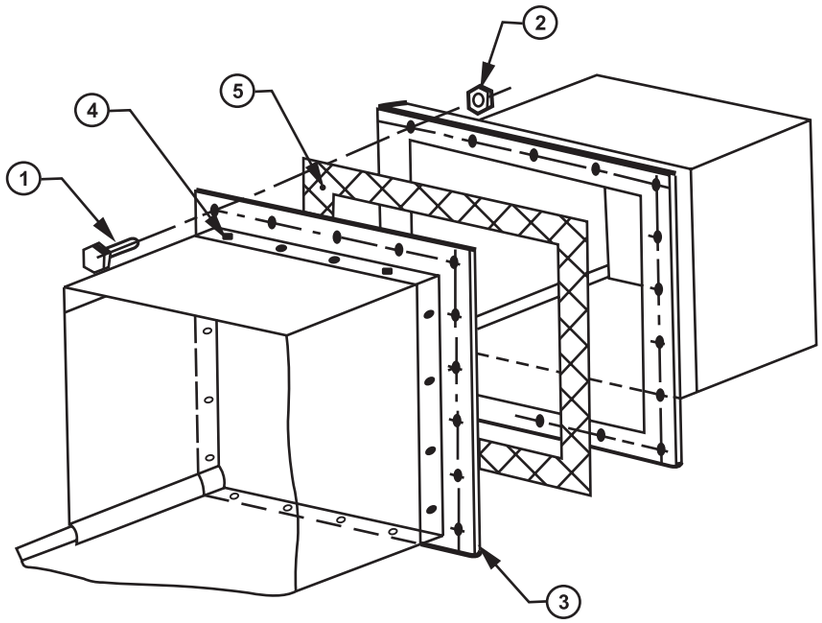


f) GROOVED SEAM

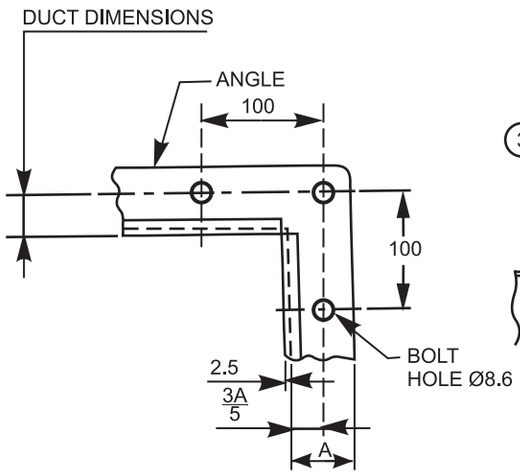
g) GROOVED SEAM

Note : All dimensions are in 'mm'

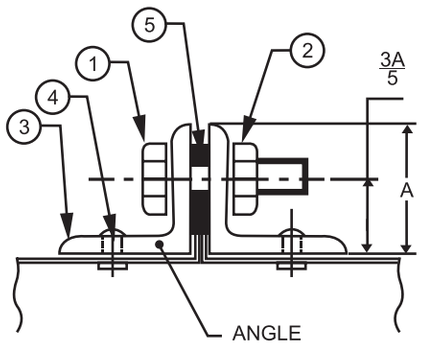
Figure 2.16 : Configuration of Seam in Duct
IS : 655 / 2006



a) STRUCTURAL DRAWING



A. DIMENSIONS OF ANGLE BOLT HOLE 8.5



b) SECTION VIEW OF FLANGE

C. MAXIMUM SPACING OF BOLT HOLES AT CORNER

1) Bolt (Full Threaded)
2) NUT
3) ANGLE FLANGE
4) RIVET (FULL CIRCUMFERENCE)
5) GASKET

Figure 2.17 : Structure of Joint by Angle Flange Technique - (IS : 655 / 2006)

All dimensions are in 'mm'

Table 2.33: Material for Joint of Low Pressure Duct by Angle Flange Technique (IS : 655 / 2006)

Long side of Duct (L) mm (1)	Joint Flange		Flange Mounting Rivet		Connecting Bolt		
	Angle Minimum Size mm (2)	Maximum Spacing mm (3)	Minimum Nominal Diameter mm (4)	Maximum Spacing of Rivets mm (5)	Minimum Nominal Diameter mm (6)	Maximum Spacing	
						Corner mm (7)	Other than Corner mm (8)
$L < 750$	25 x 25 x 3	3640	4.5	65	M8	100	150
$750 < L \leq 1500$	30 x 30 x 3	2730	4.5	65	M8	100	150
$1\,500 < L \leq 2200$	40 x 40 x 3	1820	4.5	65	M8	100	150
$2200 < L$	40 x 40 x 5	1820	4.5	65	M8	100	150

NOTES:

1. The bolts shall be located symmetrically at the central portion of flange.
2. Electrical spot welding may be employed other than riveting. The spacing shall be within 100 mm.
3. The diameter of connecting bolt shall not exceed a certain diameter which ensures enough edge distance of flange.

Table 2.34 : Material for Joint by Same Sheet Flange Technique
IS : 655 / 2006

Long Side of Duct (L)	Minimum Size of Same Sheet Flange mm				Minimum Size of Corner Metal Flange mm			Minimum Thickness of Sheet of Flange Presser Metal Fittings mm		Maximum Spacing of Joints mm	
	Height	Width	Thickness of Sheet (Thickness of Duct Sheet)		Thickness of Sheet		Nominal Diameter of Bolt	Low Pressure	High Pressure, Medium Pressure	Low Pressure	High Pressure Medium Pressure
			Low Pressure	High Pressure, Medium Pressure	Low Pressure	High Pressure, Medium Pressure					
1	2	3	4	5	6	7	8	9	10	11	12
L < 450	30	10	0.5	0.8	1.2	1.6	M8	1.0	1.2	3480	2610
450 < L ≤ 750	30	10	0.6	1.0	1.2	1.6	M8	1.0	1.2	3480	1740
750 < L ≤ 1200	30	10	0.8	1.0	1.2	1.6	M8	1.0	1.2	2610	1740
1200 < L ≤ 1500	30	10	0.8	1.2	1.6	1.6	M8	1.0	1.2	2610	1740
1 500 < L ≤ 2200	30	10	1.0	1.2	1.6	1.6	M8	1.2	1.2	1740	1740

Note: The diameter of bolts for corner metal fitting shall not exceed a certain diameter which ensures enough edge distance of flange.

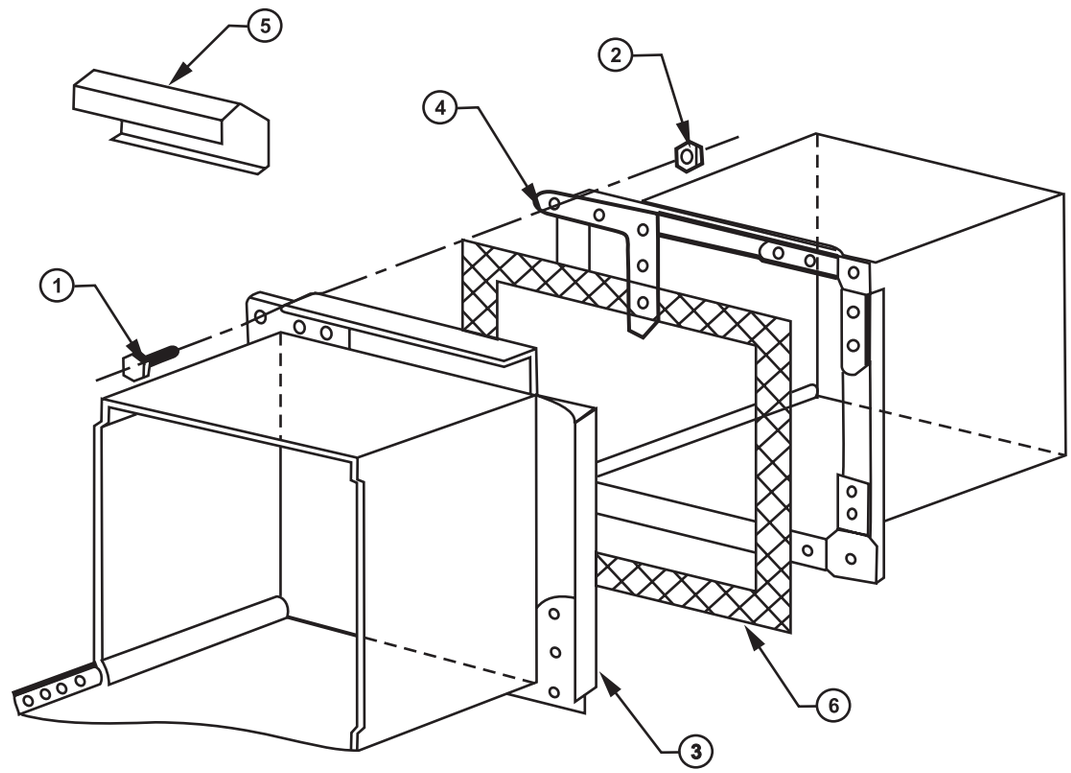
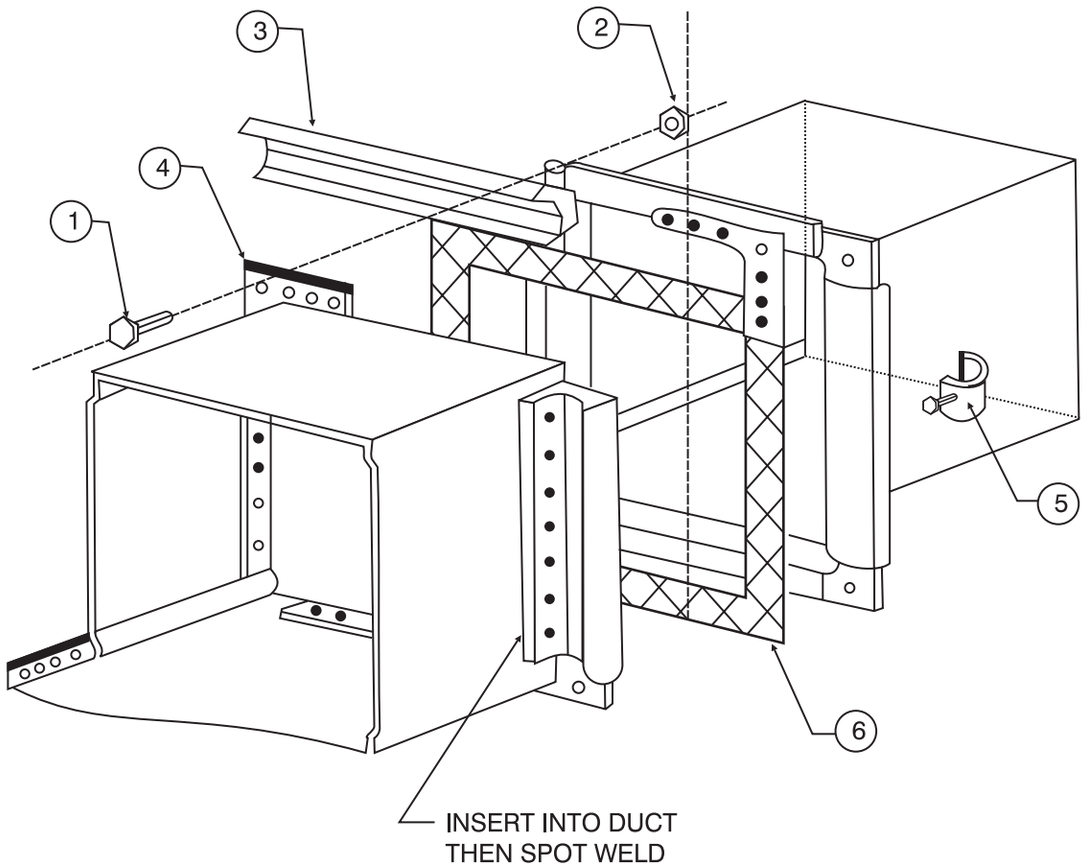
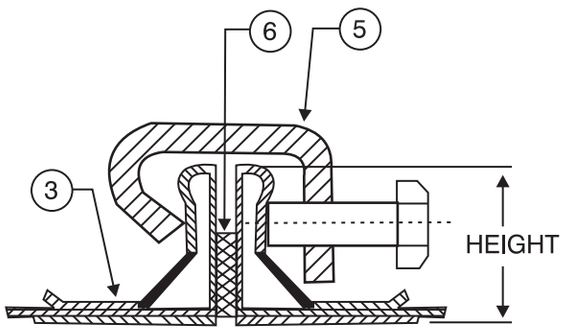


Figure 2.18: Example of Configuration of Joint by same sheet flange technique
ISS 655 -2006



a) STRUCTURAL DRAWING



1. BOLT (FOUR CORNERS ONLY)
2. NUTS (FOUR CORNERS ONLY)
3. SLIDE-ON FLANGE
4. CORNER METAL FITTING (CORNER PIECES)
5. FLANGE PRESSURE METAL FITTINGS (NUTS, CLAMPS, ETC.)
6. GASKET

Figure 2.19 : Example of Configuration of Joint by slide - on flange technique
IS : 655 / 2006

Table 2.35 : Joint Flange of Slide on Flange Technique (IS: 655 / 2006)

Long side of Duct mm	Minimum Size of Joint Flange .						Maximum spacing
	Low Pressure Duct		Medium Pressure Duct		High Pressure Duct		
	Height mm	Thickness of Sheet mm	Height mm	Thickness of Sheet mm	Height mm	Thickness of Sheet mm	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$L < 450$	19	0.6	20	0.9	30	1.2	3680
$450 < L \leq 750$	20	0.9	20	0.9	30	1.2	3680
$750 < L \leq 1500$	20	0.9	30	1.2	30	1.2	2760
$1500 < L \leq 2200$	30	1.2	30	1.2	40	1.5	1840
$2200 < L$	30	1.2	40	1.5	40	1.5	1840

Table 2.36: Minimum Values of Thickness of Sheet for Corner Metal Fittings and Diameter of Bolt (IS : 655 / 2006)

Long side of Duct (L) Mm	Low Pressure Duct		Medium Pressure Duct		High Pressure Duct	
	Thickness of Sheet mm	Nominal Diameter of Bolt mm	Thickness of Sheet mm	Nominal Diameter of Bolt mm	Thickness of Sheet mm	Nominal Diameter of Bolt mm
(1)	(2)	(3)	(4)	(5)	(6)	(7)
$L<450$	2.0	M8	2.3	M8	3.2	M10
$450 < L \leq 750$	2.3	M8	2.3	M8	3.2	M10
$750 < L \leq 1500$	2.3	M8	3.2	M10	3.2	M10
$1\,500 < L \leq 2200$	3.2	M10	3.2	M10	4.0	M12
$2200 < L$	3.2	M10	3.2	M12	4.0	M12

Note: The diameter of bolts for corner metal fitting shall not exceed certain diameter, which ensures enough edge distance of flange.

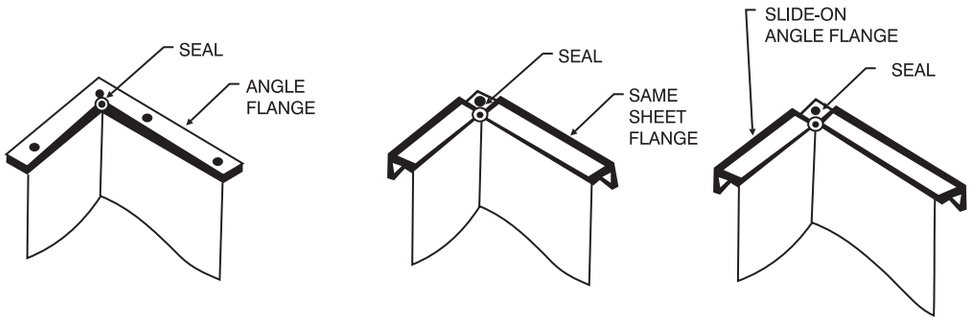
Table 2.37 : Fixing Spacing and Number of Flange Pressure Metal Fittings (with Bolt) Size of Joint Flange (IS : 655 / 2006)

Long side of Duct mm (L)	Low Pressure Duct		Medium Pressure Duct		High Pressure Duct	
	Number of pieces	Maximum Spacing mm	Number of Pieces	Maximum Spacing mm	Number of Pieces	Maximum Spacing mm
(1)	(2)	(3)	(4)	(5)	(6)	(7)
$L < 450$	0	-	0	-	0	-
$450 < L \leq 1000$	0	-	1	700	1	650
$1000 < L \leq 1300$	1	1000	1	700	1	650
$1300 < L \leq 1400$	1	1000	1	700	2	670
$1400 < L \leq 2000$	1	1000	2	700	2	670
$2000 < L$	2	1000	3	800	3	700

Table 2.38: Longitudinal Reinforcement between Joints of Rectangular Duct (IS : 655 / 2006)

Width of Duct (w)	External Reinforcement		Mounting Position	Mounting Bolt	
	Minimum Size of Rigid Polyvinyl Chloride Angle mm	Minimum Size of Steel Flat mm		Minimum Nominal Diameter	Maximum Spacing mm
(1)	(2)	(3)	(4)	(5)	(6)
$2000 < w \leq 2500$	60 x 60 x 7	50x4	One position	M8	150

Note: The diameter of mounting bolt shall not exceed a certain diameter which ensures enough edge distance of Flange.

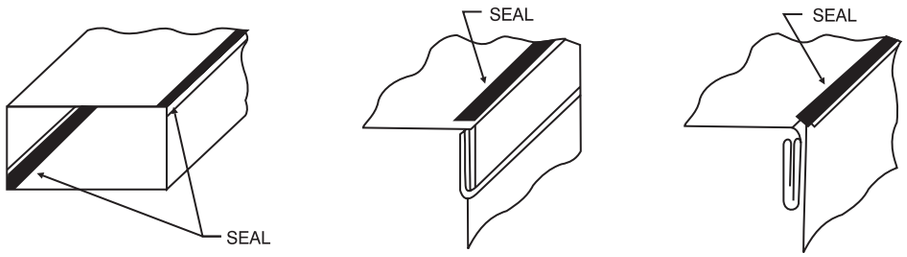


a) DUCT OF ANGLE FLANGE TECHNIQUE

b) DUCT OF SAME SHEET FLANGE TECHNIQUE

c) DUCT OF SLIDE-ON FLANGE TECHNIQUE

Figure 2.20 : Example of 'N' Seal Position (IS: 655 / 2006)

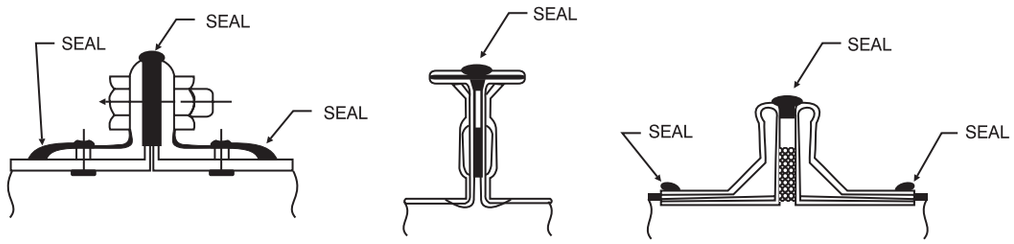


a) SEAL OF LONGITUDINAL SEAM

b) SEAL OF PITTSBURG LOCK SEAM

c) BUTTON PUNCH SNAP SEAM

Figure 2.21 : Example of 'A' Seal Position (IS: 655 / 2006)

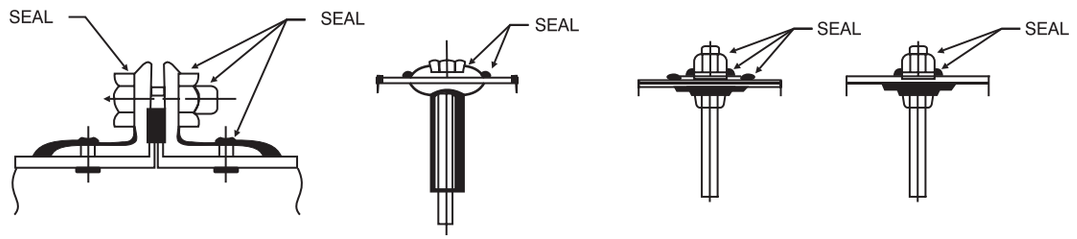


a) ANGLE FLANGE TECHNIQUE

b) SAME SHEET FLANGE TECHNIQUE

c) SLIDE-ON FLANGE TECHNIQUE

Figure 2.22 : Example of 'B' Seal Position (IS: 655 / 2006)



a) AROUND RIVET AND BOLT b) TIE ROD c) Y TIE ROD c) TIE ROD

Figure 2.23 : Example of 'C' Seal Position (IS: 655 / 2006)

Table 2.39 : Unreinforced Duct (Wall Thickness) as per SMACNA

Duct Dimension	Pressure Class, in. wg						
	Positive or Negative						
	1/2 in.	1 in.	2 in.	3 in.	4 in.	6 in.	10 in.
8 in. and under	26	26	26	24	24	24	22
9 - 10 in.	26	26	26	24	22	22	20
11 - 12 in.	26	26	26	24	22	20	18
13 - 14 in.	26	26	24	22	20	20	18
15 - 16 in.	26	26	24	22	20	18	16
17 - 18 in.	26	26	22	20	18	18	16
19 - 20 in.	24	24	20	18	18	16	
21 - 22 in.	22	22	18	18	18	16	
23 - 24 in.	22	22	18	18	18	16	
25 - 26 in.	20	20	18	18	16		
27 - 28 in.	18	18	18	18	16		
29 - 30 in.	18	18	18	18	16		
31 - 36 in.	16	16	16	16			
37 - 42 in.	16	16					
43 - 48 in.	16	16					

This table gives minimum duct wall thickness (gauge) for use of flat type joint systems. Plain S, and hemmed S. connectors are limited to 2 in. wg maximum. Slips and drives must not be less than two gauges lighter than the duct wall, not below 24 g. Double S slips must be 24 g for ducts 30 in. wide or less and 22 g for greater width.

Table 2.40: Minimum Thickness of Slip / Drive

Duct Gauge	26 to 22	20	18	16
Minimum Flat Slip & Drive Gauge	24	22	20	18

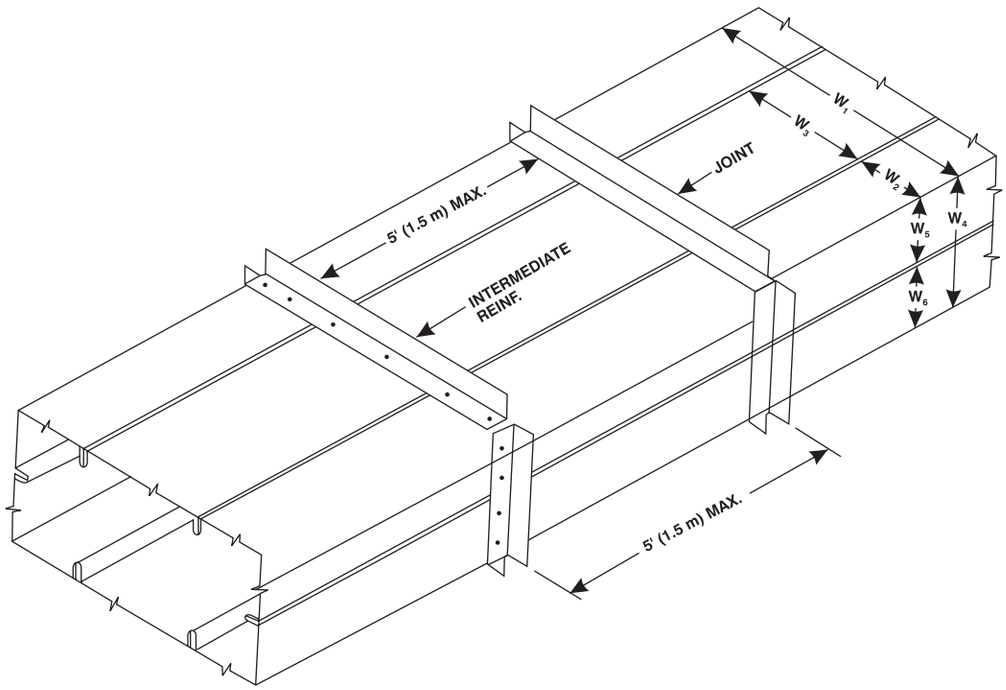


Figure 2.24 : Inside Standing Seam - Longitudinal 2 in.$^{(Unit)}$ Wg

NOTES :

1. Use duct gauge required by greatest sub division of width and the selected spacing 5', (1.5 m) max or the unseamed side, whichever is of greater thickness.
2. Minimum standing seam sizes are 1" (25 mm) for ducts, 42" (1067 mm) and less, 1 - 1/2" (38.1 mm) for 43" (1092 mm) overall width, and upper.
3. Stitch weld seams on exterior or bolt, screw or button punch seams on interior.

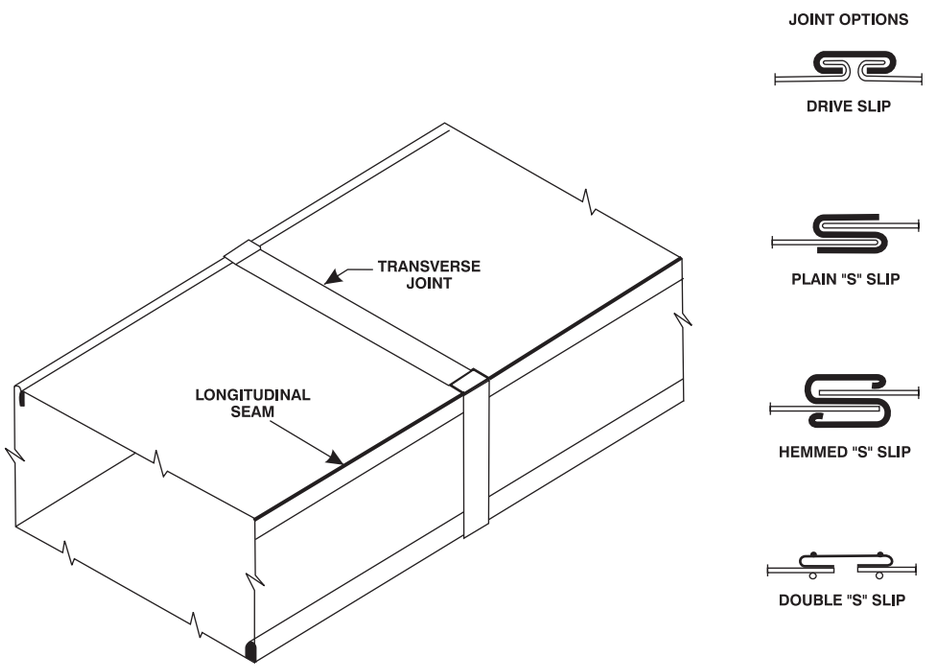


Figure 2.25 : Unreinforced Duct - SMACNA

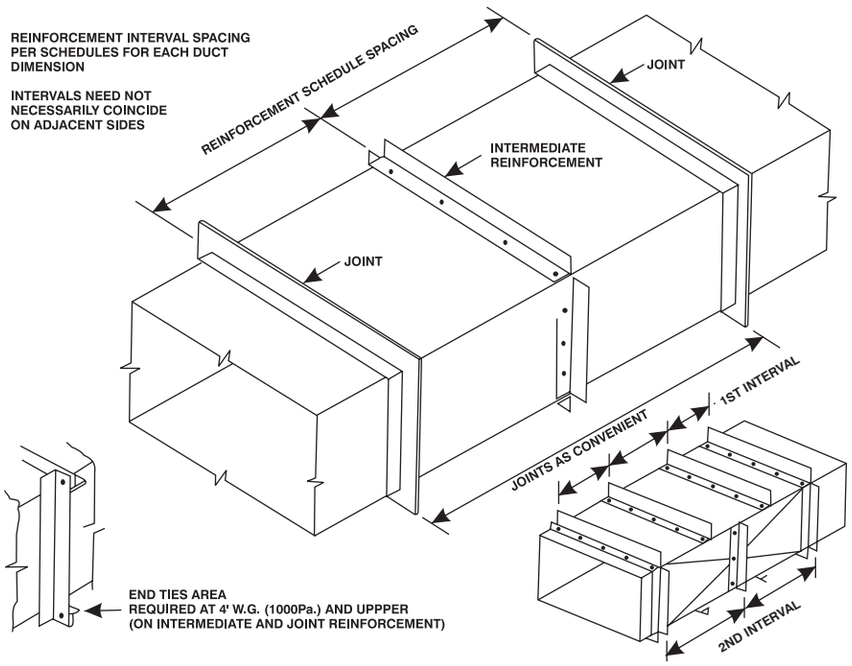


Figure 2.26 : Duct Reinforced on all sides - SMACNA

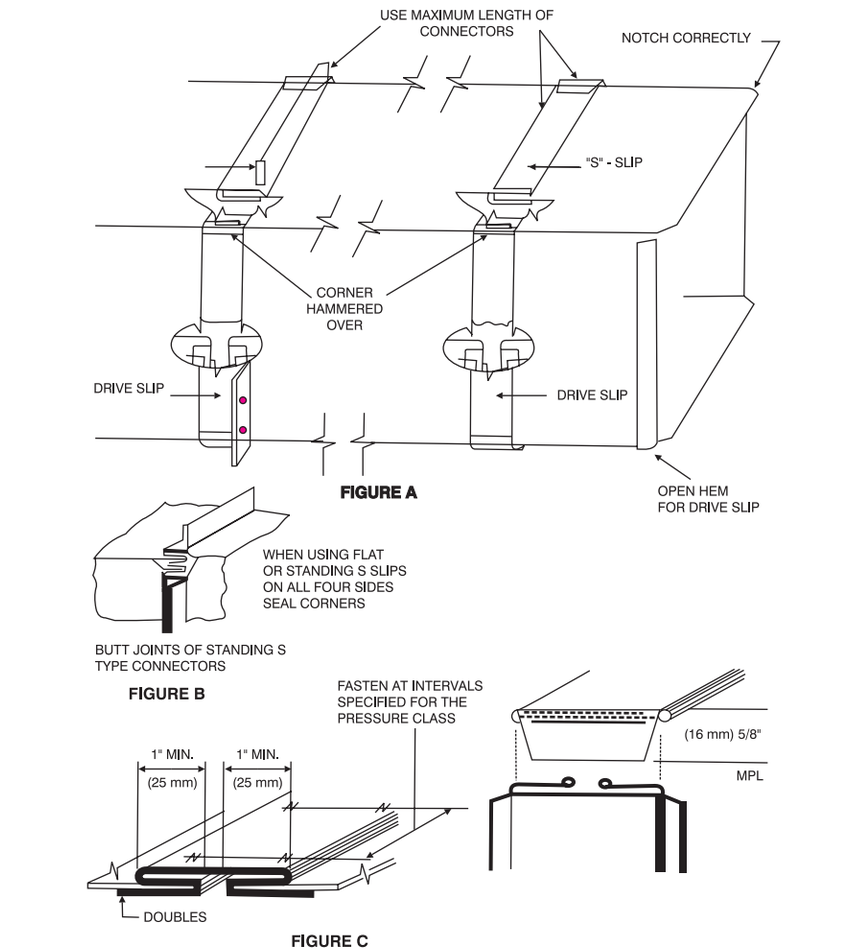


Figure 2.27 : Corner Closures - Slips and Drives - SMACNA

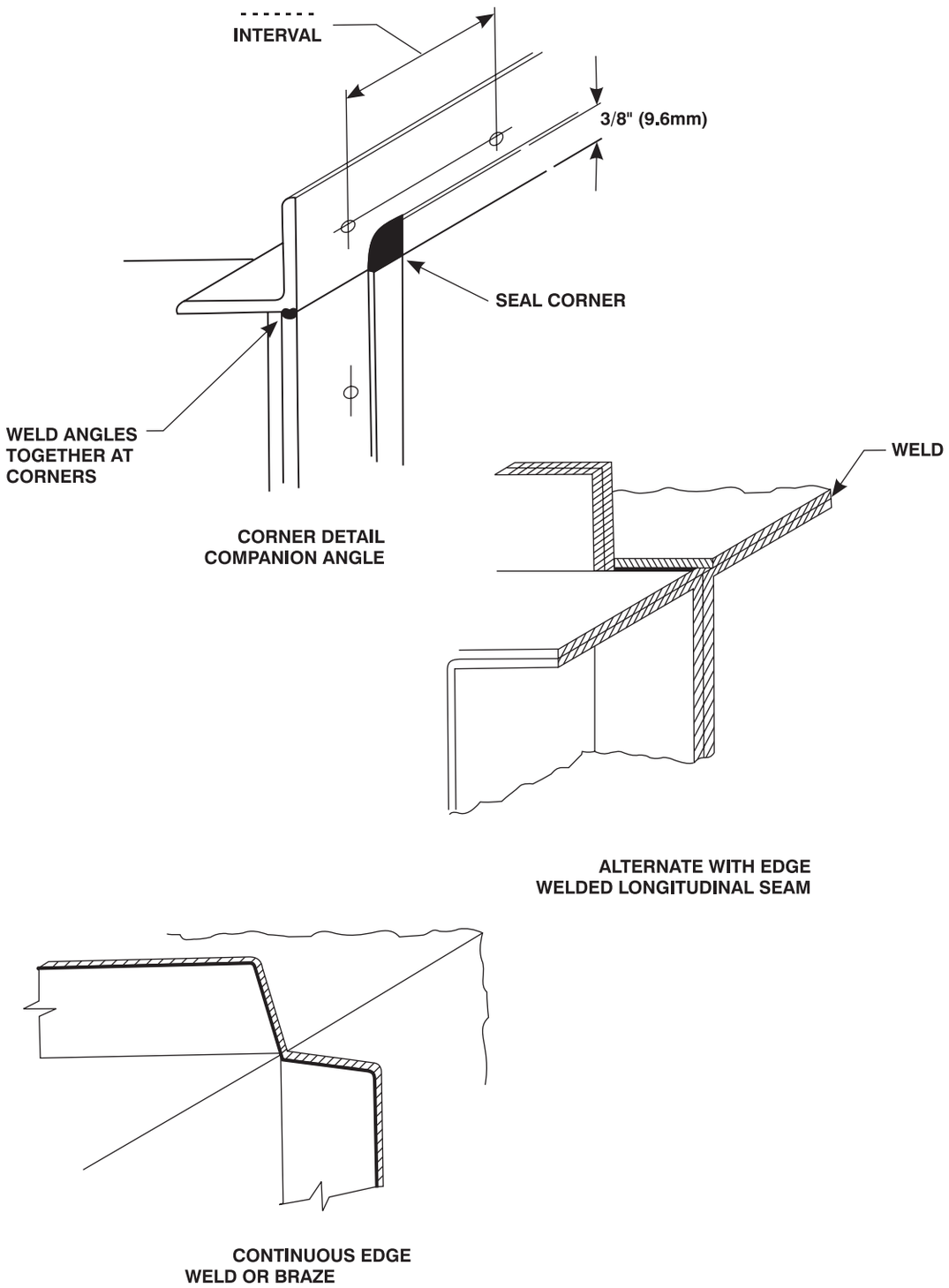


Figure 2.28 : Corner Closures - Flanges - SMACNA

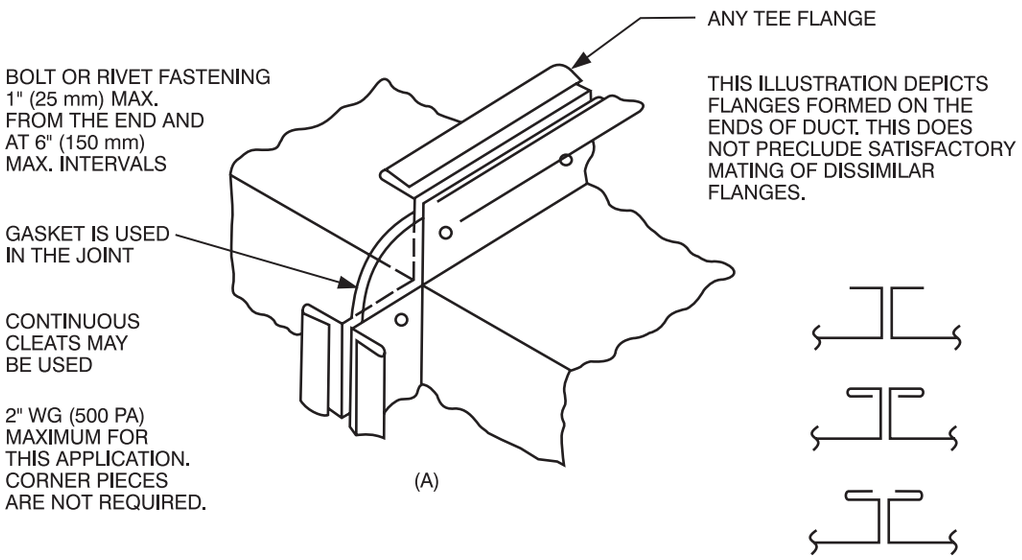


Figure 2.29 : Corner Closures - Flanges - SMACNA

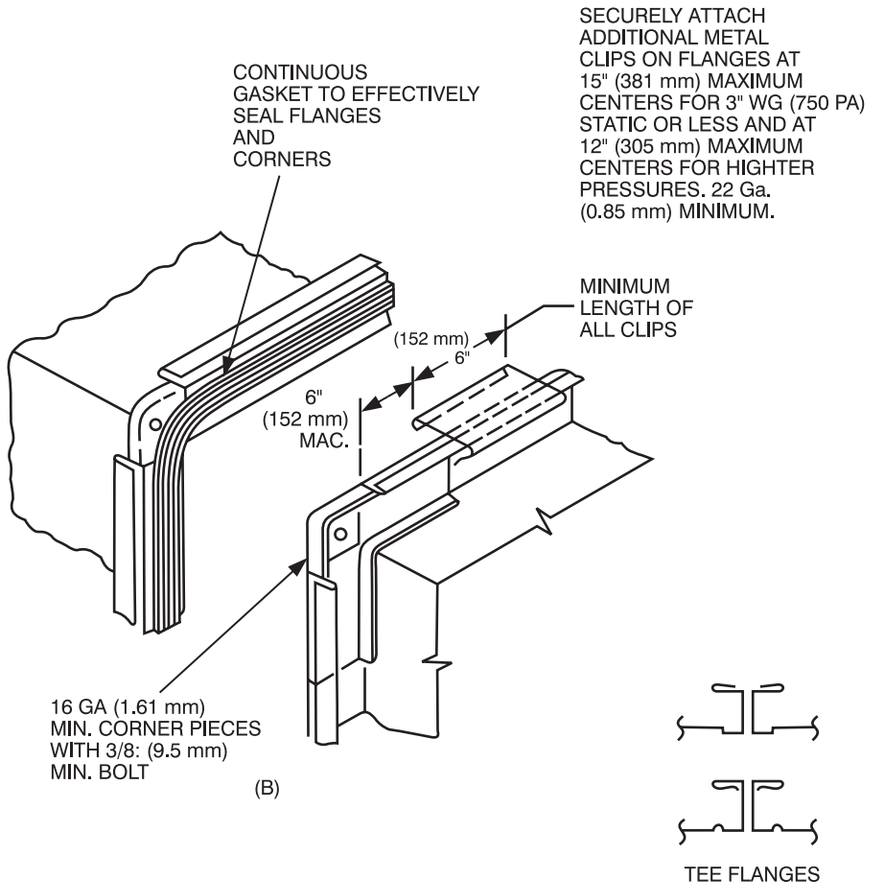


Figure 2.30 : Corner Closures - Flanges - SMACNA

Table 2.41 : Allowable Loads in Pounds for Trapeze Hangers

Trapeze	Angles													Channels		
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	0	P
Length, In.	1" x 1" 16 ga	1" x 1" 1/8	1½" x 1½" 16ga	1½" x 1½" x 1/8"	1½" x 1½" x 3/16"	1½" x 1½" x ¼"	2 x 2 x 1/8"	2" x 2" x 3/16	2 x 2 x ¼"	2½" x 2½" x 3/16"	2½" x 2½" x ¼"	3 x 3 x ¼"	4 x 4 X ¼	3 inch 4.1 lb/ft²	3 Inch 6 lb/ft²	4 inch 5.4 lb/ft²
18	80	150	180	350	510	650	650	940	1230	1500	1960	-	-	-	-	-
24	75	150	180	350	510	650	650	940	1230	1500	1960	-	-	-	-	-
36	70	150	180	350	510	650	650	940	1230	1500	1960	-	-	-	-	-
42	60	130	160	340	500	620	620	920	1200	1480	1940	-	-	-	-	-
48	40	110	140	320	480	610	610	900	1190	1470	1930	-	-	-	-	-
54	-	80	110	290	450	580	580	870	1160	1440	1900	-	-	-	-	-
60	-	-	-	250	400	540	540	840	1120	1400	1860	-	-	-	-	-
66	-	-	-	190	350	490	490	780	1060	1340	1800	-	-	-	-	-
72	-	-	-	100	270	400	400	700	980	1260	1720	-	-	-	-	-
78	-	-	-	-	190	320	320	620	900	1180	1640	-	-	-	-	-
84	-	-	-	-	-	210	210	500	790	1070	1530	-	-	-	-	-
96	-	-	-	-	-	-	-	380	660	940	1400	2310	4680	4650	5980	9080
108	-	-	-	-	-	-	-	-	320	600	1060	1970	4340	3870	4950	8740
120	-	-	-	-	-	-	-	-	-	-	-	2510	7240	5760	7780	15650
132	-	-	-	-	-	-	-	-	-	-	-	1220	5950	4120	5930	13200
	-	-	-	-	-	-	-	-	-	-	-	-	4350	2540	3920	10820
	-	-	-	-	-	-	-	-	-	-	-	-	2420	-	2000	8330
Ix	0.012	0.022	0.041	0.078	0.110	0.139	0.190	0.270	0.348	0.547	0.703	1.240	3.040	1.660	2.070	3.850
Z	0.016	0.031	0.037	0.072	0.104	0.139	0.130	0.190	0.247	0.303	0.394	0.577	1.050	1.100	1.380	1.980
A	0.120	0.234	0.180	0.359	0.527	0.688	0.484	0.715	0.938	0.902	1.190	1.440	1.940	1.210	1.760	1.590
lb/ft	0.440	0.800	0.660	1.230	1.800	2.340	1.650	2.440	3.190	3.070	4.100	4.900	6.600	4.100	6.000	5.400

NOTES:

a. It is assumed that steel with a yield strength of 30,00 psi or greater is used.

b. Loads above assume that a hanger rod is 6 in. max distance from the duct side for lengths of 96 in. or less, and 3 in. for greater lengths.

Tabte 2.42 : Duct Surface area in Square Feet per Linear Foot

	DUCT DIMENSION (WIDTH)																						
	6”	**8”**	**10”**	**12”**	**14”**	**16”**	**18”**	**20”**	**22”**	**24”**	**26”**	**28”**	**30”**	**36”**	**42”**	**48”**	**54”**	**60”**	**66”**	**72”**	**84”**	**96”**	**108”**
6”	2.00	2.33	2.67	3.00	3.33	3.67	4.00	4.33	4.67	5.00	5.33	5.17	6.00	8.00	3.00	9.00	1O.OO	11.00	12.00	13.00	15.00	17.00	19.00
8”		2.67	3.00	3.33	3.67	4.00	4.33	4.67	5.00	5.33	5.67	6.00	6.33	7.33	8.33	9.33	10.33	11.33	12.33	3.33	15.33	17.33	19.33
10”			3.33	3.67	4.00	4.33	4.67	5.00	5.33	5.67	6.00	6.33	6.67	7.67	8.67	9.67	10.67	11.67	12.67	13.67	15.67	17.67	19.67
12”				4.00	4.33	4.67	5.00	5.33	5.67	6.00	6.33	6.67	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	16.00	18.00	20.00
14”					4.17	5.00	5.33	5.67	6.00	6.33	6.67	7.00	7.33	8.33	9.33	10.33	11.33	12.33	13.33	14.33	16.33	18.33	20.33
16”						5.33	5.67	6.00	6.33	6.67	7.00	7.33	7.67	8.67	9.67	10.67	11.67	12.67	13.67	14.67	16.67	18.67	20.67
18”							6.00	6.33	6.67	7.00	7.33	7.67	8.00	9.00	10.00	11.00	12.00	13.OO	14.00	15.00	17.00	19.00	21.00
20”								6.67	7.00	7.33	7.67	8.00	8.33	9.33	10.33	11.33	12.33	13.33	14.33	15.33	17.33	19.33	21.33
22”									7.33	7.67	8.00	8.33	8.87	9.67	10.67	11.67	12.67	13.67	14.67	15.67	17.67	19.67	21.67
24”										8.00	8.33	8.67	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	18.00	20.00	22.00
26”											8.67	9.00	9.33	10.33	11.33	12.33	13.33	14.33	15.33	16.33	18.33	20.33	22.33
28”												9.33	9.67	10.67	11.67	12.67	13.67	14.67	15.67	16.67	18.67	20.67	22.67
30”		DUCT DIMENSION (DEPTH)											10.00	1100	12.00	13.00	14.00	15.00	16.00	17.00	19.00	21.00	23.00
36”														12.00	13.00	14.00	15.00	16.00	17.00	18.00	20.00	22.00	24.00
42”															14.00	15.00	16.00	17.00	18.00	19.00	21.00	23.00	25.00
48”																16.00	17.00	18.00	19.00	20.00	22.00	24.00	26.00
54”																	18.00	19.00	20.00	21.00	23,00	25.00	27.00
60”																		20.00	21.00	22.00	24.00	26.00	28.00
66”																			22.00	23.00	25.00	27.00	29.00
72”																				24.00	26.00	28.00	30.00
84”																					28.00	30.00	32.00
96”																						32.00	34.00
108”																							36.00

Table 2.43 : Rectangular Duct Hangers, Minimum Size

Maximum Half of Duct Perimeter	Pair at 10 ft Spacing		Pair at 8 ft Spacing		Pair at 5 ft Spacing		Pair at 4 ft Spacing	
	Strap	Wire/Rod	Strap	Wire /Rod	Strap	Wire/Rod	Strap	Wire/Rod
P/2= 30"	1" x 22 ga	10ga (0.135")	1" x 22 ga	10ga(0.135")	1"x22ga	12ga(0.106")	1"x22ga	12ga (0.106")
P/2 = 72"	1" x 22 ga	3/8"	1" x 20 ga	1/4"	1"x22ga	1/4"	1"x22ga	1/4"
P/2 = 96"	1" x 22 ga	3/8"	1" x 18 ga	3/8"	1"x20ga	3/8"	1"x22ga	1/4"
P/2 = 120"	1 1/2" x 16 ga	1/2"	1 1/2" x 16 ga	3/8"	1"x 18 ga	3/8"	1"x20ga	1/4"
P/2 = 168"	1 1/2" x 16 ga	1/2"	1 1/2" x 16 ga	1/2"	1"x16ga	3/8"	1"x 18 ga	3/8"
P/2 = 192"	Not Given	1/2"	1 1/2" x 16 ga	1/2"	1"x 16 ga	3/8"	1"x 16 ga	3/8"
P/2 = 193" up	Special Analysis Required							

When Straps are Lap Joined Use These Minimum Fasteners	Single Hanger Maximum Allowable Load	
	Strap	Wire or Rod (Dia)
1" x 18, 20, 22 ga - two #10 or one 1/4" bolt 1" x 16 ga - two 1/4" dia 1/2" x 16 ga - two 3/8" dia Place fasteners in series, not side by side	1”x22ga-260lbs 1”x 20ga-320lbs 1”x 18 ga - 420 lbs 1”x 16ga -700 IDS 11/2”xl6ga -1100 lbs	0.106” -80 lbs 0.135” -120 lbs 1.162” -160 lbs 1/4” -270 lbs 3/8” -680 lbs 1/2” -1250 lbs 5/8” - 2000 lbs 3/4 “ - 3000 lbs

Source : SMACNA

NOTES :

a. Dimensions other than gauge are in inches.
b. Tables allow for duct weight, 1lb/sf insulation weight, and normal reinforcement and trapeze weight, but no external loads.
c. Straps are galvanized steel; other materials are uncoated steel.

Table 2.44 : Velocity Pressures

Velocity Pressure (in.wg)	Velocity Ft/Min	Velocity Pressure (in.wg)	Velocity Ft/Min	Velocity Pressure (in.wg)	Velocity Ft/Min	Velocity Pressure (in.wg)	Velocity Ft/Min
.01	400	.29	2150	.58	3050	1.28	4530
.02	565	.30	2190	.60	3100	1.32	4600
.03	695	.31	2230	.62	3150	1.36	4670
.04	800	.32	2260	.64	3200	1.40	4730
.05	895	.33	2300	.66	3250	1.44	4800
.06	980	.34	2330	.68	3300	1.48	4870
.07	1060	.35	2370	.70	3350	1.52	4930
.08	1130	.36	2400	.72	3390	1.56	5000
.09.	1200	.37	2440	.74	3440	1.60	5060
.10	1270	.38	2470	.76	3490	1.64	5120
.11	1330	.39	2500	.78	3530	1.68	5190
.12	1390	.40	2530	.80	3580	1.72	5250
.13	1440	.41	2560	.82	3620	1.76	5310
.14	1500	.42	2590	.84	3670	1.80	5370
.15	1550	.43	2620	.86	3710	1.84	5430
.16	1600	.44	2650	.88	3750	1.88	5490
.17	1650	.45	2680	.90	3790	1.92	5550
.18	1700	.46	2710	.92	3840	1.96	5600
.19	1740	.47	2740	.94	3880	2.00	5660
.20	1790	.48	2770	.96	3920	2.04	5710
.21	1830	.49	2800	.98	3960	2.08	5770
.22	1880	.50	2830	1.00	4000	2.12	5830
.23	1920	.51	2860	1.04	4080	2.16	5880
.24	1960	.52	2880	1.08	4160	2.20	5940
.25	2000	.53	2910	1.12	4230	2.24	5990
.26	2040	.54	2940	1.16	4310		
.27	2080	.55	2970	1.20	4380	2.28	6040
.28	2120	.56	2990	1.24	4460		

Notes: 1. Data for standard air (29.92 in. Hg and 70 F)

2. Data derived from the following equation

$$h_v = \left(\frac{V}{4005} \right)^2$$ Where : V = Velocity in fpm

hv - pressure difference termed ‘Velocity pressure” (in. wg)

Table 2.45: Minimum Duct Seal Levels

Duct Location	Duct Type			
	Supply		Exhaust	Return
	< 2 in. water	≥ 2 in. water		
Outdoors				
Unconditioned spaces	A	A	A	A
Conditioned spaces	B	A	B	B
(concealed ductwork)	C	B	B	B
Conditioned spaces				
(exposed ductwork)	A	A	B	B

Seal Level	Sealing Requirements
A	All transverse joints, longitudinal seams, and ductwork penetrations. Pressure-sensitive tape shall not be used as the primary sealant on metal ducts.
B	All transverse joints and longitudinal seams. Pressure sensitive tape shall not be used as the primary sealant of metal ducts.
C	Transverse joints only.

Transverse joints are connections of two ducts oriented perpendicular to flow. Longitudinal seams are joins oriented in the direction of airflow. Duct wall penetration are openings made by screws, fasteners, pipes, tubing, rods, and wires. Round and flat oval spiral lock seams need not be sealed prior to assembly, but may be coated after assembly to reduce leakage. All other connections are considered transverse joints, including but not limited to spinning, taps and other branch connections, access door frames, and duct connections to equipment.

Table 2.46 : Aluminium Sheet (Weight and Thickness)

SIZE (FT.)	SIZES IN MM	SWG OR IN.	MM (T)	WEIGHT PER SHEET KG
8 X 3	2438 X 914	1/4”	6.4	51.600
8 X 4	2438 X 1219	1/4”	6.4	39.00
8 X 3	2438 X 914	3/16”	4.877	29.500
8 X 4	2438 X 1219	3/16”	4.877	38.500
8 X 3	2438 X 914	1/8”	3.251	20.000
8 X 4	2438 X 1219	1/8”	3.251	26.200
8 X 3	2438 X 914	12	2.642	16.000
8 X 4	2438 X 1219	12	2.642	21.500
8 X 3	2438 X 914	14	2.032	13.000
8 X 4	2438 X 1219	14	2.032	16.000
8 X 3	2438 X 914	16	1.626	10.000
8 X 4	2438 X 1219	16	1.626	13.000
8 X 3	2438 X 914	18	1.219	7.500
8 X 4	2438 X 1219	18	1.219	10.000
8 X 3	2438 X 914	20	0.914	5.300
8 X 4	2438 X 1219	20	0.914	7.000
8 X 3	2438 X 914	22	0.711	4.200
8 X 4	2438 X 1219	22	0.711	6.000
8 X 3	2438 X 914	24	0.559	3.400
8 X 4	2438 X 1219	24	0.559	4.700
8 X 3	2438 X 914	26	0.457	2.800
8 X 4	2438 X 1219	26	0.457	4.000

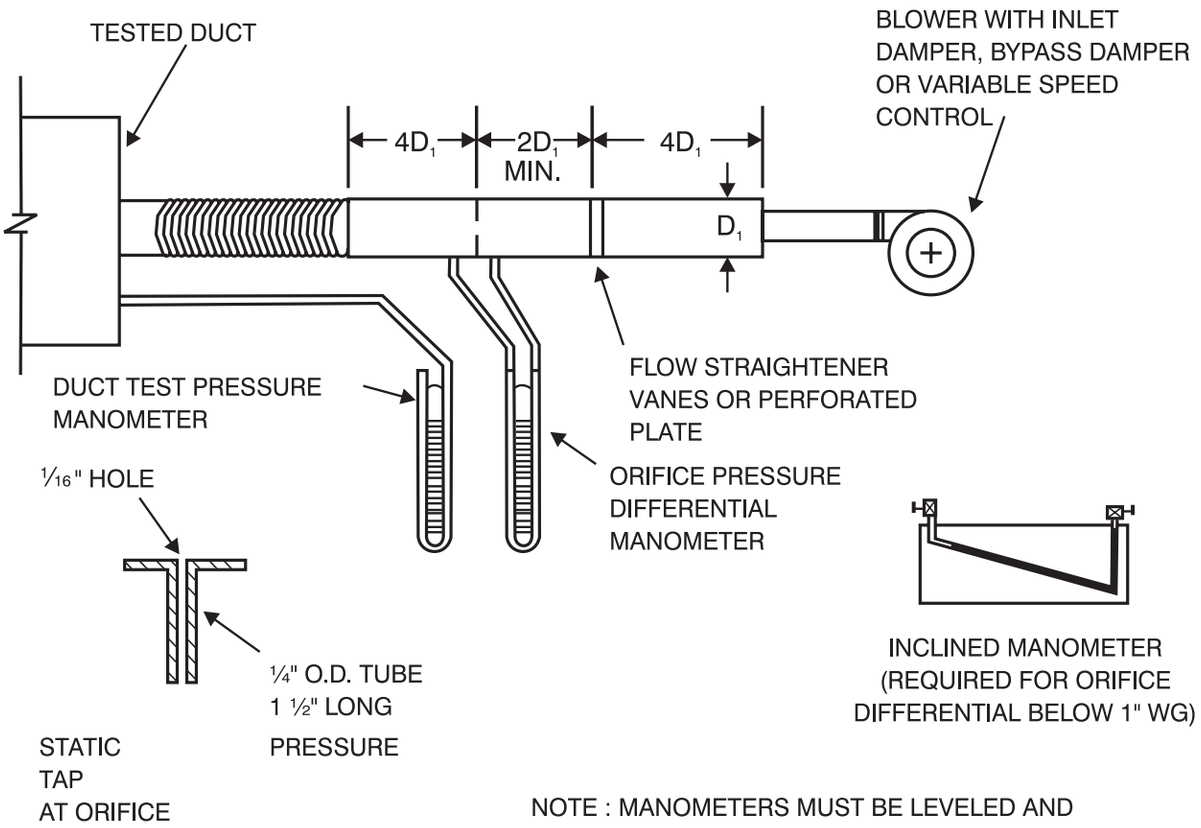
1 KG. = 2.2 IBS

Table 2.47 : Chemical Composition of CRCA Sheets
IS 513 : 2008

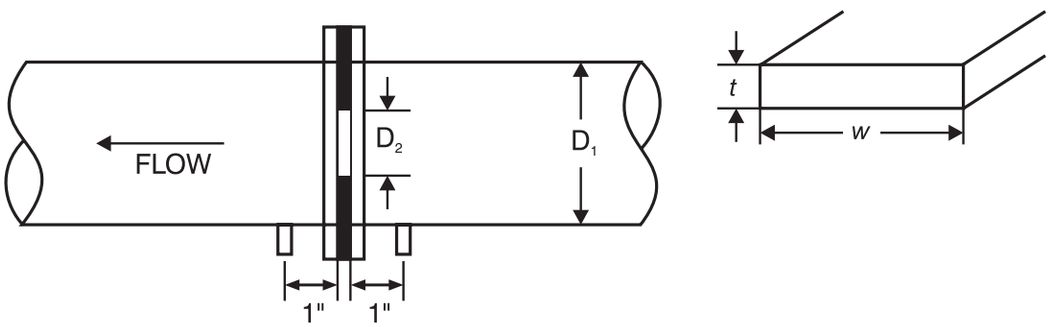
Sl. No.	Quality		Constitution, Percent, Max			
	Designation	Name	Carbon	Manganese	Sulphur	Phosphorus
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	CRO	Hard	0.25	1.7	0.045	0.050
ii)	CR1	Commercial	0.15	0.60	0.040	0.050
ill)	CR2	Drawing	0.12	0.50	0.035	0.040
iv)	CR3	Deep Drawing	0.10	0.45	0.030	0.025
v)	CR4	Extra Deep Drawing Aluminum Killed (Non-ageing)	0.08	0.40	0.030	0.020
vi)	CR5	Extra Deep Drawing (Stabilized Interstitial Free)	0.06	0.25	0.020	0.020

Table 2.48 : Louver Dampers Design

Function or Location	Application	Velocity* (fpm)	Remarks
Minimum Outdoor Air	Ventilation	500-800	The higher limit may be used with short outdoor air duct connection and long return air duct. May be single acting damper.
Maximum Outdoor Air	Permissible system resistance and balance	500-800	Should be double acting when used for throttling.
All Outdoor Air	Permissible system resistance and balance	500-800	Single acting damper may be used.
Return Air	Permissible system resistance and balance	800-1200	May be higher velocity with short return duct and long outdoor air duct. Should be double acting damper.
Dehumidifier, Face	Control space conditions	400-800	Should equal cross-sectional area of dehumidifier. Should be double acting damper.
Dehumidifier, Bypass	System balance	1500-2500	Should balance resistance of dehumidifier plus humidifier face damper. Should be double acting.
Heater Bypass	Balance	1000-1500	Should balance resistance at heater. Should be double acting.
Fan Suction or Discharge or located in duct	Available duct area	Same as duct	Use double acting damper.



NOTE : MANOMETERS MUST BE LEVELED AND ADJUSTED TO ZERO BEFORE LINE PRESSURE IS IMPOSED



LOCATION OF FLANGE (PIPE) TAPS
USE 3/32" OR 1/8" STEEL SQUARE EDGE ORIFICE PLATE

$$Q = K \times \text{Area} \times \sqrt{2 \times \Delta P}$$

Where

Q = air volume, cfm

K = coefficient of airflow from Table

D = orifice diameter, inches (D_2)

DP = Pressure drop across orifice, inches wg

D_2/D_1	0.70	0.60	0.50	0.40	0.30
A_2/A_1	0.490	0.36	0.250	0.160	0.090
K	0.699	0.650	0.623	0.608	0.600
Kp	0.52	0.63	0.73	0.82	0.88

Orifice Coefficients

Figure 2.31 : Leakage Test Meter Apparatus - Flange Taps (SMACNA)

SECTION - 3

WATER / STEAM PIPING DESIGN AND MATERIALS

INTRODUCTION

Friction in piping is the principle source of increased operating costs for water systems. For HVAC water system designers it is critical to determine the pump capacity as accurately as possible. Good piping design always balances first cost with the operating costs, taking into consideration all factors that exist in each installation.

Section 3 covers the data on Friction Losses in Pipes and Fittings, while touching on the subject of Chilled Water Piping layout. The sources include ASHRAE and HVAC Pump Handbook by Mr. James, B. Rishel etc.

In the air - conditioning industry, water is used as a medium of heat transfer for cooling, heating or heat rejection. In the cooling usage, chilled water is pumped though a network of insulated pipes, as a closed circuit, to the air flandlers or usage points located near and far from the point of generation.

In heating, hot water or low pressure steam is piped to the heat exchangers located at various points, through insulated piping network.

Heat rejection piping consists of pumping circuit connecting the heat rejection, heat exchanger and cooling towers, located in proximity to the plant room, as open circuit, using uninsulated pipes.

Various materials of construction for the application of piping is possible, and depend on the environmental conditions and availability. Tables 3.14 & 16 list the materials recommended for various applications.

Figs 3.16, 18 & 19 illustrate the classification of pumps used, and their performance data. Schematic layout of various chilled water and cooling tower piping is illustrated in Figs 3.8 to 15 & 17.

When water flows though pipes, valves and fittings, pressure drops occur and the design and size of piping and pumps have to take into account the total pressure drop in the system for a particular flow. Flow characteristics such as friction loss due to flow and related data are tabled /illustrated in Figs 3.1 to 5, 6, 7, 19, 20.

Minerals, salts and other contaminants in water can cause fouling of the pipes and the heat exchangers over a period of time. Suggested hardness of water, fouling factors to be used while selecting equipment, and safety factor of heat transfer area to be take, while designing, to offset the fouling are given in the Page 3.19.

Pages 3.32 to 3.35 have data related to thermal storage and illustrated piping circuits.

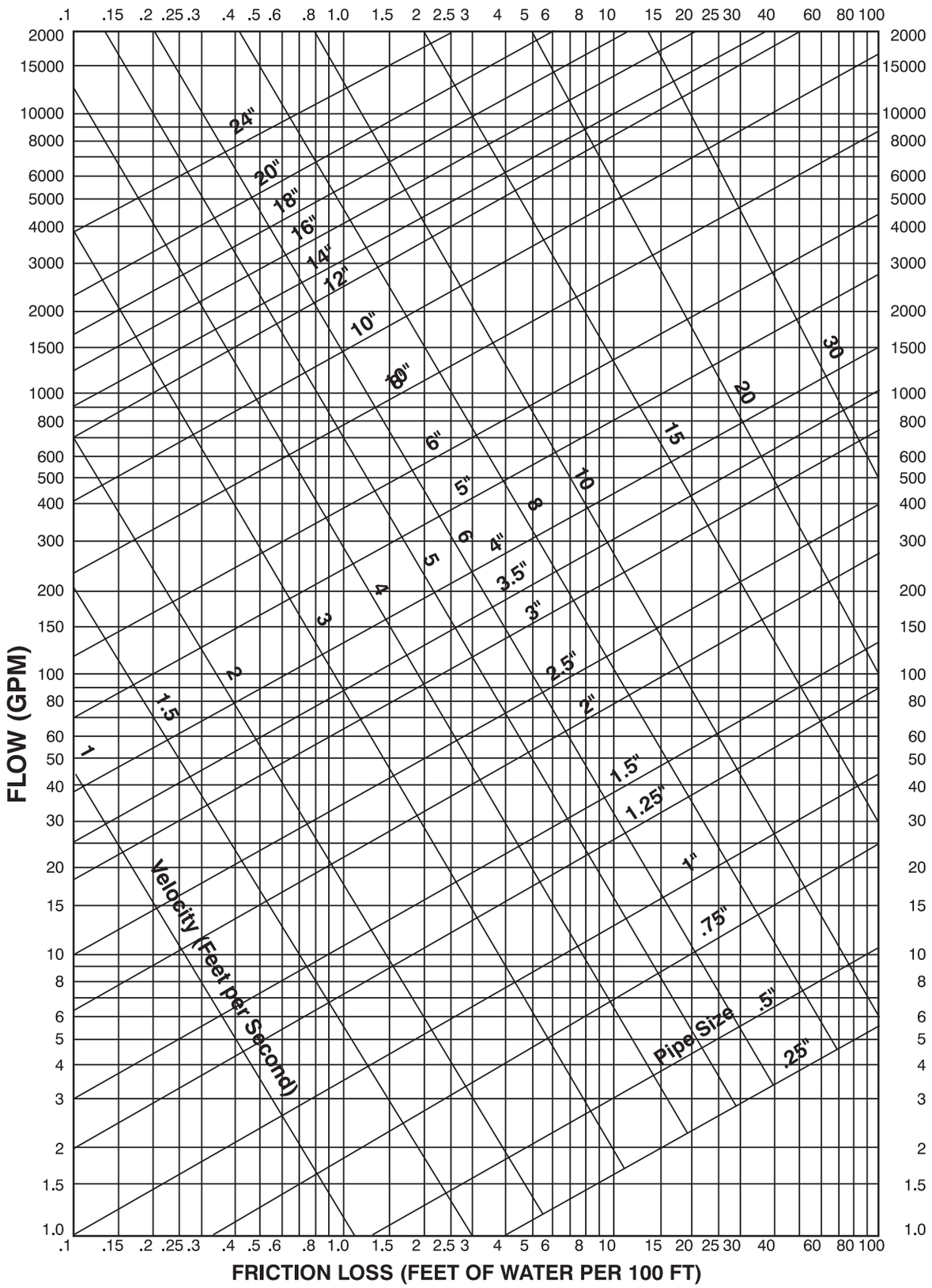


Figure 3.1 : Friction Loss for closed piping Systems (Water)
Schedule 40 pipe

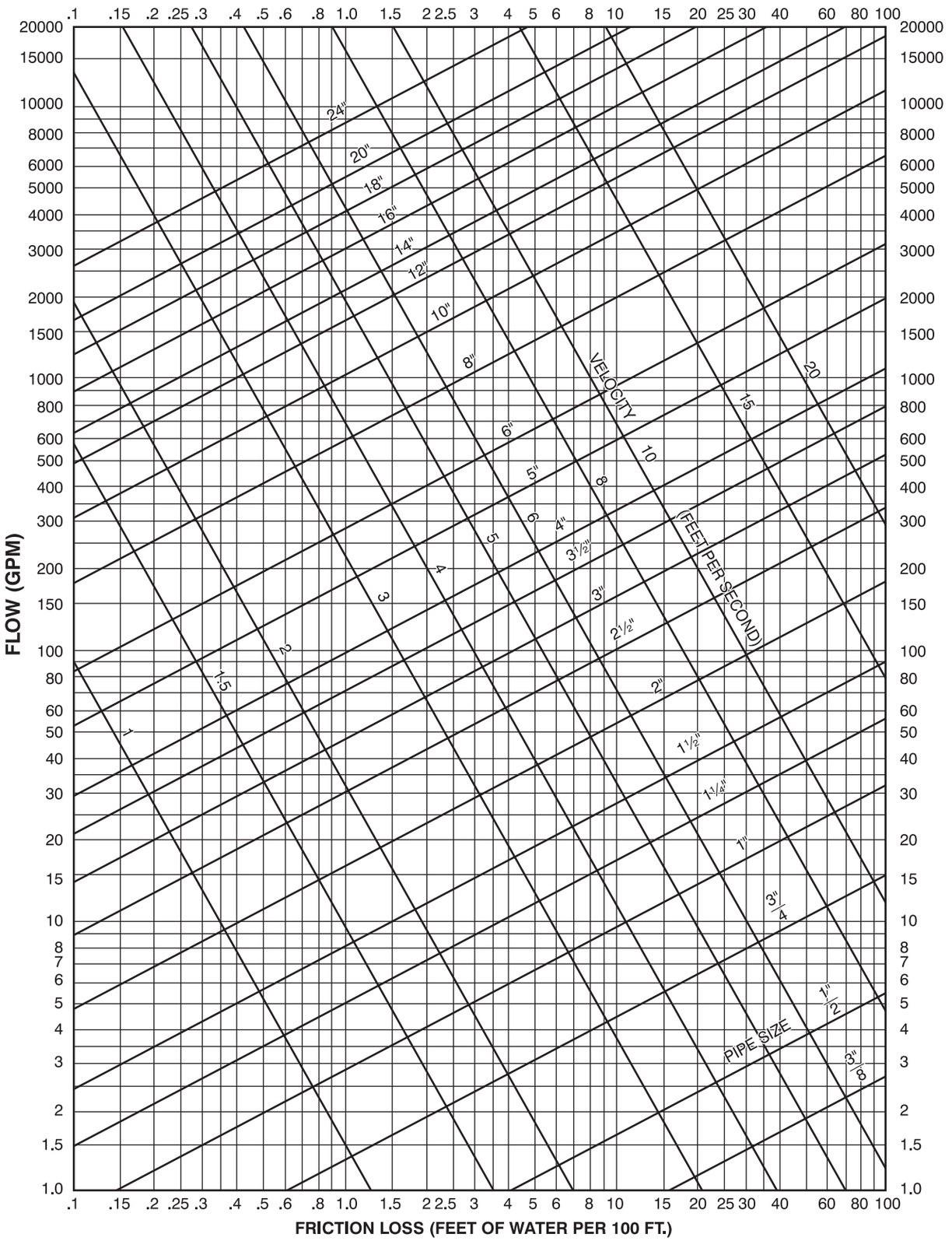
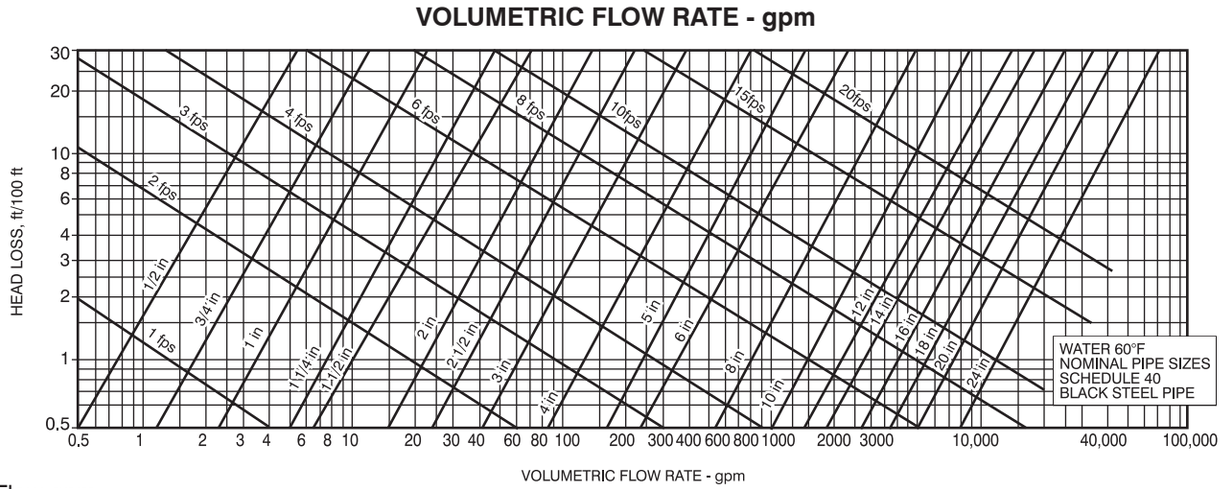


Figure 3.2 : Friction Loss for Open piping Systems (Water)

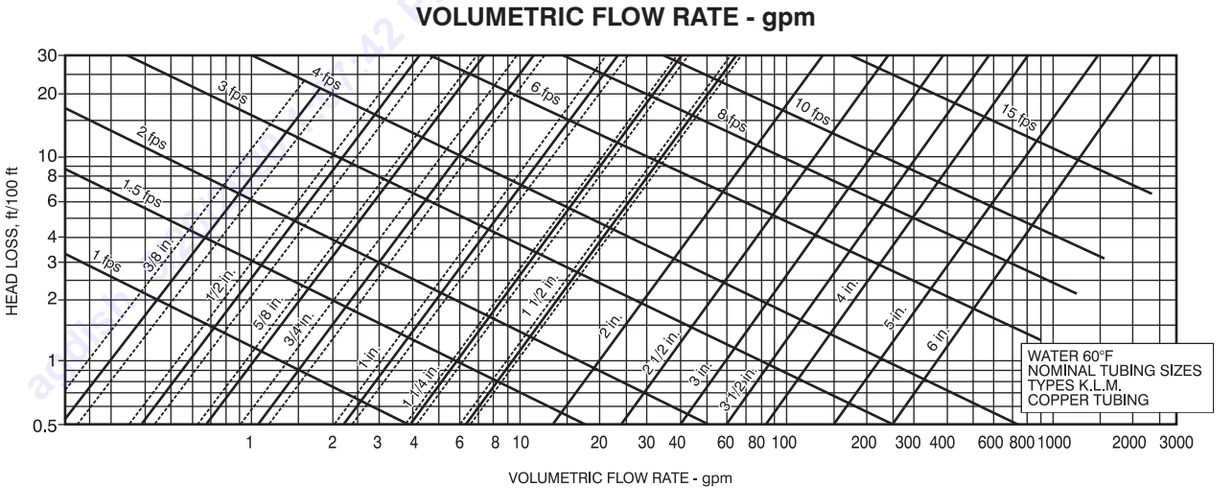
Schedule 40 pipe

PIPE SIZING



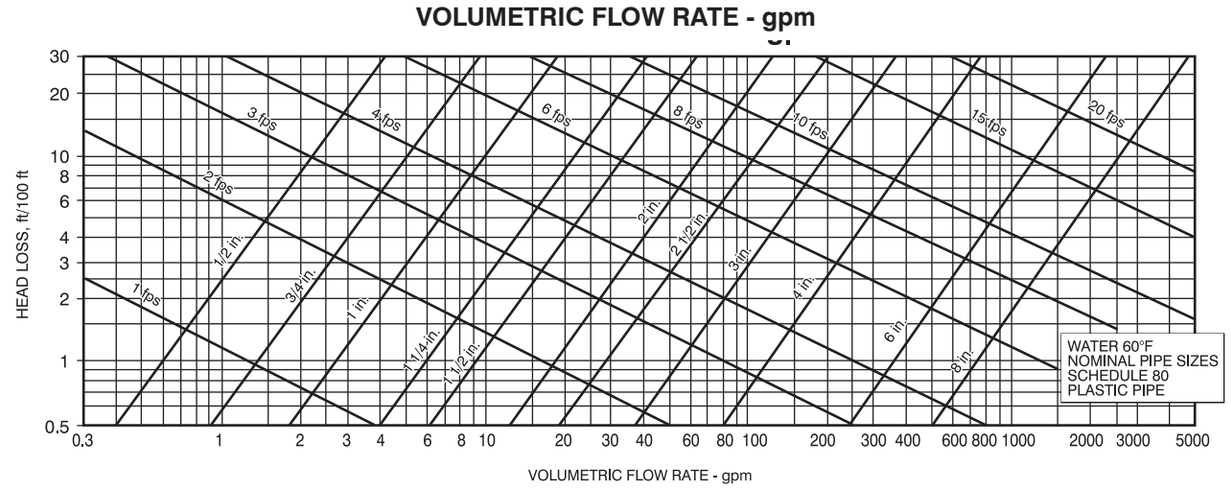
Flow gpm

Figure 3.3 : Friction loss for Water in Commercial Steel Pipe (Schedule - 40)



Flow gpm

Figure 3.4 : Friction loss for Water in Copper Pipe (Types K.L.M.)



Flow gpm

Figure 3.5 : Friction loss for Water in Plastic Pipe (Types Schematic)

Table 3.1 : Equivalent Length in Feet of Pipe for 90° elbows

Velocity fps	PIPE SIZE														
	1/2	3/4	1	1-1/4	1-1/2	2	2-1/2	3	3-1/2	4	5	6	8	10	12
1	1.2	1.7	2.2	3.0	3.5	4.5	5.4	6.7	7.7	8.6	10.5	12.2	15.4	18.7	22.2
2	1.4	1.9	2.5	3.3	3.9	5.1	6.0	7.5	8.6	9.5	11.7	13.7	17.3	20.8	24.8
3	1.5	2.0	2.7	3.6	4.2	5.4	6.4	8.0	9.2	10.2	12.5	14.6	18.4	22.3	26.3
4	1.5	2.1	2.8	3.7	4.4	5.6	6.7	8.3	9.6	10.6	13.1	15.2	19.2	23.2	27.6
5	1.6	2.2	2.9	3.9	4.5	5.9	7.0	8.7	10.0	11.1	13.6	15.8	19.8	24.2	28.8
6	1.7	2.3	3.0	4.0	4.7	6.0	7.2	8.9	10.3	11.4	14.0	16.3	20.5	24.9	29.6
7	1.7	2.3	3.0	4.1	4.8	6.2	7.4	9.1	10.5	11.7	14.3	16.7	21.0	25.5	30.3
8	1.7	2.4	3.1	4.2	4.9	6.3	7.5	9.3	10.8	11.9	14.6	17.1	21.5	25.1	31.0
9	1.8	2.4	3.2	4.3	5.0	6.4	7.7	9.5	11.0	12.2	14.9	17.4	21.9	26.6	31.6
10	1.8	2.5	3.2	4.3	5.1	6.5	7.8	9.7	11.2	12.4	15.2	17.7	22.2	27.0	32.0

Source: ASHRAE Handbook

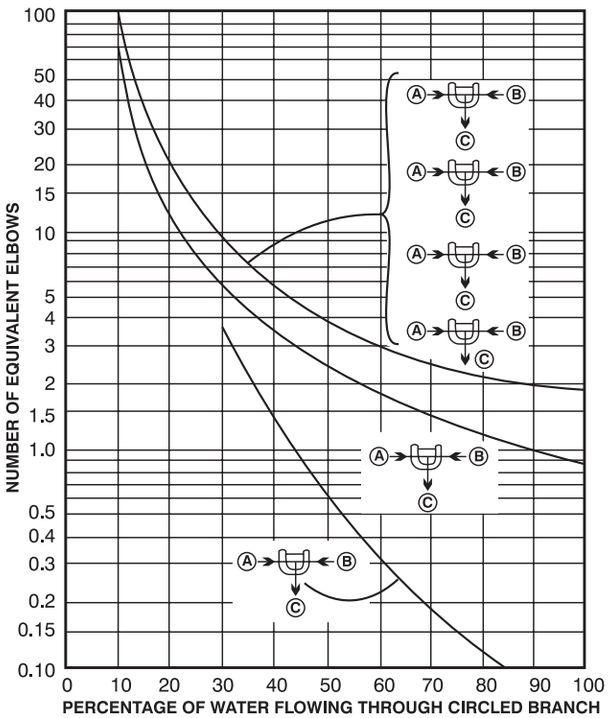


Figure 3.6 : ELBOW EQUIVALENT OF T'S AT VARIOUS FLOW CONDITIONS

NOTES:

1. Chart is based on straight lines (i.e. branches A,B and C are the same size).
2. Pressure loss in desired circuit is obtained by selecting the proper curve according to illustrations, determining the flow at the circled branch, and multiplying the pressure loss for the same size elbow at the flow rate in the circled branch by the equivalent elbows indicated.
3. When the size of an outlet is reduced, the equivalent elbows shown in the chart do not apply. Therefore the maximum loss for any circuit for any flow will not exceed 2 elbows equivalent at the maximum flow occurring in any branch of the tree.
4. Top curve is average of 4 curves, one for each circuit is shown.

Source : Carrier Handbook

Suggested Design Rules

Generally, water consumption is not a concern in most HVAC systems, since most systems are circulatory. The use of energy is important. If the recommendations and equations developed herein are adusted, efficient pumping design will result for these water systems. Following are some additional recommendations :

1. The prospective water system should be designed to the specific requirements of the owner, utilizing the following principles to achieve the most efficient system possible within first and cost budget of the project.
2. The water system should be configured to distribute the water efficiency, with a minimum use of energy wasting devices. These devices are listed here:
   a. Three-way temperature-control valves
   b. Balancing valves, manual or automatic
   c. Pressure-reducing or pressure-regulating valves
   d. Crossover bridges and return valves -

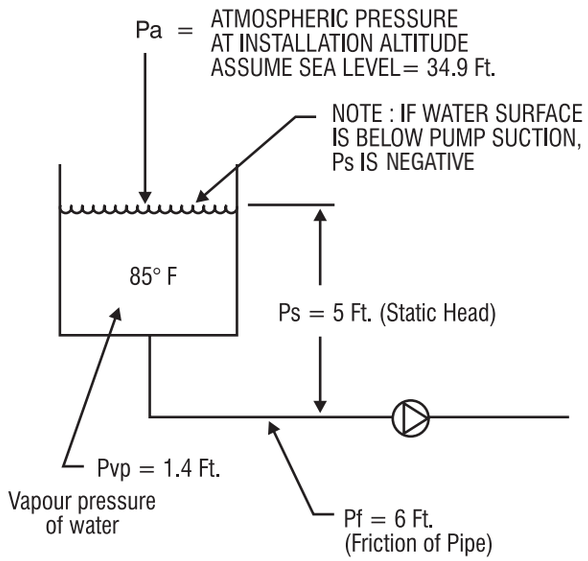
   The piping should be designed without :

   a. Reducing flanges or threaded reducing couplings
   b. Bullhead connections (e.g. two streams connected to the run connection of a tee with the discharge on the branch of the tee)

The friction for the piping should be calculated for all pipe runs, fittings and valves.

Distribution pumps should be selected for maximum efficiency, at the design condition, and within the economic constraints of the project.

Distribution pumps should be added and subtracted to avoid operation of pumps at points of high thrust and poor efficiency. Pump sequencing should achieve maximum possible system efficiency, and control valves and their actuators should be sized to ensure that they can operate at all loads on the system without lifting the valve head off the valve seat.



$$NPSHA = Pa + Ps - Pvp = Pf$$
$$= 34.0 + 5 - 1.4 - 6 = 31.6 \text{ Ft.}$$

Figure 3.7 : Net Positive Suction Head Available

Table 3.2 : Flow of Water in Steel Pipe of Larger diameters

Flow Gal/min	16-in schedule 40			18-in Schedule 40			20-in Schedule 40		
	ID = 15,000 in			ID = 16,876 in			ID = 18,812 in		
	V, ft/s	$\frac{V^2}{2g}$ — ft.	Hf, ft/100 ft	V, ft/s	$\frac{V^2}{2g}$ — ft.	Hf, ft/100 ft	V, ft/s	$\frac{V^2}{2g}$ — ft.	Hf, ft/100 ft
300	0.55	0.005	0.008	0.43	0.003	0.004	0.35	0.002	0.003
400	0.73	0.008	0.013	0.57	0.005	0.007	0.46	0.003	0.004
500	0.91	0.013	0.019	0.72	0.008	0.011	0.58	0.005	0.006
600	1.09	0.018	0.027	0.86	0.012	0.015	0.69	0.007	0.009
700	1.27	0.025	0.036	1.00	0.016	0.020	0.81	0.010	0.021
800	1.45	0.033	0.045	1.15	0.021	0.026	0.92	0.013	0.015
900	1.63	0.042	0.056	1.29	0.026	0.032	1.04	0.017	0.019
1000	1.82	0.051	0.068	1.43	0.032	0,039	1.15	0.021	0.023
1200	2.18	0.074	0.095	1.72	0.046	0.054	1.38	0.030	0.032
1400	2.54	0.100	0.127	2.01	0.063	0.072	1.62	0.041	0.042
1600	2.90	0.131	0.163	2.30	0.082	0.092	1.85	0.053	0.054
1800	3.27	0.166	0.203	2.58	0.104	0.114	2.08	0.067	0.067
2000	3.63	0.205	0.248	2.87	0.128	0.139	2.31	0.083	0.081
2500	4.54	0.320	0.377	3.59	0.200	0.211	2.89	0.129	0.123
3000	5.45	0.461	0.535	4.30	0.288	0.297	3.46	0.186	0.174
3500	6.35	0.627	0.718	5.02	0.392	0.397	4.04	0.254	0.232 '
4000	7.26	0.820	0.921	5.74	0.512	0.511	4.62	0.331	0.298
4500	8.17	1.04	1.15	6.45	0.647	0.639	5.19	0.419	0.372
5000	9.08	1.28	1.41	7.17	0.799	0.781	5.77	0.517	0.455
6000	10.9	1.84	2.01	8.61	1.15	1.11	6.92	0.745	0.645
7000	12.7	2.51	2.69	10.0	1.57	1.49	8.08	1.014	0.862
8000	14.5	3.28	3.49	11.5	2.05	1.93	9.23	1.32	1.11
9000	16.3	4.15	4.38	12.9	2.59	2.42	10.39	1.68	1.39
10000	18.2	5.12	5.38	14.3	3.20	2.97	11.5	2.07	1.70
12000	21.8	7.38	7.69	17.2	4.60	4.21	13.8	2.98	2.44
14000				20.1	6.27	5.69	16.2	4.06	3.29
16000				22.9	8.19	7.41	18.5	5.30	4.26
18000							20.8	6.71	5.35
20000							23.1	8.28	6.56

Note: V =Velocity, Feet per Second, $\frac{V^2}{2g}$ ft = Velocity Head, Feet; Hf= Friction Loss, Feet Per 100 Feet of pipe. No aging Factor Manufacturer's Tolerance, or any Factor of Safety has been included in the friction losses Hf.

Source : HVAC Pump Handbook

Table 3.3 : Flow of Water in Steel Pipe of Larger diameters

Flow Gal/min	24-in Schedule 40 ID = 22,624 in			30-in Schedule 20 ID = 29,000 in			36-in Inside Diameter		
	V, ft/s	$\frac{V^2}{2g}$ — ft.	Hf, ft/100 ft	V, ft/s	$\frac{V^2}{2g}$ — ft.	Hf, ft/100 ft	V, ft/s	$\frac{V^2}{2g}$ — ft.	Hf, ft/100 ft
300	0.24	0.001	0.001						
400	0.32	0.002	0.002	0.19	0.001	0.001			
500	0.40	0.002	0.003	0.24	0.001	0.001			
600	0.48	0.004	0.004	0.29	0.001	0.001			
700	0.56	0.005	0.005	0.34	0.002	0.001			
800	0.64	0.006	0.006	0.39	0.002	0.002			
900	0.72	0.008	0.008	0.44	0.003	0.002			
1000	0.80	0.010	0.009	0.49	0.004	0.003	0.32	0.002	0.001
1200	0.96	0.014	0.013	0.58	0.005	0.004	0.38	0.002	0.001
1400	1.12	0.019	0.017	0.68	0.007	0.005	0.44	0.003	0.002
1600	1.28	0.025	0.022	0.78	0.009	0.007	0.50	0.004	0.002
1800	1.44	0.032	0.027	0.87	0.012	0.008	0.57	0.005	0.003
2000	1.60	0.040	0.033	0.97	0.015	0.010	0.63	0.006	0.003
2500	1.99	0.062	0.050	1.21	0.023	0.015	0.79	0.010	0.005
3000	2.39	0.089	0.070	1.46	0.033	0.021	0.95	0.014	0.007
3500	2.70	0.121	0.093	1.70	0.045	0.028	1.10	0.019	0.010
4000	3.19	0.158	0.120	1.94	0.059	0.035	1.26	0.025	0.012
4500	3.59	0.200	0.149	2.19	0.074	0.044	1.41	0.031	0.015
5000	3.99	0.247	0.181	2.43	0.092	0.054	1.58	0.039	0.019 '
6000	4.79	0.356	0.257	2.91	0.132	0.075	1.89	0..56	0.026
7000	5.59	0.485	0.343	3.40	0.180	0.100	2.21	.076	0.035
8000	6.38	0.633	0.441	3.89	0.235	0.129	2.52	0.099	0.044
9000	7.18	0.801	0.551	4.37	0.297	0.161	2.84	0.125	0.055
10000	7.98	0.989	0.671	4.86	0.367	0.196	3.15	0.154	0.067
12000	9.58	1.42	0.959	5.83	0.528	0.277	3.78	0.222	0.094
14000	11.2	1.94	1.29	6.80	0.719	0.371	4.41	0.303	0.126
16000	12.8	2.53	1.67	7.77	0.939	0.478	5.04	0.395	0.162
18000	14.4	3.21	2.10	8.74	1.19	0.598	5.67	0.500	0.203
20000	16.0	3.96	2.58	9.71	1.47	0.732	6.30	0.618	0.248
22000	17.6	4.79	3.10	10.7	1.78	0.886	6.93	0.746	0.300
24000	19.2	5.70	3.67	11.7	2.12	1.05	7.56	0.888	0.357
26000	20.7	6.69	4.29	12.6	2.48	1.24	8.20	1.04	0.419
2800				13.6	2.88	1.43	8.83	1.21	0.486
30000				14.6	3.30	1.61	9.46	1.39	0.540
35000				17.0	4.49	2.17	11.03	1.89	0.724
40000				19.4	5.87	2.83	12.6	2.47	0.941
450000				21.9	7.42	3.56	14.1	3.13	1.18
50000				24.3	9.17	4.38	15.8	3.86	1.45
55000							17.4	4.70	1.75
60000							18.9	5.56	2.07
70000							22.1	7.56	2.81

Note: V = Velocity, Feet per Second, $v2/2g$ft = Velocity Head, Feet; Hf= Friction Loss, Feet per 100 Feet of pipe. No aging Factor, Manufacturer's Tolerance, or any Factor of Safety has been included in the friction losses Hf.

Source : HVAC Pump Handbook.

Table 3.4 : Flow of Water in Steel Pipe of Larger Diameters

Flow Gal/min	42-in inside Diameter		
	V.ft/s	V^2 — ft. 2g	Hf, ft/100 ft
1000	0.232	0.00083	0.00047
1500	0.347	0.00187	0.00098
2000	0.463	0.00333	0.00164
2500	0.579	0.00521	0.00246
3000	0.695	0.00750	0.00343
3500	0.811	0.0102	0.00454
4000	0.926	0.0133	0.00580
4500	1.042	0.0169	0.00720
5000	1.16	0.0208	0.00874
6000	1.39	0.0300	0.0122
7000	1.62	0.0408	0.0162
8000	1.85	0.0533	0.0208
9000	2.08	0.0675	0.0258
10000	2.32	0.0833	0.0314
12000	2.78	0.120	0.0441
14000	3.24	0.163	0.0591
16000	3.71	0.213	0.0758
18000	4.17	0.270	0.0944
20000	4.63	0.333	0.115
25000	5.79	0.521	0.175
30000	6.95	0.750	0.250
35000	8.11	1.02	0.334
40000	9.26	1.33	0.433
45000	10.42	1.69	0.545
50000	11.6	2.08	0.668
60000	13.9	3.00	0.946
70000	16.2	4.08	1.27
80000	18.5	5.33	1.66
90000	20.8	6.75	2.08
10000	23.2	8.33	2.57

Note : V =Velocity, Feet per Second, , *v2/2g*ft = Velocity Head, Feet; Hf= Friction Loss, Feet per 100 Feet of pipe. No aging Factor, Manufacturer's Tolerance, or any factor of Safety has been included in the friction losses Hf.

Source : HVAC Pump Handbook.

Table 3.5 : Friction Losses For Copper Pipe and Tubing

Flow - U.S. gal per min	Type K tubing .527" Inside dia .049" wall thk		Type L tubing .545 " inside dia .040" wall thk		Type M tubing .569 " Inside dia .028" wall thk		1/2 inch Pipe .625" Inside dia 075" wall thk	
	Velocity ft/sec	Head loss ft/100 ft	Velocity ft/sec	Head loss ft/100 ft	Velocity ft/sec	Head loss ft/100 ft	Velocity ft/sec	Head loss ft/100 ft
1/2	0.74	0.88	0.69	0.75	0.63	0.62	0.52	0.40
1	1.47	2.87	1.38	2.45	1.26	2.00	1.04	1.20
1 1/2	2.20	5.77	2.06	4.93	1.90	4.02	1.57	2.50
2	2.94	9.52	2.75	5.11	2.53	6.61	2.09	4.24
2 1/2	3.67	14.05	3.44	11.98	3.16	9.76	2.61	6.25
3	4.40	19.34	4.12	16.46	3.79	13.42	3.13	8.59
3 1/2	5.14	25.36	4.81	21.61	4.42	17.59	3.66	11.25
4	5.87	32.09	5.50	27.33	5.05	22.25	4.18	14.22
4 1/2	6.61	39.51	6.19	33.65	5.68	27.39	4.70	17.50
5	7.35	47.61	6.87	40.52	6.31	32.99	5.22	21.07
6	8.81	65.79	8.25	56.02	7.59	45.57	6.26	29.09
7	10.3	86.57	9.62	73.69	8.84	59.93	7.31	36.23
8	11.8	109.9	11.0	93.50	10.1	76.03	8.35	48.47
9	13.2	135.6	12.4	115.4	11.4	93.02	9.40	59.79
10	14.7	163.8	13.8	139.4	12.6	113.3	10.4	72.16

Table 3.6 : Friction Losses for Copper Pipe and Tubing

Flow - U.S. gal per min	Type K tubing .652” Inside dia .049” wall thk		Type L tubing .666 ” Inside dia .042” wall thk		Type M tubing -5/8 inch .690 “ Inside dia .030” wall thk	
	Velocity ft/sec	Head loss ft/100 ft	Velocity ft/sec	Head loss ft/100 ft	Velocity ft/sec	Head loss ft/100 ft
1/2	0.48	0.31	0.46	0.29	0.43	0.24
1	0.96	10.5	0.92	0.95	0.86	0.76
1 1/2	1.44	2.11	1.38	1.91	1.29	1.53
2	1.92	3.47	1.64	3.14	1.72	2.51
2 1/2	2.40	5.11	2.30	4.62	2.14	3.68
3	2.88	7.02	2.75	6.35	2.57	5.07
3 1/2	3.36	9.20	3.21	8.32	3.00	6.64
4	3.84	11.63	3.57	10.51	3.43	8.40
4 1/2	4.32	14.30	4.13	12.93	3.66	10.35
5	4.80	17.22	4.59	15.56	4.29	12.49
6	5.75	23.76	5.51	21.47	5.15	17.21
7	6.71	31.22	6.42	28.21	6.00	22.58
8	7.67	39.58	7.35	35.75	6.85	28.54
9	8.64	46.81	8.25	44.09	7.71	35.35
10	9.60	58.90	9.18	53.19	8.57	42.58
11	10.6	69.83	10.1	63.06	9.43	50.47
12	11.5	81.59	11.0	73.67	10.3	59.1
13	12.5	94.18	11.9	85.03	11.2	68.0

Source : HVAC Pump Handbook.

Table 3.7 : Friction Losses For Copper Pipe and Tubing

Flow - U.S. gal per min	Type K tubing .402" Inside dia .049" wall thk		Type L tubing .430 " inside dia .035" wall thk		Type M tubing .450 " Inside dia .025" wall thk		1/2 inch Pipe .494" Inside dia 0.0905" wall thk	
	Velocity ft/sec	Head loss ft/100 ft	Velocity ft/sec	Head loss ft/100 ft	Velocity ft/sec	Head loss ft/100 ft	Velocity ft/sec	Head loss ft/100 ft
0.2	0.51	0.66	0.44	0.48	0.40	0.39	0.34	0.26
0.4	1.01	2.15	0.88	1.57	0.81	1.27	0.67	0.82
0.5	0.52	4.29	1.33	3.12	1.21	2.52	1.00	1.03
0.8	2.02	7.02	1.77	5.11	1.61	4.12	1.34	2.66
1	2.52	10.32	2.20	7.50	2.01	6.05	1.66	3.09
1 1/2	3.78	20.86	3.30	15.15	3.02	12.21	2.51	7.04
2	5.04	34.48	4.40	20.03	4.02	20.16	3.35	12.04
2 1/2	6.30	51.03	5.50	37.01	5.03	29.80	4.19	19.11
3	7.55	70.38	6.60	51.02	6.04	41.07	5.02	20.32
3 1/2	8.62	92.44	7.70	65.98	7.04	53.90	5.86	34.52
4	10.1	117.1	8.80	84.95	8.05	68.26	6.70	43.70
4 1/2	11.4	144.4	9.90	104.6	9.05	64.11	7.53	53.82
5	12.6	174.3	11.0	126.1	10.05	101.4	8.36	64.87

Table 3.8 : Friction Losses For Copper Pipe and Tubing

Flow - U.S. gal per min	Type K tubing .745" Inside dia .065" wall thk		Type L tubing .785 " inside dia .045" wall thk		Type M tubing .811 " Inside dia .032" wall thk		3/4 inch Pipe .822" Inside dia .114" wall thk	
	Velocity ft/sec	Head loss ft/100 ft	Velocity ft/sec	Head loss ft/100 ft	Velocity ft/sec	Head loss ft/100 ft	Velocity ft/sec	Head loss ft/100 ft
1	074	0.56	0.66	0.44	0.62	0.38	0.60	0.35
2	1.47	1.84	1.33	1.44	1.24	1.23	1.21	1.16
3	2.21	3.73	1.99	2.91	1.86	2.49	1.81	2.34
4	2.94	6.16	2.65	4.81	2.48	4.12	2.42	3.86
5	3.67	9.12	3.31	7.11	3.10	6.09	3.02	5.71
6	4.41	12.57	3.98	9.00	3.72	8.39	3.62	7.86
7	5.14	16.51	4.64	12.66	4.34	11.01	4.23	10.32
8	5.88	20.91	5.30	16.28	4.96	13.94	4.83	13.07
9	6.61	25.77	5.96	20.08	5.59	17.17	5.44	16.10
10	7.35	31.08	6.62	24.19	6.20	20.70	6.04	19.41
11	8.09	36.83	7.29	28.66	6.82	24.52	6.64	22.99
12	8.83	43.01	7.95	33.47	7.44	28.63	7.25	26.84
13	9.56	49.52	8.61	38.61	8.06	33.02	7.85	30.96
14	10.3	56.66	9.27	44.07	8.68	37.69	8.45	35.33
15	11.0	64.11	9.94	49.06	9.30	42.64	9.05	39.97
16	11.8	71.97	10.6	55.97	9.92	47.86	9.65	44.05
17	12.5	80.24	11.25	62.39	10.55	53.35	10.25	50.00
18	13.2	88.92	11.92	69.31	11.17	59.10	10.85	55.40

Source : HVAC Pump Handbook.

Table 3.9 : Friction Losses for Copper Tube and Piping

Flow - U.S. gal per min	Type K tubing .995" Inside dia .065" wall thk		Type L tubing 1.025 " inside dia .050" wall thk		Type M tubing 1.055 " Inside dia .035" wall thk		1 inch Pipe 1.062" Inside dia 1265" wall thk	
	Velocity ft/sec	Head loss ft/100 ft	Velocity ft/sec	Head loss ft/100 ft	Velocity ft/sec	Head loss ft/100 ft	Velocity ft/sec	Head loss ft/100 ft
2	0.82	0.47	0.78	0.41	0.73	0.36	0.72	0.36
3	1.24	0.95	1.17	0.82	1.10	0.72	1.08	0.70
4	1.65	1.56	1.56	1.35	1.47	1.18	1.45	1.14
5	2.06	2.30	1.95	2.00	1.83	1.74	1.81	1.69
6	2.48	3.17	2.34	2.75	2.20	2.40	2.17	2.32
7	2.89	4.15	2.72	3.60	2.56	3.14	2.53	3.04
8	3.30	5.25	3.11	4.56	2.93	3.97	2.89	3.85
9	3.71	6.47	3.50	5.61	3.30	4.89	3.25	4.74
10	4.12	7.79	3.89	6.76	3.66	5.89	3.61	5.71
12	4.95	10.75	4.67	9.33	4.40	8.13	4.34	7.86
14	5.77	14.15	5.45	12.27	5.13	1069	5.05	10.36
16	6.60	17.94	6.22	15.56	5.88	13.55	5.78	13.13
18	7.42	22.14	7.00	19.20	8.60	16.72	6.50	16.20
20	8.24	26.73	7.78	23.10	7.33	20.16	7.22	19.55
25	10.30	39.87	9.74	34.56	9.16	30.09	9.03	29.15
30	12.37	55.33	11.68	47.96	11.00	41.74	10.84	40.43
35	14.42	73.06	13.61	63.31	12.82	55.09	12.65	53.37
40	16.50	93.00	15.55	80.58	14.56	70.11	14.45	67.90
45	18.55	115.1	17.50	99.72	16.50	86.75	16.25	84.02
50	20.60	139.4	19.45	120.7	18.32	105.0	18.05	101.7

Table 3.10 : Friction Losses for Copper Tube and Piping

Flow - U.S. gal per min	Type K tubing 1.245" Inside dia .065" wall thk		Type L tubing 1.265 " inside dia .055" wall thk		Type M tubing 1.291 " Inside dia .042" wall thk		1 1/4 inch Pipe 1.366" Inside dia .146" wall thk	
	Velocity ft/sec	Head loss ft/100 ft	Velocity ft/sec	Head loss ft/100 ft	Velocity ft/sec	Head loss ft/100 ft	Velocity ft/sec	Head loss ft/100 ft
5	1.31	0.79	1.28	0.74	1.22	0.67	1.09	0.51
6	1.58	1.09	1.53	1,01	1.47	0.92	1.31	0.70
7	1.84	1.43	1.79	1.32	1.71	1.20	1.53	0.91
8	1.81	1.43	2.04	1.67	1.96	1.52	1.75	1.15
9	2.01	1.81	2.30	2.06	2.20	1.87	1.96	1.42
10	2.63	2.67	2.55	2-46	2.45	2.25	2.18	1.71
12	3.16	3.69	3.06	3.42	2.93	3.10	2.62	2.35
15	3.95	5.47	3.83	5.07	3.66	4.60	3.27	3.49
20	5.26	9.13	5.10	8.46	4.89	7.87	4.26	5.81
25	6,58	13.59	6,38	12.59	6.11	11.42	5.46	8,65
30	7.90	18.83	7.65	17.44	7.33	15.52	6.55	11.98
35	9.21	24.83	8,94	23.00	8.55	20.86	7.65	15.79
40	10.5	31.57	10.2	29.24	9,77	26.51	8.74	20.06
45	11.8	38.03	11.5	36.15	11.30	32.77	9.83	24.80
50	13.2	47.20	12.8	43.71	12.2	39.63	10.9	29.98
60	15.8	65.65	15.3	60.78	14.7	55.10	13.1	41,66
70	18.4	86.82	17.9	80.38	17.1	72.85	15.3	55.07
80	21.1	110.7	20.4	102.5	19.6	92.85	17,5	70.16
90	23.7	137.2	23,0	127.0	22.0	115.1	19.6	86.91
100	26.3	166.3	25.5	153.9	24.4	139.4	21.6	105.3

Table 3.11 : Friction Losses for Copper Piping and Tubing

Flow - U.S. gal per min	Type K tubing		Type L tubing		Type M tubing		1 inch Pipe	
	1.481" Inside dia .072" wall thk		1.505 " inside dia .060" wall thk		1.527 " Inside dia .049" wall thk		1.500" Inside dia .150" wall thk	
	Velocity ft/sec	Head loss ft/100 ft	Velocity ft/sec	Head loss ft/100 ft	Velocity ft/sec	Head loss ft/100 ft	Velocity ft/sec	Head loss ft/100 ft
8	1.49	0.79	1.44	0.73	1.40	0.68	1.27	0.56
9	1.57	0.97	1.62	0.90	1.57	0.84	1.43	0.67
10	1.86	1.17	1.80	1.08	1.75	1.01	1.59	0.81
12	2.23	1.61	2.16	1.49	2.10	1.39	1.91	1.12
15	2.79	2.39	2.70	2.21	2.63	2.07	2.39	1.65
20	3.72	3.98	3.60	3.68	3.50	3.44	3.19	2.75
25	4.65	5.91	4.51	5.48	4.38	5.11	3.96	4.09
30	5.58	8.19	5.41	7.58	5.25	7.07	4.78	5.65
35	6.51	10.79	6.31	9.99	6.13	9.31	5.58	7.45
40	7.44	13.70	7.21	12.68	7.00	11.83	6.37	9.45
45	8.37	16.93	8.11	15.67	7.88	14.51	7.16	11.68
50	9.30	20.46	9.01	18.94	8.76	17.66	7.96	14.11
60	11.2	28.42	10.8	26.30	10.5	24.53	9.56	19.59
70	13.0	37.55	12.6	34.74	12.3	32.40	11.2	25.87
80	14.9	47.82	14.4	44.24	14.0	41.25	12.8	32.93
90	15.7	59.21	16.2	54.70	15.8	51.07	14.4	40.76
100	18.6	71.70	18.0	66.34	17.5	61.84	15.9	49.34
110	20.5	85.29	19.8	78.90	19.3	73.55	17.5	58.67
120	22.3	99.95	21.5	92.46	21.0	86.18	19.1	68.74
130	24.2	115.7	23.4	107.0	22.8	99.73	20.7	79.53

Source : HVAC Pump Handbook

Table 3.12 : Iron and Copper Elbow Equivalents*

Fittings	Iron Pipe	Copper Tubing
Elbow 90°	1.0	1.0
Elbow 45°	0.7	0.7
Elbow 90° long radius	0.5	0.5
Elbow Welded 90°	0.5	0.5
Reduced Coupling	0.4	0.4
Open Return Bend	1.0	1.0
Angle Radiator Valve	2.0	3.0
Radiator or Converter	3.0	4.0
Boiler or Heater	3.0	4.0
Open Gate Valve	0.5	0.7
Open Globe Valve	12.0	17.0

Table 3.13 : Specification for Mild Steel Tubes, Tubular and Other Wrought Iron Fittings

Nominal Bore(NB) mm (inches)	Class	Outside Diameter		Thickness mm	Wt. of Black Tube		Calculated Wt. of Gal. Tube	
		Max. mm	Min. mm		Plain End Kg/m	S & S Kg/m	Plain End Kg/m	S &S Kg/m
15 (1/2")	L	21.40	21.00	2.00	0.947	0.956	0.999	1.006
	M	21.80	21.00	2.60	1.21	1.22	1.264	1.274
	H	21.80	21.00	3.20	1.44	1.45	1.494	1.504
20 (3/4")	L	26.90	26.40	2.30	1.38	1.39	1.441	1.451
	M	27.30	26.50	2.60	1.56	1.57	1.622	1.632
	H	27.30	26.50	3.20	1.87	1.88	1.923	1.933
25 (1")	L	33.80	33.20	2.60	1.98	2.00	2^062	2.082
	M	34.20	33.30	3.20	2.41	2.43	2.495	2.515
	H	34.20	33.30	4.00	2.93	2.95	3.028	3.048
32 (1 1/4")	L	42.50	41.90	2.60	2.54	2.57	2.641	2.671
	M	41.90	42.00	3.20	3.10	3.13	3.207	3.237
	H	41.90	42.00	4.00	3.79	3.82	3.887	3.917
40 (1 1/2")	L	48.40	47.80	2.60	3.23	3.27	3.358	3.398
	M	48.80	47.90	3.20	3.56	3.60	3.681	3.721
	H	48.80	47.90	4.00	4.37	4.41	4.485	4.525
50 (2")	L	60.20	59.60	2.90	4.08	4.15	4.225	4.295
	M	60.80	59.70	3.60	5.03	5.10	5.166	5.236
	H	60.80	59.70	4.50	6.19	6.26	6.349	6.419
65 (2 1/2")	L	76.00	75.20	3.20	5.71	5.83	5.898	6.018
	M	76.60	75.30	3.60	6.42	6.54	6.621	6.741
	H	76.60	75.30	4.50	7.93	8.05	8.095	8.215
80 (3")	L	88.70	87.90	3.20	6.72	6.89	6.952	7.122
	M	89.50	88.00	4.00	8.36	8.53	8.586	8.756
	H	89.50	88.00	4.80	9.90	10.40	10.109	10.609
100 (4")	L	113.90	113.00	3.60	9.75	10.00	10.276	10.586
	M	115.00	113.10	4.50	12.20	12.50	12.758	13.258
	H	115.00	113.10	5.40	14.50	14.80	15.252	15.552
125 (5")	M	140.80	138.50	4.80	15.90	16.40	16.649	17.149
	H	140.80	138.50	5.40	17.90	18.40	18.619	19.119
150 (6")	M	166.50	163.90	4.80	18.90	19.50	19.700	20.000
	H	166.50	163.90	5.40	21.30	21.90	22.322	22.922

TOLERANCES

Thickness: Light Tubes : + Not limited - 8%

Medium Heavy Tubes : + Not limited -10%

Weigh :

1. Single tube (Light Series) : + 10% - 8%
2. Single tube (Medium & Heavy Series) : + 10% - 10%
3. For quantities per load of 10 tonnes min (Light Series) : + 17.5% - 5%
4. For quantities per load of 10 tonnes min (Medium Heavy tubes) : ± 7.5%

For purpose of checking Minimum weight the lot size to be 10 MT.

Table 3.14 : Application of Pipe, Fittings, and Valves for Heating and Air-Conditioning

Application	Pipe Material	Thickness	Joint type	Fitting		System	
				Class	Material	Temp, F	Maximum pressure at Temp psig
Recirculating Water	Steel (CW) Copper, hard PVC CPVC PB	Standard Type L Sch 80 Sch 8O SDR-II	Thread Braze or Silver Solder Solvent Solvent Heat Fusion Insert Crimp	125 Sch 8O Sch 8O	Cast Iron Wrought Copper PVC CPVC PB Metal	250 250 75 150 160 160	125 150
2.5 to 12 in.	A 53 BERW Steel	Standard	Weld	Standard	Wrought Steel	250	400
			Flange	150	Wrought Steel	250	250
			Flange	125	Cast Iron	250	175
			Flange	250	Cast Iron	250	400
			Groove		MI or ductile iron	230	300
	PB	SDR-11	Heat Fusion		PB	160	
Steam and Condensate	Steel (CW)	Standard	Thread	125	Cast Iron		90
2 in. & smaller			Thread	150	Malleable Iron		90
		Standard	Thread	125	Cast Iron		100
			Thread	150	Malleable Iron		125
		XS	Thread	250	Cast Iron		200
			Thread	300	Malleable Iron		250
2.5 to 12 in.	Steel	Standard	Weld	Standard	Wrought Steel		250
			Flange	150	Wrought Steel		200
			Flange	125	Cast Iron		100
	A53 ERW Steel	XS	Weld	XS	Wrought Steel		700
			Flange	300	Wrought Steel		500
			Flange	,250	Cast Iron		200
Refrigerant	Copper, hard	Type L or K	Braze		Wrought copper		
	A53, B SML Steel	Standard	Weld		Wrought Steel		

a. Maximum allowable working pressures have been derated in this table. Higher system pressures can be used for lower temperatures and smaller pipe sizes. Pipe, fillings, joints and valves must all be considered.

b. Lead and Antimony-based solders should not be used for potable water systems. Brazing and silver solders should be employed. c. Extra strong pipe is recommended for all threaded condensate piping to allow for corrosion.

Table 3.15 : Larger Diameters Pipes as per IS : 3589 Physical Data

Outside Inches	Dia. mm	Wall thickness		Weight Kg/m
		Inches	mm	
8.5/8	219.1	0.1970	5.00	26.40
"	"	0.2122	5.40	28.45
"	"	0.2362	6.00	31.53
"	"	0.2756	7.00	36.61
"	"	0.3148	8.00	41.65
	"	0.3740	9.50	49.10
10.3/4	273.05	0.1970	5.00	33.06
"	"	0.2122	5.40	35.64
"	"	0.2362	6.00	39.51
"	"	0.2756	7.00	45.92
"	"	0.314,	8.00	52.29
	"	0.3740	9.50	61.74
12.3/4	323.8	0.1970	5.00	39.30
"	"	0.2122	5.40	42,40
"	"	0.2362	6.00	47.02
"	"	0.2756	7.00	54.69
"	"	0.3148	8.00	62.30
"	"	0.3740	9.50	73.63
14	355.6	0.1970	5.00	43.23
"	"	0.2122	5.40	46.63
"	"	0.2362	6.00	51.72
"	"	0.2756	7.00	60.17
"	"	0.3148	8.00	68.58
"	"	0.3740	9.50	81.08

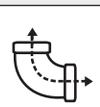
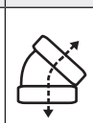
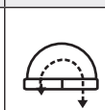
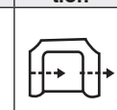
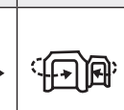
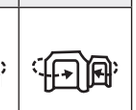
Table 3.16 : Compatibility of Plastic Materials

	PVC	CPVC	PB	HOPE	PP	ABS	PVOF	RTRP
Cold water service	R	R	R	R	R	R	R	R
Hot (140°F) water	N	R	R	R	R	R	R	R
Portable water service	R	R	R	R	R	R	R	R
Drain, Waste & Vent	R	R	N	-	R	R	-	-
Demineralized Water	R	R	-	-	R	R	R	-
Deionized Water	R	R	-	-	R	R	R	R
Salt Water	R	R	R	R	R	R	-	R
Heating (200^{0}F) Hot Water	N	N	N	N	N	N	-	R
Natural gas	N	N	N	R	N	N	-	-
Compressed air	N	N			N	R	_	-
Sunlight and weather Resistance	N	N	N	R	-	R	R	R
Underground service	R	R	R	R	R	R		R
Food handling	R	R		-	R	R	R	R

R = Recommended
N = Not Recommended = Insufficient Information

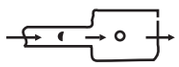
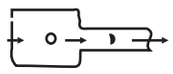
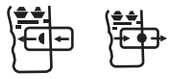
(a) Before selecting a material, check the availability of a suitable range of sizes and fittings, and of a satisfactory joining method. Also, have the manufacturer verify the best material for the purpose intended.
(b) Local building codes should be followed for compliance of the materials listed.

Table 3.17 : Fitting Losses in Equivalent Metres of Pipe

Nominal Pipe of Tube Size, mm	Smooth Bend Elbows						Smooth Bend Tees			
								Straight - Through Flow		
	90° Std[a]	90° Long Rad[b]	90° Street[a]	45° Std[a]	45° Street[b]	180° Std[a]	Flow Through Branch	No Reduc-tion	Reduced 1/4	Reduced 1/2
										
10	0.4	0.3	0.7	0.2	0.3	0.7	0.8	0.3	0.4	0.4
15	0.5	0.3	0.8	0.2	0.4	0.8	1.9	0.3	0.4	0.5
20	0.6	0.4	1.0	0.3	0.5	1.0	1.2	0.4	0.6	0.6
25	0.8	0.5	1.2	0.4	0.6	1.2	1.5	0.5	0.7	0.8
32	1.0	0.7	1.7	0.5	0.9	1.7	2.1	0.7	0.9	1.0
40	1.2	0.8	1.9	0.6	1.0	1.9	2.4	0.8	1.1	1.2
50	1.5	1.0	2.5	0.8	1.4	2.5	3.0	1.0	1.4	1.5
65	1.8	1.2	3.0	1.0	1.6	3.0	3.7	1.2	1.7	1.8
80	2.3	1.5	3.7	1.2	2.0	3.7	4.6	1.5	2.1	2.3
90	2.7	1.8	4.6	1.4	2.2	4.6	5.5	1.8	2.4	2.7
100	3.0	2.0	5.2	1.6	2.6	5.2	6.4	2.0	2.7	3.0
125	4.0	2.5	6.4	2.0	3.4	6.4	7.6	2.5	3.7	4.0
150	4.9	3.0	7.6	2.4	4.0	7.6	9	3.0	4.3	4.9
200	6.1	4.0	-	3.0	-	10	12	4.0	5.5	6.1
250	7.6	4.9	-	4.0	-	13	15	4.9	7.0	7.6
300	9.1	5.8	-	4.9	-	15	18	5.8	7.9	9.1
350	10	7.0	-	5.5	-	17	21	7.0	9.1	10
400	12	7.9	-	6.1	-	19	24	7.9	11	12
450	13	8.8	-	7.0	-	21	26	8.8	12	13
500	15	10	-	7.9	-	25	30	10	13	15
600	18	12	-	9.1	-	29	35	12	15	18

[a] R/D approximately equal to 1 [b] R/D approximately equal to 1.5

Table 3.18 : Special Fitting Losses in Equivalent Metres of Pipe

Nominal Pipe of Tube Size, mm	Sudden Enlargement, d/D			Sudden Contraction d/D			Sharp Edge		Pipe Protection	
	1/4	1/2	3/4	1/4	1/2	3/4	Entrance	Exit	Entrance	Exit
										
10	0.4	0.2	0.1	0.2	0.2	0.1	0.5	0.2	0.5	0.3
15	0.5	0.3	0.1	0.3	0.3	0.1	0.5	0.3	0.5	0.5
20	0.8	0.5	0.2	0.4	0.3	0.2	0.9	0.4	0.9	0.7
25	1.0	0.6	0.2	0.5	0.4	0.2	1.1	0.5	1.1	0.8
32	1.4	0.9	0.3	0.7	0.5	0.3	1.6	0.8	1.6	1.3
40	1.8	1.1	0.4	0.9	0.7	0.4	2.0	1.0	2.0	1.5
50	2.4	1.5	0.5	1.2	0.9	0.5	2.7	0.3	2.7	2.1
65	3.0	1.9	0.6	1.5	1.2	0.6	3.7	1.7	3.7	2.7
80	4.0	2.4	0.8	2.0	1.5	0.8	4.3	2.2	4.3	3.8
90	4.6	2.8	0.9	2.3	1.8	0.9	5.2	2.6	5.2	4.0
100	5.2	3.4	1.2	2.7	2.1	1.2	6.1	3.0	6.1	4.9
125	7.3	4.6	1.5	3.7	2.7	1.5	8.2	4.3	8.2	6.1
150	8.8	6.7	1.8	4.6	3.4	1.8	10	5.8	10	7.6
200	-	7.6	1.8	-	4.6	2.6	14	7.3	14	10
250	-	9.8	2.6	-	6.1	3.4	18	8.8	18	14
300	-	12.4	3.4	-	7.6	4.0	22	11	22	17
350	-	-	4.0	-	-	4.9	26	14	26	20
400	-	-	4.9	-	-	5.5	29	15	29	23
450	-	-	5.5	-	-	6.1	35	18	35	27
500	-	-	6.1	-	-	-	43	21	43	33
600	-	-		-	-	-	50	25	50	40

Note : Enter Table for losses at smallest diameter d
Source : Carrier Handbook

Table 3.19 : Proper Flow and Pressure Required During Flow For Different Fixtures

Fixture	Flow Pressure, psig	Flow, gpm
Ordinary basin faucet	8	3.0
Self-closing basin faucet	12	2.5
Sink faucet -3/8 in.	10	4.5
Sink faucet -1/2 in.	5	4.5
Dishwasher	15-25	a
Bathtub faucet	5	6.0
Laundry tube cock -1/4 in.	5	5.0
Shower	12	3-10
Ballcock for closet	15	30
Flush valve for closet	10-20	15-40[b]
Flush valve for urinal	15	15.0
Garden hose, 50ft and sillcock	30	5.0

Flow Pressure is the pressure in the pipe at the entrance to the particular fixture considered.

a* Varies see manufacturer's data

b* wide range due to variation in design and type of flush valve closets

Table 3.20 : Pressure drops used for sizing steam pipe*

Initial steam pressure, psig	Pressure drop per 100 ft	Total pressure drop in steam supply piping
Vaccum return	1/8 psi	1 to 2 psi
0	1/32 psi	1/16 psi
1	1/8 psi	1/4 psi
2	1/8 psi	0.5 psi
5	1/4 psi	1.5 psi
10	1/2 psi	3 psi
15	1 psi	4 psi
30	2 psi	5 to 10 psi
50	2 to 5 psi	10 to 15 psi
100	2 to 5 psi	15 to 25 psi
150	2 to 10 psi	25 to 30 psi

* Equipment control valves and so forth must be selected based on delivered pressures.

Source: ASHRAE Handbook

Table 3.21 : Suggested Hanger Spacing and Rod Size for Straight Horizontal Pipe Runs

OD inches	Standard Steel Pipe, (ft.)		Copper Tube, (ft.)	Rod Size inches
	Water	Steam	Water	
1 / 2	7	8	5	1 / 4
3 / 4	7	9	5	1 / 4
1	7	9	6	1 / 4
1 1 / 2	9	12	8	3 / 8
2	10	13	8	3 / 8
2 1 / 2	11	14	9	3 / 8
3	12	15	10	3 / 8
4	14	17	12	1 / 2
6	17	21	14	1 / 2
8	19	24	16	5 / 8
10	20	26	18	3 / 4
12	23	30	19	7 / 8
14	25	32		1
16	27	35		1
18	28	37		1 1 / 4
20	30	39		1 1 / 4
Spacing does not apply where span calculations are made or where concentrated loads are placed between supports such as flanges, Valves, specialties, etc.				

Table 3.22 : Valve Losses in Equivalent Meters of Pipe

Nominal Pipe or Tube size, mm	Straight Thru Globe[a]	Angled Globe 60⁰ - Y	Angled Globe 45⁰ - Y	Angle Valve (90⁰)	Gate	Swing Check and Ball Check	Lift Check
10	5.2	2.4	1.8	1.8	0.2	1.5	Globe And Vertical lift check same as globe valve
15	5.5	2.7	2.1	2.1	0.2	1.8	
20	6.7	3.4	2.1	2.1	0.3	2.2	
25	8.8	4.6	3.7	3.7	0.3	3	
32	12	6.1	4.6	4.6	0.5	4.3	
40	13	7.3	5.5	5.5	0.5	4.9	
50	17	9.1	7.3	7.3	0.73	6.1	
65	21	11	8.8	8.8	0.9	7.6	
80	26	13	11	11	1	9.1	
90	30	15	13	13	1.2	10	
100	37	18	14	14	1.4	12	
125	43	22	18	18	1.8	15	
150	52	27	21	21	2.1	18	
200	62	35	26	26	2.7	24	
250	85	44	32	32	3.7	30	Angle lift same as angle valve
300	98	50	40	40	4	37	
350	110	56	47	47	4.6	41	
400	125	64	55	55	5.2	46	
450	140	73	61	61	5.8	50	
500	160	84	72	72	6.7	61	
600	186	98	81	81	7.6	73	

Values are for valves in fully open position.

Table 3.23 : Fouling Factors

Recommended minimum fouling allowances (f) for water flowing at 3 ft / sec[b] or higher			
			$Ft^2h.$ F/BTU
	Distilled Water		0.0005
	Water, closed system		0.0005
	Water, open system		0.0010
	Inhibited cooling tower		0.0015
	Engine jacket		0.0015
	Treated boiler feed (212 F)		0.0015
	Hard well water		0.0030
	Untreated cooling tower		0.0033
Steam :			
	Dry, clean and oil free		0.0003
	Wet, clean and oil free		0.0005
	Exhaust from turbine		0.0010
		Non-ferrous	**Ferrous**
Brines :		**Tubes**	**Tubes**
	Methylene Chloride	None	None
	Inhibited Salts	0.0005	0.0010
	Non-inhibited salts	0.0010	0.0020
	Inhibited glycols	0.0010	0.0020
Vapours and Gases :			
	Refrigerant vapours		None
	Solvent vapours		0.0008
	Air, (clean) centrifugal compressor		0.0015
	Air, reciprocating compressor		0.0030
Other liquids :			
	Organic solvents (clean)		0.0001
	Vegetable oils		0.0040
	Quenching oils (filtered)		0.0050
	Fuel oils		0.0060
	Sea water		0.0005

b-lower velocity requires higher value

Hardness of Water

Water supplies may be divided into four groups expressed as parts per million of Calcium Carbonate.

Class A :	Less than 60	Soft
Class B :	60 - 120	Medium
Class C :	120-180	Hard
Class D :	Above 180	Very Hard
Class C & D :	Generally require softening treatment.	

pH - is a measure of acidity. pH is negative logarithm, base 10 of the concentration of the hydrogen ions, in gms / litre. Water having a pH of 7.0 is exactly neutral; a pH less than 7 is acidic: while a pH greater than 7 is alkaline. Water having a pH of 6 is mildly acidic and any figure below 5 is considered distinctly acidic, and quite corrosive, to ordinary metals. Natural unpolluted water usually has pH between 7 & 8.5.

Table 3.24 : Heat Transfer Surface Required to Offset Fouling

FOULING THERMAL RESISTANCE (h*) (sq ft/(deg-f temp diff) / Btu	OVERALL HEAT TRANSFER COEFFICIENT Btu/hr) (sq.ft) ideal F temp diff		THICKNESS OF SCALE* APPROX. (In.)	INCREASE OF REQUIRED HEAT TRANSFER AREA in % Approximate	
	Cooler	Condenser		Cooler	Condenser
Clean tubes	400	850	.002	0	0
0.0005	333	595	.004	20	45
0.001	286	460	.011	40	85
0.002	222	315	.024	80	170
0.003	100	240	.034	120	250

*Assume a mean value for the thermal conductivity of the scale of 1.0 Btu/hr (sf ft) (deg f per ft).

The overall Heat Transfer Coefficients selected for this illustration are typical for a Fooded Cooler and a Water-Cooled Refrigerant Condenser. However accurate, it is possible to have different overall Heat Transfer Coefficients depending on the systems, the effect on the overall heat transfer by the scale will vary.

(Sq.ft. inside surface of Tube in Heat Exchangers).

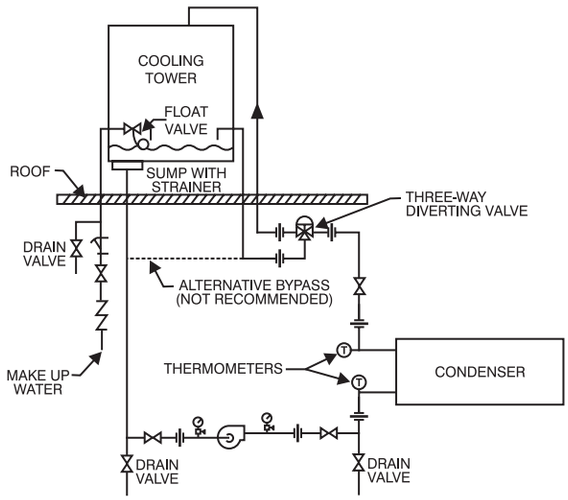


Figure 3.8 : Cooling Tower Piping System

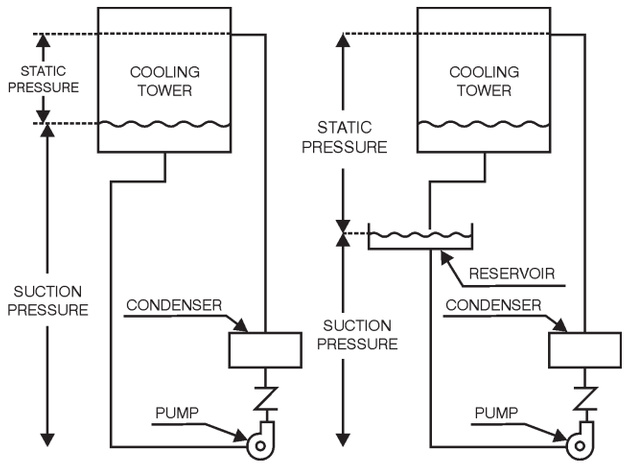


Figure 3.9 : Schematic Piping Layout Showing Static and Suction Head

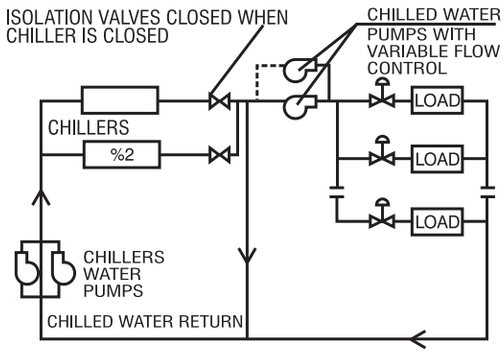


Figure 3.9a : Variable Flow Chilled-water System (Primary / Secondary)

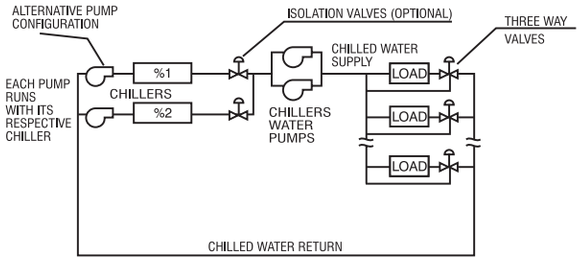


Figure 3.10 : Variable Flow Chilled Water System

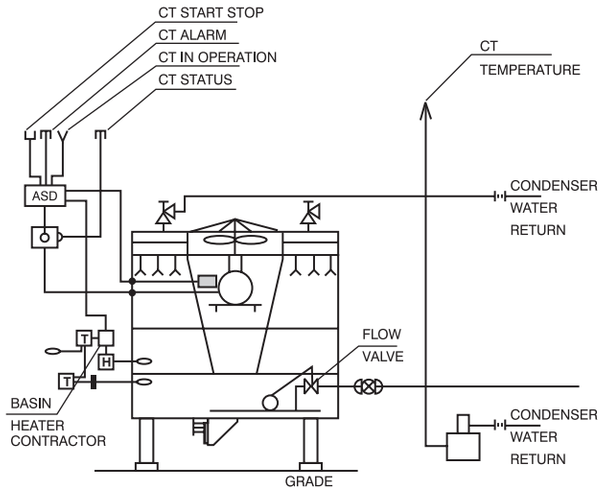
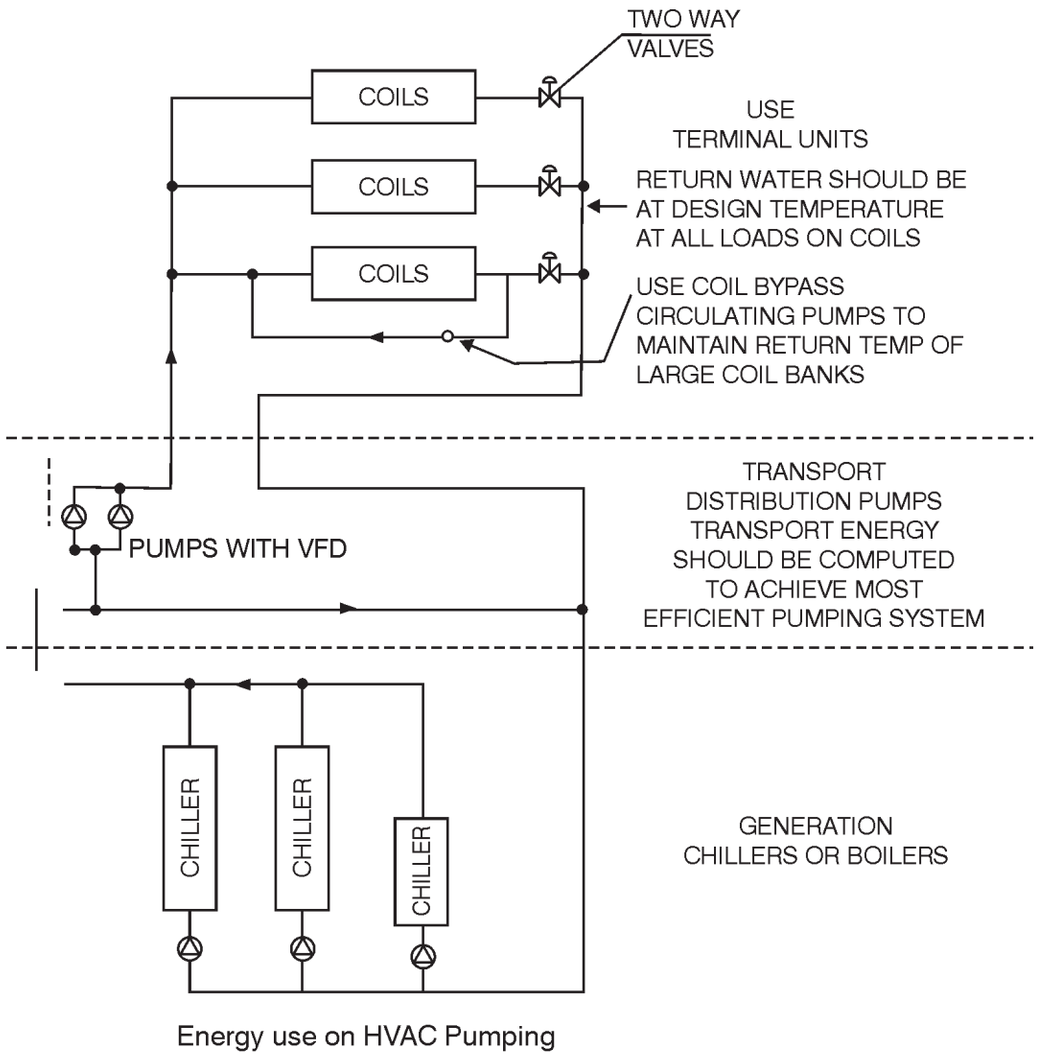
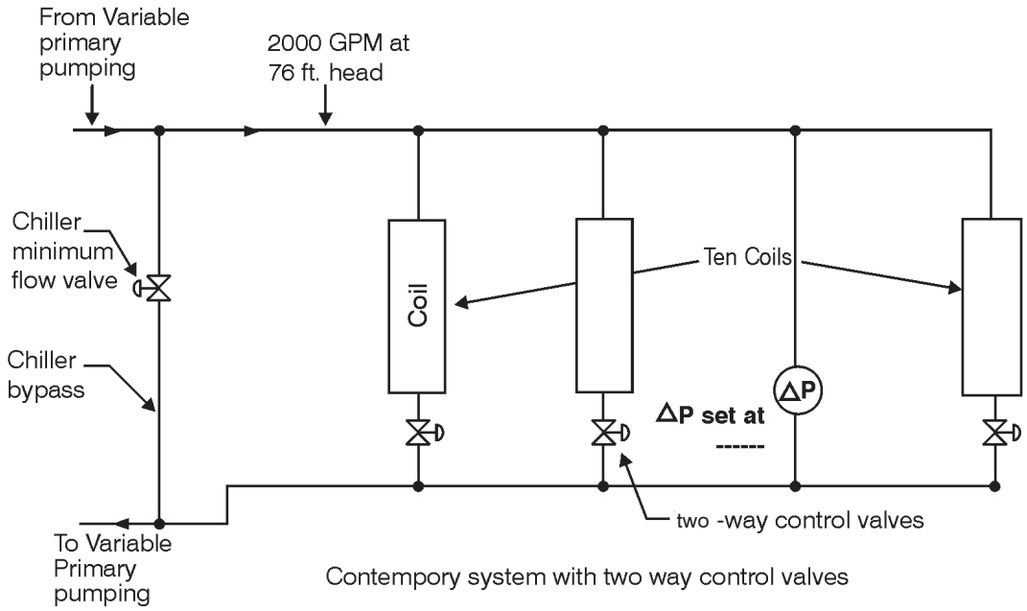


Figure 3.11 : Cooling Water

Source : ASHRAE Handbook



Energy use on HVAC Pumping



Contempory system with two way control valves

Figure 3.12 : Energy use in HVAC Pumping

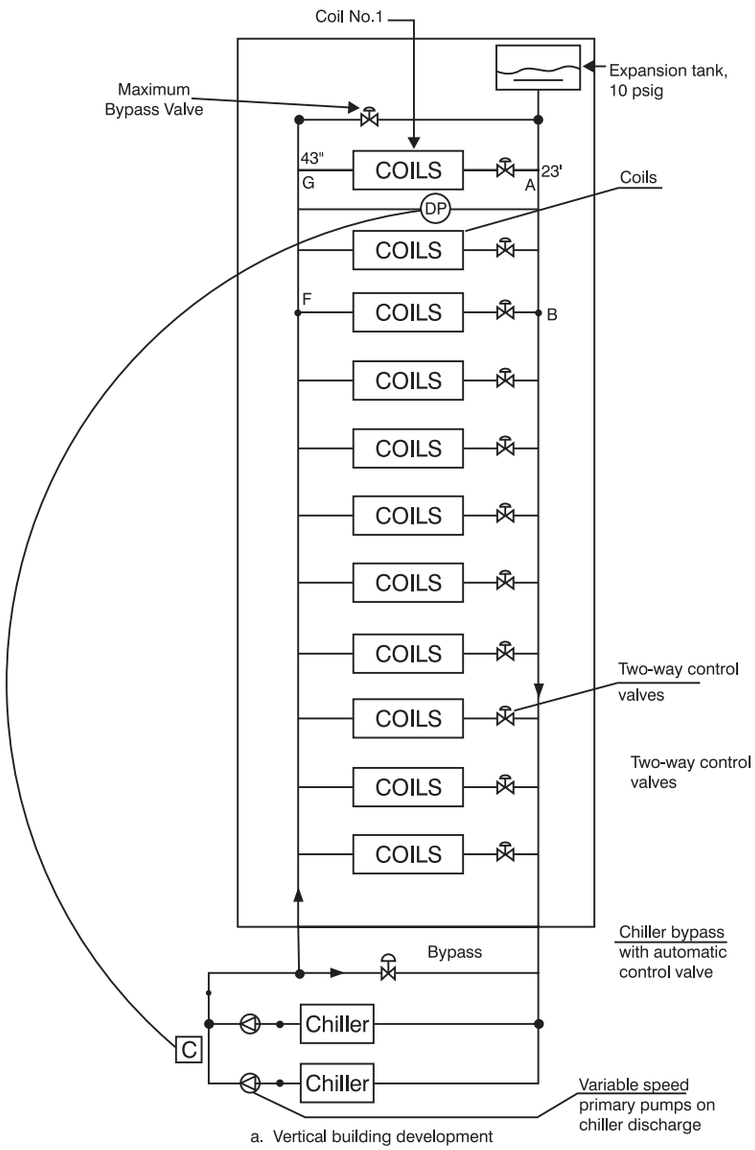


Figure 3.13 : Vertical Building Chilled Water Piping

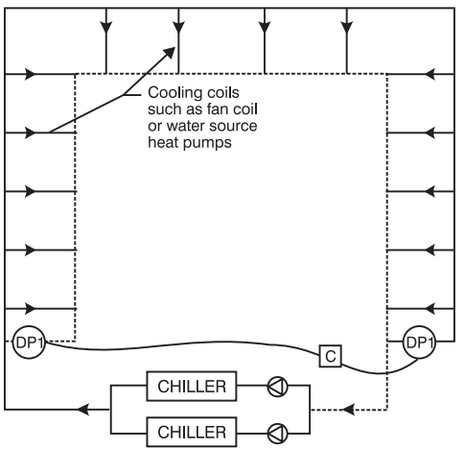


Figure 3.14 : Reverse return for low control valve differential

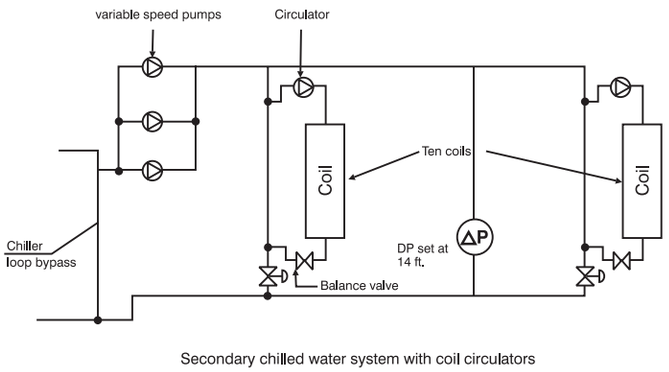


Figure 3.15 : Secondary Chilled water system with coil circulator (Example)

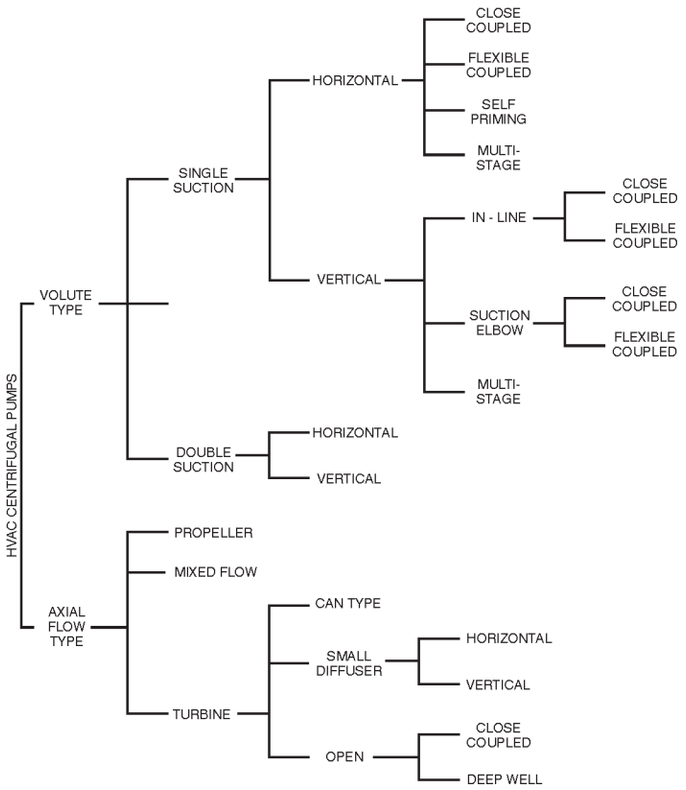


Figure 3.16 : Classification of HVAC pumps

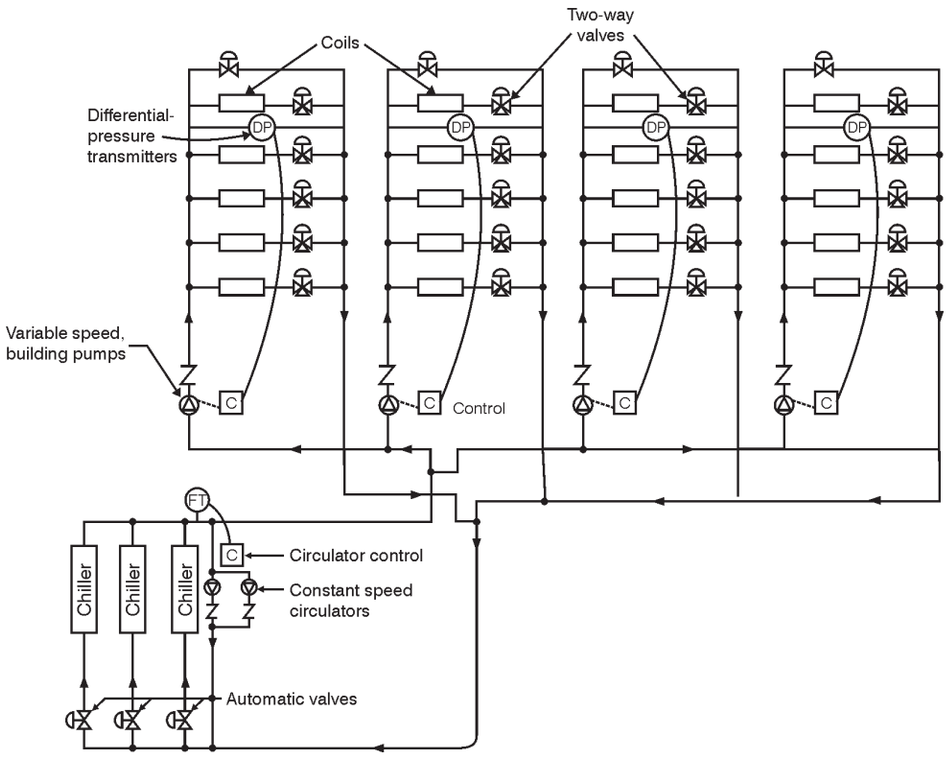
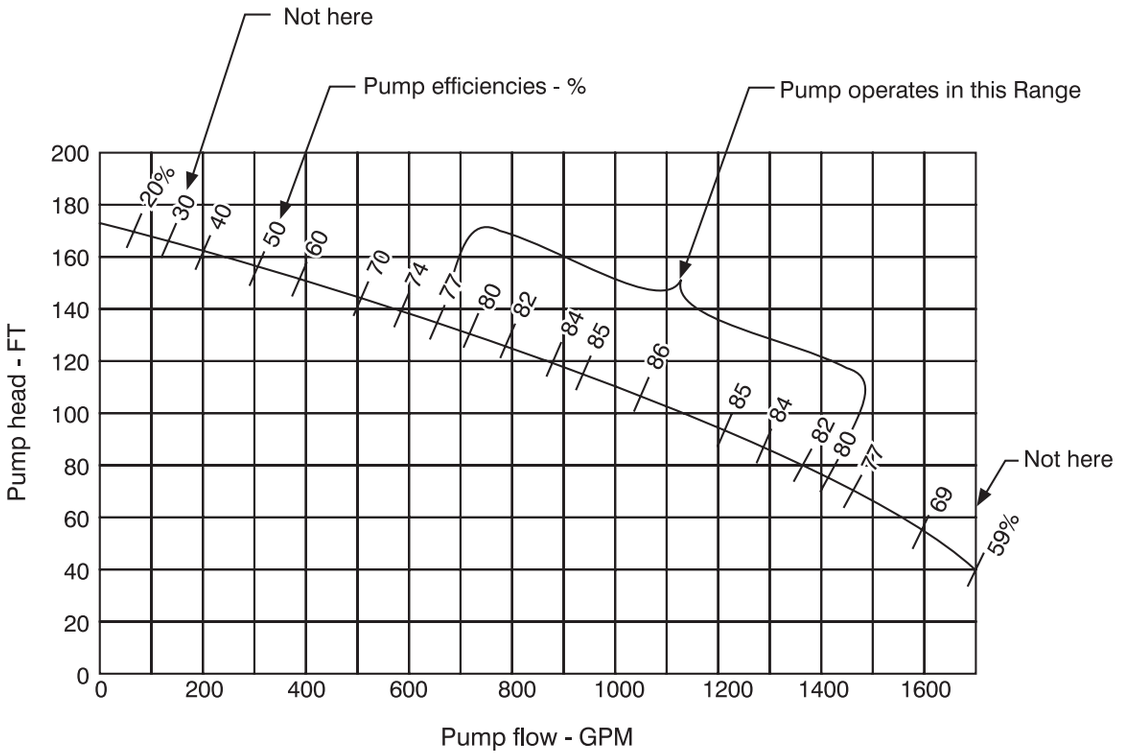


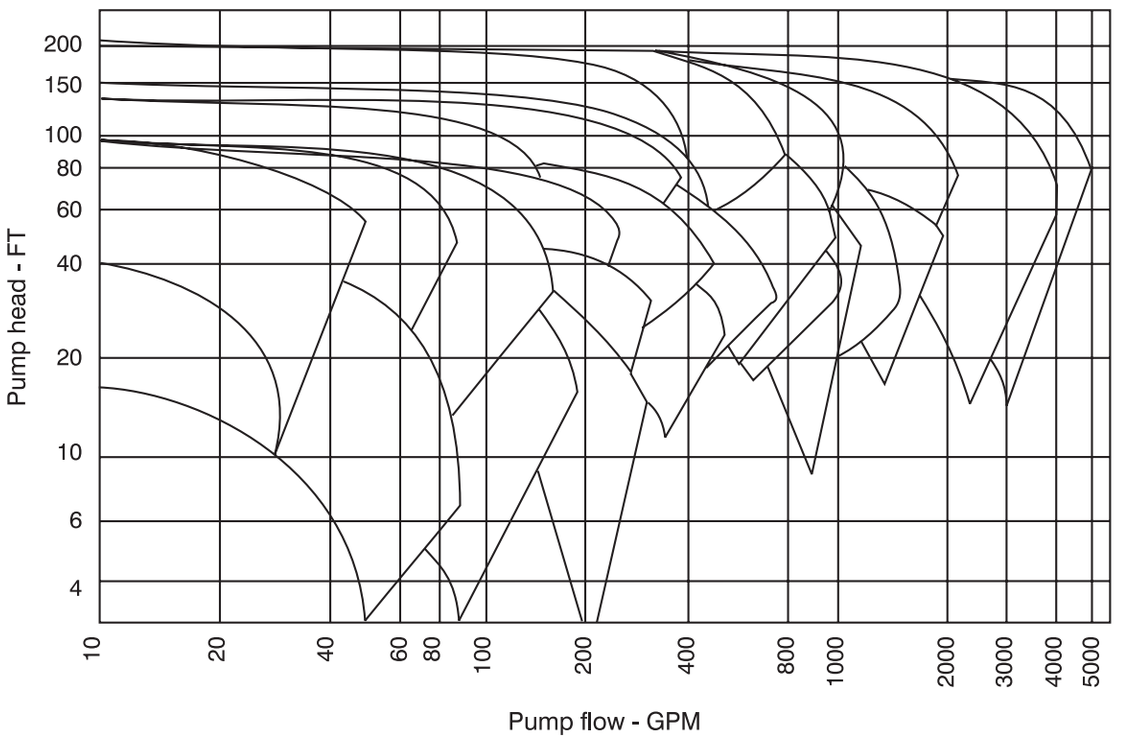
Figure 3.17 : Distributed pumping with small circulators in chilled plant

NOTE : All VFD Driver Motors are required to run at a minimum speed for proper Motor Cooling

Source : HVAC Pump Handbook



a. Typical pump head - flow curve for one pump size.



b. Family of pump head - flow curve.

Figure 3.18 : HVAC pumps and their Performance

Source : Carrier Handbook

a) Flow rate and Velocity of Steam in Schedule 40 pipe at Saturation Pressure of 0 psig

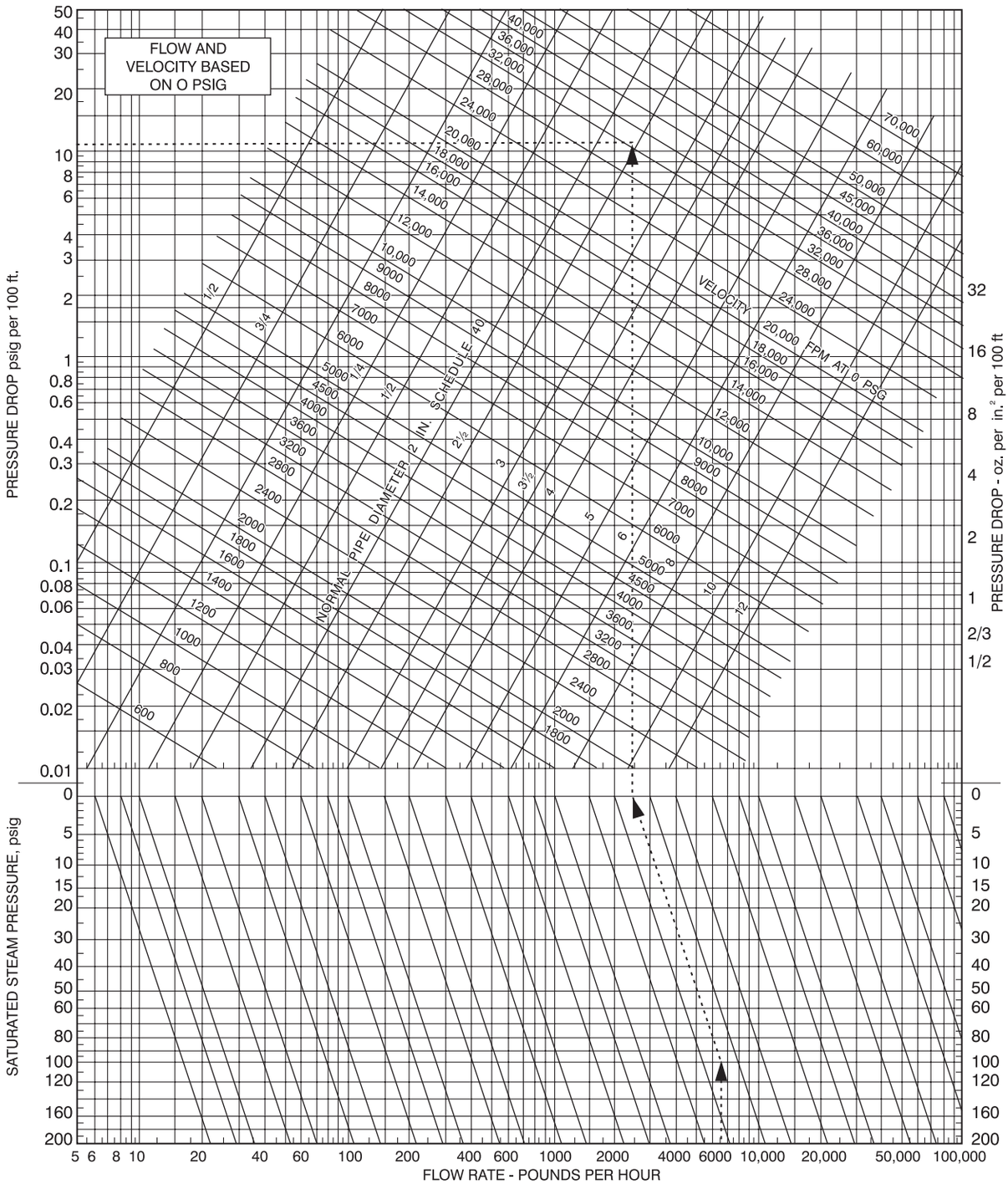


Figure 3.19 a : Steam Pipe Sizing

Source : Carrier Handbook

b) Flow rate and Velocity of Steam in Schedule 40 pipe at Saturation Pressure of 30 psig

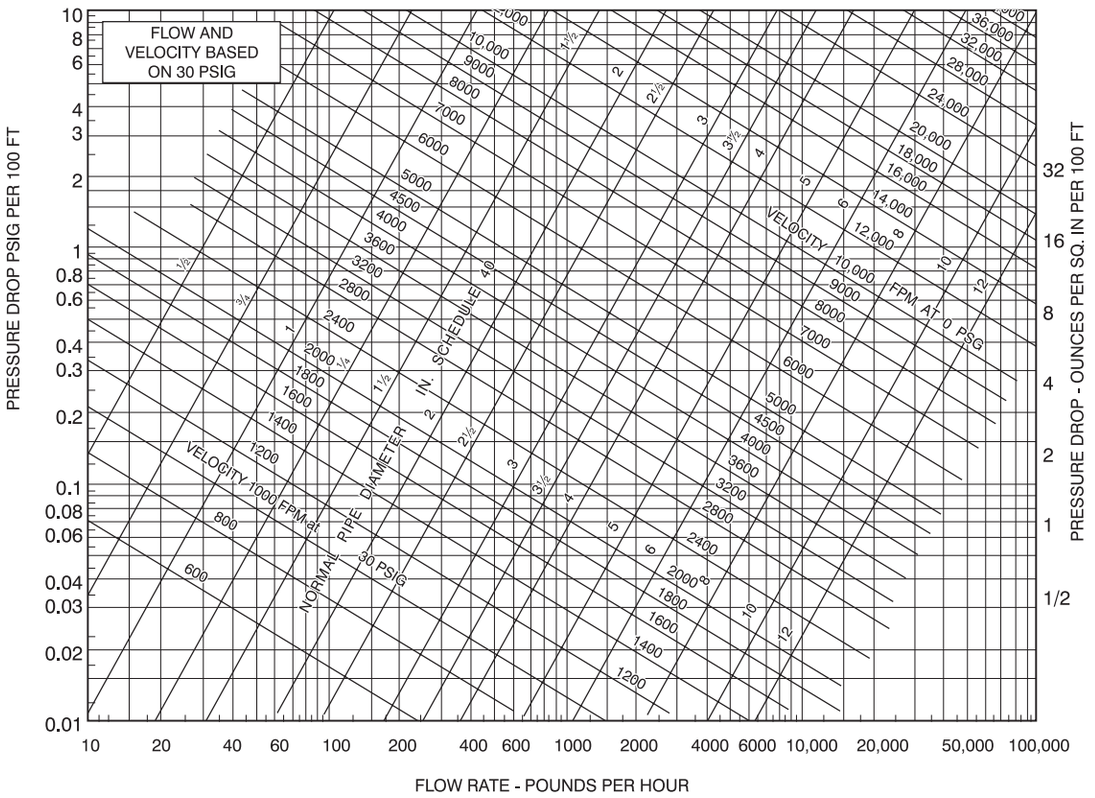


Figure 3.19 b : Steam Pipe Sizing

c) Flow rate and Velocity of Steam in Schedule 40 pipe at Saturation Pressure of 50 psig

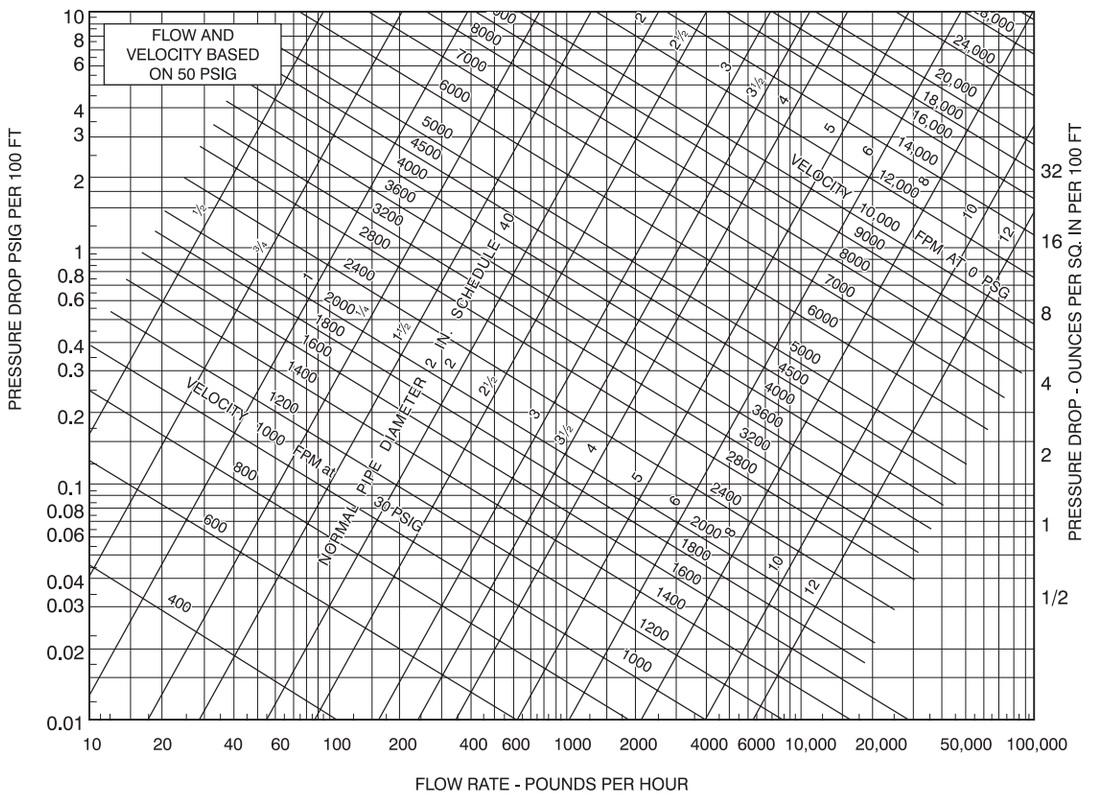


Figure 3.19 c : Steam Pipe Sizing

d) Flow rate and Velocity of Steam in Schedule 45 pipe at Saturation Pressure of 100 psig

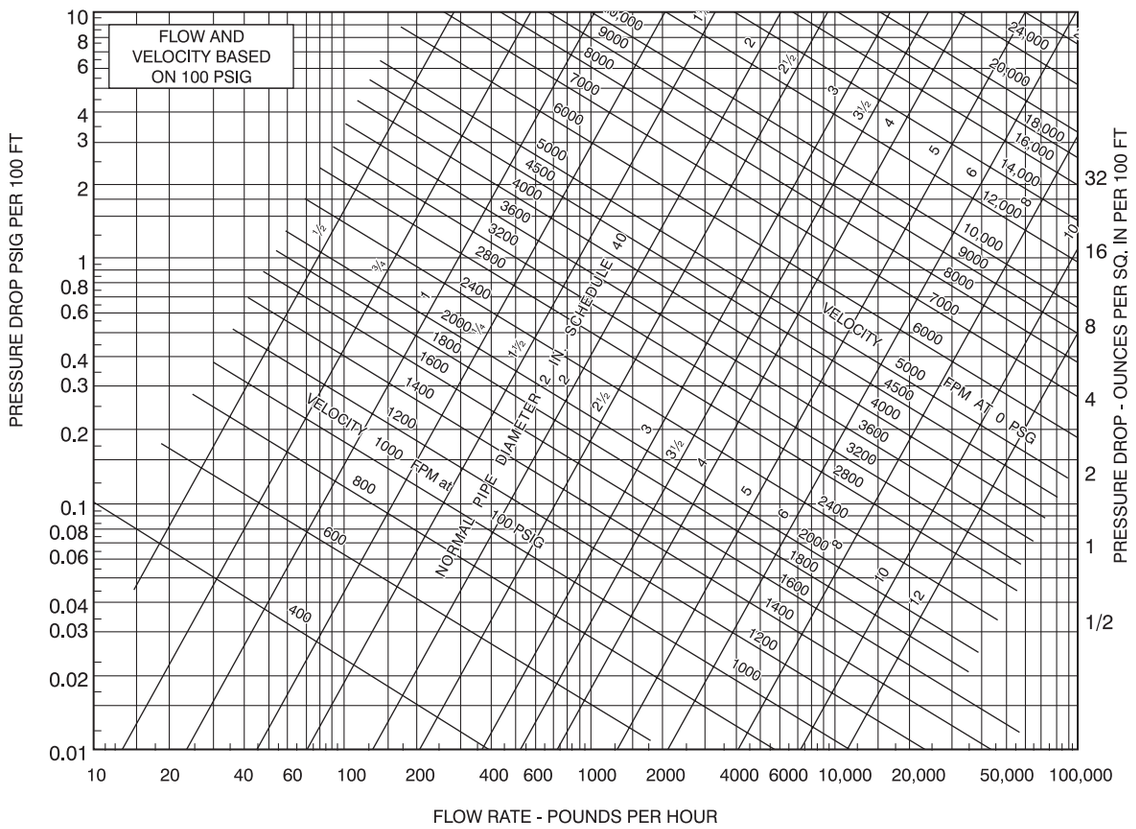


Figure 3.19 d : Steam Pipe Sizing

b) Flow rate and Velocity of Steam in Schedule 45 pipe at Saturation Pressure of 150 psig

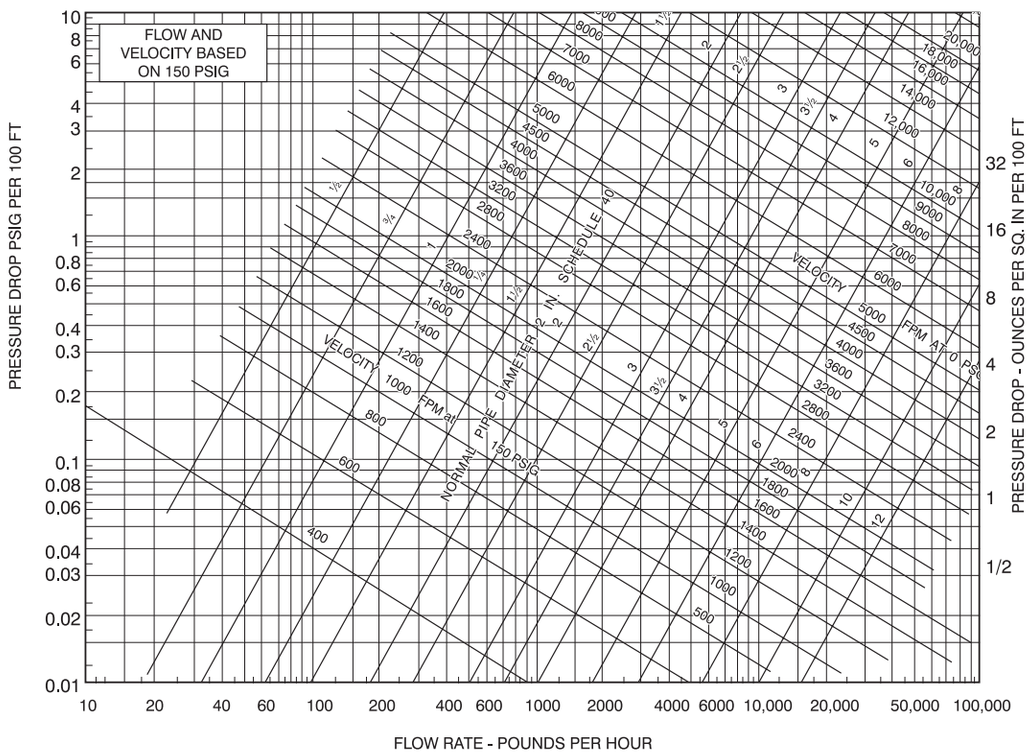


Figure 3.19 e : Steam Pipe Sizing

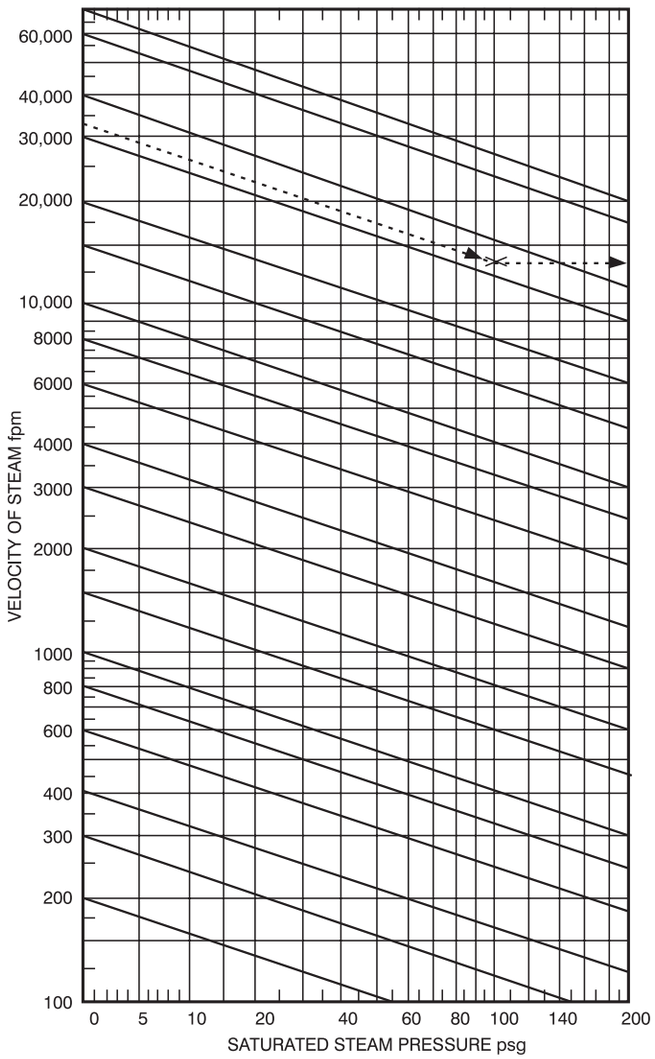


Figure 3.20 : Velocity Multiplier

Use of Basic and Velocity Multiplier Charts

Example 1. Given a flow rate of 6700 lb/h, an initial steam pressure of 100 psig. and a pressure drop of 11 psi / 100ft, find the size of the Schedule 40 pipe required and the velocity of steam in the pipe.

Solution: The following steps are illustrated by the broken line in Figures 3.19a and 3.20.

1. Enter Figure 3.19a at a flow rate of 6700 lb/h, and move vertically to the horizontal line at 100 psig.
2. Follow along inclined multiplier line (upward and to the left) to horizontal 0 psig line. The equivalent mass flow at 0 psig is about 2500lb/h.
3. Follow the 2500 lb/h line vertically until it intersects the horizontal line at 11 psi per 100 ft pressure drop. Nominal pipe size is 2-1/2 in. The equivalent steam velocity at 0 psig is about 32,700 fpm.
4. To find the steam velocity at 100 psig, locate the value of 32,700 fpm on the ordinate of the velocity multiplier chart (Figure 3.20) at 0 psig.
5. Move along the inclined multiplier line (downward and to the right) until it intersects the vertical 100 psig pressure line. The velocity as read from the right (or left) scale is about 13,000 fpm.

Note: Steps 1 through 5 would be rearranged or reversed if different data were given; as an alternate you could use the appropriate chart for 108 psi directly.

Table 3.25 : Low Pressure Steam Pipe Capacities Pounds Per Hour

NOM PIPE SIZE (Inches)	PRESSURE DROP PER 100 FT.													
	1/16 PSI (1OZ)		1/8PSI(2 OZ)		1/4PSI (4 OZ)		1/2 PSI (8 OZ)		3/4PSI (12 OZ)		1psi		2psi	
	Sat. Press.	psig	Sat Press.	psig	Sat Press.	psfg	Sat Press.	psig	Sat. Press.	psig	Sat. Press.	psig	Sat. Press.	psig
	3.5	12	3.5	12	3.5	12	3.5	12	3.5	12	3.5	12	3.5	12
3 / 4	9	11	14	16	20	24	29	35	36	43	42	50	60	73
1	17	21	26	31	37	46	54	66	68	82	81	95	114	137
1 1/4	36	45	53	66	78	96	111	138	140	170	162	200	232	280
1 1/2	56	70	84	100	120	147	174	210	218	260	246	304	360	430
2	108	134	162	194	234	285	336	410	420	510	480	590	710	850
2 1/2	174	215	258	310	378	460	540	660	680	820	780	950	1,150	1,370
3	318	380	465	550	660	810	960	1,160	1,190	1,430	1,380	1,670	1,950	2,400
3 1/2	462	550	670	800	990	1,218	1,410	1,700	1,740	2,100	2,000	2,420	2,950	3,450
4	726	800	950	1,160	1,410	1,690	1,980	2,400	2,450	3,000	2,880	3,460	4,200	4,900
5	1,200	1,430	1,680	2,100	2,440	3,000	3,570	4,250	4,380	5,250	5,100	6,100	7,500	8,600
6	1,920	2,300	2,820	3,350	3,960	4,850	5,700	7,000	7,200	8,600	8,400	10,000	11,900	14,200
8	3,900	4,800	5,570	7,000	8,100	10,000	11,400	14,300	14,500	17,700	16,500	20,500	24,000	29,500
10	7,200	8,800	10,200	12,600	15,000	18,200	21,000	26,000	26,200	32,000	30,000	37,000	42,700	52,000
12	11,400	13,700	16,500	19,500	23,400	28,400	33,000	40,000	41,000	49,500	48,000	57,500	67,800	81,000

Table 3.26: Medium Pressure Steam Pipe Capacities (30 psig)
Pounds Per Hour

NOM PIPE SIZE (Inches)	PRESSURE DROP PER 100 FT.					
	1/8 psi (2 OZ)	1/4 psi (4 OZ)	1/2 psi (8 OZ)	3/4 psi (12 OZ)	1 psi (16 OZ)	2 psi (32 OZ)
SATURATED PRESSURE (psig)						
3/4	15	22	31	38	45	63
1	31	46	63	77	89	125
1 1/4	69	100	141	172	199	281
1 1/2	107	154	219	267	309	437
2	217	313	444	543	627	886
2 1/2	358	516	730	924	1033	1460
3	651	940	1330	1628	1880	2660
3 1/2	979	1414	2000	2447	2825	4000
4	1386	2000	2830	3464	4000	5660
5	2560	3642	5225	6402	7390	10460
6	4210	6030	8590	10240	12140	17180
8	8750	12640	17860	21865	25250	35100
10	16250	23450	33200	40625	46900	66350
12	25640	36930	52320	64050	74000	104500

Table 3.27 : Important Properties of Gasket Materials

Material	Max. Service Temp ^{0}F	Important Properties
Rubber (straight)	225	Good mechanical properties. Impervious to water. Fair to good resistance to acids, alkalies. Poor resistance to oils, gasoline. Poor weathering, aging properties.
Styrene - Butadiene(SBR)	250	Better water resistance than natural rubber. Fair to good resistance to acids, alkalies. Unsuitable with gasoline, oils and solvents.
Butyl	300	Very good resistance to water, alkalies and many acids. Poor resistance to oils, gasoline, most solvents (except oxygenated).
Nitrile	300	Very good water resistance. Excellent resistance to oils, gasoline. Fair to good resistance to acids, alkalies.
Polysulfide	150	Excellent resistance to oils, gasoline, aliphatic and aromatic hydrocarbon solvents. Very good water resistance, good alkali resistance, fair acid resistance. Poor mechanical properties.
Neoprene	250	Excellent mechanical properties. Good resistance to non-aromatic petroleum fatty oils, solvents (except aromatic, chlorinated, or ketone type). Good water and alkali resistance. Fair acid resistance.
Silicone	600	Excellent heat resistance. Fair water resistance; poor resistance to steam at high pressures. Fair to good acid, alkali resistance. Poor (except Fluorosilicone rubber) resistance to oils, solvents.
Acrylic	450	Good heat resistance but poor cold resistance. Good resistance to oils, aliphatic and aromatic hydrocarbons. Poor resistance to water, alkalies, some acids.
Chlorosulphanated Polyethylene(Hypalon)	250	Excellent resistance to oxidising chemicals, ozone, weathering. Relatively good resistance to oils, grease. Poor resistance to aromatic or chlorinated hydrocarbons. Good mechanical properties.
Fluoroelastomer (Viton, Fluorel2141, Kel-F)	450	Can be used at high temperatures with many fuels, lubricants, hydraulic fluids, solvents. Highly resistant to ozone, weathering. Good mechanical properties.
Asbestos compressed Asbestos Rubber sheet	Upto 700	Large number of combinations available. Properties vary widely depending on materials used.
Asbestos: Rubber woven sheet	Upto 250	Same as above.
Asbestos - Rubber (beater addition process)	400	Same as above.
Asbestos composites	400	Same as above.
Asbestos- TFE.....		

Plastics TFE(solid) (Tetrafluoroethylene, Teflon)	500	Excellent resistance to almost all chemicals and solvents. Good heat resistance; exceptionally good low-temperature properties. Relatively low compressibility and resilience.
TFE (filled)	To 500	Selectively improved mechanical and physical properties. However, fillers may lower resistance to specific chemicals.
TFE composites	To 500	Chemical and heat resistance comparable with solid TFE. Inner gasket material provides better resiliency and deformability.
CFE (Chlorotrifluoroethylene, Kel-F)	350	Higher cost than TFE. Better chemical resistance than most other gasket materials, although not quite so good as TFE.
Vinyl	212	Good compressibility, resiliency. Resistant to water, oils, gasoline, and many acids and alkalies. Relatively narrow temperature range.
Polyethylene	150	Resists most solvents. Poor heat resistance.
Plant fiber Neoprene - impregnated wood fiber SBR-bonded cotton	175 - 230	Nonporous; recommended for glycol, oil, and gasoline to 175°F. Good water resistance.
Nitrile rubber-cellulose fiber		Resists oil at high temperatures.
Vegetable fiber, glue binder	212	Resists oil and water to 212°F.
Vulcanised fiber	212	Low cost, good mechanical properties. Resists gasoline, oils, greases, waxes, many solvents.
Inorganic fiber	to 2200°F	Excellent heat resistance, poor mechanical properties.
		Combines heat resistance and Sealing properties of Abestos with Chemical Resistance of TFE.
		Low cost : Truly compressible materials which permit substantial deflections with negligible side flow. Conform well to irregular surfaces. High resistance to oil; good resistance to water, many chemicals. Should not be used with inorganic acids, alkalies, oxidising solutions, live steam. Controlled compressibility properties. Good conformability, fatigue resistance.

Thermal storage

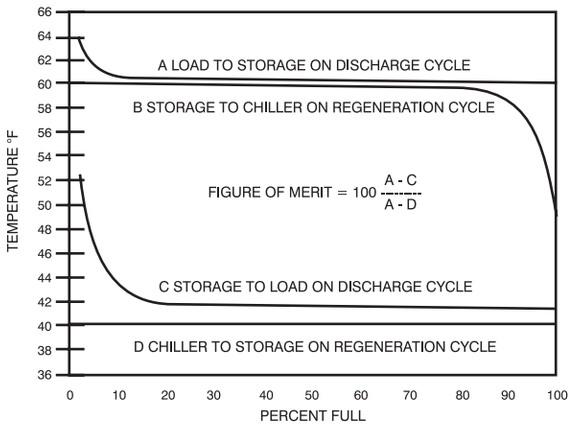


Figure 3.21 : Typical Temperature Stratification Profile in Storage Tank

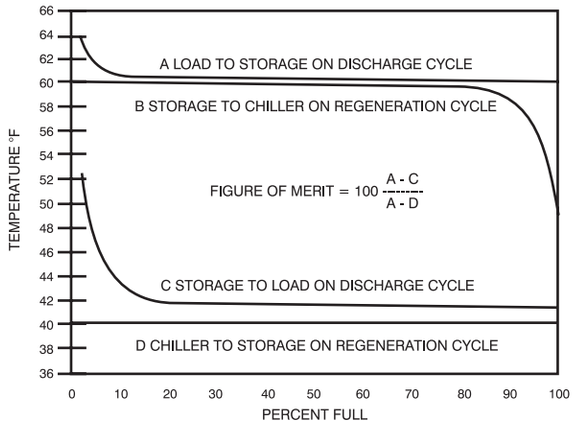


Figure 3.22 : Typical Chilled Water Storage Profiles

Table 3.28: Peak Day Full-Storage TES storage Sizing Calculation (Typical)

Time of Day*	Facility Hourly CHW Load, tons	Chilled Water TES System	
		Centrifugal Chiller Output, tons	TES Charge, ton-hours
12:00 AM	1090	2222	3365
1:00	1019	2222	4568
2:00	959	2222	5831
3:00	975	2222	7078
4:00	969	2222	8331
5:00	968	2222	9585
6:00	1274	2222	10,533
7:00	1358	2222	11,397
8:00	1457	2222	12,162
9:00	1773	2222	12,611
10:00	2176	2222	12,657
11:00	2508	2222	12,371
12:00 PM	2668	2206	11,909
1:00	2833	0	9076
2:00	2900	0	6176
3:00	2900	0	3276
4:00	2784	0	492
5:00	2588	2222	126
6:00	2348	2222	0
7:00	2077	2222	145
8:00	1945	2222	422
9:00	1836	2222	808
10:00	1711	2222	1319
11:00	1308	2222	2233
Total	**44,424**	**44,424**	
TES Tank Size, ton-hours			**12,657**

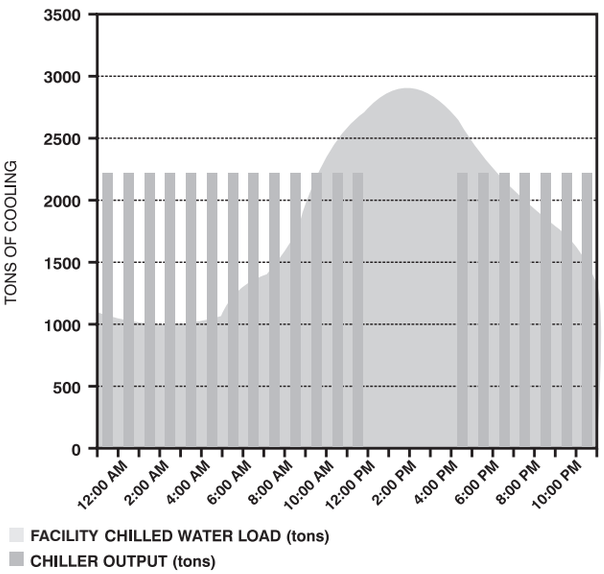


Figure 3.23 : Full Storage TES Tank Peak Day Operation Facility Cooling Load versus chiller output

Table 3.29 : Chilled Water Density

^{0}F	LB/FT^3	^{0}F	LB/FT^3	^{0}F	LB/FT^3
32	62.419	44	62.424	58	62.378
34	62.424	46	62.421	60	62.368
36	62.426	48	62.417	62	62.357
38	62.427	50	42.411	64	62.344
39	62.428	52	62.404	66	62.331
40	62.427	54	62.396	68	62.316
42	62.426	56	62.387		

Table 3.30 : Peak Day Partial-Storage TES Sizing Calculations (Typical)

Time of Day*	Facility Hourly CHW Load, tons	Chilled Water TES System	
		Centrifugal Chiller Output, tons	TES Charge, ton-hours
12:00 AM	1090	1851	1459
1:00	1019	1851	2291
2:00	959	1851	3183
3:00	975	1851	4059
4:00	969	1851	4941
5:00	968	1851	5824
6:00	1274	1851	6401
7:00	1358	1851	6894
8:00	1457	1851	7288
9:00	1773	1851	7366
10:00	2176	1851	7041
11:00	2508	1851	6384
12:00 PM	2668	1851	5567
1:00	2833	1851	4585
2:00	2900	1851	3536
3:00	2900	1851	2487
4:00	2784	1851	1554
5:00	2588	1851	817
6:00	2348	1851	320
7:00	2077	1851	94
8:00	1945	1851	0
9:00	1836	1851	15
10:00	1711	1851	155
11:00	1308	1851	698
Total	**44,424**	**44,424**	
TES Tank Size, ton-hours			**7366**

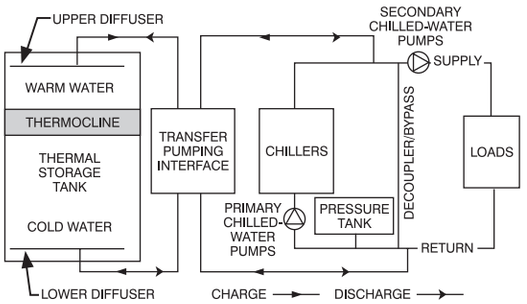


Figure 3.24 : Typical Sensible Storage Connection Scheme

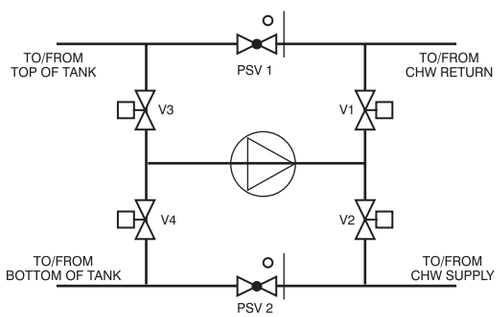


Figure 3.26 : Direct Transfer Pumping Interface

Table 3.31 : Design Day Chiller and Storage Load Contributions and Leaving Coolant Temperatures (LCT) (Typical)

HOUR	COOLING LOAD, TONS	CHILLER TONS	STORAGE TONS	STORAGE INVENTORY, TON-HOURS	PRIMARY RETURN TEMP. °F	CHILLER LCT, °F	STORAGE LCT, °F
1	0	350	350	1750		25.7	31.3
2	0	350	350	2100		25.4	31.0
3	0	350	350	2450		25.0	30.6
4	0	350	350	2800		24.4	30.0
5	0	350	350	3150		23.6	29.2
6	0	350	350	3500		22.5	28.1
7	0	0	0	3500		-	-
8	0	0	0	3500		-	-
9	750	500	-250	3250	54.0	46.0	32.3
10	650	500	-150	3100	52.4	44.4	32.4
11	700	500	-200	2900	53.2	45.2	32.5
12	750	500	-250	2650	54.0	46.0	32.9
13	800	500	-300	2350	54.8	46.8	33.3
14	850	500	-350	2000	55.6	47.6	34.3
15	950	500	450	1550	57.2	49.2	36.6
16	1000	500	-500	1050	58.0	50.0	38.6
17	950	500	450	600	57.2	49.2	39.1
18	850	500	-350	250	55.6	47.6	39.0
19	750	500	-250	0	54.0	46.0	42.0
20	0	0	0	0		-	-
21	0	350	350	350		26.2	31.8
22	0	350	350	700		26:1	31.7
23	0	350	350	1050		26.0	31.6
24	0	350	350	1400		25.9	31.5

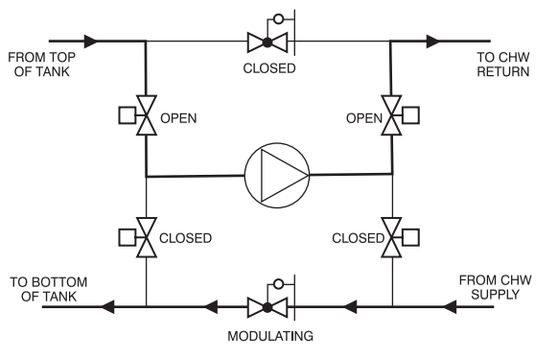


Figure 3.25 : Charge mode status of direct transfer pumping interface

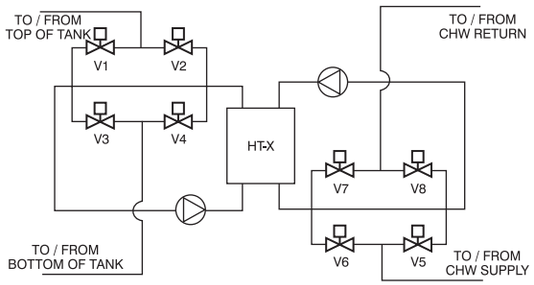


Figure 3.27 : Indirect Transfer Pumping Interface

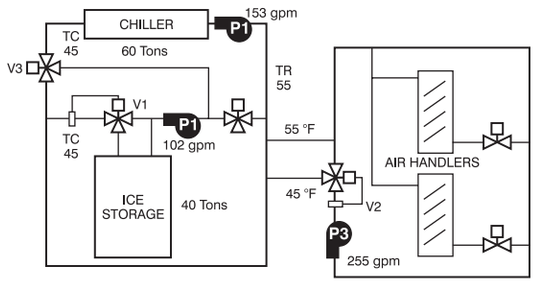


Figure 3.28 : Parallel Flow for Chiller and Storage

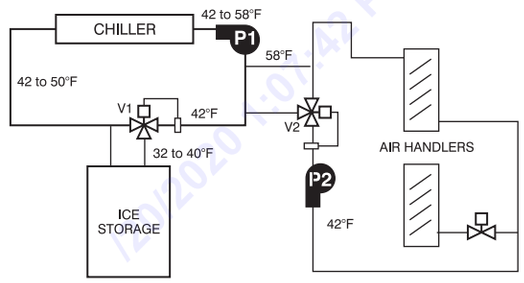


Figure 3.29 : Series Flow, Chiller Upstream

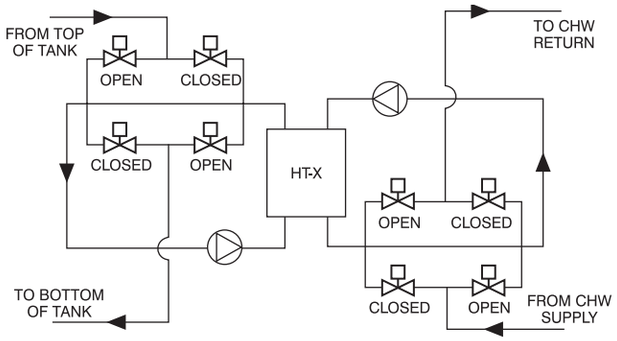


Figure 3.30 : Charge Mode status of Indirect Transfer Pumping Interface

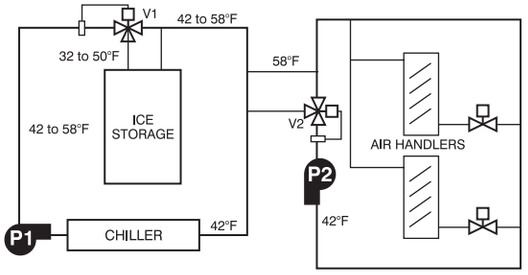


Figure 3.31 : Series Flow, Chiller Downstream

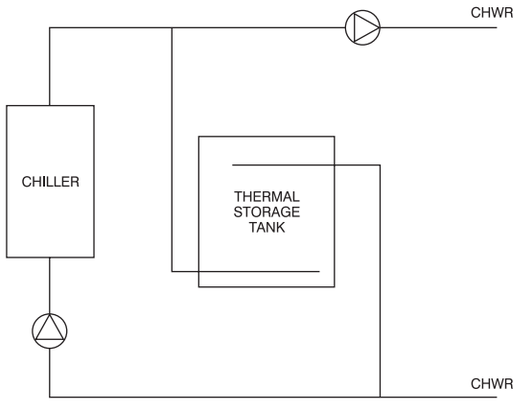


Figure 3.32 : Primary / Secondary Chilled Water Plant with Stratified storage tank as decoupler

SECTION - 4

REFRIGERANT PIPING

REFRIGERANT PIPING DESIGN

APPLICATION CONSIDERATIONS

A refrigerant piping system requires the same general design consideration as any Fluid Flow system. However, there are additional factors that critically influence system design:

The following procedure for sizing refrigerant piping is recommended:

1. The system must be designed for minimum pressure drop, since pressure loss decreases the thermal capacity and increases the power requirement in a refrigeration system.
2. The fluid being piped changes state as it circulates.
3. Since lubricating oil is miscible with refrigerants 12, 22 & 500, some provision must be made to :
   a. Minimize the accumulation of liquid refrigerant in the equipment fittings, compressor crankcase.
   b. Return oil to the compressor at the same rate at which it leaves.

DESIGN PRINCIPLES

Objectives

Refrigerant piping systems must be designed to accomplish the following:

1. Ensure proper feed to evaporators.
2. Provide practical line sizes without excessive pressure drop.
3. Protect compressors by :
   a. Preventing excessive lubricating oil from being trapped in the system.
   b. Minimizing the loss of lubricating oil from the compressor at all times.
   c. Preventing liquid refrigerant from entering the compressor, during operation and shutdown.

CONSTRUCTION MATERIAL

Metals

Halogenated refrigerants can be used satisfactorily under normal conditions with most common metals, such as steel, cast iron, brass, copper, tin, lead and aluminium. Under more severe conditions, various metal properties are affected, such as Hydrolysis and Thermal Decomposition in varying degrees. The tendency of metals to promote Thermal Decomposition of Halogenated compounds is in the following order.

(Least decomposition)Ubcibek<18-8 Stainless Steel <Nickel<Copper<1040 Steel <Aluminium<Bronze<Brass<Zinc <Silver (most decomposition)

This order is only approximate, and there may be exceptions for individual compounds or for special use conditions. The effect of metals on Hydrolysis is probably similar.

Magnesium alloys and Aluminium containing more than 2% Magnesium are not recommended for use with Halogenated compounds.

Where even trace amounts of water may be present, Zinc is not recommended for use with CFC-113. Experience with Zinc and other Fluorinated Compounds has been limited, but no unusual reactivity has been observed under normal conditions of use in dry systems.

Ammonia should never be used with copper, brass or other alloys containing copper. Further discussion of the compatibility of refrigerants and lubricants with construction materials may be found in Chapter 5 of the 2006 ASHRAE Handbook - refrigeration.

Table 4.1: Compressor capacity Vs Line Pressure Drop at 42° F Evaporator Temperature R-134a, and R-502

Suction And Hot Gas Line Pressure Drop	Compressor	
	Capacity (%)	Hp/Ton(%)
No Line Loss	100	100
2F Suction Line Loss	95.7	103.5
2F Hot Gas Line Loss	98.4	103.5
4F Suction Loss	92.2	106.8
4F Hot Gas Line Loss	96.8	106.8

Gas / Liquid Line Velocities for Halocarbon / Refrigerant

Suction Line	900 - 4000 fpm
Discharge line	2000 - 3500 fpm
Liquid Line (Condenser to Receiver)	< 100 fpm
Liquid line (Receiver to Evaporator)	< 300 fpm

USE OF PIPE CHARTS

The following procedure for sizing refrigerant piping is recommended.

1. Measure the length (in feet) of straight pipe.
2. Add 50% to obtain a trial total equivalent length.
3. If other than a rated friction loss is desired, multiply the total equivalent length by the correction factor from the table following the appropriate pipe or tubing size chart.
4. If necessary, correct for suction and condensing temperatures.
5. Read pipe size from Figures 4.1 to 4.8.
6. Find equivalent length (in feet) of fittings and hand valves from Section 3 and add to the length of straight pipe (Step 1) to obtain the Total Equivalent Length.
7. Correct as in Steps 3 and 4, if necessary.
8. Check pipe size. In some cases, particularly in Liquid and Suction lines, it may be necessary to find the actual pressure drop. To do this, use the procedure described in Steps 9 to 11.
9. Convert the friction drop (F from step 3) to psi, using refrigerant tables from Section 5.
10. Find the pressure drop through automatic valves and accessories from manufacturer's catalogs. If these are given in equivalent feet, change to psi by multiplying by the ratio:

    Step (9) / Step (6)

11. Add Steps 9 and 10. In systems in which automatic valves and accessories may create a relatively high pressure drop, the line size can be increased to minimize their effect on the system.

Table 4.2 : Equivalent Length for Fittings (feet)

Nominal Dia.	Smooth Elbows						Smooth Bend Tee Connections			
	90° Std	90° Long Radius	90° Street	45° Std	45° Street	180° Std	Tee Branch Flow	Straight Through Flow		
								No Reduction	Reduced 25%	Reduced 50%
1/2	1.4	0.9	2.3	0.7	1.1	2.3	2.7	0.9	1.2	1.4
5/8	1.6	1.0	2.5	0.8	1.3	2.5	3.0	1.0	1.4	1.6
7/8	2.0	1.4	3.2	0.9	1.6	3.2	4.0	1.4	1.9	2.0
1 1/8	2.6	1.7	4.1	1.3	2.1	4.1	5.0	1.7	4.2	2.6
1 3/8	3.3	2.3	5.6	1.7	3.0	5.6	7.0	2.3	3.1	3.3
1 5/8	4.0	2.6	6.3	2.1	3.4	6.3	8.0	2.6	3.7	4.0
2 1/8	5.0	3.3	8.2	2.6	4.5	8.2	10.0	3.3	4.7	5.0
2 5/8	6.0	4.1	10.0	3.2	5.2	10.0	12.0	4.1	5.6	6.0
3 1/8	7.5	5.0	12.0	4.0	6.4	12.0	15.0	5.0	7.0	7,5
3 5/8	9.0	5.9	15.0	4.7	7.3	15.0	18.0	5.9	8.0	9.0
4 1/8	10.0	5.7	17.0	5.2	8.5	17.0	21.0	6.7	9.0	10.0
5 1/8	13.0	8.2	21.0	6.5	11.0	21.0	25.0	8.2	12.0	13.0
6 1/8	16.0	10.0	25.0	7.9	13.0	25.0	30.0	10.0	14.0	16.0
8 1/8	20.0	13.0	-	10.0	-	33.0	40.0	13.0	18.0	20.0

Table 4.3 : Equivalent Length for Valves and Refrigeration Devices (feet)

Nominal Diameter	Globe or Solenoid	60° Wye Valve	45° Wye Valve	Angle / Valve	Gate Valve	Swing Check	Sight Glass	Filter Drier	Suction Filter
1/2	17	8	6	6	0.6	5	1.0	12	15
5/8	18	9	7	7	0.7	6	1.2	15	17
7/8	22	11	9	9	0.9	8	1.6	21	22
1 1/8	29	15	12	12	1.0	10	2.0	26	25
1 3/8	38	20	15	15	1.5	14	2.5	35	36
1 5/8	43	24	18	18	1.8	16	2.6	-	40
2 1/8	55	30	24	24	2.3	20			
2 5/8	69	35	29	29	2.8	25			
3 1/8	84	43	35	35	3.2	30			
3 5/8	100.	50	41	41	4.0	35			
4 1/8	120	58	47	47	4.5	40			
5 1/8	140	71	58	58	6.0	50			
6 1/8	170	88	70	70	7.0	60			
8 1/8	200	115	85	85	9.0	80			

Table 4.4 : R-22 Refrigerant Line Sizing Table (Tons)

	Suction									Discharge			Liquid	
SST	**0°F**			**20°F**			**40°F**			**0°F**	**20°F**	**40°F**		
ΔT	**2°F**	**1°F**	**0.5°F**	**2°F**	**1°F**	**0.5°F**	**2°F**	**1°F**	**0.5°F**	**2°F**	**1°F**	**0.5°F**	**Vel = 100fpm**	**1°F**
Δp (PSI)	**1.60**	**0.813**	**0.406**	**2.22**	**1.104**	**0.552**	**2.91**	**1.455**	**0.727**	**3.05**	**3.05**	**3.05**		**3.05**
OD (in)														
1/2	-	0.18	0.12	0.40	0.27	0.19	0.6	0.40	0.27	0.8	0.8	0.8	2.3	3.6
5/8	0.51	0.34	0.23	0.76	0.52	0.35	1.1	0.75	0.51	1.5	1.6	1.6	3.7	6.7
7/8	1.3	0.91	0.62	2.0	1.37	0.93	2.9	1.97	1.35	4.0	4.1	4.2	7.8	18.2
1 1/8	2.7	1.86	1.27	4.0	2.77	1.90	5.8	3.99	2.74	8.0	8.3	8.5	13.2	37.0
1 3/8	4.7	3.25	2.22	7.0	4.84	3.32	10.1	6.96	4:78	14.0	14.4	14.8	20.2	64.7
1 5/8	7.5	5.16	3.53	11.1	7.67	5.26	16.0	11.0	7.57	22.1	22.7	23.4	28.5	102.5
2 1/8	15.6	10.71	7.35	23.1	15.92	10.96	33.1	22.81	15.73	45.7	47.1	48.5	49.6	213.0
2 5/8	27.5	18.97	13.04	40.8	28.19	19.40	58.3	40.38	27.84	80.4	82.9	85.4	76.5	376.9
3 1/8	44.0	30.31	20.85	65.0	44.93	31.00	92.9	64.30	44.44	129.2	132.2	136.2	109.2	601.5
3 5/8	65.4	45.09	31.03	96.6	66.81	46.11	137.8	95.68	66.09	190.3	196.2	202.1	147.8	895.7
4 1/8	92.2	63.71	43.85	136.3	94.25	65.12	194.3	134.81	93.22	267.8	276.1	284.4	192.1	1263.2

Values in Table 4.4 are based on 105°F condensing temperature. Multiply table capacities by the following factors for other condensing temperatures.

CONDENSING TEMPERATURE (°F)	SUCTION LINE	DISCHARGE LINE
80	1.11	0.79
90	1.07	0.88
60	1.03	0.95
110	0.97	1.04
120	0.90	1.10
130	0.86	1.18
140	0.80	1.26

Notes - See Page 4.8

Source: Mfg. Data

Table 4.5 : R-134 a Refrigerant Line Sizing Table (Tons)

	Suction									Discharge			Liquid	
SST	**0°F**			**20°F**			**40°F**			**0°F**	**20°F**	**40°F**		
ΔT	**2°F**	**1°F**	**0.5°F**	**2°F**	**1°F**	**0.5°F**	**2°F**	**1°F**	**0.5°F**	**2°F**	**1°F**	**0.5°F**	**Vel = 100 fpm**	**1°F**
Δp (PSI)	**1.00**	**0.50**	**0.25**	**1.41**	**0.71**	**0.35**	**1.93**	**0.97**	**0.48**	**2.20**	**2.20**	**2.20**		**2.20**
OD (in)														
1/2	0.14	0.10	0.07	0.23	0.16	0.11	0.35	0.24	0.16	0.5	0.6	0.6	2.13	2.79
5/8	0.27	0.18	0.12	0.43	0.29	0.20	0.66	0.45	0.31	1.0	1.1	1.1	3.42	5.27
7/8	0.71	0.48	0.33	1.14	0.78	0.53	1.75	1.20	0.82	2.7	2.8	2.9	7.09	14
1 1/8	1.45	0.99	0.67	2.32	1.59	1.08	3.54	2.43	1.66	5.4	5.7	6.0	12.1	28.4
1 3/8	2.53	1.73	1.18	4.04	2.77	1.89	6.17	4.25	2.91	9.4	9.9	10.4	18.4	50
1 5/8	4.02	2.75	1.88	6.39	4.40	3.01	9.77	6.72	4.61	14.9	15.7	16.4	26.1	78.6
2 1/8	8.34	5.73	3.92	13.3	9.14	6.27	20.20	14.0	9.59	30.8	32.4	34.0	45.3	163
2 5/8	14.80	10.2	6.97	23.5	16.2	11.1	35.80	24.7	17.0	54.4	57.2	59.9	69.6	290
3 1/8	23.70	16.2	11.1	37.5	25.9	17.8	57.10	39.4	27.2	86.7	91.2	95.5	100	462
3 5/8	35.10	24.2	16.6	55.8	38.5	26.5	84.80	58.7	40.4	129.0	135	142.0	135	688
4 1/8	49.60	34.2	23.5	78.7	54.3	37.4	119.4	82.6	57.1	181.0	191	200.0	175	971
5 1/8	88.90	61.3	42.2	141.0	97.2	67.1	213.0	148	102	323.0	340	356.0	-	-
6 1/8	143.0	98.8	68.0	226.0	157	108	342.0	237	165	518.0	545	571.0	-	-

Values in Table 4.5 are based on 105° F condensing temperature. Multiply table capacities by the following factors for other condensing temperatures.

Condensing Temperature (°F)	Suction Line	Discharge Line
80	1.158	0.804
90	1.095	0.882
100	1.032	0.961
110	0.968	1.026
120	0.902	1.078
130	0.834	1.156

Notes - See Page 4.8

Source : Mfg. Data

Table 4.6 : R404A Refrigerant Line Size Table (Tons)

Line Size		Suction Lines (Δf=2°F)						Discharge Line (Δf=2°F)						Liquid Lines		
Type L Copper OD		-60	-40	-20	0	20	40	-60	-40	-20	2	20	40	See note a		
		Corresponding Δp, psi / 100ft.						Corresponding (Δp, psi / 100ft)						Velocity 100fpm	Δf=1°F Drop Δp=3.6	Δf=5°F Drop Δp=17.4
		0.64	0.97	1.41	1.96	2.62	3.44	3.55	3.55	3.55	3.55	3.55	3.55			
1/2		0.05	0.09	0.15	0.24	0.36	0.53	0.56	0.61	0.65	0.70	0.75	0.79	1.3	2.6	6.09
5/8		0.09	0.46	0.28	0.44	0.68	1.00	1.04	1.14	1.23	1.31	1.40	1.48	2.1	4.9	11.39
3/4		0.15	0.28	0.47	0.76	1.15	1.70	1.77	1.93	2.09	2.23	2.38	2.51	3.1	8.1	15.87
7/8		0.24	0.43	.73	1.17	1.78	2.63	2.73	2.98	3.22	3.44	3.66	3.87	4.4	12.8	29.81
1 1/8		0.49	0.88	1.49	2.37	3.61	5.31	5.52	6.01	6.49	6.96	7.40	7.81	7.5	25.9	60.17
1 3/8		0.86	1.54	2.59	4.13	6.28	9.23	9.60	10.46	11.29	12.10	12.87	13.58	11.4	45.2	104.41
1 5/8		1.36	2.44	4.10	6.53	9.92	14.57	15.14	16.49	17.80	19.07	20.28	21.41	16.1	71.4	164.68
2 1/8		2.83	5.07	8.52	13.53	20.51	30.06	31.29	34.08	36.80	39.43	41.93	44.26	28.0	147.9	339.46
2 5/8		5.03	8.97	15.07	23.88	36.16	52.96	55.04	59.95	64.74	69.36	73.76	77.85 -	43.2	261.2	597.42
3 1/8		8.05	14.34	24.02	38.05	57.26	84.33	87.66	95.48	103.11	110.47	117.48	124.00	61.7	416.2	950.09
3 5/8		11.98	21.31	35.73	56.53	85.39	125.18	129.88	141.46	152.76	163.67	174.05	183.71	83.5	618.4	1407.96
4 1/8		16.93	30,09	50.32	79.66	120.39	176.20	182.83	199.13	215.05	230.40	245.01	258.61	108.5	871.6	1982.40
5 1/8		30.35	53.85	89.97	142.32	214.82	313.91	325.75	354.81	383.16	410.51	436.55	460.78	169.1	1554.2	3255.99
6 1/8		48.89	86.74	144.47	228.50	344.70	502.77	521.74	568.28	613.69	657.499	699.20	738.00	243.1	2497.7	5648.67
8 1/8		101.60	179.88	299.39	472.46	710.75	1037.34	1076.62	1172.66	1266.36	1356.75	1442.81	1522.89	424.6	5159.7	11660.71
Steel																
IPS	SCH															
3/8	80	0.04	0.07	0.11	0.18	0.27	0.39	0.40	0.44	0.47	0.51	0.54	0.57	1.3	1.9	4.3
½	80	0.08	0.14	0.22	0.35	0.53	0.76	0.79	0.86	0.93	0.99	1.06	1.12	2.1	3.8	8.5
¾	80	0.18	0.31	0.51	0.79	1.18	1.71	1.78	1.93	2.09	2.24	2.38	2.51	3.9	8.6	19.2
1 ¼	80	0.35	0.60	0.99	1.55	2.32	3.36	3.48	3.79	4.09	4.38	4.66	4.92	6.5	16.9	37.5
1	80	0.75	1.30	2.13	3.33	4.97	7.20	7.45	8.12	8.77	9.39	9.99	10.54	11.6	36.3	80.3
1½	80	1.14	1.98	3.26	5.08	7.57	10.96	11.35	12.37	13.35	14.31	15.21	16.06	16.0	55.3	122.3
2	40	2.65	4.61	7.55	11.78	17.57	25.45	26.36	28.71	31.01	33.22	35.33	37.29	30.4	128.4	283.5
2 ½	40	4.23	7.34	12.04	18.74	27.94	40.49	41.93	45.67	49.32	52.84	56.19	59.31	43.3	204.7	450.9
3	40	7.48	12.98	21.26	33.11	49.37	71.55	74.10	80.71	87.16	93.38	99.31	104.82	66.9	361.6	179.8
4	40	15.30	26.47	43.34	67.50	100.66	145.57	150.75	164.20	177.32	189.98	202.03	213.24	115.3	735.6	1623.0
5	40	27.58	47.78	78.24	121.87	181.32	262.52	272.21	296.49	320.19	343.04	364.80	385.05	181.1	1328.2	2927.2
6	40	44.58	77.26	126.52	197.09	293.24	424.04	439.72	478.94	517.21	554.13	598.28	621.99	261.7	2148.0	4728.3
8	40	91.40	158.09	258.81	402.66	599.91	867.50	898.42	978.56	1056.75	1132.18	1203.99	1270.82	453.2	4394.4	9674.1
10	40	165.52	286.19	468.14	728.40	1083.73	1569.40	1625.34	1770.31	1911.75	2048.23	2178.15	2299.05	714.4	7938.5	17477.4
12	ID[b]	264.36	457.37	748.94	1163.62	1733.87	2507.30	2600.54	2832.50	3058.84	3277.16	3485.04	3678.47	1024.6	12681.8	27963.7
14	30	342.81	592.13	968.21	1506.59	2244.98	3246.34	3362.07	3661.96	3954.59	4236.83	4505.59	4755.67	1249.2	14619.6	36152.5
16	30	493.87	852.84	1395.24	2171.13	3230.27	4678.48	4845.26	5277.44	5699.16	6105.92	6493.24	6853.65	1654.7	23662.2	52101.2

Notes - See Page 4.8
Values in above Table are based on 105°F condensing temp. Use following correction factors for other temperatures.

Condensing Temperature (F°)	Suction Line	Discharge Line
80	1.246	0.870
90	1.150	0.922
100	1,051	0.974
110	0.948	1.009
120	0.840	1.026
130	0.723	1.043

Table 4.7 : R-410 A Refrigerant Line Size Table (Tons)

	Suction									Discharge			Liquid		
SST	0°F			20°F			40°F			0°F	20°F	40°F			
ΔT	2°F	1°F	0.5°F	2°F	1°F	0.5°F	2°F	1°F	0.5°F	2°F	1°F	0.5°F	Vel= 100 fpm	1°F	5°F
Δp (PSI)	2.57	1.29	0.64	3.46	1.73	0.87	4.50	2.25	1.13	4.75	4.75	4.75		4.75	4.75
OD(in)															
1/2	0.4	0.3	0.2	0.6	0.4	0.3	0.9	0.6	0.4	1.3	1.3	1.3	2.0	4.6	10.8
5/8	0.8	0.5	0.4	1.2	0.8	0.6	1.7	1.2	0.8	2.4	2.4	2.5	3.2	8.6	20.2
7/8	2.1	1.4	1.0	3.1	2.1	1.5	4.4	3.0	2.1	6.2	6.4	6.5	6.7	22.6	52.9
1 1/8	4.2	2.9	2.0	6.2	4.3	3.0	8.9	6.1	4.2	12.5	12.9	13.2	11.4	45.8	106.6
1 3/8	7.3	5.1	3.5	10.9	7.5	5.2	15.4	10.7	7.3	21.7	22.4	22.9	17.4	79.7	185.0
1 5/8	11.6	8.0	5.5	17.1	11.8	8.2	24.3	16.7	11.6	34.3	35.3	36.1	24.6	125.9	291.5
2 1/8	24.1	16.6	11.4	35.5	24.5	16.9	50.2	34.8	24.1	70.8	72.8	74.6	42.8	260.7	601
2 5/8	42.5	29.4	20.2	62.5	43.3	30.0	88.4	61.4	42.5	124.5	128.3	131.2	66.0	459.7	1056
3 1/8	67.8	46.8	32.4	99.5	69.1	47.8	140.8	97.9	67.9	198.4	204.3	209.0	94.2	733.0	1680
3 5/8	100.5	69.7	48.1	147.7	102.7	71.0	208.7	145.3	100.8	293.9	302.7	309.6	127.4	1087.5	2491
4 1/8	141.6	98.3	67.9	208.2	144.7	100.2	293.7	204.8	142.1	413.9	426.1	435.9	165.7	1530.2	3500
5 1/8	253.1	175.4	121.5	370.8	258.0	179.2	523.2	365.0	253.8	737.3	759.3	776.7	258.2	2729.8	622866
6 1/8	405.8	282.3	195.7	594.9	414.5	287.8	839.8	586.1	407.6	1180.9	1216.2	1244.1	371.1	4383.7	9980

Values in Table 4.7 are based on 105°F condensing temperature. Multiply table capacities by the following factors for other condensing temperatures.

Condensing Temperature (°F)	Suction Line	Discharge Line
80	1.170	0.815
90	1.104	0.889
100	1.035	0.963
110	0.964	1.032
120	0.889	1.096
130	0.808	1.160

Notes - See Page 4.8

Source: Mfg. Data

Table 4.8 : R-407 C Refrigerant Line Size Table (Tons)

	Suction									Discharge			Liquid		
SST	0°F			20°F			40°F			0°F	20°F	40°F			
ΔT	2°F	1°F	0.5°F	2°F	1°F	0.5°F	2°F	1°F	0.5°F	2°F	1°F	0.5°F	Vel= 100 fpm	1°F	5°F
Δp (PSI)	1.55	0.78	0.39	2.16	1.08	0.54	2.92	1.46	0.73	3.30	3.30	3.30		4.75	4.75
OD(in)															
1/2	0.2	0.2	0.1	0.4	0.3	0.2	0.5	0.4	0.3	0.8	0.9	0.9	2.1	3.8	8.9
5/8	0.4	0.3	0.2	0.7	0.5	0.3	1.0	0.7	0.5	1.5	1.6	1.7	3.4	7.1	16.7
7/8	1.2	0.8	0.5	1.8	1.2	0.8	2.7	1.8	1.3	4.1	4.2	4.4	6.9	18.7	43.7
1 1/8	2.3	1.6	1.1	3.6	2.5	1.7	5.4	3.7	2.6	8.2	8.5	8.9	11.8	37.9	88.2
1 3/8	4.1	2.8	1.9	6.3	4.4	3.0	9.5	6.5	4.5	14.2	14.8	15.4	18.0	66.2	153.5
1 5/8	6.4	4.4	3.0	10.0	6.9	4.7	14.9	10.3	7.1	22.5	23.4	24.3	25.5	104.7	241.9
2 1/8	13.4	9.2	6.3	20.7	14.3	9.8	30.9	21.4	14.7	46.5	48.4	50.3	44.4	217.1	499.2
2 5/8	23.6	16.3	11.2	36.6	25.3	17.4	54.5	37.8	26.1	82.0	85.4	88.7	68.5	383.7	879.9
3 1/8	37.8	26.1	17.9	58.6	40.3	27.8	86.9	60.2	41.6	130.5	136.0	141.2	97.7	611.3	1401.5
3 5/8	56.2	38.8	26.7	86.6	60.0	41.4	128.9	89.5	61.8	193.3	201.4	209.2	132.0	907.9	2076.6
4 1/8	79.2	54.7	37.7	122.1	84.6	58.5	181.3	126.1	87.3	272.6	284.0	295.0	171.8	1281.5	2923.4
5 1/8	141.6	97.9	67.6	218.1	151.2	104.7	323.5	225.1	156.1	485.5	505.8	525.3	267.8	2288.8	5209.1
6 1/8	227.9	157.6	109.0	350.4	243.2	168.4	519.6	361.7	251.1	779.0	811.6	843.0	385.0	3676.9	8344.1

Values in Table 4.8 are based on 105°F condensing temperature. Multiply table capacities by the following factors for other condensing temperatures.

Condensing Temperature (°F)	Suction Line	Discharge Line
80	1.163	0.787
90	1.099	0.872
100	1.033	0.957
110	0.966	1.036
120	0.896	1.109
130	0.824	1.182

Notes for Table 4.4, 5, 6, 7 & 8 :

1. Table capacities are in tons of refrigeration.
2. Δp = Pressure drop due to line friction, psi per 100 ft of equivalent line length.
3. Δt = corresponding change in saturation temperature, °F per 100 ft.
4. Line capacity for other saturation temperatures and Δt and equivalent lengths L_e

$$\text{Line Capacity} = \text{Table capacity} \left[\frac{\text{Table } L_e}{\text{Actual } L_e} \times \frac{\text{Actual } \Delta t}{\text{Table } \Delta t} \right]^{0.55}$$

5. Saturation temperatures Δt for other capacities and equivalent lengths L_e

$$\Delta t = \text{Table } \Delta t \left[\frac{\text{Actual } L_e}{\text{Table } L_e} \right] \times \left[\frac{\text{Actual Capacity}}{\text{Table Capacity}} \right]^{1.8}$$

Table 4.9 : R-22 Minimum Capacity For Suction Riser (Tons)

Saturated Suction Temp (^{0}F)	Suction Gas Temp (^{0}F)	Pipe O.D (inches)											
		1/2	5/8	3/4	7/8	1 1/8	1 3/8	1 5/8	2 1/8	2 5/8	3 1/8	3 5/8	4 1/8
		Area (in^2)											
		0.146	0.233	0.348	0.484	0.825	1.256	1.780	3.094	4.770	6.812	9.213	11.970
-40	-30	0.067	0.119	0.197	0.298	0.580	0.981	1.52	3.03	5.20	8.12	11.8	16.4
	-10	0.065	0.117	0.194	0.292	0.570	0.963	1.49	2.97	5.11	7.97	11.6	16.1
	10	0.066	0.118	0.195	0.295	0.575	0.972	1.50	3.00	5.5	8.04	11.7	16.3
-20	-10	0.087	0.156	0.258	0.389	0.758	1.28	1.98	3.96	6.80	10.6	15.5	21.5
	10	0.085	0.153	0.253	0.362	0.744	1.26	1.95	3.88	6.67	10.4	15.2	21.1
	30	0.086	0.154	0.254	0.383	0.747	1.26	1.95	3.90	6.69	10.4	15.2	21.1
0	10	0.111	0.199	0.328	0.496	0.986	1.63	2.53	5.04	8.66	13.5	19.7	27.4
	30	0.108	0.194	0.320	0.484	0.842	1.59	2.46	4.92	8.45	13.2	19.2	26.7
	50	0.109	0.195	0.322	0.486	0.946	1.60	2.47	4.94	8.48	13.2	19.3	26.8
20	30	0.136	0.244	0.403	0.608	1.18	2.00	3.10	6.18	10.6	16.6	24.2	33.5
	50	0.135	0.242	0.399	0.603	1.17	1.99	3.07	6.13	10.5	16.4	24.0	33.3
	70	0.135	0.242	0.400	0.605	1.18	1.99	3.08	6.15	10.6	16.5	24.0	33.3
40	50	0.167	0.300	0.495	0.748	1.46	2.46	3.81	7.6	13.1	20.4	29.7	41.3
	70	0.165	0.296	0.488	0.737	1.44	2.43	3.75	7.49	12.9	20.1	29.3	40.7
	90	0.165	0.296	0.488	0.738	1.44	2.43	3.76	7.50	12.9	20.1	29.3	40.7

Refrigeration capacity in tons is based on 90^{0}F liquid temperature and superheat as indicated by the listed temperature. Multiply table capacities by the following factors for other liquid line temperatures.

Liquid Temperature (^{0}F)								
50	60	70	80	100	110	120	130	140
1.17	1.14	1.10	1.06	0.98	0.94	0.89	0.85	0.80

Table 4.10 : R-134a Minimum Capacity For Suction Riser (Tons)

Saturated Suction Temp (^{0}F)	Suction Gas Temp (^{0}F)	Pipe O.D (inches)											
		1/2	5/8	3/4	7/8	1 1/8	1 3/8	1 5/8	2 1/8	2 5/8	3 1/8	3 5/8	4 1/8
		Area (in^2)											
		0.146	0.233	0.348	0.484	0.825	1.256	1.780	3.094	4.770	6.812	9.213	11.970
-40	-30	0.089	0.161	0.259	0.400	0.78	1.32	2.03	4.06	7.0	10.9	15.9	22.1
	-10	0.075	0.135	0.218	0.336	0.66	1.11	1.71	3.24	5.9	9.2	13.4	18.5
	10	0.072	0.130	0.209	0.323	0.63	1.07	1.64	3.28	5.6	8.8	12.8	17.8
-20	-10	0.101	0.182	0.294	0.453	0.88	1.49	2.31	4.16	7.9	12.4	18.0	25.0
	10	0.084	0.152	0.246	0.379	0.74	1.25	1.93	3.86	6.6	10.3	15.1	20.9
	30	0.081	0.147	0.237	0.366	0.71	1.21	1.87	3.73	6.4	10.0	14.6	20.2
0	10	0.113	0.205	0.331	0.510	0.99	1.68	2.6	5.19	8.9	13.9	20.3	28.2
	30	0.095	0.172	0.277	0.427	0.83	1.41	2.17	4.34	7.5	11.6	17.0	23.6
	50	0.092	0.166	0.268	0.413	0.81	1.36	2.1	4.20	7.2	11.3	16.4	22.8
20	30	0.115	0.207	0.335	0.517	1.01	1.7	2.63	5.25	9.0	14.1	20.5	28.5
	50	0.107	0.193	0.331	0.480	0.94	1.58	2.44	4.88	8.4	13.1	19.1	26.5
	70	0.103	0.187	0.301	0.485	0.91	1.53	2.37	4.72	8.1	12.7	18.5	25.6
40	50	0.128	0.232	0.374	0.577	1.12	1.9	2.94	5.87	10.1	15.7	22.9	31.8
	70	0.117	0.212	0.342	0.528	1.03	1.74	2.69	5.37	9.2	14.4	21.0	29.1
	90	0.114	0.206	0.332	0.512	1.00	1.69	2.61	5.21	8.9	14.0	20.4	28.3

Refrigeration capacity in tons is based on 90^{0}F liquid temperature and superheat as indicated by the listed temperature. Multiply table capacities by the following factors for other liquid line temperatures.

Liquid Temperature (^{0}F)								
50	60	70	80	100	110	120	130	140
1.26	1.20	1.13	1.07	0.94	0.87	0.80	0.74	0.67

Table 4.11 : R 410A Minimum Capacity for Suction Riser (Tons)

Saturated Suction Temp (^{0}F)	Suction Gas Temp (^{0}F)	Pipe O.D (inches)											
		1/2	5/8	3/4	7/8	1 1/8	1 3/8	1 5/8	2 1/8	2 5/8	3 1/8	3 5/8	4 1/8
		Area (in^2)											
		0.146	0.233	0.348	0.484	0.825	1.256	1.780	3.094	4.770	6.812	9.213	11.970
0	10	0.167	0.317	0.542	0.833	1.67	2.92	4.58	9.58	17.17	26.67	40.00	55.83
20	10	0.192	0.363	0.667	0.958	1.96	3.42	5.33	11.08	19.58	30.83	45.83	64.17
40	10	0.213	0.400	0.683	1.067	2.17	3.75	6.00	12.42	21.67	35.00	51.67	71.67

Refrigeration capacity in tons is based on 90^{0}F liquid temperature and superheat as indicated by the listed temperature. Multiply table capacities by the following factors for other liquid line temperatures.

Liquid Temperature (^{0}F)						
80	90	100	110	120	130	140
1.05	1.00	0.94	0.90	0.83	0.77	0.72

Table 4.12 : R-407C Minimum Capacity for Suction Riser (Tons)

Saturated Suction Temp (^{0}F)	Suction Gas Temp (^{0}F)	Pipe O.D (inches)											
		1/2	5/8	3/4	7/8	1 1/8	1 3/8	1 5/8	2 1/8	2 5/8	3 1/8	3 5/8	4 1/8
		Area (in^2)											
		0.146	0.233	0.348	0.484	0.825	1.256	1.780	3.094	4.770	6.812	9.213	11.970
0	10	0.127	0.242	0.413	0.642	1.31	2.29	3.58	7.42	13.08	20.83	30.83	43.33
20	10	0.150	0.283	0.483	0.758	1.54	2.67	4.25	8.75	15.42	24.58	36.67	50.83
40	10	0.171	0.325	0.550	0.867	1.75	3.08	4.83	10.00	17.50	27.83	41.67	58.33

Refrigeration capacity in tons is based on 90^{0}F liquid temperature and superheat as indicated by the listed temperature. Multiply table capacities by the following factors for other liquid line temperatures.

Liquid Temperature (^{0}F)						
80	90	100	110	120	130	140
1.05	1.00	0.95	0.90	0.85	0.80	0.74

Table 4.13 : R-22 Minimum Capacity for Discharge Riser (Tons)

Saturated Suction Temp (°F)	Discharge Gas Temp (°F)	Pipe O.D (inches)											
		1/2	5/8	3/4	7/8	1 1/8	1 3/8	1 5/8	2 1/8	2 5/8	3 1/8	3 5/8	4 1/8
		Area (in²)											
		0.146	0.233	0.348	0.484	0.825	1.256	1.780	3.094	4.770	6.812	9.213	11.970
80	110	0.235	0.421	0.695	1.050	2.03	3.46	5.35	10.70	18.3	26.8	41.8	57.9
	140	0.223	0.399	0.659	0.996	1.94	3.28	5.05	10.10	17.4	27.1	39.6	54.9
	170	0.215	0.385	0.635	0.960	1.87	3.16	4.89	9.76	16.8	26.2	38.2	52.9
90	120	0.242	0.433	0.716	1.060	2.11	3.56	5.50	11.00	18.9	29.5	43.0	69.9
	150	0.226	0.406	0.671	1.010	1.97	3.34	5.16	10.30	17.7	27.6	40.3	55.9
	180	0.216	0.387	0.540	0.956	1.88	3.18	4.92	9.82	16.9	26.3	38.4	53.3
100	130	0.247	0.442	0.730	1.100	2.15	3.83	5.62	11.20	19.3	30.1	43.9	60.8
	160	0.231	0.414	0.884	1.030	2.01	3.40	5.26	10.50	18.0	28.2	41.1	57.0
	190	0.220	0.394	0.650	0.982	1.91	3.24	3.00	9.96	17.2	26.8	39.1	54.2
110	140	0.251	0.451	0.744	1.120	2.19	3.70	5.73	11.40	19.6	30.6	44.7	62.0
	170	0.235	0.421	0.693	1.050	2.05	.046	3.35	10.70	18.3	28.6	41.8	57.9
	200	0.222	0.399	0.658	0.994	1.94	3.28	5.06	10.10	17.4	27.1	39.5	54.8
120	150	0.257	0.460	0.760	1.150	2.24	3.78	5.85	11.70	20.0	31.3	45.7	63.3
	180	0.239	0.428	0.707	1.070	2.08	3.51	5.44	10.80	18.6	29.1	42.4	58.9
	210	0.225	0.404	0.666	1.010	1.96	3.31	5.12	10.20	17.6	27.4	40.0	55.5

Refrigeration capacity in tons is based on saturated suction temperature of 20° F with 15ºF superheat at indicated saturated condensing temperature with 15ºF sub-cooling. For other saturated suction temperatures with 15º F superheat, use correction factors in the following table.

Saturated Suction Temperature (ºF)			
-40	-20	0	+40
0.92	0.95	0.97	1.02

Table 4.14 : R-134a Minimum Capacity for Discharge Riser (Tons)

Saturated Temp (°F)	Discharge Gas Temp (°F)	Pipe O.D (inches)											
		1/2	5/8	3/4	7/8	1 1/8	1 3/8	1 5/8	2 1/8	2 5/8	3 1/8	3 5/8	4 1/8
		Area (in²)											
		0.146	0.233	0.348	0.484	0.825	1.256	1.780	3.094	4.770	6.812	9.213	11.970
80	110	0.199	0.36	0.581	0.897	1.75	2.96	4.56	9.12	15.7	24.4	35.7	49.5
	140	0.189	0.311	0.535	0.825	1.61	2.72	4.20	8.39	14.4	22.5	32.8	45.6
	170	0.176	0.318	0.512	0.791	1.54	2.61	4.02	8.04	13.8	21.6	31.4	43.6
90	120	0.201	0.364	0.587	0.906	1.76	2.99	4.16	9.21	15.8	24.7	36.0	50.0
	150	0.184	0.333	0.538	0.830	1.62	2.74	4.22	8.44	14.5	22.6	33.0	45.8
	180	0.177	0.32	0.516	0.796	1.55	2.62	4.05	8.09	13.9	21.7	31.6	43.9
100	130	0.206	0.72	0.600	0.926	1.8	3.05	4.71	9.42	16.2	25.2	36.8	51.1
	160	0.188	0.34	0.549	0848	1.65	2.79	4.31	8.62	14.8	23.1	33.7	46.8
	190	0.180	0.326	0.526	0.811	1.58	2.67	4.13	8.25	14.2	22.1	32.2	44.8
110	140	0.209	0.378	0.610	0.942	1.83	3.10	4.79	9.57	16.5	25.7	37.4	52.0
	170	0.191	0.346	0.558	0.861	1.68	2.84	4.38	8.76	15.0	23.5	34.2	47.5
	200	0.183	0.331	0.534	0.824	1.61	2.72	4.19	8.38	14.4	22.5	32.8	45.5
120	150	0.212	0.383	0.618	0.953	1.86	3.14	4.85	9.69	16.7	26	37.9	52.6
	180	0.194	0.351	0.566	0.873	1.7	2.88	4.44	8.88	15.3	23.8	34.7	48.2
	210	0.184	0.334	0.538	0.830	1.62	2.74	4.23	8.44	14.5	22.6	33.0	45.8

Refrigeration capacity in tons is based on saturated suction temperature of 20° F with 15° F superheat at indicated saturated condensing temperature with 15° F sub-cooling. For other saturated suction temperatures with 15° superheat use correction factors in the following table.

Saturated Suction Temperature (ºF)			
-40	-20	0	+40
		0.96	1.04

Table 4.15 : R-410A Minimum Capacity For Discharge Riser (Tons)

Saturated Temp (^{0}F)	Discharge Gas Temp (^{0}F)	Pipe O.D (inches)											
		1/2	5/8	3/4	7/8	1 1/8	1 3/8	1 5/8	2 1/8	2 5/8	3 1/8	3 5/8	4 1/8
		Area (in^2)											
		0.146	0.233	0.348	0.484	0.825	1.256	1.780	3.094	4.770	6.812	9.213	11.970
80	140	0.33	0.610	1.060	1.590	3.19	5.54	8.75	13.80	24.40	38.90	57.80	81.70
100	160	0.34	0.628	1..92	1.638	3.29	5.71	9.01	14.21	25.13	40.07	59.53	84.15
120	180	0.35	0.647	1.125	10687	3.38	5.88	9.28	14.64	25.89	41.27	61.32	86.68

Refrigeration capacity in tons is based on 90^{0}F liquid temperature and superheat as indicated by the listed temperature. Multiply table capacities by the following factors for other liquid line temperatures.

Saturated Suction Temperature (^{0}F)			
0	20	40	60
0.90	0.94	1.00	1.06

Table 4.16 : R-407C Minimum Capacity For Discharge Riser (Tons)

Saturated Suction Temp (^{0}F)	Discharge Temp (^{0}F)	Pipe O.D (inches)											
		1/2	5/8	3/4	7/8	1 1/8	1 3/8	1 5/8	2 1/8	2 5/8	3 1/8	3 5/8	4 1/8
		Area (in^2)											
		0.146	0.233	0.348	0.484	0.825	1.256	1.780	3.094	4.770	6.812	9.213	11.970
80	140	0.29	0.530	0.913	1.390	2.79	4.85	7.67	12.10	21.30	33.99	50.70	71.40
100	160	0.30	0.546	0.940	1.432	2.87	5.00	7.90	12.46	21.94	35.01	52.22	73.54
120	180	0.31	0.562	0.969	1.475	2.96	5.15	8.14	12.84	22.60	36.06	53.79	75.75

Refrigeration capacity in tons is based on saturated suction temperature of 40^{0}F with 30^{0}F superheat at indicated saturated condensing temperature with 10^{0}F sub-cooling. For other saturated suction temperatures with 30^{0}F superheat, use correction factors in the following table.

Saturated Suction Temperature (^{0}F)			
0	20	40	60
0.96	0.98	1.00	1.02

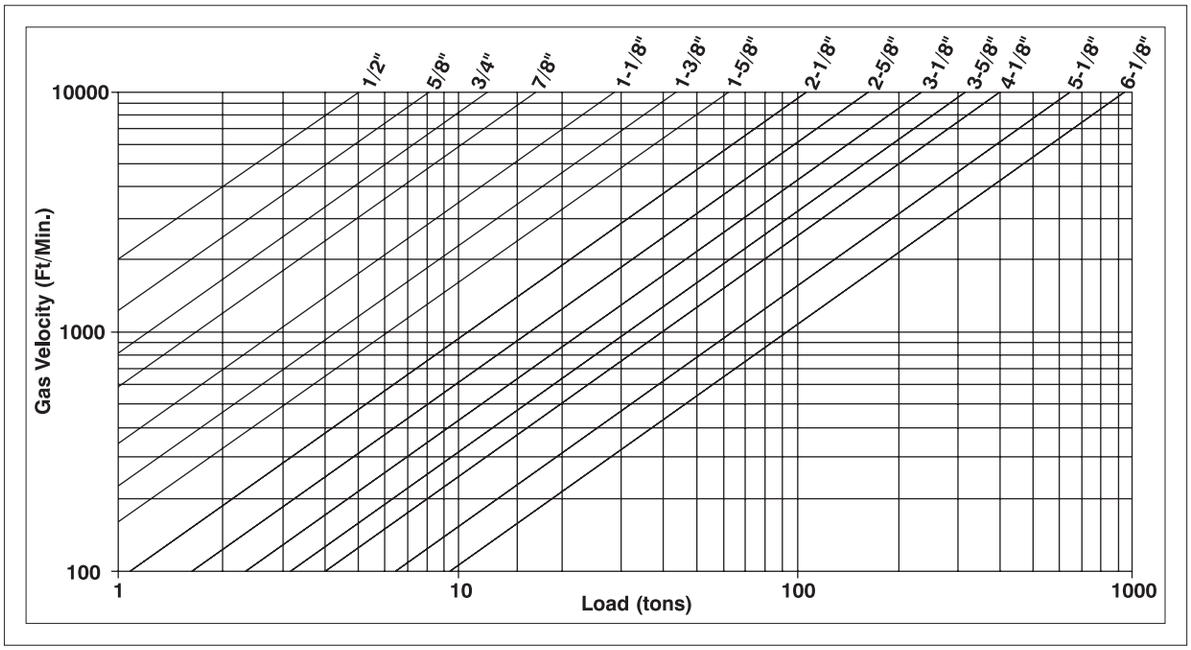


Figure 4.1 is based on 40^{0}F suction temperature and 105^{0}F condensing temperature. For other conditions, apply correction factors from Table 4.17.

Figure 4.1 : R-22 Suction Gas Velocity

Table 4.17 : R-22 Suction Gas Velocity Correction Factors

Cond Temp (^{0}F)	Suction Temperature (^{0}F)								
	10	15	20	25	30	35	40	45	50
85	1.63	1.48	1.34	1.21	1.10	1.00	0.92	0.84	0.76
90	1.67	1.51	1.37	1.24	1.13	1.02	0.93	0.85	0.78
95	1.71	1.54	1.40	1.27	1.15	1.05	0.95	0.87	0.80
100	1.75	1.58	1.43	1.30	1.18	1.07	0.98	0.89	0.82
105	1.79	1.62	1.46	1.33	1.20	1.10	1.00	0.91	0.83
110	1.84	1.66	1.50	1.36	1.24	1.12	1.02	0.94	0.86
115	1.89	1.70	1.54	1.39	1.27	1.15	1.05	0.96	0.88
120	1.94	1.75	1.58	1.43	1.30	1.18	1.08	0.98	0.90
125	1.99	1.80	1.63	1.47	1.34	1.22	1.11	1.01	0.92
130	2.05	1.85	1.67	1.52	1.38	1.25	1.14	1.04	0.95
135	2.12	1.91	1.73	1.56	1.42	1.29	1.17	1.07	0.98
140	2.19	1.97	1.78	1.61	1.46	1.33	1.21	1.10	1.01
145	2.27	2.04	1.84	1.67	1.51	1.37	1.25	1.14	1.04

Source : Mfg. Data

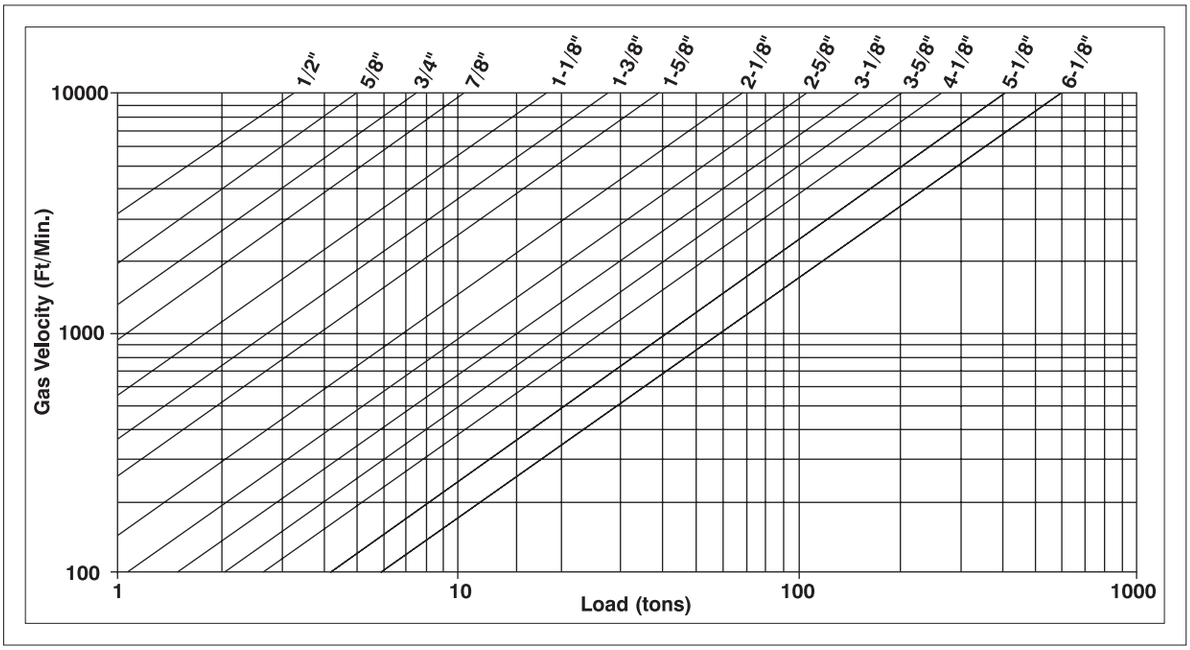


Figure 4.2 is based on 40^{0}F suction temperature and 105^{0}F condensing temperature. For other conditions, apply correction factors from Table 4.18.

Figure 4.2 : R-134a Suction Gas Velocity

Table 4.18 : R-134a Suction Gas Velocity Correction Factors

Cond Temp (^{0}F)	Suction Temperature (^{0}F)								
	10	15	20	25	30	35	40	45	50
85	1.76	1.56	1.40	1.25	1.12	1.00	0.90	0.82	0.74
90	1.81	1.61	1.43	1.28	1.15	1.03	0.93	0.84	0.76
95	1.86	1.65	1.47	1.32	1.18	1.06	0.95	0.86	0.77
100	1.91	1.70	1.52	1.35	1.21	1.09	0.98	0.88	0.80
105	1.97	1.75	1.56	1.39	1.25	1.12	1.00	0.91	0.82
110	2.04	1.81	1.61	1.44	1.29	1.15	1.04	0.93	0.84
115	2.10	1.87	1.66	1.48	1.33	1.19	1.07	0.96	0.87
120	2.18	1.93	1.72	1.53	1.37	1.23	1.10	0.99	0.90
125	2.26	2.00	1.78	1.58	1.42	1.27	1.14	1.03	0.92
130	2.35	2.08	1.85	1.65	1.47	1.32	1.18	1.06	0.96
135	2.44	2.16	1.92	1.71	1.53	1.37	1.23	1.10	0.99
140	2.55	2.26	2.00	1.78	1.59	1.42	1.27	1.14	1.03
145	2.66	2.36	2.09	1.86	1.66	1.48	1.33	1.19	1.07

Source : Mfg. Data

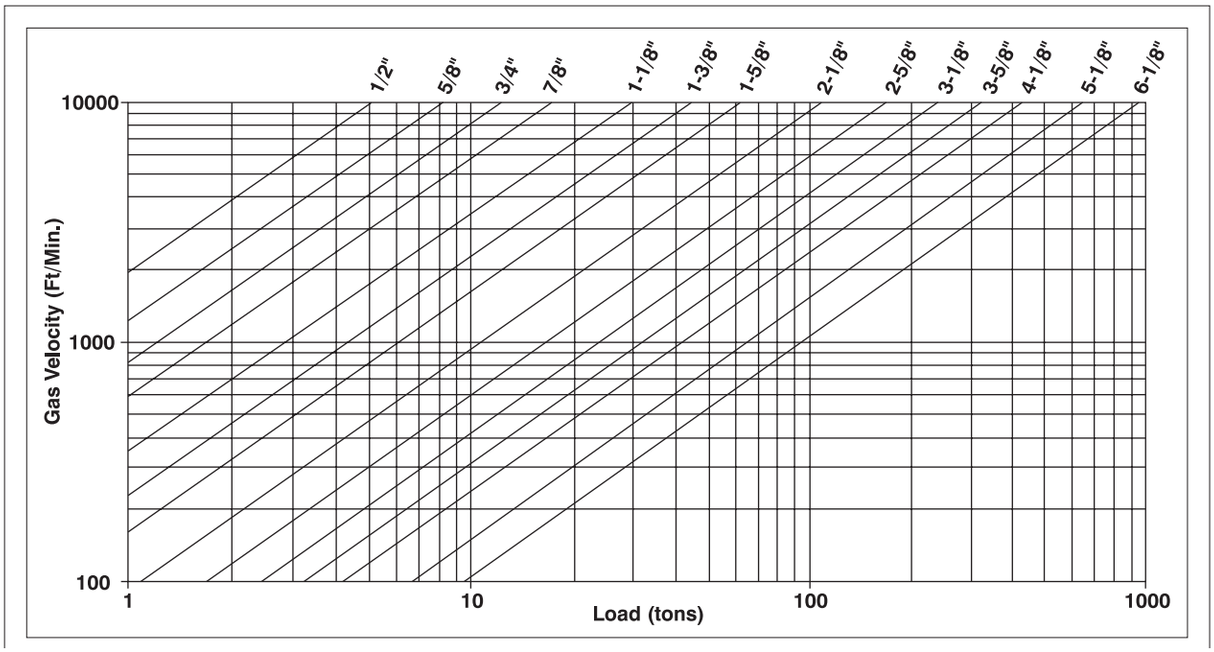


Figure 4.3 is based on 40^{0}F suction temperature and 105^{0}F condensing temperature. For other conditions, apply correction factors from Table 4.19.

Figure 4.3 : R-410A Suction Gas Velocity

Table 4.19 : R- 410A Suction Gas Velocity Correction Factors

Cond Temp (^{0}F)	Suction Temperature (^{0}F)								
	10	15	20	25	30	35	40	45	50
85	1.60	1.45	1.31	1.91	1.08	0.98	0.90	0.82	0.75
90	1.64	1.48	1.34	1.22	1.11	1.01	0.92	0.84	0.77
95	1.69	1.53	1.38	1.25	1.14	1.04	0.95	0.86	0.79
100	1.74	1.57	1.42	1.29	1.17	1.07	0.97	0.89	0.81
105	1.79	1.62	1.46	1.33	1.21	1.10	1.00	0.91	0.83
110	1.85	1.67	1.51	1.37	1.24	1.13	1.03	0.94	0.86
115	1.91	1.73	1.56	1.42	1.29	1.17	1.07	0.97	0.89
120	1.98	1.79	1.62	1.47	1.33	1.21	1.10	1.01	0.92
125	2.06	1.86	1.68	1.52	1.38	1.26	1.14	1.04	0.95
130	2.14	1.93	1.75	1.58	1.44	1.31	1.19	1.08	0.99
135	2.24	2.02	1.82	1.65	1.50	1.36	1.24	1.13	1.03
140	2.35	2.12	1.91	1.73	1.57	1.43	1.30	1.18	1.08
145	2.48	2.23	2.01	1.82	1.65	1.50	1.36	1.24	1.13

Source : Mfg. Data

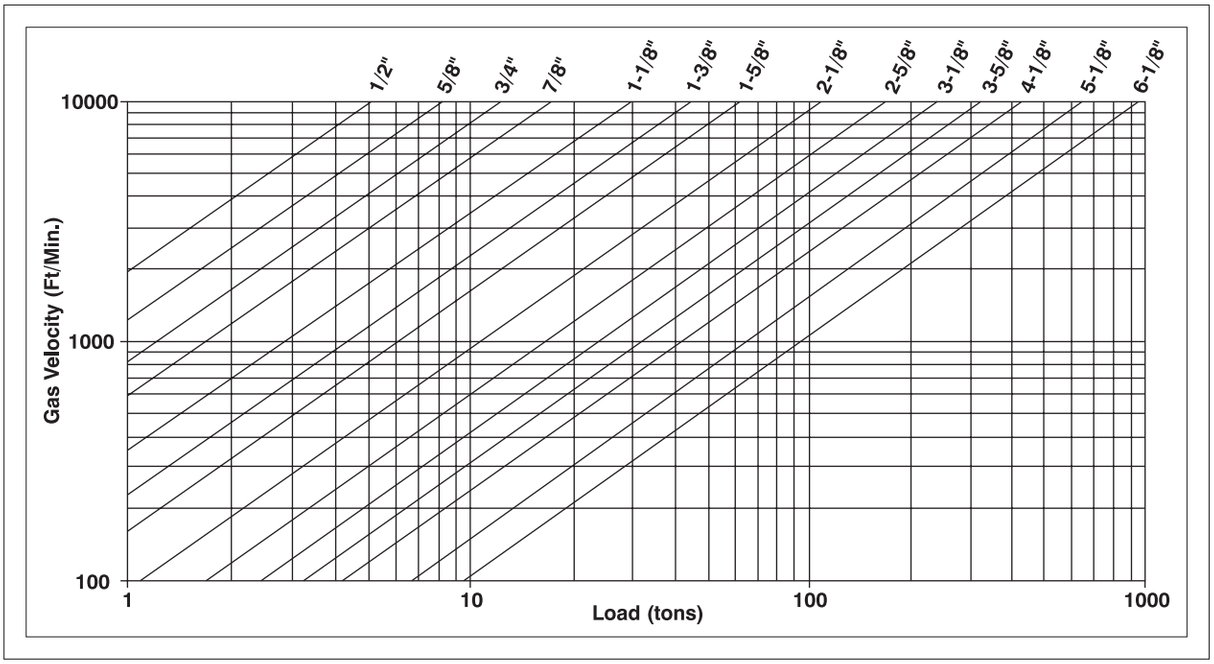


Figure 4.4 is based on 40^{0}F suction temperature and 105^{0}F condensing temperature. For other conditions, apply correction factors from Table 4.20.

Figure 4.4 : R-407C Suction Gas Velocity

Table 4.20 : R-407C Suction Gas Velocity Correction Factors

Cond Temp (^{0}F)	Suction Temperature (^{0}F)								
	10	15	20	25	30	35	40	45	50
85	1.78	1.49	1.35	1.21	1.10	0.99	0.90	0.82	0.75
90	1.82	1.53	1.38	1.24	1.12	1.02	0.92	0.84	0.76
95	1.75	1.57	1.42	1.28	1.15	1.04	0.95	0.86	0.78
100	1.80	1.62	1.46	1.31	1.19	1.07	0.97	0.88	0.80
105	1.86	1.78	1.50	1.35	1.22	1.10	1.00	0.91	0.83
110	1.91	1.72	1.54	1.39	1.26	1.14	1.03	0.93	0.85
115	1.98	1.77	1.59	1.43	1.29	1.17	1.06	0.96	0.87
120	2.04	1.83	1.75	1.48	1.34	1.21	1.09	0.99	0.90
125	2.12	1.90	1.81	1.53	1.38	1.25	1.13	1.03	0.93
130	2.20	1.97	1.77	1.59	1.43	1.29	1.17	1.06	0.96
135	2.29	2.05	1.84	1.76	1.49	1.34	1.22	1.10	1.00
140	2.38	2.13	1.91	1.72	1.55	1.40	1.26	1.15	1.04
145	2.49	2.23	2.00	1.79	1.72	1.46	1.32	1.19	1.08

Source : Mfg. Data

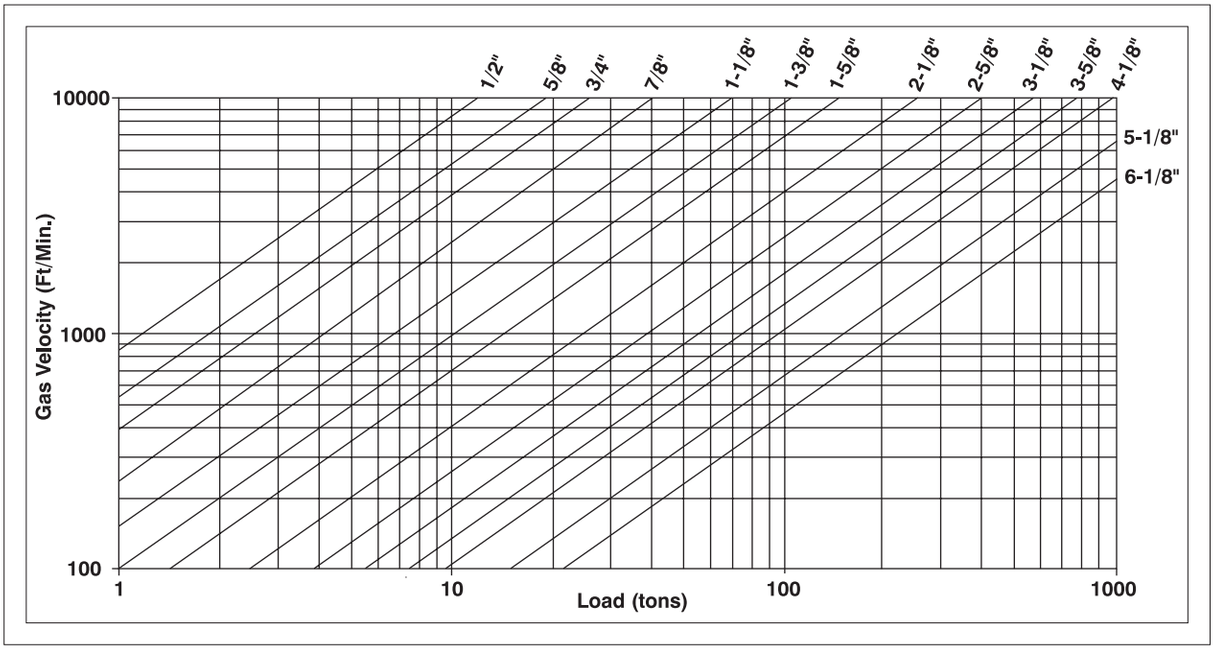


Figure 4.5 is based on 40^{0}F suction temperature and 105^{0}F condensing temperature. For other conditions, apply correction factors from Table 4.21.

Figure 4.5 : R-22 Discharge Gas Velocity

Table 4.21 : R-22 Discharge Gas Velocity Correction Factors

Cond Temp (^{0}F)	Suction Temperature (^{0}F)								
	10	15	20	25	30	35	40	45	50
85	1.20	1.23	1.26	1.28	1.31	1.34	1.37	1.39	1.42
90	1.12	1.15	1.17	1.20	1.23	1.26	1.28	1.31	1.33
95	1.05	1.08	1.10	1.13	1.16	1.18	1.21	1.23	1.26
100	0.98	1.01	1.04	1.06	1.09	1.11	1.14	1.16	1.19
105	0.92	0.95	0.97	1.00	1.03	1.05	1.07	1.10	1.12
110	0.86	0.89	0.92	0.94	0.97	0.99	1.01	1.04	1.06
115	0.81	0.84	0.86	0.89	0.91	0.93	0.96	0.98	1.01
120	0.76	0.79	0.81	0.84	0.86	0.88	0.91	0.93	0.96
125	0.72	0.74	0.76	0.79	0.81	0.84	0.86	0.88	0.91
130	0.67	0.70	0.72	0.74	0.77	0.79	0.82	0.84	0.87
135	0.63	0.65	0.68	0.70	0.73	0.75	0.78	0.80	0.82
140	0.59	0.62	0.64	0.67	0.69	0.72	0.74	0.77	0.79
145	0.55	0.58	0.60	0.63	0.66	0.68	0.71	0.73	0.76

Source : Mfg. Data

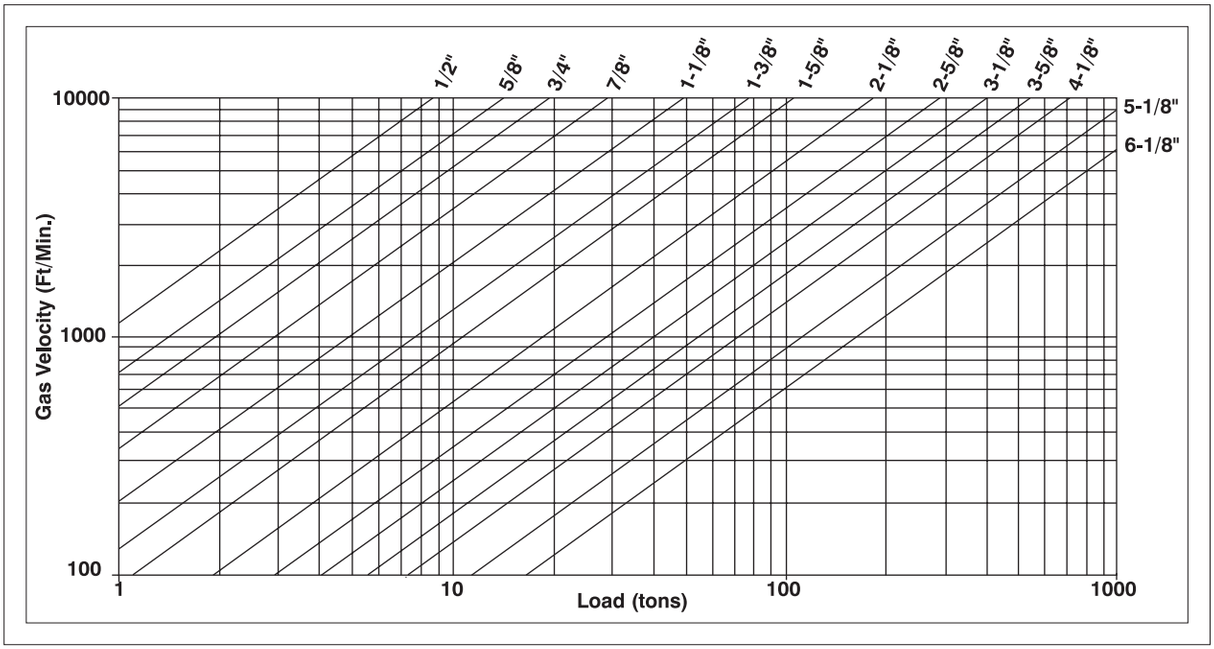


Figure 4.6 is based on 40^{0}F suction temperature and 105^{0}F condensing temperature. For other conditions, apply correction factors from Table 4.22.

Figure 4.6 : R-134a Discharge Gas Velocity

Table 4.22 : R-134a Discharge Gas Velocity Correction Factors

Cond Temp (^{0}F)	Discharge Temperature (^{0}F)								
	150	160	170	180	190	200	210	220	230
85	1.23	1.26	1.29	1.32	1.35	1.37	1.40	1.43	1.46
90	1.15	1.17	1.20	1.23	1.26	1.28	1.31	1.34	1.36
95	1.07	1.09	1.12	1.14	1.17	1.19	1.22	1.25	1.27
100	0.99	1.02	1.04	1.07	1.09	1.12	1.14	1.17	1.19
105	0.92	0.95	0.97	1.00	1.02	1.04	1.07	1.09	1.12
110	0.86	0.88	0.91	0.93	0.95	0.98	1.00	1.02	1.05
115	0.80	0.83	0.85	0.87	0.89	0.92	0.94	0.96	0.99
120	0.75	0.77	0.79	0.82	0.84	0.86	0.88	0.91	0.93
125	0.70	0.72	0.75	0.77	0.79	0.81	0.83	0.86	0.88
130	0.65	0.68	0.70	0.68	0.74	0.76	0.79	0.81	0.83
135	0.61	0.63	0.65	0.64	0.70	0.72	0.74	0.76	0.79
140	0.57	0.59	0.61	0.66	0.66	0.68	0.70	0.72	0.75
145	0.53	0.55	0.57	0.62	0.62	0.64	0.66	0.69	0.71

Source : Mfg. Data

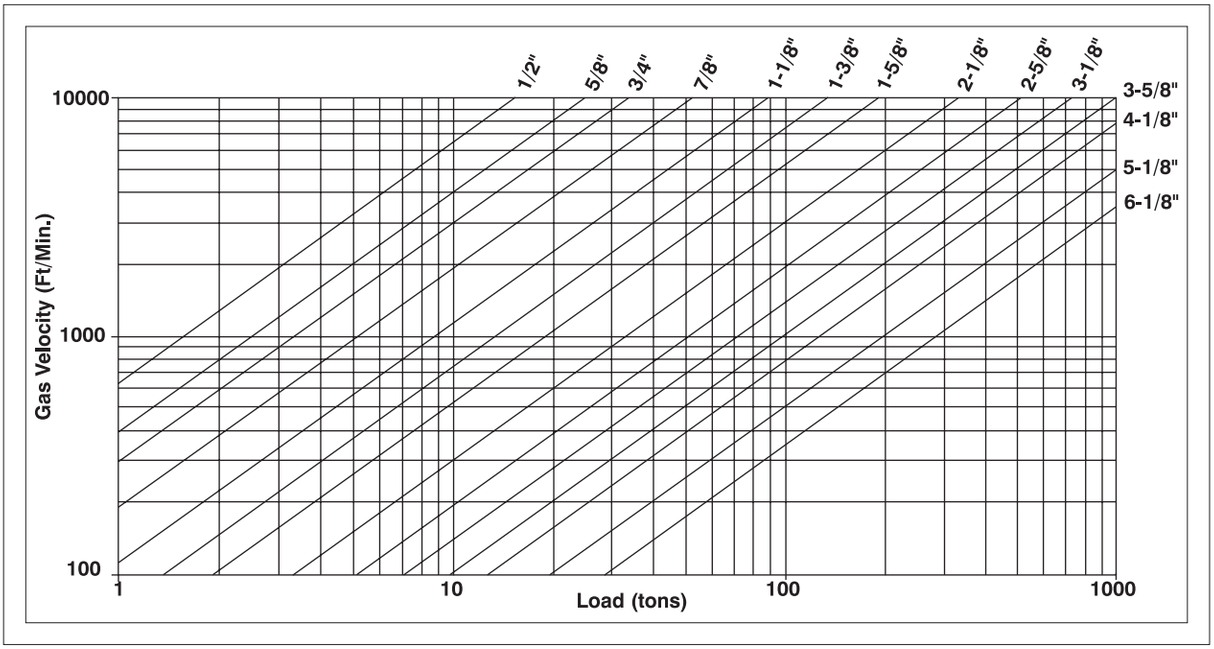


Figure 4.7 is based on 40^{0}F suction temperature and 105^{0}F condensing temperature. For other conditions, apply correction factors from Table 4.23.

Figure 4.7 : R-410a Discharge Gas Velocity

Table 4.23 : R-410a Discharge Gas Velocity Correction Factors

Cond Temp (^{0}F)	Discharge Temperature (^{0}F)								
	150	160	170	180	190	200	210	220	230
85	1.13	1.17	1.20	1.23	1.26	1.29	1.32	1.35	1.39
90	1.07	1.10	1.13	1.16	1.19	1.22	1.25	1.29	1.32
95	1.01	1.04	1.07	1.10	1.13	1.16	1.19	1.22	1.25
100	0.95	0.98	1.01	1.04	1.07	1.10	1.13	1.17	1.20
105	0.90	0.93	0.96	0.99	1.02	1.05	1.08	1.11	1.15
110	0.85	0.88	0.91	0.95	0.98	1.01	1.04	1.07	1.10
115	0.81	0.84	0.87	0.91	0.94	0.97	1.00	1.03	1.06
120	0.77	0.80	0.84	0.87	0.90	0.93	0.97	1.00	1.03
125	0.73	0.77	0.80	0.84	0.87	0.91	0.94	0.97	1.01
130	0.70	0.74	0.77	0.81	0.85	0.88	0.92	0.96	0.99
135	0.67	0.71	0.75	0.79	0.83	0.87	0.91	0.95	0.99
140	0.64	0.69	0.73	0.78	0.82	0.86	0.91	0.95	1.00
145	0.61	0.67	0.72	0.77	0.82	0.87	0.93	0.98	1.03

Source : Mfg. Data

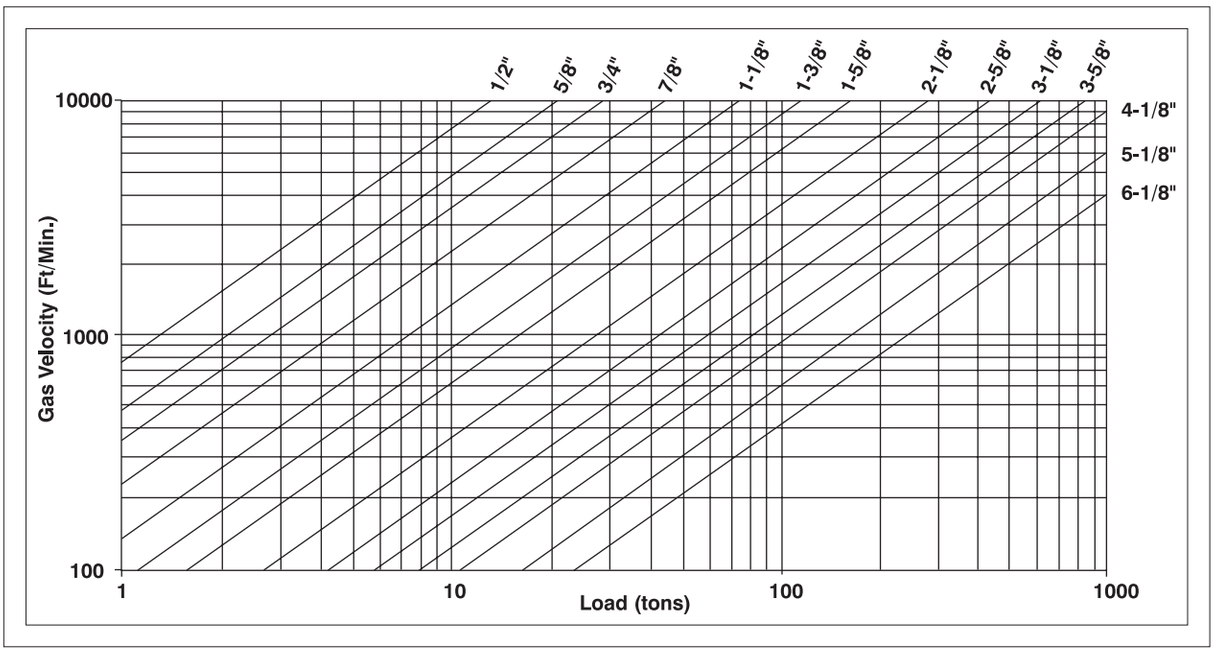


Figure 4.8 is based on 40^{0}F suction temperature and 105^{0}F condensing temperature. For other conditions, apply correction factors from Table 4.24.

Figure 4.8 : R-407C Discharge Gas Velocity

Table 4.24 : R-407C Discharge Gas Velocity Correction Factors

Cond Temp (^{0}F)	Discharge Temperature (^{0}F)								
	150	160	170	180	190	200	210	220	230
85	1.17	1.20	1.23	1.26	1.29	1.32	1.35	1.38	1.41
90	1.10	1.13	1.16	1.19	1.22	1.24	1.27	1.30	1.33
95	1.03	1.06	1.09	1.12	1.15	1.17	1.20	1.23	1.26
100	0.97	1.00	1.02	1.05	1.08	1.11	1.14	1.17	1.20
105	0.91	0.94	0.96	0.99	1.02	1.05	1.08	1.11	1.14
110	0.85	0.88	0.91	0.94	0.97	0.99	1.02	1.05	1.08
115	0.80	0.83	0.86	0.89	0.92	0.95	0.97	1.00	1.03
120	0.76	0.79	0.81	0.84	0.87	0.90	0.93	0.96	0.99
125	0.71	0.74	0.77	0.80	0.83	0.86	0.89	0.92	0.95
130	0.67	0.70	0.73	0.76	0.79	0.82	0.85	0.88	0.91
135	0.63	0.66	0.69	0.73	0.76	0.79	0.82	0.85	0.88
140	0.59	0.62	0.66	0.69	0.72	0.76	0.79	0.82	0.86
145	0.55	0.58	0.62	0.66	0.69	0.73	0.77	0.80	0.84

Source : Mfg. Data

Table 4.25 : R-22 Refrigerant Charge (lbs. Per 100 Feet of Pipe)

Line Size OD	Flow Area	Suction Line	Liquid Line	Discharge Line
		40° F	105° F	140° F
Inches	In^2	1.52 lb ft^3	68.72 lb ft^3	6.97 lb ft^3
1/2	0.145	0.15	6.92	0.70
5/8	0.233	0.25	11.12	1.13
7/8	0.484	0.51	23.10	2.34
1 1/8	0.825	0.87	39.37	3.99
1 3/8	1.257	1.33	59.99	6.08
1 5/8	1.779	1.88	84.90	8.61
2 1/8	3.905	4.13	186.36	18.90
2 5/8	4.772	5.04	227.73	23.09
3 1/8	6.812	7.20	325.08	32.97
3 5/8	9.213	9.74	439.66	44.58
4 1/8	11.977	12.66	571.57	57.96
5 1/8	18.665	19.72	890.74	90.33
6 1/8	20.832	28.35	1280.48	129.85
8 1/8	46.869	49.53	2236.69	226.81

Refrigerant weight per 100 feet of pipe is based on 105° F condensing temperature and 10° F sub-cooling, 140° F discharge temperature and 40° F saturated suction temperature

Table 4.26 : R-134a Refrigerant Charge (lbs. Per 100 Feet of Pipe)

Line Size OD	Flow Area	Suction Line	Liquid Line	Discharge Line
		40° F	105° F	140° F
Inches	In^2	1.05 lb ft^3	69.93 lb ft^3	5.46 lb ft^3
1/2	0.145	0.11	7.04	0.55
5/8	0.233	0.17	11.32	0.88
7/8	0.484	0.35	23.50	1.83
1 1/8	0.825	0.60	40.06	3.13
1 3/8	1.257	0.92	61.04	4.76
1 5/8	1.779	1.30	86.39	6.74
2 1/8	3.905	2.85	189.64	14.79
2 5/8	4.772	3.48	231.74	18.08
3 1/8	6.812	4.96	330.81	25.81
3 5/8	9.213	6.71	447.41	34.90
4 1/8	11.977	8.73	581.63	45.38
5 1/8	18.665	13.60	906.42	70.71
6 1/8	20.832	19.56	1301.03	101.65
8 1/8	46.869	34.16	2276.08	177.57

Refrigerant weight per 100 feet of pipe is based on 105° F condensing temperature and 10° F sub-cooling, 140° F discharge temperature and 40° F saturated suction temperature

Table 4.27 : R-410A Refrigerant Charge (lbs. Per 100 Feet of Pipe)

Line Size OD	Flow Area	Suction Line	Liquid Line	Discharge Line
		40° F	105° F	140° F
Inches	In^2	2.21 lb ft^3	58.37 lb ft^3	12.57 lb ft^3
1/2	0.145	0.22	5.88	1027
5/8	0.233	0.36	9.44	2.03
7/8	0.484	0.74	19.62	4.22
1 1/8	0.825	1.26	33.44	7.20
1 3/8	1.257	1.93	50.95	10.97
1 5/8	1.779	2.72	72.11	15.53
2 1/8	3.905	5.98	158.29	34.09
2 5/8	4.772	7.31	193.43	41.66
3 1/8	6.812	10.43	276.12	59.46
3 5/8	9.213	14.11	373.45	80.42
4 1/8	11.977	18.34	485.48	104.55
5 1/8	18.665	28.59	756.58	162.93
6 1/8	20.832	41.10	1087.63	234.22
8 1/8	46.869	71.79	1899.82	409.12

Refrigerant weight per 100 feet of pipe is based on 105° F condensing temperature and 10° F sub-cooling, 140° F discharge temperature and 40° F saturated suction temperature

Table 4.28 : R-407C Refrigerant Charge (lbs. Per 100 Feet of Pipe)

Line Size OD	Flow Area	Suction Line	Liquid Line	Discharge Line
		40° F	105° F	140° F
Inches	In^2	1.69 lb ft^3	64.65 lb ft^3	8.64 lb ft^3
1/2	0.145	0.17	6.51	0.87
5/8	0.233	0.27	10.46	1.40
7/8	0.484	0.57	21.73	2.91
1 1/8	0.825	0.97	37.04	4.95
1 3/8	1.257	1.48	56.43	7.55
1 5/8	1.779	2.09	79.87	10.68
2 1/8	3.905	4.59	175.32	23.44
2 5/8	4.772	5.61	214.24	28.65
3 1/8	6.812	8.01	305.83	40.89
3 5/8	9.213	10.83	413.63	55.30
4 1/8	11.977	14.09	537.72	71.90
5 1/8	18.665	21.95	837.98	112.04
6 1/8	20.832	31.56	1204.65	161.07
8 1/8	46.869	55.12	2104.22	281.34

Refrigerant weight per 100 feet of pipe is based on 105° F condensing temperature and 10° F sub-cooling, 140° F discharge temperature and 40° F saturated suction temperature

Table 4.29 : Suction, Discharge, and Liquid Line Capacities in Tons for Ammonia (Single-or High-Stage Applications)

Steel Line Size		Suction Lines (Δ °F)					Dis-charge Lines Δt = 1° F Δ 2.95	Steel Line Size		Liquid Lines	
		Saturated Suction Temperature °F									
IPS	SCH	-40	-20	0	20	40		IPS	SCH	Velocity-100 fpm	Δ Δt = 0.7° t
		Δ =0.31	Δ 0.49	Δ 0.73	Δ 1.06	Δ 1.46					
3\8	80	-	-	-	-	-	-	3/8	80	8.6	12.1
1\2	80	-	-	-	-	-	3.1	1/2	80	14.2	24.0
3\4	80	-	-	-	2.6	3.8	7.1	3/4	80	26.3	54.2
1	80	-	21.	3.4	5.2	7.6	13.9	1	80	43.8	106.4
1 1/4	40	3.2	5.6	8.9	13.6	19.9	S6..5	1 1/4	80	78.1	228.6
1 1/2	40	4.9	8.4	13.4	20.5	29.9	54.8	1 1/2	80	107.5	349.2
2	40	9.5	16.2	26.0	39.8	57.8	105.7	2	40	204.2	811.4
2 1/2	40	15.3	25.9	41.5	63.2	92.1	168.5	21/2	40	291.1	1292.6
3	40	27.1	46.1	73.5	111.9	163.0	297.6	3	40	449.6	2287.8
4	40	55.7	94.2	150.1	228.7	333.0	606.2	4	40	774.7	4662.1
5	40	101.1	170.4	271.1	412.4	600.9	1095.2	5	40	-	-
6	40	164.0	276.4	439.2	667.5	971.6	1771.2	6	40	-	-
8	40	337.2	566.8	901.1	1366.6	1989.4	3623.0	8	40	-	-
10	40	611.6	1027.2	1634.3	2474.5	3598.0	-	10	40	-	-
12	ID	981.6	1644.5	2612.4	3969.5	5764.5	-	12	ID	-	-

1. Table capacities are in Tons of Refrigeration
   Δp = pressure drop due to line friction, psi per 100 ft of equivalent line length
   ΔL = corresponding change in saturation temperature , °F per 100ft

2. Line capacity for other saturation temperature Δt and equivalent length

$$\text{Line capacity} = \text{Table capacity} \left[\frac{\text{Table } Le}{\text{Actual } Le} \times \frac{\text{Actual } \Delta t}{\text{Table } \Delta t} \right] 0.55$$

3. Saturation temperature Δt for other capacities and equivalent length

$$\Delta t = \text{Table } \Delta L = \left[\frac{\text{Actual } Le}{\text{Actual } Le} \times \frac{\text{Actual Capacity}}{\text{Table Capacity}} \right] 1.8$$

4. Values are based on 90° F condensing temperature. Multiply table capacities by the following factors for other condensing temperatures :

Condensing Temperature (°F)	Suction Line	Discharge Line
70	1.05	0.78
80	1.02	0.89
90	1.00	1.00
100	0.98	1.11

5. Discharge and liquid line capacities are based on 20° F suction. Evaporated temperature is 0° F. The capacity is affected less than 3% when applied from -40 to +40 °F extremes.

* The inside diameter of the pipe is the same as the nominal pipe size

Source: ASHRAE Handbook

Table 4.30 : Liquid Ammonia Line Capacities in overfeed systems (Capacity in tons refrigeration except as noted)

Nominal Size In.	Pumped Liquid Overfeed Ration			High Pressure Liquid at 3 psi[a]	Hot-Gas Defrost[a]	Equalizer High Side [b]	Thermosiphon Lubricant Cooling Lines Gravity Flow, [c] 1000 Btu/h		
	3 : 1	4 : 1	5 : 1				Supply	Return	Vent
1/2	10	7.5	6	30	-	-		-	-
3/4	22	16.5	13	69	9-15	50	-	-	-
1	43	32.5	26	234	16-27	100	-	-	-
1 1/4	93.5	70	56	286	38-38	150	-	-	-
1 1/2	146	110	87.5	439	39-64	225	200	120	203
2	334	250	200	1016	65-107	300	470	300	362
2 1/2	533	400	320	1616	108-152	500	850	530	638
3	768	576	461	2886	153-246	1000	1312	870	1103
4	1365	1024	819	-	247-411	2000	2261	1410	2000
5	-	-	-	-	-	-	3550	2214	3624
6	-	-	-	-	-	-	5130	3200	6378
8	-	-	-	-	-	-	8847	5533	11596

a) *Rating for Hot-Gas branch lines under 100 ft with minimum inlet pressure of 105 psig, defrost pressure of 70 psig and -20^0 F evaporators designed for 10° F temperature differential.

b) Line size based on experience using total system evaporator tons.

c) Values for line sizes above 4 inches are extrapolated.

Source : ASHRAE 2010 - Fundamentals

Table 4.31 : Copper Tube Data

Nominal Size, in	Type	Wall Thickness t, in.	Diameter		Surface Area		Cross Section		Weight		Working Pressure ASTM B88 to 250°F	
			Outside d, in	Inside d, in	Outside ft² / ft	Inside ft² / ft	Metal Area in²	Flow Area in²	Tube lb/ft.	Water	Annealed psig	Drawn psig
1/4	K	0.035	0.375	0.305	0.098	0.080	0.037	0.073	0.145	0.032	851	1596
	L	0.030	0.375	0.315	0.098	0.082	0.033	0.078	0.126	0.034	730	1368
3/8	K	0.049	0.500	0.402	0.131	0.105	0.069	0.127	0.269	0.055	894	1676
	L	0.035	0.500	0.430	0.131	0.113	0.051	0.145	0.198	0.063	638	1197
	M	0.025	0.500	0.450	0.131	0.118	0.037	0.159	0.145	0.069	456	855
1/2	K	0.049	0.625	0.527	0.164	0.138	0.089	0.218	0.344	0.094	715	1341
	L	0.040	0.625	0.545	0.164	0.143	0.074	0.233	0.285	0.101	584	1094
	M	0.028	0.625	0.569	0.164	0.149	0.053	0.254	0.203	0.110	409	766
5/8	K	0.049	0.750	0.652	0.196	0.171	0.108	0.334	0.418	0.144	596	1117
	L	0.042	0.750	0.666	0.196	0.174	0.093	0.348	0.362	0.151	511	958
3/4	K	0.065	0.875	0.745	0.229	0.195	0.165	0.436	0.641	0.189	677	1270
	L	0.045	0.875	0.785	0.229	0.206	0.117	0.484	0.455	0.209	469	879
	M	0.032	0.875	0.811	0.229	0.212	0.085	0.517	0.328	0.224	334	625
1	K	0.065	1.125	0.995	0.295	0.260	0.216	0.778	0.839	0.336	527	988
	L	0.050	1.125	1.025	0.295	0.268	0.169	0.825	0.654	0.357	405	765
	M	0.035	1.125	1.055	0.295	0.276	0.120	0.874	0.464	0.378	284	532
1-1/4	K	0.065	1.375	1.245	0.360	0.326	0.268	1.217	1.037	0.527	431	808
	L	0.055	1.375	1.265	0.360	0.331	0.228	1.257	0.884	0.544	365	684
	M	0.042	1.375	1.291	0.360	0.338	0.176	1.309	0.682	0.566	279	522
	DWV	0.040	1.375	1.295	0.360	0.339	0.168	1.317	0.650	0.570	265	497
1-1/2	K	0.072	1.625	1.481	0.425	0.388	0.351	1.723	1.361	0.745	404	758
	L	0.060	1.625	1.505	0.425	0.394	0.295	1.779	1.143	0.770	337	631
	M	0.049	1.625	1.527	0.425	0.400	0.243	1.831	0.940	0.792	275	516
	DWV	0.042	1.625	1.541	0.425	0.403	0.209	1.865	0.809	0.807	236	442
2	K	0.083	2.125	1.959	0.556	0.513	0.532	3.014	2.063	1.304	356	668
	L	0.070	2.125	1.985	0.556	0.520	0.452	3.095	1.751	1.339	300	573
	M	0.058	2.125	2.009	0.556	0.526	0.377	3.170	1.459	1.372	249	467
	DWV	0.042	2.125	2.041	0.556	0.534	0.275	3.272	1.065	1.416	180	338
2-1/2	K	0.095	2.625	2.435	0.687	0.637	0.755	4.657	2.926	2.015	330	619
	L	0.080	2.625	2.465	0.687	0.645	0.640	4.772	2.479	2.065	278	521
	M	0.065	2.625	2.495	0.687	0.653	0.523	4.889	2.026	2.116	226	423
3	K	0.109	3.125	2.907	0.818	0.761	1.033	6.637	4.002	2.872	318	596
	L	0.090	3.125	2.945	0.818	0.771	0.858	6.812	3.325	2.947	263	492
	M	0.072	3.125	2.981	0.818	0.780	0.691	6.979	2.676	3.020	210	394
	DWV	0.045	3.125	3.035	0.818	0.795	0.435	7.234	1.687	3.130	131	246
3-1/2	K	C.120	3.625	3.385	0.949	0.886	1.321	8.999	5.120	3.894	302	566
	L	0.100	3.625	3.425	0.949	0.897	1.107	9.213	4.291	3.987	252	472
	M	0.083	3.625	3.459	0.949	0.906	0.924	9.397	3.579	4.066	209	392
4	K	0.134	4.125	3.857	1.080	1.010	1.680	11.684	6.510	5.056	296	555
	L	0.110	4.125	3.905	1.080	1.022	1.387	11.977	5.377	5.182	243	456
	M	0.095	4.125	3.935	1.080	1.030	1.203	12.161	4.661	5.262	210	394
	DWV	0.058	4.125	4.009	1.080	1.050	0.741	12.623	2.872	5.462	128	240
5	K	0.160	5.125	4.805	1.342	1.258	2.496	18.133	9.671	7.846	285	534
	L	0.125	5.125	4.875	1.342	1.276	1.963	18.665	7.609	8.077	222	417
	M	0.109	5.125	4.907	1.342	1.285	1.718	18.911	6.656	8.183	194	364
	DWV	0.072	5.125	4.981	1.342	1.304	1.143	19.486	4.429	8.432	128	240
6	K	0.192	6.125	5.741	1.603	1.503	3.579	25.886	13.867	11.201	286	536
	L	0.140	6.125	5.845	1.603	1.530	2.632	26.832	10.200	11.610	208	391
	M	0.122	6.125	5.881	1.603	1.540	2.301	27.164	8.916	11.754	182	341
	DWV	0.083	6.125	5.959	1.603	1.560	1.575	27.889	6.105	12.068	124	232
8	K	0.271	8.125	7.583	2.127	1.985	6.687	45.162	25.911	19.542	304	570
	L	0.200	8.125	7.725	2.127	2.022	4.979	46.869	19.295	20.280	224	421
	M	0.170	8.125	7.785	2.127	2.038	4.249	47.600	16.463	20.597	191	358
	DWV	0.109	8.125	7.907	2.127	2.070	2.745	49.104	10.637	21.247	122	229

Source: ASHRAE Handbook

Table 4.32 : Seamless Steel Pipe Data

Nominal Size, in	Pipe OD in	Schedule Number or Weight	Wall Thick-ness t, in	Inside Diameter	Surface Area		Cross Section		Weight		Working Pressure[c] ASTM A5 B to 400°F		
					Outside ft² / ft	Inside ft² / ft	Metal Area in²	Flow Area, in²	Pipe lb./ft	Water b./ft	Mfr. Process	Joint Type	psig
1/4	0.540	40 ST	0.088	0.364	0.141	0.095	0.125	0.104	0.424	0.045	CW	T	188
		80 XS	0.119	0.302	0.141	0.079	0.157	0.072	0.535	0.031	cw	T	871
3/8	0.675	40 ST	0.091	0.493	0.177	0.129	0.167	0.191	0.567	0.083	cw	T	203
		80 XS	0.126	0.423	0.177	0.111	0.217	0.141	0.738	0.061	cw	T	820
1/2	0.840	40 ST	0.109	0.622	0.220	0.163	0.250	0.304	0.85	0.131	cw	T	214
		80 XS	0.147	0.546	0.220	0.143	0.320	0.234	1.087	0.101	cw	T	753
3/4	1.050	40 ST	0.113	0.824	0.275	0.216	0.333	0.533	1.13	0.231	cw	T	217
		80 XS	0.154	0.742	0.275	0.194	0.433	0.432	1.47	0.187	cw	T	681
1	1.315	40 ST	0.133	1.049	0.344	0.275	0.494	0.864	1.68	0.374	cw	T	226
		80 XS	0.179	0.957	0.344	0.251	0.639	0.719	2.17	0.311	cw	T	642
1-1/4	1.660	40 ST	0.140	1.380	0.435	0.361	0.669	1.50	2.27	0.647	cw	T	229
		80 XS	0.191	1.278	0.435	0.335	0.881	1.28	2.99	0.555	cw	T	594
1-1/2	1.900	40 ST	0.145	1.610	0.497	0.421	0.799	2.04	2.72	0.881	cw	T	231
		80 XS	0.200	1.500	0.497	0.393	1.068	1.77	3.63	0.765	cw	T	576
2	2.375	40 ST	0.154	2.067	0.622	0.541	1.071	3.36	3.65	1.45	cw	T	230
		80 XS	0.218	1.939	0.622	0.508	1.480	2.95	5.02	1.28	cw	T	551
2-1/2	2.875	40 ST	0.203	2.469	0.753	0.646	1.700	4.79	5.79	2.07	cw	T	533
		80 XS	0.276	2.323	0.753	0.608	2.250	4.24	7.66	1.83	cw	T	835
3	3.500	40 ST	0.216	3.068	0.916	0.803	2.230	7.39	7.57	3.20	cw	T	482
		80 XS	0.300	2.900	0.916	0.759	3.020	6.60	10.25	2.86	cw	T	767
4	4.500	40 ST	0.237	4.026	1.178	1.054	3.170	12.73	10.78	5.51	cw	T	430
		80 XS	0.337	3.826	1.178	1.002	4.410	11.50	14.97	4.98	cw	T	695
6	6.625	40 ST	0.280	6.065	1.734	1.588	5.580	28.89	18.96	12.50	ERW	W	696
		80 XS	0.432	5.761	1.734	1.508	8.400	26.07	28.55	11.28	ERW	W	1209
8	8.625	30	0.277	8.071	2.258	2.113	7.260	51.16	24.68	22.14	ERW	W	526
		40 ST	0.322	7.981	2.258	2.089	8.400	50.03	28.53	21.65	ERW	r w	643
		80 XS	0.500	7.625	2.258	1.996	12.76	45.66	43.35	19.76	ERW	w	1106
10	10.75	30	0.307	10.136	2.814	2.654	10.07	80.69	34.21	34.92	ERW	w	485
		40 ST	0.365	10.020	2.814	2.623	11.91	78.85	40.45	34.12	ERW	w	606
		XS	0.500	9.750	2.814	2.552	16.10	74.66	54.69	32.31	ERW	w	887
		80	0.593	9.564	2.814	2.504	18.92	71.84	64.28	31.09	ERW	w	1081
12	12.75	30	0.330	12.090	3.338	3.165	12.88	114.8	43.74	49.68	ERW	w	449
			0.375	12.000	3.338	3.141	14.58	113.1	49.52	48.94	ERW	w	528
		40 ST	0.406	11.938	3.338	3.125	15.74	111.9	53.48	48.44	ERW	w	583
		XS	0.500	11.750	3.338	3.076	19.24	108.4	65.37	46.92	ERW	w	748
		80	0.687	11.376	3.338	2.978	26.03	101.6	88.44	43.98	ERW	w	1076
14	14.00	30 ST	0.375	13.250	3.665	3.469	16.05	137.9	54.53	56.67	ERW	w	481
		40	0.437	13.126	3.665	3.436	18.62	135.3	63.25	58.56	ERW	w	580
		XS	0.500	13.000	3.665	3.403	21.21	132.7	72.04	57.44	ERW	w	681
		80	0.750	12.500	3.665	3.272	31.22	122.7	106.05	53.11	ERW	w	1081
16	16.00	30 ST	0.375	15.250	4.189	3.992	18.41	182.6	62.53	79.04	ERW	w	421
		40 XS	0.500	15.000	4.189	3.927	24.35	176.7	82.71	76.47	ERW	w	596
18	18.00	ST	0.375	17.250	4.712	4.516	20.76	233.7	70.54	101.13	ERW	w	374
		30	0.437	17.126	4.712	4.483	24.11	230.3	81.91	99.68	ERW	w	451
		XS	0.500	17.000	4.712	4.45	27.49	227.0	93.38	98.22	ERW	w	530
		40	0.562	16.876	4.712	4.418	30.79	223.7	104.59	96.80	ERW	w	607
20	20.0	20ST	0.375	19.250	5.236	5.030	23.12	291.0	78.54	125.94	ERW	w	3
		30XS	0.500	19.000	5.236	4.074	30.63	283.5	104.05	122.69	ERW	w	4
		40	0.593	18.814	5.236	4.925	36.15	278.0	122.82	120.30	ERW	w	5

Numbers are Schedule numbers as per ASME Standard B36 10M; ST=Standard Weight; XS = Extra Strong.
[b]T= Thread; W = Weld
12.5% of t for mill tolerance on pipe wall thickness, plus / minus.
An arbitrary corrosion allowance of 0.025 in. for pipe sizes through NPS 2 and 0.065 in. from NPS 2 1/2 through 20 inches plus a thread cutting allowance for sizes through NPS 2 is to be considered.

Source: ASHRAE Handbook

Table 4.33 : Internal Working Pressure for Copper Tube Joints

Alloy Used for Joints	Service Temperature ^{0}F	Internal Working Pressure, psi					
		Water and Noncorrosive Liquid and Gases Nominal Tube Size (Type K,L,M), in.					Sat. Stream and Condensate
		1/4 to 1	11/4 to 2	2 1/2 to 4	5 to 8[a]	10 to 12	1/4 to 8
50-50 Tin/lead solder	100	200	175	150	130	100	-
(ASTM B32 Gr 50 TA)	150	150	125	100	90	70	-
	200	100	90	75	70	50	-
	250	85	75	50	45	40	15
95-5 Tin/antimony[b] solder	100	500	400	300	270	150	-
(ASTMB 32 Gr 50 TA)	150	400	350	275	250	150	-
	200	300	250	200	180	140	-
	250	200	175	150	135	110	15
Brazed alloys melting between	100 to 200	d	d	d	d	d	-
Above 1000^0 F	250	300	210	170	150	150	-
	350	270	190	150	150	150	120

Source: Based on ASME standard B 31.9, Building Services Piping

Table 4.34 : Weight of Copper Tubes in Various Sizes and Gauges - External Diameter Weight in Kilograms per meter

Wall Thickness / SWG	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	30
External Diameter In Inches																								
1/4	-	-		-			.273	.262	.24	.231	.214	.196	.175	.151	.139	.126	.112	.098	.090	.083	.076	.069	.063	.053
5/16		-	-	-	-	-	.390	.365	.335	.312	.286	.259	.229	.196	.179	.162	.143	.125	.115	.106	.096	.088	.080	0.067
3/8	-	.631	.619	.599	.569	.541	.507	.465	.425	..393	.358	.322	.283	.241	.220	.198	.175	.152	.140	.128	.116	.106	.096	.081
7/16	-	.829	.799	.761	.713	.671	.624	.572	.515	.474	.430	.385	.337	.286	.260	.234	.206	.179	.165	.151	.137	.125	.113	.095
%	1.065	0.027	0.979	0.923	0.857	0.802	0.742	0.676	0.605	0.555	0.501	0.448	0.391	0.331	0.301	0.270	0.238	0.206	0.189	0.173	0.157	0.144	.130	.109
9/16	1.281	1.225	1.160	1.085	1.001	.933	.859	.779	.695	.636	.574	.511	.445	.376	.341	.306	.269	.233	.214	.196	.177	.162	.147	.123
5/8	1.497	1.423	1.340	1.247	1.145	1.063	.976	.883	.785	.717	.646	.574	.499	.421	.382	.342	.301	.260	.239	.219	.198	.181	.163	.138
11/16	1.713	1.621	1.20	1.409	1.289	1.194	1.093	.986	.875	.798	.718	.637	.553	.466	.422	.378	.332	.387	.264	.242	.218	.199	.180	.152
3/4	1.929	1.819	1.700	1.571	1.354	1.324	1.210	1.090	.965	.879	.790	.700	607	511	.463	.414	.364	.314	.288	.264	.238	.218	.197	.160
13/16	2.145	2.017	1.880	1.733	1.578	1.455	1.327	1.193	1.055	0.960	.863	.763	.661	.556	.503	.450	.395	.341	.313	.287	.259	.236	.214	.1802
7/8	2.361	2.215	2.060	1.895	1.722	1.585	1.144	1.297	1.145	1.041	.935	.826	.715	.601	.544	.486	.427	.368	.338	.310	.279	.255	.230	.194
15/16	2.577	2.413	2.240	2.057	1.866	1.716	1.561	1.401	1.235	1.122	LOOT1	0.889	.769	.646	.584	.522	.459	.395	.363	.322	.299	.273	.247	.208
1	2.793	2.611	2.42P	2.219	2.010	1.846	1.678	1.504	1.325	1.203	1.079	.952	.823	.691	.625	.558	.490	.422	.987	.355	.320	.292	.264	.222
1-1/8	3.225	3.0074	2.780	2.543	2.298	2.107	1.912	1.711	1.505	1.365	1.223	1.078	.931	.781	.706	.630	.553	.476	437	.400	.361	.329	297	.250
1-1/4	3.657	3.403	3.140	2.868	2.586	2.368	2.146	1.918	1.685	1.527	1.367	1.204	1.039	.871	.787	.702	.616	.530	.486	.445	.401	.366	.331	.278
1-3/8	4.090	3.799	3.500	3.192	2.874	2.630	2.380	2.125	1.865	1.689	1.511	1.330	1.147	.961	.868	.774	.679	.854	.536	.490	.442	.403	.364	.306
1-1/2	4.522	3.245	3.860	3.516	3.162	2.891	2.614	2.332	2.045	1.851	1.309	1.456	1.255	1.051	.949	.846	.742	.638	.585	536	.483	.440	.398	.344
1-5/8	4.954	4.592	4.220	3.840	3.450	3.152	2.848	2.539	2.225	2.013	1.799	1.582	1.363	1.142	1.030	0.918	.805	.692	.635	.581	.525	.477	.431	.362
1-3/4	5.386	4.988	4.580	4.164	3.738	3.413	3.082	2.746	2.405	2.175	1.943	1.708	1.471	1.232	1.111	0.990	.868	.746	.684	.626	.564	.515	.465	.390
1-7/8	5.818	5.834	4.941	4.488	4.026	3.674	3.316	2.953	2.586	2.337	2.087	1.834	1.579	1.322	1.192	1.062	.931	.800	.734	.671	.605	.552	.498	.418
2	6.250	5.780	5.301	4.812	4.314	3.935	3.550	3.161	2.766	2.499	2.231	1.960	1.687	1.412	1.273	1.134	.994	.854	.784	.717	.646	.589	.532	.446
2-1/8	6.682	6.176	5.661	5.136	4.602	4.196	3.784	3.368	2.946	2.661	2.375	2.086	1.795	1.502	1.354	1.206	1.057	.908	.833	.762	.687	.626	.565	.474
2-1/4	7.114	6.572	6.021	5.460	4.890	4.457	4.018	3.575	3.126	2.823	2.519	2.121	1.903	1.592	1.435	1.278	1.120	0.962	0.883	0.807	.727	.663	.599	.502
2-3/8	7.547	6.968	6.381	5.784	5.179	4.178	4.252	3.782	3.306	2.986	2.663	2.338	2.011	1.682	1.516	1.350	1.183	1.016	0.932	0.852	0.768	.700	.632	.530
2-1/2	7.979	7.364	6.741	6.108	5.467	4.979	4.487	3.989	3.486	3.148	3.807	2.464	2.119	1.772	1.597	1.422	1.246	1.070	0.982	0.898	0.809	0.737	.666	.558
	1.327	1.116	0.922	.747	.590	.485	.389	.305	.230	.187	.148	.113	.083	.057	.047	.037	.028	.021	0.17	.015	.012	.010	.008	.006

Table 4.35 : Soft Copper Tubing Physical Data

Standard Size	Nominal Dimensions			Theoretical Areas Based on Nominal Dimensions		
	Outside Diameter Inches	Inside Diameter Inches	Wall Thickness (Inches)	Cross Sectional Area of Bore (Sq. Inches)	External Surface (Sq. Feet. Per Lin. Ft.)	Internal Surface (Sq. Feet. Per Lin. Ft.)
1/8	.125	.65	.030	.0032	.0327	0.0170
3/16	.188	.128	.030	.0129	.0492	.0335
1/4	.250	.190	.030	.0284	.0655	.0497
5/16	.312	.248	.032	.0483	.0187	.0649
3/8	.375	.311	.032	.0760	.0982	.0814
1/2	.500	.436	.032	.149	.131	.114
5/8	.625	.555	.035	.242	.164	.145
3/4	.750	.666	.042	.348	.196	.174
7/8	.875	.785	.045	.484	.229	.206
1 1/8	1.125	1.025	.050	.0825	.294	.268
1 3/8	1.375	1.265	.050	1.26	.360	.331

Table 4.36 : Relative Sizes of Branches and Mains

Size of Main	Number and Size of Branches Main will Supply
1/2	Two -3/8"
3/4"	Two - 1/2"
1"	Two -3/4"
1 -1/4"	Two - 1" or One 1" and Two - 3/4"
1 -1/2"	Two - 1-1/4" or One 1-1/4" and Two - 3/4"
2"	Two - 1-1/2" or One - 1-1/2" and Two - 1-1/4"
2 - 1/2"	Two - 1-1/2" and Two - 1-1/4" or One - 2' and Two - 1-1/4"
3"	One - 2-1/2" and One - 2" or Two - 2" and Two - 1-1/2"
3-1/2"	Two - 2-1/2" or One - 3" and One -2" or Four - 2"
4"	One - 3-1/2" and One - 2-1/2" or Two - 3" or Three - 2-1/2" and One - 2" or Six - 2"

Table 4.37 : Recommended Support Spacing for Schedule 40 Pipes

NOMINAL PIPE SIZE (in)	DISTANCE BETWEEN SUPPORTS (ft)
3/4 - 1-1/4	8
3 - 3-1/2	10
1-1/2 - 2-1/2	12
4 - 6	14
8 -12	16
14 - 24	20

Table 4.38 : Recommended Support Spacing For Copper Tubing

TUBE OD (in.)	DISTANCE BETWEEN SUPPORTS (ft)
5/8	6
7/8 -1-1/8	8
1-2/8 - 2-1/8	10
2-5/8 - 5-1/8	12
6-1/8 - 8-1/8	14

Table 4.39 : Temperature versus pressure drop

Refrigerant	Suction Pressure Drop		Discharge Pressure drop		Liquid Pressure Drop	
	°F (°C)	PSI (kPa)	°F (°C)	PSI (kPa)	°F (°C)	PSI (kPa)
R-22	2 (1.1)	2.91 (20.1)	1 (0.56)	3.05 (21.0)	1 (0.56)	3.05 (21.0)
R-406C	2 (1.1)	2.92 (20.1)	1 (0.56)	3.3 (22.8)	1 (0.56)	3.5 (24.1)
R-410A	2 (1.1)	4.5 (31.0)	1 (0.56)	4.75 (32.8)	1 (0.56)	4.75 (32.8)
R-134a	2 (1.1)	1.93 (13.3)	1 (0.56)	2.2 (15.2)	1 (0.56)	2.2 (15.2)

Note: Suction and discharge pressure drops based on 100 equivalent feet (30.5 m) and 40°F (4.4°C) saturated temperature.

Refrigerant	Pressure Drop PSI / ft (kPa/m) Riser
R-22	0.50 (11.31)
R-407C	0.47 (10.63)
R-410A	0.43 (9.73)
R-134a	050 (11.31)

Based on saturated liquid refrigerant at 100°F (37.7°C)

Table 4.40 : Initial and Final Concentrations of Refrigerants at Different Locations

Location	HFC-32/HFC-125/HFC-134a Weight %	
	Initial	After 4 leak / recharge
Receiver Inlet	23.2/25.5/51.3	20.1/22.6/57.3
Receiver Outlet	22.9/25.3/51.8	20.0 / 22.6 / 57.4
Evaporator Inlet	29.7 / 30.8 / 39.5	26.8 / 28.4 / 44.8
Evaporator Outlet	22.1 / 24.9/53.0	19.9/22.5/57.6
Condenser Inlet	25.0 / 26.6 / 48.4	21.6/23.6/54.9
Condenser Outlet	24.2/26.1/49.7	21.4/23.5/55.0

Table 4.41 : Reduction in Performance After Refrigerant Leak / Recharge

Parameter	Reduction, % calculated with R-407C concentrations	Reduction, % calculated with real concentrations
Refrigeration	2.7	11.0
Electrical COP	1.0	3.9
Volumetric Capacity	3.0	8.0

SECTION - 5

REFRIGERANT, SECONDARY COOLANTS AND LUBRICANTS

Source for all Charts from ASHRAE Handbook

Table 5.1 : Refrigerants Pressure Temperature

ºF TEMP	R717 psig	R22 psig	R134a psig	R404a psig	R507 psig
-60	18.6	11.9	21.6	-	
-55	16.7	9.2	20.2	-	
-50	14.4	6.4	18.6	0.64	1.1
-45	11.8	2.7	16.7	2.77	3.3
-40	8.8	0.6	14.7	5.12	5.7
-35	5.5	2.6	12.3	7.72	8.4
-30	1.7	4.9	9.7	10.57	11.3
-25	1.2	7.5	6.8	14.39	14.6
-20	3.5	10.2	3.6	17.08	23.8
-18	4.5	11.4	2.2	18.52	19.5
-16	5.6	12.6	0.7	19.47	21.0
-14	6.7	13.9	0.4	21.55	22.6
-12	7.8	15.2	1.2	23.15	24.3
-10	9.0	16.5	2.0	24.79	26.0
-8	10.2	17.9	2.8	26.50	27.7
-6	11.5	19.4	3.7	28.25	29.6
-4	12.8	20.9	4.6	30.07	31.4
-2	14.2	22.4	5.5	31.94	33.4
0	15.6	24.0	6.5	33.87	35.3
1	16.4	24.8	7.0	34.86	36.4
2	17.1	25.7	7.5	35.87	37.4
3	17.9	26.5	8.0	36.89	38.5
4	18.7	27.4	8.6	37.92	39.5
5	19.5	28.3	9.1	38.97	40.6
6	20.3	29.1	9.7	40.04	41.7
7	21.1	30.0	10.2	41.12	42.8
8	22.0	31.0	10.8	42.22	44.0
9	22.8	31.9	11.4	43.34	45.1
10	23.7	32.8	12.0	44.47	46.3
11	24.6	33.8	12.6	45.62	47.5
12	25.5	34.8	13.2	46.79	48.7
13	26.4	35.8	13.8	48.97	49.9
.14	27.4	36.8	14.4	49.17	51.1
15	28.3	37.8	15.1	50.39	52.4
16	29.3	38.8	15.7	51.63	53.6
17	30.3	39.9	16.4	52.88	54.9
18	31.3	40.9	17.1	54.35	56.2
19	32.4	42.0	17.7	L 55.44	57.6
20	33.4	43.1	18.4	56.75	58.9
21	34.5	44.2	19.2	58.08	60.3
22	35.5	45.3	19.9	59.42	61.7
23	36.6	46.5	20.6	60.79	63.1
24	37.7	47.6	21.4	61.17	64.5
25	38.8	48.8	22.1	63.57	65.9
26	40.0	50.0	22.9	64.99	67.4
27	41.2	51.2	23.7	66.44	68.9
28	42.4	52.4	24.5	67.90	70.4
29	43.7	53.7	25.3	69.38	71.9
30	44.9	54.9	26.1	70.88	73.4
31	46.1	56.2	26.9	72.40	75.0
32	47.4	57.5	27.8	73.94	76.6
33	48.7	58.8	28.6	85.50	78.2
34	50.0	60.2	29.5	77.08	79.8
35	51.4	61.5	30.4	81.68	81.4
36	52.7	62.9	31.3	80.31	83.1
37	54.1	64.3	32.2	81.95	85.5
38	55.5	65.7	33.1	83.62	86.3
39	57.0	67.1	34.1	85.31	88.3
40	58.4	68.6	35.0	87.02	90.3
41	59.2	70.0	36.0	88.72	91.3
42	61.4	71.5	37.0	90.50	93.3

Table 5.1 : Refrigerants Pressure Temperature (Contd.)

^{0}F TEMP	R717 psig	R22 psig	R134a psig	R404a psig	R507 psig
43	62.9	73.0	38.0	92.98	95.3
44	64.5	74.5	39.0	94.08	97.3
45	66.1	76.1	40.0	95.90	99.3
46	67.6	77.0	41.1	7.75	101.3
47	69.3	79.2	42.2	99.61	103.3
48	70.9	0.8	43.2	101.5	105.3
49	72.6	82.4	44.3	103.42	106.3
50	74.3	84.1	45.4	105.36	108.3
55	83.2	92.6	51.2	115.41	119.3
60	92.6	101.6	57.4	126.08	130.3
65	102.8	111.3	64.0	137.39	141.3
70	113.8	121.5	71.1	149.38	154.3
75	125.5	132.2	78.7	162.05	166.3
80	138.0	143.7	86.7	175.45	180.3
85	151.4	155.7	95.2	189.54	195.3
90	165.5	168.4	104.3	204.51	210.3
95	180.6	181.9	113.9	220.22	226.3
100	196.7	196.0	124.1	236.76	243.3
105	213.9	210.8	134.9	254.15	260.3
110	231.8	226.4	146.4	272.43	279.3
115	251.0	242.8	158.4	291.62	299.3
120	271.1	260.0	171.1	347.75	319.3
125	292.5	278.1	184.5	332.85	341.3
130	314.9	297.0	198.7	354.96	364.3
135	338.8	316.8	213.5	377.96	388.3
140	363.5	337.5	229.2	377.30	413.3
145	390.2	L 359.1	245.6	402.30	439.3
150	417.4	381.7	262.8	427.30	467.3
155	447.0	405.4	281.0	454.02	-

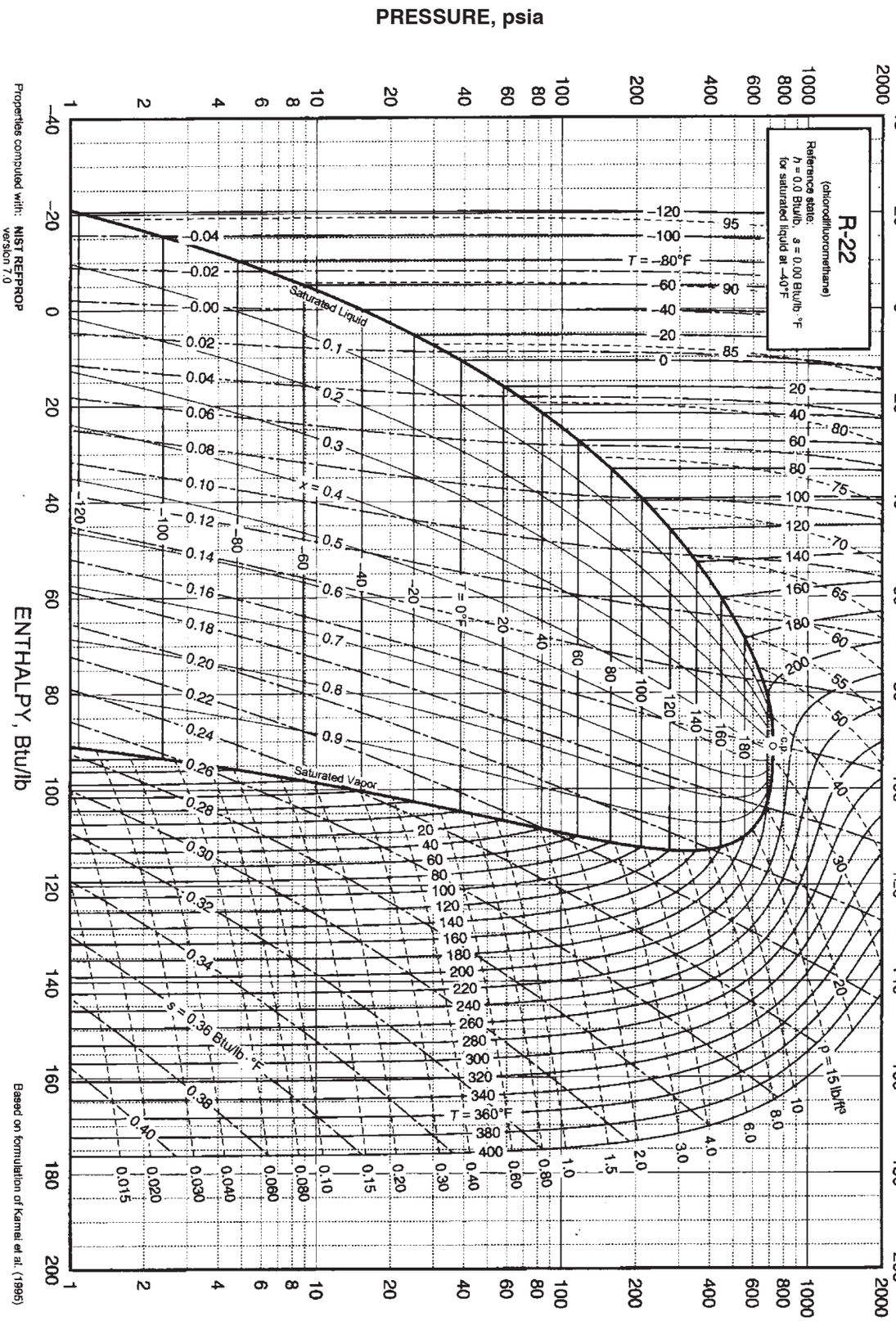


Fig. 2 Pressure-Enthalpy Diagram for Refrigerant 22

Figure 5.1 : Pressure Enthalpy Diagram R-22

Table 5.2 : Thermophysical Properties of Refrigerants R-22

Refrigerant 22 - (Chlorodifluoromethane) Properties of Saturated Liquid and Saturated Vapor

Temp* F	Pressure psia	Density lb/ft³	Volume ft³/lb	Enthalpy Btu/lb		Enthalpy Btu/lb °F		Specific Heat C_p Btu/lb °F		C_p / C_v Vapor	Vel. of Sound ft/s		Viscosity lb_m/ft.h		Thermal cond., Btu/h*ft.°F		Surface Tension	Temp* °F
		Liquid	Vapour	Liquid	Vapor	Liquid	Vapor	Liquid	Vapor		Liquid	Vapor	Liquid	Vapor	Liquid	Vapor	dyne/m	
-150	0.263	98.28	146.06	-28.119	87.566	-0.07757	0.29600	0.2536	0.1185	1.2437	3716	469.7	2.093	0.0174	0.0831	0.00255	28.31	-150
-140	0.436	97.36	90.759	-25.583	88.729	-0.06951	0.28808	0.2536	0.1204	1.2404	3630	476.2	1.874	0.0180	0.0814	0.00267	27.34	-140
-130	0.698	96.44	58.384	-23.046	89.899	-0.06170	0.28090	0.2536	0.1223	1.2375	3544	482.4	1.692	0.0186	0.0797	0.00280	26.36	-130
-120	1.082	95.52	38.745	-20.509	91.074	-0.05412	0.27439	0.2537	0.1244	1.2350	3458	488.5	1.537	0.0191	0.0780	0.00293	25.40	-120
-110	1.629	94.59	26.44	-17.970	92.252	-0.04675	0.26846	0.2540	0.1265	1.2330	3373	494.2	1.405	0.0197	0.0763	0.00306	24.44	-110
-100	2.388	93.66	18.511	-15.427	93.430	-0.03959	0.26307	0.2543	0.1288	1.2315	3287	499.7	1.290	0.0203	0.0747	0.00320	23.49	-100
-95	2.865	93.19	15.623	14.154	94.018	-0.03608	0.26055	0.2546	0.1300	1.2310	3245	502.4	1.238	0.0206	0.0739	0.00327	23.02	-95
-90	3.417	92.71	13.258	-12.880	94.605	-0.03261	0.25815	0.2549	0.1312	1.2307	3202	504.9	1.189	0.0208	0.0731	0.00334	22.55	-90
-85	4.053	92.24	11.309	-11.604	95.191	-0.02918	0.25585	0.2552	0.1324	1.2305	3160	507.4	1.144	0.0211	0.0723	0.00341	22.08	-85
-80	4.782	91.76	9.6939	-10.326	95.775	-0.02580	0.25366	0.2556	0.1337	1.2304	3118	509.8	1.101	0.0214	0.0715	0.00348	21.61	-80
-75	5.615	91.28	8.3487	-9.046	96.337	-0.02245	0.25155	0.2561	0.1350	1.2305	3075	512.2	1.060	0.0217	0.0708	0.00355	21.15	-75
-70	6.561	90.79	7.2222	-7.763	96.937	-0.01915	0.24954	0.2566	0.1363	1.2308	3033	514.4	1.021	0.0220	0.0700	0.00363	20.68	-70
-65	7.631	90.31	6.2744	-6.477	97.514	-0.01587	0.24761	0.2571	0.1377	1.2313	2990	516.5	0.985	0.0223	0.0692	0.00370	20.22	-65
-60	8.836	89.82	5.4730	-5.189	98.087	-0.01264	0.24577	0.2577	0.1392	1.2320	2948	518.6	0.951	0.0225	0.0684	0.00378	19.76	-60
-55	10.190	89.33	4.7924	-3.897	98.657	-0.00943	0.24400	0.2583	0.1406	1.2328	2906	520.5	0.918	0.0228	0.0677	0.00386	19.30	-55
-50	11.703	88.33	4.2119	-2.602	99.224	-0.00626	0.24230	0.2591	0.1422	1.2339	2863	522.4	0.887	0.0231	0.0669	0.00394	18.85	-50
-45	13.390	88.33	3.7147	-1.303	99.786	-0.00311	0.24067	0.2598	0.1438	1.2352	2863	522.4	0.887	0.0231	0.0661	0.00402	18.40	-45
-41.46[b]	14.696	87.97	3.4054	-0.381	100.181	-0.00091	0.23955	0.2604	0.1449	1.2362	2791	525.3	0.837	0.0236	0.0656	0.00407	18.08	-41.46[b]
-40	15.262	87.82	3.2872	0.000	100.343	0.00000	0.23910	0.2606	0.1454	1.2367	2778	525.8	0.829	0.0237	0.0654	0.00410	17.94	-40
-35	17.336	87.32	2.9181	1.308	100.896	0.00309	0.23759	0.2615	0.1471	1.2384	2736	527.3	0.802	0.0240	0.0646	0.00418	17.49	-35
-30	19.624	86.80	2.5984	2.620	101.443	0.00615	0.23615	0.2625	0.1488	1.2404	2694	528.7	0.776	0.0242	0.0639	0.00426	17.05	-30
-25	22.142	86.29	2.3204	3.937	101.984	0.00918	0.23475	0.2635	0.1506	1.2426	2651	530.0	0.751	0.0245	0.0631	0.00435	16.60	-25
-20	24.906	85.76	2.0778	5.260	102.519	0.01220	0.23341	0.2645	0.1525	1.2451	2609	531.2	0.728	0.0248	0.0624	0.00444	16.16	-20
-15	27.929	85.24	1.8656	6.588	103.048	0.01519	0.23211	0.2656	0.1544	1.2479	2566	532.3	0.705	0.0251	0.0617	0.00452	15.72	-15
-10	31.230	84.71	1.6792	7.923	103.570	0.01815	0.23086	0.2668	0.1564	0.2510	2524	533.2	0.683	0.0254	0.0609	0.00461	15.28	-10
-5	34.824	84.17	1.5150	9.263	104.085	0.02110	0.22965	0.2681	0.1585	1.2544	2481	534.0	0.662	0.0257	0.0602	0.00471	14.85	-5
0	38.728	83.63	1.3701	10.610	104.591	0.02403	0.22848	0.2694	0.1607	1.2581	2438	534.7	0.642	0.0260	0.0595	0.00480	14.41	0
5	42.960	83.08	1.2417	11.964	105.090	0.02694	0.22735	0.2708	0.1629	1.2622	2396	535.3	0.622	0.0262	0.0587	0.00489	13.98	5
10	47.536	82.52	1.1276	13.325	105.580	0.02983	0.22625	0.2722	0.1652	1.2666	2353	535.7	0.603	0.0265	0.0580	0.00499	13.55	10
15	52.475	81.96	1.0261	14.694	106.061	0.03270	0.22519	0.2737	0.1676	1.2714	2310	536.0	0.585	0.0268	0.0573	0.00509	13.13	15
20	57.795	81.39	0.9354	16.070	106.532	0.03556	0.22415	0.2753	0.1702	1.2767	2268	536.1	0.568	0.0271	0.0566	0.00519	12.70	20
25	63.514	80.82	0.8543	17.455	106.994	0.03841	0.22315	0.2770	0.1728	1.2824	2225	536.1	0.551	0.0274	0.0558	0.00530	12.28	25
30	69.651	80.24	0.7815	18.848	107.445	0.04124	0.22217	0.2787	0.1755	1.2886	2182	535.9	0.534	0.0277	0.0551	0.00540	11.86	30
35	76.225	79.65	0.7161	20.250	107.884	0.04406	0.22121	0.2806	0.1783	1.2953	2139	535.9	0.518	0.0280	0.0544	0.00551	11.45	35
40	83.255	79.05	0.6572	21.662	108.313	0.04686	0.22028	0.2825	0.1813	1.3026	2096	535.1	0.503	0.0283	0.0537	0.00562	11.04	40
45	90.761	78.44	0.6040	23.083	108.729	0.04966	0.21936	0.2845	0.1844	1.3105	2053	534.4	0.488	0.0286	0.0530	0.00574	10.63	45
50	98.763	77.83	0.5558	24.514	109.132	0.05244	0.21847	0.2856	0.1877	1.3191	2010	533.6	0.473	0.0289	0.0522	0.00586	10.22	50
55	107.28	77.20	0.5122	25.956	109.521	0.05522	0.21758	0.2889	0.1911	1.3284	1947	532.6	0.459	0.0292	0.0515	0.00598	9.82	55
60	116.33	76.57	0.4725	27.409	109.897	0.05798	0.21672	0.2913	0.1947	1.3385	1924	531.5	0.445	0.0296	0.0508	0.00611	9.41	60
65	125.94	75.92	0.4364	28.874	110.257	0.06074	0.21586	0.2938	0.1985	1.3495	1880	530.1	0.432	0.0299	0.0501	0.00625	9.02	65
70	136.13	75.27	0.4035	30.350	110.602	0.06350	0.21501	0.2964	0.2025	1.3615	1836	528.6	0.419	0.0302	0.0494	0.00638	8.62	70
75	146.92	74.60	0.3734	31.839	110.929	0.06625	0.21417	0.2992	0.2067	1.3746	1793	526.9	0.406	0.0305	0.0487	0.00653	8.23	75
80	158.33	73.92	0.3459	33.432	111.239	0.06899	0.21333	0.3022	0.2112	1.3889	1749	525.0	0.394	0.0309	0.0479	0.00668	7.84	80
85	170.38	73.23	0.3207	34.859	111.530	0.07173	0.21250	0.3054	0.2160	1.4046	1705	522.9	0.381	0.0312	0.0472	0.00684	7.46	85
90	183.09	72.52	0.2975	36.391	111.801	0.07447	0.21166	0.3089	0.2212	1.4218	1660	520.6	0.369	0.0316	0.0465	0.00701	7.08	90
95	196.50	71.80	0.2762	37.938	112.050	0.07721	0.21083	0.3126	0.2267	1.4407	1615	518.1	0.358	0.0320	0.0458	0.00718	6.70	95
100	210.61	71.06	0.2566	39.502	112.276	0.07996	0.20998	0.3166	0.2327	1.4616	1570	515.4	0.346	0.0324	0.0450	0.00737	6.33	100
105	225.46	70.30	0.2385	41.084	112.478	0.08270	0.20913	0.3209	0.2391	1.4849	1525	512.4	0.335	0.0328	0.0443	0.00757	5.96	105
110	241.06	69.52	0.2217	42.686	112.653	0.08545	0.20827	0.3257	0.2461	1.5107	1479	509.2	0.324	0.0332	0.0436	0.00778	5.60	110
115	257.45	68.72	0.2062	44.308	112.799	0.08821	0.20739	0.3309	0.2538	1.5396	1433	505.8	0.313	0.0336	0.0428	0.00801	5.24	115
120	274.65	67.90	0.1918	45.952	112.914	0.09098	0.20649	0.3367	0.2623	1.5722	1387	502.1	0.302	0.0341	0.0421	0.00825	4.88	120
125	292.69	67.05	0.1785	47.316	112.996	0.9376	0.20557	0.3431	0.2717	1.6090	1340	498.1	0.292	0.0346	0.0413	0.00851	4.53	125
130	311.58	66.18	0.1660	49.316	113.040	0.09656	0.20462	0.3504	0.2822	1.6509	1292	493.9	0.281	0.0351	0.0406	0.00880	4.19	130
135	331.37	65.27	0.1544	51.041	113.043	0.09937	0.20364	0.3585	0.2941	1.6990	1244	489.4	0.271	0.0356	0.0399	0.00911	3.85	135
140	352.08	64.32	0.1435	52.798	113.000	0.10222	0.20261	0.3679	0.3076	1.7548	1195	484.6	0.260	0.0362	0.0391	0.00946	3.51	140
145	373.74	63.34	0.1334	54.591	112.907	0.10509	0.20153	0.3787	0.3233	1.8201	1146	479.5	0.250	0.0369	0.0383	0.00984	3.18	145
150	396.38	62.31	0.1238	56.425	112.756	0.10800	0.20040	0.3913	0.3416	1.8976	1095	474.1	0.240	0.0375	0.0376	0.01027	2.86	150
155	420.04	61.22	0.1149	58.305	112.539	0.11096	0.19919	0.4063	0.3633	1.9907	1044	468.4	0.230	0.0383	0.0368	0.01076	2.54	155
160	444.75	60.07	0.1064	60.240	112.247	0.11397	0.19790	0.4243	0.3897	2.1047	992	462.3	0.219	0.0391	0.0361	0.01131	2.24	160
165	470.56	58.84	0.0984	62.237	111.866	0.11705	0.19650	0.4467	0.4225	2.2474	939	455.8	0.209	0.0400	0.0353	0.01195	1.93	165
170	497.50	57.53	0.0907	64.309	111.378	0.12022	0.19497	0.4750	0.4643	2.4310	884	449.0	0.198	0.0410	0.0346	0.01270	1.64	170
175	525.62	56.10	0.0834	66.474	110.760	0.12350	0.19328	0.5124	0.5198	2.6759	828	441.7	0.188	0.0422	0.0340	0.01360	1.36	175
180	554.98	54.52	0.0764	68.757	109.976	0.12693	0.19136	0.5641	0.5972	3.0184	769	433.9	0.176	0.0436	0.0335	0.01470	1.09	180
185	585.63	52.74	0.0695	71.196	108.972	0.13056	0.18916	0.6410	0.7132	3.2317	706	425.6	0.165	0.0452	0.0332	0.01609	0.83	185
190	617.64	50.67	0.0626	73.859	107.654	0.13450	0.18651	0.7681	0.9067	4.3857	639	416.6	0.152	0.0474	0.0334	0.01793	0.58	190
195	651.12	48.14	0.0556	76.875	105.835	0.13893	0.18316	1.020	1.295	6.090	565	406.9	0.138	0.0502	0.0347	0.02061	0.35	195
200	686.20	44.68	0.0479	80.593	103.010	0.17835	0.17835	1.778	2.472	11.190	480	395.8	0.121	0.0547	0.0395	0.02574	0.15	200
205.06[c]	723.74	32.70	0.0306	91.208	91.208	0.16012	0.16012	∞	∞	∞	0	0.0	-	-	∞	∞	0.00	205.06

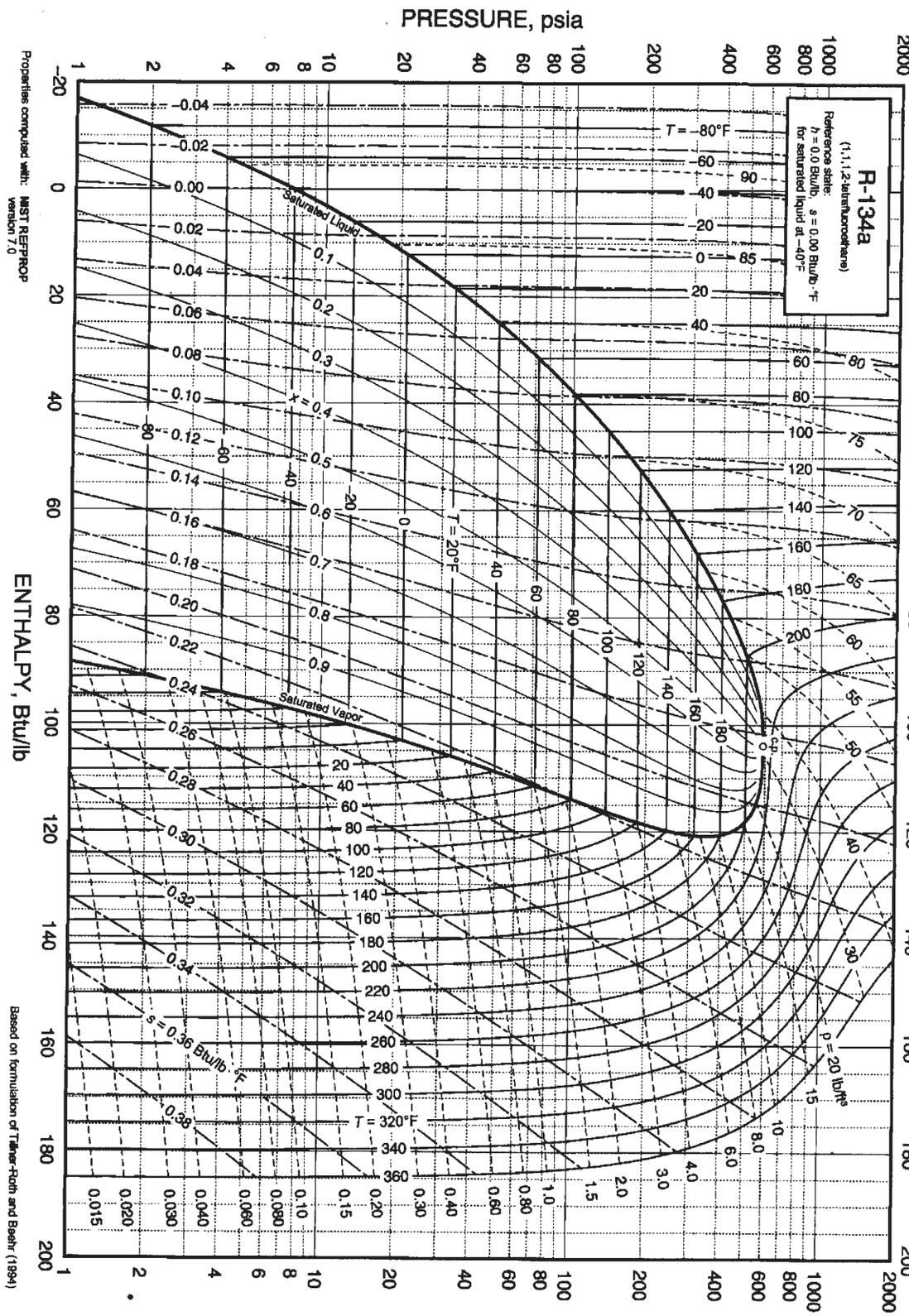


Figure 5.2 : Pressure Enthaply Diagram R-134a

Table 5.3 : Thermophysical Properties of Refrigerants

R-134A - (1,1,1,2-Tetrafluoroethane) Properties of Saturated Liquid and Saturated Vapor

Temp* F	Pressure psia	Density lb/ft³	Volume ft³/lb	Enthalpy Btu/lb		Enthalpy Btu/lb °F		Specific Heat C_p Btu/lb °F		C_p / C_v Vapor	Vel. of Sound ft/s		Viscosity lb_m/ft.h		Thermal cond., Btu/h*ft.°F		Surface Tension dyne/m	Temp* °F
		Liquid	Vapour	Liquid	Vapor	Liquid	Vapor	Liquid	Vapor		Liquid	Vapor	Liquid	Vapor	Liquid	Vapor		
-153.94[0]	0.057	99.33	568.59	-32.992	80.362	-0.09154	0.27923	0.2829	0.1399	1.1637	3674	416.0	5.262	0.0156	0.0840	0.00178	28.07	-153.94[0]
-150	0.072	98.97	452.12	-31.878	80.907	-0.08791	0.27629	0.2830	0.1411	1.1623	3638	418.3	4.790	0.0159	0.0832	0.00188	27.69	-150
-140	0.129	98.05	260.63	-29.046	82.304	-0.07891	0.26941	0.2834	0.1443	1.1589	3545	424.2	3.880	0.0164	0.0813	0.00214	26.74	-140
-130	0.221	97.13	156.50	-26.208	83.725	-0.07017	0.26329	0.2842	0.1475	1.1559	3452	429.9	3.238	0.0170	0.0794	0.00240	25.79	-130
-120	0.365	96.20	97.481	-23.360	85.168	-0.06166	0.25784	0.2853	0.1508	1.1532	3360	435.5	2.762	0.0176	0.0775	0.00265	24.85	-120
-110	0.583	95.27	62.763	-20.500	86.629	-0.05337	0.25300	0.2866	0.1540	1.1509	3269	440.8	2.396	0.0182	0.0757	0.00291	23.92	-110
-100	0.903	94.33	41.637	-17.626	88.107	-0.04527	0.24871	0.2881	0.1573	1.1490	3178	446.0	2.105	0.0187	0.0739	0.00317	22.99	-100
-90	1.359	93.38	28.381	-14.736	89.599	-0.03734	0,24490	0.2898	0.1607	1.1475	3087	450.9	1.869	0.0193	0.0722	0.00343	22.07	-90
-80	1.993	92.42	19.825	-11.829	91.103	-0.02959	0.24152	0.2916	0.1641	1.1465	2998	455.6	1.673	0.0199	0.0705	0.00369	21.16	-80
-75	2.392	91.94	16.711	-10.368	91.858	-0.02577	0.23998	0.2925	0.1658	1.1462	2954	457.8	1.587	0.0201	0.0696	0.00382	20.71	-75
-70	2.854	91.46	14.161	-8.903	92.614	-0.02198	0.23854	0.2935	0.1676	1.1460	2909	460.0	1.509	0.0204	0.0688	0.00395	20.26	-70
-65	3.389	90.97	12.060	-7.432	93.372	-0.01824	0.23718	0.2945	0.1694	1.1459	2866	462.1	1.436	0.0207	0.0680	0.00408	19.81	-65
-60	4.002	90.49	10.321	-5.957	94.131	-0.01452	0.23590	0.2955	0.1713	1.1460	2822	464.1	1.369	0.0210	0.0671	0.00420	19.36	-60
-55	4.703	90.00	8.8733	4.476	94.890	-0.01085	0.23470	0.2965	0.1731	1.1462	2778	466.0	1.306	0.0212	0.0663	0.00433	18.92	-55
-50	5.501	89.50	7.6221	-2.989	95.650	-0.00720	0.23358	0.2976	0.1751	1.1466	2735	467.8	1.248	0.0215	0.0655	0.00446	18.47	-50
-45	6.406	89.00	6.6438	-1.498	96.409	-0.00358	0.23252	0.2987	0.1770	1.1471	2691	469.6	1.193	0.0218	0.0647	0.00460	18.03	45
40	7.427	88.50	5.7839	0.000	97.167	0.00000	0.23153	0.2999	0.1790	1.1478	2648	471.2	1.142	0.0221	0.0639	0.00473	17.60	40
-35	8.576	88.00	5.0544	1.503	97.924	0.00356	0.23060	0.3010	0.1811	1.1486	2605	472.8	1.095	0.0223	0.0632	0.00486	17.16	-35
-30	9.862	87.49	4.4330	3.013	98.679	0.00708	0.22973	0.3022	0.1832	1.1496	2563	474.2	1.050	0.0226	0.0624	0.00499	16.73	-30
-25	11.299	86.98	3.9014	4.529	99.433	0.01058	0.22892	0.3035	0.1853	1.1508	2520	475.6	1.007	0.0229	0.0616	0.00512	16.30	-25
-20	12.898	86.47	3.4449	6.051	100.184	0.01406	0.22816	0.3047	0.1875	1.1521	2477	476.8	0.968	0.0231	0.0608	0.00525	15.87	-20
-15	14.671	85.95	3.0514	7.580	100.932	0.01751	0.22744	0.3060	0.1898	1.1537	2435	477.9	0.930	0.0234	0.0601	0.00538	15.44	-15
-14.93[b]	14.696	85.94	3.0465	7.600	100.942	0.01755	0.22743	0.3061	0.1898	1.1537	2434	477.9	0.929	0.0234	0.0601	0.00538	15.44	-14.93[b]
-10	16.632	85.43	2.7109	9.115	101.677	0.02093	0.22678	0.3074	0.1921	1.1554	2393	478.9	0.864	0.0237	0.0593	0.00552	15.02	-10
-5	18.794	84.90	2.4154	10.657	102.419	0.02433	0.22615	0.3088	0.1945	1.1573	2350	479.8	0.860	0.0240	0.0586	0.00565	14.60	-5
0	21.171	84.37	2.1579	12.207	103.156	0.02771	0.22557	0.3102	0.1969	1.1595	2308	480.5	0.828	0.0242	0.0578	0.00578	14.18	0
5	23.777	83.83	1.9330	13.764	103.889	0.03107	0.22502	0.3117	0.1995	1.1619	2266	481.1	0.798	0.0245	0.0571	0.00592	13.76	5
10	26.628	83.29	1.7357	15.328	104.617	0.03440	0.22451	0.3132	0.2021	1.1645	2224 '	481.6	0.769	0.0248	0.0564	0.00605	13.35	10
15	29.739	82.74	1.5623	16.901	105.339	0.03772	0.22403	0.3147	0.2047	1.1674	2182	482.0	0.741	0.0250	0.0556	0.00619	12.94	• 15
20	33.124	82.19	1.4094	18.481	106.056	0.04101	0.22359	0.3164	0.2075	1.1705	2140	482.2	0.715	0.0253	0.0549	0.00632	12.53	20
25	36.800	81.63	1.2742	20.070	106.767	0.04429	0.22317	0.3181	0.2103	1.1740	2098	482.2	0.689	0.0256	0.0542	0.00646	12.12	25
30	40.784	81.06	1.1543	21.667	107.471	0.04755	0.22278	0.3198	0.2132	1.1777	2056	482.2	0.665	0.0258	0.0535	0.00660	11.72	30
35	45.092	80.49	1.0478	23.274	108.167	0.05079	0.22241	0.3216	0.2163	1.1818	2014	481.9	0.642	0.0261	0.0528	0.00674	11.32	35
40	49.741	79.90	0.9528	24.890	108.856	0.05402	0.22207	0.3235	0.2194	1.1862	1973	481.5	0.620	0.0264	0.0521	0.00688	10.92	40
45	54.749	79.32	0.8680	26.515	109.537	0.05724	0.22174	0.3255	0.2226	1.1910	1931	481.0	0.598	0.0267	0.0514	0.00703	10.53	45
50	60.134	78.72	0.7920	28.150	110.209	0.06044	0.22144	0.3275	0.2260	1.1961	1889	480.3	0.578	0.0270	0.0507	0.00717	10.14	50
55	65.913	78.11	0.7238	29.796	110.871	0.06362	0.22115	0.3297	0.2294	1.2018	1847	479.4	0.558	0.0273	0.0500	0.00732	9.75	55
60	72.105	77.50	0.6625	31.452	111.524	0.06680	0.22088	0.3319	0.2331	1.2079	1805	478.3	0.539	0.0275	0.0493	0.00747	9.36	60
65	78.729	76.87	0.6072	33.120	112.165	0.06996	0.22062	0.3343	0,2368	1.2145	1763	477.0	0.520	0.0278	0.0486	0.00762	8.98	65
70	85.805	76.24	0.5572	34.799	112.796	0.07311	0.22037	0.3368	0.2408	1.2217	1721	475.6	0.503	0.0281	0.0479	0.00777	8.60	70
75	93.351	75.59	0.5120	36.491	113.414	0.07626	0.22013	0.3394	0.2449	1.2296	1679	474.0	0.485	0.0284	0.0472	0.00793	8.23	75
80	101.39	74.94	0.4710	38.195	114.019	0.07939	0.21989	0.3422	0.2492	1.2382	1636	472.2	0.469	0.0287	0.0465	0.00809	7.86	80
85	109.93	74.27	0.4338	39.913	114.610	0.08252	0.21966	0.3451	0.2537	1.2475	1594	470.1	0.453	0.0291	0.0458	0.00825	7.49	85
90	119.01	73.58	0.3999	41.645	115.186	0.08565	0.21944	0.3482	0.2585	1.2578	1551	467.9	0.437	0.0294	0.0451	0.00842	7.13	90
95	128.65	72.88	0.3690	^ 3.392	115.746	0.08877	0.21921	0.3515	0.2636	1.2690	1509	465.4	0.422	0.0297	0.0444	0.00860	6.77	95
100	138.85	72.17	0.3407	45.155	116.289	0.09188	0.21898	0.3551	0.2690	1.2813	1466	462.7	0.407	0.0301	0.0437	0.00878	6.41	100
105	149.65	71.44	0.3148	46.934	116.813	0.09500	0.21875	0.3589	0.2747	1.2950	1423	459.8	0.393	0.0304	0.0431	0.00897	6.06	105
110	161.07	70.69	0.2911	48.731	117.317	0.09811	0.21851	0.3630	0.2809	1.3101	1380	456.7	0.378	0.0424	0.0424	0.00916	5.71	110
115	173.14	69.93	0.2693	50.546	117.799	0.10123	0.21826	0.3675	0.2875	1.3268	1337	453.2	0.365	0.0312	0.0417	0.00936	5.36	115
120	185.86	69.14	0.2493	52.382	118.258	0.10435	0.21800	0.3723	0.2948	1.3456	1294	449.6	0.351	0.0316	0.0410	0.00958	5.03	120
125	199.28	68.32	0.2308	54.239	118.690	0.10748	0.21772	0.3775	0.3026	1.3666	1250	445.6	0.338	0.0320	0.0403	0.00981	4.69	125
130	213.41	67.49	0.2137	56.119	119.095	0.11062	0.21742	0.3833	0.3112	1.3903	1206	441.4	0.325	0.0324	0.0396	0.01005	4.36	130
135	228.28	66.62	0.1980	58.023	119.468	0.11376	0.21709	0.3897	0.3208	1.4173	1162	436.8	0.313	0.0329	0.0389	0.01031	4.04	135
140	243.92	65.73	0.1833	59.954	119.807	0.11692	0.21673	0.3968	0.3315	1.4481	1117	432.0	0.301	0.0334	0.0382	0.01058	3.72	140
145	260.36	64.80	0.1697	61.915	120.108	0.12010	0.21634	0.4048	0.3435	1.4837	1072	426.8	0.288	0.0339	0.0375	0.01089	3.40	145
150	277.61	63.83	0.1571	63.908	120.366	0.12330	0.21591	0.4138	0.3571	1.5250	1027	421.2	0.276	0.0344	0.0368	0.01122	3.09	150
155	295.73	62.82	0.1453	65.936	120.576	0.12653	0.21542	0.4242	0.3729	1.5738	980	415.3	0.264	0.0350	0.0361	0.01158	2.79	155
160	314.73	61.76	0.1343	68.005	120.731	0.12979	0.21488	0.4362	0.3914	1.6318	934	409.1	0.253	0.0357	0.0354	0.01199	2.50	160
165	334.65	60.65	0.1239	70.118	120.823	0.13309	0.21426	0.4504	0.4133	1.7022	886	402.4	0.241	0.0364	0.0346	0.01245	2.21	165
170	355.53	59.47	0.1142	72.283	120.842	0.13644	0.21356	0.4675	0.4400	1.7889	837	395.3	0.229	0.0372	0.0339	0.01297	1.93	170
175	377.41	58.21	0.1051	74.509	120.773	0.13985	0.21274	0.4887	0.4733	1.8984	786	387.7	0.218	0.0381	0.0332	0.01358	LJ.66	175
180	400.34	56.86	0.0964	76.807	120.598	0.14334	0.21180	0.5156	0.5159	2.0405	734	379.6	0.206	0.0391	0.0325	0.01430	1.39	180
185	424.36	55.38	0.0881	79.193	120.294	0.14693	0.21069	0.5512	0.5729	2.2321	680	371.0	0.194	0.0403	0.0318	0.01516	1.14	185
190	449.52	53.76	0.0801	81.692	119.822	0.15066	0.20935	0.6012	0.6532	2.5041	624	361.8	0.182	0.0417	0.0311	0.01623	0.90	190
195	475.91	51.91	0.0724	84.343	119.123	0.15459	0.20771	0.6768	0.7751	2.9192	565	352.0	0.169	0.0435	0.0304	0.01760	0.67	195
200	503.59	49.76	0.0647	87.214	118.097	0.15880	0.20562	0.8062	0.9835	3.6309	502	341.3	0.155	0.0457	0.0300	0.01949	0.45	200
205	532.68	47.08	0.0567	90.454	116.526	0.16353	0.20275	1.0830	1.4250	5.1360	436	329.4	0.140	0.0489	0.0300	0.02240	0.26	205
210	563.35	43.20	0.0477	94.530	113.746	0.16945	0.19814	2.1130	3.0080	10.5120	363	315.5	0.120	0.0543	0.0316	0.02848	0.09	210
213.91[c]	588.75	31.96	0.0313	103.894	103.894	0.18320	0.18320	∞	∞	∞	0.0	0	-	-	∞	∞	0.00	213.91

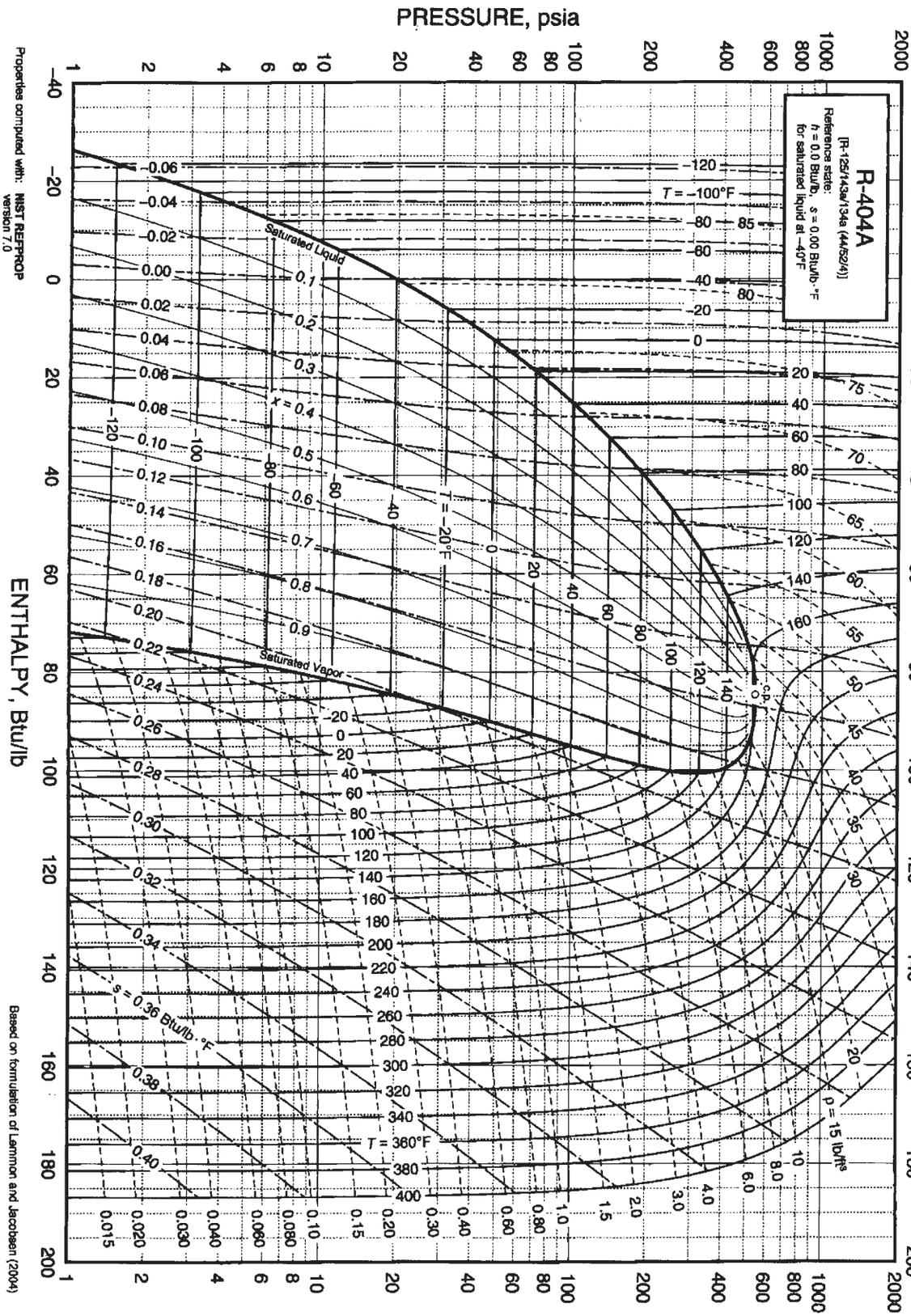


Figure 5.3 : Pressure Enthaply Diagram R-404A

Table 5.4 : Thermophysical Properties Of Refrigerants

R-404A [R-125/143a/134a(44/52/4)] Properties of Liquid on Bubble Line and Vapor on Dew Line

Press-ure psia	Temp.* ^{0}F		Density lb/ft^3	Volume ft^3/lb	Enthaply Btu/lb		Enthaply Btu/lb* ^{0}F		Specific Heat C_p Btu/lb* ^{0}F		C_p/C_v Vapour	Vel. of Sound ft/s		Viscosity lb$_m$/ft&h		Thermal Cond. Btu/h*ft. ^{0}F		Surface Tension dyne/ cm	Press-ure psia
	Bubble	Dew	Liquid	Vapor	Liquid	Vapor	Liquid	Vapor	Liquid	Vapor		Liquid	Vapor	Liquid	Vapor	Liquid	Vapor		
1	-129.56	-127-50	89.61	36.2311	-26.33	71.76	-0.07039	0.22616	0.2907	0.1554	1.161	3173	439.8	1.695	0.0181	0.0695	0.00369	17.42	1
1.5	-120.05	-118.11	88.64	24.7754	-23.56	73.11	-0.06215	0.22201	0.2901	0.1589	1.160	3050	444.6	1.518	0.0186	0.0678	0.00388	16.92	1.5
2	-112.90	-111.03	87.92	18.9245	-21.49	74.14	-0.05611	0.21920	0.2900	0.1615	1.159	2964	448.1	1.403	0.0190	0.0666	0.00403	16.53	2
2.5	-107.10	-105.29	87.33	15.3578	-19.81	74.98	0.05129	0.21710	0.02902	0.1637	1.159	2898	450.7	1.320	0.0193	0.0657	0.00414	16.22	2.5
3	-102.18	-100.42	86.83	12.9493	-18.38	75.69	-0.04727	0.21544	0.2905	0.1656	1.159	2845	452.9	1.255	0.0195	0.0647	0.00425	15.94	3
4	-94.08	-92.40	86.01	9.8941	-16.02	76.86	-0.04076	0.21292	0.2912	0.1688	1.159	2760	456.3	1.159	0.0199	0.0634	0.00442	15.49	4
5	-87.49	-85.87	85.33	8.0300	-14.10	77.82	-0.03555	0.21106	0.2920	0.1715	1.159	2694	458.9	1.088	0.0203	0.0623	0.00456	15.11	5
6	-81.89	-80.32	84.76	6.7705	-12.46	78.64	-0.03119	0.20960	0.2929	0.1738	1.159	2639	461.0	1.033	0.0205	0.0614	0.00468	14.79	6
7	-77.00	-75.46	84.25	5.8607	-11.02	79.35	-0.02742	0.20841	0.2937	0.1758	1.160	2592	462.7	0.989	0.0208	0.0606	0.00478	14.50	7
8	-72.64	-71.14	83.80	5.1716	-9.74	79.98	-0.02409	0.20741	0.2944	0.1777	1.161	2551	464.1	0.952	0.0210	0.0599	0.00488	14.25	8
10	-65.08	-63.64	83.01	4.1954	-7.51	81.07	-0.01839	0.20581	0.2959	0.1811	1.162	2481	466.4	0.«92	0.0214-	0.0587	0.00505	13.79	10
12	-58.65	-57.25	82.34	3.5353	-5.60	82.00	0.0136	0.20457	0.2974	0.1840	1.164	2422	468.1	0.845	0.0217	0.0577	0.00519	13.41	12
14	-53.01	-51.65	81.74	3.0582	-3.91	82.81	-0.00944	0.20357	0.2987	0.1866	1.166	2372	469.4	0.806	0.0220	0.0568	0.00532	13.06	14
14.7	-51.20	-49.85	81.55	2.9217	-3.37	83.07	-0.00812	0.20326	0.2991	0.1875	1.166	2355	469.8	0.795	0.0221	0.0566	0.00536	12.95	14.7
16	-47.98	46.65	*1.20	2.6968	-2.41	83.53	-0.00577	0.20273	0.3000	0.1891	1.167	2327	470.4	0.774	0.0222	0.0561	0.00544	12.75	16
18	-43.42	-42.11	80.71	2.4132	-1.03	84.18	-0.00246	0.20203	0.3012	0.1913	1.169	2286	471.2	0.747	0.0225	0.0554	0.00554	12.47	18
20	-39.24	-37.96	80.26	2.1845	0.23	84.78	0.00055	0.20141	0.3024	0.1935	1.171	2249	471.9	0.723	0.0227	0.0548	0.00564	12.20	20
22	-35.37	-34.11	79.83	1.9960	1.40	85.32	0.00332	0.20088	0.3035	0.1955	1.173	2215	472.4	0.701	0.0229	0.0542	0.00573	11.96	22
24	-31.77	-30.53	79.44	1.8379	2.50	85.83	0.00588	0.20041	0.3046	0.1974	1.175	2184	472.8	0.682	0.0230	0.0537	0.00582	11.73	24
26	-28.39	-27.17	79.06	1.7033	3.53	86.30	0.00827	0.19998	0.3056	0.1992	1.176	2154	473.1	0.665	0.0232	0.0532	0.00590	11.52	26
28	-25.21	-24.01	78.71	1.5873	4.51	86.75	0.01051	0.19960	0.3067	0.2010	1.178	2127	473.3	0.649	0.0234	0.0527	0.00598	11.31	28
30	-22.20	-21.02	78.37	1.4863	5.44	87.16	0.01263	0.19925	0.3077	0.2027	1.180	2101	473.5	0.634	0.0235	0.0523	0.00605	11.12	30
32	-19.34	-18.17	78.05	1.3974	6.32	87.56	0.01463	0.19894	0.3086	0.2043	1.182	2076	473.6	0.621	0.0237	0.0519	0.00612	10.94	32
34	-16.62	-15.46	77.74	1.3187	7.16	87.93	0.01653	0.19864	0.3096	0.2059	1.184	2052	473.6	0.608	0.0238	0.0515	0.00619	10.76	34
36	-14.01	-12.87	77.44	1.2484	7.97	88.29	0.01834	0.19838	0.3105	0.2074	1.186	2030	473.6	0.597	0.0239	0.0511	0.00625	10.59	36
38	-11.52	-10.39	77.15	1.1852	8.75	88.62	0.02007	0.19813	0.3115	0.2089	1.188	2008	473.5	0.586	0.0241	0.0507	0.00632	10.43	38
40	-9.12	-8.01	76.87	1.1281	9.50	88.95	0.02172	0.19790	0.3124	0.2104	1.190	1987	473.4	0.576	0.0242	0.0504	0.00638	10.27	40
42	-6.81	-5.71	76.60	1.0763	10.22	89.26	0.02331	0.19768	0.3133	0.2119	1.192	1967	473.3	0.566	0.0243	0.0501	0.00644	10.12	42
44	4.59	-3.50	76.34	1.0290	10.92	89.56	0.02484	0.19748	0.3141	0.2133	1.194 '	1948	473.1	0.557	0.0244	0.0497	0.00649	9.97	44
46	-2.44	-1.36	76.09	0.9857	11.60	89.84	0.02632	0.19729	0.3150	0.2146	1.196	1930	472.9	0.548	0.0245	0.0494	0.00655	9.83	46
48	-0.36	0.71	75.84	0.9459	12.25	90.12	0.02774	0.19711	0.3158	0.2160	1.198	1912	472.7	0.540	0.0246	0.0492	0.00660	9.70	48
50	1.65	2.71	75.60	0.9091	12.89	99.38	0.02911	0.19694	0.3167	0.2173	1.200	1894	472.5	0.532	0.0247	0.0489	0.00665	9.56	50
55	6.43	7.47	75.03	0.8285	14.41	91.01	0.03237	0.19655	0.3188	0.2206	1.205	1853	471.8	0.514	0.0250	0.0482	0.00678	9.25	55
60	10.89	11.90	74.48	0.7609	15.84	91.58	0.03539	0.19621	0.3208	0.2237	1.210	1814	471.0	0.498	0.0252	0.0476	0.00690	8.95	60
65	15.07	16.07	73.97	0.7033	17.19	92.11	0.03822	0.19590	0.3228	0.2267	1.215	1778	470.1	0.483	0.0254	0.0470	0.00701	8.67	65
70	19.02	20.00	73.47	0.6537	18.47	92.61	0.04088	0.19562	0.3247	0.2297	1.220	1744	469.2	0.470	0.0257	0.0465	0.00712	8.41	70
75	22.76	23.72	72.99	0.6104	19.69	93.07	0.04339	0.19537	0.3267	0.2325	1.226	1712	468.1	0.457	0.0259	0.0460	0.00723	8.16	75
80	26.32	27.27	72.54	0.5724	20.86	93.50	0.04578	0.19514	0.3286	0.2354	1.231	1681	467.0	0.446	0.0261	0.0455	0.00733	7.92	80
85	29.71	30.64	72.09	0.5387	21.98	93.91	0.04804	0.19492	0.3305	0.2382	1.236	1651	465.9	0.435	0.0263	0.0450	0.00742	7.70	85
90	32.96	33.88	71.67	0.5085	23.05	94.30	0.05021	0.19471	0.3324	0.2409	1.242	1623	464.7	0.425	0.0264	0.0446	0.00753	7.48	90
95	36.07	36.98	71.25	0.4815	24.09	94.66	0.05229	0.19452	0.3342	0.2436	1.248	1596	463.5	0.416	0.0266	0.0442	0.00763	7.27	95
100	39.07	39.96	70.84	0.4570	25.10	95.00	0.05428	0.19434	0.3361	0.2464	1.254	1569	462.2	0.407	0.0268	0.0438	0.00772	7.07	100
110	44.73	45.60	70.06	0.4145	27.01	95.64	0.05804	0.19400	0.3399	0.2518	1.266	1520	459.6	0.391	0.0271	0.0430	0.00792	6.69	110
120	50.02	50.86	69.32	0.3789	28.82	96.21	0.06155	0.19368	0.3437	0.2572	1.279	1473	456.8	0.376	0.0275	0.0423	0.00810	6.34	120
130	54.99	55.81	68.60	0.3485	30.53	96.73	0.06485	0.19338	0.3475	0.2626	1.292	1429	454.0	0.363	0.0278	0.0416	0.00829	6.01	130
140	59.68	60.48	67.90	0.3222	32.16	97.20	0.06795	0.19309	0.3514	0.2682	1.306	1387	451.1	0.351	0.0281	0.0410	0.00848	5.69	140
150	64.13	64.91	67.23	0.2994	33.73	97.62	0.07090	0.19281	0.3553	0.2739	1.321	1347	448.2	0.339	0.0284	0.0404	0.00866	5.4	150
160	68.36	69.13	66.57	0.2793	35.23	98.01	0.07371	0.19253	0.3594	0.2797	1.336	1309	445.2	0.329	0.0288	0.0399	0.00885	5.12	160
170	72.40	73.15	65.93	0.2614	36.68	98.37	0.07639	0.19226	0.3635	0.2857	1.353	1273	442.1	0.319	0.0291	0.0394	0.00904	4.85	170
180	76.26	76.99	65.30	0.2454	38.08	98.69	0.07896	0.19198	0.3678	0.2919	1.370	1238	439.0	0.310	0.0294	0.0388	0.00922	4.60	180
190	79.97	80.68	64.68	0.2311	39.44	98.98	0.08143	0.19170	0.3722	0.2984	1.388	1204	435.8	0.301	0.0297	0.0384	0.00941	4.36	190
200	83.53	84.23	64.07	0.2181	40.76	99.25	0.08381	0.19143	0.3767	0.3051	1.408	1171	432.6	0.293	0.0300	0.0379	0.00961	4.13	200
220	90.27	90.94	62.87	0.1955	43.29	99.70	0.08833	0.19085	0.3864	0.3194	1.450	1108	426.1	0.277	0.0307	0.0370	0.01000	3.70	220
240	96.57	97.21	61.70	0.1764	45.70	100.05	0.09259	0.19026	0.3969	0.3353	1.498	1048	419.4	0.263	0.0313	0.0362	0.01041	3.30	240
260	102.48	103.09	60.53	0.1601	48.02	100.32	0.09663	0.18962	0.4086	0.3530	1.553	991	4112.6	0.250	0.0320	0.0354	0.01084	2.93	260
280	108.06	108.64	59.37	0.1460	50.25	100.51	0.10047	0.18895	0.4216	0.3730	1.616	936	405.7	0.238	0.0328	0.0347	0.01131	2.59	280
300	113.34	113.90	58.20	0.1336	52.42	100.61	0.10417	0.18823	0.4364	0.3959	1.690	884	398.7	0.227	0.0335	0.0340	0.01180	2.28	300
320	118.36	118.89	57.03	0.1226	54.54	100.64	0.10773	0.18745	0.4534	0.4226	1.778	832	391.5	0.216	0.0343	0.0333	0.01235	1.98	320
340	123.14	123.65	55.83	0.1127	56.61	100.58	0.11118	0.18660	0.4733	0.4543	1.883	783	384.2	0.206	0.0352	0.0326	0.01294	1.71	340
360	127.71	128.19	54.61	0.1038	58.65	100.43	0.11456	0.18566	0.4972	0.4927	2.013	734	376.8	0.196	0.0362	0.0320	0.01360	1.46	360
380	132.09	132.54	53.35	0.0956	60.67	100.20	0.11787	0.18464	0.5265	0.5404	2.174	685	369.2	0.187	0.0373	0.0315	0.01435	1.22	380
400	136.28	136.71	52.03	0.0881	62.68	99.85	0.12114	0.18349	0.5635	0.6014	2.383	638	361.5	0.177	0.0385	0.0309	0.01520	1.01	400
450	146.07	146.42	48.36	0.0713	67.80	98.42	0.12934	0.17987	0.7246	0.8714	3.313	519	341.6	0.154	0.0423	0.0298	0.01806	0.54	450
500	154.97	155.22	43.51	0.0556	73.49	95.51	0.13833	0.17416	1.2912	1.8068	6.526	396	320.1	0.128	0.0488	0.0299	0.02348	0.18	500
548.24	162.50	162.50	35.84	0.0279	80.85	80.85	0.14987	0.14987	-	-	-	-	-	-	-	-	-	0.00	548.24

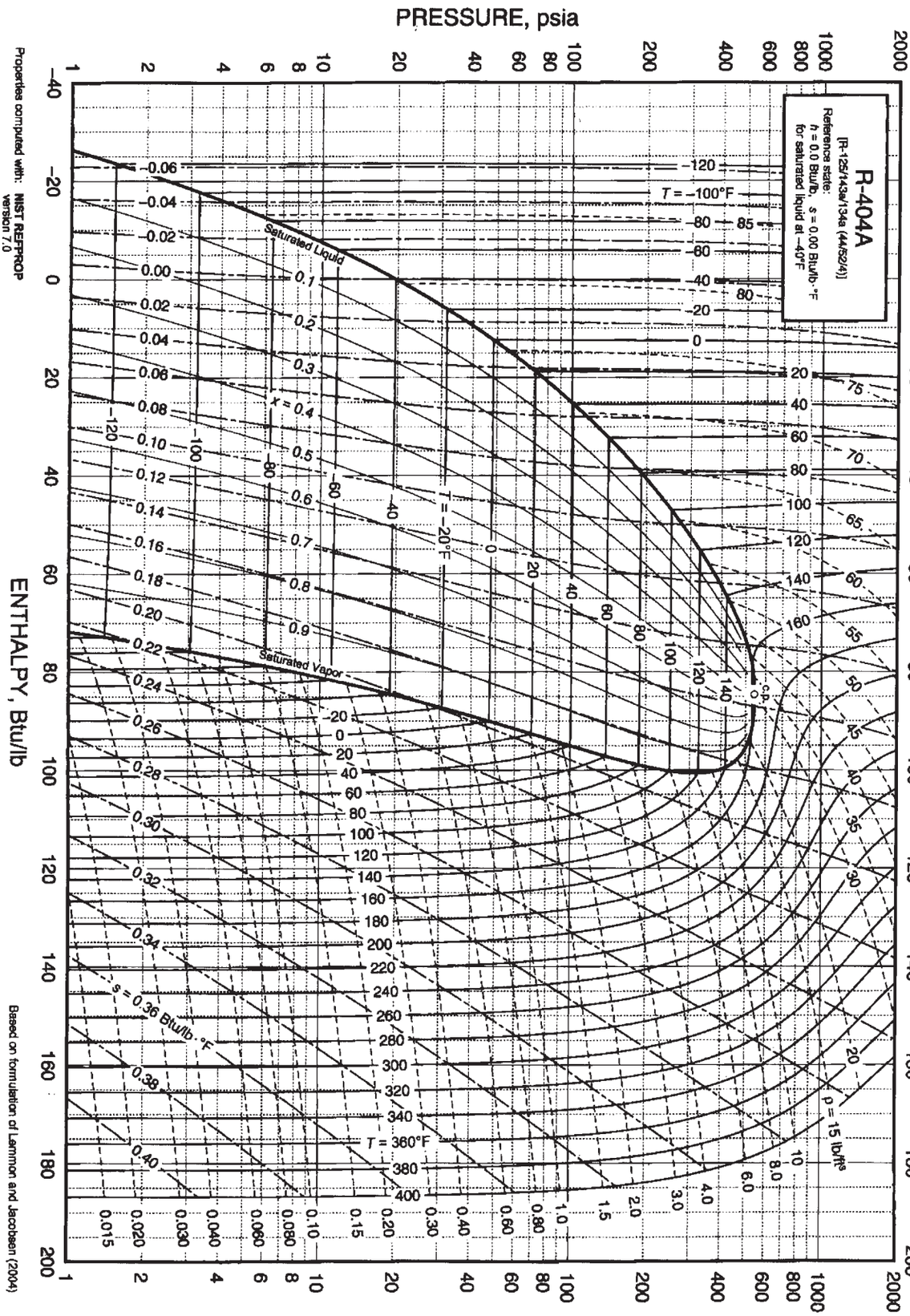


Figure 5.4 : Pressure Enthaply Diagram R-407C

Table 5.5 : Thermophysical Properties Of Refrigerants

R-407C [R-32/125/134a (23/25/52)] Properties of Liquid on Bubble Line and Vapor on Dew Line

Press-ure	Temp.* ^{0}F		Density lb/ft^3	Volume ft^3/lb	Enthaply Btu/lb		Enthaply Btu/lb* ^{0}F		Specific Heat C_p Btu/lb* ^{0}F		C_p/C_v Vapour	Vel. of Sound ft/s		Viscosity lb_m/ft&h		Thermal Cond. Btu/h*ft. ^{0}F		Surface Tension	Press-ure
psia	Bubble	Dew	Liquid	Vapor	Liquid	Vapor	Liquid	Vapor	Liquid	Vapor		Liquid	Vapor	Liquid	Vapor	Liquid	Vapor	dyne/cm	psia
1	-125.19	-111.30	94.24	43.0887	-26.34	93.96	-0.07002	0.28254	0.3065	0.1568	1.183	3404	484.3	2.112	0.0199	0.0894	0.00385	25.65	1
1.5	-115.58	-101.85	93.28	29.4430	-23.40	95.34	-0.06135	0.27716	0.3063	0.1600	1.182	3300	489.5	1.867	0.0204	0.0874	0.00403	24.66	1.5
2	-108.36	-94.75	92.55	22.4776	-21.18	96.37	-0.05499	0.27346	0.3063	0.1624	1.181	3225	493.3	1.712	0.0208	0.0860	0.00416	23.93	2
2.5	-102.52	-88.99	91.97	18.2333	-19.39	97.21	-0.04994	0.27066	0.3065	0.1644	1.181	3166	496.2	1.601	0.0212	0.0848	0.00427	23.34	2.5
3	-97.57	-84.12	91.47	15.3685	-17.87	97.92	-0.04572	0.26841	0.3068	0.1662	1.181	3117	498.6	1.515	0.0214	0.0839	0.00436	22.84	3
4	-89.43	-76.11	90.64	11.7361	-15.37	99.09	-0.03889	0.26495	0.3074	0.1693	1.181	3037	502.4	1,389	0.0219	0.0823	0.00452	22.02	4
5	-82.81	-69.61	89.97	9.5211	-13.34	100.03	-0.03345	0.26234	0.3081	0.1719	1.182	2974	505.3	1.299	0.0222	0.0810	0.00465	21.36	5
6	-77.20	-64.09	89.40	8.0252	-11.60	100.83	-0.02889	0.26025	0.3087	0.1742	1.182	2921	507.6	1.229	0.0225	0.0799	0.00476	20.81	6
7	-72.30	-59.27	88.89	6.9450	-10.09	101.52	-0.02496	0.25852	0.3094	0.1762	1.183	2875	509.5	1.172	0.0228	0.0789	0.00485	20.32	7
8	-67.94	-54.97	88.44	6.1272	-8.74	102.13	-0.02149	0.25705	0.3100	0.1781	1.184	2835	511.1	1.125	0.0230	0.0781	0.00494	19.90	8
10	-60.38	-47.55	87.66	4.9690	-6.39	103.19	0.01556	0.25464	0.3112	0.1814	1.186	2765	513.8	1.050	0.0234	0.0766	0.00509	19.16	10
12	-53.96	-41.23	86.98	4.1864	4.38	104.08	-0.01059	0.25272	0.3123	0.1844	1.188	2707	515.8	0.992	0.0238	0.0754	0.00522	18.54	12
14	48.34	-35.71	86.39	3.6210	-2.62	104.85	-0.00629	0.25114	0.3133	0.1871	1.189	2656	517.4	0.945	0.0241	0.0743	0.00534	18.00	14
14.70[b]	46.53	-33.93	86.19	3.4593	-2.06	105.10	-0.00492	0.25065	0.3137	0.1880	1.190	2639	517.9	0.930	0.0241	0.0739	0.00537	17.82	14.7
16	-43.32	-30.78	85.85	3.1928	-1.05	105.54	-0.00249	0.24979	0.3143	0.1896	1.191	2610	518.7	0.906	0.0243	0.0733	0.00544	17.52	16
18	-38.77	-26.31	85.36	2.8570	0.39	106.15	0.00092	0.24863	0.3153	0.1919	1.193	2570	519.8	0.872	0.0246	0.0725	0.00553	17.08	18
20	-34.61	-22.23	84.91	2.5862	1.70	106.71	0.00402	0.24760	0.3162	0.1941	1.195	2532	520.7	0.843	0.0248	0.0717	0.00562	16.69	20
22	-30.76	-18.45	84.50	2.3632	2.92	107.22	0.00687	0.24668	0.3172	0.1961	1.197	2498	521.4	0.817	0.0250	0.0710	0.00570	16.33	22
24	-27.18	-14.93	84.10	2.1761	4.06	107.70	0.00950	0.24586	0.3180	0.1981	1.199	2466	522.0	0.794	0.0252	0.0703	0.00578	15.99	24
26	-23.83	-11.64	83.73	2.0169	5.13	108.14	0.01196	0.24510	0.3189	0.1999	1.201	2436	522.6	0.773	0.0253	0.0697	0.00585	15.68	26
28	-20.66	-8.54	83.38	1.8798	6.15	108.55	0.01426	0.24442	0.3197	0.2017	1.203	2408	523.0	0.754	0.0255	0.0691	0.00592	15.38	28
30	-17.67	-5.60	83.05	1.7603	7.10	108.93	0.01643	0.24378	0.3205	0.2034	1.205	2382	523.4	0.737	0.0257	0.0685	0.00598	15.11	30
32	-14.84	-2.82	82.73	1.6553	8.02	109.30	0.01848	0.24319	0.3213	0.2051	1.207	2356	523.6	0.721	0.0258	0.0680	0.00605	14.84	32
34	-12.13	-0.17	82.43	1.5622	8.89	109.64	0.02042	0.24265	0.3221	0.2067	1.209	2332	523.9	0.706	0.0260	0.0675	0.00610	14.59	34
36	-9.55	2.37	82.14	1.4791	9.72	109.97	0.02227	0.24213	0.3229	0.2083	1.211	2309	524.1	0.692	0.0261	0.0670	0.00616	14.36	36
38	-7.07	4.79	81.85	1.4095	10.53	110.28	0.02404	0.24165	0.3236	0.2098	1.213	2288	524.2	0.679	0.0262	0.0666	0.00622	14.13	38
40	-4.70	7.12	81.58	1.3371	11.30	110.58	0.02573	0.21420	0.3244	0.2113	1.215	2267	524.3	0.667	0.0263	0.0661	0.00627	13.91	40
42	-2.41	9.37	81.32	1.2759	12.04	110.86	0.02735	0.24077	0.3251	0.2127	1.217	2246	524.3	0.656	0.0265	0.0657	0.00632	13.71	42
44	-0.20	11.53	81.06	1.2201	12.76	111.13	0.02891	0.24036	0.3258	0.2141	1.219	2227	524.4	0.645	0.0266	0.0653	0.00637	13.51.	44
46	1.93	13.61	80.82	1.1690	13.46	111.39	0.03041	0.23998	0.3265	0.2155	1.221	2208	524.4	0.635	0.0267	0.0649	0.00642	13.31	46
48	3.98	15.63	80.58	1.1220	14.13	111.64	0.03186	0.23961	0.3272	0.2169	1.223	2190	524.3	0.626	0.0268	0.0646	0.00646	13.13	48
50	5.98	17.58	80.34	1.0786	14.79	111.88	0.03326	0.23926	0.3279	0.2182	1.225	2172	524.3	0.617	0.0269	0.0642	0.00651	12.95	50
55	10.71	22.21	79.78	0.9835	16.34	112.44	0.03656	0.23844	0.3296	0.2214	1.230	2130	524.0	0.596	0.0272	0.0633	0.00663	12.53	55
60	15.13	26.53	79.25	0.9037	17.81	112.96	0.03963	0.23771	0.3313	0.2246	1.235	2091	523.6	0.577	0.0274	0.0626	0.00673	12.13	60
65	19.27	30.58	78.75	0.8359	19.19	113.44	0.04250	0.23703	0.3329	0.2276	1.240	2054	523.2	0.560	0.0276	0.0618	0.00684	11.77	65
70	23.18	34.40	78.27	0.7774	20.49	113.88	0.04519	0.23641	0.3346	0.2305	1.245	2019	522.6	0.544	0.0278	0.0611	0.00694	11.43	70
75	26.88	38.02	77.82	0.7264	21.74	114.29	0.04773	0.23548	0.3362	0.2333	1.250	1986	522.0	0.530	0.0280	0.0605	0.00703	11.10	75
80	30.39	41.46	77.38	0.6816	22.92	114.67	0.05014	0.23530	0.3378	0.2361	1.255	1955	521.3	0.517	0.0282	0.0598	0.00712	10.80	80
85	33.75	44.73	76.95	0.6419	24.06	115.03	0.05243	0.23480	0.3393	0.2389	1.260	1925	520.6	0.505	0.0284	0.0593	0.00721	10.51	85
90	36.96	47.87	76.54	0.6064	25.16	115.37	0.05462	0.23432	0.3409	0.2416	1.266	1896	519.8	0.493	0.0286	0.0587	0.00730	10.23	90
95	40.04	50.87	76.15	0.5746	26.21	115.68	0.05671	0.23387	0.3424	0.2442	1.271	1869	519.0	0.483	0.0288	0.0582	0.00739	9.97	95
100	43.00	53.75	75.76	0.5458	27.23	115.98	0.05871	0.23344	0.3440	0.2468	1.276	1842	518.1	0.473	0.0289	0.0576	0.00747	9.72	100
110	48.60	59.21	75.02	0.4959	29.16	116.53	0.06250	0.3265	0.3471	0.2520	1.287	1792	516.3	0.454	0.0293	0.0567	0.00763	9.25	110
120	53.83	64.30	74.32	0.4540	30.99	117.03	0.06602	0.23191	0.3502	0.2570	1.298	1745	514.3	0.438	0.0296	0.0558	0.00780	8.81	120
130	58.75	69.08	73.64	0.4183	32.72	117.47	0.06932	0.23122	0.3533	0.2621	1.310	1700	512.3	0.423	0.0299	0.0549	0.00796	8.41	130
140	63.39	73.59	72.99	0.3875	34.36	117.88	0.07244	0.23508	0.3264	0.2671	1.321	1658	510.2	0.409	0.0302	0.0541	0.00812	8.03	140
150	67.79	77.86	72.37	0.3607	35.94	118.24	0.07538	0.22997	0.3596	0.2721	1.334	1618	508.0	0.396	0.0304	0.0534	0.00828	7.67	150
160	71.98	81.92	71.76	0.3372	37.45	118.57	0.07818	0.22638	0.3628	0.2772	1.346	1580	505.7	0.385	0.0307	0.0527	0.00844	7.33	160
170	75.97	85.79	71.17	0.3163	38.90	118.87	0.08086	0.22882	0.3660	0.2824	1.359	1543	503.4	0.374	0.0310	0.0520	0.00860	7.01	170
180	79.80	89.49	70.59	0.2976	40.30	119.15	0.08341	0.22828	0.3693	0.2876	1.373	1508	501.1	0.364	0.0312	0.0514	0.00876	6.71	180
190	83.47	93.04	70.02	0.2808	41.66	119.39	0.085587	0.22776	0.3727	0.2929	1.387	1474	498.7	0.354	0.0315	0.0507	0.00893	6.42	190
200	87.00	96.45	69.47	0.2656	42.97	119.61	0.08823	0.22725	0.3761	0.2983	1.401	1441	496.3	0.345	0.0317	0.0501	0.00909	6.15	200
220	93.69	102.90	68.40	0.2393	45.49	119.99	0.09271	0.22625	0.3832	0.3095	1.432	1379	491.4	0.328	0.0323	0.0490	0.00942	5.64	220
240	99.94	108.92	67.35	0.2171	47.88	120.29	0.09691	0.22529	0.3907	0.3213	1.466	1320	486.3	0.313	0.0328	0.0480	0.00976	5.17	240
260	105.82	114.56	66.33	0.1982	50.17	120.52	0.10088	0.22434	0.3986	0.3338	1.502	1265	481.2	0.299	0.0333	0.0470	0.01011	4.73	260
280	111.37	119.88	65.33	0.1819	52.36	120.68	0.10464	0.22340	0.4070	0.3473	1.542	1211	475.9	0.287	0.0339	0.0461	0.01048	4.33	280
300	116.64	124.91	64.34	0.1676	54.48	120.78	0.10824	0.22246	0.4161	0.3618	1.586	1160	470.5	0.275	0.0344	0.0452	0.01086	3.96	300
320	121.66	129.69	63.37	0.1550	56.53	120.82	0.11168	0.22152	0.4260	0.3777	1.635	1111	465.1	0.264	0.0350	0.0444	0.01126	3.61	320
340	126.45	134.24	62.39	0.1438	58.53	120.80	0.11500	0.22056	0.4368	0.3951	1.689	1063	459.6	0.253	0.0356	0.0436	0.01169	3.28	340
360	131.03	138.58	61.42	0.1337	60.47	120.73	0.11821	0.21958	0.4487	0.4143	1.750	1017	454.0	0.243	0.0362	0.0428	0.01215	2.97	360
380	135.43	142.73	60.44	0.1246	62.38	120.61	0.12132	0.21857	0.4620	0.4358	1.819	972	448.3	0.234	0.0368	0.0421	0.01264	2.68	380
400	139.66	146.71	59.46	0.1163	64.25	120.42	0.12435	0.21753	0.4769	0.4600	1.897	927	442.6	0.225	0.0375	0.0414	0.01317	2.41	400
450	149.59	155.98	56.92	0.0984	68.84	119.71	0.13167	0.21473	0.5248	0.5373	2.151	819	427.8	0.204	0.0394	0.0398	0.01469	1.79	450
500	158.73	164.41	54.21	0.0835	73.37	118.56	0.13879	0.21152	0.5982	0.6546	2.541	712	412.5	0.184	0.0417	0.0383	0.01661	1.26	500
550	167.22	172.09	51.15	0.0706	78.00	116.83	0.14595	0.20765	0.7284	0.8572	3.217	606	396.5	0.164	0.0447	0.0370	0.01920	0.80	550
600	175.17	179.07	47.39	0.0586	83.04	114.18	0.15363	0.20253	1.0271	1.2973	4.683	498	379.3	0.144	0.0491	0.0363	0.02308	0.42	600
650	182.79	185.22	41.60	0.0457	89.56	109.19	0.16351	0.19401	2.4146	3.0022	10.265	387	358.6	-	-	-	-	0.11	650
673.36[c]	186.94	186.94	31.59	0.0317	99.99	99.99	0.17797	0.17797	-	-	-	-	-	-	-	-	-	0.00	673.36

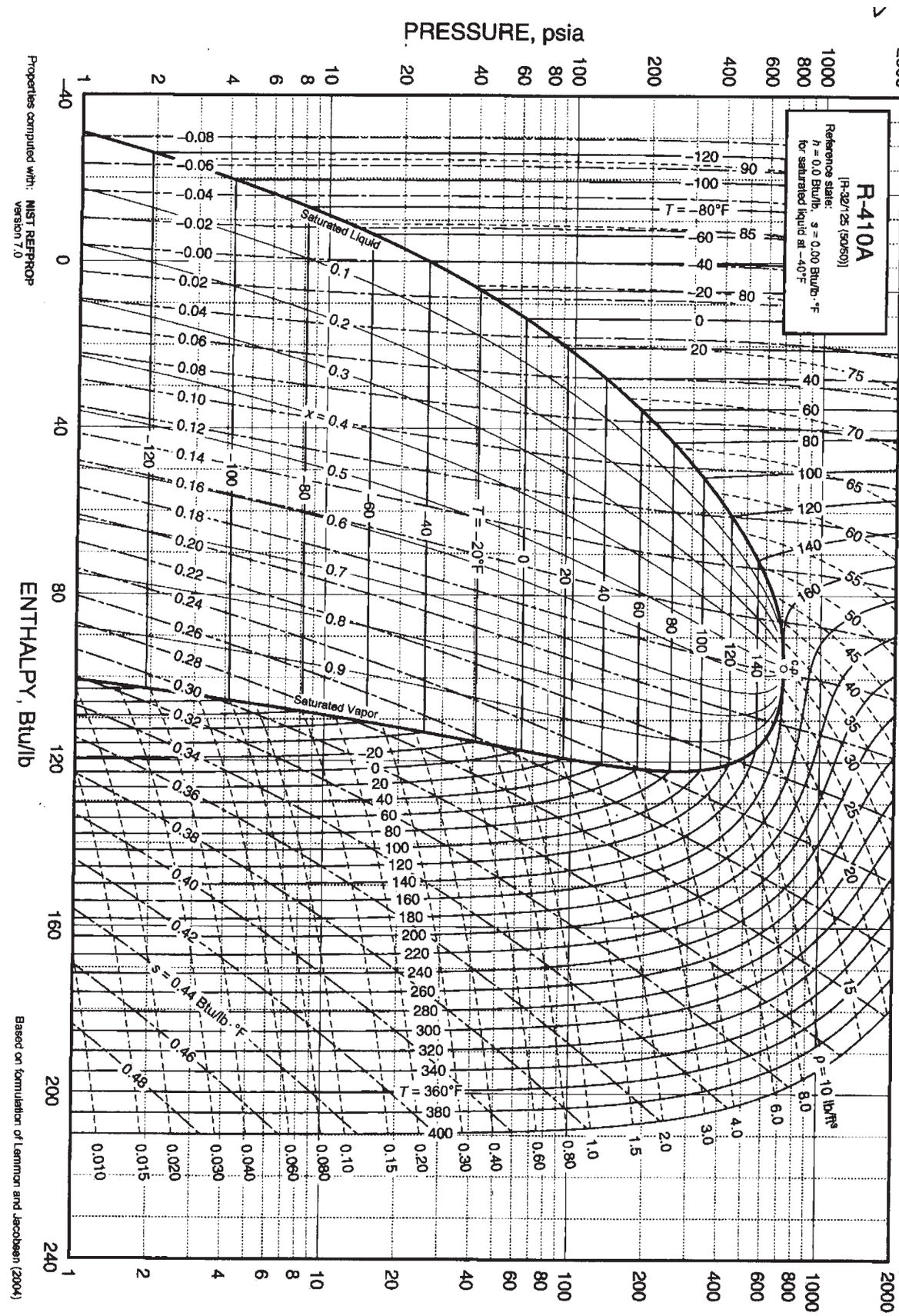


Figure 5.5 : Thermophysical Properties of Refrigerants R-410A

Table 5.6 : Thermophysical Properties of Refrigerants

R-410A [R-32/125 (50/50)] Properties of Liquid on Bubble Line and Vapor on Dew Line

Press-ure	Temp.* ^{0}F		Density lb/ft^3	Volume ft^3/lb	Enthaply Btu/lb		Enthaply Btu/lb* ^{0}F		Specific Heat C_p Btu/lb* ^{0}F		C_p/C_v Vapour	Vel. of Sound ft/s		Viscosity lb$_m$/ft&h		Thermal Cond. Btu/h*ft. ^{0}F		Surface Tension	Press-ure
psia	Bubble	Dew	Liquid	Vapor	Liquid	Vapor	Liquid	Vapor	Liquid	Vapor		Liquid	Vapor	Liquid	Vapor	Liquid	Vapor	dyne/cm	psia
1	-135.16	-134.98	92.02	47.6458	-30.90	100.62	-0.08330	0.32188	0.3215	0.1568	1.228	3369	518.6	1.795	0.01%	0.1043	0.00421	25.62	1
1.5	-126.03	-125.87	91.10	32.5774	-27.97	101.90	-0.07439	0.31477	0.3212	0.1600	1.227	3287	524.5	1.605	0.0201	0.1023	0.00431	24.64	1.5
2	-119.18	-119.02	90.41	24.8810	-25.76	102.86	-0.06786	0.30981	0.3213	0.1626	1.227	3226	528.7	1.483	0.0205	0.1008	0.00439	23.91	2
2.5	-113.63	-113.48	89.84	20.1891	-23.98	103.63	-0.06267	0.30602	0.3214	0.1648	1.228	3176	531.9	1.394	0.0208	0.0996	0.00446	23.32	2.5
3	-108.94	-108.78	89.36	17.0211	-22.47	104.27	-0.05834	0.30296	0.3216	0.1668	1.228	3135	534.6	1.325	0.0211	0.0985	0.00451	22.82	3
4	-101.22	-101.07	88.57	13.0027	-19.98	105.33	-0.05133	0.29820	0.3221	0.1703	1.229	3066	538.8	1.222	0.0216	0.0968	0.00461	22.01	4
5	-94.94	-94.80	87.92	10.5514	-17.96	106.18	-0.04574	0.29455	0.3226	0.1733	1.230	3010	542.0	1.148	0.0219	0.0954	0.00469	21.35	5
6	-89.63	-89.48	87.36	8.8953	-16.24	106.89	-0.04107	0.29162	0.3231	0.1760	1.232	2963	544.6	1.090	0.0223	0.0942	0.00476	20.80	6
7	-84.98	-84.84	86.87	7.6992	-14.74	107.50	-0.03704	0.28916	0.3236	0.1785	1.233	2922	546.7	1.043	0.0225	0.0931	0.00482	20.32	7
8	-80.85	-80.71	86.44	6.7935	-13.40	108.05	-0.03349	0.28705	0.3241	0.1807	1.234	2885	548.5	1.003	0.0228	0.0922	0.00488	19.90	8
10	-73.70	-73.56	85.67	5.5105	-11.08	108.97	-0.02743	0.28356	0.3251	0.1848	1.237	2821	551.5	0.940	0.0232	0.0905	0.00498	19.16	10
12	-67.62	-67.48	85.02	4.6434	-9.10	109.75	-0.02235	0.28075	0.3261	0.1884	1.240	2767	553.8	0.891	0.0235	0.0891	0.00507	18.55	12
14	-62.31	-62.16	84.44	4.0168	-7.36	110.42	-0.01795	0.27840	0.3270	0.1917	1.243	2720	555.6	0.850	0.0238	0.0879	0.00515	18.01	14
14.70[b]	-60.60	-60.46	84.26	3.8375	-6.80	110.63	-0.01655	0.27766	0.3274	0.1928	1.244	2704	556.2	0.838	0.0239	0.0875	0.00517	17.84	14.7
16	-57.56	-57.42	83.93	3.5423	-5.80	111.01	-0.01407	0.27638	0.3279	0.1947	1.245	2677	557.1	0.817	0.0241	0.0868	0.00522	17.53	16
18	-53.27	-53.13	83.45	3.1699	-4.39	111.54	0.01059	0.27461	0.3288	0.1975	1.248	2639	558.4	0.788	0.0244	0.0858	0.00528	17.10	18
20	-49.34	-49.19	83.02	2.8698	-3.09	112.01	0.00743	0.27305	0.3297	0.2002	1.251	2603	559.4	0.763	0.0246	0.0849	0.00535	16.71	20
22	-45.70	-45.56	82.61	2.6225	-1.89	112.45	-0.00452	0.27164	0.3305	0.2027	1.254	2571	560.3	0.740	0.0248	0.0841	0.00540	16.35	22
24	-42.32	-42.18	82.23	2.4151	-0.77	112.85	-0.00184	0.27036	0.3313	0.2050	1.256	2540	561.1	0.720	0.0250	0.0833	0.00546	16.02	24
26	-39.15	-39.01	81.87	2.2386	0.28	131.22	0.00067	0.26919	0.3321	0.2073	1.259	2512	561.7	0.702	0.0252	0.0826	0.00551	15.71	26
28	-36.17	-36.02	81.54	2.0865	1.27	113.56	0.00301	0.26811	0.3329	0.2094	1.261	2485	562.3	0.686	0.0254	0.0819	0.00556	15.42	28
30	-33.35	-33.20	81.21	1.9540	2.22	113.88	0.00522	0.26711	0.3337	0.2115	1.264	2459	562.7	0.671	0.0255	0.0813	0.00561	15.14	30
32	-30.68	-30.53	80.90	1.8375	3.11	114.19	0.00730	0.26617	0.3345	0.2135	1.267	2435	563.1	0.657	0.0257	0.0806	0.00565	14.88	32
34	-28.13	-27.98	80.61	1.7343	3.97	114.47	0.00928	0.26530	0.3352	0.2154	1.269	2412	563.4	0.644	0.0258	0.0801	0.00570	14.63	34
36	-25.69	-25.54	80.33	1.6422	4.79	114.74	0.01116	0.26448	0.3360	0.2173	1.272	2390	563.7	0.632	0.0260	0.0795	0.00574	14.40	36
38	-23.36	-23.20	80.05	1.5594	5.57	115.00	0.01296	0.26371	0.3367	0.2191	1.274	2368	563.9	0.621	0.0261	0.0790	0.00578	14.17	38
40	-12.12	-20.96	79.79	1.4847	6.33	115.24	0.01467	0.26297	0.3374	0.2208	1.277	2348	564.1	0.610	0.0262	0.0785	0.00582	13.96	40
42	-18.96	-18.81	79.54	1.4168	7.06	115.47	0.01632	0.026228	0.3382	0.2226	1.279	2328	564.3	0.600	0.0264	0.0780	0.00586	13.75	42
44	-16.89	-16.73	79.29	1.3549	7.76	115.69	0.01791	0.26162	0.3389	0.2242	1.282	2309	564.4	0.591	0.0265	0.0775	0.00589	13.55	44
46	-14.88	-14.73	79.05	1.2982	8.45	115.90	0.01943	0.26098	0.3396	0.2259	1.284	2291	564.4	0.582	0.0266	0.0771	0.00593	13.56	46
48	-12.94	-12.79	78.82	1.2460	9.11	116.10	0.02090	0.26038	0.3403	0.2275	1.287	2273	564.5	0.574	0.0267	0.0766	0.00597	13.18	48
50	-11.07	-10.91	78.59	1.1979	9.75	116.30	0.02232	0.25980	0.3410	0.2290	1.289	2256	564.5	0.566	0.0268	0.0762	0.00600	13.00	50
55	-6.62	-6.45	78.05	1.0925	11.27	116.75	0.02568	0.25845	0.3427	0.2328	1.295	2215	564.4	0.547	0.0271	0.0752	0.00610	12.58	55
60	-2.46	-2.30	77.54	1.0040	12.70	117.16	0.02880	0.25722	0.3445	0.2365	1.301	2176	564.2	0.530	0.0273	0.0743	0.00619	12.20	60
65	1.43	1.60	77.06	0.9287	14.05	117.53	0.03171	0.25610	0.3462	0.2400	1.308	2140	563.9	0.515	0.0275	0.0734	0.00628	11.83	65
70	5.10	5.27	76.60	0.8638	15.33	117.88	0.03444	0.25505	0.3478	0.2434	1.314	2105	563.5	0.502	0.0278	0.0726	0.00636	11.49	70
75	8.58	8.75	76.15	0.8073	16.54	118.20	0.03702	0.25408	0.3495	0.2467	1.320	2073	563.0	0.489	0.0280	0.0719	0.00645	11.17	75
80	11.88	12.06	75.73	0.7576	17.70	118.49	0.03946	0.25316	0.3512	0.2499	1.326	2042	562.4	0.477	0.0282	0.0711	0.00653	10.87	80
85	15.03	15.21	75.32	0.7135	18.81	118.77	0.04178	0.25231	0.3528	0.2531	1.333	2012	561.8	0.467	0.0284	0.0704	0.00661	10.59	85
90	18.05	18.22	74.93	0.6742	19.88	119.02	0.04400	0.25149	0.3545	0.2562	1.339	1983	561.2	0.457	0.0285	0.0698	0.00669	10.31	90
95	20.93	21.11	74.54	0.6389	20.91	119.26	0.04611	0.25072	0.3561	0.2592	1.345	1956	560.4	0.447	0.0287	0.0692	0.00677	10.05	95
100	23.71	23.89	74.17	0.6070	21.90	119.48	0.04815	0.24999	0.3578	0.2622	1.352	1929	559.7	0.438	0.0289	0.0685	0.00684	9.80	100
110	28.96	29.14	73.46	0.5515	23.79	119.89	0.05198	0.24862	0.3611	0.2681	1.365	1879	558.1	0.422	0.0292	0.0674	0.00700	9.34	110
120	33.86	34.05	72.78	0.5051	25.27	120.24	0.05555	0.24736	0.3644	0.2738	1.378	1832	556.3	0.407	0.0295	0.0064	0.00715	8.91	120
130	38.46	38.65	72.13	0.4655	27.25	120.56	0.05890	0.24618	0.3678	0.2795	1.392	1787	554.5	0.394	0.0298	0.0654	0.00730	8.50	130
140	42.80	42.99	71.51	0.4314	28.85	120.83	0.06205	0.24508	0.3712	0.2852	1.406	1744	552.6	.0381	0.0301	0.0645	0.00745	8.13	140
150	46.91	47.11	70.90	0.4016	30.38	121.08	0.06503	0.24403	0.3746	0.2908	1.420	1704	550.6	0.370	0.0304	0.0636	0.00760	7.78	150
160	50.82	51.02	70.32	0.3755	31.85	121.29	0.06787	0.24304	0.3781	0.2965	1.435	1666	548.6	0.360	0.0306	0.0628	0.00775	7.44	160
170	54.56	54.76	69.75	0.3523	33.27	121.48	0.07057	0.24210	0.3816	0.3022	1.451	1629	546.5	0.350	0.0309	0.0620	0.00791	7.13	170
180	58.13	58.33	69.20	0.3316	34.63	121.65	0.07316	0.24119	0.3851	0.3080	1.467	1593	544.4	0.341	0.0311	0.0612	0.00807	6.83	180
190	61.55	61.76	68.66	0.3130	35.95	121.79	0.07565	0.24031	0.3888	0.3139	1.483	1559	542.2	0.332	0.0314	0.0605	0.00823	6.55	190
200	64.84	65.05	68.13	0.2962	37.22	121.91	0.07804	0.23946	0.3925	0.3200	1.500	1526	540.0	0.324	0.0317	0.0598	0.00839	6.28	200
220	71.07	71.28	67.10	0.2669	39.67	122.09	0.08258	0.23783	0.4001	0.3325	1.537	1462	535.6	0.309	0.0321	0.0585	0.00873	5.77	220
240	76.89	77.10	66.11	0.2424	41.99	122.20	0.08683	0.23628	0.4081	0.3457	1.576	1403	531.0	0.296	0.0326	0.0573	0.00908	5.31	240
260	82.35	82.57	65.14	0.2215	44.21	122.25	0.09084	0.23478	0.4165	0.3599	1.169	1346	526.3	0.283	0.0330	0.0562	0.00945	4.88	260
280	87.51	87.73	64.19	0.2034	46.34	122.24	0.09464	0.23333	0.4255	0.3751	1.665	1293	521.5	0.272	0.0335	0.0552	0.00983	4.48	280
300	92.40	92.61	63.26	0.1876	48.40	122.18	0.09827	0.23190	0.4350	0.3915	1.716	1241	516.6	0.261	0.0340	0.0542	0.01024	4.11	300
320	97.04	97.26	62.34	0.1736	50.38	122.07	0.10175	0.23049	0.4452	0.4094	1.772	1191	511.6	0.251	0.0345	0.0533	0.01067	3.76	320
340	101.48	101.69	61.42	0.1613	52.31	121.91	0.10509	0.22909	0.4564	0.4290	1.833	1143	506.6	0.242	0.0350	0.0524	0.01113	3.44	340
360	105.71	105.93	60.52	0.1501	54.19	121.70	0.10832	0.22769	0.4685	0.4507	1.901	1097	501.4	0.233	0.0355	0.0515	0.01162	3.13	360
380	109.78	109.99	59.61	0.1401	56.03	121.44	0.11145	0.22629	0.4820	0.4747	1.977	1051	496.2	0.225	0.0361	0.0507	0.01214	2.85	380
400	113.68	113.89	58.70	0.1310	57.83	121.13	0.11450	0.22488	0.4971	0.5016	2.063	1007	490.9	0.217	0.0366	0.0499	0.01271	2.58	400
450	122.82	123.01	56.39	0.114	62.23	120.14	0.12182	0.22124	0.5443	0.5857	2.333	900	477.2	0.198	0.0381	0.0481	0.01433	1.96	450
500	131.19	131.38	53.97	0.0952	66.54	118.80	0.12888	0.21732	0.6143	0.7083	2.728	795	462.8	0.181	0.0399	0.0465	0.01636	1.44	500
550	138.93	139.09	51.32	0.0814	70.89	117.02	0.13590	0.21295	0.7303	0.9059	3.367	692	447.5	0.164	0.0421	0.0451	0.01902	0.98	550
600	146.12	146.25	48.24	0.0690	75.47	114.59	0.14320	0.20777	0.9603	1.2829	4.579	588	431.0	0.147	0.0450	0.0440	0.02275	0.59	600
692.78[c]	158.40	158.40	34.18	0.0293	90.97	90.97	0.16781	0.16781	-	-	-	-	-	-	-	-	-	0.00	692.78

LUBRICANTS

Table 5.7: Recommended viscosity ranges for lubricants in small and commercial systems

Refrigerant	Type of Compressor	Lubricant SSU	Visc. @ at 100^{0}F
Ammonia	Screw	280-300	60-65
Ammonia	Reciprocating	150-300	32-65
Carbon Dioxide	Reciprocating	280-300a	60-65a
Refrigerant 407 C	Scroll	100-300	22-68
Refrigerant 407 C	Reciprocating	150-300	32-68
Refrigerant 410 A	Scroll	1000-300	22-68
Refrigerant 134a	Centrifugal	280-300	60-65
Refrigerant 134a	Screw	280-300	60-65
Refrigerant 22	Centrifugal	280-400	60-86
Refrigerant 22	Reciprocating	150-300	32-65
Refrigerant 22	Scroll	280-300	60-65
Refrigerant 22	Screw	280-300	60-173
Halogenated refrigerants	Screw	150-4000	32-800

Table 5.8 : Typical Properties of Refrigerant Lubricants - Industrial Refrigeration

Type of Compressor	Lubricant Viscosities at 100 °F	
	SSU	cSt
Where lubricant may enter refrigeration system or compressor cylinders	150 to 300	32 to 65
Where lubricant is prevented from entering system or cylinders :		
In force-feed or gravity systems	500 to 600	108 to 129
In splash systems	150 to 160	32 to 34
Steam-driven compressor cylinders when condensate is reclaimed for ice-making	High-viscosity lubricant (30 to 35 cSt (140 to 165 SSU)viscosity at 210^{0}F	
Some applications may require lighter lubricants of 75 to 85 SSU C14 to 17. Others may required heavier lubricants of 500 to 600 SSU unit. Ammonia and carbon dioxide compressors with special forced feed or gravity circulation.		

Table 5.9 : Mutual Solubility of Refrigerant and Mineral Oil

Complete Miscibility	Partially Miscible			
	High Miscibility	Intermediate Miscibility	Low Miscibility	Immiscible
R-11	R-1331	R-22	R-13	Ammonia
R-12	R-501	R-114	R-14	C02
R-21	R-123		R-11 5	R-134a
R-11 3			R-152a	R-407C
R-500			R-C318	R-410A
			R-502	

Table 5.10 : Typical Properties of Refrigerant Lubricants

Property	Method	Mineral Lubricants					Synthetic Lubricants			
		Naphthalenic			Paraffinic	Alkylben-zene	Ester		Glycol	
Viscosity, cSt(SSU) at 10^{0}F	ASTM D445	33.1 (155)	61.9(287)	68.6 (318)	34.2(160)	31.7(149)	30 (142)	100 (463)	29.9(141)	90 (417)
Viscosity Index	ASTM D2270	0	0	46	95	27	111	98	210	235
Specific gravity	ASTM D1298	0.913	0.917	0.9	0.862	0.872	0.995	0.972	0.99	1.007
Color	ASTM D1 500	0.5	1	1	0.5					
Refractive Index	ASTM 01 747	1.5015	1.5057	1,4918	1,4752					
Relative molecular mass	ASTM D2503	300	321	345	378	320	570	840	750	1200
Pour point ° F	ASTM D97	43	-40	-37	0	-50	-54	-22	-51	-40
Flow point ° F	ASHRAE 86	-63	-60	-60	-31	-100				
Flash point ° F	ASTM D92	340	360	400	395	350	453	496	399	334
Fire point ° F	ASTM D92	390	400	450	450	365				
Composition										
Carbon type	n-d-m									
% C_A	Van Nes and	14	16	7	3	24				
% C_N	Waston(1951)	43	42	46	32	None				
% C_P		43	42	47	65	76				
Molecular composition	ASTM D2549-									
% Saturates		62	59	78	87	None				
% Aromatics		38	41	22	13	100				
Aniline point, ° F	ASTMD611	160	165	197	220	125				
Critical solution temperature	-	25	35	74	81	-100				
With R-22, ° F										

Source : ASHRAE Handbook

SUNISO GS (Mfg. data)

SUNISO GS Oils are miscible well with HCFC and CFC refrigerants such as R-22, R-502 and R-12 while featuring excellent stability and giving long trouble-free service life in the refrigeration systems using the above refrigerants. In addition, SUNISO GS Oils also perform excellently with natural refrigerants such as R-717, R-600a and R-290.

SUNISO SL-S Synthetic Refrigeration Oils (Mfgs. Data)

SUNISO SL-S series are synthetic refrigeration oils designed specifically for use in refrigeration compressors for refrigerators, freezers, chillers and industrial refrigeration systems to be charged with hydrofluorocarbon (MFC) refrigerants.

- SUNISO SL-S series have optimum miscibility and compatibility with MFC refrigerants such as R-134a and R404A.
- SUNISO SL-S series are formulated by selected polyol ester basestocks and additives, featuring the following characteristics.

Table 5.11 : Physical Properties - SUNISO - Oils Data

Property			SUNISO 3GS	SUNISO 4GS	SUNISO 5GS
Density	15^{0}C	g/cm^3	0.909	0.915	0.921
Color	ASTM		L0.5	L1.0	L1.0
Viscosity	40^{0}C	mm^2/s	29.5	54.9	94.6
Viscosity	100^{0}C	mm^2/s	4.31	5.97	7.78
Flash Point	COG	^{0}C	178	188	208
Pour Point		^{0}C	-40	-35	-27.5
Total Acid No.		mgKOH/g	0.01	0.01	0.01
Aniline Point		^{0}C	75.4	79.8	80.4
Water		ppm	20	20	20
Flow Point		^{0}C	-53	-46	-35

Table 5.12: Physical Properties - SUNISO Oils-Data

ISO Viscosity Classification			SUNISO SL-10S	SUNISO SL-15S	SUNISO SL-225	SUNISO SL-325
			ISO VG10	ISO VG15	ISO VG22	ISO VG32
Density	15^{0}C	g/cm^2	0.928	0.94	0.951	0.956
Color	ASTM		L0.5	L0.5	L0.5	L0.5
Viscosity	40^{0}C	mm^2/s	10.1	15	22.5	32.3
Viscosity	100^{0}C	mm^2/s	2.50	3.22	4.14	5.14
Flash Point	COG	^{0}C	182	196	212	230
Pour Point		^{0}C	<-50	<-50	<-50	-22.5
Total Acid Number		mgKOH/g	0.01	0.01	0.01	0.01
Water Content		ppm	35	35	35	35
Miscibility	Oil/R134-a=1/4^{0}C		-52	-40	-30	-20
Resistivity	25^{0}C	Ωcm	5.0x10^{13}	7.0x10^{13}	4.0x10^{14}	4.0x10^{14}

SECTION 6

THERMAL INSULATION OF DUCTS AND PIPES

Introduction

Thermal insulation is a barrier causing the reduction of heat transfer between objects in thermal contact or in range of radiative influence. Thermal Insulation can be achieved with specially engineered methods or processes, as well as with suitable object shapes and materials.

Heat flow is a natural phenomena and an inevitable consequence of contact between objects of differing temperature. Thermal insulation provides a region of insulation in which thermal conduction is reduced or thermal radiation is reflected rather than absorbed by the lower-temperature body.

Maintaining acceptable temperatures in buildings (by heating and cooling) uses a large proportion of global energy.

Many forms of thermal insulation also reduce noise and vibrations, both coming from the outside and from other rooms inside a building, thus producing a more comfortable environment.

Space Heating and Cooling Systems distribute heat or cold throughout buildings by means of piping or ductwork or using pre-fabricated pipe insulation that reduces energy to and from unoccupied rooms, and prevents condensation from occurring on cold and chilled pipe work.

Factors influencing performance

The insulating capability of a material is measured as thermal conductivity (k). Low thermal conductivity is equivalent to high insulating capability or resistance to heat flow (R-value).

Insulation performance is influenced by many factors. The most prominent of which include:

Thermal conductivity (“k” or “λ” value), Surface emissivity (“ε” value), Insulation Thickness, Density, Specific Heat Capacity and Thermal Bridging.

It is important to note that the factors influencing performance may vary over time as materials age or environmental conditions change.

Table 6.1 : Temperature limits of some common insulation materials

Insulation Material	Temperature Range	
	Low	High
	(°F)	(°F)
Calcium Silicate	0	1200
Cellular Glass	-450	900
Elastomeric Foam	-70	250
Fiberglass	-20	1000
Mineral Wool, Ceramic Fiber		2200
Mineral Wool, Glass	32	480
Mineral Wool, Stone	32	1400
Phenolic foam		300
Polyisocyanurate or polyiso	-290	300
Polystyrene	-60	165
Polyurethane	-350	250

Table 6.2 : Basic Types of Insulation - Low Temperature

-103°F through 60°F

Type	Form	Temp. Range	K-Factor* / Imperial	Mean Temp. (F)	Notes
GLASS CELLULAR	Pipe Covering, Block	-450°F to 800°F	0.33	40°	Good strength, water and vapor resistant. Non-combustible. Poor abrasion resistance.
GLASS FIBER	Pipe Covering, Board, Blanket	from 455°F to 850°F from 455°F to 850°F from 455°F to 850°F	0.24 0.22 0.21	40° 40° 40°	Good workability, non combustible. Water absorbent. Readily available. Vapour retarder required. Low compressive strength.
ELASTOMERIC FOAM	Pipe, Sheet Roll	-40°F to 220°F	0.27	50°	Closed cell, good workability, finish not required. Limited thickness to meet flame spread/ smoke. Requires UV protection.
POLYSTYRENE (Extruded)	Pipe Covering, Board	297°F to 165°F	0.24	40°	Lightweight. Good workability. (Check manufacturers' data) Combustible. Some are treated for fire retardancy.
POLYSTYRENE (Expanded)	Pipe Covering, Board	-40°F to 175°F	0.25	40°	All are closed cell except expanded Polystyrenes.
POLYURETHANE	Pipe Covering, Sheet	-40°F to 212°F	0.18	40°	K-value may change as these materials age. Combustible.
POLYURETHANE	Pipe Covering, Sheet, Roll	-134°F to 212°F	0.25	50°	High flame spread and smoke.
POLYISOCYANU-RATE	Pipe Covering, Sheet	- 297°F to 300°F	0.18	40°	Lightweight. Good workability. (Check manufacturers' data) Some are treated for fire retardancy. K values may change with age.

NOTE: Special attention must be given to installation and vapour seal.
*K-Factor Imperial = Btu.in./h.ft2. °F

Table 6.3 : Basic Types of Insulation- Intermediate Temperature 60°F

Type	Form	Temp. Range	K-Factor* / Imperial	Mean Temp. (F)	Notes
CALCIUM SILICATE	Pipe Covering Block Segments Type I	to 1200°F	0.45	200°	High compression strength. Good workability. Water absorbent. Non-combustible. High flexural strength. Resistant to abrasion. See manufacturers' data for shrinkage factors.
GLASS CELLULAR	Pipe Covering Block Segments Type I	to 800°F	0.35 0.44	75° 200°	Good strength. Water and vapour resistant. Non-combustible. Poor abrasion resistance. Subject to thermal shock. For applications over 204°C (400°F) see manufacturers' specifications.
GLASS FIBER	Pipe Covering Board	from 850°F to 1000°F	0.26 0.23	75° 75°	Good workability. Non-combustible. Water absorbent. Low compression resistance.
GLASS FIBER	Blanket	1000"F	0.23	75°	General purpose material, many facings available.
MINERAL FIBER	Pipe Covering Block Board Blanket	1200°F to 1895°F to 1200°F to 1200°F	0.26 0.26 0.26 0.33	75° 75° 75° 75°	Good workability. Non-combustible. Water absorbent. Low compression resistance.
PERLITE (Expanded)	Pipe Covering Board	to 1200°F	0.53	200°	Good workability. Non-combustible. Poor abrasion resistance. Special packaging required to protect materials. Corrosion inhibitor.
ELASTOMERIC FOAM	Pipe Covering-1 Sheet-11 Roll	-40°F to 220°F	0.30	75°	Closed cell. Finish not required. Good workability. May require UV protection. Flame spread/smoke limited.
POLYSTYRENE (Extruded)	Pipe Covering Board	-297°F to 165°F	0.26	75°	Lightweight, Excellent workability, (combustible although some are treated for fire retardancy. (Check manufacturers' data sheet for properties). High flame spread/smoke.(Check manufacturers' data sheets for values). K value may change as these materials age.
POLYSTYRENE (Expanded)	Pipe Covering Board	40°F to 175°F	0.27	75°	Lightweight, Good workability (Check manufacturers' data sheets). Some are treated for fire retardancy. K values may change with age.
POLYURETHANE	Pipe Covering	-40°F to 225°F	0.19	75°	
POLYETHYLENE	Pipe Covering	-94°F to 212°F	0.26	75°	
POLYISOCYANURATE	Pipe Covering Board	-297°F to3 00°F	0.19	75°	
CALCIUM SILICATE	Pipe Covering Block Segments Type II	1200°F to 1600°F	0.60 0.70	500° 500°	High compressive strength. Good cutting characteristics. Water absorbent. Non-combustible. High flexural strength. Resistant to abrasion. See manufacturers' data for shrinkage factors.
GLASS CELLULAR HIGH TEMP	Pipe Covering Block Segments Type II	to 800°F	0.72	500°	Good strength. Water and Vapour resistant. Non-combustible. Poor abrasion resistance. Subject to thermal shock. For application over 204°C (400°F), see manufacturers' specifications.
GLASS FIBER	Pipe Covering Board Blanket	850°F to 1000°F to	0.58 0.80 0.60 0.23	500° 500° 500°	Good Workability. Water absorbent. Non-combustible. Check manufacturers' data for specific properties. Low compression resistance.
MINERAL FIBER	Pipe Covering Block Board Blanket	1200°F to 1895°F to 1200°F to 1200°F	0.50 0.64 0.70 0.70	500° 500° 500° 500°	Good workability, Iron-combustible.* Low compressive resistance. Water absorbent.
PERLITE (Expanded)	Pipe Covering Block	to 1200°F	0.74	500°	Good workability. Non-combustible. Check manufacturers' data for specific properties. Poor abrasion resistance. Special packaging required to protect material. Corrosion inhibitor.
CERAMIC FIBER (Refractory Fiber)	Block Board Blanket	to 2300°F to 2300° F	0.60 0.56	500° 500°	Temperature range varies with manufacturer, style and type.
CEMENTS Hydraulic Setting Cement High Temperature Mineral Wool Finishing Cement (Mineral Fiber or Vermiculite)	Type I Type II Type III	100-1200°F 100-1600°F 100-1800°F	(1.05) (1.12) 1.26)	482° 482° 482°	One coat application - insulating and finishing. Slow drying. Rough texture - Pointing and insulating and filling. Used over basic insulation - Smooth finish usually 1/8" or ¼" thick application.

Table 6.4 : Protective Coverings And Finishes

PLEASE NOTE: The following items are classified for use as Weather barriers and/or Vapour Retarders. They also serve other purposes listed for protective coverings (i.e. mechanical abuse, corrosion, appearance, and hygiene), but each must be considered on its own merits for these aspects.

WEATHER BARRIERS

Type	Composition	Fasteners	Notes
JACKETS	1. Films laminated to felts or foil	Contact adhesives and/or tape	Corrosion resistant. Bacteria and Mildew resistant.
	2. Stainless steel (various alloys -available with factory-applied moisture retarder)	Bands, screws or rivets	Excellent mechanical strength. Corrosion, Mildew and Bacteria resistant. Excellent fire resistance.
	3. Galvanized steel (coated and with factory-applied moisture retarder)	Bands, screws or rivets	Good mechanical strength and fire resistance.
	4. Aluminum alloys (preferably with factory-applied moisture retarder)	Bands, screw or rivets	Fair mechanical strength, good workability. Poor fire resistance.
	5. Polyvinyl Chloride (PVC)	Mechanical fasteners, adhesive, or matching tape	May require protection from ultra-violet radiation. Resists chemicals and bacteria. Washable surface for food processing applications.
	6. High Impact Plastics (ABS)	ABS welding adhesive or mechanical fasteners	
	7. Plastic film (PVDC)	Adhesive or tape	Corrosion, Bacteria, mildew and Chemically resistant. May require protection from ultraviolet radiation. Workable surface for food processing applications.
MASTICS	1. Asphalt emulsion	Apply with reinforcing mesh	Water base. A breather mastic.
	2. Asphalt cut-back	Apply with reinforcing mesh	Solvent base. Also a vapour barrier.
	3. Resin emulsion	Apply with reinforcing mesh	Tough. Resilient film.
	4. Polyvinyl acetate	Apply with reinforcing mesh	Tough. Resilient film.
	5. Acrylic	Apply with reinforcing mesh	Tough. Resilient film.

*Covering shall not be termed a weather barrier unless its joint and overlaps are adequate to prevent the entry of rainwater.

Table 6.5 : Comparison of Properties of Thermal Insulation Materials

Sl.No.	Characteristics	Rigid Urethane foam	Expanded Polystyrene	Resin Bonded glass wool	Resin Bonded mineral wool	Phenolic foam
1.	Physical Form	Freon-filled. Closed Cell rigid plastic foam	Air-filled. Closed Cell rigid Thermoplastic foam	Open-cell, Resilient resilient bonded Glass wool	Open-cell resilient mat. of resin bonded fiber drawn from rock of slag	Open cell rigid Phenolic foam
2.	Density (lb/cft)	2	0.81 to 1.56	0.75 to 3	2.5 to 9	1.5 to 2
3.	Thermal Conductivity (Kcal / mh°C)	0.014 (initial) 0.019 (design)	0.028 (initial) (for 18 (Kg/m3 density 0.032 (design)	0.032 (for 32 Kg/m^3 density)	0.035 (for 32 Kg/m3 density)	0.021 (initial) 0.0266 (design)
4.	Compressive Strength at 10% deformation psi	26	10.5 to 15	Negligible	Negligible	10.7 to 17.0
5.	Fire Performance	Self extinguishing as per ASTM D 1692-68 and IS 4671 - 1968. It achieves class I Surface spread of flame as per BS 476: Part 7 And Mean extent of Burn value is 'nil' as per ASTM D 1692	Normal variety not self extinguishing as per IS 4671. Rapid spread of fire over the surface on fire occurrence	The glass fibre melt and fuse during fire. The resin burns up.	Although the mineral fibre Is incombustible the resin Is affected by fire	Self- extinguishing (non-flammable) as per ASTM-D1692. It achieves Class I and Class P as per BS 476
6.	Water Vapour Permeability (per-inch)	2.5	2.4	Very high	Very high	10
7.	Water absorption	Negligible	Negligible	Very high	Very high	Very high
8.	Service temperature	-328 F to + 266F Special grades can withstand temperatures Upto +302°F	-328°F C to 176°F	32.2°F to 450°F	32.2°F to 450°F	320°F to 266°F
9.	Friability	Not friable	Not friable	Friable	Friable	Extremely Friable
10.	Effect of chemicals	Unaffected by dilute acids, alkalines, solvent based adhesives, lubricants, bitumen	Unaffected by dilute acid and alkalines	Glass firbres are unaffected by acids and alkalines	Mineral fibres are affected by dilute acids and resin by alkalies	Unaffected by dilute alkalies and acids
11.	Effect of microbes and vemin	Not attacked by vermin, mould, pests, insects, birds etc.	Gets eaten by rats, ants, birds etc. Also sustains growth of mould	Not attacked by microbes and pests	Not attacked by microbes and pests	Not attacked by microbes and pests

Note : Data is compiled from leaflets and other sources. For correct information, consult Manufacturer.

Table 6.6 : Building Insulation Materials - Roof / Walls / Floor Etc.

Insulation may be categorized by its composition (Material), by its form (Structural or Non-structural), or by its functional mode (Conductive, Radiative, Convective). Non-structural forms include Batts, Blankets, Loose-fill, Spray foam, and Panels. Structural Foams include Insulating Concrete foams, Structured panels, and Straw bales. Sometimes a Thermally Reflective surface called a Radiant Barrier is added to a material to reduce the transfer of heat through radiation as well as conduction. Following is a table of materials, most of which have been used for insulating buildings.

R-Value per inch given in imperial units (Typical values are approximations based on the average of available results)	
Material	**ft2.°F.h/ (BTU.in)**
Vacuum insulated panel	R-30-R-50
Silica aerogel	R-10
Polyurethane rigid panel (CFC/HCFC expanded) initial	R-7-R-8
Polyurethane rigid panel (CFC/HCFC expanded) aged 5-10 years	R-6.25
Polyurethane rigid panel (pentane expanded) initial	R-6.8
Polyurethane rigid panel (pentane expanded) aged 5-10 years	R-5.5
Foil-faced Polyurethane rigid panel (pentane expanded)	
Foil-faced Polyisocyanurate rigid panel (pentane expanded) initial	R-6.8
Foil-faced Polyisocyanurate rigid panel (pentane expanded) aged 5-10 years	R-5.5
Polyisocyanurate spray foam	R4.3-R-8.3
Closed-cell polyurethane spray foam	R-5.5-R-6.5
Phenolic spray foam	R4.8-R-7
Thinsulate clothing insulation	R-5.75
Urea-formaldehyde panels	R-5-R-6
Urea foam	R-5.25
Extruded expanded polystyrene (XPS) high-density	R-5-R-5.4
Polystyrene boards	R-5.00
Phenolic rigid panel	R-4-R-5
Urea-formaldehyde foam	R4-R-4.6
High-density fiberglass batts	R-3.6-R-5
Extruded expanded polystyrene (XPS) low-density	R-3.6-R4.7
Icynene loose-fill (pour fill)	R-4
Molded expanded polystyrene (EPS) high-density	R-4.2
Air-entrained concrete	R-3.90
Home Foam	R-3.9
Fiberglass batts	R-3.1-R4.3
Cotton batts (Blue Jean insulation)	R-3.7
Molded expanded polystyrene (EPS) low-density	R-3.85
Icynene spray	R-3.6
Open-cell polyurethane spray foam	R-3.6
Cardboard	R-3-R4
Rock and slag wool batts	R-3-R-3.85
Cellulose loose-fill	R-3-R-3.8
Cellulose wet-spray	R-3-R-3.8
Rock and slag wool loose-fill	R-2.5-R-3.7
Fiberglass loose-fill	R-2.5-R-3.7
Polyethylene foam	R-3
Cementitious foam	R-2-R-3.9
Perlite loose-fill	R-2.7
Wood panels, such as sheathing	R-2.5
Fiberglass rigid panel	R-2.5
Vermiculite loose-fill	R-2.13-R-2.4
Vermiculite	R-2.13
Straw bale	R-1.45
Papercrete	R-2.6-R-3.2
Softwood (most)	R-1.41
Wood chips and other loose-fill wood products	R-1
Snow	R-1
Hardwood (most)	R-0.71
Brick	R-0.2
Glass[2]	R-0.14
Poured concrete	R-0.08

Table 6.7: Performance Property guide for Insulation Materials

	Calcium Silicate	Flexible Elasto-meric	Mineral Fiber	Cellular Glass	Cellular Polysty-rene	Cellular Polyiso-cyanurate	Cellular Phenolic	Cellular Polyolefin
ASTM Standard	C533	C534	C 547, C533, C 612	C552	C578	C591	C1126	C1427
Type/grade listed	Type I	Type I	Type IV B	Type I	Type XIII	Type IV	Type III	Type I
		Grade I	Category I	Grade I		Grade II	Grade I	Grade I
Max. operating temperature, °F	1200	220	1200	800	165	300	257	200
Min. operating temperature, °F	140	-70	0	-450	-297	-297	-40	-150
Min. Compressive resistance, psi	100 at 5%	NS	NS	60 at failure	20 at 10%	21 at 10%	18	NS
Max. thermal conductivity, Btu-in/h-ft^2, °F								
0 °F mean	NA	0.26	NA	0.27	0.22	0.18	0.13	0.33
25°F	NA	NS	0.23	NS	0.23	NS	NS	NS
75°F	NA	0.28	0.24	0.31	0.26	0.18	0.13	0.35
200°F	0.45	NA	0.30	0.40	NA	0.24	NA	NA
400°F	0.55	NA	0.42	0.58	NA	NA	NA	NA
600°F	0.66	NA	0.63	NA	NA	NA	NA	NA
Maximum water vapor permeability, Petm.in	NS	0.10	NA	0.005	1.5	4.0	0.15	0.05
Maximum liquid water absorption, % volume	NS	0.2	NS	0.5	0.5(24 h)	0.5(24 h)	3.0 TO 8.0	0.2
Maximum water vapor sorption, % weight	NS	NS	5	NS	NS	NS	NS	NS
Maximum surface burning characteristics	0/0	25/50	25/50	5/0	NS	NS	25/50	NS
Note: NA= Not Applicable, NS= Not Stated (i.e., ASTM Standards do not include a value for this property). Properties not stated do not necessarily indicate that material is not appropriate for a given application depending on that property. See previous editions of ASHRAE Handbook-Fundamentals for data on historical insulation materials.								

Preventing Surface Condensation

Condensation occurs when water vapour comes in contact with a surface that has a temperature lower than the dew point of that vapour. To prevent condensation from occurring on the warm side of insulated rooms, pipes, ducts and equipment, insulation should be sufficiently thick to ensure that the insulation surface temperature always exceeds the dew-point temperature, of air surrounding it.

Figure 6.1 illustrates the steady-state heat transfer for which the following relationship can be used to calculate the data in Figure 6.2.

$$q = (tb - tp)/Rs = (tp - tp - to)Ri \qquad (1)$$

since

$$Rs/Ri = (tb - tp)/(tp - to) \qquad (2)$$

where

q = heat flow rate, Btu/h*ft^2

t_b = ambient still air dry-bulb temperature °F

t_p = dew point, °F

R_s = surface thermal resistance, 0.62 °F*ft^2*h/Btu

R_i = insulation thermal resistance, L/k, °F*ft^2*h/Btu

L = thickness, in. (After calculating L, Figure 14 can be used to obtain the actual thickness as needed for pipe insulation)

k = mean thermal conductivity, Btu/h*ft^2 (=F/in)

Equivalent thickness is the thickness of insulation on a flat surface that would be required to give the same rate of heat transmission per unit area of outer surface of insulation, as on a cylinder or pipe.

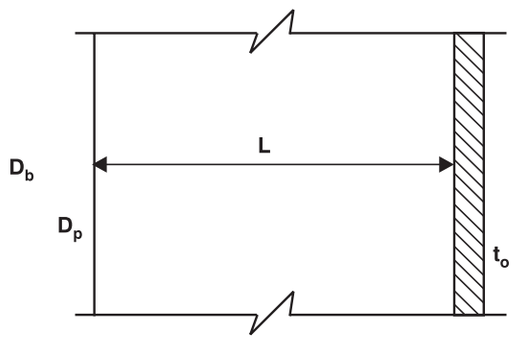


Figure 6.1 : Steady State Heat Transfer

$L = r_s \ln(r_s/r_i)$ (3)

Where

r_s = outer radius of insulation, in consistent units

r_i = inner radius of insulation, in consistent units

The approximate thickness of insulation L required to prevent condensation on flat metallic surfaces can be obtained from Figure 6.2, which gives the approximate thermal resistance needed to prevent condensation. The formula L = Rk can be used to find thickness. In Figure 6.2, t_m is the mean temperature for a specific insulating material, and is the arithmetic average of t_b and t_o:

$$t_m = (t_b + t_0)/2$$

A more accurate determination of the insulation thickness L needed to control condensation can be made with the formulas in Figure 6.1. When pipes are involved, Figure 6.3 can be applied to relate the thickness of insulation, as determined by either of the methods discussed previously, to the actual thickness needed. By entering ***Figure 6.3*** with L as the thickness needed on a flat surface (noted as equivalent thickness) and moving vertically until the curve for the pipe size involved is intersected, the actual thickness needed is found by moving horizontally to the Y axis. When choosing pipe insulation, always use the next greater nominal thickness than the thickness determined.

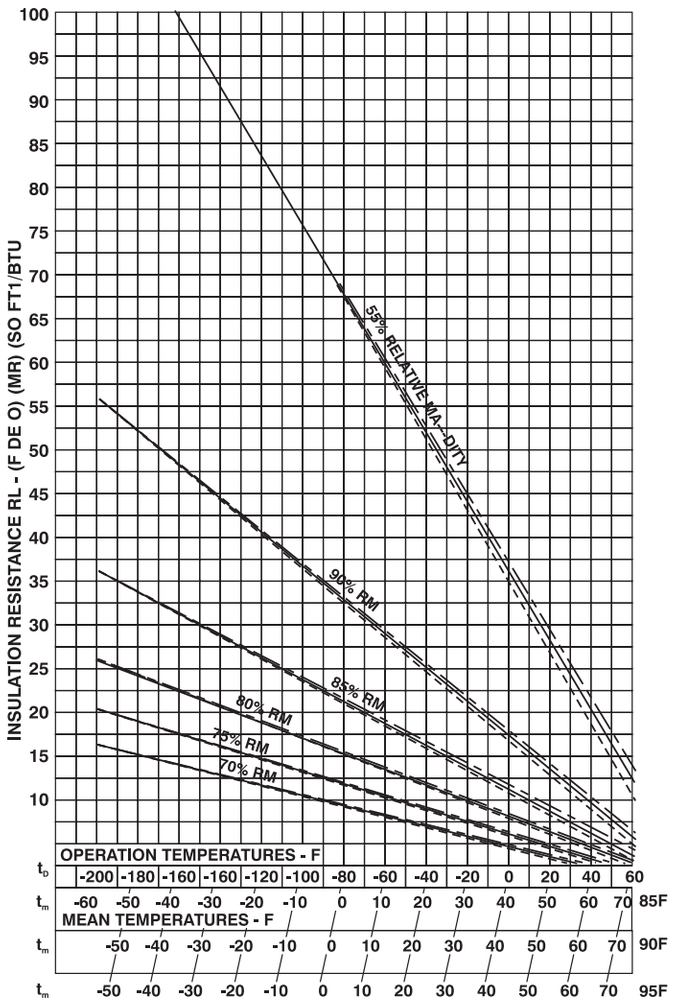


Figure 6.2 : Thermal Resistance of Insulation to prevent surface condensation

Example: A nominal 4-in. pipe operates at 10°F in ambient still-air conditions of 90°F and 90% rh. The mean temperature is 50°F. The insulation specified has a thermal conductivity of 0.28 Btu/11 ‘1 e (°F/in) at the mean temperature, according to manufacturers’ tables.

Solution: Using Figure 6.2, locate the insulation resistance needed to prevent condensation and obtain R = 14.8. Since R= L/k, the thickness required for a flat surface or the equivalent thickness L for any pipe size is:

$$L = Rk = 14.8 \times 0.28 = 4.14 \text{ in.}$$

To find the actual thickness needed on a 4-in, pipe, read the Equivalent Thickness Scale in Figure 6.3 from L of 4.1 in. to pipe size of 4 in. and find the actual thickness of 2.9 in. on the ordinate. Select next higher standard thickness of 3 in.

Heat Loss/gain through ducts

Duct Heat Gains or Losses must be known to calculate Supply Air quantities, Supply Air Temperatures, and Coil loads. To estimate Duct Heat Transfer and entering or leaving Air Temperatures, use equations (4) through (6).

$$Q_l = \frac{UPL}{12}\left[\left(\frac{te+tl}{2}\right)\right] t_a \quad \text{----- (4)}$$

$$te = \frac{tl\,(y+1) - 2ta}{(y-1)} \quad \text{---------- (5)}$$

$$tl = \frac{tl\,(y+1) - 2ta}{(y-1)} \quad \text{---------- (6)}$$

where

y = 2.4 AV^P/UPL for rectangular ducts

y = 0.6 DV^P/UL for round ducts

A = Cross-sectional area of duct, in 2

V = average velocity, fpm

D = diameter of duct, in.

L = duct length, ft

Q_i = heat loss/gain through duct walls, Btu/h

(negative for heat gain)

U = overall heat transfer coefficient of duct wall,

(Btu/(h*ft^2 ,°F)

P = Perimeter of bare or insulated duct, in.

p = density , lbm/ft^3

te = temperature of air entering duct, ° F

tl = temperature of air leaving duct, ° F

ta = temperature of air surrounding duct, ° F

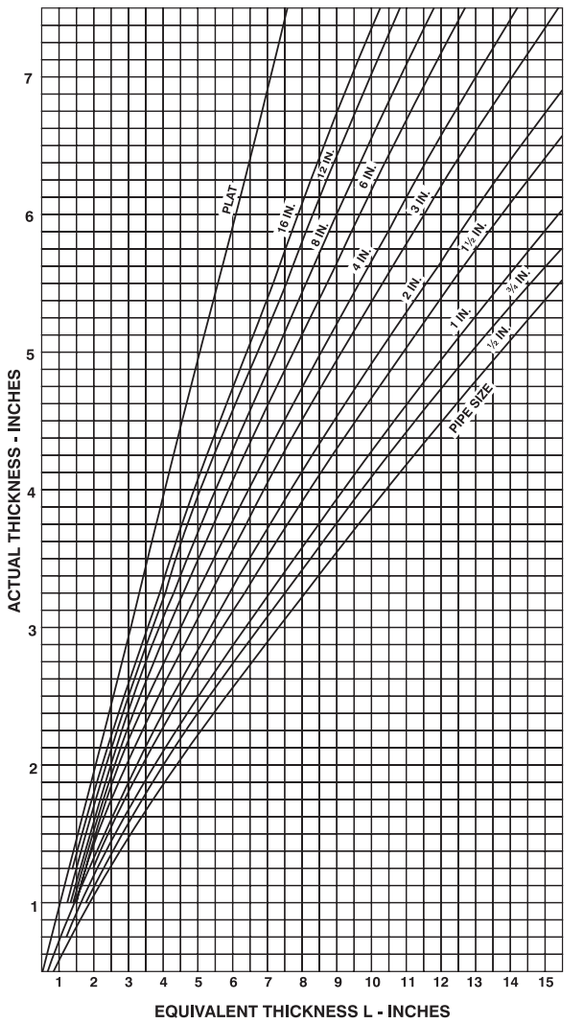


Figure 6.3: Conversion of Equivalent Thickness to Actual Thickness for Pipe Insulation

Example 1. A 65-ft length of 24 in. by 36 in. insulated sheet metal duct, freely suspended, conveys heated air through a space maintained above freezing at 40° F. Based on heat loss calculations for the heated zone, 17,200 cfm of standard air at a supply air temperature of 122° F is required. The duct is connected directly to the heated zone. Determine the air temperature entering the duct and the duct heat loss.

Solution: Calculate duct velocity using the following equation:

$$V = \frac{(144)\ (17{,}200\ \text{cfm})}{(24\ \text{in.})\ (26\ \text{in.})} = 2900\ \text{fpm}$$

Calculate entering air temperature using Equation (5) :

U = 0.73 Btu/ (h*f t^2*F) (U can be calculated)

P= 2 (24 in. + 36 in.) = 120 in

$$Y \quad \frac{(2.4)(2.4\ \text{tn.})(36\ \text{m.})(2900\ /\text{pm})(0.075\ \text{Wm/ft3}}{\left(0.73\ \frac{\text{Btu}}{\text{h}}\ \text{ft2*F}\right)\ (120\ \text{in.})(65/\text{t})} \quad 79.2$$

$$Te = \frac{122°F\ (79.2+1) - (2X40°F)}{(79.2-1)} = 124.1°F$$

Calculate duct heat loss using Equation (4):

$$QI = \frac{(0.73\ \frac{Btu}{h*ft2*°F})\ (120in)\ (65\ ft)}{12}$$

$$x\ \{\ \frac{124.1°F + 122°F}{2} - 40°F\ \}\ = 39{,}200\ Btu/h.$$

Table 6.8 : Maximum difference between Supply Air temperature and Room Dewpoint without condensing Moisture on Ducts (F)

AIR CONDITIONS SURROUNDING DUCT	AIR VELOCITY IN STRAIGHT RUN OF DUCT (FPM)											
	Painted	Bright Metal	Painted	Bright Metal	Painted	Bright Metal	Painted	Bright Metal	Painted	Bright Metal	Painted	Bright Metal
DB (F) RH (%)	480		800		1200		1600		2000		3000	
45	20	15	15	9	11	8	8	5	7	4	5	3
50	18	13	13	8	10	7	7	5	6	4	4	3
55	15	11	11	7	8	6	6	4	5	3	4	2
74-100	13	10	10	6	7	5	5	3	4	3	3	2
60												
70	9	7	7	4	5	4	4	2	3	2	2	2
80	6	4	4	3	3	2	2	2	2	1	2	1
85	4	3	3	2	2	2	2	1	2	1	1	1
Value of f²/U-1	..90	.66	.66	.42	.49	.31	.37	.24	.31	.20	.23	.15

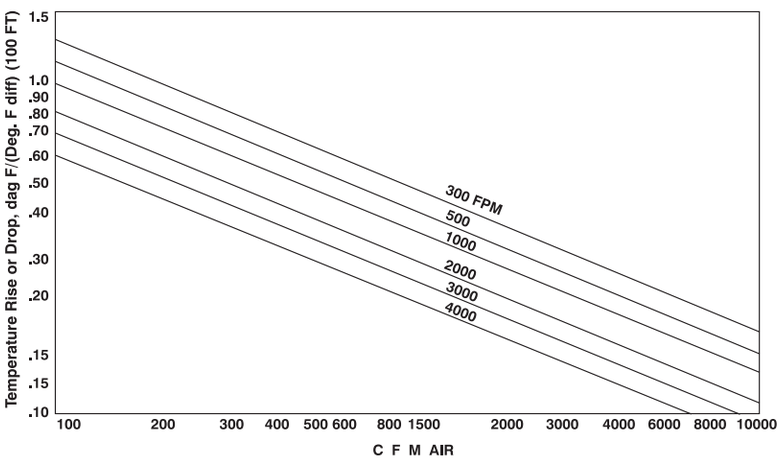


Figure 6.4: Duct Heat Gain or Loss

EQUATION:

Where: tdp = duct surface temp, assumed equal to room dewpolnt

NOTES:

1. Based on bare rectangular duct with a 2:1 aspect ratio.
2. To avoid heat gain and reduced efficiency of cooling systems, condensation of water on surfaces, and potential corrosion problems, pipes in cooling systems should always be insulated.
3. As a rule of thumb, the insulation thickness of Chilled Water, Refrigerant and Brine Systems should be no less than indicated as follows :

Table 6.9 : Insulation Thickness Required to Prevent Surface Condensation

Relative Humidity, %	Thickness, in.
20	-
30	0.1
40	0.2
50	0.3
60	0.5
70	0.7
80	1.3
90	2.9
95	6.0
Note: Calculated using Equation (14), assuming surface conductance of 1.2 Btu/h-ft2 °F and insulation with thermal conductivity of 0.30 Btu-in/h-ft2 °F. Different assumed values yield different results.	

Table 6.10 : Insulation thickness of Cooling Systems

System	Operating Temperature	Pipe Size (inches)				
		< 1”	1 1/4" -2"	2 1/2" -4"	5" -6"	>8"
	(°F)	insulation Thickness (Inches)				
Chilled Water	40-55	0.5	0.75	1.0	1.0	1.0
Refrigerant	<40	1.0	1.5	1.5	1.5	1.5
Brine	<40	1.0	1.5	1.5	1.5	1.5

The insulation of a cooling system should be made of micro-cellular cross-linked polyethylene foam with low water vapor diffusion.

Table 6.11 : Recommended Insulation Thickness of Phenolic Foam, in inches

AMBIENT AIR TEMPERATURE : 104°F
RELATIVE HUMIDITY : 85%
WEATHER BARRIER : ALUMINIUM CLADDING

OPERATING TEMP. RANGE DEG. F.	PIPE DIAMETERS (N.b.) VALVES & FITTINGS - inch															Vessels, columns and Flat Surfaces
	1/2	3/4	1”	1 1/2”	2”	3”	4”	6”	8”	10”	2”	14”	16”	18”	20”	
39.2° F and above	0.984	0.984	1.186	1.186	1.577	1.577	1.577	1.577	1.968	1.968	1.968	2.359	2.359	2.359	2.359	2.359
39.2F to 26.6F	1.577	1.577	1.577	1.577	1.968	1.968	1.968	1.968	2.359	2.359	2.359	2.359	2.952	2.952	2.952	2.952
-2.2F to -25.6F	1.577	1.577	1.577	1.968	1.968	2.561	2.952	2.952	2.952	2.952	2.952	2.952	3.545	3.545	3.545	3.545
24.8F to -0.4F	1.968	1.968	1.968	2.561	2.561	2.75	2.952	2.952	3.545	3.545	3.545	3.545	3.545	3.936	3.936	3.936
27 .2F to -50.8 F	1.968	2.561	2.952	2.952	3.141	3.141	3.545	3.545	3.936	3.936	3.936	4.327	4.327	4.529	4.529	4.529
52.6 F to -76 F	2.561	2.952	3.565	3.545	3.545	3.545	3.936	3.936	4.327	4.327	4.327	4.718	4.718	5.109	5.109	4.718
-77.8 to -101.4F	2.952	2.952	3.545	3.545	3.545	3.936	4.321	4.718	4.718	4.718	4.318	5.109	5.109	5.50	5.50	5.702
-103Fto-124.6F	2.952	2.952	3.545	3.545	3.565	3.936	4.321	5.109	5.109	4.109	5.109	5.50	5.891	5.891	5.891	6.093
-126.4 to -148F	3.545	3.545	3.936	3.936	3.936	4.327	4.718	5.109	5.107	5.50	5.109	5.891	6.282	6.282	6.282	6.484
-149.8Fto-175F	3.545	3.545	3.936	4.138	4.327	4.529	5.109	5.109	5.90	5.50	5.89	6.282	6.282	6.282	6.282	7.090
-176.4 to -200.8F	3.936	3.936	4.327	4.327	4.718	4.718	5.109	5.56	5.5	5.50	5.891	6.282	6.484	6.484	6.484	1.090
-202F to -225.4F	3.936	3.936	4.327	5.529	4.718	5.109	5.311	5.5	5.891	5.891	6.282	6.484	6.484	6.484	6.484	7.487
-227 .2F to -250.6F	3.936	4.327	4.327	4.718	4.718	5.109	5.5	5.891	5.891	5.891	6.282	6.484	6.875	6.484	6.875	7.872
-252.4F to -274F	4.327	4.718	492	5.109	5.5	5.5	5.5	6.282	6.282	6.282	6.875	6.875	7.481	6.875	7.4814	8.265
-275.8F to -70.2F	4.718	4.920	5.109	5.50	5.891	5.89	6.282	6.573	6.673	7.09	7.09	7.872	7.872	7.872	8.263	8.654

Manufacturer’s Data - converted from mm
Based on average conditions. Should be modified to suit individual technical requirements.

Table 6.12 : Recommended Thickness of Expanded polystyrene (in mm) for pipe insulation at various operating temperatures

TEMP°F	1/2"	3/4"	1	1 1/4"	1 1/2"	2"	2 1/2"	3"	4"	5"	6"
68	.984	.984	.984	.984	.984	.984	1.577	1.577	1.577	1.968	r.968
50	.984	.984	1.577	1.577	1.577	1.577	1.577	1.577	1.968	1.968	1.968
32	1.577	1.572	1.577	1.968	1.968	1.968	1.968	1.968	1.968	1.968	2.952
14	1.968	1.572	1.968	1.968	2.561	2.581	2.952	2.952	2.952	2.952	2.952
-4	1.968	1.968	2.561	2.952	2.952	2.952	2.952	2.952	3.91	3.91	3.91
-22	2.56	1.968	2.952	2.952	3.91	3.91	3.91	3.91	3.91	3.91	4.894
-40	2.95	2.952	3.91	3.91	3.91	3.91	3.91	3.91	4.894	4.894	4.894
-58	3.91	3.91	3.91	3.91	3.91	3.91	4.894	4.894	4.894	5.702	5.878
-76	3.91	3.91	4.894	4.894	4.894	4.894	4.894	4.894	5.878	5.878	5.878
-94	4.894	4.894	4.894	4.894	4.894	5.878	5.878	5.878	5.878	6.862	6.862

Manufacturer's Data - Converted from mm
Based on average conditions. Should be modified to suit individual technical requirements.

Table 6.13: Recommended Thickness of High Density Polyethylene (in inches) for pipe insulation at various operating temperatures

TEMP°C	NOMINAL PIPE DIA. IN INCHES					
	1/2"	1"	1 1/2"	2"	3"	4"
68°	0.32	0.391	0.391	0.391	0.391	0.391
50°	0.391	0.472	0.593	0.593	0.593	0.593
32°	0.593	0.593	0.782	0.782	0.782	0.782
14°	0.782	0.782	0.984	0.984	0.984	1.984
-4°	0.984	0.984	1.18	1.18	1.18	1.18
-22°	0.984	1.18	1.18	1.18	1.378	1.378
-40°	1.18	1.18	1.378	1.378	1.577	1.577
-58°	1.18	1.378	1.577	1.577	1.577	1.968

Manufacturer's Data. Converted from mm
Based on average conditions. Should be modified to suit individual technical requirements.

Table 6.14: Recommended Thickness of Polyurethane Foam (in inches) for pipe insulation at various operating temperatures

Bore of pipe (")	50°F to 32°F	32°F to 14°F	14°F to -4°F	-4°F to 22°F
1/2	0.984	1.18	1.968	1.968
3/4	0.984	1.18	1.968	1.968
1	0.984	1.18	1.968	1.968
1 1/2	0.984	1.18	1.968	2.952
2	1.18	1.18	1.968	2.952
2 1/2	1.18	1.18	1.968	2.952
3	1.18	1.968	1.968	2.952
4	1.18	1.968	1.968	2.952
5	1.968	1.968	1.968	2.952
6	1.968	1.968	1.968	2.952
Flat Surface / Equipments	1.18	1.968	2.952	3.91

Manufacturer's data. Converted from mm.
Based on average conditions. Should be modified to suit individual technical requirements.

Table 6.15 : Thickness Recommendation to Control Condensation in Pipe insulation of Cooling Lines - Nitrile Foam Rubber

DESIGN CONDITIONS	PIPE SIZE	PIPELINE TEMPERATURE			
		58°F	44.6°F	36.5°F	0°F
MILD CONDITION (80°F) 50% RH	0.394 in. ID to 3 in IPS Above 3 in. IPS to 5 in IPS Above 5 in. IPS to 10 in. IPS	0.355 0.355 0.515	0.355 0.515 0.515	0.355 0.515 0.515	0.75 0.984 --------
NORMAL CONDITION (85°F) 70% RH	0.394 in. ID to 3 in IPS Above 3 in. IPS to 5 in IPS Above 5 in. IPS to 10 in. IPS	0.355 0.575 0.515	0.515 0.515 0.515	0.515 0.515 0.750	0.984 1.22 1.022
SEVERE CONDITION (90°F) 80% RH	0.394 in. ID to 3 in IPS Above 3 in. IPS to 5 in IPS Above 5 in. IPS to 10 in. IPS	0.575 0.515 0.515	0.75 0.984 0.984	0.75 0.984 1.22	1.499 1.499 1.968
EXTREMELY SEVERE CONDITION (90°F) 85% RH	0.394 in. ID to 3 in IPS Above 3 in. IPS to 5 in IPS Above 5 in. IPS to 10 in. IPS	0.515 0.75 --------	0.984 1.22 1.22	0.984 1.22 1.499	1.499 1.968 1.968

Table 6.16 : Thickness Recommendation for insulation of Ducting, Tanks and Equipment of Cooling Systems - Nitrile Foam Rubber

DESIGN CONDITIONS	METAL SURFACE TEMPERATURE				
	59°F	53.6°F	44.6°F	36.5°F	5°F
80°F 50% RH	0.355	0.355	0.515	0.75	.984
85°F 70% RH	0.515	0.515	0.75	0.984	1.22
90°F 80% RH	0.515	0.75	0.984	1.22	1.968
90°F 85% RH	0.984	0.984	1.22	1.499	1.968

AVERAGE PHYSICAL PROPERTIES	RATING	AVERAGE PHYSICAL PROPERTIES	RATING
Density (ASTMD1 667)	76.6 kg/m^3	Thermal Stability (% shrinkage) 7 days - 200°F	4.5
Thermal Conductivity (ASTM C518) at 10°C mean temp.	0.292 Btu in / ft^2 hr°F	7 days - 220°F Spread of Flame (UL94)	5.5
Temperature Limits °C	-40°F to +221°F	Flexibility	Self Extinguishing
Water Absorption (%W/W) (ASTM C272)	4.37	Weather & Ultraviolet Resistance	Excellent
Water Vapour Permeability (ASTM E96)	1.63 9.33 x10^{-8}	Chemical Resistance	Good
Perm - In. Max g/Pa.sm2		Odour	Negligible
Ozone Resistance	Excellent	Mildew Resistance	No Fungal growth

Manufacturer's Data

Table 6.17 : Minimum Duct Insulation R-Value[a] Cooling and Heating Only Supply Ducts and Return Ducts

Climate Zone	Duct Location						
	Exterior	Ventilated attic	Unvented attic above insulated ceiling	Unvented Attic with roof insulation[a]	Unconditioned Space[b]	Indirectly Conditioned Space[c]	Buried
Heating-Only Ducts							
1.2	None	None	None	None	None	None	None
3	R-3.5	None	None	None	None	None	None
4	R-3.5	None	None	None	None	None	None
5	R-6	R-3.5	None	None	None	None	R-3.5
6	R-6	R-6	R-3.5	None	None	None	R-3.5
7	R-8	R-6	R-6	None	R-3.5	None	R-3.5
8	R-8	R-8	R-6	None	R-6	None	R-6
Cooling-Only Ducts							
1	R-6	R-6	R-8	R-3.5	R-3.5	None	R-3.5
2	R-6	R-6	R-6	R-3.5	R-3.5	None	R-3.5
3	R-6	R-6	R-6	R-3.5	R-1.9	None	None
4	R-3.5	R-3.5	R-6	R-1.9	R-1.9	None	None
5,6	R-3.5	R-1.9	R-1.9	R-1.9	R-1.9	None	None
7,8	R-1.9	R-1.9	R-1.9	R-1.9	R-1.9	None	None
Return Ducts							
1 to 8	R-3.5	R-3.5	R-3.5	None	None	None	None

[a]Insulation R-values, measured in (h-ft^2 °F)/ Btu, are for the Insulation as installed and do not include Film Resistance. The required minimum thickness does consider Water Vapor transmission and possible Surface Condensation.
[b]Includes crawlspaces, both Ventilated and Non-ventilated.
[c]Includes Return Air Plenums with or without exposed roofs above.

Table 6.18: Minimum Pipe Insulation Thickness[a]

Fluid Design Operating Temp Range (°F)	Insulation Conductivity		Nominal Pipe or tube Size (in.)				
	Conductivity Btu-in(h-ft^2-^{0}f)	Mean Rating Temp °F	<1	1 to < 1-1/2	1-1/2 to <4	4 to < 8	≥8
Heating Systems (Steam, Steam Condensate, and Hot Water)[a,b]							
> 350	0.32 - 0.34	250	2.5	3.0	3.0	4.0	4.0
251 - 350	0.29-0.32	200	1.5	2.5	3.0	3.0	3.0
201-250	0.27-0.30	150	1.5	1.5	2.0	2.0	2.0
141-200	0.25-0.29	125	1.0	1.0	1.0	1.5	1.5
105-140	0.22-0.28	100	0.5	0.5	1.0	1.0	1.0
Domestic and Service Hot-Water Systems							
105+	0.22-0.28	100	0.5	0.5	1.0	1.0	1.0
Cooling Systems (Chilled Water, Brine, and Refrigerant)[d]							
40-60	0.22-0.28	100	0.5	0.5	1.0	1.0	1.0
<40	0.22-0.28	100	0.5	1.0	1.0	1.0	1.5

[a] For insulation outside the stated conductivity range, the minimum thickness (T) shall be determined as follows: T=r{(1+t/r) K/k-1} where T-minimum insulation thickness (in), r=actual outside radius of pipe (in.) t=insulation thickness listed in this table for applicable fluid temperature and pipe size, K=conductivity of alternate material at mean rating temperature indicated for the applicable fluid temperature (Btu-in/h.ft20F) and k=the upper value of the conductivity range listed in this table for the applicable fluid temperature.
[b] These thicknesses are based on energy efficiency considerations only. Additional insulation is sometimes required relative to safety issues / surface temperature.
[c] Piping insulation is not required between the control valve and coil on run-outs when the control valve is located within 4 ft of the coil and the pipe size is 1 in. or less.
[d] These thicknesses are based on energy efficiency considerations only. Issues such as water vapor permeability or surface condensation sometimes require vapor re-traders or additional insulation.

Table 6.19 : Minimum Duct Insulation R-Value,[a] Combined Heating and Cooling Supply Ducts and Return Ducts

Climate Zone	Duct Location						
	Exterior	Ventilated Attic	Unvented Attic above insulated Ceiling	Unvented Attic with Roof insulation	Unconditioned Space[b]	Indirectly Conditioned Space[c]	Buried
Supply Ducts							
1	R-6	R-6	R-8	R-3.5	R-3.5	None	R-3.5
2	R-6	R-6	R-6	R-3.5	R-3.5	None	R-3.5
3	R-6	R-6	R-6	R-3.5	R-3.5	None	R-3.5
4	R-6	R-6	R-6	R-3.5	R-3.5	None	R-3.5
5	R-6	R-6	R-6	R-1.9	R-3.5	None	R-3.5
6	R-8	R-6	R-6	R-1.9	R-3.5	None	R-3.5
7	R-8	R-6	R-6	R-1.9	R-3.5	None	R-3.5
8	R-8	R-8	R-8	R-1.9	R-6	None	R-6
Return Ducts							
1to8	R-3.5	R-3.5	R-3.5	None	None	None	None

[a] Insulation R-Values, measured in (h-ft^2,°F)/Btu, are for the insulation as installed and do not include film resistance. The required minimum thickness does consider water vapor transmission and possible surface condensation.
[b] Includes crawlspaces, both ventilated and non-ventilated.
[c] Includes return air plenums with or without exposed roofs above.

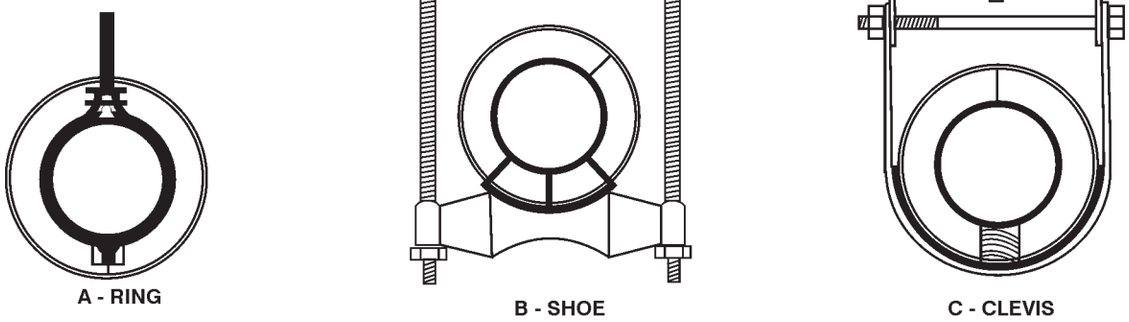


Figure 6.5 : Insulating Pipe Hangers

Table 6.20 : Minimum Saddle spacing for Use with Fibrous Glass Pipe Insulation

Pipe Size NPS	Insulation Thickness, in.	Minimum Saddle Length, in.								
		Hanger Spacing, ft								
		4	5	6	7	8	9	10	11	12
1	0.5	5	5	6	8					
	1	3	3	5	5					
	1.5	3	3	5	5					
	2	3	3	3	3					
	3	3	3	3	3					
2	0.5	6	8	8	11	11	12	14		
	1	5	5	6	8	9	11	11		
	1.5	5	5	6	8	8	9	9		
	2	5	5	5	6	6	8	8		
	3	5	5	5	6	6	6	8		
3	0.5			12	15	17	20	21	24	26
	1			11	12	15	17	18	20	23
	1.5			9	11	12	14	15	17	18
	2			9	9	11	12	14	14	15
	3			9	9	11	12	14	14	15

[a] For pipe sizes above 3 in. NPS, use high-density inserts to support the pipe.

Table 6.21: Minimum Saddle spacing for Use with 2 lb/ft³ Polyisocyanurate Foam Insulation (0.5 to 3 in. thick)

Pipe Size NPS	Minimum Saddle Length, in.								
	Hanger Spacing, ft								
	4	5	6	7	8	9	10	11	12
3	4	4	4	4	4	4	4	4	6
4	4	4	4	6	6	6	8	8	8
6	6	6	6	6	8	8	8	8	8
8	8	8	8	8	8	8	8	8	12
10	8	8	8	12	12	12	12	12	12
12	8	8	12	12	12	12	12	12	12
16	12	12	18	18	18	18	18	18	18

* 22 gauge hung; 20 gauge setting

Table 6.22 : Emittance Data of Commonly Used Materials

Material	Emittance E at - 80°F
All-service jacket (ASJ)	0.9
Aluminum Paint	0.5
Aluminum	
Anodized	0.8
Embossed	.0.1
Oxidized	0.1 to 0.2
Polished	0.04
Aluminum-Zinc coated steel	0.06
Canvas	0.7 to 0.9
Colored mastic	0.9
Copper	
Highly polished	0.03
Oxidized	0.8
Elastomeric or Polyisobytylene	0.9
Galvanized steel	
Dipped or dull	0.3
New, bright	0.1
Iron or steel	0.8
Painted metal	0.8
Plastic pipe of jacket thickness (PVC, PVDF, PVDC, or PET)	0.9
Roofing felt and black mastic	0.9
Rubber	0.9
Silicon-impregnated fiberglass fabric	0.9
Stainless steel, new, cleaned	0.2

Note: Calculated using Equation (14), assuming surface conductance of 1 .2 Btu/h-ft2 °F and insulation with thermal conductivity of 0.30 Btu-in/h-ft² °F. Different assumed values yield different results.

Controlling surface temperatures

$(Q_{ims} - Q_{surf})$

Table 6.23 : Inner and Outer Diameters of Standard Tubing Insulation

Tube Size, in.	Tube OD in.	insulation ID, in.	Insulation OD, in.								
			Insulation Nominal Thickness, in.								
			1	1.5	2	2.5	3	3.5	4	4.5	5
3/8	0.500	0.52	2.38	3.50	4.50	5.56	6.62	-	-	-	-
1/2	0.625	0.64	2.88	3.50	4.50	5,56	6.62	-	-	-	-
3/4	0.875	0.89	2.88	4.00	5.00	6.62	7.62	8.62	9.62	10.75	11.75
1	1.125	1.14	2.88	4.00	5.00	6.62	7.62	8.62	9.62	10.75	11.75
1 1/4	1.375	1.39	3.50	4.50	5.56	6.62	7.62	8.62	9.62	10.75	11.75
1 1/2	1.625	1.64	3.50	4.50	5.56	6.62	7.62	8.62	9.62	10.75	11.75
2	2.125	2.16	4.00	5.00	6.62	7.62	8.62	9.62	10.75	11.75	12.75
21/2	2.625	2.66	4.50	5.56	6.62	7.62	8.62	9.62	10.75	11.75	12.75
3	3.125	3.16	5.00	6.62	7.62	8.62	9.62	10.75	11.75	12.75	14.00
31/2	3.625	3.66	5.56	6.62	7.62	8.62	9.62	10.75	11.75	12.75	14.00
4	4.125	4.16	6.62	7.62	8.62	9.62	10.75	11.75	12.75	14.00	15.00
5	5.125	5.16	7.62	8.62	9.62	10.75	11.75	12.75	14.00	15.00	16.00
6	6.125	6.20	8.62	9.62	10.75	11.75	12.75	14.00	15.00	16.00	17.00

Table 6.24 : Inner and Outer Diameters of Standard Pipe Insulation

Pipe Size NPS	Pipe OD in.	insulation ID, in.	Insulation OD, in.								
			Insulation Nominal Thickness, in.								
			1	1.5	2	2.5	3	3.5	4	4.5	5
1/2	0.84	0.86	2.88	4.00	5.00	6.62	7.62	8.62	9.62	10.75	11.75
3/4	1.05	1.07	2.88	4.00	5.00	6.62	7.62	8.62	9.62	10.75	11.75
1	1.315	1.33	3.50	4.50	5.56	6.62	7.62	8.62	9.62	10.75	11.75
1 1/4	1.660	1.68	3.50	5.00	5.56	6.62	7.62	8.62	9.62	10.75	11.75
1 1/2	1.900	1.92	4.00	5.00	6.62	7.62	8.62	9.62	10.75	11.75	12.75
2	2.375	2.41	4.50	5.56	6.62	7.62	8.62	9.62	10.75	11.75	12.75
21/2	2.875	2.91	5.00	6.62	7.62	8.62	9.62	10.75	11.75	12.75	14.00
3	3.500	3.53	5.66	6.62	7.62	8.62	9.62	10.75	11.75	12.75	14.00
31/2	4.000	4.03	6.62	7.62	8.62	9.62	10.75	11.75	12.75	12.75	14.00
4	4.500	4.53	6.62	7.62	8.62	9.62	10.75	11.75	12.75	14.00	15.00
41/2	5.000	5.03	7.62	8.62	9.62	10.75	11.75	12.75	14.00	14.00	15.00
5	5.563	5.64	7.62	8.62	9.62	10.75	11.75	12.75	14.00	15.00	16.00
6	6.625	6.70	8.62	9.62	10.75	11.75	12.75	14.00	15.00	16.00	17.00
7	7.625	7.70	-	10.75	11.75	12.75	14.00	15.00	16.00	17.00	18.00
8	8.625	8.70	-	11.75	12.75	14.00	12.00	16.00	17.00	18.00	19.00
9	9.625	9.70	-	2.75	14.00	15.00	16.00	17.00	18.00	19.00	20.00
10	10.75	10.83	-	4.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00
11	11.75	11.83	-	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00
12	12.75	12.84	-	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00
14	14.00	14.09	-	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00

Table 6.25 : Inner and Outer Diameters of Standard Flexible Closed-Cell Pipe Insulation

Pipe Size, NPS	Pipe OD in.	Insulation ID, in.	Insulation OD, in.		
			Insulation Nominal Thickness, in.		
			0.5	0.75	1
1/2	0.84	0.97	1.87	2.47	2.97
3/4	1.05	1.13	2.03	2.63	3.13
1	1.315	1.44	2.44	2.94	3.44
1 1/4	1.660	1.78	2.78	3.38	3.78
1 1/2	1.900	2.03	3.03	3.63	4.03
2	2.375	2.50	3.50	4.10	4.50
21/2	2.875	3.00	4.00	4.60	5.00
3	3.500	3.70	4.66	5.26	5.76
31/2	4.000	4.20	5.30	5.90	6.40
4	4.500	4.70	5.88	6.40	6.90
5	5.563	5.76	6.86	7.46	7.96
6	6.625	6.83	7.93	8.53	9.03
8	8.625	8.82	9.92	10.52	-

Table 6.26 : Inner and Outer Diameters of Standard Flexible Closed-Cell Tubing Insulation

Tube Nominal Size, in.	Tube OD in.	Insulation ID, in.	Insulation OD, in.		
			Insulation Nominal Thickness, in.		
			0.5	0.75	1
3/8	0.500	0.600	1.500	1.950	-
1/2	0.625	0.750	1.650	2.150	2.750
3/4	0.875	1.000	1.950	2.500	3.000
1	1.125	1.250	2.220	2.850	3.250
1 1/4	1.375	1.500	2.500	3.100	3.500
1 1/2	1.625	1.750	2.750	3.350	3.750
2	2.125	2.250	3.250	3.850	4.250
21/2	2.625	2.750	3.750	4.350	4.750
3	3.125	3.250	4.250	4.850	5.250
31/2	3.625	3.750	4.850	5.450	5.950
4	4.125	4.250	5.350	5.950	6.450

SECTION - 7

NOISE AND VIBRATION

Source : ASHRAE HANDBOOK

Wavelength and Frequency

The Wavelength of Sound in Air is given by,

$$\lambda = \frac{c_a}{f} \qquad \text{Eq. 1}$$

Where

λ is the wavelength in feet (M)

c_a is the speed of sound, which is 1120 feet per second or

(341 m/s) at sea level.

f is the frequency in Hz.

Decibels

The very large range in Sound Pressure make a logarithmic scale more convenient. Decibels (dB) are always referenced to base signal. Knowing the base reference is critical because the term “decibels” in acoustics is used for Sound Pressure and Sound Power. In the case of Sound Pressure, the reference is 0.00002 Pascal, which is the threshold of hearing.

$Lp=20Log(P/0.00002)$ Eq. 2

Where

Lp is the sound pressure in Decibels (dB)

P is the sound pressure in Pascal

For sound power the reference is 10^{-12} Watts

$Lw=10\ Log\ (W/10^{-12})$ Eq. 3

Where

Lp is the sound power in Decibels (dB)

W is the sound power in Watts

Decibel Addition and Subtraction

Since Decibels are logarithmic, they cannot simply be added. For instance, 40 dB + 40 dB is not 80 dB, it is 43 dB. Decibels can be added as follows:

$Ls=10Log(10^{L1/10}+10^{L2/10}+10^{L3/10}+.....)$ Eq. 4

Add the following values together;

$L_1 = 80$ dB

$L_2 = 82$ dB

$L_3 = 84$ dB

$L_4 = 93$ dB

$L_5 = 72$ dB

$L_{total} = 10\ Log\ (10^{80/10} + 10^{82/10} + 10^{84/10} + 10^{93/10}+10^{72/10})$

$= 94$ dB

Table 7.1 : Decibel Addition Chart

When two Decibel values differ by	Add the following number to the higher number
0 or 1 dB	3 dB
2 or 3 dB	2 dB
4 to 9 dB	1 dB
10 dB or more	0 dB

Decibel subtraction is accomplished as follows:
$Ls = 10 \text{ Log } (10^{L1/10} - 10^{L2/10} - 10^{L3/10} .....)$

Table 7.2 : Octave Band properties

Center Frequency	16	31.5	63	125	250	500	1000	4000	8000
Max Freq. (Hz)	23	44	88	88	175	350	700	2800	5600
Min. Freq (Hz)	11	22	44	175	350	700	1400	5600	11200
Wavelength (ft)	70	36	18	8.96	4.48	2.24	1.	0.28	0.14

NOISE CRITERIA (NC)

Noise Criteria or NC curves are the most common standard for indoor spaces. They were developed to take into account human response to Sound Pressure Levels in different Octave Bands. Since humans are less sensitive to Sound Pressure in the lower bands, a higher Sound Pressure Level was deemed acceptable.

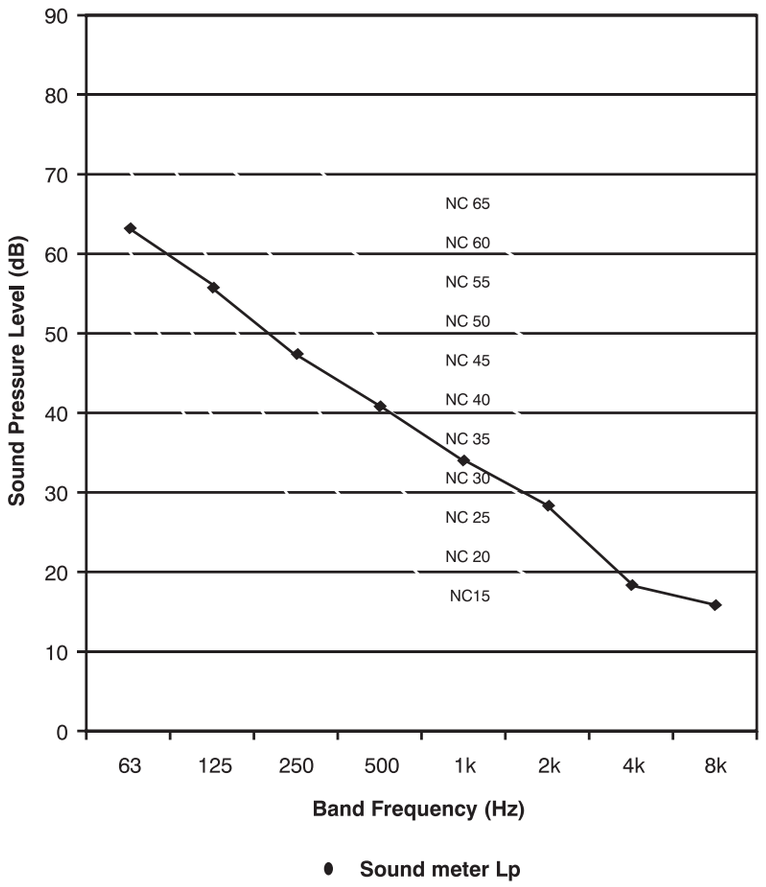


Figure 7.1 : NC Curves

Table 7.3 : Sound Pressure Levels for Each NC Level

NC LEVELS	CENTER FREQUENCY							
	63	125	250	500	1000	2000	4000	8000
15	47	36	29	22	17	14	12	11
20	51	40	33	26	22	19	17	16
25	54	44	37	31	27	24	22	21
30	57	48	41	35	31	29	28	27
35	60	52	45	40	36	34	33	32
40	64	56	50	45	41	39	38	37
45	67	60	54	49	46	44	43	42
50	71	64	58	54	51	49	48	47
55	74	67	62	58	56	54	53	52
60	77	71	67	63	61	59	58	57
65	80	75	71	68	66	64	63	62

Room Criterion (RC)

Room Criterion or RC curves are currently the favored method for determining sound levels by ASHRAE. The RC system was developed to overcome the shortcomings of the NC system. They account for spectrum shape as well sound level. The RC system also uses the 16.5 and 31 Hz bands, which allows the criteria to account for acoustically produced vibration in light building construction. However, the RC calculations should only be performed when valid data exists. If the available values for 16.5 and 31 HZ date are not available, it should not be extrapolated from available values for RC calculations.

RC curves are based on 16 Hz through 4000 Hz Octave bands. The RC value is the a average of the 500, 1000 and 2000 HZ bands. The slope of each line is -5 dB per octave band as shown in Fig.7.2-RC curves. In addition to the numerical value, RC criteria also includes one or more of the above data to denote specifics about the spectral shape of sound. The letter R denotes Rumble. This occurs whenever any specific RC value is more than 5 dB greater than the standard curve values in the 500 Hz and below octave bands.

The Letter H indicates Hiss. This occurs whenever any specific RC value is more than 3 dB greater than the standard curve values above the 500 Hz Octave band, if the specific dB levels are between the dead bands, then the letter N is used to denote neutral. This sound will not have any identity with frequency and will sound bland.

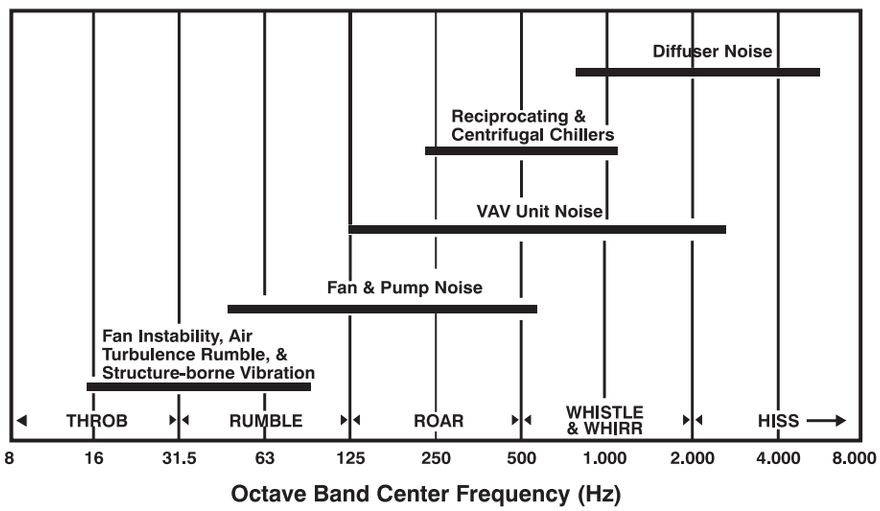


Figure 7.2 : RC Curves

Table 7.4 : Sound Pressure Levels For NR Levels

	31	63	125	250	500	1000	2000	4000	8000
NR 0	55	36	22	12	5	0	-4	-6	-8
NR 10	62	43	31	21	15	10	7	4	2
NR 20	69	51	39	31	24	20	17	14	13
NR 30	76	59	48	40	34	30	27	25	23
NR 40	83	67	57	49	44	40	37	35	33
NR 50	89	75	66	59	54	50	47	45	44
NR 60	96	83	74	68	63	60	57	55	54
NR 70	103	91	83	77	73	70	68	66	64
NR 80	110	99	92	86	83	80	78	76	74
NR 90	117	107	100	96	93	90	88	86	85
NR 100	124	115	109	105	102	100	98	96	95
NR 110	130	122	118	114	112	110	108	107	105
NR 120	137	130	126	124	122	120	118	117	116
NR 130	144	138	135	133	131	130	128	127	126

A-WEIGHTED SOUND PRESSURE (dBA)

A-weighted Sound Pressure is “corrected” to more closely resemble the hearing characteristics of the human ear. The human ear approximates the A-Weighted curve in the 20 to 30 dB range. At these low sound levels, the ear has relatively poor sensitivity to low frequency sound. Table 7.5 shows the adjustments for A-weighted sound with very large adjustments in the lower frequency bands. There is also Band C-Weighted Sound data, which is meant for louder sound levels. These sound levels are not as common as A-weighted values.

A-weighted sound criteria is most commonly used in outdoor sound evaluations. It is often used in City Building Codes when referencing the maximum acceptable Sound Pressure Levels at the property line. It is popular because it is a single number that most Sound Meters can measure and indicate.

Table 7.5 : A-Weighted Octave Band Adjustments

Band	63	125	250	500	1000	2000	4000	8000
Adjustment	-26	-16	-9	-3	0	1	1	-1

Table 7.6 : Comparison of Sound Rating Methods

Method	Overview	Considers Speech Interference	Evaluates Sound Quality	Components Currently Rated by Method
NC	Can rate components. No quality assessment. Does not evaluate low frequency rumble.	Yes	No	Air Terminals Diffusers
RC	Used to evaluate systems. Should not be used to evaluate components. Can be used to evaluate sound quality. Provides some diagnostic capability.	Yes	Yes	
NR	Can rate components. No quality assessment. Does not evaluate low frequency rumble.	Yes	No	
dBA	Can be determined using sound level meter. No quality assessment. Frequently used for outdoor noise ordinances.	Yes	No	Cooling Towers Water Chillers Condensing Units

Table 7.7 : Typical Municipal Code Noise Limits

Type of District	Max Level(dBA)	
	7am-7pm	7pm to 7am
Single Family Residential	50	45
Multi Family Residential	55	50
Commercial	60	55
Industrial	70	70

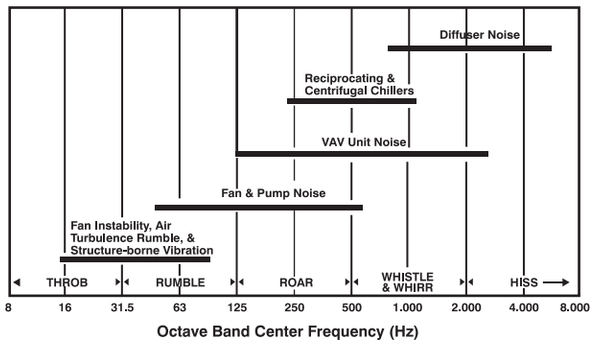


Figure 7.3 : Frequency Ranges where various HVAC equipment affect sound levels[3]

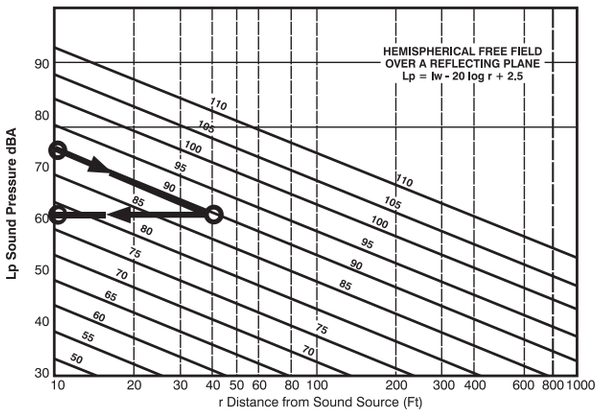


Figure 7.4 : Graph of Sound pressure V/s. Distance in a free field

Table 7.8 : Typical Sound Absorption Coefficients

Material	Octave Bands						
	63	125	250	500	1000	2000	4000
Brick unglazed	0.02	0.03	0.03	0.03	0.04	0.05	0.07
Brick unglazed, Painted	0	0.01	0.01	0.02	0.02	0.02	0.03
Carpet on Concrete	0.01	0.02	0.06	0.14	0.37	0.6	0.65
Carpet on Foam rubber	0.06	0.08	0.27	0.39	0.34	0.48	0.63
Concrete Block, light, porous	0.25	0.36	0.44	0.31	0.29	0.39	0.25
Concrete Block, dense, painted	0.07	0.1	0.05	0.06	0.07	0.9	0.08
8" Acoustic Block	0.47	0.67	0.64	0.51	0.75	0.77	0.69
12" Acoustic Block	0.67	0.95	0.89	0.55	0.74	0.81	0.72
Concrete or Terrazzo Floor	0	0.01	0.01	0.015	0.02	0.02	0.02
Linoleum, Asphalt, Rubber or Cork Tile on Concrete	0.01	0.02	0.03	0.03	0.03	0.03	0.02
Wood Floor	0.1	0.15	0.11	0.1	0.07	0.06	0.07
Glass	0.25	0.35	0.25	0.18	0.12	0.07	0.04
Curtain Wall	0.126	0.18	0.06	0.04	0.03	0.02	0.02
Closed Curtains	0.06	0.07	0.31	0.49	0.75	0.7	0.6
Drywall on Glazed Tile	0.2	0.29	0.1	0.05	0.04	0.07	0.09
Marble or Glazed Tile	0	0.01	0.01	0.01	0.01	0.02	0.02
Drywall on Brick wall	0.01	0.013	0.015	0.02	0.03	0.04	0.05
Wood Paneling	0.2	0.28	0.22	0.17	0.09	0.1	0.11
2" 3 pcf Fiberglass insulation	0.15	0.22	0.82	1	1	1	1
3" 3 pcf Fiberglass insulation	0.48	0.53	1	1	1	1	1
4" 3 pcf Fiberglass insulation	0.76	0.84	1	1	1	1	0.97
Suspended ceiling ¾" to 1" for Acoustic Tile	0.4	0.58	0.59	0.69	0.86	0.84	0.75
Suspended Ceiling 2" to 3"	0.49	0.73	0.71	0.76	0.89	0.75	0.58

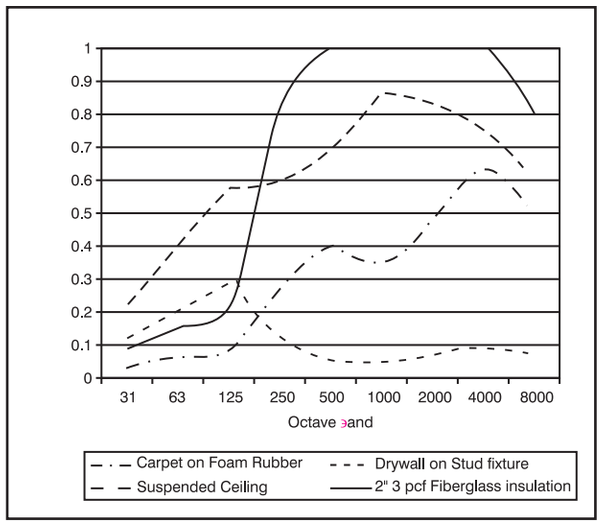


Figure 7.5 : Typical Sound Absorption Coefficients

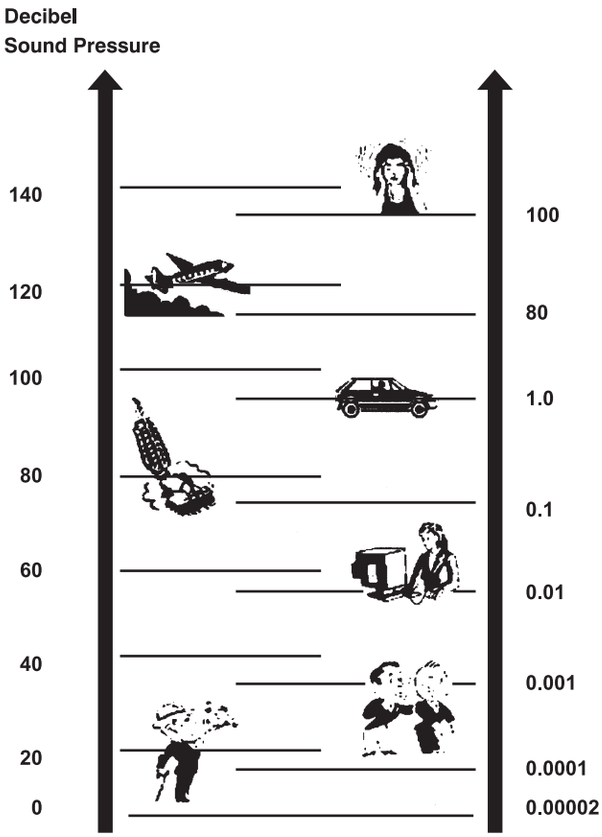


Figure 7.6 : Typical Sound Pressure Levels

Table 7.9 : Sound Sources, Transmission Paths, and Recommended Noise Reduction Methods

Sound Source	Transmission Path No.
Circulating Fans: Grilles; Registers; Diffusers, Unitary Equipment in Room	1
Induction Coil and Fan Powered VAV mixing units	1,2
Unitary Equipment located outside of room served, remotely located Air Handling Equipment such as Fans, Blowers. Dampers, Duct Fittings and Air Washers	2,3
Compressors, Pumps and other Reciprocating and Rotating Equipment (excluding Air Handling Equipment)	4,5,6
Cooling Towers; Air Cooled Condensers	4,5,6,7
Exhaust Fans; Window Air - Conditioners	7,8
Sound transmission between rooms	9,10

No	Transmission Paths	Noise Reduction Methods
1.	Direct sound radiated from sound source to ear. Reflected sound from walls, ceilings and floor.	Direct sound can be controlled only by selecting quiet equipment. Reflected sound is controlled by adding sound absorption to the room and to equipment location.
2	Air and structure-borne sound radiated from casings and through walls of ducts and plenums is transmitted through walls and ceiling into room.	Design and duct and fittings for low turbulence; locate high velocity ducts in noncritical areas; isolate ducts and sound plenums from structure with neoprene or spring hangers.
3	Airborne sound radiated through supply and return air ducts to diffusers in room and then to listener by Path 1.	Select fans for minimum sound power; use ducts lined with sound absorbing material; use silencers or sound plenums in supply and return air ducts.
4	Noise transmitted through equipment room walls and floors to adjacent rooms.	Locate equipment rooms away from critical areas; use masonry blocks or concrete for equipment room walls and floor.
5	Vibration transmitted via building structure to adjacent walls and ceilings, from which it radiates as noise into room by Path 1.	Mount all machines on properly designed vibration isolators; design mechanical equipment room for dynamic loads; balance rotating and reciprocating equipment.
6	Vibration transmission along pipes and duct walls.	Isolate pipe and ducts from structure with neoprene or spring hangers; install flexible connectors between pipes, ducts and vibrating machines.
7	Noise radiated to outside, enters room through open windows.	Locate equipment away from critical areas; use barriers and covers to interrupt noise paths; select quiet equipment.
8	Inside noise follows Path 1.	Select quiet equipment.
9	Noise transmitted to an air diffuser in a room, into a duct, and out through an air diffuser in another room.	Design and install duct attenuation to match wall transmission loss between rooms.
10	Sound transmission through, over, and around room partition.	Extend partition to ceiling slab and tightly seal all around, seal all pipes, conduits, ducts and other partition penetrations.

Table 7.10 : Sound Pressure Scales

Unit	Measurement of	Application and / or Remarks
dB	Sound Pressure level	
dB(A)	A - Weighted sound pressure level	General environmental and industrial sound measurement level recommendations, etc.
dB(B)	B - Weighted sound pressure level	Subjectivity better than dB (A) for moderate sound levels, but little used (55-85 dB).
dB(C)	C - Weighted sound pressure level	Better for sound levels above 85 dB; commonly used as signal source for analyzers.
dB(D)	D - Weighted sound pressure level	Used for aircraft noise measurement only.
dB(1)	Impulse sound pressure level	
dB(A1)	A- Weighted Impulse or peak sound pressure level	Generally recommended for impulse sound measurement.
dB(B1)	B - Weighted Impulse or peak sound pressure level	Very rarely used.
dB(C1)	C - Weighted Impulse or peak sound	Very rarely used.

Table 7.11 : Subjective Effect of Changes in Sound Pressure Level, Broadband Sounds

Changes in Sound Pressure Level	Apparent changes in Loudness
3dB	Just noticeable
5dB	Clearly noticeable
10 dB	Twice (or half) as loud

Tabie 7.12 : Guidelines for Determining Equipment Sound Levels in Presence of Contaminating Background Noise

Measurement A minus Measurement B	Correction to Measurement A to Obtain Equipment Sound Level
10 dB or more	0 dB
6 to 9 dB	-1 dB
4 to 5 dB	-2 dB
3 dB	-3 dB
2 dB	-4 dB
1 dB	-7 dB
0 dB	Equipment Sound Level is at least 9 dB below Measurement A

Table 7.13 : Typical Sound Power Outputs

Source	Approximate Power Output	
	Watts	Decibel re 10^{-12} W
Saturn Rocket	10^{8}	200
Turbojet Engine[a]	10^{5}	170
Jet Aircraft at takeoff [b]	10^{4}	160
Turboprop at takeoff	1000	150
Prop Aircraft at takeoff[c]	100	140
Large pipe Organ	10	130
Small Aircraft Engine	1	120
Blaring Radio	0.1	110
Automobile at Highway speed	0. 01	100
Voice (shouting)	0.001	90
Garbage Disposal Unit	10^{-4}	80
Voice, (conversation level)	10^{-5}	70
Electronic Equipment Ventilation Fan	10^{-6}	60
Office Air Diffuser	10^{-7}	50
Small Electric Clock	10^{-8}	40
Voice, (soft whisper)	10^{-9}	30
Rustling leaves	10^{-10}	20
Human breath	10^{-11}	10
Threshold of hearing	10^{-12}	0

a. with after burner *b Four Jet Engines
*c Four Propeller Engines

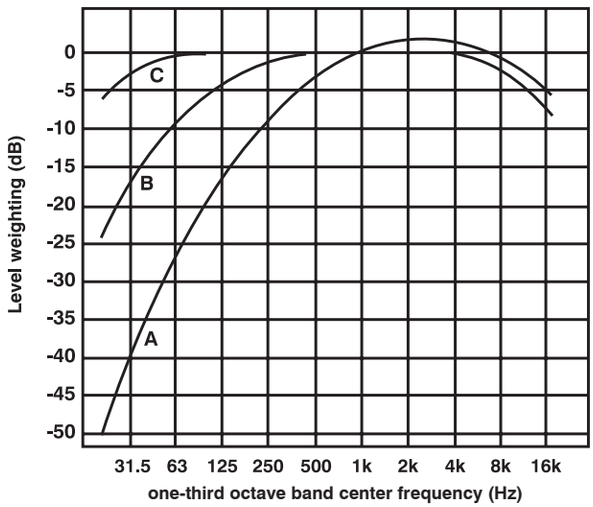


Figure 7.7 : International standard A, B and C-weighting curves for sound level meters

Table 7.14 : Recommended Indoor design Goals for Air-conditioning System Sound Control

(Note : These are for unoccupied space, with all systems operating)

Type of Area	Recommended RC or NC Criteria Range
1. Private Residences	25 to 30
2. Apartments	25 to 30
3. Hotels / Motels	
a. Individual Rooms or Suites	30 to 35
b. Meeting / Banquet Rooms	25 to 30
c. Halls, Corridors, Lobbies	35 to 40
d. Service / Support Areas	40 to 50
4. Offices	
a. Executive	25 to 30
b. Conference Rooms	25 to 30
c. Private	30 to 35
d. Open-plan Area	35 to 40
e. Computer Equip. Rooms	40 to 45
f. Public Circulation	40 to 45
5. Hospitals and Clinics	
a. Private Rooms	25 to 30
b. Wards	30 to 40
c. Operating Rooms	35 to 40
d. Corridors	35 to 40
e. Public Area	35 to 40
6. Churches	25 to 30
7. Schools	
a. Lecture Halls and Classrooms	25 to 30
b. Open-plan Classrooms	30 to 35
8. Libraries	35 to 40
9. Private Residences	
a. Apartments, Condominiums	25 to 35
10. Performing Arts	
a. Drama Theatre	25 max.
b. Concert and Recital Halls	-----
c. Music Teaching Studios	25 max.
d. Music Practice Rooms	25 max.
1 1. Laboratories	
a. Testing / Research, Minimal speech Communication	45-55
b. Research, extensive phone use speech communication	40-50
c. Group teaching	35-45
12. Court Rooms	
a. Unamplified Speech	25-35
b. Amplified Speech	30-40

Note : Indicated NC or RC is only for guidelines, actual value is determined as per end user requirements.

Table 7.15: Recommended Ambient Sound Levels for Different Areas of Occupancy in Buildings (Space Furnished but unoccupied) Australian Standard 2107-1997

Types of occupancy / activity	Recommended Sound level (dB(A))
Lecture Rooms, Assembly Halls, Conference Venues	30
Audio-visual Areas	40
Computer Rooms (teaching)	40
Computer Rooms (working)	45
Conference Rooms, Seminar Rooms, Tutorial Rooms	30
Corridors and Lobbies	45
Drama Studios	30
Libraries (reading)	40
Music Studios and Concert Halls	30
Professional and Administrative Offices	35
Design Offices, Drafting Offices	40
Private Offices	35
Reception Areas	40
Airport terminals	45
Restaurants	40
Hotel Bar	45
Private House (sleeping)	25
Private House (recreation)	30

Table 7.16 : Maximum Recommended "Free" Supply Outlet and Return Air Opening Velocities Needed to Achieve Specified Acoustic Design Criteria

Type of Opening	Design RC (N)	Free Opening Airflow Velocity, m/s
Supply air outlet	45	3.2
	40	2.8
	35	2.5
	30	2.2
	25	1.8
Return air opening	45	3.8
	40	3.4
	35	3.0
	30	2.5
	25	2.2
Notes: The presence of diffusers or grilles can increase sound levels a little or lot depending on how many diffusers or grilles are installed and on their design, construction, installation, etc. Thus, allowable outlets or opening air flow velocities should be reduced accordingly.		

Table 7.17: Sound Attenuation in Unlined Rectangular Sheet Metal Ducts

Duct Size, mm x min	P/A	Attenuation, dB/m			
		Octave Band Centre Frequency, Hz			
		63	125	250	>250
150 x 150	0.26	0.98	0.66	0.33	0.33
305 x 305	0.13	1.15	0.66	0.33	0.20
305 x 610	0.10	1.31	0.66	0.33	0.16
610 x 610	0.07	0.82	0.66	0.33	0.10
1220 x 1220	0.03	0.49	0.33	0.23	0.07
1830 x 1830	0.02	0.33	0.33	0.16	0.07

Table 7.18 : Ceiling Plenum Attenuation with T-Bar Suspension

Description	63	125	250	500	1000	2000	4000	8000
No suspended Ceiling	0	0	0	0	0	0	0	0
Mineral Fiber 1 lb. Density	3	6	8	10	16	21	36	21
Mineral Fiber 0.5 lb. Density	3	5	7	9	15	20	23	18
Glass Fiber 0.1 lb Density, 5/8" Thick	3	6	5	7	7	8	9	7
Glass Fiber 0.6 lb Density, 2" Thick	4	7	8	11	15	19	25	20
Glass Fiber with TL Backing 0.6 lb. Density, 2" Thick	4	7	8	12	27	22	29	23
Drywall Ceiling	8	11	15	15	17	17	18	14
Double Drywall Ceiling	14	17	21	21	23	23	24	19

Table 7.19 : Flexible Ducts Attenuation

Dia Length	Octave Band							
	63	125	250	500	1000	2000	4000	8000
4 in by 3 ft	2	3	3	8	9	11	7	5
5 in by 3 ft	2	3	4	8	10	10	7	5
6 in by 3 ft	2	3	4	8	10	10	7	5
7 in by 3 ft	2	3	5	8	9	10	6	5
8 in by 3 ft	2	3	5	8	9	9	6	5
9 in by 3 ft	2	3	6	8	9	9	6	5
10 in by 3 ft	2	3	6	8	9	9	5	4
12 in by 3 ft	2	2	5	8	9	8	5	4
14 in by 3 ft	1	2	4	7	8	7	4	3
16 in by 3 ft	1	1	2	6	7	6	2	2

Table 7.20 : End Reflection Duct terminated in Free Space

Size Dia	Octave Band							
	63	125	250	500	1000	2000	4000	8000
6	20	14	9	5	2	1	0	0
8	18	12	7	3	1	0	0	0
10	16	11	6	2	1	0	0	0
12	14	9	5	2	1	0	0	0
16	12	7	3	1	0	0	0	0
20	10	6	2	1	0	0	0	0
24	9	5	2	1	0	0	0	0
28	8	4	1	0	0	0	0	0
32	8	3	1	0	0	0	0	0
36	6	3	1	0	0	0	0	0
48	5	2	1	0	0	0	0	0
72	3	1	0	0	0	0	0	0

Table 7.21 : Transmission Loss Values Across Barriers

Description	Octave Band								
	31	63	125	250	500	1000	2000	4000	8000
4" poured concrete	29	35	36	36	41	45	50	54	58
8" poured concrete	34	36	37	41	45	49	53	57	61
12" poured concrete	36	36	38	44	48	51	55	59	63
8" Hollow core concrete Block	29	35	36	36	41	45	49	53	57
12" Hollow core concrete Block	32	36	36	37	43	47	51	55	59
4" Metal Stud wall with 5/8" Drywall	8	11	20	30	37	.47	40	44	35
4" Metal Stud Wall, 5/8" Drywall and 2" 3 lb/ft 3 fiberglass insulation	9	14	23	40	45	53	47	48	38
4" Metal Stud Wall with 2 layers 5/8" Drywall	11	19	27	40	46	52	48	48	38
4" Metal Stud Wall, 2 Layers 5/8" Drywall and 2" 3 lb/ft 3 fiberglass insulation	13	24	32	43	50	52	49	50	40
1/8 in Single Pane Glass	2	8	13	19	23	27	27	27	31
1/4 in Single Pane Glass	7	14	20	25	27	28	28	31	34
1/4 in Double Pane Glass, 1/2 in. air gap	13	18	23	26	29	34	31	34	38
Wood, Hollow core Door	0	2	7	12	17	18	19	22	30
Wood, Solid Core Door	12	17	18	19	22	30	35	39	43
2 in Acoustic Metal Door	23	25	31	34	37	39	43	47	45
4 in Acoustic Metal Door	27	29	34	36	40	45	49	51	49
Two 4 in Acoustic Doors, 3 in Separation	42	48	54	60	67	75	84	90	95

Table 7.22 : End Reflection Duct Terminated in Wall

Size Dia	Octave Band							
	63	125	250	500	1000	2000	4000	8000
6	18	13	8	4	1	0	0	0
8	16	11	6	2	1	0	0	0
10	14	9	5	2	1	0	0	0
12	13	8	4	1	0	0	0	0
16	10	6	2	1	0	0	0	0
20	9	5	2	1	0	0	0	0
24	8	4	1	0	0	0	0	0
28	7	3	1	0	0	0	0	0
32	6	2	1	0	0	0	0	0
36	5	2	1	0	0	0	0	0
48	4	1	0	0	0	0	0	0
72	2	1	0	0	0	0	0	0

Table 7.23 : Correction Co-efficient for Wall Construction

Quality of Construction		T
Excellent	No acoustic leaks or penetration	0.00001
Good	Very few acoustic leaks and penetration	0.0001
Average	Many acoustic leaks and penetration	0.001
Poor	Many acoustic leaks and visible holes	0.1

Table 7.24 : Maximum Recommended Duct Velocities to Achieve Specified Acoustic Design Criteria

Main Duct Location	Max. Velocity(fpm)		
	Design RC	Rectangular Duct	Round Duct
In Shaft or above Drywall Celling	45	3500	5000
	35	2500	3500
	25	1700	2500
	45	2500	4500
Above Suspended Acoustic Ceiling	35	1750	3000
	25	1200	2000
	45	2000	3900
Duct Located Within Occupied Space	35	1450	2600
	25	950	1700

Table 7.25 : Maximum Recommended "Free" Supply Outlet and Return Air Opening Velocities to Achieve Specified Acoustic Design Criteria

Type of Opening	Design RC	"Free" Opening Air Velocity (fpm)
Supply Air Outlet	45	625
	40	560
	35	500
	30	425
	25	350
Return Air Opening	45	750
	40	675
	35	600
	30	500
	25	425

Table 7.26 : Insertion Loss for Rectangular Unlined Duct

Size in	Band							
	63	125	250	500	1000	2000	4000	8000
6x6	0.3	0.2	0.1	0.1	0.1	0.1	0.1	0.1
12x12	0.35	0.2	0.1	0.06	0.06	0.06	0.06	0.06
12x24	0.04	0.2	0.1	0.05	0.05	0.05	0.05	0.05
24x24	0.25	0.2	0.1	0.03	0.03	0.03	0.03	0.03
48x48	0.15	0.1	0.07	0.2	0.2	0.2	0.2	0.2
72x72	0.1	0.1	0.05	0.2	0.2	0.2	0.2	0.2

Table 7.27 : Insertion Loss for Round Unlined Duct

Duct Dia in in inches	Band							
	63	125	250	500	1000	2000	4000	8000
<7	0.03	0.03	0.05	0.05	0.1	0.1	0.1	0.08
7<D<15	0.03	0.03	0.03	0.05	0.07	0.07	0.07	0.05
15<D<30	0.02	0.02	0.02	0.03	0.05	0.05	0.05	0.04
30<D<60	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.016



Figure 7.8 : Typical Elbow Fitting

The insertion loss for elbows is found by multiplying the center band frequency in kHz with the width of the elbow in inches as shown in Figure. 7.9, Typical Elbow Fitting, using 125 Hz and a round unlined 24-inch elbow as an example.

Table 7.28 : Insertion Loss For Square Elbows Without Turning Vanes

Size Dia	Insertion Loss	
	Unlined Elbows	Lined Elbows
fw < 1.9	0	0
1.9<fw<3.8	1	1
3.8 < fw < 7.5	5	6
7.5<fw<15	8	11
15<fw<30	4	10
fw>30	3	10

Table 7.29 : Insertion Loss for Square Elbows Without Turning Vanes

Size Dia	Insertion Loss	
	Unlined Elbows	Lined Elbows
fw < 1.9	0	0
1.9<fw<3.8	1	1
3.8 < fw < 7.5	4	4
7.5<fw<15	6	7
fw<15	4	7

Table 7.30 : Insertion Loss for Round Elbows without Turning Vanes

Size Dia	Insertion Loss
	Unlined Elbows
fw < 1.9	0
1.9<fw<3.8	1
3.8 < fw < 7.5	2
fw > 7.5	3

For fw values, refer ASHRAE

Table 7.31 : Insertion Loss for Acoustically Lined Circular Ducts with 25-mm Fiberglass Lining

Dimensions, mm	63	125	Attenuation, dB/m Octave Band Centre Frequency, HZ					
			250	500	1000	2000	4000	8000
152	1.25	1.94	3.05	5.02	7.12	7.58	6.69	4.13
203	1.05	1.77	2.92	4.92	7.09	7.12	6.00	3.87
254	0.89	1.64	2.79	4.86	7.22	6.69	5.38	3.67
305	0.75	1.51	2.66	4.76	7.15	6.27	4.86	3.44
356	0.62	1.38	2.53	4.69	7.02	5.87	4.40	3.28
406	0.52	1.25	2.40	4.59	6.82	5.48	3.97	3.12
457	0.43	1.15	2.26	4.49	6.59	5.12	3.61	2.95
508	0.36	1.02	2.13	4.40	6.30	4.76	3.28	2.85
559	0.26	0.92	2.00	4.30	5.94	4.40	3.02	2.72
610	0.23	0.82	1.87	4.20	5.61	4.07	2.79	2.62
660	0.16	0.72	1.74	4.07	5.22	3.74	2.59	2.53
711	0.10	0.62	1.61	3.94	4.79	3.41	2.43	2.43
762	0.07	0.52	1.48	3.81	4.36	3.12	2.26	2.33
813	0.03	0.46	1.38	3.67	3.94	2.85	2.17	2.26
864	0	0.36	1.25	3.51	3.51	2.59	2.07	2.17
914	0	0.26	1.15	3.35	3.05	2.33	1.97	2.10
965	0	0.20	1.02	3.15	2.62	2.10	1.0	2.00
1016	0	0.10	0.92	2.99	2.23	1.87	1.80	1.90
1067	0	0.03	0.82	5.76	1.84	1.64	1.74	1.80
1118	0	0	0.75	2.56	1.48	1.44	1.67	1.71
1168	0	0	0.66	2.33	1.15	1.28	1.57	1.57
1219	0	0	0.59	2.07	0.85	1.12	1.48	1.44
1270	0	0	0.49	1.80	0.62	0.95	1.35	1.31
1321	0	0	0.46	1.51	0.43	0.83	1.21	1.12
1372	0	0	0.39	1.21	0.30	.072	1.02	0.95
1422	0	0	0.33	0.92	0.26	0.59	0.82	0.72
1473	0	0	0.33	0.56	0.26	0.52	0.59	0.49
1523	0	0	0.26	0.20	0.33	0.46	0.30	0.23

Table 7.32 : Insertion Loss for Acoustically Lined Circular Ducts with 50-mm Fiberglass Lining

Dimensions, mm	63	125	Attenuation, dB/m Octave Band Centre Frequency, HZ					
			250	500	1000	2000	4000	8000
152	1.84	2.62	4.49	7.38	7.12	7.58	6.69	4.13
203	1.67	2.46	4.36	7.32	7.19	7.12	6.00	3.87
254	1.51	2.33	4.23	7.22	7.22	6.69	5.38	3.67
305	1.38	2.20	4.10	7.15	7.15	6.27	4.86	3.44
356	1.25	2.07	3.97	7.05	7.02	5.87	4.40	3.28
406	1.15	1.94	3.84	6.96	6.82	5.48	3.97	3.12
457	1.05	1.84	3.71	6.89	6.59	5.12	3.61	2.95
508	0.95	1.71	3.58	6.79	6.30	4.76	3.28	2.85
559	0.89	1.61	3.44	6.66	5.97	4.40	3.02	2.72
610	0.82	1.51	3.31	6.56	5.61	4.07	2.79	2.62
660	0.79	1.41	3.18	6.43	5.22	3.74	2.59	2.53
711	0.72	1.31	3.05	6.33	4.79	3,41	2.43	2.43
762	0.69	1.21	2.95	6.17	4.36	3.12	2.46	2.33
813	0.66	1.12	2.82	6.04	3.94	2.85	2.17	2.26
864	0.62	1.05	2.69	5.87	3.51	2.59	2.07	2.17
914	0.59	0.95	5.59	5.71	3.05	2.33	1.97	2.10
965	0.56	0.89	2.49	5.54	2.62	2.10	1.90	2.00
1016	0.52	0.79	2.40	5.35	2.23	1.87	1.80	1.90
1067	0.49	0.72	2.30	5.15	1.84	1.64	1.74	1.80
1118	0.43	0.66	2.20	4.92	1.48	1.44	1.67	1.71
1168	0.39	0.56	2.10	4.69	1.15	1.28	1.57	1.57
1219	0.36	0.49	2.03	4.46	0.85	1.12	1.48	1.44
1270	0.30	0.39	1.97	4.20	0.62	0.95	1.35	1.31
1321	0.23	0.33	1.90	3.90	0.43	0.82	1.21	1.12
1372	0.16	0.26	1.84	3.61	0.30	0.72	1.02	0.95
1422	0.07	0.16	1.80	3.28	0.26	0.59	0.82	0.72
1473	0	0.10	1.74	2.95	0.26	0.52	0.59	0.49
1523	0	0	1.74	2.59	0.33	0.46	0.30	0.23

Table 7.33 : Insertion Loss for Rectangular Sheet Metal Ducts with 25-mm Fiberglass Lining

Dimensions, mm	Attenuation, dB/m Octave Band Centre Frequency, HZ							
	63	125	250	500	1000	2000	4000	8000
102x102	6.56	6.76	7.15	12.01	33.14	33.99	15.75	9.42
102x152	4.89	5.35	6.20	10.93	29.20	29.36	14.47	8.99
102x203	4.20	4.69	5.74	10.37	27.13	26.97	13.81	8.76
102x254	3.81	4.33	5.45	10.01	25.59	25.52	13.35	8.63
152x152	3.54	4.07	5.25	9.78	25.00	24.54	13.06	8.53
152x254	2.69	3.15	4.43	8.73	21.39	20.54	11.78	8.07
152x305	2.53	2.95	4.23	8.43	20.44	19.49	11.45	7.94
152x457	2.26	2.59	3.87	7.94	18.83	17.75	10.86	7.74
203x203	2.53	2.95	4.23	8.43	20.44	19.49	11.45	7.94
203x305	2.13	2.43	3.67	7.68	18.01	16.83	10.53	7.61
203x457	1.97	2.20	3.41	7.28	16.73	15.49	10.04	7.41
203x610	1.84	1.97	3.15	6.86	15.42	14.07	9.51	7.22
254x254	2.07	2.33	3.58	7.51	17.52	16.31	10.33	7.55
254x406	1.80	1.94	3.08	6.76	15.16	13.81	9.38	7.19
254x508	1.74	1.80	2.92	6.50	14.34	12.93	9.06	7.05
254x762	1.67	1.67	2.69	6.14	13.19	11.78	8.60	6.86
305x305	1.84	1.97	3.15	6.86	15.42	14.07	9.51	7.22
305x457	1.67	1.71	2.79	6.23	13.58	12.17	8.76	6.92
305x610	1.64	1.57	2.59	5.94	12.63	11.19	8.33	6.76
305x914	1.31	1.41	2.43	5.59	11.61	10.17	7.91	6.56
381x381	1.67	1.67	2.69	6.14	13.19	11.78	8.60	6.86
381x559	1.31	1.44	2.46	5.61	11.71	10.24	7.94	6.59
381x762	1.18	1.28	2.23	5.28	10.79	9.35	7.51	6.43
381x1143	1.05	1.12	2.03	4.99	9.94	8.50	7.12	6.23
457x457	1.31	1.41	2.43	5.58	11.61	10.17	7.91	6.56
457x635	1.08	1.15	2.10	5.05	10.14	8.69	7.22	6.27
457x914	0.98	1.05	1.94	4.82	9.51	8.07	6.92	6.14
457x1372	0.89	0.92	1.77	4.53	8.76	7.35	6.56	5.97
610x610	0.98	1.05	1.94	4.82	9.51	8.07	6.92	6.14
610x914	0.82	0.85	1.67	4.40	8.37	6.99	6.36	5.91
610x1219	0.75	0.79	1.54	4.17	7.78	6.40	6.07	5.77
610x1829	0.69	0.69	1.41	3.94	7.19	5.84	5.74	5.61
762x762	0.79	0.82	1.61	4.30	8.14	6.76	6.27	5.84
762x1143	0.69	0.69	1.41	3.94	7.19	5.84	5.27	5.61
762x1524	0.62	0.62	1.28	3.71	6.66	5.35	5.48	5.48
914x914	0.69	0.69	1.41	3.94	7.19	5.84	5.75	5.61
914x1372	0.59	0.56	1.12	3.58	6.33	5.05	5.28	5.38
914x1829	0.52	0.52	1.25	3.38	5.87	4.63	5.05	5.25
1067x1067	0.59	0.59	1.25	3.64	6.43	5.15	5.35	5.41
1067x1620	0.52	0.49	1.05	3.31	5.64	4.43	4.92	5.18
1067x2134	0.46	0.46	0.98	3.15	5.28	4.10	4.69	5.09
1219x1219	0.52	0.52	1.12	3.38	5.87	4.63	5.05	5.25
1219x1820	0.46	0.43	0.95	3.08	5.18	4.00	4.66	5.05

Table 7.34 : Insertion Loss for Rectangular Sheet Metal Ducts with 50-mm Fiberglass Lining

Dimensions, mm	Attenuation, dB/m Octave Band Centre Frequency, HZ							
	63	125	250	500	1000	2000	4000	8000
102x102	11.61	12.50	14.83	24.97	33.14	33.99	15.75	9.42
102x152	8.43	9.81	12.83	22.77	29.20	29.36	14.47	8.99
102x203	7.05	8.53	11.78	21.59	27.13	26.97	13.81	8.76
102x254	6.30	7.81	11.15	20.87	25.85	25.52	13.35	8.63
152x152	5.84	7.32	10.73	20.34	25.00	24.54	13.06	8.53
152x254	4.17	5.54	8.99	18.18	21.39	20.54	11.78	8.07
152x305	3.81	5.12	8.56	17.59	20.44	19.49	11.45	7.94
152x457	3.28	4.43	7.81	16.57	18.83	17.75	10.86	7.74
203x203	3.81	5.12	8.56	17.59	20.44	19.49	11.45	7.94
203x305	3.05	4.10	7.41	16.04	18.01	16.83	10.53	7.61
203x457	2.72	3.64	6.82	15.22	16.73	16.49	10.04	7.41
203x610	2.43	3.22	6.23	14.34	15.42	14.07	9.51	7.22
254x254	2.89	3.94	7.19	15.72	17.52	16.31	10.33	7.55
254x406	2.36	3.12	6.14	14.17	15.16	13.81	9.38	7.19
254x508	2.23	2.85	5.77	13.62	14.34	12.93	9.06	7.05
254x762	2.03	2.56	5.28	12.83	13.19	11.78	8.60	6.86
305x305	2.43	3.22	6.23	14.34	15.42	14.07	9.51	7.22
305x457	2.10	2.66	5.45	13.09	13.58	12.17	8.76	6.92
305x610	1.97	2.40	5.02	12.40	12.63	11.19	8.33	6.76
305x914	1.57	2.10	4.66	11.68	11.61	10.17	7.91	6.56
381x381	2.03	2.56	5.28	12.83	13.19	11.78	8.60	6.86
381x559	1.57	2.13	4.69	11.75	11.71	10.24	7.94	6.59
381 x762	1.38	1.87	4.27	11.09	10.79	9.35	7.51	6.43
381x1143	1.21	1.61	3.87	10.47	9,94	8.50	7.12	6.23
457x457	1.57	2.10	4.66	11.68	11.61	10.17	7.91	6.56
457x635	1.25	1.67	3.97	10.60	10.14	8.69	7.22	6.27
457x914	1.12	1.51	3.67	10.10	9.51	8.07	6.92	6.14
457x1372	0.98	1.31	3.35	9.55	8.76	7.35	6.56	5.97
610x610	1.12	1.51	3.67	10.10	9.51	8.07	6.92	6.14
610x914	0.92	1.21	3.18	9.22	8.37	6.99	6.36	5.91
610x1219	0.85	1.08	2.92	8.76	7.78	6.40	6.07	5.77
610x1829	0.75	0.95	2.66	8.23	7.19	5.84	5.74	5.61
762x762	0.89	1.15	3.08	9.06	8.14	6.76	6.27	5.84
762x1143	0.75	0.95	2.66	8.23	7.19	5.84	5.74	5.61
762x1524	0.69	0.85	2.43	7.81	6.66	5.35	5.48	5.48
914x914	0.75	0.95	2.66	8.23	7.19	5.84	5.74	5.61
914x1372	0.62	0.79	2.30	7.51	6.33	5.05	5.28	5.38
914x1829	0.56	0.69	2.10	7.15	5.87	4.63	5.05	5.25
1067x1067	0.66	0.79	2.33	7.64	6.43	5.15	5.35	5.41
1067x1620	0.56	0.66	2.00	6.96	5.64	4.43	4.92	5.18
1067x2134	0.49	0.56	1.77	6.46	5.12	3.97	4.63	5.09
1219x1219	0.56	0.69	2.10	7.15	5.87	4.63	5.25	5.25
1219x1820	0.49	0.56	1.80	6.53	5.18	4.00	5.05	5.05

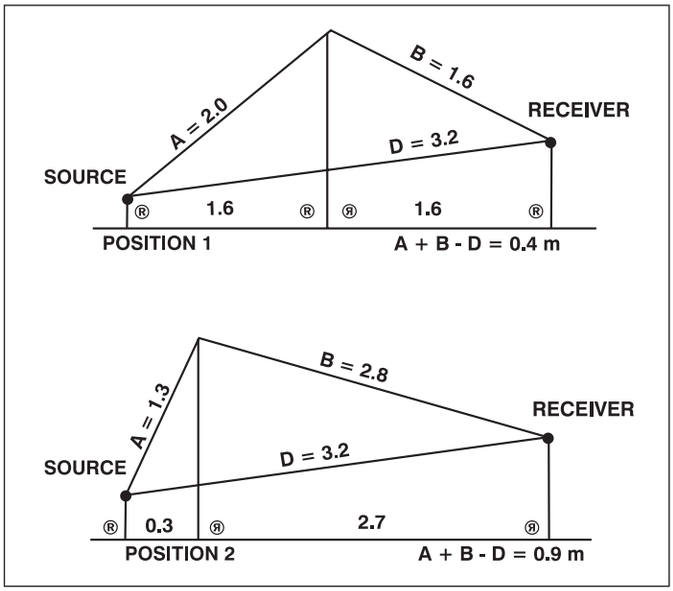


Figure 7.9 : Noise Barriers

Table 7.35 : Insertion Loss Values of an Ideal Solid Barrier

Path-Length Difference m	Insertion Loss, dB Octave Band Centre Frequency, HZ							
	31	63	125	250	500	1000	2000	4000
0.003	5	5	5	5	5	6	7	8
0.006	5	5	5	5	5	6	8	9
0.015	5	5	5	5	6	7	9	10
0.03	5	5	5	6	7	9	11	13
0.06	5	5	6	8	9	11	13	16
0.15	6	7	9	10	12	15	18	20
0.3	7	8	10	12	14	17	20	22
0.6	8	10	12	14	17	20	22	23
1.5	10	12	14	17	20	22	23	24
3.0	12	15	17	20	22	23	24	24
6.1	15	18	20	22	23	24	24	24
15.2	18	20	23	24	24	24	24	24

Table 7.36 : Octave Band in Which Blade Frequency Increment (BFI) Occurs[a]

Fan Type	Octave Band in Which BFI Generally Occurs
Centrifugal	
Airfoil, backward curved	250 Hz
Backward inclined	
Forward curved	500 Hz
Radial blade, pressure blower	125 Hz
Vaneaxial	125 Hz
Tubeaxial	63 Hz
Cooling Tower	
Propeller	63 Hz

[a]Use for estimating purpose. For speeds of 1750 rpm (29 rps), move the BFI to the next higher octave band. Where actual fan is known, use manufacturer's data.

Prediction of Fan Sound Power Levels

Fans generate a tone at the Blade Passage Frequency, and the strength of this tone depends, in part, on the type of fan. To account for this Blade Passage Frequency, an increase should be made in the Octave Band into which the Blade Frequency falls. The number of Decibels to be added to this Band is called the Blade Frequency Increment (BFI). Blade Frequency (Bf) is:

B_f = rps x no. of blades or [(rpm x no. of blades)/60] .....(1)

The number of blades and the fan rpm (rps) can be obtained from the fan selection catalog. If this catalog is unavailable, Table 7.37 can be referred for estimation.

Table 7.37 : Correction Factor C, for Off-Peak Operation

Static Efficiency % of Peak	Correction Factor dB
90 to 100	0
85 to 89	3
75 to 84	6
65 to 74	9
55 to 64	12
50 to 54	15

Table 7.38 : Specific Sound Power Levels (dB re 1pW) and Blade Frequency Increments (BFI) for Various Types of Fans

Fan Type	Wheel Size	Octave Band Center Frequency, Hz							
		63	125	250	500	1000	2000	4000	BFI
Centrifugal									
Airfoil, backward	Over 36 in. (900 mm)	32	32	31	29	28	23	15	3
Curved, backward	Under 36 in. (900 mm)	36	38	36	34	33	28	20	
Inclined									
Forward curved	All	47	43	39	33	28	25	23	2
Radial blade	Over 40 in. (1000mm)	45	39	42	39	37	32	30	
Pressure blower	40 in. (1000 mm) to 20 in.	55	48	48	45	45	40	38	8
	(500 mm)								
	Under 20 in. (500 mm)	63	57	58	50	44	39	38	
Vaneaxial	Over 40 in. (1000mm)	39	36	38	39	37	34	32	
	Under 40 in. (1000mm)	37	39	43	43	43	41	28	6
Tubeaxial	Over 40 in. (1000mm)	41	39	43	41	39	37	34	
	Under 40 in. (1000mm)	40	41	47	46	44	43	37	5
Propeller - cooling tower	All	48	51	58	56	55	52	46	5

Note: These values are the Specific Power Levels radiated from either the Inlet or the Outlet of the Fan. If the total Sound Power Level being radiated is desired, add 3 dB to the above values.

Table 7.39 : Typical Noise Levels Produced by Mechanical Room Equipment

Noise Source	Typical Noise Level[a]	TR - Tons Refrig. hp = Horsepower	Comments	Standard Error of Estimate[b]	Estimated Uncertainly	Reference
Centrifugal Chillers[c]	Lp (1 m) = 60 +11 Log (TR) dB(A)		See table below for typical octave band Spectrum shape	4dB		Blazier(1972)
Reciprocating Chillers	Lp (1m) = 71+ 9 Log (TR) dB (A)			5dB		Blazier(1972)
Absorption Machines	Lp (1m)<85dB(A)		Noise produced by suction pump and auxiliary equipment		±5dB	Blazier(1972)
Circulating pumps	Lp (1m) = 77 + 10 Log (hp) dB(A)				±5dB	Heinter (1968),Kugler et al. (1973)
Boilers	Lp (1 m) < 88 dB (A)		Forced draft type		±5dB	Blazier(1972)
Casing Radiation, Vane Axial Fans	Lw(case) = Lw (fan) - 10 dB		Lw(case)= A weighted Sound Power of Fan Case		±5dB	
Casing Radiation, Central Station Centrifugal Fans	Lw (case) = Lw (fan) -15 dB		Lw(Fan) = A - weighted Sound Power of Fan Inlet		±5dB	

Octave Band levels in dB refer to A-weighted Levels	63	125	250	500	1000	2000	4000	
Centrifugal Chiller, Internal Geared, medium to full load	-8	-5	-6	-7	-8	-5	-8	Sessier (1973)
Centrifugal Chiiller, Direct Drive, medium to full load	-8	-6	-7	-3	-4	-7	-12	Miller (1970)
Centrifugal Chiller, >1000 ton, medium to full load,	-11	-11	-8	-8	-4	-6	-13	
Reciprocating chiller, all loads	-19	-11	-7	-1	-4	-9	-14	

a Equation gives the mean value to be anticipated for equipment of current manufacture at full load.

b The Standard Error of Estimate is a measure of the variation to be anticipated from machine to machine due to differences in design, size, and point of operation. Statistically, two of the three machines sampled over a range of sizes among different manufacturers would be expected to have noise level differences lying within the range of ± 1 standard error about the mean.

c During light load operation, Centrifugal Chiller Noise Levels can be expected to increase about 5 dB in all Octave Bands not containing the Compressor Shaft Frequency or the final stage Blade Passage Frequency. These bands typically increase 10 to 13 dB (shaft frequency band) and to 10 dB (Blade Pass Frequency Band).

Table 7.40 : Attenuation of Miscellaneous Items of Equipment

Fan Type	Octave Band Center Frequency, Hz							
	63	125	250	500	1K	2K	4K	Hz
Bag or Roll Filter	0	2	2	2	4	7	12	dB
Absolute Filter	3	5	5	5	7	8	12	dB
Humidifier	3	3	3	4	4	4	5	dB
Heating / Cooling Coils								
1 -2 Rows	1	1	1	1	1	2	2	dB
>2 Rows	2	2	2	2	2	4	5	dB
Spray Washer	2	3	2	3	3	4	4	dB
Thermal Wheel	-	-	-	2	2	3	4	dB

VIBRATION

Isolator efficiency

The performance of Vibration Isolator can be quantified in terms of efficiency. This efficiency is the amount of the Vibratory force that the Isolator absorbs. An Efficiency of 90 percent means that 10 percent of the Force is transmitted to the Structure. Equation 3 is a straightforward theoretical equation that is used to calculate the transmissibility, T, of an isolator.

$$T = (fd/fn)^2 - 1 \text{ - - - - - - - - } (3)$$

Where

Fd = disturbing frequency of machinery, Hz

Fn = natural frequency of Isolator, Hz

This expression shows that there are two factors that determine transmissibility, fd and fn. The value of fd is easily obtained if the speed of the Equipment in RPM is known. The units of RPM are units of frequency but are usually converted from RPM to cycles per sec (Hz). For example, an 1800 RPM Pump has an fd of 30 Hz. Equation 3 indicates that for a given fn, T increases as fd (or speed of equipment) decreases.

The next question, of course, is how to determine fn. Equation 4 is used to calculate this:

$$fn = 3.131/SD \text{ - - - - - - - - - } (4)$$

Where

SD = static deflection of isolator, inches

This equation introduces a value for the static deflection, SD. The SD is the amount that the Spring (or other Isolator) will compress under the Static Load of the Equipment. Increasing the SD decreases the value of fn, and this in turn increases T.

This analysis brings out two important principles.

• Lower - speed equipment results in higher transmission of vibration to the structure.

• Larger spring SD leads to lower transmission of vibration to the structure.

Determining T and SD

The procedure for specifying an isolator is first to determine an appropriate transmissibility and then use Equations 3 and 4 to calculate the needed SD. The appropriate T will vary depending on the magnitude of the vibratory force, the type of structure, the type of occupancy, etc., Before discussing specific applications, it is important to understand the basic assumptions that were made to obtain Equations 3 and 4.

The significant assumption that is made with Equation 3 is that the Structural System is infinitely rigid. A slab on grade can come very close to this, but for any upper Floor of Roof application, the Structural System will have resiliency. A useful way to consider the stiffness of the floor is to compare the deflection of the Slab caused by the piece of equipment being considered to the SD of the isolator. The structure must be at least 10 times as stiff as the isolator for Equation 3 to be reasonably accurate.

For example, consider a 3600 rpm Emergency Generator located on the roof of a building. Using the technique discussed above, we find that a 1/2 in. deflection isolator will result in a transmissibility of 0.005 The calculated T will be accurate only if the deflection of the structure caused by the weight of the generator is less than 0.05 in. If it turns out that the structural deflection is larger, say 0.075 in., then the isolator's deflection must be increased to 10 times this, or 3/4 in. In general, if the deflection of the isolator is at least 1 in. then the resiliency of the structure is not a factor, but it is important to be able to identify situations that might be exceptions and check to be sure.

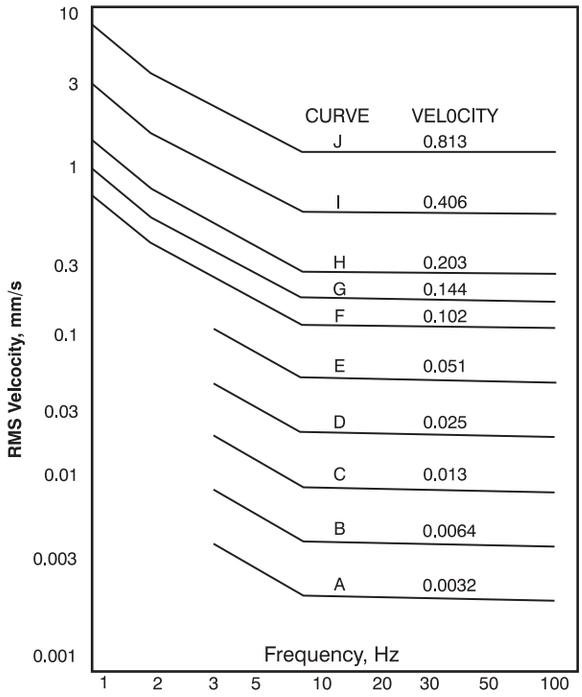


Figure 7.10 : Building Vibration Criteria

Vibration Criteria

Vibration criteria can be specified relative to three areas : (1) Human response to vibration, (2) Vibration levels associated with potential damage to sensitive equipment in a building, and (3) Vibration severity of a vibrating machine. Fig 7.11 and Table 7.41 present recommended acceptable vibration criteria for vibration that can exist in a building structure. For sensitive equipment, acceptable vibration values specified by equipment manufacturers should be used. If acceptable values are not available from equipment manufacturers, the values specified in Fig.7.12 can be used.

Table 7.41 : Equipment Vibration criteria

Equipment	Allowable rms Velocity, mm/s
Pumps	3.3
Centrifugal compressors	3.3
Fans (vent sets, centrifugal, axial)	2.3

Table 7.42 : Equipment Vibration criteria

Human Occupancy	Time of Day	Curve[a]
Workshops	All	J
Office areas	All	I
Residential (good environmental standards)	0700-2200[b] 2200-0700[b]	H-I G
Hospital Operating rooms and critical work areas	All	F
Equipment Requirements Curve		**Curves**
Computer areas		H
Bench microscopes up to 100 X magnification; laboratory robots		F
Bench microscopes up to 400 X magnification: Optical and other precision balances; coordinate measuring machines; metrology laboratories: Optical comparators; microelectronics manufacturing equipment - Class A[c]		E
Microsurgery, eye surgery, neurosurgery; bench microscope at magnification greater than 400 x; Optical equipment on isolation tables; microelectronics manufacturing equipment - Class B[c]		D
Electron microscopes up to 30,000 X magnification: microtones; magnetic resonance images; Microelectronics manufacturing equipment - Class C[c]		C
Electron microscopes at magnification greater than 30,000 X; mass spectrometers; cell implant equipment; microelectronics manufacturing equipment - Class DC		B
Unisolated laser and optical research systems; microelectronics manufacturing equipment - Class E[c]		A

[a] See Figure 7.10 for corresponding curves.

[b] In areas where individuals are sensitive to vibration, use curve H.

[c] Classes of microelectronics manufacturing equipment: Class A : Inspection, probe test, and other manufacturing support equipment.
Class B: Aligners, steppers, and other critical equipment for photolithography with line widths of 3 mm or more.
Class C : Aligners, steppers, and other critical equipment for photolithography with line widths of 1 mm.
Class D : Aligners, steppers, and other critical equipment for photolithography with line widths of 0.5 mm; includes electron-beam systems.
Class E : Aligners, steppers, and other critical equipment for photolithography with line widths of 0.25 mm: includes electron-beam systems.

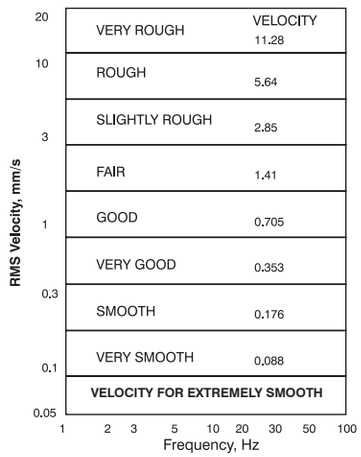


Figure 7.11 : Equipment Vibration Criteria

Table 7.43 : Equipment Vibration Criteria

Equipment	Maximum Allowable Vibration Peak-to-peak Displacement	
	Mil	mm
Pumps		
1800 rpm	2	0.05
3600 rpm	1	0.025
Centrifugal compressors, Fans (vent sets, centrifugal, axial)		
Under 600 rpm	4	0.1
600 to 1000 rpm	3	0.0750
1000 rpm to 2000 rpm	5	0.05
Over 2000 rpm	1	0.025
1 mil= 0.001 inch		

Table 7.44 :The Natural Frequency of an Isolator as a Function of its Static Deflection Under Load

Static Deflection	Natural Frequency		Static Deflection	Natural Frequency	
In.	Hz	cpm	In.	Hz	cpm
0.02	22.0	1320	2.7	1.9	114
0.04	15.7	940	3.0	1.8	108
0.06	12.8	770	3.4	1.7	102
0.01	10.0	600	3.8	1.6	96
0.2	7.0	420	4.4	1.5	90
0.3	6.0	360	5.0	1.4	84
0.4	5.0	300	6.0	1.3	78
0.6	4.0	240	7.0	1.2	72
0.8	3.5	210	8.0	1.1	66
1.1	3.0	180	10.0	1.0	60
1.2	2.8	168	12.0	0.9	54
1.4	2.6	156	15.0	0.8	48
1.7	2.4	144	20.0	0.7	42
2.0	2.2	132	27.0	0.6	36
2.4	2.0	120	39.0	0.5	30

Table 7.45 : Recommended Deflection Ranges for Common Types of Industrial Isolators

Deflection Range	Isolater
0.5 inch, and greater	Steel spring or air spring.
0.3 to 0.5 inch	Elastomeric mounts in tandem.
0.1 to 0.25 inch	Single elastomeric mounts 2 to 4 layers of ribbed neoprene pads.
0.1 inch, and under	Single layer of ribbed neoprene pad.

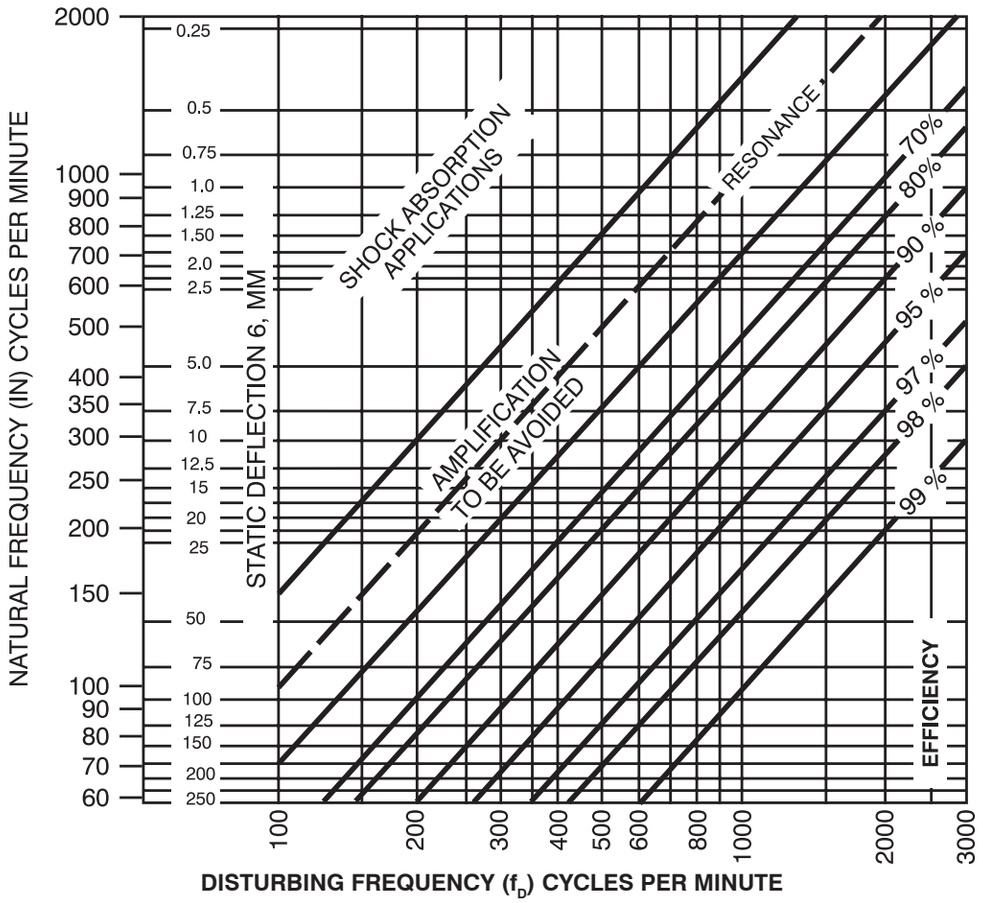


Figure 7.12 : Isolator Natural Frequency

Table 7.46 : Recommended Spring Diameters (inches) For Free-Standing Springs

Load Range, Lb	Maximum Deflection (in Inches)			
	1	1.5	2	3.5
Recommended Spring Dia, inches				
up to 250	2.5		3.5	5.5
250 to 500	3.5	4.0	4.5	7.0
500 to 1000	4.5	4.5	5.5	7.5
1000 to 2000	5.0	5.5	7.0	8.0

Table 7.47 : Common Causes of Vibration other than unbalance at Rotation Frequency

Frequency	Source
0.5 x rpm	Vibration at approximately 0.5 rpm can result from improperly loaded Sleeve Bearings. This vibration will usually suddenly disappear as equipment coasts down from operating speed.
2 x rpm	Equipment not tightly secured or bolted down.
2 x rpm	Misalignment of couplings or shafts usually results in vibration at twice rotational frequency and generally, a relatively high axial vibration.
Many x rpm	Defective Antifriction (ball, roller) Bearings usually result in low amplitude, high frequency, erratic vibration. Because defective bearings usually produce noise rather than any significantly measurable vibrations, it is best to check all bearings with a stethoscope or similar listening device.

Table 7.48 : Selection Guide for Vibration Isolation

Equipment Type	Shaft Power kW and other	rpm	Equipment Location (Note 1)												References Notes
			Slab on Grade			Up to 6m Floor Span			6- to 9-m Floor Span			9- to 12-m Floor Span			
			Base Type	Isolator Type	Min Deft mm,	Base Type	Isolator Type	Min Deft, mm,	Base Type	Isolator Type	Min. Deft. mm,	Base Type	Isolator Type	Min Deft, m m,	
Refrigeration Machines and Chillers															
Bare Compressors	All	All	A	2	6	C	3	20	C	3	45	C	4	65	2,3,12
Reciprocating	All	All	A	2	6	A	4	20	A	3	45	A	4	65	2,3,12
Centrifugal	All	All	A	1	6	A	4	20	A	3	45	A	3	45	2,3,4,12
Open centrifugal	All	All	C	1	6	C	4	20	C	3	45	C	3	45	
Absorption	All	All	A	1	6	A	4	20	A	3	45	A	3	45	
Air Compressors and Vaccum Pumps															
Tank-mounted	Up to 7.5	All	A	3	20	A	3	20	A	3	45	A	3	45	3,13,15
	1 1 and over	Ail	C	3	20	C	3	20	C	3	45	C	3	45	3,13,15
Base-mounted	All	All	C	3	20	C	3	20	C	3	45	C	3	45	3,13,14,15
Large reciprocating	All	All	C	3	20	C	3	20	C	3	45	C	3	45	3,13,14,15
Pumps															
Closed coupled	Up to 5.6	All	B	2	6	C	3	20	C	3	20	C	3	20	16
	7.5 and over	All	C	3	20	C	3	20	C	3	45	C	3	45	16
	3.7 to 19	All	A	3	20	A	3	45	A	3	45	A	3	45	
	22 and over	All	A	3	45	A	3	45	A	3	45	A	3	65	
End suction and split case	Up to 30	All	C	3	20	C	3	20	C	3	45	C	3	45	16
	37 to 93	All	C	3	20	C	3	20	C	3	45	C	3	45	10,16
	110 and over	All	C	3	20	C	3	45	C	3	45	C	3	65	10,16
Cooling Towers	All	Up to 300	A	1	6	A	4	90	A	4	90	A	4	90	5,8,18
		301 to 500	A	1	6	A	4	65	A	4	65	A	4	65	5,18
		500 and over	A	1	6	A	4	20	A	4	45	A	4	45	5,18
Boilers -Fire-tube	All	All	A	1	6	B	4	45	B	4	65	B	4	65	4
Axial Fans, Fan Heads, Cabinet Fans, and Fan Sections															
Up lo 560 mm dia.	All	All	A	2	6	A	3	20	A	3	20	C	3	20	4,9
610 mm dia. and over	Up to 500	Up to 300	B	3	65	C	3	90	C	3	90	C	3	90	9
	Pa.s.p	300 to 500	B	3	20	B	3	45	C	3	65	C	3	65	9
		501 & over	B	3	20	B	3	45	B	3	45	B	3	45	9
	501 Pa.s.p	Up to 300	C	3	65	C	3	90	C	3	90	C	3	90	3,9
	And over	300 to 500	C	3	45	C	3	45	C	3	65	C	3	65	3,8,9
		501 & over	C	3	20	C	3	45	C	3	45	C	3	65	3,8,9
Centrifugal Fans															
Up to 560 mm dia	All	All	B	2	6	B	3	20	B	3	20	C	3	45	9,19
610 mm dia. and over	Up to 30	Up to 300	B	3	65	B	3	90	B	3	90	B	3	90	8..19
		300 to 500	B	3	45	B	3	45	B	3	65	B	3	65	8,19
		501 & over	B	3	20	B	3	20	B	3	20	B	3	45	8,19
	37 and over	Up to 300	C	3	65	C	3	90	C	3	90	C	3	90	2,3,8,9,18
Propeller Fans															
Wall-mounted	Ail	All	A	1	6	A	1	6	A	1	6	A	1	6	
Roof-mounted	All	All	A	1	6	A	1	6	B	4	45	D	4	45	
Heat Pumps	All	All	A	3	20	A	3	20	A	3	20	A/D	3	45	
Condensing Units	All	All	A	1	6	A	4	20	A	4	45	A/D	4	45	
Packaged AH, AC, H and V units															
All	Up to 7.5	All	A	3	20	A	3	20	A	3	20	A	3	20	19
	1 1 and over	Up to 300	A	3	20	A	3	90	A	3	90	C	3	90	2,4,8,19
	Up to 1 kPa s.p	301 to 500	A	3	20	A	3	65	A	3	65	A	3	65	4,19
		501 and over	A	3	20	A	3	45	A	3	45	A	3	45	4,19
	1 1 and over	Up to 300	B	3	20	C	3	90	C	3	90	C	3	90	2,3,4,8,9
	1 kPa s.p	301 to 500	B	3	20	C	3	45	C	3	65	C	3	65	2,3,4,9
	and over	501 & over	B	3	20	C	3	45	C	3	45	C	3	65	2,3,4,9
Packaged Rooftop Equipment	All	A/D	1	6	D	3	20				See Note 17				5,6,8,17
Ducted to Rotating Equipment															
Small fans, electric-powered	Up to 283 Us	All	A	3	13	A	3	13	A	3	13	A	3	13	7
Boxes	284 L/s & over	All	A	3	2	A	3	20	A	3	20	A	3	20	7
Engine-Driven Generators	All	All	3	20	C	3	3	45	C	3	65	C	3	90	2,3,4

Base Types :

A. No base, isolators attached directly to equipment (Note 27)
B. Structural steel rails or base (Notes 28 and 29)
C. Concrete inertia base (Note 30)
D. Curb-mounted base (Note 31)

Isolator Types:

A. Pad, rubber, or glass fiber (Notes 20 and 21)
B. Rubber floor isolator or hanger (Notes 20 and 25)
C. Spring floor isolator or hanger (Notes 22, 23 and 25)
D. Restrained spring isolator (Notes 22 and 24)
E. Thrust restraint (Note 26)

Notes for Vibration Isolator Selection Guide : The notes in this section are keyed to the numbers listed In the column title “Reference Notes” in Table 7.48 and to other reference numbers throughout the table. While the guide is conservative, cases my arise where Vibration Transmission to the Building is still excessive. If the problem persists after all short circuits have been eliminated, it can almost always be corrected by increasing Isolator deflection, using low-frequency air springs, changing operating speed, reducing vibratory output by additional balancing or, as a last resort, changing floor frequency by stiffening or adding more mass.

Note 1. Isolator deflections is shown or based on a floor stiffness that can be reasonably expected for each floor span and class of equipment.

Note 2. For large equipment capable of generating substantial vibratory forces and structure-borne noise, increase isolator deflection, If necessary, so isolator stiffness is at least 0.10 times the floor stiffness.

Note 3. For noisy equipment adjoining or near noise-sensitive areas, see the text section on mechanical equipment room sound isolation.

Note 4. Certain designs cannot be installed directly on Individual isolator (Type A) and the equipment manufacturer or a vibration specialist should be consulted on the need for supplemental support (Base type).

Note 5. Wind load conditions must be considered. Restraint can be achieved with restrained spring Isolator (Type 4) supplemental bracing, or limit stops.

Note 6. Certain types of equipment require a curb mounted base (Type D). Airborne noise must be considered.

Note 7. See the text section on resilient pipe hangers and supports for hanger locations adjoining equipment and in equipment rooms.

Note 8. To avoid Isolator resonance problems, select isolator deflections so that resonance frequency is 40% or less of the lowest operating speed of equipment.

Note 9. To limit undesirable movement, Thrust Restraints (Type 5) are required for all ceiling-suspended and floor mounted units operating at 50 mm and more total static pressure.

Note 10. Pumps over 55 kW may require extra mass and restraining devices.

Isolation for Specific Equipment

Note 12. Refrigeration Machines: Large Centrifugal, Hermetic, and Reciprocating Refrigeration Machines generate very high noise levels, and special attention is required when such equipment is installed in upper stories or near noise-sensitive areas. If such equipment is to be located near extremely noise-sensitive areas, confer with an acoustical consultant.

Note 13. Compressors : The two basic reciprocating Compressors are (1) Single - and Double-cylinders, Vertical, Horizontal or L-head, which are usually Air Compressor, and (2) Y,W and multihead and multicylinder Air and Refrigeration Compressors, single-and double-Cylinders compressors generate high vibratory forces requiring large inertia bases (Type C) and are generally not suitable for upper-storey locations. If so, equipment manufacturer, and a vibration specialist should be consulted for design of the isolation system.

Note 14. Compressors: When using Y,W and Multihead and Multicylinder Compressors, obtain the magnitude of unbalanced forces from the equipment manufacturer, so that the necessity for an inertia base can be evaluated.

Note 15. Compressors : Base-mounted compressors through 4 kW and Horizontal Tank-type air compressors through 8 kW can be installed directly on Spring Isolators (Type 3) with Structural Bases (Type B) if required, and compressors 10 to 75 kW on Spring Isolators (Type 3) with Inertia Bases (Type C) with a mass of one to two times the compressor mass.

Note 16. Pumps : Concrete Inertia bases (Type C) are preferred for all flexible coupled pumps and are desirable for most close-coupled pumps, although steel bases (TypeB) can be used. Close-coupled pumps should not be installed directly on individual Isolators (Type A) because the impeller usually overhangs the motor support base, causing the rear mounting to be in tension. The primary requirements for Type C bases are strength and shape to a accommodate base ellow base supports. Mass is not usually a factor except for pumps over 55kW, where extra mass helps limit excess movement due to starting torque and forces. Concrete Bases (Type C) should be designed for a thickness as follows, of one-tenth the longest dimension with minimum thickness as follows; (1) for up to 20 kW, 150mm; (2) for 30 to 55kW,200mm; and for 75kW and higher; 300mm pumps over 55 kW and multistage pumps may exhibit excessive motion at start-up; supplemental restraining devices can be installed if necessary. Pumps over 90kw may generate high starting forces, so a vibration specialist should be consulted for installation recommendations.

Note 17. Packaged Rooftop Air-conditioning Equipment : This equipment is usually on light structure that is susceptible to sound and vibration transmission. The noise problem is further compounded by curb-mounted equipment, which requires large roof openings for supply and return air.

The Table shows type D Vibration Isolator selections for all spans up to 6m, but extreme care must be taken for equipment located on spans of over 6m, especially if construction is open web joists or thin low-density slabs. The recommended procedure is to determine if additional roof deflection is 6mm or under, the Isolator can be selected for 15 times additional roof deflection. If additional roof deflection is over 6mm supplemental stiffening should be installed or the unit should be relocated.

For units, especially large units, capable of generating high noise levels, consider (1) mounting the unit on a platform above the roof deck to provide an air gap (buffer zone) and (2) locating the unit away from the roof penetration thus permitting acoustical treatment of ducts before they enter the building. Some rooftop equipment have compressors, fans and other equipment isolated internally. This isolation is not always reliable because of internal short circuiting, inadequate static deflection, or panel resonances. It Is recommended that a rooftop equipment be isolated externally, as if internal isolation were not used.

Note 18. Cooling Towers : These are normally isolated with restrained spring isolators (Type 4) directly under the tower or tower dunnage. Occasionally, high deflection isolators are proposed for use directly under the motor fan assembly, but this arrangement must be used with extreme caution.

Note 19. Fans and Air Handling Equipment : The following should be considered in selecting isolation systems for fans and air-handling equipment. Fans with wheel diameters of 560 mm and under and all fans operating at speeds to 300 rpm do not generate large vibratory forces. For fans operating under 300 rpm, select isolator deflection so that the isolator natural frequency is 40% or less of the fan speed. For example, for a fan operating at 275 rpm, an isolator natural frequency of 110 rpm (1.8 Hz) or lower is required (0.4 x 2 75=110 rpm). A 75 mm deflection isolator (Type 3) can provide this isolation.

Flexible duct connectors should be installed at the intake and discharge of all fans and air-handling equipment to reduce vibration transmission to air ducts. Inertia bases (Type C) are recommended for all class 2 and 3 fans and air handling equipment, because extra mass permits the use of stiffer springs, which limit movement. Thrust restrain (Type 5) that incorporate the same deflection as isolators should be used for all fan heads, all suspended fans, and all base-mounted and suspended air-handling equipment operating at 500 Pa and over total static pressure.

VIBRATION ISOLATORS; MATERIALS, TYPES AND CONFIGURATIONS

Notes 20 through 31 are useful for evaluating commercially available Isolators for HVAC equipment. The Isolator selected for particular application depends on the required deflection, but life, cost, and suitability must also be considered.

RUBBER PADS (Type 1)  **RUBBER MOUNTS (Type 2)**	**Note 20.** Rubber isolators are available in pad (Type 1) and molded (Type 2) configurations. Pads are used in single or multiple layers. Molded isolators come in range of 30 to 70 durometer (a measure of stiffness). Material in excess of 70 durometer is usually ineffective as an isolator. Isolators are designed for up to 13 mm deflection, but are used where 8 mm or less deflection is required. Solid rubber and composite fabric and rubber pads are also available. They provide high load capacities with small deflection and are used as noise barriers under Columns and for Pipe Supports. These pad types work well only when they are properly loaded and the weight load is evenly distributed over the entire pad surface. Metal loading plates can be used for this purpose.
GLASS FIBER PADS (Type 1) 	**Note 21.** Precompressed glass fiber isolation pads (Type 1) constitute inorganic inert material and are available in various sizes in thickness of 25 to 100 mm, and in a capacities of up to 3.4 MPa. Their manufacturing process assures long life and a constant natural frequency of 7 to 15 Hz over the entire recommended load range. Pads are covered with an elastomeric coating to increase damping and to protect the glass fiber. Glass fiber pads are most often used for the isolation of concrete foundations and floating floor construction.
SPRING ISOLATOR (Type 3) 	**Note 22.** Steel springs are the most popular and versatile isolators for HVAC applications because they are available for almost any deflection and have a virtually unlimited life. All spring isolators should have a rubber Acoustical Barrier to reduce transmission high frequency vibration and noise that can migrate down the steel spring coil. They should be corrosion-protected, if installed outdoors in a corrosive environment. The basic types include: **Note 23.** Open spring isolators (Type 3) consist of a top and bottom load plate with an adjustment bolt for leveling. Springs should be designed with a horizontal stiffness of at least 100% of the vertical stiffness to assure stability, 50% travel beyond rated load and safe solid stresses.

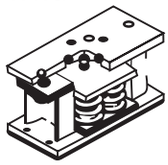
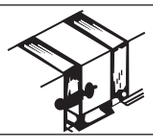
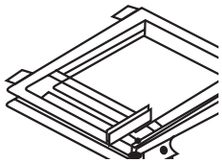
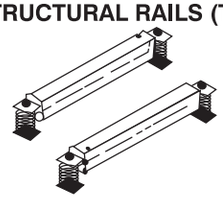
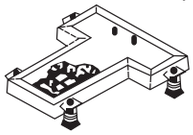
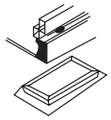
RESTRAINED SPRING ISOLATOR (Type 4) 	**Note 24.** Restrained Spring Isolators (Type 4) have hold-down bolts to limit vertical movement. They are used with (a) equipment with large variations in mass (boilers, refrigeration machines) to restrict movement and prevent strain on piping when water is removed, and (b) outdoor equipment, such as cooling towers, to prevent excessive movement because of wind load. Spring criteria should be the same as for open spring isolators, and restraints should have adequate clearance so that they are activated only when a temporary restraint is needed. Housed spring isolators consist of two telescoping housings separated by a resilient material. Depending on design and installation, housed spring isolators can bind and short circuit. Their use should be avoided.
AIR SPRINGS  ROLLING LOBE  BELLOWS	Air Springs can be designed for any frequency but are economical only in applications with natural frequencies of 1.33 M Hz or less (1.50 mm or greater deflection). Their use is advantageous in that they do not transmit high-frequency noise and are often used to replace high deflection springs on problem jobs. Constant air supply is required, and there should be an air dryer in the air supply.
RUBBER HANGER (Type 2)  **SPRING HANGER (Type 3)** 	**Note 25.** Isolation Hangers (Type 2 and 3) are used for suspended pipe and equipment and have rubber, springs, or a combination of spring and rubber elements. Criteria should be the same as for open spring isolators. To avoid short circuiting, hangers should be designed for 20 to 35° angular hanger rod misalignment. Swivel or traveler arrangement may be necessary for connection to piping systems subject to large thermal movements.
THRUST RESTRAINT (Type 5) 	**Note 26.** Thrust Restraints (Type 5) are similar to spring hangers or isolators and are installed in pairs to resist the thrust caused by air pressure.
Direct Isolation (Type A)	**Note 27.** Direct Isolation (Type A) is used when equipment is unitary and rigid and does not require additional support. Direct isolation can be used with large chillers, packaged air-handling units, and air-cooled condensers. If there is any doubt that the equipment can be supported directly on Isolators, use structural bases (Type B) or inertia bases (Type C) or consult the equipment manufacturer.
STRUCTURAL BASES 	**Note 28.** Structural bases (Type B) are used where equipment cannot be supported at individual locations and/or where some means is necessary to maintain alignment of component parts. These bases can be used with spring or rubber isolators (Type 2 and 3) and should have enough rigidity to resist all starting and operating forces without supplemental hold-down devices. Bases are made in rectangular configurations using structural members with a depth equal to one-tenth the longest span between isolators, with a minimum depth of 100 mm. Maximum depth is limited to 300 mm except where structural or alignment considerations dictate otherwise.
STRUCTURAL RAILS (Type B) 	**Note 29.** Structural rails (Type B) are used to support equipment that does not require unitary base or where the Isolators are outside the equipment and rails act as a cradle. Structural rails can be used with spring or rubber isolators, and should be rigid enough to support the shipment without flexing. Usual industry practice is to use structural members with a depth of one-tenth of the longest span between Isolators with a minimum depth of 100 mm. Maximum depth is limited to 300 mm, except where structural consideration dictate otherwise.
CONCRETE BASES (Type C) 	**Note 30.** Concrete Bases (Type C) consist of a steel pouring form usually with welded-in reinforcing bars, provisions for equipment hold-down, and isolator brackets. Like structural bases, concrete bases should be rectangular or T-shaped and for rigidity, have a depth equal to one-tenth the longest span between isolators, with a minimum of 150 mm. Base depth need not exceed 300 mm unless it is specifically required for mass, rigidity, or component alignment.
CURB ISOLATION (Type D) 	**Note 31.** Curb isolation systems (Type D) are specifically designed for curb-supported rooftop equipment and have spring isolation with a watertight and airtight curb assembly. The roof curbs are narrow to accommodate the small diameter of the springs within the rails, with static deflection in the 25 to 75 mm range to meet the design criteria described for Type 3.

Table 7.49 : National Standards on Occupational Noise Exposure Limits

EEC member State	Steady Noise level (dB(A))	Time of exposure (h)	Halving Rate (db(A))	Over-Riding Limit (db(A))	Impulse Peak SPL (db)	Impulses (no./day)
Germany	90	8	-	-	-	-
France	90	40	-	-	-	-
Belgium	90	40	5	110	140	100
Luxembourg	-	-	-	-	-	-
Netherlands	-	-	-	-	-	-
UK	90	8	3	135	150	-
Irish Republic	90	-	-	-	-	-
Italy	90	8	5	115	140	-
Denmark	90	8	3	115	115	-
Others						
Sweden	85	8	3	115 fast	140	-
Norway	85	8	3	110 fast	-	-
USA (Fed.)	90	8	5	115	140	100
Canada (Fed.)	90	8	5	115	140	-
Australia	90	8	3	115	-	-

Table 7.50 : Pumping System Noise Analysis Guide

Complaint	Possible Cause	Recommended Action
Pump or System Noise	Shaft misalignment	• Check and realign
	Worn coupling	• Replace and realign
	Worn pump / motor bearings	• Replace, check manufacturer's lubrication recommendations
		• Check and realign shafts
	Improper foundation or Installations	• Check foundation bolting or proper grouting
		• Check possible shifting caused by piping expansion / contraction
		• Realign shafts
	Pipe vibration and / or strain caused by pipe expansion/contraction	• Inspect, alter, or add hangers and expansion provision to eliminate strain on pump(s)
	Water velocity	• Check actual pump performance against specified, and reduce impeller diameter as required
		• Check for excessive throttling by balance valves or control valves
	Pump operating close to or beyond end point of performance curve	• Check actual pump performance against specified, and reduce impeller diameter as required
	Entrained air or low suction pressure	• Check expansion tank connection to system relative to pump suction
		• If pumping from cooling tower sump or reservoir, check line size
		• Check actual ability or pump against installation requirements
		• Check for vortex entraining air into suction line

Table 7.51 Recommended Live Length[a] of Flexible Rubber and Metal Hose

Nominal Diameter, mm	Length, mm	Nominal Diameter, mm	Length, mm
20	300	100	450
25	300	125	600
40	300	150	600
50	300	200	600
65	300	250	600
80	450	300	900
a Live length is end-to-end length for integral flanged rubber hose and is end-to-end less total fitting length for all other types			

SECTION 8

ELECTRICAL MOTORS, STARTERS, CABLES AND MEASUREMENT SENSORS

Temperature and Humidity Sensors

Location of Space Sensors

Space Sensors and Controllers must be located where they accurately sense the variables they control and, where the condition is representative of the area (zone) they serve. In large open areas having more than one zone, thermostat sensors should be located in the middle of their zones to prevent them from sensing inaccurate conditions.

Sensors are placed in the following locations :

- **Wall-mounted Thermostats** or Sensors are usually placed on inside walls or columns in the space they serve. Avoid outdoor wall locations. Mount thermostats at generally accessible heights and in locations where they will not be affected by heat from sources such as direct sun rays, wall pipes or ducts, convectors, or direct air currents from diffusers or equipments (e.g. Copy Machines, Coffee makers, Refrigerators). The wall itself should be sealed tightly if it penetrates a pressurized supply air plenum either under the floor or overhead. Air circulation should be ample and unimpeded by furniture or other obstructions, and the thermostat should be protected against mechanical injury. Thermostats in spaces such as corridors, lobbies, foyers should be used to control those areas only.
- **Return Air Thermostat** can control floor-mounted unitary conditioners such as induction or fan - coil units OF the ventilators. On induction and fan-coil units the sensing element is behind the return air grille. On classroom unit ventilators, that use up to 100% outdoor air for natural cooling, however, a forced-flow sampling chamber should be provided for the sensing element, which should be located carefully to avoid radiant effect and to ensure adequate air velocity across the element.

If return air sensing is used with a central fan system, locate the sensing element as near as possible to the space being controlled, to eliminate any influence from other spaces and effect of any heat gain loss in the duct. Where light fixtures are used to return air to a ceiling plenum, the return air sensing element can be located in the return air opening. Be sure to offset the set point to compensate for heat from the light fixtures.

- **Diffuser-mounted Thermostats usually** have sensing elements mounted on circular or square ceilling supply diffusers and depend on aspiration of room air into the supply airstream. They should be used only on high aspiration diffusers adjusted for a horizontal air pattern. The diffuser on which the element is mounted should be in the center of the occupied area of the controlled zone.
- $C0_2$ sensors for DCV are usually located in spaces with high occupant densities i.e. conference rooms, auditoriums, court-rooms. Locating the sensor in return air ducts / plenums that serve multiple spaces, measures average concentrations and does not provide information on CO_2 levels in rooms with the highest concentrations.

Table 8.1 : Common Temperature Measurement Techniques

Measurement Means	Application	Approximate Range °F	Uncertainty °F	Limitations
Liquid-in-glass Thermometers				
Mercury-in-glass	Temperature of gases and liquids by contact	-36/100	0.05 to 3.6	In gases, accuracy affected by radiation
Organic fluid	Temperature of gases and liquids by contact	-333/400	0.05 to 3.6	In gases, accuracy affected by radiation
Resistance Thermometers				
Platinum	Precision; remote readings temperature of fluids or solids by contact	-430/1800	Less than 0.0002 to 0.2	High cost; accuracy affected by radiation in gases
Rhodium / Iron	Transfer standard for cryogenic applications	-460/-400	0.0002 to 0.2	High cost, accuracy affected by radiation
Nickel	Remote readings; temperature by contact	-420/400	0.02 to 2	Accuracy affected by radiation in gases
Germanium	Remote readings; temperature by contact	-460/400	0.0002 to 0.2	‘‘
Thermostats	Remote readings; temperature by contact	Up to 400	0.0002 to 0.2	‘‘
Thermocouples				
Pt-Rh / Pt (type S)	Standard for thermocouples in IPTS-68, not on ITS-90	32/2650	0.2 to 5	High Cost
Au/Pt	Highly accurate reference thermometer for laboratory applications	-60/1800	0.1 to 2	High Cost
Types K and N	General testing of high temperature; remote rapid readings by direct contact	Up to 2300	0.2 to 18	Less accurate than Pt-Rh/Pt or Au/Pt
Iron/Constantan (type J)	Same as above	Up to 1400	0.2 to 10	Subject Oxidation
Copper/Constantan (type T)	Same as above; especially suited for low temperature	Up to 660	0.2 to 5	
Ni-Cr/Constantan (type E)	Same as above; especially suited for low temperature	Up to 1650	0.2 to 13	
Bimetallic thermometers	For approximate temperature	-4/1200	2	Usually much more time lag, unsuitable for remote use
Pressure-bulb thermometers				
Gas-filled bulb	Remote reading	-100/1200	4	Use caution to ensure installation is correct
Vapor-filled bulb	Remote reading	-25/500	4	Use caution to ensure installation is correct
Liquid-filled bulb	Remote reading	-60/2100	4	Use caution to ensure installation is correct
Optical Pyrometers	For intensity of narrow spectral band of high-temperature radiation (remote)	1500 and up	30	Generally requires knowledge of surface emissivity
Infrared (IR) Radiometers	For intensity of total high-temperature radiation (remote)	Any range		
IR Thermography	Infrared imaging	Any range		Generally requires knowledge of surface emissivity
Seger cones (Fusion Pyrometers)	Approximate temperature (within temperature source)	1200/3600	90	

Table 8.2 : Thermocouple Tolerances On Initial Values Of Electromotive Force Versus Temperature

Thermocouple Type	Materfeii Identification	Temperature Range, °F	Reference Junction Tolerance at 32°F[a]	
			Standard Tolerance (Whichever is greater)	Special Tolerance (Whichever is greater)
T	Copper versus Constantan	32 to 700	±1.8°For±0.75%	±0.9°For±0.4%
J	Iron versus Constantan	32 to 1400	±4°For±0.75%	±2°For±0.4%
E	Nickel/10% Chromium versus Constantan	32 to 1600	±3.1°For±0.5%	±1.8°For±0.4%
K	Nickel/10% Chromium versus 5% Aluminum, Silicon	32 to 2300	±4°For±0.75%	±2°For±0.4%
N	Nickel/14% Chromium, 1.5% Silicon versus, Nickel/4.5% Silicon, 0.1% Magnesium	32 to 2300	±4»For±0.75%	±2°For±0.4%
R	Platinum/13% Rhodium versus Platinum	32 to 2700	±2.7°For±0,25%	±1.1°For±0.1%
S	Platinum/10% Rhodium versus Platinum	32 to 2700	±2.7°F or ±0.25%	±1.1°For±0.1%
B	Platinum/30% Rhodium versus Platinum/6% Rhodium	1600 to 31 00	±0.5%	±0.25%
T	Copper versus Constantan	-328 to 32	±1.8°For±1.5%	c
E	Nickel/10% Chromium versus Constantan	-328 to 32	±3.1°For±1%	c
K	Nickel/10% Chromium versus 5% Aluminum, Silicon	-328 to 32	±4»For±2%	c

SOURCE: ASHRAE HANDBOOK

Table 8.3 : Humidity Sensor Properties Humidity Measurement

Any instrument that can measure the humidity or psychrometric state of air is a hygrometer, and many are available. The indication sensors used on the instruments respond to different moisture contents. These responses are related to factors such as wet bulb temperature, relative humidity, humidity (mixing) ratio, dew point, and frost point temperature.
Table 3 lists instruments for measuring humidity. Each is capable of accurate measurement under certain conditions and within specific limitations. The following section describes the various instruments in more detail.

Type of Sensor	Sensor Category	Method of Operation	Approximate Range	Some Uses	Approximate Accuracy
Psychrometer	Evaporative Cooling	Temperature measurement bulb	32 to180°F	Measurement Standard	± 3 to 7% rh
Adiabatic Saturation Psychrometer	Evaporative Cooling	Temperature measurement of thermodynamic wet bulb	40 to 85°F	Measurement Standard	± 0.2 to 2% rh
Chilled Mirror	Dew Point	Optical determination moisture formation	-110to200°F	Measurement, Control, Meteorology	±0.4 to 4°F
Heated Saturated Salt Solution	Water Vapor Pressure	Vapor Pessure depression in salt solution	-20 to 160°F	Measurement, Control, Meteorology	±3°F
Hair	Mechanical	Dimensional change	5 to 100%rh	Measurement, Control	± 5% rh
Nylon	Mechanical	Dimensional change	5 to 100%rh	Measurement, Control	± 5% rh
Dacron thread	Mechanical	Dimensional change	5 to 100%rh	Measurement	± 7% rh
Goldbeater's skin	Mechanical	Dimensional change	5 to 100%rh	Measurement	+ 7% rh
Cellulosic materials	Mechanical	Dimensional change	5 to 100%rh	Measurement, Control	± 5% rh
Carbon	Electrical	Dimensional change	5 to 100% rh	Measurement	± 5% rh
Dunmore type	Electrical	Impedance	7 to 98% rh at 40 to 140°F	Measurement, Control	±1.5rh
Polymer Film Electronic Hygrometer	Electrical	Impedance or capacitance	10 to 100% rh	Measurement Standard	± 2 to 3% rh
Ion exhange resin	Electrical	Impedance or capacitance	10 to 100% rhat -40 to 190°F	Measurement, Control	± 5% rh
Porousceramic	Electrical	Impedance or capacitance	Upto 400° Fdp	Measurement, Control	±1 to 1.5%rn
Aluminum oxide	Electrical	Optical Diodes	-110 to 140° Fdp	Trace moisture measurement, Control	±2°Fdp
Electrolytic hygrometer	Electrolytic I and II	Electrolysis due to absorbed Moisture	1 to 1000 ppm	Measurement	
Infrared laser Diode	Electrical	Optical diodes	0.1 to 100 ppm	Trace moisture measurement, Control	± 0.1 ppm
Surface Acoustic Wave	Electrical	SAW Attenuation	85 to 98% rh	Measurement, Control	±1%rh
Piezoelectric	Mass sensitive	Mass changes due to absorbed moisture	-100 to O°F	Trace moisture measurement, Control	±2to10°Fdp
Radiation Absorption	Moisture / Absorption	Moisture absorption of UV or IR radiation	Oto180° Fdp	Measurement, Control, Meteorology	±4°Fdp, ± 5% rh
Gravimetric	Direct measurement of mixing ratio	Comparison of sample gas with dry airstream	120 to 20,000 ppm mixing ratio	Primary standard, research and laboratory	±0.1 3 of reading
Color change	Physical	Color changes	10 to 80% rh	Warning device	±10%rh

Notes: 1. This table does not include all available technology for humidity measurement.
2. Approximate range for device types listed is based on surveys of device manufacturers.
3. Approximate accuracy is based on manufacturer's data.
4. Presently NIST only certifies instruments with operating ranges within -103 to 212° F dp.

Table 8.4 : Air Velocity Measurement

Measurement Means	Application	Range from	Precision	Limitations
Smoke puff or airborne Solid Tracer	Low air velocities highly, directional	5 to 50	10 to 20%	Valuable in tracing air movement.
Deflecting Vane Anemometer	Air velocities in rooms, at outlets etc., directional	30 to 24,000	5%	Requires periodic calibration check.
Revolving (rotating) Vane Anemometer	Moderate Air velocities in ducts and rooms Somewhat directional	100 to 3000	2 to 5%	Subject to significant errors when variations in velocities with space or time are present. Easily damaged. Affected by turbulence, requires periodic calibration.
Thermal (hot-wire or hot-film) Anemometer	a. Low air velocities : Directional and Omnidirectional available b. Transient velocity and turbuence	50 to 10,000	2 to 10%	Requires accurate calibration at frequent intervals. Some are relatively costly. Affected by thermal plume because of self-heating.
Pitot tube	Standard (typically hand-held) instrument for measuring single-point duct velocities	180 to 10,000 with Micromanometer; 600 to 10,000 with Draft Gauges; 10,000 up with Nanometer	2 to 5%	Accuracy falls off at low end of range because of square-root relationship between velocity and dynamic pressure. Also affected by alignment with flow direction.
Impact tube and Sidewall or Static tap	High velocities, small tubes, where air direction may be variable	120 to 10,000 with micromanometer; 600 to 10,000 with Draft gauges; 10,000 up with manometer	2 to 5%	Accuracy depends on constancy of static pressure across stream section.
Cup Anemometer	Meteorological	Up to 12,000	2 to 5%	Poor accuracy at low air velocity (<500 fpm)
Ultrasonic	Large instruments : Meterological Small instruments in duct and room air velocities	1 to 6000	1 to 2%	High cost
Laser Doppler Velocimeter (LDV)	Calibration of air velocity instruments	1 to 6000	1 to 3%	High cost and complexity limit LDVs to laboratory applications. Requires seeding of flow with particles, and transparent optical access (window).
Particle Image Velocimetry (PIV)	Full-field (2D, 3D) velocity measurements in rooms, outlets	0.02 to 100	10%	High cost and complexity limit measurements to laboratory applications. Requires seeding of flow with particles, and transparent optical access (window).
Pitot array, Self-averaging differential pressure typically using equalizing manifolds	In Duct assemblies, ducted or fan inlet probes.	600 to10,000	±2 to>40% of reading	Performance depends heavily on quality and range of associated Differential Pressure Transmitter. Very susceptible to measurement errors caused by duct placement and temperature changes. Nonlinear output (square-root function). Mathematical averaging errors likely because of sampling method. Must be kept clean to function properly. Must be set up and field calibrated to hand-held reference, or calibrated against nozzle standard.
Piezometer and Piezoring variations, Self-Averaging diffential pressure using equalizing manifolds	Centrifugal fan inlet cone	600 to 10,000	+ 5 to > 40% of reading	Performance depends heavily on quality and range of required Differential Pressure Transmitter. Very susceptible to measurement errors caused by inlet cone placement, inlet obstructions, and temperature changes. Nonlinear output (square-root function). Must be kept clean. Must be field-calibrated to hand field reference.
Vortex Shedding	In-duct assemblies, ducted or ducted probes	450 to 6000	±2.5 to 10% of reading	Highest cost per sensing point. Largest physical size. Low temperature accuracy questionable. Must be set up and field calibrated to hand-held reference.
Thermal (analog electronic) using Thermistors	In-duct assemblies or ducted probes	50 to 5000	± 2 to 40% of reading	Mathematical averaging errors may be caused by analog electronic circuitry when averaging nonlinear signals. Sensing point may not be independent. May not be able to compensate for temperatures beyond a narrow range. Must be set up and field-calibrated to hand-held reference. Must be recalibrated regularly to counteract “drift”.
Thermal Dispersion (Microcontroller-based using Thermistors to independently determine Temperatures and Velocities	Ducted Fan Inlet probes, bleed velocity sensors	20 to 10,000	±2 to 10% of reading	Cost increases with number of sensor assemblies in array. Not available with flanged frame. Honeycomb air straighteners not recommended by manufacturer. Accuracy verified only to -20°F. Not suitable for abrasive or high temperature environments.
Thermal (analog electronic) using RTDs	In-duct assemblies or ducted probes; Stainless Steel and Platinum RTDs have industrial environment capabilities	100 to18,000	± 1 to 20% of reading	Requires long duct/pipe runs, sensitive to placement conditions. Mathematical averaging errors may be caused by analog electronic circuitry when averaging nonlinear signals. Must be recalibrated regularly to counteract “drift” Fairly expensive.

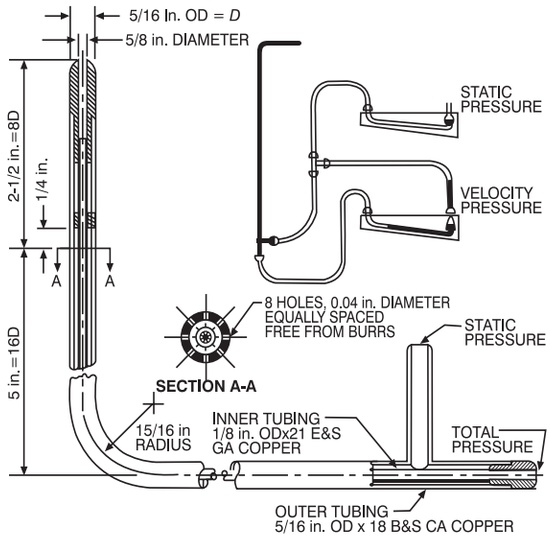


Figure 8.1 : Standard Pitot Tube

$$V = 1096.5 \sqrt{\frac{PN/pw}{0.075 \times y!}}$$

where V = velocity, fpm
PN/*pw* - velocity pressure (pitot-tube manometer reading), in. of water
y ! = density of air, lbm/ft ^ 3

Source : ASHRAE 2009

Table 8.5 : Volumetric or Mass Flow Rate Measurement

Measurement Means	Application	Range	Precision	Limitations
Orifice and Differential Pressure Measurement System	Flow through pipes, ducts, and plenums for all fluids	Above Reynolds number of 5000	1 to 5%	Discharge Coefficient and accuracy influenced by installation conditions.
Nozzle and Differential Pressure Measurement System	Flow through pipes, ducts, and plenums for all fluids	Above Reynolds number of 5000	0.5 to 2.0%	Discharge Coefficient and accuracy influenced by installation conditions.
Venturi Tube and Differential Pressure Measurement System	Flow through pipes, ducts, and plenums for all fluids	Above Reynolds number of 5000	0.5 to 2.0%	Discharge Coefficient and accuracy influenced by installation conditions.
Timing given Mass or Volumetric Flow	Liquids or gases; used to calibrate other flow meters	Any	0.1 to 0.5%	System is bulky and slow.
Rotameters	Liquids or gases	Any	0.5 to 5.0%	Should be calibrated for fluid being metered
Displacement Meter	Relatively small volumetric flow with high pressure loss	As high as 1000 cfm, depending on type	0.1 to 2.0% depending on type	Most types required calibration with fluid being metered.
Gasometer or Volume Displacement	Short-duration tests; used to calibrate other flow meters	Total flow limited by available volume of containers	0.5 to 1.0%	-
Thomas meter (Temperature rise of steam caused by Electrical Heating)	Elaborate setup justified by need for good accuracy	Any	1%	Uniform Velocity. Usually used with gases.
Element of Resistance to Flow and Differential Pressure Measurement System	Used for check where system has calibrated resistance element	Lower limit set by readable pressure drop	1 to 5%	Secondary reading depends on accuracy of calibration.
Turbine flow Meters	Liquids or gases	Any	0.25 to 2.0%	Uses electronic readout.
Single-or multipoint instrument for measuring velocity at specific point in flow	Primarily for installed air-handling systems with no special provision for flow measurement	Lower limit set by accuracy of velocity measurement instrumentation	2 to 10%	Accuracy depends on uniformity of flow and completeness of traverse. May be affected by disturbances near point of measurement.
Heat Input and Temperature: changes with Steam and Water coil	Check value in heater or cooler tests	Any	1 to 3%	
Laminar flow Element and Differential Pressure Measurement System	Measure liquid or gas volumetric flow rate. Nearly linear relationship with pressure drop. Simple and easy to use	0.0001 to 2000 cfm	1%	Fluid must be free of dirt, oil, and other impurities that could plug meter or affect its calibration.
Magneto hydrodynamic Flow Meter (Electromagnetic)	Measures electrically conductive fluids, slurries. Meter does not obstruct flow. No moving parts	0.1 to 10,000 gpm	1%	At present state of the art conductivity of fluid must be greater than 5 μmhos/cm.
Swirl Flow Meter and Vortex Shedding Meter	Measure liquid or gas flow in pipe. No moving parts	Above Reynolds number of 10"	1%	-

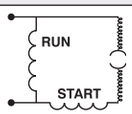
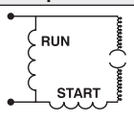
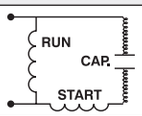
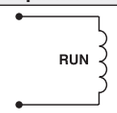
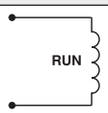
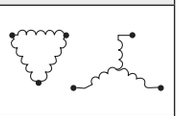
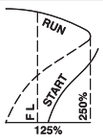
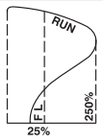
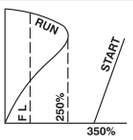
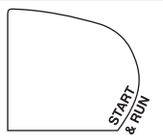
Table 8.6 : Motor and Motor Control Equipment Voltage (Alternate Current)

System Nominal Voltage	International Equipment Name plates voltage ratings			
	Three Phase	Single Phase	Three Phase	Single Phase
127	-	127	-	127
200	200/200	200	230/208 or 230/200	-
220	220/240	220/240 or 230/200	230/208 or 230 / 200	230 / 208
230	230/208	220.240 or 230/208	230/208 or 230.208	230.208
250	-	250	-	-
380	380/415	-	460/380	-
400	380/415	-	460/380	-
415	380/415	-	-	-
440	440	-	460	-
480	500	-	-	-

Hermetic's Motors

A Hermetic Motor usually consists of a stator and a rotor without shaft, end shields are bearings, with the motor and compressor sealed in a common chamber. Winding insulation system must be impervious to the action of refrigerants and lubricating oil. Hermetic motors are used in both welded and accessible hermetic / semi-hermetic versions.

Table 8.7: Characteristics of AC Motors (Non-hermetic)

	Split Phase	Permanent Split-Capacitor	Capacitor Start Indication-Run	Capacitor - Start Capacitor - Run	Shaded Pole	Three Phase
Connection Diagram						
Typical Speed Torque Curves						
Starting Method	Centrifugal switch	None	Centrifugal switch	Centrifugal switch	None	None
Ratings HP	0.05 to 0.5	0.05 to 0.1	0.125 to 5	0.125 to 5	0.01 to 0.25	0.5 and up
Approximate Full Load Speeds at 50 Hz. (2 pole, 4 pole)	2875/1438	2875/1438	2875/1438	2917/1458	2583/1292	2917/1458
Torque Rotor Breakdown	125 to 1510% 250 to 300%	30 to 150% 250 to 300%	250 to 350% 250 to 300%	250% 250%	25% 125%	150 to 350% 250 to 300%
Speed Classification	Constant	Constant	Constant	Constant	Or adjustable	Constant
Full Load Power Factor	60%	95%	65%	95%	60%	80%
Efficiency	Medium	High	Medium	High	Low	High-Medium
Source : ASHRAE 2012						

MOTOR STARTER

Motor Starters start, stop, protect, and control the motor. They sense motor current based on a time curve. The shorter the time, the more current they let through. They may also limit the number of motor starts in a given period of time so the motor does not exceed its ANSI rating. Another cause for concern is the starter's ambient temperature. If it is different from the ambient temperature around the motor controller, the thermal overloads need to be sized accordingly.

Several motor starter types are available, and they can function in several different ways. The direction line starter is the simplest but may disturb electric service because of high motor-starting current requirements. The part-winding reduces voltages, and Star Delta starters all act by reducing the starting voltage on the motor. Fan and pump loads can usually be started this way thereby reducing starting current draw and demand, but sacrifices motor starting speed. Soft-start starters also reduce the voltage and limit demand during starting, thereby causing stress on the electric system during motor starting. Variable-frequency drives (VFDs) are also used to soft-start a motor, and are designed to control acceleration during starting as well as optimise motor speed to its load.

A VFD converts ac to dc and then back to variable-frequency, variable-voltage ac. Motor speed is varied by varying frequency of the ac output voltage, typically using Pulse-Width Modulation (PWM). This power conversion process results in distorted input current and may contribute to building power system voltage distortion. When motors and other loads are supplied from a distorted voltage source their operating temperatures may rise.

Table 8.8 : Fuse Wire Table

Fusing Current Amps	Copper		Aluminum		Plated Tin		Tin		Alloy Tin		Lead	
	Dia in.	S.W.G (app.)	Dia in.	S.W.G (app.)	Dia in.	S.W.G (app.)	Dia in.	S.W.G. (app.)	Dia in.	S.W.G (app.)	Dia in.	S.W.G. (app.)
1	.0021	47	.0226	46	.0035	43	.0072	37	.0083	35	.0081	35
2	.0034	43	.0041	42	.0056	39	.0113	31	.0132	29	.0128	30
3	.0044	41	.0054	39	.0074	36	.0149	28	.0173	27	.0168	27
4	.0053	39	.0065	37	.0089	55	.0181	26	.0210	25	.0203	25
5	.0062	38	.0076	36	.0104	33	.0210	25	.0243	23	.0236	23
10	.0098	33	.0120	30	.0164	27	.0334	21	.0386	19	.0373	20
15	.0129	30	.0158	28	.0215	24	.0437	19	.0506	18	.0491	18
20	.0156	28	.0191	25	.0261	23	.0529	17	.0613	16	.0595	17
25	.0181	26	.0222	324	.0303	21	.0614	16	.0711	15	.0690	15
30	.0205	25	.0250	23	.0342	20	.0694	15	.0803	14	.0779	14
35	.0227	24	.0277	22	.0379	20	.0769	14	.0890	13	.0864	13
40	.0248	23	.0303	21	.0414	19	.0840	14	.0973	13	.0944	13
45	.0268	22	.0328	21	.0448	19	.0909	13	.1052	12	.1021	12
50	.0288	22	.0352	20	.0480	18	.0975	13	.1129	11	.1095	12
60	.0325	21	.0397	19	.0542	17	.1101	11	.1275	10	.1237	10
70	.0360	21	.0440	19	.0601	16	.1220	10	.1413	9	.1371	9
80	.0394	19	.0481	18	.0657	16	.1334	10	.1544	8	.1499	9
90	.0426	19	.0520	18	.0711	15	.1443	9	.1671	8	.162	8
100	.0457	18	.0558	17	.0762	14	.1548	8	.1792	7	.1739	7
120	.0516	17	.0630	16	.0861	13	.1748	7	.2024	6	.1964	6

Table 8.9 : Energy Limiting H.R.C Cartridge Fuse Links Direct on Line Start Squirrel Cage Induction Motors

Fuse Link Size Amps	Systems Line Voltage						
	200	380	480	415	440	500	550
	Motor hp	Motor hp	Motor hp	Motor hp	Motor hp	Motor hp	Motor hp
20	3	5	7.5	7.5	7.5	7.5	10
30	7.5	12.5	12.5	15	15	15	20
60	12.5	20	25	25	25	30	35
100	25	40	45	50	50	60	60
200	70	125	125	125	125	150	175
300	100	200	200	200	225	250	250
400	150	250	300	300	300	350	400
600	250	400	400	400	500	500	600
800	300	500	600	600	600	750	800
ASSISTED START							
20	5	12.5	12.5	12.5	15	15	15
60	10	15	20	20	20	25	25
100	20	40	40	45	45	50	60
120	40	60	70	75	80	90	100
200	80	125	125	150	150	175	200
300	125	200	225	225	225	250	300
400	150	250	300	300	300	350	400
600	250	400	400	400	500	500	600
800	300	500	600	600	600	750	800

CAPACITORS :
Fuse - Links for use of Capacitor circuits should be derated to approximately two-thirds of their current rating.

Table 8.10 : MCB (Current Limiters) Selection Chart Full load current/Recommended rating of MCBs

Load in KW	Motor Rating HP	Single Phase 240V	Motor DOL Starting Amps.	Three Phase 415V	Motor DOL Starting Amps.
0.04	0.05	0.4	1	0.135	0.5
0.075	0.1	0.75	1	0.25	0.5
0.11	0.125	0.99	1	0.3	0.5
0.12	0.15	1.20	1.6	0.4	0.5
0.15	0.2	1.5	1.6	0.49	0.5
0.18	0.25	1.76	2	0.585	1
0.23	0.33	2.25	3	0.75	1
0.4	0.5	3.35	4	1.1	1.6
0.55	0.75	4.43	6	1.48	1.6
0.75	1.0	5.28	6	2	2
0.92	1.25	6.48	6	2.16	3
1.1	1.5	7.17	10	2.5	3
1.5	2.0	9.65	10	2.5	4
2.25	3.0	13.63	16	5	6
3.0	4.0	18.4	20	6.5	6
3.75	5.0	22.4	25	7.5	10
4.5	6.0	30	32	11	16
5.5	7.5	32.5	32	11	16
7.5	10	42.75	40	14	16
9.3	12.5	-	-	18	20
11	15	-	-	21	20
13	17.5	-	-	24	25
15	20	-	-	28	32
18.5	25	-	-	35	40
22	30	-	-	40	40

MCBs FOR AIR CONDITIONERS

1	Ton capacity	-	10A
1.5	Ton Capacity	-	16A
2.	Ton Capacity	-	20A

Table 8.11 : CISM-M AND D50S-WP Rectangular Bus Bar: Mechanical And Electrical Characteristics

Size	Section Area (in.)	CIS-M D.C. Resistence (Max.) at 200C (microhms/ft)	D50S-WP D.C Resistence (Max) at 200 C (microhms/ft)	Resistance X at 1ft. Spacing at 50 c/s (micro. ft.)	Moment of inertia (In.)		Section Modulus (In.)		Radius of Gyration (In.)	
					Ix-x	Iy-y	Zx-x	Zy-y	Kx-x	Ky-y
1 x 1/4	0.250	54.30	59.24	72.0	0.021	0.001	0.042	0.008	0.289	0.072
11/2 x 1/4	0.375	36.20	39.49	65.6	0.070	0.002	0.094	0.016	0.434	0.072
2 x 1/4	0.500	27.15	29.62	60.7	0.167	0.003	0.167	0.024	0.578	0.072
2 x 1/4	0.625	21.72	23.72	56.8	0.326	0.003	0.260	0.026	0.723	0.072
3 x 1/4	0.750	18.10	19.75	53.6	0.563	0.004	0.375	0.031	0.867	0.072
4 x 1/4	1.000	13.58	14.81	48.6	1.333	0.005	0.667	0.042	0.156	0.072
5 x 1/4	1.250	10.86	11.85	44.5	2.604	0.007	1.042	0.052	1.445	0.072
6 x 1/4	1.500	9.05	9.87	41.0	4.500	0.008	1.500	0.063	1.734	0.072
2 x 3/8	0.750	18.10	19.75	59.7	0.250	0.009	0.250	0.048	0.577	0.108
3 x 3/8	1.125	12.07	13.16	053.1	0.844	0.013	0.563	0.070	0.867	0.108
4 x 3/8	1.500	9.05	9.87	48.0	2.000	0.018	1.000	0.094	1.156	0.108
5 x 3/8	1.875	7.24	7.99	44.0	3.906	0.022	1.563	0.117	1.445	0.108
6 x 3/8	2.250	6.04	6.58	40.9	6.750	0.026	2.250	0.141	1.734	0.108
8 x 3/8	3.000	4.52	4.94	35.8	16.000	0.036	4.000	0.187	2.312	0.108
3 x 1/2	1.500	9.05	9.87	52.1	1.125	0.031	0.750	0.125	0.867	0.145
4 x 1/2	2.000	6.79	7.40	47.5	2.667	0.042	1.333	1.067	1.156	0.145
5 x 1/2	2.500	5.43	5.92	43.6	5.208	0.052	2.083	1.208	1.445	0.145
6 x 1/2	3.000	4.52	4.94	40.4	9.000	0.063	3.000	0.250	1.734	0.145
8 x 1/2	4.000	3.39	3.70	35.3	21.330	0.083	5.332	0.332	2.312	0.145
10 x 1/2	5.000	2.71	2.96	29.5	41.670	0.104	8.334	0.416	2.890	0.145

Table 8.12 : D50S-W - Rectangular Bus Bar - Current Ratings

Size in	1 Bar		2 Bars		3 Bars		4 Bars	
	50 c/s		50 C/s		50 c/s		50 c/s	
	D.C	A.C	D.C	A.C	D.C	A.C	D.C	A.C
	AMPERES							
1x1/4	355	355	710	705	980	970	1120	1100
1x1/2x1/4	520	520	1030	1020	1380	1350	1585	1535
2x1/2 xl/4	670	670	1315	1290	1765	1705	2050	1940
3x1/4	970	960	1805	1740	2440	2310	2860	2620
4x1/4	1260	1235	2260	2140	3060	2800	3640	2300
5x1/4	1545	1505	2700	2510	3660	3240	4410	3700
6x1/4	1840	1780	3130	2860	4290	3680	5250	4240
2x1/2	840	830	1560	1500	2090	1970	2460	2260
3x3/8	1210	1180	2180	2050	2940	2660	3510	3030
4x3/8	1550	1495	2710	2480	3660	3150	4400	3560
5x3/8	1940	1860	3290	2930	4450	3660	5400	4200
6x3/8	2260	2120	3770	3340	5140	4080	6320	4680
8x3/8	2940	2750	4800	4150	6500	4900	8060	5740
3x 1/2	1405	1355	2450	2240	3290	2830	4000	3240
4x1/2	1830	1740	3100	2720	4170	3360	5100	3900
5x1/2	2230	2080	3720	3120	5040	3900	6170	4550
6x1/2	2620	2420	4300	3500	5850	4400	7200	5100
8x 1/2	3380	3060	5450	4450	7420	5300	9110	6150
10x 1/2	4080	3640	6500	5000	8860	6000	10900	6850

Table 8.13 : Aluminum Conductor Steel Reinforced Properties (A.C.S.R)

CONDUCTOR			ELECTRICAL PROPERTIES								MECHANICAL PROPERTIES					
COD NAME	Nominal Copper Area Equivalent Area		Calculated Area of Aluminium	Calculated Resistance at 20°C when corrected to Standard Wt. Ohm/km	Approx. Carrying 40°C Amp	Current Capacity 45°C Amp.	Standard & Wire Diameter (mm)				Conduct (-) or Diameter	Conductor Area	Approx. Weight KG/KM			Approx. Ultimate Strength
							Aluminium		Steel							
	mm²	SWG	mm²				No.	Dia	No.	Dia	mm	mm2	Total	Al	St	Kg.
MOLE	6.5	6	10.47	271800	-	-	6	1.50	1	1.50	4.50	12.37	43	29	14	407
SQUIRREL	13	6	20.71	137400	115	107	6	2.11	1	2.11	6.33	24.48	85	58	27	771
GOPHER	16	7	25.91	109800	133	123	6	2.36	1	2.36	7.08	30.62	106	72	34	952
WEASEL	20	6	31.21	091160	150	139	6	2.59	1	2.59	7.77	36.68	128	87	41	1126
FERRET	25	4	41.57	067950	181	164	6	3.00	1	3.00	9.00	49.48	171	116	55	1503
RABBIT	30	3	52.21	054490	206	193	6	3.35	1	3.35	10.05	61.70	214	145	69	1860
MINK	40	2	62.32	045660	234	217	6	3.66	1	3.66	10.98	73.65	255	173	82	2207
HORSE	42	-	71.58	039770	-	-	12	2.79	7	2.79	13.95	116.20	542	204	338	6108
BEAVER	45	1	74.07	038410	261	242	6	3.99	1	3.99	11.97	87.53	303	205	96	2613
RACCOON	48	1/2/0	77.83	036560	270	250	6	4.09	1	4.09	12.27	91.97	318	215	103	2746
OTTER	50	1/0	82.85	034340	281	260	6	4.22	1	4.22	12.66	97.91	339	230	109	2923
CAT	55	11/2/0	94.21	030200	305	283	6	4.50	1	4.50	13.50	111.30	385	261	124	3324
DOG	65	2/0	103.60	027450	324	300	6	4.72	7	1.57	14.16	118.50	394	288	106	3299
LEOPARD	80	4/0	129.70	021930	375	348	6	5.28	7	1.76	15.84	148.00	493	360	133	4137
COYOTE	80	4/0	128.50	022140	375	348	26	2.54	7	1.90	15.86	151.60	521	365	156	4638
TIGER	80	4/0	126.10	022210	382	354	30	2.36	7	2.36	16.52	161.80	604	363	241	5758
WOLF	95	5/0	154.30	018440	430	396	30	2.59	7	2.59	18.13	195.00	727	436	291	6880
LYNX	110	6/0	179.00	015890	475	440	30	2.79	7	2.79	19.53	226.20	844	506	338	7950
PANTHER	130	7/0	207.00	013750	520	482	30	3.00	7	3.00	21.00	261.10	976	586	390	9127
LION	140	-	232.50	012230	555	515	30	3.18	7	3.18	22.26	293.90	1097	659	438	10210
BEAR	160	-	258.10	011020	595	552	30	3.35	7	3.35	23.45	326.10	1219	734	485	11310
GOAT	185	-	316.50	008989	680	630	30	3.71	7	3.71	25.97	400.00	1492	896	596	13780
SHEEP	225	-	366.10	007771	745	690	30	3.99	7	3.99	27.93	462.60	1726	1036	690	15910
KUNDAH	250	-	394.40	007434	-	-	42	3.50	7	1.94	26.82	424.80	1282	1120	162	9002
DEER	260	-	419.30	006786	806	747	30	4.27	7	4.27	29.69	529.80	1977	1188	789	18230
ZEBRA	260	-	418.60	006800	795	736	54	3..18	7	3.18	28.62	484.50	1623	1185	438	13316
ELK	300	-	465.70	006100	860	796	30	4.50	7	4.50	31.50	588.40	2196	1320	876	20240
CAMEL	300	-	464.50	006125	-	-	54	3.35	7	3.35	30.15	537.70	1804	1318	486	14750
MOOSE	325	-	515.70	005517	900	835	54	3.53	7	3.53	31.77	597.00	2002	1463	539	16250
MORKULLA	330	-	549.20	005182	-	-	42	4.13	7	4.13	31.68	591.70	1790	1564	226	12236
SPARROW	20	6	33.16	085780	-	-	6	2.67	1	2.67	8.01	39.22	135	92	43	1203
FOX	22	6	36.21	078570	165	135	6	2.79	1	2.79	8.37	42.92	149	101	48	1303
GUINEA	49	1/0	78.56	036200	-	-	12	21.92	7	2.92	14.60	127.20	590	224	336	6664
LARK	125	-	196.10	014510	-	-	30	2.92	7	2.92	29.44	247.80	922	556	366	8659

Table 8.14 : All Aluminum (Standard) Conductors Properties (A.A.C)

Nominal Copper Area mm^2	Calculated Equivalent Area of Aluminum mm^2	Calculated Resistance at 20°C when corrected to Standard Weight Ohm / km	Approx Current Carrying Capacity Amp.		Strand Wire Diameter		Conductor Diameter	Conductor Area	Approx. Weight	Approx Ultimate Strength	Calculated coefficient of Linear Expansion	Calculated Final Modulus of Elasticity $Kg/cm^2\ 10^{-6}$
			40°C Temp	45°C Temp	No.	Dia (mm)	mm	mm^2	Kg/km	Kg.	$Cx10^{-6}$	
7.5	12.23	2.32600	-	-	7	1.50	4.50	12.37	34	220	23.0	0.6187
13	20.89	1.36200	-	-	7	1.96	5.88	21.22	58	385	23.0	0.6187
16	26.56	1.07100	-	-	7	2.21	6.63	26.85	73	485	23.0	0.6187
20	32.37	0.87870	-	-	7	2.44	7.32	32.73	89	580	23.0	0.6187
25	42.33	0.67210	178	165	7	2.79	8.37	42.80	117	737	23.0	0.6187
30	52.26	0.54440	204	189	7	3.10	9.30	52.84	144	892	23.0	0.6187
40	62.86	0.45260	229	212	7	3.40	10.20	63.55	174	1051	23.0	0.6187
45	72.84	0.39060	252	234	7	3.66	10.95	73.65	201	1203	23.0	0.6187
48	77.70	0.36620	264	245	7	3.78	11.34	78.55	215	1272	23.0	0.6187
50	83.13	0.34220	272	255	7	3.91	11.73	84.05	230	1356	23.0	0.6187
60	94.56	0.30090	298	276	7	4.17	12.51	95.60	251	1523	23.0	0.6187
65	104.80	0.27150	318	295	7	4.39	13.17	106.00	290	1673	23.0	0.6187
80	132.20	0.21520	-	-	19	3.00	15.00	134.30	369	2228	23.0	0.6082
90	148.50	0.19160		-	19	3.18	15.90	150.90	414	2484	23.0	0.6082
110	183.00	0.15550	460	386	19	3.53	17.65	186.00	511	2985	23.0	0.6082
130	209.90	0.13560	504	468	19	3.78	18.90	213.20	586	3381	23.0	0.6082
140	233.60	0.12170	540	500	19	3.99	19.95	237.60	652	3736	23.0	0.6082
160	261.50	0.10880	575	534	19	4.22	21.10	265.80	730	4144	23.0	0.6082
185	317.50	0.08959	655	608	19	4.65	23.25	322.70	886	4947	23.0	0.6082
225	367.20	0.07749	720	660	19	5.00	25.00	373.10	1025	5695	23.0	0.6082
260	421.90	0.06743	790	734	19	5.36	26.80	428.70	1175	6516	23.0	0.6082
300	473.60	0.05982	850	790	37	4.09	28.63	486.10	1343	7289	23.0	0.5976
325	518.40	0.05488	895	830	37	4.27	29.89	529.80	1464	7878	23.0	0.5976
20	33.45	0.85060	-	-	7	2.48	7.44	33.81	92	582	23.0	0.6187
25	42.02	0.67700	-	-	7	2.78	8.34	42.49	116	730	23.0	0.6187

Table 8.15 : Aluminum Strips Weight (Appx.) in K.G. per 12 RFT

Width (in.)	Width (mm)	1/8" 3.2mm	3/16" 4.76mm	1/4" 6.4mm	3/8" 9.53mm	1/2" 12.7mm
1 inch or	25.4 mm	0.820	1.200	1.600	2.300	3.200
1 1/4 "	31.8mm	1.000	1.600	2.000	3.200	4.000
1 1/2"	38.1 mm	1.300	-	2.400	3.500	4.800
1 3/4"	44.5 mm	1.400	-	2.800	-	-
2"	50.8 mm	-	-	3.200	4.800	6.400
3"	63.5 mm	-	-	4.000	6.000	8.000
4"	76.2 mm	-	-	4.800	6.000	9.500
5"	101.6mm	-	-	6.500	-	13.000
6"	127.0mm	-	-	-	-	16.600
7"	152.4mm	-	-	9.900	-	19.800
8"	203.2 mm	-	-	-	19.00	-

Table 8.16 : Recommended Cable Sockets (Tinned Copper) For Aluminum Conductor

Aluminum Conductor			Recommended		Cable Socket	
Area mm^2	Standard in mm	Overall Diameter mm	B.S. Ref. Number	Amp	Bore Diameter mm	Outside Diameter mm
	1/2.80	2.80	4EL	30	6.2	8.0
	1/3.55	3.55	4EL	30	6.2	8.0
16	7/1 .70	5.10	7EL	60	9.5	11.4
25	7/2.24	6.72	10EL	100	11.9	13.9
35	7/2.50	7.50	10EL	100	11.9	13.9
50	7/3.00 10/1.80	9.00	1 1 EL	150	14.3	17.2
70	19/2.24	11.20	11 EL	150	14.3	17.2
95	19/2.50	12.50	13EL	200	16.7	19.9
120	37/2.06	14.42	14EL	300	20.6	24.3
150	37/2.24	15.68	14EL	300	20.6	24.3
185	37/2.50	17.50	14EL	300	20.6	24.3
225	37/2.80	19.60	5EL	400	23.8	27.8
240	37/3.00	21.00	5EL	400	23.8	27.8
300	61/2.50	22.50	17EL	500	26.2	31.5
400	61/3.00	27.00	18E	-	31.8	40.9
500	61/3.25 91/2.65	29.25 29.15	18E	-	31.8	40.9
625	91.3.00	33.00	20E	-	30.6	46.3
B.S. 91: 1954* these are current ratings of the sockets and should not be taken as aluminum conductor current ratings.						

Table 8.17 : Starting Torques and Currents

Method of Starting	Direction Line	Star Delta	Auto Transformer		
			30%	60%	75%
% Line Voltage	100	58	50	60	75
% Full Load Current	500	170	125	180	280
% Full Load Torque	125	42	32	45	70

Table 8.18 : Comparison of Starters

Type of Starter	Percent Tap	Starting Characteristics (Percent of rated value)					Advantages	Limitations
		Voltage at Motor	Motor Current	Line Current	Torque	Torque Efficiency		
REDUCED VOLTAGE								
Auto Transformer	80	80	80	64	64	100	1. Starting characteristics easily adjusted. 2. Provides maximum torque per line ampere for reduced voltage starters (high torque efficiency). 3. Closed transition starting	1. Additional external voltage reducing component impose additional limits to daily cycle.
(Closed Transition Standard	65 50	65 50	65 50	42 25	42 25	100 100		
REDUCED CURRENT INRUSH								
Star Delta (Open or closed Transition)		100	33	33	33	100	1. Starting daily cycle usually limited by motor heating only. 2. High torque efficiency for all speeds. 3. No torque dips or unusual stresses because full winding energized. 4. Closed circuit transition type eliminates line surges during transition from start to run.	1. Starting characteristics not adjustable. 2. Requires motor v normally delta winding with all brought out for connection to control.

Table 8.19 : Ready Reckoner for DOL start Motors - 415 V. 3phase, 50 Hz

Motor Rating		Full Load Current - Amps	Overload Relay Range - Amps	Recommended Backup HRC Fuse -Amps	Recommended Switchgear Rating - Amps	Recommended Cable size -Sq. mm	
HP	KW					Al	Cu
0.5	0.37	1	1.0-1.6	4	16	4	2.5
0.75	0.55	1.4	1-2	6	16	4	2.5
1	0.75	2	1.5-2.5	6	16	4	2.5
1.5	1.1	2.6	2.5-4	10	16	4	2.5
2	1.5	3.5	2.5-4	16	16	4	2.5
3	2.2	4.8	4-6.5	16	16	4	2.5
5	3.7	7.5	6-10	25	32	6	4
7.5	5.5	11	9-14	25	32	6	4
10	7.5	14	10-16	35	63	6	4
12.5	9.3	18	13-21	35	63	10	6
15	11	22	18-24	50	63	10	6
20	15	28	20-32	63	63	10	6
25	18.5	35	28-42	80	100	16	10
30	22	40	28-42	100	100	16	10

Table 8.20 : Ready Reckoner for Star Delta start Motors - 415 V. 3phase, 50 Hz

Motor Rating		Full Load Current		Overload Relay Range - Amps.	Recommended Backup HRC Fuse - Amps	Recommended Switchgear Rating - Amps	Recommended Cable size - Aluminium Sq. mm	
HP	KW	Line Amps	Phase Amps				Supply Side	Motor Side
10	7.5	15	9	6-10	25	32	4	2.5
12.5	9.3	18	10.4	9-14	35	63	6	4
15	11	22	12.7	10-16	35	63	6	4
20	15	29	16.8	13-21	63	63	10	6
25	18.5	35	20.2	18-24	50	63	16	6
30	22.5	40	23	20-32	63	125	16	6
35	26	47	27	20-32	63	125	25	10
40	30	53	30.6	20-32	63	125	25	10
45	33.5	60	36	28-42	100	250	35	16
50	37	66	38	28-42	100	250	35	16
60	45	80	46	45-70	125	250	50	25
75	55	100	57	45-70	160	250	70	35
90	67.5	120	69	60-100	200	250	95	50
100	75	135	78	60-100	200	250	95	50
125	90	165	95	90-150	250	300	150	70
150	110	200	115	90-150	250	400	185	95
175	130	230	133	120-200	320	400	240	120
200	150	275	159	120-200	350	400	240	120

Table 8.21 : Recommended Capacitor Ratings

For direct connection to Induction Motors to improve power factor to 0.95 or better at all loads

Motor HP	KVAR Ratings when Motor speed is				
	3000 rpm	1500 rpm	1000 rpm	750 rpm	500 rpm
2.5	1	1	1.5	2	2.5
5	2	2	2.5	3.5	4
7.5	2.5	3	3.5	4.5	5.5
10	3	4	4.5	5.5	6.5
15	4	5	6	7.5	9
20	25	30	40	50	60
25	6	7	9	10.5	14.5
30	7	8	10	12	17
40	9	10	13	15	21
50	11	12.5	16	18	25
60	_13	14.5	18	20	28
70	15	16.5	20	22	31
80	17	19	22	24	34
90	19	21	24	26	37
100	21	23	26	28	40
110	23	25	28	30	43
120	25	27	30	32	46
130	27	29	32	34	49
140	29	31	34	36	52
145	30	32	35	37	54
150	31	33	36	38	'55
155	32	34	37	39	56
160	33	35	38	40	57
165	34	36	39	41	59
170	35	37	40	42	60
175	36	38	41	43	61
180	37	39	42	44	62
185	38	40	43	45	63
190	38	40	43	45	65
200	40	42	45	47	67
250	45	50	55	60	70

Selection of Power Cables

Power cables are generally selected considering the application. However, following parameters play an important role :

1) Maximum operating voltage 2) Insulation level 3) Frequency 4) Load to be carried
5) Possible overloading duration & magnitude 6) Route length and Voltage drop
7) Mode of insulation considering installation environment such as ambient & ground temperature, chemical & physical properties of soil 8) Flame retardant properties 9) Plant safety requirements

Table 8.22 : AC Current Rating of Paper Insulated Power Cables

Nominal Area of conductor	Unarmored 3 Single Core Touching			3 CORE UNARMOURED AND UNARMOURED CABLE						3 CORE UNARMOURED AND UNARMOURED CABLE					
				Belted Cable			Screened Cable			Belted Cable			Screened Cable		
mm^2	Ground Amp	Duct Amp	Air Amp	Ground Amp	Duct Amp	Air Amp	Ground Amp	Duct Amp	Air Amp	Ground Amp	Duct Amp	Air Amp	Ground Amp	Duct Amp	Air Amp
16	63	62	66	55	50	50	60	51	59	58	49	50	61	54	59
25	78	82	88	72	64	65	73	66	77	72	64	68	80	65	77
35	93	96	105	84	77	79	92	77	93	84	74	80	95	80	93
50	115	115	130	105	94	100	115	94	115	105	92	100	115	100	115
70	140	140	165	130	115	125	140	115	140	130	115	125	140	125	140
95	165	165	200	155	135	155	165	135	175	155	135	155	165	145	175
120	185	185	230	170	150	175	185	155	200	170	155	175	185	160	200
150	210	205	265	190	170	200	210	175	230	190	175	200	205	180	230
185	240	230	300	220	195	230	245	200	265	220	200	230	235	210	265
225	260	250	340	240	210	260	270	225	280	240	220	260	260	235	280
240	270	260	355	260	235	275	285	235	315	250	225	275	275	240	310
300	305	285	400	300	265	315	310	265	355	280	250	310	300	265	345
400	355	335	490	345	300	375	360	320	405	320	285	365	340	305	395
500	395	365	570	385	330	425	405	350	460	360	310	415	385	330	450
625	445	410	670	410	365	480	435	390	520	385	345	470	410	370	510
800	495	455	750	-	-	-	-	-	-	-	-	-	-	-	-
1000	550	495	820	-	-	.	-	-	-	-	-	-	-	-	-

Note : The current ratings tabulated above are based on current ratings of cables published by Indian Standards Institution IS:3 961 (Part 1) 1967 and are subject to the following assumptions:
Thermal Resistivity of soil - 150 ohm/cm Ambient Air Temperature - 40°C Ground Temperature - 30°C Depth of Laying - 900 mm

Table 8.23 : Estimated Current Ratings for Copper and Aluminum Conductor, Vulcanized Rubber P.V.C. or Polythene Insulated Cables (Single, Twin, Three and Four Core)

Standard COPPER Conductor			Continuous Current Rating (Subject to Voltage Drop)				Standard Aluminum Conductor		
			Air or open trench						
Item	Area Sq. Inches)	Strand / Dia Inches	In conduit, Troughing or Casing (2 Single Core Cables amp.	2 Single Core Cables Amp.	3 or 4 Single Cables Amp	One/twin Core DC or AC Amp.	One 3 or 4 Core Cable Balanced 3 phase Amp.	Area (Sq. Inch)	Strand (mm)
1	2	3	4	5	6	7	8	9	10
1	.0015	1/.044	5	5	5	5	5	-	-
2	.002	3/.0299	10	10	10/9	10	8/7	1.5	1/1.40
3	.003	3/.036	15	15	13/12	15	10/11	2.5	1/1.80
4	.0045	7/.029	20	20	15	20	15	-	-
5	-	-	20	20	17	20	14	4	1/2.24
6	-	-	27	27	24	27	19	6	1/2.80
7	.0076	7/.036	28	28	25	28	20	-	-
8	-	-	34	34	31	34	24	10	1/3.55
9	.01	7/.044	36	36	32	36	25	-	-
10	.0145	7/.052	43	43	39/38	43	30	16	7/1.70
11	.0225	7/.064	53	53	48	53	34	-	-
12	-	-	59	59	54	59	42	25	7/2.24
13	.03	19/.044	62	62	56	62	43	-	-
14	-	-	69	69	62	69	48	35	7/2.50
15	.04	19/.052	74	74	67	74	52	-	-
16	-	-	91	91	82	91	62	50	7/3.00 19/1.80
17	.06	19/.064	-	97	88	97	68	-	-
18	.075	19/.072	-	123	107	115	78	-	-
19	-	-	-	134	118	118	82	70	19/2.24
20	-	-	-	135	138	135	94	95	19/2.50
21	.1	19/.083	-	160	140	140	98	-	-
22	.12	37/.064	-	177	158	158	109	-	-
23	-	-	-	184	170	162	114	120	37/2.06
24	.15	37/.072	-	205	185	180	126	-	-
25	-	-	-	210	185	181	127	150	37/2.24
26	-	-	-	246	216	209	146	185	37/2.50
27	.2	37.083	-	250	220	218	153	-	-
28	-	-	-	290	248	240	169	225	37/2.80
29	.25	37/.093	-	293	260	252	178	-	-
30	.3	37/.103	-	335	295	284	199	-	-
31	-	-	-	354	302	289	201	300	61/2.50
32	.4	61/.093	-	425	360	342	240	-	-
33	-	-	-	435	372	-	400	-	61/3.00
34	.5	61/.103	-	480	410	-	-	-	-
35	-	-	-	480	411	-	-	500	91/2.65
36	-	-	-	566	484	-	-	625	91/3.00
37	.75	91/.103	-	610	520	-	-	-	-
38	1.0	127/.103	-	740	630	-	-	-	-

Ratings at Ambient Temperature 30°C.

For Ambient Temperature other than 30°C the current ratings should be multiplied by the following ratings factors:

Rating Factor	- 25°C	35°C	40°C	45°C
	1.13	.86	.69	.49

In the above Table, current ratings (subject to voltage drop) have been given for Copper Conductor Cables (in conventional British Standard Sizes) and also for the Cables with Aluminum Conductors (in the now metric sizes as per I.S. 1753-1961). From this chart the required size of Aluminum Conductor can be established if either the Current Rating or the size of the Copper Conductor is known.

To establish the size of the Aluminum conductor against your requirement, read off the Current Rating for the conventional Copper Conductor Cable (say 7/.064) and select the Conductor size from the last two columns (25 sq.mm.) which has a current rating equal to or nearest to that of the Copper Conductor Cable.

Table 8.24 : Current Ratings And Rating Factors For PVC Cable : Current Ratings of Single, Twin and Multi-Core PVC Heavy Duty Cables 650-1100 V (Aluminum Conductors)

Nominal Area of Conductor sqmm	Single Core Cables				Twin & Multi-core Cables			
	Laid direct in ground		In air		Laid direct in ground		In air	
	2 Cables Amp.	3 Cables Amp.	2 Cables Amp.	3 Cables Amp.	Twin Core Amp	3, 3 1/2, 4 Core Amp.	Twin Core Amp	3.37.4 Core Amp
1.5	-	-	-	-	18	16	16	13
2.5	-	-	-	-	25	21	21	18
4	36	31	32	27	32	28	27	23
6	44	39	41	35	40	32	35	30
10	59	51	56	47	55	46	47	40
16	75	66	72	64	70	60	59	51
25	97	86	99	84	90	76	78	70
35	120	100	120	105	110	92	99	86
50	145	120	150	130	135	110	125	105
70	170	140	185	155	-	135	-	130
95	205	175	215	190	-	165	-	155
120	230	195	240	220	-	185	-	180
150	265	220	270	250	-	210	-	205
185	300	240	305	290	-	235	-	240
225	325	260	340	325	-	265	-	270
240	335	270	350	335	-	275	-	280
300	370	295	395	380	-	305	-	315
400	410	325	455	435	-	335	-	375

Table 8.25 : XLPE (Cross-Linked Polyethene) Cables Current Ratings for 6.6,11 and 22 KV. Single / Multi-core Armored / Unarmored Cables Aluminum Conductors

Conductor for Area	For Single Core (3 Phase System) Cables								For Multi-core Cables	
			In Ground		In Air					
	Laid	Flat	Laid	Trefoil	Laid	Flat	Laid	Trefoil	In Ground	In Air
sq.mm.	A	A	A	A	A	A	A	A	A	A
25	115	115	100	100	115	120	105	105	95	95
35	135	135	125	125	145	150	130	130	115	115
50	155	160	145	145	175	180	165	155	140	140
70	195	200	180	185	215	225	200	200	165	175
95	230	230	215	215	265	270	240	240	185	200
120	255	265	240	245	300	315	275	280	205	230
150	285	300	275	275	335	360	315	325	235	265
185	315	335	300	310	375	410	360	365	275	310
240	355	390	350	355	440	485	415	430	305	345
300	395	435	390	400	495	555	480	495	340	395
400	450	515	460	470	580	670	580	590	405	460
500	500	560	515	530	640	780	660	680	-	-
630	545	650	570	595	715	885	750	780		
800	615	740	650	670	805	1020	850	890		
1000	675	825	720	745	900	1155	950	1010		
Continuous Current Ratings of XLPE Cables Basic Assumption : The Current ratings of XLPE cables are based on the following assumptions and calculated in accordance with the recommendations of IEC 287.										

Table 8.26 : Earthing Ready Reckoner : Equipment Earthing - Size of Earth Lead (Transformer, Motors, Generators, Switchgears Etc.)

Rating of Equipment (3 Ph. 5 Hz.) in KVA	SIZE OF EARTHING CONDUCTOR	
	Bare Copper Conductor	G.I. Conductor
UPTO5	14SWG	8 SWG
6 to 15	10SWG	8 SWG
16 to 50	10SWG	25 x 3 mm
51 to 75	8SWG	25 x 3 mm
76 to 100	6SWG	25 x 3 mm
101 to 125	4SWG	25x6 mm
126 to 150	2 SWG or 25x3 mm	25 x 6 mm
151 to 200	2 SWG or 25x3 mm	40 x 6 mm
201 & above	25x6	50 x 6 mm
Note : *Three phase equipments should be earthed using 2 runs of Earthing Conductor		

Table 8.27 : Current Ratings for Copper Conductor Vulcanized Rubber Insulated Flexible Cables to IS 434

Nominal Cross Sectional Area	No. and Diameter of Wires	250 / 440V Grade				650 /1100V Grade				No. and Diameter of Wires	Nominal Cross Sectional Area
		Single Core	Twin	Three Core	Four Core	Single Core	Twin	Three Core	Four Core		
Sq. mm	mm	Amp.	Amp.	Amp.	Amp.	Amp.	Amp.	Amp.	Amp.	mm	Sq. mm
6	85/.300	55	44	38	34	55	45	38	36	85/.300	6
10	62/.450	77	60	52	47	75	60	52	47	62/.450	10
16	101/.450	105	82	70	64	100	80	70	64	101/.450	16
25	157/.450	140	105	91	82	130	105	92	83	157/.450	25
35	220/.450	170	130	110	100	160	130	120	100	220/.450	35
50	314/.450	220	160	140	130	205	160	140	125	314/.450	50
70	158/.750	-	-	-	-	250	200	175	155	158/.750	70
95	215/.750	-	-	-	-	300	240	205	190	215/.750	95
120	272/.750	-	-	-	-	345	270	240	220	272/.750	120
150	340/.750	-	-	-	-	415	320	285	260	340/.750	150
185	419/.750	-	-	-	-	465	360	315	295	419/.750	185
240	543/.750	-	-	-	-	540	420	365	340	543/.750	240
300	679/.750	-	-	-	-	640	495	435	400	679/.750	300
400	905/.750	-	-	-	.	770	-	-	-	905/.750	400
Note: Alternative conductor constructions are allowed for flexible cables in I.S. 434 and the above ratings are values for the different constructions.											

Table 8.28 : Overload Relay Selection

Motor & 415V	Rating 3 Phase	Full Load Current (Approx)	Relay Scale	Back-up fuse recommended	
HP	KW	AMPS		HRC (Amps,)	Rewirable (SWG.)
0.05	0.04	0.175	0.15-0.25	1	-
0.10	0.075	0.28	0.25-0.40	2	-
0.125	0.11	0.40	0.25-0.40	2	-
0.15	0.12	0.45	0.40-0.65	4	35
0.20	0.15	0.57	0.4-0.65	4	35
0.25	0.18	0.70	0.6-1.0	4	35
0.33	0.23	0.88	0.6-1.0	6	32
0.50	0.40	1.20	1.0-1.6	6	32
0.75	0.55	1.6	1.5-2.5	6	32
1.00	0.75	2.0	1.5-2.5	6	25
1.25	0.92	2.1	1.5-2.5	10	25
1.50	1.10	2.5	2.54.0	10	25
1.75	1.30	3.0	2.5-4.0	15	25
2.00	1.50	3.5	2.5-4.0	15	25
2.50	1.80	4.8	4.0-6.5	15	25
3.00	2.25	5.0	4.0-6.5	15	25
4.0	3.00	6.2	4.0-6.5	20	23
5.0	3.75	7.5	6.0-10.0	20	23
6.0	4.50	9.0	6.0-10.0	25	21
7.5	5.50	11.0	9.0-14.0	25	21
Recommended use of accurate and non-deteriorating HRC Fuse.					

Table 8.29 : Current Capacity and Size of Cables for Distribution Transformers

Distribution Transformer KVA	Full load current 400 Volts Side	Size of PVC Cable Aluminum
	Amps.	Sq. mm
1	1.44	4x2.5
10	14.40	4x4
25	39.10	4x10
50	72.2	4x16
75	108.3	3 1/2 x 35
100	144.4	3 1/2 x 50
200	289.3	31/2 x185
300	433.0	3 1/2 x 300
500	800	3 1/2 x 500

Table 8.30 : Metric Wire Approximate Weights and Lengths

Dia. inch	Diameter mm	Cross Section Area/ sq.mm	Copper		Steel		Aluminum		Diam-eter mm	Nearest S.W.G. Gauge No	Nearest A.W.G. Gauge No.	Nearest R.W..G. Gauge No.	Nearest Thick Wire Gauge
			M/Kg	Kg / 1000 Mtr	M/Kg	Kg / 1000 Mtr	M/Kg	Kg / 1000 Mtr					
0.1969	5.00	19.6375	5.73	174.50	6.46	154.70	18.87	53.00	5.00	6		6	
0.1772	4.50	15.9063	7.07	141.40	7.96	125.30	23.29	42.94	4.50	7		7	
0.1575	4.00	12.5680	8.95	111.70	10.10	99.02	29.48	33.92	4.00	8	6	8	43
0.1398	3.55	9.8992	11.36	88.00	12.82	88.01	37.41	26.73	3.55	9	7	9	42
0.1240	315	7.7941	14.44	69.26	16.29	61.39	47.45	21.03	3.15	10	8	11	40
0.1102	2.80	6.1583	18.27	54.72	20.61	48.51	60.20	16.61	2.80	11	9	12	38
0.0984	2.50	4.9093	22.92	43.62	25.86	38.67	75.53	13.24	2.50	12	10	13	35
0.0882	2.24	3.9413	28.55	35.02	32.22	31.04	94.07	10.63	2.24	13	11	14	30
0.0787	2.00	3.1420	35.82	27.92	40.40	24.75	117.90	8.479	2.00	14	11	14	30
0.0709	1.80	2.5450	49.20	22.62	44.85	20.06	145.50	6.873	1.80	15	13	15	29
0.0630	1.60	2.0109	55.96	17.87	63.13	15.84	182.7	5.427	1.60	16	14	16	26
0.0551	1.40	1.5396	73.10	13.68	82.51	12.12	240.9	4.151	1.40	17	15	17	24
0.0492	1.25	1.2273	91.74	10.90	103.5	9.662	302.1	3.310	1.25	18	16	18	22
0.0441	1.12	0.98533	114.2	8.756	128.8	7.762	376.0	2.659	1.12		17	19	20
0.0394	1.00	0.78550	143.2	6.980	161.6	6.1	471	2.119	1.00	19	18		18
0.03543	0.90	0.63625	176.9	5.653	199.5	5.011	582.7	1.716	0.90	20	19	20	16
0.03150	0.80	0.50272	223.8	4.467	252.5	3.960	737.4	1.386	0.80	21	20	21	14
0.02795	0.71	0.39597	284.3	3.518	320.7	3.118	936.3	1.068	0.71	22	21	22	12
0.02480	0.63	0.31176	361.1	2.769	407.5	2.454	1,189	0.8410	0.63	23	22	23	10
0.02205	0.56	0.24633	454.9	2.189	515.5	1.940	1,504	0.6648	0.58	24	23	24	9
0.01969	0.50	0.19637	573.0	1.745	683.3	1.547	1,886	0.5300	0.50	25	24	25	8
0.01772	0.45	0.15906	707.4	1.413	798.7	1.252	2,330	0.4291	0.45	26	25	26	7
0.01575	0.40	0.12568	895.2	1.117	1,009	0.9902	2,948	0.3392	0.40	27	26	27	6
0.01398	0.355	0.98992	1,136	0.8799	1,282	0.7800	3,742	0.2672	0.355	29	27	28	
0.01240	0.315	0.77941	1,444	0.6923	1,629	0.6137	4,755	0.2103	0.315	30	28	30	
0.01102	0.280	0.061583	1,827	0.5473	2,061	0.4851	6,016	0.1662	0.280	32	29		
0.00984	0.250	0.049094	2,293	0.4360	2,857	0.3865	7,552	0.1324	0.250	33	30	31	
0.00882	0.224	0.039413	2,854	0.3503	3,220	0.3105	9,398	0.1064	0.224	34	31	32	
0.00787	0.200	0.031420	3,582	0.2792	4,040	0.2475	11,792	0.0848	0.200	36	32	33	
0.00709	0.180	0.025450	4,419	0.2263	4,985	0.2006	14,556	0.0687	0.180	37	33	34	
0.00630	0.160	0.020109	5,596	0.1797	6,313	0.1584	18,416	0.0543	0.160	38	34		
0.0055	0.140	0.015396	7,315	0.1367	8,257	0.1211	24,096	0.0415	0.140	39	35		
	0.125	0.012273	9,174	0.1090	10,351	0.0966	30,211	0.0331	0.125	40	36	36	
0.00441	0.112	0.009853	11,420	0.0875	12,903	0.0775	37,593	0.0266	0.122	41	37		
0.00394	0.100	0.007855	14,320	0.0698	16,181	0.0618	47,169	0.0212	0.100	42	38	38	
0.00354	0.090	0.006362	17,699	0.0565	20,000	0.0500	58,139	0.0172	0.090	43	39		
0.00315	0.080	0.005027	22,371	0.0447	25,252	0.0396	73,529	0.0136	0.080	44	40		
0.00280	0.071	0.003959	28,409	0.0352	32,051	0.0312	98,457	0.0107	0.071	45	41		
0.00248	0.063	0.003117	36,101	0.0277	40,816	0.0245	119,047	0.0084	0.063	46	42		
0.00220	0.056	0.002463	45,662	0.0219	51,548	0.0194	149,253	0.0067	0.058		43		
0.00200	0.050	0.001964	57,143	0.0175	65,416	0.0155	188,600	0.0053	0.050	47	44		
0.00177	0.045	0.001590	70,922	0.0141	80,000	0.0125	232,000	0.0043	0.045		45		
0.00158	0.040	0.001257	89,286	0.0112	101,000	0.0099	294,000	0.0034	0.040	48	46		
0.00142	0.036	0.001018	109,890	0.0091	125,000	0.0080	370,000	0.0027	0.038		47		
0.00126	0.032	0.000804	140,845	0.0071	158,700	0.0063	454,500	0.0022	0.032	49	48		
0.00110	0.028	0.000616	185,185	0.0054	204,000	0.0049	588,000	0.0017	0.028		49		
0.00098	0.025	0.000491	232,558	0.0043	263,000	0.0038	769,000	0.0013	0.025	50	50		

Conversions

Meters x 3.28 = Feet Pounds x 0.4536 = Kilos

Feet x 0.3048 = Meters Sq. mm x 0.0015 = Sq. Ins

Kilo x 2.205 = Pounds Sq. Ins. x 645.15 = Sq.mm

Table 8.31 : Capacities of PVC Conductors

Cable Size	Conductor Size and Gauge			
Nominal Conductor Size mm²	16mm or 5/8 in.	20 mm or 3/4 in.	25 mm or 1 in.	32 mm or 1 1/4 in.
1.0	6	9	19	30
1.5	5	8	18	26
1.5	5	7	15	24
2.5	4	6	13	21
2.5	3	5	11	17
4	2	4	8	13
6	2	3	6	10
10	-	2	4	6
16	-	-	3	4
25	-	-	2	3
35	-	-	-	2
50	-	-	-	-

Table 8.32 : Cross Sectional Areas of Steel Conductors

Size	Nominal cross sectional area mm²	
	Light Gauge	Heavy Gauge
16	47	72
20	59	92
25	89	131
32	116	170

Table 8.33: Weight Chart in Kgs. of Hylam Sheets

Thickness	6'*4'	4'*4'	4'*3'	4'*2*	3'*2'	3'*1'	2'X2'	1'x1'
0.8 mm	2.55	1.70	1.27	0.96	0.72	0.36	0.48	100 gms
1.00 mm	3.30	2.20	1.65	1.20	0.82	0.41	0.60	125 gms
1.20 mm	3.66	2.66	1.90	1.44	0.92	0.46	0.80	150 gms
1.50 mm	5.00	3.84	2.50	1.80	1.35	0.67	0.90	187 gms
2.00 mm	6.2	4.84	3.08	2.40	1.80	0.90	1.20	250 gms
3.00 mm	10.00	7.00	5.00	3.60	2.70	1.35J	1.80	375 grns
4.80 mm	15.00	12.00	7.50	5.76	4.32	2.16	2.88	625 gms
6.00 mm	20.00	13.33	10.00	7.20	5.20	2.60	3.60	800 gms
9.5 mm	30.00	19.73	15.00	11.40	8.60	4.30	5.76	1250 gms
12.70 mm	40.57	27.10	20.00	15.24	11.43	5.715	7.62	1700 gms
16.00 mm	50.00	39.03	25.00	19.20	14.40	7.20	9.50	2000 gms
18.00 mm	56.00	37.33	28.00	20.50	14.90	7.45	10.3	2600 gms
19.50 mm	60.00	40.00	30.00	23.40	15.40	7.90	11.90	3000 gms

Table 8.34: Thickness in mm & Weight in Kgs. Approximate Reflection Factor of Common Surface Materials & Colors

Materials	Reflection Factor %	Colour	Reflection factor %
White Plaster	90-95	White	80
White Paper	80	Light Grey	66
Silvered Mirrors	70-85	Primrose Yellow	65
Chromium Plate	65	Plate Pink	51
Polished Aluminum	62	Light Green	45
Limestone	35-38	Plate Blue	44
Polished Marble	30-70	Medium Grey	42
Tracing Cloth	30	Sky Blue	34
Grey Cement	20-30	Olive Green	21
Granite	20-25	Medium Brown	17
Red Brick	10-15	Cardinal Red	19
Black Paper		Dark Grey	17

Table 8.35 : Incandescent Lamp Data

Fitting	Finish	Watts	Lumens		
			110 V	230 V	250 V
Vacuum	Single Coil Clear	15 25	135 225	120 230	115 225
Gas Filled	Coiled Coil Clear	40 60	500 840	425 720	415 700
		100	1580	1380	1340
		150	2480	2200	2160
		200	3450	3100	3050
		300	-	4850	4800
	Single Coil Clear	500 1000	9400 20200	8300 18600	8200 18400
		1500	31500	29500	29500
	Coiled Coil Inside White	40 60	465 780	395 670	385 650
		100	1460	1280	1240

Table 8.36 : High Pressure Mercury Vapour Lamps

Voltage	Nominal Lamp Voltage	Nominal Lamp Current	Starting Period in S	Cap	Luminous Non (Clear) Fluorescent	Fluorescent
80	115	0.80	3.5	3 Pin BC	3100	3400
125	125	1.15	1.5	3 Pin BC	5400	5800
250	135	2.00	4	E40	11500	12500
400	140	3.20	4	E40	21000	25000
700	140	5.40	4	E40	34000	37000
1000	145	7.50	4	E40	52000	55000
After 100 burning hours.						

INSULATION CLASS

The National Electrical Manufacturers Association (NE MA) has established insulation classes to meet Motor Temperature requirements found in different operating environments. The four insulation classes are A. B. F. and H. Class F is commonly used. Class A is seldom used. Before a motor is started, its windings are at the temperature of the surrounding air. This is known as Ambient Temperature. NEMA has standardized on an Ambient Temperature of 40°C. or 104°F within a defined altitude range for all motor classes.

Temperature will rise in the motor as soon as it is started. Each insulation class has a specified allowable temperature rise. The combination of Ambient Temperature and Allowed Temperature Rise equals the maximum winding temperature in a motor. A motor with Class F insulation, for example, has a maximum temperature rise of 105°C when operated at a 1.0 Service Factor. The maximum winding temperature is 145° C (40° ambient plus 105°C rise). A margin is allowed to provide for a point at the center of the motor's windings where the temperature is higher. This is referred to as the motor's hot spot.

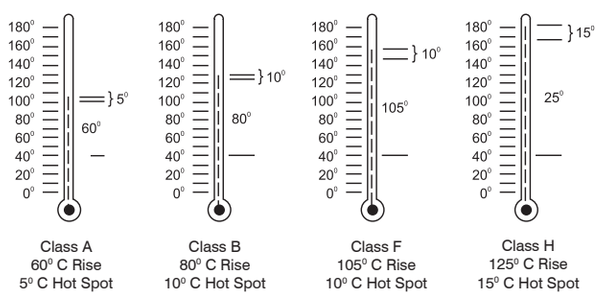


Figure 8.2 : Degree of Protection

The operating temperature of a motor is important for efficient operation and long life. Operating a motor above the limits of the Insulation Class reduces the motor's life expectancy. A 10° C increase in the operating temperature can decrease the motor's insulation life expectancy by as much as 50%.

Table 8.37: Fluorescent Tubular Lamp Data

Tube rating in watts	Tube length in mm	Tube diameter In mm	Lamp Voltage In Volts	Lamp Current in Amps	Lamp* Depreciation	Light Colour	Nominal Luminous Flux Lumens	Bright SHLB
20	590 (2ft)	38	58	0.37	10%	White Cool Daylight	1160 970	0.62 0.50
40	1200 (4ft)	38	103	0.43	10%	White Daylight	2770 2440	0.70 0.63
65-80 in 80 Circuit	1550 (5ft)	38	110	0.57	13%	Cool Daylight	4000	0.83
65-80 in 80 Circuit	1550 (5ft)	38	102	0.88	13%	Cool Daylight	4440	0.92
80	1550 (5ft)	38	102	0.88	15%	White Cool Daylight	5230 4440	1.00 0.92

* The percentage by which the nominal luminous flux decreases after 2000 burning hours.
After 100 Burning hours.

Table 8.38 : Effect of Variation of Voltage and Frequency on Motor Performance

Characteristic	Voltage		Frequency	
Torque Starting & Maximum	110%	90%	105%	95%
	Increase 21%	Decrease 19%	Decrease 10%	Increase 11%
Speed				
Synchronous	No change	No change	Increase 5%	Decrease 5%
Full Load	Increase 1 %	Decrease 1/.5%	Increase 5%	Decrease 5%
Current				
No load	Increase 10-15%	Decrease 10-1 2%	Decrease 5-6%	Increase 5-6%
Starting	Increase 10-12%	Decrease 10-12%	Decrease 5-6%	Increase 5-6%
Full Load	Decrease 7%	Increase 1 1 %	Slight Decrease	Slight Decrease
Temp Rise	Decrease 3-4° C	Increase 6.7° C	Slight Decrease	Slight Decrease
Overload Capacity	Increase 21%	Decrease 19%	Slight Decrease	Slight Decrease
Magnetic Noise	Slight Increase	Slight Decrease	Slight Decrease	Slight Increase
Efficiency				
Full Load	Increase 0.5-1%	Decrease 2%	Slight Increase	Slight Decrease
Power Factor				
Full Load	Decrease 3%	Increase 1%	Slight Increase	Slight Decrease

2. For Rotary Motion

$$PL = \frac{M \times N}{974 \times Eff} Kw$$

Where
M = Torque for movement in Kgm.
N = Motor speed in RPM

Ensure the rated output of Motor is greater than the Power PL

Table 8.39 : Degree of Protection

The degree of protection as classified in IS 4691 is given below. It is denoted by two digits. The first digit denotes protection against solid bodies or particles and the second digit denotes protection against liquid.

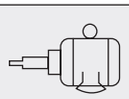
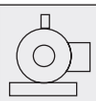
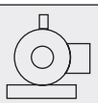
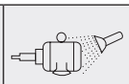
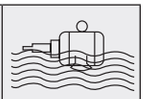
Second Characteristic Numeral								
First	Characteristic Numeral	No Protection	Water falling Vertically shall not harm	Water falling up to 15° from vertical shall not harm	Water falling upto 60° from vertical shall not harm	Water splashes shall not harm	Water projected by nozzle shall not harm	Water from heavy seas shall not harm
1	2	3	4	5	6	7	8	9
0	No Protection							
1	Special Protection against bodies 50 mm dia.							
2	DP protection against bodies 12 mm dia.		IP 21	IP 22	IP 23			
4	TEFC Protection against bodies 12 mm dia.					IP 44		
5	TEFC Protection against powder					IP54	IP 55	IP 56

Table 8.40 : Terminal Box Data - Motors

Frame Size	Cable Entry size	Max. Cu. Cable Size DOL starting	Max. Cu Cable Size Star-Delta Starting	Terminal Stud size
56-71	1 x 3/4"	3C x 2.5 m m2	-	M4
80-90	1 x 3/4"	3C x 4 m m2		M4
100-132	2 x 1"	3C x 10m m2	2 x 3C x 10mm2	M5
160-180	2 x 1"	3C x 35 m m2	2 x 3C x 25 m m2	M6
200-250	2 x 2," 1 x 3/4"	3C x 120mm2	2 x 3C x 70 m m2	M8
280-315	2 x 2"	3C x 240 m m2	2 x 3C x 150 m m2	M12
355	2 x 3", 2 x 1"	3C x 400 m m2	2 x 3C x 300 m m2	M16

Table 8.41 : Bearing Arrangement

Frames upto 180 have sealed bearings which are lubricated for life. Frames 200 & above have regreasing arrangement as a standard feature in both Standard & Flameproof Motors

Standard Motors			Flameproof Motors			Regreasing time (Hrs)	
Frame size	DE side	NDE side	Frame size	DE side	NDE side	2P	4P & above
56	6200ZZ	6200ZZ	-	-	-	-	-
63	620 1ZZ	6201 ZZ	63FLP	6203ZZ	6203ZZ	-	-
71	6202ZZ	6202ZZ	71 FLP	6203ZZ	6203ZZ	-	-
80	6204ZZ	6204ZZ	80FLP	6204ZZ	6204ZZ	-	-
90S/L	6205ZZ	6205ZZ	90 FLP	6205ZZ	6205ZZ	-	-
100L	6206ZZ	6206ZZ	100L FLP	6206ZZ	6206ZZ	-	-
112M	6206ZZ	6206ZZ	112MFLP	6306ZZ	6306ZZ	-	-
13257M	6208ZZ	6208ZZ	132MFLP	6308ZZ	6308ZZ	-	-
160M/L	6309ZZ	6309ZZ	160L FLP	6309ZZ	6309ZZ	-	-
180M/L	6310ZZ	631 OZZ	180L FLP	631 OZZ	631 OZZ	-	-
200L	6312	6312	200L FLP	6312	6312	3,500	8,000
2255/M	6313	6313	225M FLP	6313	6313	3,500	8,000
250/M	6315	6315	250M FLP	6315	6315	2,500	6,000
280S/M	6317	6317	280M FLP	6317	6317	2,000	5,000
315S/M/L	6319	6319	-	-	-	2,000	4,000
355 S/M/L	6322	6322	-	-	-	2,000	3,000

Standard Motors - Mechanical Dimensions

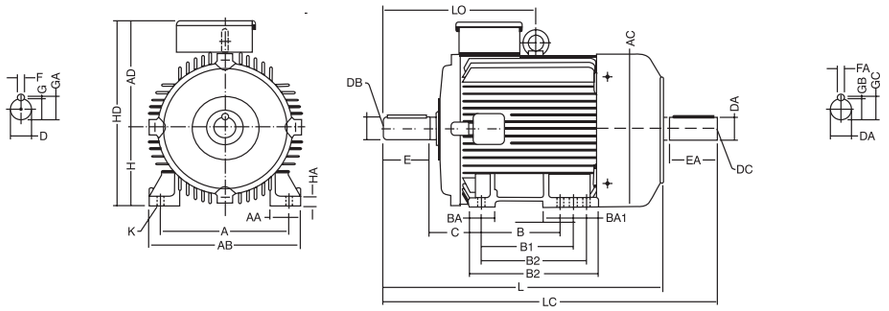
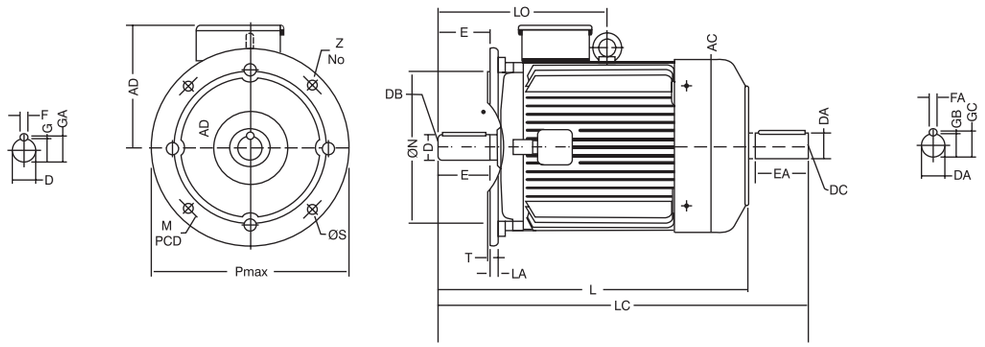
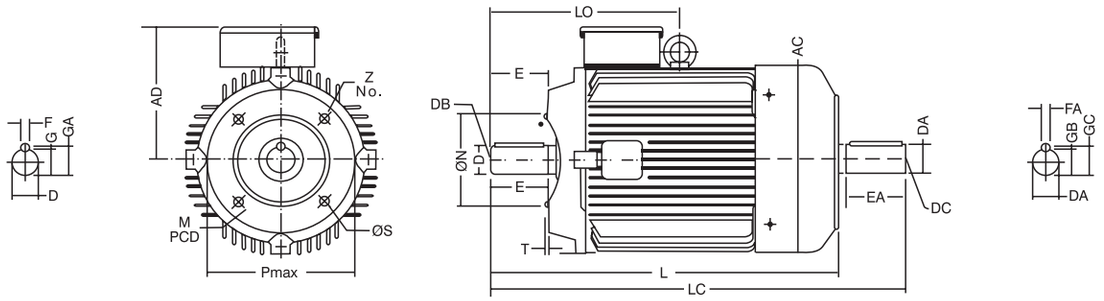


Figure 8.3 : Foot Mounted Motors (B3)



Flange mounted Motors (B5)



Face Mounted Motors (B14)

Table 8.42 : Dimensions

Frame Size	Motor Type	General					Foot mounted motors (B3)													
		L	LC	LD	AC	AD	A	B	B1	B2	C	H	K	AA	AB	BB	BA	BA1	HA	HD
3555	HS1/HS2	1492	1647	748	701	586	610	500	-	-	254	355	28	122	730	770	160	270	50	941
355M	HS1/HS2							-	560	-										
355L	HS1/HS2							-	-	630										
3555X	HS1/HS2	1522	1707	778				500	-	-										
355MX	HS1/HS2							-	560	-										
355LX	HS1/HS2							-	-	630										

Frame Size	Motor Type	Flange mounted motors (BS)							DE Shaft						NDE Shaft					
		P max	M PCD	ON	0>5	Z No.	T max	LA	D	DB	E	F	GA	G	DA	DC	EA	FA	GC	GB
3555	HS1/HS2	800	740	680	24	8	6	26	75	M24	140	20	79.5	67.5	65	M24	140	18	69	58
355M	HS1/HS2																			
355L	HS1/HS2																			
3555X	HS1/HS2								95		170	25	100	86	85		170	22	90	76
355MX	HS1/HS2																			
355LX	HS1/HS2																			

Suffix “X” denotes other than 2 pole motors.

Dimensions of Foot (B3), Flange (B5) & Face (B14) Mounted Motors

Frame Size	Motor Type	General					FOOT MOUNTED MOTOR (B3)												FLANGE MOUNTED MOTOR (B5)							FACE MOUNTED MOTOR (B14)						DE, NDE SHAFT					
		L	LC	LD	AC	AD	A	B	B1	C	H	K	AA	AB	BB	BA	BA1	HA	HD	P MAX	M PCD	ON	OS	Z NO.	T MAX.	LA	P MAX	M PCD	ON	OS	Z NO.	T	D, D1	DB DC	E EA	F, FA	GA GC	G, GB
56	HS1	180	204	-	110	80	90	71	-	36	56	6	25	110	91	-	-	6	136	140	115	95	10		3	9	80	65	50	MS		2.5	9	M4	20	3	10.2	7.2
63	HS1	206	236	-	124	100	100	80	-	40	63	7	27	122	102	27	27	7	163								90	75	60				11		23	4	12.5	8.5
71	HS1/ HS2	240	272	-	140	107	112	90	-	45	71	7	31	134	112	31	31	8	178	160	130	110					105	85	70				14	M5	30	5	16	11
80	HS1 / HS2	282	326	-	158	125	125	100	-	50	80	10	30	150	125	31	36	9	205	200	165	130	12		35	10	120	100	80	M6		3	16	M6	40	6	21.5	15.5
80	HS2	302	346																																			
90S	HS1	319	376	-	180	133	140	100	-	56	90	10	13	168	124	33	37	10	223																		
90SL	HS1/ HS2	344	401						125						149												140	115	95	M8			24	M8	50	8	27	20
90L	HS2	375	432	-				-																													
100L	HS1/ HS2	374	440	221	198	153	160	140	-	63	100	12	43	200	180	46	46	14	253	250	215	180	15	4	4	11	160	130	110	M8	4	3.5	28	M10	68	8	31	24
100L	HS1/ HS2	384	446																																			
112M	HS2	398	464	228	222	168	190	140	-	70	112	12	49	230	180	47	47	15	280																		
112M	HS1/ HS2	433	499																																			
132S	HS1/ HS2	451	538	260	262	185	216	140	-	89	132	12	52	256	180	47	47	16	317	300	265	230				12	200	165	130	M12			38	M12	80	10	41	33
132SM	HS2	489	576						178						218		85																					
132M	HS1/ HS2	508	595					-																														
160M	HS1/ HS2	589	706	354	314	216	254	210	-	108	160	15	64	304	260	60	60	20	376	350	300	250				13							42	M16	110	12	45	37
160ML	HS1/ HS2	633	750						254						304		104																					
180M	HS1/ HS2	655	772	381	354	236	279	241	-	121	180	15	65	335	297	66	66	24	416														48		110	14	51.5	42.5
180ML	HS1/ HS2	693	810						279						335		103																					
200L	HS1/ HS2	760	880	416	395	276	318	305	-	133	200	19	84	386	365	74	74	26	476	400	350	300				15							55		110	16	59	49
225S	HS1/ HS2	805	925	436	435	297	356	286	-	149	225	19	90	428	371	74	95	28	522	450	400	350		8	5	16							55		110	16	59	49
225M	HS1/ HS2							-	311																													
225SX	HS1/ HS2	835	985	466				286	-																								60		140	18	64	53
225MX	HS1/ HS2							-	311																													
250M	HS1/ HS2	930	1085	483	481	319	406	349	-	164	250	24	105	490	433	93	93	38	569	550	500	450	19				.	.	.	.	.	.	60	20	140	18	64	53
250MX	HS1/ HS2																																65				69	58
280S	HS1/ HS2	1040	1195	590	543	426	457	368	-	190	280	24	100	557	483	90	145	42	706														65		140	18	69	58
280M	HS1/ HS2							-	419																													
280SX	HS1/ HS2							368	-																								75		140	20	79.5	67.5
280MX	HS1/ HS2							-	457																													
315S	HS1/ HS2	1155	1332	611	621	452	508	406	-	216	315	28	112	620	533	100	151	46	767	660	600	550	24	8	6	23							65		140	18	69	58
315M	HS1/ HS2							-	457																													
315L	HS1/ HS2	1318	1505	666				457	508						616		191																80		170	22	85	71
315SX	HS1/ HS2	1185	1392	641				406	-						533		151																					
315MX	HS1/ HS2							-	457																													
315LX	HS1/ HS2	1348	1665	696				457	508						616		191																					

Suffix "X" denotes Motors other than 2 Pole Motor

Cooling Tower Motor - Mechanical Dimensions for Direct Drive

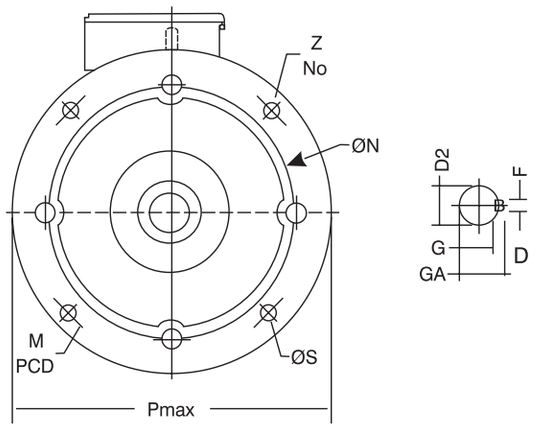


Introduction

Cooling Tower motors are specially designed flange mounted motors in totally enclosed construction to suit air conditioning & refrigeration industries. They are provided with special long shaft construction with external threaded end to directly mount the fan blades. This also helps in the better cooling of the motor. Motors are compact in design & less in weight to facilitate easy maintenance.

Range:

Power : 0.37 to 22.0 kW
Polarity : 4P, 6P, 8P, 10P & 12P
Mounting : B5 flange mounted
Frame size : 71 to 280
Voltage : 415V± 10% or as required
Frequency : 50HzV± 5% or as required
Ambient : 45°C
Altitude : Upto 1000m above m.s.l
Enclosure : Totally enclosed (TE)
Protection : IP55
Insu. class : Class F insulation with temp, rise limited to class B.



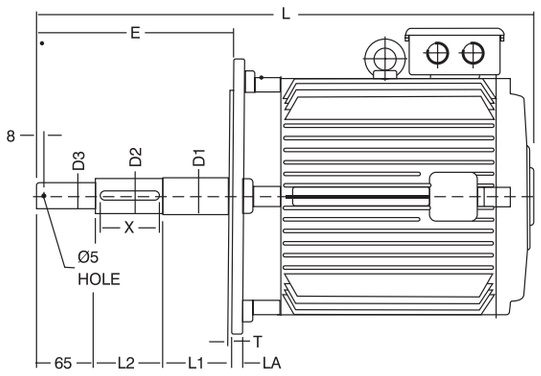


Table 8.43 : Dimensions - Cooling Tower Motors

Frame	D1	D2	D3	F	G	GA	L1	L2	E	P Max	M PCD	ØN	ØS	Z No,	T	LA	X	L
71	15	14	M12	5	11	16	50	40	155	160	130	110	10		3.5	9	35	331
80	20	19		6	15.5	21.5												368
90S	25	24	M16		20	27				200	165	130	12		3.5	10	45	380
90L				8			50	55	170									405
100L	30	28	M24		24	31				250	215	180	15		4	11	45	432
112M																		446
132S	40	38		10	33	41				300	265	230		4		12	65	515
132M							75	75	215									553
160M	45	42		12	37	45				350	300	250	19		5	13	55	614
160L			M30															658
180M	50	48		14	42.5	51.5											110	727
180L																		765
200L	60	55		16	49	59	100	120	285	400	350	300				15		846
225MX	65	60		18	53	64				450	400	350		8		16		850
250MX	75	65	M36		58	69				550	500	450	24			18		920
280MX	85	75		20	68	80										18		1025

Table 8.44 : Cooling Tower Motor - Electrical Performance

Electrical performance for Cooling Tower 3 Phase Sq. cage Induction Motors, suitable, for 415V± 10%, 50HZ ± 5%, Ambient Temperature 45°C, Class 'F' insulation with class B temperature rise, IPSS protection. Totally Enclosed (TE) construction, (S1) duty.

Output		Frame	Type Designation	Speed (rpm)	Curr. (A)	Tongue (kgm)	Efficiency %			Power Factor			STA	STT	POT	GD^2 (KGM^2)
KW	HP						FL	3/4L	1/2L	FL	3/4L	1QL				
0.37	0.50	71	2HL1 073-04	1380	1.05	0.26	66.0	65.0	58.0	0.74	0.64	0.53	3.5	1.9	2.1	0.0022
0.75	1.0	80	2HL1 083-04	1415	1.75	0.52	74.0	73.0	68.0	0.81	0.70	0.55	4.5	2.0	2.3	0.0049
		90S	2HL1 090-06	925	2.0	0.79	72.0	71.0	66.0	0.72	0.64	0.52	5.0	2.2	2.4	0.0095
1.1	1.5	90S	2HL1 090-04	1415	2.5	0.76	76.5	76.0	74.0	0.80	0.70	0.55	5.0	2.2	2.5	0.0072
		90L	2HL1 096-06	930	2.9	1.15	75.0	74.0	69.0	0.70	0.58	0.42	5.0	2.2	2.4	0.0122
		100L	2HL1 106-08	700	3.0	1.53	74.0	73.0	71.0	0.69	0.60	0.48	4.0	1.8	2.0	0.0296
		132S	2HL1 130-12	460	3.8	2.33	70.0	68.0	64.0	0.58	0.50	0.40	3.5	1.7	1.9	0.0826
1.5	2.0	90L	2HL1 096-04	1420	3.3	1.03	79.0	79.0	F77.0	0.80	0.70	0.55	5.0	2.2	2.5	0.0093
		100L	2HL1 106-06	940	3.5	1.55	76.0	75.0	71.0	0.78	0.73	0.60	5.0	2.0	2.3	0.0269
		112M	2HL1 123-08	705	3.9	2.07	77.0	77.0	74.0	0.69	0.64	0.51	4.0	1.9	2.1	0.0467
		132S	2HL1 130-10	555	4.5	2.63	74.0	74.0	71.0	0.63	0.55	0.43	4.5	2.0	2.2	0.0826
		132M	2HL1 133-12	460	4.9	3.18	71.0	70.0	66.0	0.60	0.52	0.42	3.5	1.7	1.9	0.1198
2.2	3.0	112M	2HL1 123-06	945	4.9	2.27	80.0	79.5	75.5	0.78	0.70	0.55	5.0	2.0	2.3	0.0047
		132S	2HL1 130-08	710	5.2	3.02	79.0	79.0	76.0	0.75	0.65	0.52	5.0	2.2	2.4	0.0826
		132M	2HL1 133-10	555	5.7	3.86	78.0	78.0	76.0	0.69	0.61	0.49	4.5	2.0	2.2	0.1198
		160M	2HL1 163-12	465	6.0	4.61	79.0	79.0	75.0	0.65	0.54	0.45	4.5	2.0	2.2	0.2072
3.7	5.0	1325	2HL1 130-06	950	7.5	3.79	82.5	82.5	81.5	0.83	0.73	0.64	5.0	2.0	2.3	0.0826
		132M	2HL1 133-08	710	8.6	5.08	81.0	81.0	79.0	0.74	0.65	0.52	5.0	2.2	2.4	0.1156
		160M	2HL1 163-10	560	9.0	6.44	81.0	81.0	79.0	0.71	0.62	0.50	5.0	2.1	2.3	0.2072
		160L	2HL1 166-12	465	10.0	7.75	80.0	80.0	77.0	0.64	0.55	0.42	4.5	2.0	2.2	0.2857
5.5	7.5	132M	2HL1 133-06	950	11.0	5.64	85.0	85.0	83.5	0.82	0.77	0.67	5.0	2.0	2.3	0.1156
		160M	2HL1 163-08	720	12.0	7.44	86.0	86.0	83.0	0.74	0.68	0.58	5.0	2.0	2.2	0.2565
		180M	2HL1 183-10	560	14.0	9.57	82.0	81.5	80.0	0.67	0.58	0.45	5..0	2.0	2.2	0.5057
		180L	2HL1 186-12	470	15.0	11.40	82.0	82.0	80.0	0.62	0.54	0.42	4.5	1.9	2.1	0.5949
7.5	10.0	160M	2HL1 163-06	960	15.0	7.61	87.0	87.0	84.5	0.80	0.76	0.68	5.5	2.0	2.3	0.2625
		160L	2HL1 166-08	720	15.7	10.15	87.0	87.0	85.0	0.76	0.71	0.58	5.0	2.0	2.2	0.3440
		180L	2HL1 186-10	565	18.0	12.93	83.0	82.5	80.0	0.70	0.62	0.48	5.0	2.0	2.2	0.5949
		180L	2HL1 187-12	470	20.0	15.54	82.0	82.0	80.0	0.64	0.55	0.43	4.5	1,9	2.1	0.6544
9.3	12.5	160L	2HL1 166-06	965	17.5	9.39	88.0	88.0	85.0	0.84	0.81	0.70	5.5	2.0	2.3	0.3440
		180M	2HL1 183-08	725	20.0	12.49	87.5	87.5	85.0	0.74	0.70	0.57	5.0	2.0	2.2	0.5057
		180L	2HL1 187-10	570	22.0	15.89	84.0	83.5	81.0	0.70	0.62	0.49	5.0	2.0	2.2	0.6544
		180L	2HL1 188-12	470	23.0	19.27	84.0	84.0	82.0	0.67	0.59	0.46	4.5	1.9	2.1	0.7734
11.0	15.0	160L	2HL1 167-06	970	20.5	11.05	88.5	88.5	87.5	0.84	0.81	0.70	5.5	2.0	2.3	0.3440
		180L	2HL1 186-08	725	24.0	14.78	88.0	88.0	85.0	0.72	0.68	0.55	5.0	2.0	2.3	0.5949
		180L	2HL1 188-10	570	25.0	18.80	85.0	85.0	83.0	0.72	0.64	0.50	5.0	2.0	2.2	0.7734
		200L	2HL1 206-12	485	33.0	22.09	84.5	84.0	81.0	0.55	0.47	0.38	4.5	1.9	2.1	1.2654
15.0	20.0	200L	2HL1 206-08	725	31.0	20.15	88.5	88.0	86.0	0.76	0.72	0.60	5.0	2.0	2.2	1.0123
		200L	2HL1 206-10	575	34.0	25.41	86.5	86.0	84.0	0.71	0.63	0.52	4.5	2.0	2.2	1.2654
		225MX	2HL1 223-12	480	40.0	30.44	85.5	85.5	83.5	0.61	0.54	0.43	4.0	1.8	2.0	1.8378
18.5	25.0	225MX	2HL1 223-10	575	43.0	31.34	89.0	89.0	87.0	0.67	0.60	0.50	4.0	2.0	2.2	1.8378
		250MX	2HL1 253-12	485	54.0	37.15	86.5	86.0	82.0	0.55	0.48	0.37	4.0	1.9	2.1	2.5127
22.0	30.0	280MX	2HL1 283-12	485	56.0	44.18	89.0	89.0	87.0	0.61	0.54	0.44	4.0	1.8	2.0	5.2502

All figures are subject to tolerance as per IS: 325.
All the above ratings can be offered in flameproof enclosure, wherever applicable.

Flameproof Motors

Hazardous areas are defined as those locations where explosive gas - air mixtures may occur in dangerous concentrations and are defined in accordance to Indian Standard IS 5572(Pt.1). The general classification is as highlighted in the following table.

Zone	Classification of Area as per IS 5572 (Part 1}	Use of Electrical Equipment
Zone "0"	Area in which hazardous atmosphere is continuously present	Use of motors is to be avoided as far as possible. Use intrinsically safe or pressurized electrical equipment
Zone “1”	Area in which hazardous atmosphere is likely to be present at any time under normal operating conditions	Flameproof motors with Type EX 'd' as specified in IS 2148
Zone "2"	Area in which hazardous atmosphere is likely to be present only under abnormal operating conditions & for a short period	Motors with all electrical contacts to be enclosed in flameproof enclosure and conform to IS 6381 and designated as Type "e" or IS 9628 and designated as Type "n"

Customers are to select the motor type depending on the type of area of operation of the motors and should generally follow the guidelines given above in conjunction with the relevant Indian Standards specified above.

Classification of hazardous gases:

Hazardous gases have been classified in IS 2148, VDE 0171 and IS 5572 (Part 1) and are associated with only Flameproof motors as listed below:

Note: FLP motors are offered suitable for Gas Groups, I, IIA and IIIB only. For any other gas not specified in the table below, one has to refer relevant IS for the motor selection.

Group Of Enclosures Suitable For Particular Flammable Gas Or Vapour As Per IS:2148-1981

Group of Enclosures	Gas or Vapour			
1	Methane (firedamp)			
IIA	Ammonia	Hexane	Acetone	Chloroethylene
	Industrial Methane*	Heptane	Ethyl methyl ketone	Methanol
	Blast furnace gas	Iso-octane	Methyl acetate	Ethanol
	Carbon monoxide	Decane	Ethyl acetate	Iso-butanol
	Propane	Benzene	n-Propyl acetate	n-butanol
	Butane	Xylene	n- Butyl acetate	Amyl alcohol
	Pentane	Cyclohexene	Amyl acetate	Ethyl nitrate
IIB	1,3 -Butadiene, Ethelene	Diethyl ether	Ethylene oxide	Town gas**
IIC	Hydrogen			

*Industrial methane includes Methane mixed with not more than 10% by volume of Hydrogen.
** Town gas may contain not more than 57% by volume of Hydrogen & not more than 16% by volume of Carbon Monoxide. The remaineder being the mixture of Paraffin Hydrocarbons & Inert gas.

Paint & Finish : All motors are given special treatment of primer & paint to internal as well as external surfaces. All external surfaces are coated with Epoxy Polyamide based in dark admiralty grey shade (No.632) as per IS:5.

Maintaining the type of Protection during operation:

Each motor must be provided with a protective circuit breaker or an equally effective device. In particular, the following should be noted.

1. The joint faces must not be remachined nor finished or coated with varnish or pain. The surfaces must be kept metallically clean. A thin film of oil grease must be applied as protection against rust. The use of gaskets at points where there were originally none is not permitted.
2. Defective mounting screws and bolts must be replaced promptly by new ones of a material with at least the same tensile-strength as the original ones.
3. Care should be taken to see that all screws, bolts, nuts etc., used for fixing the parts of flameproof enclosures are provided with spring washers originally supplied.

NOTE:

A cable sealing box is mandatory in the following cases.

a) All motors for use for Gas group.

b) When cable size is more than 1 inch, for Gas Group MA & IIB.

TECHNICAL DATA
CURRENT CARRYING CAPACITY & CONDUCTORS

The Current Capacity given in the following tables are based on the assumption shown below

1) Maximum Conductor Temperature : 90°C
2) Maximum Ambient Temperature : In Air (Voltage upto 1.9/3.3 (3.6) kv) 30°C (Voltage 6.6 kV upto and including 33 kV) 25°C In ground 15°C
3) Ground Thermal Resistivity : 1.2°cm/W
4) Laying Depth for voltage upto 1 KV - 0.5M
   For higher voltage above 1kV - 0.8M
5) For other conditions, the rating factors included should be applied

Table 8.45 : Rating Factors for Cable in Free Air

FOR VOLTAGE UPT0 1.9 / 3.3 (3.6) kV							
Ambient Air	**20°C**	**25°C**	**30°C**	**35°C**	**40°C**	**45°C**	**50°C**
Rating Factor	1.09	1.04	1.00	0.96	0.91	0.87	0.82
FOR VOLTAGE 6.6 kV UPTO AND INCLUDING 132 kVs							
Ambient Air Temperature	20°C	25°C	30°C	35°C	40°C	45°C	50°C
Rating Factor	1.05	1.00	0.95	0.91	0.86	0.80	0.75

All the ratings for cables run in air are based upon the assumption that they are shielded from direct sunlight and without restriction of ventilation.

Effect of grouping cables : No reduction in rating is necessary where there is free circulation of air around the conductors provided that:

1. The horizontal clearance between conductors is not less than twice the overall diameter of an individual cable.
2. The vertical clearance between conductors is not less than four times the diameter of an individual cable.
3. If the number of conductors exceeds three, they are installed in a horizontal plane.

Table 8.46 : Rating Factors for Cable in Ground

FOR VOLTAGE UPT0 1 .9 / 3.3 (3.6) kV								
Ambient Air Temperature	**10°C**	**15°C**	**20°C**	**25°C**	**30°C**	**35°C**	**40°C**	**45°C**
Rating Factor	1.03	1.00	0.97	0.93	0.89	0.85	0.81	0.77

Table 8.47 : Group rating factors for circuits of three single core cable, in trefoil and laid flat touching horizontal formation

Cable Voltage (kV	No. of Circuits	Spacing of Circuit between (centres cable groups)					
		Touching		0.15m	0.3m	0.45m	0.6m
		Trefoil	Laid Flat				
0.6/1	2	0.77	0.80	0.82	0.88	0.90	0.93
	3	0.65	0.68	0.72	0.79	0.83	0.87
	4	0.59	0.63	0.67	0.75	0.81	0.85
	5	0.55	0.58	0.63	0.72	0.78	0.83
	6	0.52	0.56	0.60	0.70	0.77	0.82
	7	0.50	0.54	0.58	0.68	0.76	0.81
	8	0.48	0.52	0.56	0.66	0.75	0.79
	9	0.46	0.50	0.54	0.64	0.74	0.78
	10	0.44	0.48	0.52	0.62	0.73	0.77
1.9/3.3 to 12.7/22	2	0.78	0.80	0.81	0.85	0.88	0.90
	3	0.66	0.69	0.71	0.76	0.80	0.83
	4	0.60	0.63	0.65	0.72	0.76	0.80
	5	0.55	0.58	0.61	0.68	0.73	0.77
	6	0.52	0.55	0.58	0.68	0.72	0.76
	7	0.49	0.52	0.55	0.63	0.69	0.74
	8	0.46	0.49	0.51	0.60	0.66	0.72
	9	0.43	0.46	0.48	0.56	0.63	0.70
	10	0.40	0.43	0.45	0.53	0.61	0.68
19/33 to 76/132	2	0.79	0.81	0.81	0.85	0.88	0.90
	3	0.67	0.70	0.71	0.76	0.80	0.83
	4	0.62	0.65	0.65	0.72	0.76	0.80
	5	0.57	0.60	0.60	0.68	0.73	0.76
	6	0.54	0.57	0.57	0.66	0.72	0.76

Table 8.48 : Group rating factors for Multicore Cable in Horizontal Formation

Cable Voltage (kV	No. of Circuits	Spacing of Circuit between (centers cable groups)				
		Touching	0.15m	0.3m	0.45m	0.6m
0.6/1	2	0.81	0.87	0.91	0.93	0.94
	3	0.70	0.78	0..84	0.87	0.90
	4	0.63	0.74	0.81	0.86	0.89
	5	0.59	0.70	0.78	0.83	0.87
	6	0.55	0.67	0.76	0.82	0.86
	7	0.52	0.64	0.74	0.79	0.83
	8	0.50	0.62	0.72	0.77	0.81
	9	0.48	0.60	0.70	0.75	0.79
	10	0.46	0.58	0.68	0.73	0.77
1.9/3.3 to 12.7/22	2	0.80	0.85	0.89	0.90	0.92
	3	0.69	0.75	0.80	0.84	0.86
	4	0.63	0.70	0.77	0.80	0.84
	5	0.57	0.66	0.73	0.78	0.81
	6	0.55	0.63	0.71 -	0.76	0.80
	7	0.53	0.60	0.68	0.74	0.78
	8	0.50	0.57	0.66	0.72	0.76
	9	0.48	0.55	0.64	0.70	0.74
	10	0.46	0.53	0.62	0.68	0.73
19/33 to 76/132	2	0.80	0.83	0.87	0.89	0.91
	3	0.70	0.73	0.78	0.82	0.85
	4	0.64	0.68	0.74	0.78	0.82
	5	0.59	0.63	0.70	0.75	0.79
	6	0.56	0.60	0.68	0.74	0.78

Table 8.49 : Rating Factors for Soil Thermal Resistivity

Conductor Size (mm2)	Soil Thermal Resistivity (Km / W)						
	0.8	0.9	1.0	1.5	2.0	2.5	3.0
Single Core Cables							
Upto 150	1.16	1.11	1.07	0.91	0.81	0.73	0.67 "
From 185 to 400	1.17	1.12	1.07	0.90	0.80	0.72	0.66
From 500 to 1200	1.18	1.13	1.08	0.90	0.79	0.71	0.65
Multicore Cables							
Upto 16	1.09	1.06	1.04	0.95	0.86	0.79	0.74
From 25 to 150	1.14	1.10	1.07	0.93	0.84	0.76	0.70
From 185 to 400	1.16	1.11	1.07	0.92	0.82	0.74	0.68

Table 8.50 : Rating Factors for depth of Laying (to centers of cable or trefoil group of cable)

Depth of Laying (m)	0.6/1 (1.2) kV Cables			1.9 / 3.3 (3.6) kV to 19 / 33 (36) kV Cables	
	Upto 50 mm^2	70mm^2 to 300mm^2	Above 300mm^2	Upto 300mm^2	Above 300mm^2
0.5	1.00	1.00	1.00	1.00	1.00
0.6	0.99	0.98	0.97	1.00	1.00
0.8	0.97	0.96	0.94	1.00	1.00
1.00	0.95	0.94	0.92	0.98	0.97
1.25	0.94	0.92	0.90	0.96	0.95
1.50	0.93	0.91	0.89	0.95	0.94
1.75	0.92	0.89	0.87	0.94	0.92
2.00	0.91	0.88	0.86	0.92	0.90
2.50	0.90	0.87	0.85	0.91	0.89
3.0 or Above	0.89	0.86	0.83	0.90	0.88

Table 8.51 : Current Ratings for 0.6 /1 (1.2) kV Unarmoured XLPE Cable

Conductor Size (mm2)	Current Rating						Voltage Drop		
	In Air			In Ground					
	1C	2C	3/4c	1C	2C	3/4c	1C	2C	3/4C
	(A)			(A)			(inV / A/m)		
COPPER CONDUCTOR									
1.5	25	26	23	35	39	33	27	31	27
2.5	33	36	32	46	52	43	16	19	16
4	44	49	42	59	67	56	10	12	10
6	56	63	54	73	85	71	6.8	7.9	6.8
10	77	86	75	98	113	95	4.0	4.7	4.0
16	102	115	100	125	146	122	2.5	2.9	2.5
25	135	149	127	161	190	158	1.62	1.9	1.65
35	169	185	158	193	229	191	1.18	1.35	1.15
50	207	225	192	228	265	223	0.87	1.00	0.87
70	268	289	246	279	326	274	0.62	0.69	.60
95	328	352	298	335	391	329	0.47	0.52	0.45
120	383	410	346	380	445	375	0.39	0.42	0.37
150	444	473	399	426	499	421	0.33	0.35	0.30
185	510	542	456	482	566	478	0.28	0.29	0.26
240	607	641	538	558	658	556	0.24	0.24	0.21
300	703	741	621	629	745	630	0.21	0.21	0.185
400	823	865	741	712	849	719	0.195	0.19	0.165
500	946	-	-	802	-	-	0.180	-	-
630	1069	-	-	900	-	-	0.170	-	-
0.170	-	-							
800	1214	-	-	1002	-	-	0.165	-	-
0.165	-	-							
1000	1349	-	-	1090	-	-	0.155	-	-
0.155	-	-							
ALUMINIUM CONDUCTOR									
6	46	49	42	60	69	58	1.0	12	10
10	60	67	58	75	87	73	6.8	7.9	6.8
16	78	91	77	97	113	94	4.2	4.8	4.2
25	103	108	97	125	147	123	2.7	3.1	2.7
35	129	135	120	149	177	148	1.9	2.2	1.95
50	159	164	146	177	205	173	1.4	1.65	1.45
70	206	211	187	217	253	213	0.98	1.15	0.97
95	253	257	227	259	303	255	0.74	0.84	0.72
120	296	300	263	295	346	291	0.60	0.66	0.58
150	343	346	304	331	387	326	0.49	0.55	0.47
185	395	397	347	375	440	371	0.41	0.45	0.39
240	471	470	409	436	511	432	0.34	0.35	0.31
300	547	543	471	492	579	490	0.29	0.29	0.26
400	663	645	570	564	665	563	0.24	0.25	0.21
500	770	-	-	643	-	-	0.21	-	-
630	899	-	-	733	-	-	0.19	-	-
800	1038	-	-	825	-	-	0.19	-	-
1000	1211	-	-	924	-	-	0.16	-	-

* Single core cable with Aluminum wire armour

Table 8.52 : Current Ratings for 0.6 /1 (1.2) kV Armoured XLPE Cable

Conductor Size (mm2)	Current Rating						Voltage Drop		
	In Air			In Ground					
	1C	2C	3/4c	1C	2C	3/4c	1C	2C	3/4c
	(A)			(A)			(inV / A/m)		
COPPER CONDUCTOR									
1.5	28	29	25	36	40	33	27	31	27
2.5	37	39	33	47	52	43	16	19	16
4	48	52	44	61	67	56	10	12	10
6	60	66	56	75	84	70	6.8	7.9	6.8
10	82	90	78	100	113	94	4.0	4.7	4.0
16	106	115	99	127	141	119	2.5	2.9	2.5
25	140	152	131	163	183	152	1.62	1.9	1.65
35	170	188	162	195	219	182	1.18	1.35	1.15
50	222	228	197	231	259	217	0.87	1.00	0.87
70	285	291	251	284	317	266	0.62	0.69	0.60
95	346	354	304	340	381	319	0.47	0.52	0.45
120	402	410	353	386	433	363	0.39	0.42	0.37
150	463	472	406	431	485	406	0.33	0.35	0.30
185	529	539	463	485	547	458	0.28	0.29	0.26
240	625	636	546	558	632	529	0.24	0.24	0.21
300	720	732	628	623	708	592	0.21	0.21	0.185
400	815	847	728	691	799	667	0.195	0.19	0.165
500	918	-	-	765	-	-	0.180	-	-
630	1027	-	-	841	-	-			
800	1119	-	-	888	-	-			
1000	1214	-	-	942	-				
ALUMINIUM CONDUCTOR									
6	49	52	44	61	69	57	1.0	12	10
10	63	67	57	77	87	73	6.8	7.9	6.8
16	82	85	74	98	108	91	4.2	4.8	4.2
25	108	112	98	127	138	116	2.7	3.1	2.7
35	132	138	120	151	165	139	1.9	2.2	1.95
50	162	166	145	177	196	165	1.4	1.65	1.45
70	207	211	185	218	241	203	0.98	1.15	0.97
95	252	254	224	260	288	244	0.74	0.84	0.72
120	292	303	264	296	343	278	0.60	0.66	0.58
150	337	345	305	331	385	311	0.49	0.55	0.47
185	391	412	350	374	437	353	0.41	0.45	0.39
240	465	473	418	433	507	409	0.334	0.35	0.31
300	540	540	488	486	572	461	0.29	0.29	0.26
400	625	628	562	563	655	534	0.24	0.25	0.21
500	714	-	-	629	-	-	0.21	-	-
630	801	-	-	701	-	-	0.19	-	-
800	890	-	-	111	-	-	0.18	-	-
1000	980	-	-	854	-	-			

* Single core cable with Auminum wire armour

Table 8.53 : Current Ratings for 1.9 / 3.3 (3.6) kV Armoured XLPE Cable

Conductor Size (mm2)	In Air			In Ground		
	Single Core[a]		3 Core	Single Core[b]		3 Core
	Trefoil	Flat		Trefoil	Flat	
	(A)	(A)		(A)	(A)	(A)
Copper Conductor						
50	230	287	204	222	230	207
70	288	357	257	271	279	254
95	353	434	315	324	331	305
120	411	492	365	366	369	345
150	468	553	415	409	409	387
185	534	622	476	460	454	436
240	630	715	560	528	512	502
300	717	793	640	589	560	563
400	817	851	734	651	595	633
500	924	929	-	720	641	-
630	1041	1007	-	789	684	-
800	1131	1054	-	831	703	-
1000	1227	1121	-	880	735	-
Aluminium Conductor						
50	173	217	155	170	176	158
70	216	270	194	208	215	194
95	264	328	237	248	256	233
120	308	377	276	282	288	265
150	350	424	313	315	320	297
185	402	483	360	355	359	336
240	475	561	425	410	409	389
300	544	631	489	460	453	439

* Single core cable with aluminum wire armour

Table 8.54 : Current Ratings for Armoured XLPE Cable

Conductor Size	3.8/8.6(7.2)kVto8.7/15kV (17.5)				12.7/22(24)kVto19/33kV (36)			
	In Air		In Ground		In Air		In Ground	
	Single Core[ab] Trefoil	3 Core	Single Core[a] Trefoil	3 Core	Single Core[a] Trefoil	3 Core	Single Core* Trefoil	3 Core
	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)
Copper Conductor								
50	235	220	220	210	245	225	220	210
70	285	270	270	255	300	275	270	255
95	360	330	320	300	360	330	320	295
120	415	375	360	340	425	380	360	335
150	470	430	410	380	485	430	410	375
185	540	490	460	430	550	490	460	420
240	640	570	530	490	650	570	530	480
300	740	650	600	540	740	650	600	530
400	840	740	680	600	850	740	690	590
500	990	-	750	-	980	-	760	-
630	1110	-	830	-	1130	-	850	-
800	1270	-	920	-	1280	-	930	-
Aluminium Conductor								
50	180	170	170	160	190	175	170	160
70	225	210	210	195	235	215	210	195
95	280	250	250	230	280	260	250	230
120	320	295	280	265	330	300	280	260
150	365	330	320	300	375	335	320	290
185	425	385	360	335	430	390	360	330
240	500	450	415	380	510	460	415	380
300	580	510	475	435	580	520	475	425
400	670	590	540	490	680	600	550	480
500	790	-	610	-	790	-	610	-
630	910	-	680	-	920	-	690	-
800	1060	-	770	-	1060	-	770	-

Copper wire screened
Source : Mfg. Data

SECTION - 9

GREEN BUILDINGS

Sustainability

What is Sustainability?

Sustainability is based on a simple principle: Everything that we need for our survival and well-being depends, either directly or indirectly, on our natural environment. Sustainability creates and maintains the conditions under which humans and nature can co-exist in productive harmony, that permit fulfilling the social, economic and other requirements of present and future generations.

Sustainability is important to making sure that we have and will continue to have water, energy, materials and resources to protect human health and our environment.

Sustainable development Is a pattern of economic development in which resource use aims to meet human needs while preserving the environment so that these needs can be met not only in the present, but also for generations to come. The term 'sustainable development, means the development that "meets the needs of the present without compromising the ability of future generations to meet their own needs. There is an additional focus on the present generations' responsibility to improve the future generations' life by restoring the previous ecosystem damage and resisting contributing to further ecosystem damage".

In the year 1995, a summary of a World Watch Report #124 of March1995 published the results of a survey regarding buildings. World Watch authors noted that a building consumes 40% of world energy production - excluding the energy that is required to harvest, process, manufacture and transport all the materials used to construct and maintain the buildings, 6.6% of all water pumped out of natural flows and 25% of all virgin wood harvested ends up in buildings-excluding the quantity which goes into the interiors and the furniture; to achieve sustainable environmental design, it is imperative that the entire design method, approach and discipline be structured. Every component, every guideline, every aspect of design must consider implications of the adjective 'environment'; as such, environmental design must be thought of as an overall approach; its limits go well beyond the practice of design to every aspect of society.

Rating Systems for Green Buildings

To ensure that a building is of sustainable and green design in construction and operation, it becomes easier to follow a rating system that has been stipulated by a body of professionals or an authorized institution that will carry out a detailed analysis on the measures taken by the owner in the construction process and will validate and cross check. There are certain metrics in place to measure and evaluate each of the construction activities for its compliance to green building aspects.

The institutions that certify a building as Green in India and to what level that each of the sustainable features has been implemented and followed and their rating systems are as noted below:

* Indian Green Building Council (IGBC) - **LEED India**
* The Energy and Resources Institute (TERI) - **GRIHA**

LEED stands for Leadership in Energy and Environment Design; this is implemented across the world by US Green Building Council (USGBC); IGBC is the organization that collaborates with the USGBC in bringing the systems and procedures that are laid down by the USGBC and modify the same to the context that is prevalent in India in the building construction aspects;

Confederation of Indian Industry (CII) and Indian Green Building Council (IGBC) has developed Rating Systems to systematically evaluate the level of sustainable measures that a building takes in the following areas of building design and construction:

* Buildings that are under New Construction and major renovations category
  - o LEED India for NC (New Construction)
* Buildings that are under Core and Shell type of construction
  - o LEED India for CS (Core and Shell)
* Residential Homes and Apartment Complex
  - o IGBC Green Homes
* Buildings that have Factory category of operations
  - o IGBC Green Factory Building Rating System
* Existing Buildings
  - o IGBC Green Existing Buildings (Operations & Maintenance) Rating System

Approach to making a building Green

In order to make an independent home or a residential campus or a commercial building "a **Green Building or a high performance building or a Sustainable building",** following sustainable measures are to be addressed; "Green", per se is a kind of a brand name whereas Sustainability or a High Performance Building is a generic feature:

The systematic approach to constructing and ensuring that a building is Green is to follow the sustainable building design practices in the following areas of construction;

* Site Selection and Planning (Sustainable Site selection) (SS)
* Efficient use of Water (WE)
* Improving Energy Efficiency and Atmosphere (EA)
* Proper use of Materials and Resources (MR)
* Enhancing Indoor Environmental Quality (IEQ)

*** Summary of Credit Points under Different Categories**

100 possible points under the five core categories - SS, WE, EA, MR & IEQ.

6 possible points under 'Innovation in Design'

4 possible points under 'Regional Priority'

Credit Point Thresholds for Different Levels of Certification

Certified	40 - 49 Points
Silver	50 - 59 Points
Gold	60 - 79 Points
Platinum	80 Points and above

TERI (The Energy Research Institute) has come out with a system that is called GRIHA - Green Rating for Integrated Habitat Assessment which is the National Rating System of India. GRIHA has been conceived by TERI and developed jointly with the Ministry of New and Renewable Energy, Government of India. It is a green building 'design evaluation system' and is suitable for buildings in different climatic zones. Across the world, there are various rating systems that are being followed as per the local norms and standards; also, when a rating system is developed, it takes into account the local building and services design practices in construction and evolves a certain metrics for benchmarking and evaluation; just to give an idea of the rating systems developed and implemented through the globe:

* Australia - Green Star
* UK - BREEAM
* Abu Dhabi - Pearl Rating
* Qatar-Qatar Sustainability Assessment System-QSAS
* Singapore - Green Mark Benefits of Green Buildings

1. Environmental friendly and minimum damage to environment
2. Better market value for builder/developer
3. Better health for occupant
4. Minimum energy bills for occupant/owner

LEED 2011 for India NC - Checklist

Sustainable Sites (SS)		**26 Possible Points**
Prerequisite 1	Construction Activity Pollution Prevention Required	1
Credit 1	Site Selection	5
Credit 2	Development Density and Community Connectivity	1
Credit 3	Brownfield Redevelopment	6
Credit 4.1	Alternative Transportation—Public Transportation Access	1
Credit 4.2	Alternative Transportation—Bicycle Storage and Changing Rooms	3
Credit 4.3	Alternative Transportation—Low-Emitting and Fuel-Efficient Vehicles	2
Credit 4.4	Alternative Transportation—Parking Capacity	1
Credit 5.1	Site Development—Protect or Restore Habitat	1
Credit 5.2	Site Development—Maximize Open Space	1
Credit 6.1	Stormwater Design—Quantity Control	1
Credit 6.2	Stormwater Design—Quality Control	1
Credit 7.1	Heat Island Effect—Nonroof	1
Credit 7.2	Heat Island Effect—Roof	1
Credit 8	Light Pollution Reduction	1
Water Efficiency (WE)		**10 Possible Points**
Prerequisite 1	Water Use Reduction Required	
Credit 1	Water Efficient Landscaping	2-4
Credit 2	Innovative Wastewater Treatment and Reuse	2
Credit 3	Water Use Reduction	2-4
Energy and Atmosphere (EA)		**35 Possible Points**
Prerequisite 1	Fundamental Commissioning of Building Energy Systems Required	
Prerequisite 2	Minimum Energy Performance Required	
Prerequisite 3	Fundamental Refrigerant Management Required	
Credit 1	Optimize Energy Performance	1-19
Credit 2	On-site Renewable Energy	1-7
Credit 3	Enhanced Commissioning	2
Credit 4	Enhanced Refrigerant Management	2
Credit 5	Measurement and Verification	3
Credit 6	Green Power	2
Materials and Resources (MR)		**14 Possible Points**
Prerequisite 1	Storage and Collection of Recyclables Required	
Credit 1.1	Building Reuse—Maintain Existing Walls, Floors and Roof	1-3
Credit 1.2	Building Reuse—Maintain Existing Interior Nonstructural Elements	1
Credit 2	Construction Waste Management	1-2
Credit 3	Materials Reuse	1-2
Credit 4	Recycled Content	1-2
Credit 5	Regional Materials	1-2
Credit 6	Rapidly Renewable Materials	1-2
Credit 7	Certified Wood	1-2
Indoor Environmental Quality (IEQ)		**15 Possible Points**
Prerequisite 1	Minimum Indoor Air Quality Performance Required	
Prerequisite 2	Environmental Tobacco Smoke (ETS) Control Required	
Credit 1	Outdoor Air Delivery Monitoring 1	
Credit 2	Increased Ventilation 1	
Credit 3.1	Construction Indoor Air Quality Management Plan—During Construction	1
Credit 3.2	Construction Indoor Air Quality Management Plan—Before Occupancy	1
Credit 4.1	Low-Emitting Materials—Adhesives and Sealants	1
Credit 4.2	Low-Emitting Materials—Paints and Coatings	1
Credit 4.3	Low-Emitting Materials—Flooring Systems	1
Credit 4.4	Low-Emitting Materials—Composite Wood and Agrifiber Products	1
Credit 5	Indoor Chemical and Pollutant Source Control	1
Credit 6.1	Controllability of Systems—Lighting	1
Credit 6.2	Controllability of Systems—Thermal Comfort	1
Credit 7.1	Thermal Comfort—Design	1
Credit 7.2	Thermal Comfort—Verification	1
Credit 8.1	Daylight and Views—Daylight	1
Credit 8.2	Daylight and Views—Views	1
Innovation in Design (ID)		**6 Possible Points**
Credit 1	Innovation in Design	1-5
Credit 2	LEED Accredited Professional	1
Regional Priority (RP)		**4 Possible Points**
Credit 1	Regional Priority	1-4

Summary of Credit Points under Different Categories
100 possible points under the five core categories - SS, WE, EA, MR & IEQ
6 possible points under 'Innovation in Design'
4 possible points under 'Regional Priority'
Credit Point Thresholds for Different Levels of Certification
Certified - 40 - 49 points
Silver - 50 - 59 points
Gold - 60 - 79 points
Platinum - 80 points and above

TERI (The Energy Research Institute) has a rating system that is called **GRIHA - Green Rating for Integrated Habitat Assessment;** GRIHA has been conceived by TERI and developed jointly with the Ministry of New and Renewable Energy, Government of India. It is a green building design evaluation system that is suitable for buildings in different climatic zones and to evaluate for the measure of sustainable measures that have been taken into consideration.

Criteria of the Rating System: The criteria have been categorized as follows.

1. Site Selection and Site Planning
Conservation and efficient utilization of resources
Criterion 1 Site Selection.
Criterion 2 Preserve and protect the landscape during construction/compensatory depository forestation.
Criterion 3 Soil conservation (till post-construction).
Criterion 4 Design to include existing site features.
Criterion 5 Reduce hard paving on-site and /or provide shaded hard - paved surfaces.
Criterion 6 Enhance outdoor lighting system efficiency.
Criterion 7 Plan utilities efficiently and optimize on-site circulation efficiency.
Health and well-being during construction
Criterion 8 Provide at least, the minimum level of sanitation / safety facilities for construction workers.
Criterion 9 Reduce air pollution during construction.
2. Building Planning and Construction Stage
3. Water
Criterion 10 Reduce landscape water requirement.
Criterion 11 Reduce building water use.
Criterion 12 Efficient water use during construction.
Energy: end use
Criterion 13 Optimize building design to reduce the, conventional energy demand.
Criterion 14 Optimize the energy performance of the building within specified comfort limits.
Energy: embodied and construction
Criterion 15 Utilization of fly ash in the building structure.
Criterion 16 Reduce volume, weight, and time of construction by adopting an efficient technology (e.g. pre-cast systems, ready-mix concrete, etc.).
Criterion 17 Use low-energy material in the interiors.
Energy: renewable
Criterion 18 Renewable energy utilization.
Criterion 19 Renewable energy-based hot - water system.
Recycle, recharge, and reuse of water
Criterion 20 Wastewater treatment
Criterion 21 Water recycle and reuse (including rainwater).
Waste management
Criterion 22 Reduction in waste during construction.
Criterion 23 Efficient waste segregation.
Criterion 24 Storage and disposal of waste.
Criterion 25 Resource recovery from waste.
Health and well-being during post-construction occupation
Criterion 26 Use of low-VOC (volatile organic compounds) paints / adhesives / sealants.
Criterion 27 Minimize ozone - depleting substances
Criterion 28 Ensure water quality.
Criterion 29 Acceptable outdoor and indoor noise levels.
Criterion 30 Tobacco and smoke control.
Criterion 31 Provide the minimum level of accessibility for persons with disabilities.
4. Building Operation and Maintenance
Criterion 32 Energy audit and validation.
Criterion 33 Building operation and maintenance.
5. Innovation Criterion
Criterion 34 Innovation points.

GRIHA has a 100 point system consisting of some core points, which are mandatory to be met while the rest are optional points, which can be earned by complying with the commitment of the criterion for which the point is allocated. Different levels of certification (one star to five stars) are awarded based on the number of points earned. The minimum points required for certification is 50. Buildings scoring 50 to 60 points, 61 to 70 points, 71 to 80 points, and 81 to 90 points will get 'one star', 'two stars', 'three stars' and 'four stars' respectively. A building scoring 91 to 100 points will get the maximum rating viz. five stars.

Point Scored	Rating
50-60	One Star
61-70	Two Stars
71-80	Three Stars
81-90	Four Stars
91-100	Five Stars

EA Prerequisite 1: Fundamental Commissioning of Building Energy Systems
Required
Intent
To verify that the project's energy-related systems are installed, and calibrated to perform according to the owner's project requirements, basis of design and construction documents.

Benefits of commissioning include reduced energy use, lower operating costs, fewer contractor callbacks, better building documentation, improved occupant productivity and verification that the systems perform in accordance with the owner's project requirements.

Requirements
The following commissioning process activities must be completed by the project team:

- Designate an individual as the commissioning authority (CxA) to lead, review and oversee the completion of the commissioning process activities.
  - o The CxA must have documented commissioning authority experience in at least 2 building projects.
  - o The individual serving as the CxA must be independent of the project design and construction management, though the CxA may be an employee of any firm providing those services. The CxA may be a qualified employee or consultant of the owner.
  - o The CxA must report results, findings and recommendations directly to the owner.
  - o For projects smaller than 50,000 gross square feet (5,000 gross square meters), the CxA may be a qualified person on the design or construction team

who has the required experience.

- The owner must document the owner's project requirements. The design team must develop the basis of design. The CxA must review these documents for clarity and completeness. The owner and design team must be responsible for updates to their respective documents.
- Develop and incorporate commissioning requirements into the construction documents.
- Develop and implement a commissioning plan.
- Verify the installation and performance of the systems to be commissioned.
- Complete a summary commissioning report.

Commissioned Systems

Commissioning process activities must be completed for the following energy-related systems, at a minimum:

- Heating, ventilating, air-conditioning and refrigeration (HVAC&R) systems (mechanical and passive) and associated controls
- Lighting and daylighting controls
- Domestic hot water systems
- Renewable energy systems (e.g. wind, solar)

Potential Technologies & Strategies

Engage a CxA as early as possible in the design process. Determine the owner's project requirements, develop and maintain a commissioning plan for use during design and construction and incorporate commissioning requirements in bid documents. Assemble the commissioning team, and prior to occupancy verify the performance of energy consuming systems. Complete the commissioning reports with recommendations prior to accepting the commissioned systems.

Owners are encouraged to seek out qualified individuals to lead the commissioning process. Qualified individuals are identified as those who possess a high level of experience in the following areas:

- Energy systems design, installation and operation.
- Commissioning planning and process management.
- Hands-on field experience with energy systems performance, interaction, start-up, balancing, testing, troubleshooting, operation and maintenance procedures.
- Energy systems automation control knowledge.

Owners are encouraged to consider including water-using systems, building envelope systems, and other systems in the scope of the commissioning plan as appropriate. The building envelope is an important component of a facility that impacts energy consumption, occupant comfort and indoor air quality. While this prerequisite does not require building envelope commissioning, an owner can achieve significant financial savings and reduce risk of poor indoor air quality by including it in the commissioning process.

The LEED 2011 complete Reference Guide for India provides guidance on the rigor expected for this prerequisite for the following:

Owner's project requirements

- Basis of design
- Commissioning plan
- Commissioning specification
- Performance verification documentation
- Commissioning report

EA Prerequisite 2: Minimum Energy Performance

Required Intent

To establish the minimum level of energy efficiency for the proposed building and systems to reduce environmental and economic impacts associated with excessive energy use.

Requirements

Whole Building Energy Simulation

Demonstrate a 10% improvement in the proposed building performance rating for new buildings, or a 5% improvement in the proposed building performance rating for major renovations to existing buildings, compared with the baseline building performance rating.

Calculate the baseline building performance rating according to the building performance rating method in Appendix G of ANSI / ASHRAE / IESNA Standard 90.1-2007 (with errata but without addenda) using a computer simulation model for the whole building project.

Appendix G of Standard 90.1-2007 requires that the energy analysis done for the building performance rating method include all energy costs associated with the building project. To achieve points using this credit, the proposed design must meet the following criteria:

Comply with the mandatory provisions (Sections 5.4, 6.4, 7.4, 8.4, 9.4 and 10.4) in Standard 90.1-2007 (with errata but without addenda18)

Include all energy costs associated with the building project.

Compare against a baseline building that complies with Appendix G of Standard 90.1-2007 (with errata but without addenda). The default process energy cost is 25% of the total energy cost for the baseline building. If the building's process energy cost is less than 25% of the baseline building energy cost, the LEED submittal must include documentation substantiating that process energy inputs are appropriate.

For the purpose of this analysis, process energy is considered to include, but is not limited to, office and general miscellaneous equipment, computers, elevators and escalators, kitchen cooking and refrigeration, laundry washing and drying, lighting exempt from the lighting power allowance (e.g., lighting integral to medical equipment) and other facilities (e.g., waterfall pumps).

Regulated (non-process) energy includes lighting (for the interior, parking garage, surface parking, facade, or building grounds, etc. except as noted above), heating, ventilation and air-conditioning (HVAC) (for space heating, space cooling, fans, pumps, toilet exhaust, parking garage ventilation, kitchen hood exhaust, etc.), and service water heating for domestic or space heating purposes.

Process loads must be identical for both the baseline building performance rating and the proposed building performance rating. However, project teams may follow the exceptional calculation method (ANSI / ASHRAE / IESNA Standard 90.1-2007 G2.5) to document measures that reduce process loads. Documentation of process load energy savings must include a list of the assumptions made for both the base and the proposed design, and theoretical or empirical information supporting these assumptions.

OR

Demonstrate performance that is equivalent to the above requirements by substituting appropriate benchmarks, protocols and metrics that use a local standard for establishing a baseline, and measure performance relative to that baseline.

NOTE: The desired comfort temperature range can be taken upto a maximum of 26 $\pm$ 2 deg C. In whole building simulation, the same comfort temperature range should be applied for both the base case and design case.

Potential Technologies & Strategies

Design the building envelope and systems to meet baseline requirements. Use a computer simulation model to assess the energy performance and identify the most cost-effective energy efficiency measures. Quantify energy performance compared with a baseline building.

If ECBC (Energy Conservation Building Code of India) or other local code has demonstrated quantitative and textual equivalence following, at a minimum, the U.S. Department of Energy (DOE) standard process for commercial energy code determination, then the results of that analysis may be used to correlate local code performance with ANSI / ASHRAE / IESNA Standard 90.1-2007. Details on the DOE process for commercial energy code determination can be found at http://www.energycodes.gov/implement/determinations_com .stm.

EA Prerequisite 3 : Fundamental Refrigerant Management Required Intent

To reduce stratospheric ozone depletion.

Requirements

Zero use of chlorofluorocarbon (CFC)-based refrigerants in new base building heating, ventilating, air - conditioning and refrigeration (HVAC & R) systems. When reusing existing base building HVAC equipment, complete a comprehensive CFC phase-out conversion prior to project completion. Phase-out plans extending beyond the project completion date will be considered on their merits.

Potential Technologies & Strategies

When reusing existing HVAC systems, conduct an inventory to identify equipment that uses CFC-based refrigerants and provide a replacement schedule for these refrigerants. For new buildings, specify HVAC equipment in the base building that uses no CFC-based refrigerants.

EA Credit 1: Optimize Energy Performance

1-19 Points

Intent

To achieve increasing levels of energy performance beyond the prerequisite standard to reduce environmental and economic impacts associated with excessive energy use.

Requirements

Project teams documenting achievement using the below approach are assumed to be in compliance with EA Prerequisite 2: Minimum Energy Performance.

Whole Building Energy Simulation (1-19 points)

Demonstrate a percentage improvement in the proposed building performance rating compared with the baseline building performance rating. Calculate the baseline building performance according to Appendix G of ANSI / ASHRAE / IESNA Standard 90.1-2007 (with errata but without addenda 19) using a computer simulation model for the whole building project. The minimum energy cost savings percentage for each point threshold is as follows -

New Buildings	Existing Building Renovations	Points
12%	8%	1
14%	10%	2
16%	12%	3
18%	14%	4
20%	16%	5
22%	18%	6
24%	20%	7
26%	22%	8
28%	24%	9
30%	26%	10
32%	28%	11
34%	30%	12
36%	32%	13
38%	34%	14
40%	36%	15
42%	38%	16
44%	40%	17
46%	42%	18
48%	44%	19

Appendix G of Standard 90.1-2007 requires that the energy analysis done for the building performance rating method include all the energy costs associated with the building project. To achieve points under this credit, the proposed design must meet the following criteria:

Compliance with the mandatory provisions (Sections 5.4, 6.4, 7.4, 8.4, 9.4 and 10.4) in Standard 90.1-2007 (with errata but without addenda).

Inclusion of all the energy costs within and associated with the building project.

Comparison against a baseline building that complies with Appendix G of Standard 90.1-2007 (with errata but without addenda). The default process energy cost is 25% of the total energy cost for the baseline building. If the building's process energy cost is less than 25% of the baseline building energy cost, the LEED submittal must include documentation substantiating that process energy inputs are appropriate.

For the purpose of this analysis, process energy is considered to include, but is not limited to, office and general miscellaneous equipment, computers, elevators and escalators, kitchen cooking and refrigeration, laundry washing and drying, lighting exempt from the lighting power allowance (e.g., lighting integral to medical equipment) and other (e.g., waterfall pumps).

Regulated (non-process) energy includes lighting (e.g., for the interior, parking garage, surface parking, facade, or building grounds, etc. except as noted above), heating, ventilating, and air - conditioning (HVAC) (e.g., for space heating, space cooling, fans, pumps, toilet exhaust, parking garage ventilation, kitchen hood exhaust, etc.), and service water heating for domestic or space heating purposes.

For this credit, process loads must be identical for both the baseline building performance rating and the proposed building performance rating. However, project teams may follow the exceptional calculation method (ANSI / ASHRAE / IESNA Standard 90.1-2007 G2.5) to document measures that reduce process loads. Documentation of process load energy savings must include a list of the assumptions made for both the base and proposed design, and theoretical or empirical information supporting these assumptions.

OR

Demonstrate performance that is equivalent to the above requirements by substituting appropriate benchmarks, protocols and metrics that use a local standard for establishing a baseline, and measure performance relative to that baseline.

NOTE:

The desired comfort temperature range can be taken upto a maximum of 26 ± 2 deg C. In whole building simulation, the same comfort temperature range should be applied for both the base case and design case.

Potential Technologies & Strategies

Design the building envelope and systems to maximize energy performance. Use a computer simulation model to assess the energy performance and identify the most cost-effective energy efficiency measures. Quantify energy performance compared with a baseline building.

If ECBC (Energy Conservation Building Code of India) or

local code has demonstrated quantitative and textual equivalence following, at a minimum, the U.S. Department of Energy (DOE) standard process for commercial energy code determination, the results of that analysis may be used to correlate local code performance with ANSI / ASHRAE / IESNA Standard 90.1-2007. Details on the DOE process for commercial energy code determination can be found at http://www.energycodes.gov/implement/determinations_com .stm

EA Credit 2: On-site Renewable Energy

1-7 Points

Intent

To encourage and recognize increasing levels of on-site renewable energy self-supply to reduce environmental and economic impacts associated with fossil fuel energy use.

Requirements

Use on-site renewable energy systems to offset building energy costs. Calculate project performance by expressing the energy produced by the renewable systems as a percentage of the building's annual energy cost and use the table below to determine the number of points achieved.

Use the building annual energy cost calculated in EA credit 1: Optimise energy performance, to determine the estimated electricity use.

The minimum renewable energy percentage for each point threshold is as follows:

Percentage Renewable Energy	Points
1%	1
3%	2
5%	3
7%	4
9%	5
11%	6
13%	7

Potential Technologies & Strategies

Assess the project for nonpolluting and renewable energy potential including solar, wind, geothermal, low-impact hydro, biomass and bio-gas strategies. When applying these strategies, take advantage of net metering with the local utility.

EA Credit 3: Enhanced Commissioning

2 Points

Intent

To begin the commissioning process early in the design process and execute additional activities after systems performance verification is completed.

Requirements

Implement, or have a contract in place to implement the following additional commissioning process

activities in addition to the requirements of EA Prerequisite 1: Fundamental Commissioning of Building Energy Systems and in accordance with the LEED 2011 complete Reference Guide for India:

- Prior to the start of the construction documents phase, designate an independent commissioning authority (CxA) to lead, review and-oversee the completion of all commissioning process activities.
  - o The CxA must have documented commissioning authority experience in at least 2 building projects.
  - o The individual serving as the CxA:
  - Must be independent of the work of design and construction.
  - Must not be an employee of the design firm, though he or she may be contracted through them.
  - Must not be an employee of, or contracted through, a contractor or construction manager holding construction contracts.
  - May be a qualified employee or consultant of the owner.
- The CxA must report results, findings and recommendations directly to the owner.
- The CxA must conduct, at a minimum, one commissioning design review of the owner's project requirements basis of design, and design documents prior to the mid-construction documents phase and back-check the review comments in the subsequent design submission.
- The CxA must review contractor submittals applicable to systems being commissioned for compliance with the owner's project requirements and basis of design. This review must be concurrent with the review of the architect or engineer on record and submitted to the design team and the owner.
- The CxA or other project team members must develop a systems manual that gives future operating staff the information needed to understand and optimally operate the commissioned systems.
- The CxA or other project team members must verify that the requirements for training operating personnel and building occupants have been completed.
- The CxA must be involved in reviewing the operation of the building with operations and maintenance (O&M) staff and occupants within 10 months after substantial completion. A plan for resolving outstanding commissioning-related issues must be included.

Potential Technologies & Strategies

Although it is preferable that the CxA be contracted by the owner, for the enhanced commissioning credit the CxA may also be contracted through the design firms or construction management firms not holding construction contracts.

The LEED 2011 complete Reference Guide for India provides detailed guidance on the rigor expected for the following process activities:

- Commissioning design review
- Commissioning submittal review
- Systems manual.

EA Credit 4: Enhanced Refrigerant Management

2 Points

Intent

To reduce ozone depletion and support early compliance with the Montreal Protocol while minimizing direct contributions to climate change.

Requirements

OPTION 1

Do not use refrigerants.

OR

OPTION 2

Select refrigerants and heating, ventilation, air-conditioning and refrigeration (HVAC&R) equipment that minimize or eliminate the emission of compounds that contribute to ozone depletion and climate change. The base building HVAC&R equipment must comply with the following formula, which sets a maximum threshold for the combined contributions to ozone depletion and global warming potential:

Imperial Units
LCGWP + LCODP x 105 < 100

Metric Units
LCGWP + LCODPx105<13

Calculation definitions for LCGWP+LCODPx105 ≤ 100 (Imperial units)	Calculation definitions for LCGWP + LCODP x 105 ≤ 1 3 (Metric units)
LCODP = [ODPr x (Lr x Life +Mr) x Rc]/Life	LCODP = [ODPr x (Lr x Life +Mr) x Rc]/Life
LCGWP = [GW'Pr x (Lr x Life +Mr) x Rc]/Life	LCGWP = [GWPr x (Lr x Life +Mr) x Rc]/Life
LCODP: Lifecycle Ozone Depletion Potential (lbCFC 11/ Ton-Year)	LCODP: Lifecycle Ozone Depletion Potential (kgCFC11/ (kW/year))
LCGWP: Lifecycle Direct Global Warming Potential (lb CO2/Ton-Year)	LCGWP: Lifecycle Direct Global Warming Potential (kg C02/(kW/year))
ODPr: Ozone Depletion Potential of Refrigerant (0 to 0.2 lbCFC 11/lbr)	ODPr: Ozone Depletion Potential of Refrigerant (0 to 0.2kgCFC11/kgr)
GWPr: Global Warming Potential of Refrigerant (Oto12,OOOlbC02/lbr)	GWPr: Global Warming Potential of Refrigerant (0 to 12,000 kg C02/kgr)
Lr: Refrigerant Leakage Rate (0.5% to 2.0%; default of 2% unless otherwise demonstrated)	Lr: Refrigerant Leakage Rate (0.5% to 2.0%; default of 2% unless otherwise demonstrated)
Mr: End-of-life Refrigerant Loss (2% to 10%; default of 10% unless otherwise demonstrated) Rc: Refrigerant Charge (0.5 to 5.0 lbs of refrigerant per ton of gross ARI rated cooling capacity)	Mr: End-of-life Refrigerant Loss (2% to 10%; default of 10% unless otherwise demonstrated) Rc: Refrigerant Charge (0.065 to 0.65 kg of refrigerant per kW of ARI rated or Eurovent Certified cooling capacity)
Life: Equipment Life (10 years; default based on equipment type, unless otherwise demonstrated)	Life: Equipment Life (default based on equipment type, unless otherwise demonstrated)

For multiple types of equipment, a weighted average of all base building HVAC&R equipment must be calculated using the following formula:

$$\frac{\sum(LCGWP + LCODPx1O^5) \times Qunit}{Qtotal} \leq 100$$

$$\frac{\sum((LCGWP + LCODP \times 10^5) \times Qunit}{Qtotal} < 13$$

Calculation definitions for [[∑ (LCGWP + LCODP x 105) x Qunit] / [Qtotal]] < 100 (Imperial Unit)	**Calculation definitions for [[∑ (LCGWP + LCODP x 105) x Qunit] / [Qtotal]] < 13 (Metric Unit)**
Qunit = Gross ARI rated cooling capacity of an individual HVAC or refrigeration unit (Tons)	Qunit = Total gross ARI rated cooling capacity of all HVAC or refrigeration unit (kW)
Qtotal = Eurovent Certified cooling capacity of an individual HVAC or refrigeration unit (kW)	Qtotal = Total Eurovent Certified cooling capacity of all HVAC or refrigeration (kW)

Small HVAC units (defined as containing less than 0.5 pounds of refrigerant) and other equipment, such as standard refrigerators, small water coolers and any other cooling equipment that contains less than 0.5 pounds of refrigerant, are not considered part of the base building system and are not subject to the requirements of this credit.

Do not operate or install fire suppression systems that contain ozone-depleting substances such as CFCs, hydrochlorofluorocarbons (HCFCs) or halons.

Potential Technologies & Strategies

Design and operate the facility without mechanical cooling and refrigeration equipment. Where mechanical cooling is used, utilize base building HVAC&R systems for the refrigeration cycle that minimize direct impact on ozone depletion and global climate change. Select HVAC&R equipment with reduced refrigerant charge and increased equipment life. Maintain equipment to prevent leakage of refrigerant to the atmosphere. Use fire suppression systems that do not contain HCFCs or halons.

SECTION - 10

UNITS AND CONVERSIONS

Table 10.1 : SI Base and Supplementary Quantities and units

Quantity and dimension	SI unit	SI unit Symbol
Base quantity or "dimension"		
Length	Meter	m
Mass	Kilogram	kg
Time	Second	s
Electric current	Ampere	A
Thermodynamic temperature	Kelvin	K
Amount of substance	Mole	mol
Luminous intensity	Candela	cd
Supplementary quantity or		
"dimension"		
Plane angle	Radian	rad
Solid angle	Steradian	sr

*When the mol is used, the elementary entities must be specified, they may be atoms, molecules, ions, electrons or other particles, or specified groups of such particles.

Table 10.2 : Derived units of SI which have Special Names

Quantity	unit	Symbol	Formula
Frequency (of a periodic phenomenon)	hertz	Hz	l/s
Force	newton	N	$(kg\text{-}m)s^2$
Pressure, stress	pascal	Pa	N/m2
Energy, work, quantity of heat	joule	J	N*m
Power, radiant flux	watt	w	J/s
Quantity of electricity, electric charge	coulomb	C	A*s
Electric potential, potential difference electromotive force	volt	V	W/A
Capacitance	farad	F	C/V
Electric resistance	ohm	W	V/A
Conductance	Siemens	S	A/V
Magnetic-flux	weber	Wb	V*s
Magnetic flux density	testla	T	wb/m^2
Inductance	henry	H	wb/A
Luminous flux	lumen	lm	cd*sr
Illumination	lux	lx	lm/m^2
Activity (of radionuclides)	becquerel	Bq	l/s
Absorbed dose	gray	GV	J/kg

Table 10.3 : Additional Common Derived Units of SI

Quantity	Unit	Symbol
Acceleration	Meter per second squared	m/s^2
Angular acceleration	Radian per second squared	rad/s^2
Angular velocity	Radian per second	rad/s
Area	Square meter	m^2
Concentration (of amount of substance)	Mole per cubic meter	mol/m^3
Current density	Ampere per square meter	A/m^2
Density, mass	Kilogram per cubic meter	Kg/m^3
Electric-charge density	Coulomb per cubic meter	C/m^3
Electric-field strength	Volt per meter	V/m
Electric-flux density	Coulomb per square meter	C/m^2
Energy density	Joule per cubic meter	J/m^3
Entropy	Joule per Kelvin	J/K
Heat capacity	Joule per Kelvin	J/K
Heat-flux density Irradiance	Watt per square meter	W/m^2
Luminance	Candela per square meter	Cd/m^2
Magnetic-field strength	Ampere per meter	A/m
Molar energy	Joule per mole	J/mol
Molar entropy	Joule per mole-Kelvin	J/(mol-K)
Molar - heat capacity	Joule per mole-Kelvin	J/(mol-K)
Moment of force	Newton-meter	N*m
Permeability	Henry per meter	H/m
Permittivity	Farad per meter	F/m
Radiance	Watt per square-meter-steradian	$W/(m^2*sr)$
Radiant intensity	Watt per steradian	W/sr
Specific-heat capacity	Joule per kilogram-Kelvin	J/(kg*K)
Specific energy	Joule per kilogram	J/Kg
Specific entropy	Joule per kilogram-Kelvin	J/(kg*K)
Specific volume	Cubic meter per kilogram	m^3/kg
Surface tension	Newton per meter	N/m
Thermal conductivity	Watt per meter-Kelvin	W/(m*k)
Velocity	Meter per second	m/s
Viscosity, dynamic	Pascal-second	Pa*s
Viscosity, kinematic	Square meter per second	m^2/s
Volume	Cubic meter	m^3
Wave number	1 per meter	l/m

Table 10.4 : SI Prefixes

Multiplication factor	Prefix	Symbol
$1000\ 000\ 000\ 000\ 000\ 000 = 10^{18}$	exa	E
$1000\ 000\ 000\ 000\ 000 = 10^{15}$	peta	P
$1000\ 000\ 000\ 000 = 10^{12}$	tera	T
$1000\ 000\ 000 = 10^{9}$	giga	G
$1000\ 000 = 10^{6}$	mega	M
$1000 = 10^{3}$	kilo	k
$100 = 10^{2}$	hecto	h
$10 = 10^{1}$	deka	da
$0.1 = 10^{-1}$	deci	d
$0.01 = 10^{-2}$	centi	c
$0.001 = 10^{-3}$	mill!	m
$0.000\ 001 = 10^{-6}$	micro	m
$0.000000001 = 10^{-9}$	nano	n
$0.000\ 000\ 000\ 001 = 10^{-12}$	pico	P
$0.000\ 000\ 000\ 000\ 001 = 10^{-15}$	femto	f
$0.000\ 000\ 000\ 000\ 000\ 001 = 10^{-18}$	atto	a

Table 10.5 : Conversion Factors: Customary and Commonly Used Units to SI Units

Quantity	Customary or commonly used unit	SI unit	Alternate SI Unit	Conversion factor; multiply customary unit by factor to obtain SI unit
Length	naut mi	km		1.852* E + 00
	mi	km		1.609344* E+00
	chain	m		2.01168* E+01
	link	m		2.01168* E-01
	fathom	m		1.8288* E+00
	yd	m		9.144* E-01
	ft	m		3.048* E-01
		cm		3.048* E + 01
	in	mm		2.54* E +01
	in	cm		2.54 * E+00
	mil	mm		2.54 * E +01
Area	mi2	km^2		2.589 988 E +00
	section	ha		2.589 988 E +02
	acre	ha		4.046856 E-01
	ha	m2		1.000000* E-04
	yd2	m2		8.361274 E-01
	ft2	m2		9.290304 E-02
	In2	mm^2		6.451 6* E +02
		cm^2		6.451 6* E +00
Volume	Cubem	km^3		4.168 182 E +00
	acre ft.	m^3		1.233482 E+03
		ham		1233482 E -01
	yd3	m^3		7.645 549 E -01
	bbl (42 U.S. gal)	m^3		1.589873 E-01
	ft3	m^3		2.831685 E-02
		dm^3	L	2.831 685 E + 01
	U.K gal	m^3		4.546092 E-03
		dm^3	L	4.546 092 E + 00
	U.S gal	m^3		3.785412 E-03
		dm^3	L	3.785412 E + 00
	U.K.qt	dm^3	L	1.136523 E + 00
	U.S.qt	dm^3	L	9.463529 E-01
	U.Spt	dm^3	L	4.731765 E-01
	U.K.floz	cm^3		2.841 307 E + 01
	U.S.floz	cm^3		2.957353 E + 01
	In3	cm^3		1.638706 E + 01
Plane angle	rad	rad		1
	deg(o)	rad		1.745329 E-02
	min (')	rad		2.908882 E-04
	sec(")	rad		4.848137 E-06
Solid angle	sr	sr		1
Time	year	a		1
	week	d		7.0* E + 00
	H	s		3.6* E +03
		min		6.0* E + 01
	min	s		6.0* E + 01
		h		1.666667 E-02
	mms	ns		1
Mass	U.K. ton	Mg	T	1.016047 E+00
	U.S. ton	Mg	T	9.071847 E-01
	U.K. cwt	Kg		5.080234 E + 01
	U.S.cwt	Kg		4.535 924 E + 01
	lbm	Kg		4.535924 E-01
	oz (troy)	g		3.110348 E + 01
	oz (av)	g		2.834 952 E + 01
	gr	mg		6.479 891 E + 01

Table 10.6 : Conversion Factors: US Customary and Commonly Used Units to SI Units

Quantity	Customary or commonly used unit	SI unit	Alternate SI Unit	Conversion factor; multiply customary unit by factor to obtain SI unit
ENTHALPY CALORIC VALUE, HEAT, ENTROPY, HEAT CAPACITY				
Caloric value, enthalpy (mass basis)	BTU/lbm	MJ/kg		2.326000 E-03
		KJ/kg	J/g	2.326000 E + 00
		Kwh/kg		6.461112 E -04
	Cal/g	KJ/kg	J/g	4.184* E + 00
	Cal/lbm	J/kg		9.224141 E + 00
Calorific value, enthalpy	Kcal/(g * mol)	kJ/kmol		4.184* E + 03
	BTU/(lb * mol)	kJ/kmol		2.326000 E + 00
Calorific value (volume basis solids and liquids)	BTU/U.S. gal	MJ/m^3	KJ/dm^3	2.787163 E-01
		kJ/m^3		2.787163 E + 02
		Kwh/ m^3		7.742119 E-02
	BTU/U.K. gal	MJ/m^3	KJ/dm^3	2.320800 E-01
		kJ/m^3		2.320800 E-02
		Kwh/ m^3		6.446667 E-02
	BTU/ft^3	MJ/m^3	KJ/dm^3	3.725895 E-02
		kJ/m^3		1.034971 E-02
		Kwh/ m^3		4.184* E + 00
	Cal/ml	MJ/m^3		3.581692 E-01
	(ft.lbf)/U.S gal	kJ/m^3		4.184* E + 03
Calorific value (volume basic - gases)	Cal/ml	kJ/m^3	J/dm^3	4.184* E+00
	Kcal/ m^3	kJ/m^3	J/dm^3	3.725895 E + 01
	BTU/ft^3	kJ/m^3	J/dm^3	1.034971 E-02
		Kwh/m		4.1866* E + 00
Specific entropy	BTU/(lbm*°R	KJ/(kg *K)	J/(g* K)	4.1864* E + 00
	Cal/(g *K)	KJ/(kg *K)	J/(g* K)	4.1864* E + 00
	Kcal/(kg*^{0}C)	KJ/(kg *K)	J/(g* K)	3.6* E + 03
Specific-heat capacity (mass basis)	Kwh(kg*^{0}C)	KJ/(kg *K)	J/(g* K)	4.1866* E + 00
	BTU(kg*^{0}C)	KJ/(kg *K)	J/(g* K)	4.1864* E + 00
	kcal(kg*^{0}C)	KJ/(kg *K)	J/(g* K)	4.1864* E + 00
TEMPERATURE, PRESSURE, VACCUM				
Temperature (Absolute)	^{0}RF	K		5/9
	K	k		1
Temperature (Traditional)	^{0}F	°C		5/9(o F-32)
Temperature (Differential)	^{0}F	K,°C		5/9
Pressure	Atm (760 mm Hg at	Mpa		1.013250* E-01
	0° Cor 14.696 psi)	Kpa		1.013250* E + 02
		bar		1.013250* E + 00
	bar	MPa		1.0* E-01
		kPa		1.0* E-02
	mmHg(0°C) = torr	MPa		6.894757 E-03
		kPa		6.894757 E + 00
		bar		6.894 757 E - 02
	mmHg((0^{0}C)	kPa		3.376 85 E + 00
	Mbar	kPa		2.4884 E-01
	mmHg = torr(0°C)	kPa		1.333224 E-01
	cmH20 (4^0 C)	kPa		9.806 38 E-02
	Lbf/ft2(psf)	kPa		4.788 026 E - 02
	mHg	Pa		1.333224 E-01
	Bar	Pa		1.0* E-01
	Dyn/cm^2	Pa		1.0* E-01
Vacuum, draft	inHg(60^{0}p)	kPa		3.376 85 E + 00
	InH20(39-2^{0}F)	kPa		2.49082 E-01
	InH20(60^{0}F)	kPa		2.4884 E-01
	MmHg(0°C)=torr	kPa		1.333224 E-01
	cmH20(4°C)	kPa		9.806 38 E-02

Table 10.7 : Conversion Factors : Customary and Commonly Used Units to SI Units

Quantity	Customary or commonly used unit	SI unit	Alternate SI Unit	Conversion factor-multiply customary unit by factor to obtain SI unit
Liquid head	ft	m		3.048* E-01
	In	mm		2.54* E+ 01
		cm		2.54* E + 00
Pressure drop/length	psi/ft	kPa/m		2.262059 E + 01
DENSITY, SPECIFIC VOLUME, CONCENTRATION, DOSAGE				
Density	lbm/ft³	Kg/m³		1.601 846 E + 01
		G/m³		1.601846 E + 04
	lbm / U.S. gal.	Kg/m³		1.198264 E + 02
		g/cm³		1.198264 E-01
	lbm / U.K. gal.	Kg/m³		9.977633 E + 01
	lbm/ft3	Kg/m³		1.601846 E + 01
		g/m³		1.601846 E -02
	g/cm³	Kg/m³		1.0* E + 03
	lbm/ft³	Kg/m³		1.601846 E + 01
Concentration (mass/ mass)	Wt%	Kg/kg		1.0* E-02
		9/kg		1.0* E + 01
	Wtppm	mg/kg		1
Concentration (mass/ volume)	lbm /bbl	Kg/m³	g/dm3	2.853010 E +00
	g/U.S gal	Kg/m³		2.641 720 E - 01
	g/U.K. gal	Kg/m³	g/i	2.199692 E -01
	lbm/1000U.Sgal	g/m³	mg/d m3	1.198264 E + 02
	lbm/1000U.Kgal	g/m³	mg/d m3	9.977633 E + 01
	gr/U.Sgal	mg/m³	mg/d m3	1.711806 E + 01
	grffi3	g/m³		2.288351 E + 03
	lbm/1000 bbl	g/m³	mg/d m3	2.853010 E +00
	mg/U.S gal	g/m³	mg/d m3	2.641720 E-01
	gr/100ft³	m g/m³		2.288 351 E + 01
Concentration (volume / volume)	ft3 /ft³	m³/m³		1
	bbl / (acre.ft)	m³/m³		1.288931 E-04
	vol %	m³/m³		1.0* E -02
	U. K. gal/ Ft³	d m³/ m³	l/m3	1.605437 E + 02
	U.S.gal/ Ft³	d m³/ m³	l/m3	1.336806 E + 02
	mL/U.Sgal	d m³/ m³	l/m3	2.641720 E-01
	mL/U.K gal	d m³/ m³	l/m3	2.199692 E-01
	vol ppm	cm³/m³		1
		d m³ı m³	L/m3	1.0* E-03
	U.K gal/1000 bbl	cm³/m³		2.859403 E + 01
	U.S gal/1000 bbl	cm³ım³		2.380952 E + 00
	U.Kpt/1000bbl	cm³ım³		3.574253 E + 00
	Std ft3(60°F,atm)/bbl	Kmol/ m³		7.51821 E-03
ENERGY, WORK, POWER				
Energy, work	Therm	MJ		1.055056 E + 02
		kJ		1.055056 E + 05
		Kwh		2.930711 E + 01
	U.S. tonPmi	MJ		1.401744 E + 01
	hp*h	MJ		2.684 520 E + 00
		KJ		2.684520 E + 03
		Kwh		7.456999 E-01
	Ch*h or CV*h	MJ		2.647 780 E + 00
		kJ		2.647 780 E + 03
		Kwh		7.354999 E-01
	kWh	Mj		3.6* E + 00
		kJ		3.6* E + 03
	Chu	kJ		1.899101 E + 00
		Kwh		5.275280 E-04
	BTU	kJ		1.055056 E + 00
		kWh		2.930711 E-04

Table 10.8 : Conversion Factors : Customary and Commonly Used Units to SI Units

Quantity	Customary or commonly used unit	SI unit	Alternate SI Unit	Conversion factor; multiply customary unit by factor to obtain SI unit
	Kcal	kj		4.184* E + 00
	cal	kJ		4.184* E-03
	fflbf	kJ		1.355818 E-03
	Lbf-ft	kj		1.355818 E-03
	J	kJ		1.0* E-03
	(lbf-ft2)/S^2	kJ		4.214011 E-05
	Hsrg	J		1.0* E-07
Impact energy	KgPm	J		9.806 650* E + 00
	lbf-ft	J		1.355818 E + 00
Surface energy	erg/cm^2	mJ/m^2		1.0* E+00
Power	Million BTU/h	MW		2.930711 E-01
	Ton of refrigeration	kW		3.516853 E+00
	BTU/s	kW		1.055056 E + 00
	kW	kW		1
	Hydraulic horsepower-HPP	kW		7.46043 E-01
	Hp (electric)	kW		7.46* E-01
	Hp (550 ft lbf)/S	kW		7.456999 E-01
	ChorCV	kW		7.354999 E-01
	BTU/min	kW		1.758427 E-02
	(ft*lbf)/s	kW		1.355818 E-03
	Kcal/h	W		1.162222 E + 00
	BTU/h	W		2.930711 E-01
	(ft*lbf)/min	W		2.259697 E-02
Power/area	BTU/(s-ft^2)	kW/m^2		1.135653 E + 01
	Cal/(h*cm^2)	kW/m^2		1.162222 E-02
	BTU/(h-ft^2)	kW/m^2		3.154591 E-03
Heat-release rate, mi*ing power	hp/ft^3	kW/m^3		2.633414 E + 01
	Cal/ (h*cm^3)	kW/m^3		1.162222 E + 00
	BTU / (f ft^3)	kW/m^3		3.725 895 E + 01
	BTU/(h-ft^3)	kW/m^3		1.034971 E-02
Cooling duty (machinery)	BTU /(bhp*h)	W/kW		3.930 148 E - 01
Specific fuel consumption	lbm /(hp*h)	mg/J		1.689659 E-01
(mass basis)		kg/kWh		6.082774 E-01
Specific fuel consumption (volume basis)	m3/kWh	dm^3/MJ		2.777778 E + 02
	U.S gal/(hp*h)	dm^3/MJ		1.410089 E + 00
	U.Kpt/(hp*h)	dm^3/MJ		2.116806 E-01
Fuel consumption	U.K gal/mi	dm^3 /100km		2.824 807 E + 02
	U.S ga/mi	dm^3 /100km		2.352 146 E + 02
	mirU.S. gal	km/ d m^3		4.251437 E-01
	mi/U.K gal	km/ d m^3		3.540064 E-01
Velocity (linear) speed	Knot	km/h		1.852* E+00
	mi/h	km/h		1.609344* E+00
	ft/s	m/s		3.048* E-01
		cm/s		3.048* E+ 01
	ft/min	m/s		5.08* E-03
	ft/h	mm/s		8.466667 E-02
	ft/day	mm/s		3.527 778 E - 03
		m/d		3.048* E-01
	in/s	mm/s		2.54* E+ 01
	in/min	mm/s		4.233333 E-01
Corrosion rate	in / year (ipy)	mm/a		2.54* E+ 01
	mil/year	mm/a		2.54* E-02
Rotational frequency	r/min	r/s		1.666667 E-02
		rad/s		1.047198 E-01

Table 10.9 : Conversion Factors : Customary and Commonly Used Units to SI Units

Quantity	Customary or commonly used unit	SI unit	Alternate SI Unit	Conversion factor; multiply customary unit by factor to obtain SI unit
Acceleration (rotational)	rpm/s	rad/s2		1.047198 E- 01
Momentum	(lbm*ft)/s	Kg*m)/s		1.382550 E- 01
Force	U.K .tonf	kN		9.964016 E + 00
	U.S. tonf	kN		8.896443 E + 00
	Kgf(kp)	N		9.806650 E + 00
	lbf	N		4.448222 E + 00
	dyn	mN		1.0 E-02
Bending moment, torque	U.S tonf.ft	kN*m		2.711636 E + 00
	Kgfm	N*m		9.806650 E + 00
	lbfft	N*m		1.355818 E + 00
	lbfin	N*m		1.129848 E-01
Bending moment, length	(lbf*ft)/in	(N*m)/m		5.337866 E + 01
	(lbfin)/in	(N*m)/m		4.448222 E + 00
Moment of inertia	lbm*ft^2	Kg*m^2		4.214011 E-02
Stress	U.S tonf/in^2	MPa		1.378951 E + 01
	Kgf/mm^2	MPa		9.806650* E + 00
	U.S.tonf/ft^2	MPa		9.576052 E-02
	lbf/in^2(psi)	MPa		6.894757 E-03
	lbf/ft^2(psi)	kPa		4.788026 E-02
	dyn/cm^2	Pa		1.0* E-01
Mass/length	lbm/ft	Kg/m		1.488164 E + 00
Mass/area structural loading	U.S. ton/ft^2	Mg/ m^2		9.674855 E + 00
Bearing capacity (mass basis)	lbm/ft2	Kg/m^2		4.882428 E + 00
MISCELLANEOUS TRANSPORT PROPERTIES				
Diffusivity	ft2/s	m^2/s		9.290304* E-02
	m2/s	m m^2/s		1.0* E + 06
	ft2/s	m^2/s		2.58064* E-05
Thermal resistance	(°C*m^2*h)/kcal	(K*m^2)/kW		8.604208 E + 02
	(°F*ft^2*h)/BTU	(K*m^2)/kW		1.761102 E + 02
Heat flux	BTU/(h*tFF)	kW/ m^2		3.154591 E-03
Thermal Conductivity	(cal*m)/(s*cm^2*°C)	W /(m*K)		4.184* E + 02
	(BTU*ft)/(h*fFF)	W/(m*K)		1.730735 E + 00
		(kJ*m)/h* m2'K)		6.230646 E + 00
	(kcal*m)/(h*m^2*°C)	W/(m*K)		1.162222 E + 00
	BTU*in/(h*ft^2*°F)	W/(m*K)		1.442279 E-01
	(cal*cm)/(h*cm^2*°C)	W/(m*K)		1.162222 E-01
Heat-transfer coefficient	cal/(s*cm^2*°C)	kW/(m^2/K)		4.184* E + 01
	BTU/(s*ft^2*F)	kW/(m^2/K)		2.044175 E + 01
	cal/((h*cm^2*°C)	kW/(m^2*K)		1.162222 E-02
	BTU/(h*ft^2*F)	kW/(m^2*K)		5.678263 E-03
		(kJ)/h* m^2/K)		2.044175 E + 01
	BTU/(h*ft^2*F)	kW/(m^2*K)		5.678263 E-03
	Kcal/(h*m^2*°C)	kW/(m^2*K)		1.162222 E-03
Volumetric heat-transfer	BTU/(h*ft^3*°F)	kW/(m^3'K)		6.706611 E + 01
Coefficient	BTU/(h*rP*°F)	kW/(m^3*K)		1.862947 E-02
Surface tension	dyn/cm	mN/m		1
Viscosity (dynamic)	(lbfs)/in^2	Pa*s		6.894757 E + 03
	(lbfs)/ft^2	Pa*s		4.788026 E + 01
	(kgfs)/m^2	Pa*s		9.806650* E + 00
	lbm /(ft*s)	Pa*s		1.488164 E + 00
	(dyn*s)/S	Pa's		1.0* E-01
	cP	Pa*s		1.0* E-03
	Lbm/ (ft*h)	Pa*s		4.133789 E-04

Table 10.10: Conversion Factors : Customary and Commonly Used Units to SI Units

Quantity	Customory or commonly used unit	SI unit	Alternate SI Unit	Conversion factor; multiply customary unit by factor to obtain SI unit
Viscosity (kinematic)	ft^2/s	m2/s		9.290304* E-02
	In^2/s	mm2/s		6.451 6* E + 02
	$m^{2/n}h$	mm2/s		2.777778 E+02
	$ft^{2/}h$	m2/s		2.58064* E-05
	cSt	mm2/s		1
Permeability	darcy	mm2		9.869233 E-01
	millidarcy	mm2		9.869233 E-04
Mass-transfer coefficient	(lb*mol)/(h-ft^2(lb-mol/ft^3	m/s		8.467 E-05
	(g*mol)/ (s*m^2(g*mol/L)	m/s		1.0 E + 01

*indicates that the conversion factor is exact
+Conversion factors for length, area, and volume are based on the international foot. The international foot is longer by 2 parts in 1 million than the U.S Survey foot (land-measurement use)

Note: The following unit symbols are used in the table

Unit Symbol	Name	Unit Symbol	Name	Unit Symbol	Name
A	ampere	Gy	Gray	Oe	oersted
a	annum (year)	H	Henry	W	ohm
Bb	becquerel	h	Hour	Pa	pascal
C	Coulomb	ha	Hectare	rad	radian
cd	Candela	Hz	Hertz	r	revolution
Ci	curie	J	Joule	S	siemens
d	day	K	Kelvin	s	second
°C	degree Celsius	u	Liter	“	second
0	degree	Im	Lumen	sr	steradian
dyn	dyne	Lx	Lux	st	stokes
F	farad	M	Meter	T	tesia
fc	footcandle	'min	Minute	t	tonne
G	gauss	Sec	Second	V	volt
G	gram	N	Newton	W	watt
gr	grain	naut mi	US Nautical Mile	Wb	weber

Table 10.11 : Alphabetical Listings of Common Conversions

To convert from	To	Multiply by
Acres	Square feet	43,560
Acres	Square meters	4074
Acres	Square miles	0.001563
Acre-feet	Cubic meters	1233
Ampere-hours (absolute)	Coulomb (absolute)	3600
Angstrom units	Inches	3.937x10-9
Angstrom units	Meters	1x10-¹°
Angstrom units	Microns	1.10-4
Atmospheres	Millimeters of mercury at 32 f	760
Atmospheres	Dynes per square centimetre	1.0133x106
Atmospheres	Newtons per square meter	101,325
Atmospheres	Feet of water at 39.1F	33.90
Atmospheres	Grams per square centimetre	1033.3
Atmospheres	Inches of mercury at 32 F	29.921
Atmospheres	Pounds per square foot	2116.3
Atmospheres	Pounds per square inch	14.696
Bags (cement)	Pounds (cement)	94
Barrels (cement)	Pounds (cement)	376
Barrels (oil)	Cubic meters	0.15899
Barrels (oil)	Gallons	42
Barrels(U.S. liquid)	Cubic meters	0.11924
Barrels(U.S. liquid)	Gallons	31.5
Barrels per day	Gallons per minute	0.02917
Bars	Atmospheres	0.9869
Bars	Newtons per square meter	1x105
Bars	Pounds per square inch	14.504
Board feet	Cubic feet	1/12
Boiler horsepower	BTU per hour	33,480
Boiler horsepower	Kilowatts	9.803
BTU	Calories (gram)	252
BTU	Centigrade heat units (c.h.u or p.c.u)	0.55556
BTU	Foot-Pounds	777.9
BTU	Horsepower-hours	3.929x104
BTU	Joules	1055.1
BTU	Litre-atmospheres	10.41
BTU	Pounds carbon to CCt	6.88x10-5
BTU	Pounds water evaporated from and at	
	212 F	0.001036
BTU	Cubic foot-atmospheres	0.3676
BTU	Kilowatt-hours	2.930x10-"
BTU per cubic foot	Joules per cubic meter	37,260
BTU per hour	Watts	0.29307
BTU per minute	Horsepower	0.02357
BTU per pound	Joules per kilogram	2326
BTU per pound per degree	Calories per gram per degree	
Fahrenheit	Centigrade	1
BTU per second	Joules per gram per degree	4186.8
BTU per square foot per hour	Kelvin	
BTU per square foot per min	Watts	
BTU per square foot per sec	Joules per square meter per second	1054.4
For temperature gradient of	Kilowatts per square foot	3.1546
1 F. Per inch	Calories, gram (15° C),per square	0.1758
BTU (60 F) per degree Fahrenheit	Centigrade per second for temperature	1.2405
Bushels (U.S.dry)	Gradient of 1 °C per centigrade	
Bushels (U.S dry)	Calories per degree centigrade	453.61.2444
Calories, gram	Cubic feet	0.03524
Calories, gram	Cubic meters	3.968X10-3
Calories, gram	BTU	3.087
Cabries, gram	Foot-pounds	4.1868
Calories, gram	Joules	4.130X10-2
Calories, gram, per gram per degree °C	Litre-atmosphere	1.5591x10*
Calories, kilogram	Horsepower-hours	4168.8
Calories, kilogram per	Joules per kilogram per degree	0.0011626
Second	Kelvin	
Candle power (spherical	Kilowatt hours	4.185
	Kilowatts	12.556
Carats (metric)	Grams	0.2
Centigrade heat units	BTU	1.8
Centimetres	Angstrom units	1.0»108
Centimetres	Feet	0.03281
Centimetres	Inches	0.03937
Centimetres	Meters	0.01
Centimetres	Microns	10,000
Centimetres of mercury at 0°C	Atmosphere	0.013158
Centimetres of mercury at 0°C	Feet of water at 39.1 °F	0.4460
Centimetres of mercury at 0°C	Newtons per square meter	1333.2
Centimetres of mercury at 0°C	Pounds per square foot	27,845
Centimetres of mercury at 0°C	Pounds per square inch	0.19337
Centimetres per second	Feet per minute	1.9685
Centimetres of water at 4° C	Newtons per square meter	98.064
Centistokes	Square meters per second	LOxlO-6
Circular mills	Square centimetres	5.067X10-6
Circular mills	Square inches	7.854x10-'
Circular mills	Square meter	0.7854
Cords	Cubic feet	128
Cubic centimetres	Cubic feet	3.532x10-5
Cubic centimetres	Gallons	2.6417x104
Cubic centimetres	Ounces (U.S.fluid)	0.03381
Cubic centimetres	Quarts (U.S.fluid)	0.0010567
Cubic feet	Bushels (U.S)	0.8.36
Cubic feet	Cubic centimetres	28,317
Cubic feet	Cubic , meters	0.028317
Cubic feet	Cubic yards	0.03704
Cubic feet	Gallons	7.481
Cubic feet	Litres	28.316
Cubic foot atmospheres	Foot-pounds	2116.3
Cubic foot atmospheres	Liter-atmospheres	28.316
Cubic feet of water (60 F)	Pounds	62.37
Cubic feet per minute	Cubic centimetres per second	472.0
Cubic feet per minute	Gallons per second	0.1247
Cubic feet per second	Gallons per minute	448.8
Cubic feet per second	Million gallons per day	0.64632
Cubic inches	Cubic meters	1. 6387x1 0-5
Cubic yards	Cubic meters	0.76456
Curies	Disintegrations per minute	2.2x10'2
Curies	Coulombs per minute	1.1x1012
Degrees	Radians	0.017453
Drams (apothecaries or troy)	Grams	3.888
Drams(avoirdupois)	Grams	1.7719
Dynes	Newtons	1x10-5
Ergs	Joules	1x10-'
Faradays	Coulombs (abs.)	96,500
Fathoms	Feet	6
Feet	Meters	0.3048
Feet per minute	Meters	0.5080
Feet per minute	Centimetre per second	0.011364
Feet per (second)2	Meters per (second)2	0.3048
Feet of water at 39.2 F	Newtons per square meter	2989
Foot-poundals	BTU.	3.995x10-5
Foot-poundals	Joules	0.04214
Foot-poundals	Liter-atmospheres	4.159x10-"
Foot-pounds	BTU	0.0012856
Foot-pounds	Calories, gram	0.3239
Foot-pounds	Foot-poundals	32.174
Foot-pounds	Horsepower-hours	5.051x10-'
Foot-pounds	Kilowatt-hours	3.766x10-'
Foot-pounds	Litre-atmospheres	0.013381
Foot-pounds force	Joules	1.3558

Foot-pounds per second	Horsepower	0.0018182
Foot-pounds per second	Kilowatts	0.0013558
Furlongs	Miles	0.125
Gallons) (U.S. liquid)	Barrels (U.S. liquid)	0.03175
Gallons	Cubic meters	0.003785
Gallons	Cubic feet	0.13368
Gallons	Litres	3.785
Gallons	Ounces (U.S. fluid)	128
Gallons per minute	Cubic feet per hour	8.021
Gallons per minute	Cubic feet per second	0.002228
Grains	Grams	0.06480
Grains	Pounds	1/7000
Grains per cubic foot	Grams per cubic meter	2.2884
Grains per Gallon	Parts per million	17.118
Grams	Drams (avoirdupois)	0.5644
Grams	Drams (troy)	0.2572
Grams	Grains	15.432
Grams	Kilograms	0.001
Grams	Pounds (avoirdupois)	0.0022046
Grams	Pounds (troy)	0.002679
Grams per cubic centimetre	Pounds per cubic foot	62.43
Grams per cubic centimetre	Pounds per gallon	8.345
Grams per litre	Grains per gallon	58.42
Grams per litre	Pounds per cubic foot	0.0624
Grams per square centimetre	Pounds per cubic foot	2.0482
Grams per square centimetre	Pounds per square inch	0.014223
Hectares	Acres	2.4471
Hectares	Square meter	10,000
Horsepower (British)	BTU per minute	42.42
Horsepower (British)	BTU per hour	2545
Horsepower (British)	Foot-pounds per minute	33,000
Horsepower (British)	Foot-pounds per second	550
Horsepower (British)	Watts	745.7
Horsepower (British)	Horsepower	1.0139
Horsepower (British)	Pounds carbon to C02 per hour	0.175
Horsepower (British)	Pounds, water evaporated per hour at 212 F	2.64
Horsepower (metric)	Foot-pounds per second	542.47
Horsepower (metric)	Kilogram-meters per second	75.0
Hours(mean solar)	Seconds	3600
Inches	Meters	0.0254
Inches of mercury at 60 F	Newtons per square meter	3376.9
Inches of water at 60 F	Newtons per square meter	248.84
Joules (absolute)	BTU (mean)	9.480x1 0*
Joules (absolute)	Cafories gram (mean)	0.2389
Joules (absolute)	Cubic foot-atmospheres	0.3485
Joules (absolute)	Foot-pounds	0.7376
Joules (absolute)	Kilowatt-hours	2.7778x10-'
Joules (absolute)	Litre-atmosphere	0.009869
Kilocalories	Joules	4186.8
Kilograms	Pounds (avoirdupois)	2.2046
Kilograms force	Newtons	9.807
Kilograms per square centimetre	Pounds per square inch	14.223
Kilometres	Miles	0.6214
Kilowatt-hours	BTU	3414
Kilowatt-hours	Foot-pounds	2.6552x1 O6
Kilowatts	Horsepower	1.3410
Knots (international)	Meters per second	0.5144
Knots (nautical miles per hour)	Miles per hour	1.1516
Lambers	Candles per square inch	2.054
Litre-atmospheres	Cubic foot atmospheres	0.03532
Litre-atmospheres	Foot-pounds	74.74
Litre	Cubic feet	0.03532
Litre	Cubic meters	0.001
Litre	Gallons	0.26418
Lumens	Watt	0.001496
Micro microns	Microns	1.0MO-6
Microns	Angstrom units	1.0x10*

Microns	Meters	1.0x10-6
Miles (nautical)	Feet	6080
Miles (nautical)	Miles (U.S.statute)	1.1516
Miles	Feet	5280
Miles	Meters	16.9.3
Miles per hour	Feet per second	1.4667
Miles per hour	Meters per second	0.4470
Milliliters	Cubic centimetres	1
Milliliters	Meters	0.001
Milliliters of mercury at ° C	Newtons per square meter	133.32
Milli microns	Microns	0.001
Mils	Inches	0.001
Mils	Meters	2.54 x 10-5
Minims (U.S.)	Cubic centimetres	0.06161
Minutes (angle)	Radians	2.909 x 10"
Minutes (mean solar)	Seconds	60
Newtons	Kilograms	0.110197
Ounces (avoirdupois)	Kilograms	0.02835
Ounces (avoirdupois)	Ounces (troy)	0.9115
Ounces (U.S fluids)	Cubic meters	2.957 x 10-5
Ounces (troy)	Ounces (apothecaries)	1.000
Pints (US. Liquid)	Cubic meters	4.732 x 10-"
Poundals	Newtons	0.13826
Pounds (avoirdupois)	Grains	7000
Pounds (avoirdupois)	Kilograms	0.45359
Pounds (avoirdupois)	Pounds (troy)	1.2153
Pounds per cubic foot	Grams per cubic centimetre	0.016018
Pounds per cubic foot	Kilograms per cubic meter	16.1018
Pounds per square foot	Atmospheres	4.725 x 104
Pounds per square foot	Kilograms per square meter	4.882
Pounds per square inch	Atmosphere	0.06805
Pounds per square inch	Kilograms per square centimetre	0.07031
Pounds per square inch	Newtons per square meter	6894.8
Pounds Force	Newtons	4.44852
Pounds force per square foot	Newtons per square meter	47.88
Pounds water evaporated from and at 212 F	Horsepower-hours	0.379
Pounds-centigrade units (p.c.u)	BTU	1.8
Quarts (U.S.liquid)	Cubic meters	9.464 x 10-4
Radians	Degrees	57.30
Revolutions per minute	Radians per second	0.10472
Seconds (angle)	Radians	4.848 x 10-6
Slugs	Gee pounds	1
Slugs	Kilograms	14.594
Slugs	Pounds	32.17
Square centimetres	Square feet	0.001010764
Square feet	Square meters	0.0929
Square feet per hour	Square meters per second	2.581 x 10-5
Square inches	Square centimetres	6.452
Square inches	Square meters	6.452 x 10-'
Square yards	Square meters	0.8361
Stokes	Square meters per second	1.0 xlO"1
Tons (bng)	Kilograms	1016
Tons (long)	Pounds	2240
Tons (metric)	Kilograms	1000
Tons (metric)	Pounds	2204.6
Tons (metric)	Tons (short)	1.1023
Tons (short)	Kilograms	907.18
Tons(short)	Pounds	2000
Tons (refrigeration)	BTU per hour	12,000
Tons (British, shipping)	Cubic Feet	42.00
Tons (U.S shipping)	Cubic Feet	40.00
Torr (mm. mercury, 0 C)	Newtons per square meter	133.32
Watts	BTU per hour	3.413
Watts	Joules per second	1
Watts	Kilogram-meters per second	0.10197
Watt-hours	Joules	3600
Yards	Meters	0.9144

UNITS AND CONVERSIONS

Table 10.12 : Conversion To SI Units

Multiply	By	To obtain	Multiply	By	To obtain
acre	0.4047	Ha	In.lb (torch moment)	113	mN.m
bar	*100	Kpa	In2	645	mm2
barrel (42 U.S. gal petroleum)	159	L	In3 (volume)	16.4	mL
	0.159	m3	In3min(SCIM)	0.273	mUs
BTU(International Table)	1.055	kJ	In3 (section modules)	16400	mm3
BTU/ft3	37.3	KJ/m3,J/ 1	In4 (section moment)	416200	mm4
BTU / gal	0.279	kJ/L	Km/h	0.278	m/s
BTU*ft /h/*ft2*°F	1.731	W /(m*K)	kWh	*3.60	MJ
BTU * in /(h* ft2 *°F) thermal	0.1442	W / (m*k)	kW /1000cfm	2.12	J/L
conductivity					
			Kilopond (Kgforce)	9.81	N
BTU/h	0.2931	W	Kip (100015)	4.45	kN
BTU / ft2	11.36	kJ/m2	Kip /in2 (ksi)	6.895	MPa
BTU /(h * ft2)	3.155	W/m2	Litre	*0.001	m3
BTU/(h*ft*°F)			Met	*58.15	W/m2
(overall heat transfer coefficient, U)	5.678	WW / (m2*K)	Microm(m) of mercury (60°F)	133	MPa
BTU/b	2.326	Kj/kg	Mile	1.61	Km
BTU/(lb*°F) (specific heat, cp)	4.184	Kj /kg*K	Mile, nautical	1.85	Km
Bushel	0.03624	m3	Mph	1.61	Km/h
Calory, gram	4.187	J	Mph	0.447	m/s
Calory, Kilogram; Kilocalorie	4.187	kJ	Millibar	'0.100	kPa
Centipoise, dynamic viscosity, m	*1.00	mPa*s	Mm of mercury (60° F)	0.133	kPa
Centistokes, Kinematic viscosity	*1.00	mm2/s	Mm of water (60°F)	9.80	Pa
clo	0.155	m2"K/W	Ounce (mass, avoirdupois)	28.35	g
dyne per cm2	*0.100	Pa	Ounce (force or thrust)	0.278	N
EDR hot water (150 BTU/h)	44.0	W	Ounce (liquid, U.S)	29.6	mL
EDR steam (240 BTU/h)	70.3	W	Ounce inch (torque, moment)	7.06	mN*m
EER	0.293	COP	Ounce (avoirdupois) per gal.	7.49	9/L 2
tr	"0.3048	m	Perm (permeance)	57.45	ng /(s*m Pa)
H	*304.8	mm	Perm inch (permeability)	1.46	Ng(s*m*Pa)
ft / min, fpm	*0.00508	m/s	Pint (liquid, U.S)	473	Ml
ft/s, fps	"0.3048	m/s	Pound		
ft of water	2.99	kPa	Lb (mass)	0.4536	Kg
ft of water/ 100 ft pipe	0.0981	kPa/m	Lb (mass)	453.6	G
ft2	0.09290	m	Ibt (force or thrust)	4.45	g
ft2 * h*° F /BTU (thermal	0.176	m2"K/W	Lb /ft(uniform load)	1.49	Kg/m
Resistance, R)			Lbm /(ft*h) (dynamic viscosity)	0.413	mPa*s
ft2/s, Kinematic viscosity n	92,900	mm/s	Lb /(ft*s) (dynamic viscosity.m)	1490	mPa*s
ft3	28.32	L	IbrS/ft2 (dynamic viscosity)	47.88	Pa*s
ft3	0.02832	m3	Lb/h	0.126	g/s
ft3/h, cfh	7.866	mUs	Lb/min	0.00756	Kg/s
ft3/min/cfm	0.4719	Us	Lb/h [steam at 212°F (100°C)]	0.284	kW
ft3 ls, cfs	28.32	Us	Lb/ft2	47.9	Pa
ft*lb, (torque or moment)	1.36	N*m	Lb/ft2	4.88	Kg/m2
FWb(work)	1.36	J	Lb /ft3 (density, r)	16.0	Kg/m3
ft- lb/ lb (specific energy)	2.99	j/kg	Lb /gallon	120	Kg/m3
ft- lb/ min power	0.0226	w	Ppm (by mass)	*1.00	Mg/kg
Footcandle	1.076	i*	Psi	6.895	kPa
gallon (U.S., *231 in3)	3.7854	L	Quad	1.055	EJ
gph	1.05	mUs	Quart (liquid U.S)	0.946	L
gpm	0.0631	Us	Square (100ft2)	9.29	M2
gpm/ft2	0.6791	U(s* m2)	Tablespoon (approximately)	15	mL
gpm/ton refrigeration	0.0179	mL/J	Tablespoon (approximately)	5	mL
grain (1/7000lb)	0.0648	g	Therm (U.S)	105.5	MJ
gr/gal	17.1	mg/L	Ton, long (2240 lb)	1.016	Mg
gr/lb	0.143	g/kg	Ton, short (2000 lb)	0.907	Mg
Horsepower (boiler)	9.81	kW	Ton, refrigeration (12000 BTU/h)	3.52	kW
Horsepower (550 fp:lb/s)	0.746	kW	Torr(1mmHgatO°C)	133	Pa
inch	*25.4	mm	Watt per square foot	10.8	W/m2
in. of mercury (60 F)	3.377	kPa	Yd	*0.9144	M
In. of water (60 F)	248.8	Pa	Yd2	0.836	m2
In /100ft, thermal expansion	0.833	mm/m	Yd3	0.7646	m3

To Obtain	By	Divide	To Obtain	By	Divide

Note : Units are U.S. values unless noted otherwise.
* conversion factor is exact.

Table 10.13 : Conversion Factors

Pressure psi	In. of water (60° F)	In. Hg (32° f)	Mm Hg atmosphere	Mm Hg (32° f)	bar	Kgf/cm2	Pascal
1 0.036091 0.491154 14.6960 0.0193368 14.5038 14.223 1.45038x104	= 27.708 1 13.609 407.19 0.53578 401.86 394.1 4.0186 x 10-3	= 2.0360 0.073483 1 29.921 0.03937 29.530 28.959 2.953 x 10-4	= 0.068046 2.4559x10-3 0.033421 1 0.00131579 0.98692 0.96784 9 3962 x 10-6	= 51.715 1.8665 25.400 760.0 1 750.062 735.559 0.00750	=0.069948 2.4884x10-3 0.033864 1.101325* 0.0013332 1 0.98066 10-5	= 0.07030696 2.537 x 1C-3 0.034532 1.03323 0.0013595 1.01972 1 1.0192x10-5	= 6894.8 248.84 3386.4 101.325* 133.32 105* 98,066.5* 1
Mass	Lb (avoir.)		Grain		Ounce (avoir)		Kg
	1 1.4286x10-4 0.06250 2.20462		=7000* 1 437.5* 15,432		=16* 2.2857x10-3 1 35.274		=0.45359 6.4800x10-5 0.028350 1
Volume	Cubic Inch		Cubic foot		gallon	Litre	Cubic metre (m)
	1 1728* 231.0* 61.002374 61,023.74		=5.787x10-4 1 0.13368 0.035315 35.315		=4.239x10-3 7.08455 1 0.264173 264.173	=0.0163871 28.317 3.7854 1 10000	=1.63871x10-5 0.028317 0.0037854 0.001* 1
Energy	BTU		ft*lb		Calorie (cal)	Joule (J)	Watt-second (w*s)
	1 102851 x10-3 3.9683x 10-3 9.4782 X10-"		=778.17 1 3.08803 0.73756		=251.9957 0.32383 1 0.23885	=1055.056 1.355818 4.1868 1	1055.056 1.355818 4.1868 1
Density	Lb/ft3		Lb/gal		g/cm3		Kg/m3(g/L)
	1 7.48055 62.4280 0.0624280		=0.133680 1 8.34538 0.008345		=0.016018 0.119827 1 0.001		16.018463 119.827 1000 1
Specific Volume	ft3/lb		Gal/ lb		Cm3/g		m3/kg(L/g)
	1 0.133680 0.016018 16.018463		=7.48055 1 0.119827 119.827		=62.4280 8.34538 1 10000		=0.0624280 0.008345 0.001 1
Specific Heat or Entropy	BTU/lb*°F		Cal/ (g*K)		kJ(kg*K)		
	1 1.0 0.23885		=1 1 0.23885		=4.1868* 4.1868* 1		
Enthalpy	BTU /lb		Cal/g		J/g		
	1 1.8 0.42992		=0.5556 1 0.23885		= 2.326* 4.1868* 1		
Thermal Conductivity	BTU/h*ft*°F		Cal/(s*m*°C)		W/(m*K)		
	1 241.91 0.57779		=4.138 x 10-3 1 2.3885 x 10-3		=1.7307 418.68 1		
Viscosity (absolute) poise		1 poise = 1 dyne=sec/cm2 = C.a Pa*s = 1 g /(cm*s)					
		lb*s/ft2	lb*h/ft2	kg / (m*s)	N*s / m2	lbm / (ft*s)	
	1 478.8026 1,723,689 10 14.8819	= 2.0885x10-3 1 3600 0.020885 3.1081 x 10-2	=5.8014x10-7 2.7778 x 10-4 1 5.8014 x10-6 3 8.6336 x 10-6	=0.1 47.88026 172,369 1 1.4882	=0.1 47.88026 172,369 1 1.4882	= 6.71955x10-2 32.17405 115,827 0.0671955 1	
Coefficient of Heat Transfer BTU/h*ft2°F 1 7373.5 0.2048 0.1761		cal / (s*cm2*°C) = 1.3562x10-4 1 2.7778x 10-5 2.3885 x 10-5		kcal/(h*m2*°c) = 4.8824 36,000 1 0.8598		W/(m2*K) = 5,6783 41,868* 1.1630* 1	

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Table 10.14 : Temperature Converter

Deg C	Deg F	Deg C	Deg F	Deg C	Deg F
-40	-40.00	+15	+59.0	+70	+158.0
-39	-38.2	+16	+60.8	+71	+159.8
-38	-36.4	+17	+62.6	+72	161.6
-37	-34.6	+18	+64.4	+73	163.4
-36	-32.8	+19	+66.2	+74	165.2
-35	-31.0	+20	+68.0	+75	167.0
-35	-29.2	+21	+69.8	+76	168.8
-33	-27.4	+22	+71.6	+77	170.6
-32	-25.6	+23	+73.4	+78	172.4
-31	-23.8	+24	+75.2	+79	174.2
-30	-22.0	+25	+77.0	+80	176.0
-29	-20.2	+26	+78.8	+81	177.8
-28	-18.4	+27	+80.6	+82	179.6
-27	-16.6	+28	+82.4	+83	181.4
-26	-14.8	+29	+84.2	+84	183.2
-25	-13.0	+30	+86.0	+85	185.0
-24	-11.2	+31	+87.8	+86	186.8
-23	-9.4	+32	+89.6	+87	188.6
-22	-7.6	+33	+91.4	+88	190.4
-21	-5.8	+34	+93.2	+89	192.2
-20	4.0	+35	+95.0	+90	194
-19	-2.2	+36	+96.8	+91	195.8
-18	-0.4	+37	+98.6	+92	187.6
-17	+1.4	+38	+100.4	+93	199.4
-16	+3.2	+39	+102.2	+94	201.2
-15	+5.0	+40	+104.0	+95	203
-14	+6.8	+41	+105.8	+96	204.8
-13	+8.6	+42	+107.6	+97	206.6
-12	+10.4	+43	+109.4	+98	208.4
-11	+12.2	+44	+111.2	+99	210.0
-10	+14.0	+45	+113.0	+100	212.0
-9	+15.8	+46	+114.8	+101	213.8
-8	+17.8	+47	+116.6	+102	215.6
-7	+19.4	+48	+118.4	+103	217.4
-6	+21.2	+49	+120.2	+104	219.2
-5	+23.0	+50	122.0	+105	221.0
-4	+24.8	+51	+123.8	+106	222.8
-3	+26.6	+52	+125.6	+107	224.6
-2	+28.4	+53	+127.4	+108	226.4
-1	+30.2	+54	+129.2	+109	228.2
0	+32.0	+55	+131.0	+110	230.0
+1	+33.8	+56	+132.8	+111	231.8
+2	+35.6	+57	+134.6	+112	233.6
+3	+37.4	+58	136.4	+113	235.4
+4	+39.2	+59	+138.2	+114	237.2
+5	+41.0	+60	+140.0	+115	239.0
+6	+42.8	+61	+141.8	+116	240.8
+7	+44.6	+62	+143.6	+117	242.6
+8	+46.4	+63	+145.4	+118	244.4
+9	+48.2	+64	+147.2	+119	246.2
+10	+50.0	+65	+149.0	+120	248.0
+11	+51.8	+66	+150.8	+121	249.8
+12	+53.6	+67	+152.6	+122	+251.6
+13	+55.4	+68	+154.4	+123	253.4
+14	+57.2	+69	+156.2	+124	+255.2
C=5/9 (F-32)			F=9/5(C)+32		

SECTION 11

IS CODES AND STANDARDS

IS CODES AND STANDARDS

AIR-CONDITIONING EQUIPMENT

IS 659: 1964 (First revision)
Safety code for air-conditioning

IS 660: 1963 (1st revision)

Safety code of mechanical refrigeration

IS 1391: Part I & Part II (1992) Room air - conditioners (unitary and split)

IS 2370: 1963
Sectional cold rooms, (walk- in-cooler)

IS 2371 :1973
Solid drawn copper alloyed tubes for condensers, evaporators, heaters and cooler tubes using saline hard water, (withdrawn) (suspended by IS 1545, 1982)

IS 2372: 1991
Timber for cooling towers (1st revision)

IS 3315: 1994
Evaporative air coolers. (Desert coolers) (2nd revision)

IS 3615: 1967
Glossary of terms used in refrigeration and air-conditioning.

IS 4831 :1968
Recommendation on units and symbols for refrigeration.

IS 5111 :1993
Testing of refrigeration compressors (1st revision)

IS 6272: 1987
Industrial cooling fans (Man coolers)

IS 7896:1975(2001)
Data for outside design conditions for air-conditioning for Indian cities

IS 8148 : 2003
Packaged air conditioners. (1st revision)

IS 8188: 19761999
Code of practice for treatment of water in cooling towers

IS 8362 : 1977
Copper and copper alloy rolled plates for condensers and heat exchangers

IS 8667:1977
Purchasers data sheet for cooling towers for process industry

IS 9612: 1980
Aluminum tubes for refrigeration purposes

IS 10470 :1983
Aircooled heat exchangers

IS 10617 Part I : 2013
Hermetic compressors

IS 10873 : 1983 (reaffirmed 1993)
Data sheet for aircooled heat exchangers.

IS 11327 : 1985 (reaffirmed 1991) Requirements for refrigerants condensing units.

IS 11329 : 1985 (reaffirmed 1991)
Finned type heat exchangers for room air - conditioners (Amendment 1)

IS 11330 : 1985 (reaffirmed 1991) Oil separators

IS 12357 : 1988 (reaffirmed 1993)
Suppliers data sheet for clean air equipments (Laminar flow)

IS 11338 : 1985 (reaffirmed 1991) Thermostats for use in refrigeration, air - conditioners etc.

SP 7: 1983 Group 4 National Building code.

CHIMNEYS

IS 1649 : 1962 (reaffirmed 1992)
Code of practice for design and construction of flues in chimneys for domestic heating appliances. (1st revision)

IS 4998: Part I, 1992
Criteria for design reinforced concrete chimneys

IS 6533 : Part I & Part II, 1989
Code of practice for design and construction of steel chimneys

ELECTRICAL WIRES & CABLES, LT & HT GRADE

IS 282 : 1982
Hard drawn copper conductors for overhead power transmission

IS 398 : 1976 Part 1,2,3,4,5 : 1996/96/76/94/92 Aluminum conductors for overhead transmission purposes

IS 694:2010
PVC Insulated and sheathed, cables/cords with rigid and flexible conductor for rated voltages upto and including 450/750 V

IS 1554: 1988 Part I & Part II
PVC insulated (heavy duty) cables for working voltage upto 1100V, part 2 for 3300V

IS 692 : 1994 including 11000 V
Paper insulated, lead sheathed cables for rated voltage up to including 33 KV electric supply

IS 732 : 1989
Code of practice for electrical wiring installations

EARTHING

IS 3043:1987
Code of practice for earthing

IS 3151 : 1982
Earthing transformers

IS 12776:2002
Galvanized stand for earthing

FUSES

IS 2208:1976
HRC fuse links upto 650 V. (Third revision)

IS 2086: 1993
Carriers and bases used in rewirable type electric fuses upto 650 Volts.

MOTORS

IS 325 : 1996, three phase induction motors

IS 900 : Code of practice for installation and maintenance of induction motors

IS 996 : 1979, single phase A.C. induction motors for general purpose

IS 12615: 2004, Energy efficient induction motors,3ph squirrel gauge

IS 6362: Method of cooling

IS 12075: 2008 Mechanical vibration of Rotating Electric motors

IS 12065: 1987, Permissible limits of Noise levels

IS 2148 : 2004, Specification for flameproof motors

IS 1231 : 1974

Dimension of 3 Phase foot mounted motors
IS 2223 : 1983, Dimension of 3 phase flange mounted motors

IS 2253 : 1974, Types of constructions and mounting of motors

IS 2968 : Dimensions of slide rail for electric motors

IS 4722 : 2001

Rotating electric machines

IS 1580: 1983

SP: 30:1985
National electrical code.

SWITCH GEAR & CONTROLS

IS 2607:1981
Air break isolators for voltage not exceeding 1000 V.

IS 13118:1991 Circuit breakers A.C

IS 2959:1975
Contractors of A.C for voltage up to 1100 V.

IS 2675: 1975
Enclosed distribution fuse boards and cutouts for and voltages not exceeding 100V AC and 1200V DC

IS 4237:1982
General requirements for switch gear and control gear for voltages not exceeding 1000 V AC or 1200 V DC

IS 13947 - 1993, Part 4 specification for low voltage switch gear

IS 8623: 1993 Part 1, 2 and 3.
Low voltage switch gear and control gear assembles

IS 10118: 1982, Part I to Part IV
Code of practice for selection, installation and maintenance of switch gear and control gear

WIRING ACCESSORIES

IS 3854: 1997
Switches for domestic and similar purposes

IS 1293 : 2005
3 pin plugs and sockets outlets.

IS 3837 : rigid steel conduits for Accessories for electrical wiring

IS 9537 : parts 1,2,3,4,5,6 & 8 in the year 1980 /1981/1 983/1983 / 2000 / 2000 / 2003 respectively, conduits for electrical installation - Rigid non metallic conduits

Acoustics

IS 2526: 1963
Code of practice for acoustical design of auditoriums and conference halls. (Amendment-1)

152264:2010
Preferred frequencies for acoustical measurements

IS 3483 : 1965 (reaffirmed 2010 Code of practice for noise reduction in industrial buildings

IS 4954 : 1968 (reaffirmed 2010)
Recommendations for noise for abatement in town planning

IS 4758 : 1968 (reaffirmed 2012)
Methods of measurement of noise emitted by machines

IS 9736 : 1981 (reaffirmed 2010)
Glossary of terms applicable to acoustics in buildings

Is 9901 : Part I & Part II - Part-9 (reaffirmed 2007) Measurement of sound insulation in buildings and building elements

IS 9989 : 1981 (reaffirmed 2008)
Assessment of noise with respect to community response

IS 9876 : 1981 (reaffirmed 2007)
Guide to the measurement of air borne acoustical noise and evaluation of its effects on man

IS 10423 : 1982(reaffirmed 2008) Personal sound exposure meter

IS 12998: Part I & Part II, 1991
Test code and method of measurements of air borne noise emitted by electrical machinery Part I engineering method, Part II survey method

IS 12710:1989
Glossary of terms used in acoustic emission testing

IS 11050 : Part I, Part II & Part III, 1984 (reaffirmed 1991) Rating of sound insulation in buildings elements

IS 14280:1995
Mechanical vibration - balancing - shaft and fitment key conversion

IS 14259: 1995
Vibration and shock - isolators, procedure and fitment key characteristics

IS 12065:1987
Permissible limits of noise level for electrical machines

IS 1950: 1962 (reaffirmed 1991)
Code of practice for sound insulation of non-industrial buildings (Amendment -1)

IS 7194: 1994
Assessment of noise exposure during work for hearing conservation purpose

IS 4729 : Measurement and evaluation of vibration for motors (withdrawn).

PIPE & FITTINGS

IS 638 : 1979 Sheet rubber jointing gaskets

IS 1239 : Part I & Part II 1990/1992
steel tubes. IS 1239, part 2 1992 mild steel tubular and other wrought steel pipe fitting (4th revision)

IS 1367: Part 1 to Part 18
Technical supply conditions for threaded steel fasteners

IS 2501 : 1995
Solid drawn - copper tubes for general engineering purposes(3rd version)

IS 3076 :1985 (reaffirmed 1991)
Low density polyethylene pipes for portable water supplies. (2nd revision, Amendment 1)

IS 5822: 1994
Code of practice for laying of electrically welded steel pipes for water supply (2nd revision)

IS 6630 : 1985 (reaffirmed 1990)
Seamless ferrite alloy steel pipes for high temperature steam service (1st revision)

IS 6392 : 1971 (reaffirmed 1988) Steel pipe flanges (Amendment 1)

IS 10773: 1995
Wrought copper tubes for refrigeration and air-conditioning purposes.

PUMP AND VALVES

IS 778: 1984
Copper alloy gate, globe and check valves for water works purposes.

IS 779 : 1994
Water meters (domestic type)

IS 780 : 1984(reaffirmed 1990)
Sluice valves for water works purposes. (50 to 300 mm size) 6th revision , Amendment 3)

IS 781 : 1984
Cast copper alloy, screw down , bib taps and stop valves for water services

IS 1520: 1980
Horizontal centrifugal pumps for clear
cold , fresh water (2nd revision)

IS 2685 : 1971 (reaffirmed 1992)
Code of practice for selection , installation and maintenance of sluice valves (1st revision)

IS 2906 : 1984 (reaffirmed 1990)
Specification for sluice valves for water works purposes 350 to 1200mm size (3rd revision, Amendment)

IS 3233 :1965 (reaffirmed 1992)
Glossary of terms for safety and relief valves and their parts.

IS 4854 - Part I, II 1969, Part III 1984 Glossary of terms for valves and their parts

IS 5312 : Part I 1984, part II 1986 (reaffirmed 1990, 1991) Swing check type non return valves

IS 5659 : 1970 (reaffirmed 1991) Pumps for process water (Amendment 1)

IS 8092 : 1992 (reaffirmed 1990)
Code for inspection of surface quality of steel castings for valves, fittings, and other piping components . (Visual method) (1st revision).

IS 8418: 1999
Horizontal centrifugal self - priming pump specifications (First revision)

IS 8472: 1977(1998)
Regenerative pumps for clear, cold water, specification (First revision)

IS-11951 - 2009 : pumpset for desert coolers - specification(First revision)

IS 9137 : 1978 (reaffirmed 1993)
Code for acceptance test for centrifugal, mix flow and axial pumps Class C (Amendment 4)

IS 1952 : 1980 (reaffirmed 1993)
Horizontal centrifugal mono set pumps for clear, cold fresh water (Amendment 1)

IS 10596 : Part I, II, III &IV, 1983 Code of practice for selection, installation, operation and maintenance of pumps for industrial applications

IS 10981 : 1983 (reaffirmed 1993)
Code of acceptance test for centrifugal mixed flow and axial flow pumps - Class B

IS 11745: 1986
Technical supply conditions for positive displacement reciprocating pumps

IS 12969: 1990
Method of test for quality characteristics of valves

IS 12992 :1993, Part I , 1990 Part II Safety relief valves

IS 13095: 1991
Butterfly valve for general purposes

REFRIGERANT GAS AND LUBRICANTS

IS 310: 1954
Methods of sampling and test for lubricants (Part I & Part II) Superseded by IS 1447 and IS 1448

IS 718: 197 (reaffirmed 1991)
Carbon tetrachloride (2nd revision) (Amendment 2)

IS 4578: 1989
Lubricating oils for refrigeration machinery (1st revision)

IS 6849 : Part I & Part II, 1993 Positive displacement vacuum pumps.

IS 9466 : 1980 (reaffirmed 1993)
Viscosity classification of industrial liquid lubricants

ISO-817: 2005
Refrigerant number - Refrigerant system

SAFETY

IS 954 : 1989
Functional requirements for carbon dioxide tender for fire brigade use (2nd revision)

IS 1641 : 1988 (reaffirmed 1993)
Code of practice for fire safety of buildings (general): General principles of fire grading and classification. (1st revision)

IS 1642 : 1989
Code of practice for fire safety of buildings (General) Details of construction (1st revision) (1645 supersedes 1642)

IS 1643 : 1988 (reaffirmed 1993)
Code of practice for safety of buildings (General) Exposure hazard (1st revision)

IS 1644 : 1988 (reaffirmed 1993)
Code of practice for safety of buildings (General) Exit requirements and personal hazard

IS 1646 : 1982 (reaffirmed 1990)
Code of practice for safety of buildings (General) : Electrical installation (1st revision)

IS 3786 : 1983 (reaffirmed 1991)Methods of computation of frequency and severity rates for industrial injuries and classification of industrial accidents. (1st revision)

IS 3808 : 1979 (reaffirmed 1990)
Methods of test for non-combustibility of building materials (1st revision).

IS 5311 : 1969 (reaffirmed 1990) Code of safety for carbon tetrachloride.

IS 6382 : 1984 (reaffirmed 1990)
Code of practice for design and installation of fixed carbon dioxide for fire extinguishing system (1st revision)

IS 7969 : 1975 (reaffirmed 1991) Safety
code for handling and building material (Amendment 1).

SHEET METAL WORK

IS 277 : 2003
Galvanized steel sheet (5th revision, Amendment 2)

IS 513 : 2008
Cold rolled low carbon steel sheets and strings

IS 655 : 1963 (reaffirmed 1991)
Metal air ducts (revised) (Amendments 3)

IS 1079: 1994
Hot rolled carbon steel sheets, and strings
IS 1977 : 1975 (reaffirmed 1992) Structural steel (ordinary quality)

IS 2062 : 2006
Steel for general structural purposes

IS 3768 : 1989 (reaffirmed 1994)
Ventilation ducting - venyl coated, flexible (1st revision)

IS 7613 : 1975 (reaffirmed 1991)
Method of testing panel type air filters for air-conditioning and ventilation purpose

THERMAL INSULATION

IS 334 : 1982 2002
Glossary of terms relating to bitumen and tar (2nd revision)

IS 661 : 1974 (reaffirmed 2000)
Code of practice for thermal insulation of cold storages. (2nd revision) (Amendment 2)

IS 1397: 1990
Kraft paper (2nd revision)

IS 2094 : 1996,1999,1999 - Parts 1,2&3 Heaters for bitumen and emulsion (2nd revision)

IS 3069:1994
Glossary of terms, symbols and units relating to thermal insulation materials (1st revision)

IS 3129 : 1985 (reaffirmed 2010)
Low density particle boards (1st revision)

IS 3144 : 1992 (reaffirmed 2010)
Mineral wool thermal insulations - Methods of tests. (2nd revision).

IS 3346 : 1980 (reaffirmed 2010)
Method of determination of thermal conductivity of thermal insulation materials (2 slab guarded hot plate method) (1st revision)

IS 3677 : 1985 (reaffirmed 1990)
Unbounded rock and slag wool for thermal insulation (2nd revision) (superseding IS 5696)

IS 3792 : 1978 (reaffirmed 1992)
Guide for heat insulation of non-industrial buildings (1st revision)

IS 4671 : 1984 (reaffirmed 2010) Expanded polystyrene for thermal insulation purposes (1st revision)

IS 14164-2008
Code of practice for thermal insulation of materials above - 80 Deg C upto 750 Deg C

IS 8154 : 1993 (reaffirmed 2010)
Preformed calcium silicate insulation (for temperature upto 650 Deg C)

IS 8183:1993
Bonded mineral wool (1st revision)

IS 9403 : 1980 (reaffirmed 1990)
Method of test for thermal conductance and transmittance of built up sections by means of guarded hot box

IS 9428 : 1993 (reaffirmed 2010)
Preformed calcium silicate insulation for temperature upto 950 Deg C

IS 9489 : 1980 (reaffirmed 2010)
Method of test for thermal conductivity of materials by means of heat flow meter

IS 9742 : 1993 (reaffirmed 2010)
Sprayed mineral wool insulation. (1st revision) (Amendment 1)

IS 9842 : 1994 (reaffirmed 2010)
Preformed fibrous pipe insulation (1st revision)

IS 10556 : 1983 (reaffirmed 2010)
Code of practice for storage and handling of thermal insulation materials.

IS 11239 : Part 1 to Part 3 :2009, Part 4 : 1985, Part 5 : 2009, Part 6 to Part 13 in 1985, 1988 and 1992

Methods of test for cellular thermal insulation materials: Dimensions, dimensional stability, apparent density, water vapour transmission rate, volume percent of open and closed cells, heat distortion term, co-efficient of linear thermal expansion at low temp., flame height, time of burning and loss of mass, water absorption, flexural strength, compressive strength, horizontal burning characteristics, determination of flammability by oxygen index. Parts 6 to 13 reaffirmed in 2008, Part 4 reaffirmed in 2010.

IS 11246:1992
Glass fibre reinforced polyester resin (reaffirmed 2007)

IS 12436 : 1988 (reaffirmed 2010)
Preformed rigid polyurethane foams for thermal insulation

IS 13204 : 1991 (TUR and polyisocyanurite rigid phenolic foams for thermal insulation (reaffirmed 2010)

IS 13205: 1991
Code of practice for the application of polyurethane insulation by the in-situ pouring method (reaffirmed 2010)

VENTILATION

IS 2312 : 1967 (reaffirmed 1991)
Propeller type AC ventilation fans (1st revision) (Amendment 7)

IS 3103:1975
Code of practice for industrial ventilation (1st revision)

IS 3588 : 1987 (reaffirmed 1991) Electric axial flow fans (1st revision)

IS 4894 : 1987 (reaffirmed 1991) Centrifugal fans (1st revision)

IS: 13368 - 1992 Method of test for double inlet

SECTION 12

INTERNATIONAL CODES AND PRACTICE

INTERNATIONAL CODES & PRACTICE

Sl. No.	Description	Publisher	Reference
1	Commercial low pressure Velocity duct system design	ACCA	Manual Q
2	HVAC Systems- Applications I Edition	SMACNA	SMACNA
3	HVAC Systems -Duct design 1990	SMACNA	SMACNA
4	HVAC Air duct leakage test Manual 1985	SMACNA	SMACNA
5	HVAC duct construction Standards - Metal & flexible I Edition, 1985	SMACNA	SMACNA
6	HVAC duct systems inspection Guide, 1989	SMACNA	SMACNA
7	Rectangular industrial duct construction 1977	SMACNA	SMACNA
8	Round Industrial duct Construction 1977	SMACNA	SMACNA
9	Thermoplastic duct (PVC) Construction Manual (Rev.a.1974)	SMACNA	SMACNA
10	Gravimetric & duct spot procedures for testing air cleaning devices used In general ventilation for removing participate matter	ASHRAE	ANSI/ ASHRAE 52.1-1992
11	Method for sodium flame test air filters	BSI	BS 3928
12	Methods of test for atmospheric dust spot efficiency & part 1 synthetic dust weight arrestance	BSI	BS6540
13	High efficiency, particulate air filter 1990	UL	ANSI/UL 586-1990
14	Methods of testing liquid chilling packages	ASHRAE	ASHRAE 30-1978
15	Absorption water - chilling packages	AHRI	AHRI 560-82
16	Centrifugal or rotary screw water chilling packages	AHRI	AHRI 550-90
17	Reciprocating water chilling packages	AHRI	AHRI 590-86
18	Forced - circulation air cooling and air heating coils	AHRI	AHRI 410-91
19	Methods of testing forced to circulation air cooling and air heating coils	ASHRAE	AHRI 410-91
20	Thermal environmental conditions for human occupancy	ASHRAE	ANSI/ ASHRAE 55-2013
21	Acceptance test code for water cooling towers, mechanical draft, fan. Assistant type evaluation of results and thermal testing of wet and dry cooling towers(1990)	CTI'	CTI- ATC 105-1990
22	Code of measurement of sound from water cooling towers	CTI	CTI- ATC 128-1981
23	Energy conservation guidelines	SMACNA	SMACNA 1984
24	Energy recovery equipment and systems, air to air	SMACNA 1991	SMACNA
25	Retrofit of building energy system and processes	SMACNA	SMACNA 1982
26	Laboratory methods for testing	ASHRAE	ANSI/ASHRAE 51-1985 ANSI/AMCA 210-1985
27	Fire dampers, 1990	UL	ANSI -UL 555-1985
28	Fire protection handbook 17th edition	NFPA	NFPA
29	Standards of Tubular Exchanger Manufacturers Association 7th edition, 1988	TEMA	TEMA
30	Refrigeration piping	ASME	ASME/ANSI B-31. 5/1987
31	Scheme for identification of piping system	ASME	ANSI /ASME A-1 3.1/1 981 (R1985)
32	Number designation and safety classification of refrigerants	ASHRAE	ANSI/ ASHRAE 34-1992
33	Refrigeration oil	ASHRAE Guide description lines 3-1 990	ASHRAE
34	Refrigerant recovery recycling equipment, 1989	UL	ANSI/UL 1963-1991
35	Practices for measurement, testing and balancing of building, air-conditioning and refrigeration system		ANSI/ASHRAE 111-1988
36	HVAC systems	SMACNA	SMACNA
37	HVAC systems testing, adjusting and balancing	ASHRAE	ANSI/ ASHRAE 62-1989
38	ASHRAE 90-1-1989 : Energy efficient design of new buildings except low rise residential buildings		
39	ASHRAE 15-1994 : Safety code for mechanical refrigeration		
40	Thermal DVP Test US Military MIL-STD - 282		
41	Federal standard 209 : Clean room and clean workstation requirements, controlled environment		
42	ASHRAE 100-1989 : Energy conservation in existing buildings		
43	ASHRAE Guidelines: Guideline 1 -1989 - Commissioning of HVAC systems		

ISO - 5659 - 2 (1994)	Test Methods for Optical Density
NFPA - 270	Test Methods for Optical Density
ASTMD5424	Test Methods for Optical Density
BS-6853 : 1999	Smoke Observation & Toxic fume Generation Characteristics
UL - 555 S	Smoke and Fire Dampers

ABBREVIATIONS AND ADDRESSES

ACCA - Air-conditioning Contractors of America.
1513, 26th Street, NW, Washington, D.C.20036.

AMCA - Air Movement & Control Association Inc.
SOW, University Drive, Arlington Heights, IL 60004-1893.

AHRI - Air-conditioning Heating and Refrigeration Institute
4301, North Fairfax Drive, Suite 425, Arlington, VA 22203.

ASHRAE - American Society of Heating and Refrigerating & Air-conditioning Engineers Inc.
1791, Tulli Circle, NE, Atlanta, GA 30329.

ASME - American Society of Mechanical Engineers.
345E, 47th Street, New York, NY 10017. For ordering publications. ASME Marketing dept. Box 2350, Fairfield, NJ 07007-2350.

ANSI - American National Standards Institute
11, West, 42nd street, New York, NY 10036.

BSI - British Standards Institution
2, Park Street, London, W1A, 2BS, England.

NFPA - National Fire Protection Association
No.1, Batterymarch Park, P.O.Box 9101, Quincy, MA 02269-9101.

TEMA- Tubular exchanger Manufacturers Association Inc.
25N, Broadway, Tarrytown, NY 10591.

UL - Underwriters Laboratories Inc.
333, Pfingsten road, Northbrook, IL 60062-2096.

CTI - Cooling Tower Institute
P.O.Box 73383, Houston, Tx 77273.

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SECTION 13

SAFETY FOR AIR-CONDITIONING AND REFRIGERATION ENGINEERS

Safety For Air-conditioning and Refrigeration Engineers

There is perhaps no industry that holds a greater variety of possible hazards to those engaged in it than the refrigeration industry. Not only are there hazards connected with moving machinery that is powered by electric motors with complex, automatic electric control systems, but the refrigeration process involves the use of various refrigerant gases and liquids under pressure. These refrigerants present high pressure or explosion hazards, and all of them are toxic or suffocating in varying degrees. Also, in certain industrial uses of refrigeration, the products that are refrigerated are sometimes toxic, corrosive, flameable or explosive. Moreover, many accidents come from handling refrigerated products - heavy blocks of ice, cases of foods and machinery. The installation, service and maintenance personnel are subject to accidents in the use of tools - slipping screwdrivers, power saws and drills, torch burns, bursting gas cylinders, falling ladders and many other accidents that may occur in the day to day work of the mechanic.

Machinery is being constantly improved as to safety, with guards, barriers, automatic safety valves, electrical stop switches, and other forms of protective devices. National, state and city codes impose safer practices and safer equipment.

Despite all of these measures the record of accidents in the refrigeration industry is high. To lower this high accident rate, everyone in the refrigeration industry must become more safety-minded, and must be constantly alert to prevent accidents.

The greatest burden in improving the safety record lies on each individual. All sorts of protective devices can be used, laws can be passed, safety campaigns can be waged; but if a man is careless, he can be hurt. He must constantly be on the lookout to protect himself and others. He must not do things blindly by routine. He must think, and pay attention to what he is doing. There is no substitute for vigilance. Safe workmanship saves time, material, money and suffering.

Types of Accidents

Accidents can be more effectively avoided, if we recognize their sources and causes, for then we can be on the lookout for them.

Accidents in the refrigeration industry can be divided into six general classes according to the cause and nature of the injury.

- Physical injuries from Mechanical Causes
- Electrical injuries
- Injuries Due to High Pressure
- Burns and Scalds
- Injuries Due to Explosions
- Breathing Toxic Gases

Physical Injuries From Mechanical Causes

These originate from moving machinery, handling heavy crates or blocks of ice, falls, or from the use of tools. They constitute the largest percentage of accidents in the refrigeration industry.

In this category are:

Smashed fingers, toes, hands or feet, from being hit with hammers or from having heavy objects dropped on them. Cut or torn flesh, or eyes put out from slipping screwdrivers, saws, drills or other edged tools. Being struck by parts dislodged and thrown at high speed from moving machines. Broken arms, legs or other serious accidents from being caught in moving machinery. Falls from ladders or on slick floors.

Some protection from this type of accident can be afforded by guards on the machines, automatic trip switches, electric eye, and other mechanical and electrical protective devices; but the best safeguard is the constant vigilance of the workman.

Use of Tools

1. Keep tools clean and in good condition. Screwdriver blades should be kept sharp and square; handles should be of a non-conditioning material.
2. Use of the right type and size of tool. Use box wrenches in preferences to end wrenches; use adjustable wrenches as little as possible; do not use files as punches or gouges; they are brittle and likely to shatter.
3. Use handles on files.
4. Do not put edge tools, such as chisel, punches and open knives in your pockets, even temporarily; keep guards on sharp edges or point of tools in tool kits.
5. Wear goggles when grinding tools, or when working on any job that may involve flying pieces of material.

Miscellaneous Precautions

1. Finger rings are dangerous, and should not be worn when a man is at work.
2. Do not stick fingers or tools into moving machinery nor into automatic machines or fans that may start suddenly.
3. Place ladders carefully, with both legs of the base of the ladder secured, and at a distance from the wall equal to % of the length of the ladder.

Electrical Injuries

Any electric current can be dangerous directly or indirectly, but 115 volts or more, can and often does kill by electric shock.

Electrical Safety Rules

1. Do not renew a blown fuse until you are satisfied to the cause and have rectified the irregularity.
2. Do not close any switch unless you are familiar with the circuit which it controls and know the reason for it being opened.
3. Do not touch or tamper with any electrical gear or conductor, unless you have made sure that it is DEAD AND EARTHED.
4. Do not work on the live circuit without the express orders of the supervisor. Make certain that all safety precautions have been taken and you are accompanied by a second person competent to render first aid and artificial respiration.
5. Do not disconnect earthing connections or render ineffective the safety gadgets installed on mains and apparatus.
6. Do not open or close switch or fuse slowly or hesitatingly, do it quickly and positively.
7. Do not USE WIRES WITH POOR INSULATION.
8. Do not touch an electric circuit when your hands are wet, or bleeding from a cut or an abrasion.
9. Do not work on energized circuits without taking extra precautions, such as use of rubber gloves.
10. Do not disconnect a plug by pulling when the switch is on.
11. Do not use fire extinguishers on electrical equipments unless it is clearly marked for that purposes. Use sand and blankets instead.
12. Do not throw water on equipment in case of fire.
13. Do not attempt to disengage a person in contact with live apparatus which you can switch off immediately. Insulate yourself from earth by standing on rubber mat or dry board before attempting to get him clear. Do not touch his body, push him with a piece of dry wood.
14. Do not discontinue artificial respiration until recovery or death is clarified by doctor.
15. Do not allow visitors and unauthorized persons to touch or handle electrical apparatus or come within the danger zone of H.V. apparatus.
16. Do not test any circuit with bare fingers.

Injuries Due To High Pressure

A basic characteristic of mechanical refrigeration is the use of various fluids, both gases and liquids, that are at pressure above atmospheric pressure. They must therefore be contained and transmitted in tanks, pipes and other vessels so constructed that they will not allow the fluids to leak, and are strong enough that they will withstand maximum pressure without splitting or bursting, under extreme conditions of use.

Refrigerant Cylinders

Refrigerant cylinders are designed and constructed for definite maximum pressure and for definite quantities of refrigerant that are based on specified maximum temperatures, usually 130 Deg.F. If the cylinders are subjected to temperature above those specified, the liquid expands to entirely fill the cylinder; extremely high hydrostatic pressures develop, and the cylinder bursts.

Do not overfill cylinders, and do not put a flame on them. Do not place cylinders in a hot place or near or against a hot object, such as a stove, radiator or boiler. To do so invites accidents.

Corrosion

Moisture in refrigerating systems causes acids that may corrode parts of systems and so weaken them as to make them potentially dangerous. Moisture with fluorinated hydrocarbons forms negligible amounts of acids but for systems working above 32 Deg. F with R12/R22 the water will cause considerable corrosions. Keep systems dry whether they are giving expansion valve freeze-up trouble or not.

Copper or copper alloys cannot be used in an ammonia system as ammonia, with some moisture, forms 'aqua ammonia', which attacks copper and copper alloys.

Ammonia and mercury react to form an explosive and flammable gas. Mercury column or manometers should not be used on ammonia systems.

Water supply lines, gate valves, fittings, automatic pressure and control valves should be inspected occasionally and badly corroded or weakened parts replaced.

Precautions

1. Do not overfill containers.
2. Do not allow pressure containing vessels to become over-heated.
3. Do not put a flame on a refrigerant cylinder, receiver, or other vessel that may contain liquid refrigerant.
4. Do not change to a higher pressure refrigerant without first checking to determine if the equipment is constructed strong enough for higher pressure requirement.
5. Always put on both low and high pressure gauges before servicing a system. Observe these gauges frequently.
6. Before loosening bolts or screws, see that the pressure in the part has been relieved. Gaskets may hold the pressure temporarily, but fail suddenly, throwing the full charge of refrigerant in the face of the workman. There have been numerous accidents of this nature, resulting in blindness or other serious injuries.
7. Use pressure relief valves on all refrigerant cylinders and other vessels that may be subject to excessive pressures.
8. Do not allow a compressor to liquid pump or 'slug oil'.

Burns and Scalds

The fire hazard connected with working on of with refrigerating equipment may be classified under six chief sources: refrigerants, other gases, solvents, fuels, construction materials and refrigerated products.

Refrigerant and Other Gases

Fluorinated hydrocarbons are non-flammable refrigerants and hence cause no danger. Ammonia is moderately flammable and care is required while handling. Among other gases used in AC & R industry acetylene is highly flammable. Do not allow acetylene to escape into a room for a flame or an electric spark may ignite it. Oxygen is not flammable. However, it supports combustion. Oxygen coming in contact with oils and flammable materials may lead to spontaneous combustion which may lead to fire or explosion. Carbon dioxide, hydrogen and nitrogen are non-flammable gases. Carbon tetrachloride which is used as a solvent is also non-flammable.

Construction Materials

Keep machines clean! This does not mean merely wiping the dust off. It means keeping them dry, including places difficult to clean, such as finned condensers, motors, etc. If necessary, remove them and do a good job of cleaning them.

An oily machine is a frequent source of a big fire. Cleanliness of equipment cannot be over emphasized.

Firefighting Precautions

1. When using a fire extinguisher, direct the stream at the base of flame, not on the flame itself.
2. Never throw water on an oil, gasoline, naphtha or grease fire. Water does more harm than good, as it merely spreads the fire.
3. Do not leave oily rags or mops around. They often cause 'spontaneous combustion' and burst into flames, frequently in an out-of-way, unobserved place, or during the night, so that the fire gets a big start before it is discovered.
4. Ensure that smoldering cigarettes and matches are disposed off carefully.
5. Do not pull down burning materials with your hands; use a stick.
6. Change your working clothes as soon as possible if you get them oily; they make a potential torch of you.
7. Be careful in fighting an electrical fire, burning of smoldering insulation, or motors. The stream from a hose, and some fire extinguishers, is a good conductor of electricity, so you may get a serious or fatal shock.
8. Handle flammable gases with utmost care.
9. Never discharge flammable gases in an unventilated room, nor in a room in which there is a flame, either in sight or hidden in a water heater, coffee urn, etc.

10. If you know, or have any reason whatever to suspect, that there is any flammable gas in a room, take no chances; ventilate the room at once. Do not strike a match nor carry a lighted torch, or even a cigarette into a room in which a flammable gas may be present. Do not operate an electric switch. Especially do not turn a switch off; there is more arc at 'break' than at 'make'. The electric arc, even if it is inside a switch box, (unless it is the uncommon vapour-proof type) may ignite the gas.

Breathing Toxic Gases

In refrigeration, the term 'toxic' is more frequently used with gases that we may breathe, and which poison us by being taken into our blood by means of the lungs.

Asphyxiation

Ammonia and sulfur dioxide gases are very powerful, and they immediately attack the eyes, throat and mucous membranes.

Precautions against breathing toxic gases :

If the nature of the various refrigerants and other gases and fumes are understood, and if reasonable care is exercised, a refrigeration service engineer need have no fear of possible toxic hazards from refrigerants.

However, he must be careful, and in particular he should observe the following:

1. Don't breathe in any gas any more than is absolutely necessary. None of them are harmless under all conditions.
2. Don't ignore the possible danger of a gas just because it has very little odor. The odor of a gas is no indication of its toxicity.
3. Don't discharge any gas into any unventilated room.
4. Don't discharge any of the halocarbon gases, into a room in which there is a fire, flame, or electric heating element.
5. Don't hesitate to use a gas mask if it is necessary to enter a room that you know or suspect has any of the toxic gases in it.
6. Don't leave leaks in refrigerating equipment that may fill the room with gas and cause trouble to someone.
7. Don't breathe fumes from acids, caustics, carbon tetrachloride, benzol, ketone, xylene or other toxic cleaning materials. Always keep rooms well ventilated when using cleaning solvents.
8. Don't breathe in fumes from broken fluorescent lamps; they are poisonous.
9. Don't break up fluorescent lamps as you would an ordinary lamp. You may cut yourself or otherwise get beryllium poisoning, which is extremely dangerous.

SECTION 14

GLOSSARY

GLOSSARY

A

A-Scale: A filtering system that has characteristics which roughly match the response characteristics of the human ear at low sound levels (below 55 dB sound pressure level, but frequently used to gauge levels upto 85 dB). A-scale measurements are often referred to as dB(A).

Absolute Pressure: Air at standard conditions (70°F air at sea level with a barometric pressure of 29.92 in. Hg.) exerts a pressure of 14.696 psi. This is the pressure in a system when the pressure gauge reads zero. So the absolute pressure of a system is the gauge pressure (pounds per square inch) added to the atmospheric system work and the symbol is "psia".

Absorbent: A material which, due to an affinity for certain substances, extracts one or more such substances from a liquid or gaseous medium with which it contacts and which changes physically or chemically, or both, during the process. Calcium chloride is an example of a solid absorbent, while solutions of lithium chloride, lithium bromide, and ethylene glycols are liquid absorbents.

Absorber Surface: The surface of the collector plate which absorbs solar energy and transfers it to the collector plate.

Absorptance: The ratio of the amount of radiation absorbed by a surface to the amount of radiation incident upon it.

Absorption: A process whereby a material extracts one or more substances present in an atmosphere or mixture of gases or liquids accompanied by the material's physical and/or chemical changes.

Absorption Unit: Is a factory tested assembly of component parts producing refrigeration for comfort cooling by the application of heat. This definition shall apply to those absorption units which also produce comfort heating.

Acceleration: The time rate of change of velocity; i.e., the derivative of velocity; with respect to time.

Acceleration due to Gravity: The rate of increase in velocity of a body falling freely in a vacuum. Its value varies with latitude and elevation. The International Standard is 32.174ft. per second per second.

Actuator: A controlled motor, relay or solenoid in which the electric energy is converted into a rotary, liner, or switching action. An actuator can effect a change in the controlled variable by operating the final control elements a number of times. Valves and dampers are examples of mechanisms which can be controlled by actuators.

Adiabatic Process: A thermodynamic process during which no heat is added to, or taken from, a substance or system.

Adjustable Differential: A means of changing the difference between the control cut-in and cut-out points.

Adsorbent: A material which has the ability to cause molecules of gases, liquids, or solids to adhere to its internal surfaces without changing the adsorbent physically or chemically. Certain solid materials, such as silica gel and activated alumina, have this property.

Adsorption: The action, associated with the surface adherence, of a material in extracting one or more substances present in an atmosphere or mixture of gases and liquids, unaccompanied by physical or chemical change. Commercial adsorbent materials have enormous internal surface.

Aerodynamic Noise: Also called generated noise, self-generated noise; is noise of aerodynamic origin in a moving fluid arising from flow instabilities. In duct systems, aerodynamic noise is caused by airflow through elbows, dampers, branch wires, pressure reduction devices, silencers and other duct components.

Air, Ambient: Generally speaking, the air surrounding an object.

Air, Dry: Air without contained water vapour; air only.

Air, Outdoor: Air taken from outdoors and, therefore, not previously circulated through the system.

Air, Outside: External air, atmosphere exterior to refrigerated or conditioned space; ambient (surrounding) air.

Air, Recirculated: Return air passed through the conditioner before being again supplied to the conditioned space.

Air, Reheating of: In an air - conditioning system, the final step in treatment, in the event the temperature is too low.

Air, Return: Air returned from conditioned or refrigerated space.

Air, Saturated: Moist air in which the partial pressure of the water vapour is equal to the vapour pressure of water at the existing temperature. This occurs when dry air and saturated water vapour coexist at the same dry-bulb temperature.

Air, Standard: Dry air at a pressure of 29.92 in. Hg at 69.8 F temperature and with a specific volume of 13.33 ft/lb.

Air Changes: A method of expressing the amount of air leakage into or out of a building or room in terms of the number of building volumes or room values exchanged.

Air-Conditioner, Unitary: An evaporator, compressor, and condenser combination; designed in one or more assemblies, the separate parts designed to be assembled together.

Air - Conditioning, Comfort: The process of treating air so as to control simultaneously its temperature, humidity, cleanliness and distribution to meet the comfort requirements of occupants of the conditioned space.

Air - Conditioning Unit: An assembly of equipment for the treatment of air so as to control, simultaneously, its temperature, humidity, cleanliness and distribution to meet the requirements of a conditioned space.

Air Cooler: A factory-encased assembly of elements whereby the temperature of air passing through the device is reduced.

Air Diffuser: A circular, square, or rectangular air distribution outlet, generally located in the ceiling and comprised of deflecting members discharging supply air in various directions and planes, and arranged to promote mixing of primary air with secondary room air.

Air Gap: An air gap in a potable water distribution system is the unobstructed vertical distance through the free atmosphere between the lowest opening from any pipe or faucet supplying water to a tank, plumbing fixture or other device and the floor level rim of the receptacle.

Air Washer: A water spray system or device for cleaning, humidifying, or dehumidifying the air.

Airborne Sound: Sound which reaches the point of interest by radiation through the air.

Algae: A minute fresh water plant growth which forms a scum on the surface of recirculated water apparatus interfering with fluid flow and heat transfer.

Alternating Current (AC): A source of power for an electrical circuit which periodically reverses the polarity of its charge.

Ampacity: A wire's ability to carry current safely, without undue heating. The term formerly used to describe the characteristic was current-capacity of the wire.

Amperage: The flow of current in an electrical circuit measured in "amperes," abbreviated "amps" (A)

Amplitude of Ground Surface Temperature Variation: Peak annual fluctuation of ground surface temperature about a mean value.

Anemometer: An instrument for measuring the velocity of a fluid.

Anticipating Control: One which, by artificial means, is activated sooner than it would be without such means, to produce a smaller differential of the controlled property. Heat and cool anticipators are commonly used in thermostats.

Anticipators: Small heater elements in two-position temperature controllers which deliberately cause false indications of temperature in the controller in an attempt to minimize the override of the differential and smooth out the temperature variation in the controlled space.

Approach: In an evaporative cooling device, the difference between the average temperature of the circulating water leaving the device and the average wet-bulb temperature of the entering air. In a conduction heat exchanger device, the temperature difference between the leaving treated fluid and the entering working fluid.

Aspect Ratio: In air distribution outlets, the ratio of the length of the core opening of a grille, face, or register to the width. In rectangular ducts, the ratio of the width to the depth.

Aspiration: Production of movements in a fluid by suction created by fluid velocity.

Attenuation: The sound reduction process in which sound energy is absorbed or diminished in intensity as the result of energy conversion from sound to motion or heat.

Autumnal Equinox (See Also Vernal Equinox):

The position of the sun midway between its lowest and highest altitude during autumn; it occurs on September 21.

Auxiliary Contacts: A set of contacts that perform a secondary function, usually in relation to the operation of a set of primary contacts.

Averaging Element: A thermostat sensing element which will respond to the average duct temperature.

Azimuth Angle (Solar) : The angular direction of the sun with respect to the south.

B

Backflow: The unintentional reversal of flow in a potable water distribution system which may result in the transport of foreign materials or substances into the other branches of the distribution system.

Background Noise: Sound other than the wanted signal. In room acoustics, the irreducible noise level measured in the absence of any building occupants.

Barometer: Instrument for measuring atmospheric pressure.

Bimetallic Elements: One formed of two metals having different coefficients of thermal expansion such as are used in temperature indicating and controlling devices.

Boiling Point: The temperature at which the vapour pressure of a liquid equals the absolute external pressure at the liquid-vapour interface.

Branch Circuit: Wiring between the last over current device and the branch circuit outlets.

Breakout Noise: The term used in Great Britain for the transmission or radiation of noise from some part of the duct systems to an occupied space in the building. In the United States, the terms “flanking” “and duct radiation” are more frequently used; however, the team “breakout noise” seems more descriptive.

British Thermal Unit (Btu): The Btu is defined as the heat required to raise the temperature of a pound of water from 59° to 60° F.

Btuh: Number of Bt’s transferred during a period of one hour.

Bulb: The name given to the temperature sensing device located in the fluid for which control or indication is provided. The bulb may be liquid-filled, gas-filled, or gas- liquid filled, changes in temperature produce pressure changes within the bulb which are transmitted to the controller.

Building Envelope: The elements of a building which enclose conditioned spaces through which energy may be transferred to or from the exterior.

Bus Bar: A heavy, rigid metallic conductor which carries a large current and makes a common connection between several circuits. Bus bars are usually uninsulated and located where the electrical service enters a building; that is, in the main distribution cabinet.

Bus Duct: An assembly of heavy bars of copper or aluminium that acts as a conductor of large capacity.

Bypass: A pipe or duct, usually controlled by valve or damper, for conveying a fluid around an element of a system.

C

Calibration: Process of dividing and numbering the scale of an instrument; also of correcting or determining the error of an existing scale, or of evaluating one quantity in terms of readings of another.

Capacitance: The property of an electric current that permits the storage of electrical energy in an electrostatic field and the release of the energy at a later time.

Capacitor (Condenser): An electrical device that will store an electric charge used to produce a power factor change.

Capacity, Latent: The available refrigerating capacity of an air-conditioner for removing latent heat from the space to be conditioned.

Capillary: The name given to the thin tube attached to the bulb which transmits the bulb pressure changes to the controller or indicator. The cross-sectional area of the capillary is extremely small compared to the cross-section of the bulb so that the capillary, which is usually outside of the controlled fluid will introduce the smallest possible error in the signal being transmitted from the bulb.

Capillary Tube: The capillary tube is a Meeting device made from a thin tube approximately 2 to 20 feet long and from 0.025 to 0.090 inches in diameter which feeds liquid directly to the evaporator. Usually limited to systems of 1 ton or less, it performs all of the functions of the thermal expansion valve when properly sized.

Cathodic Protection: The process of providing corrosion protection against electrolytic reactions that could be deleterious to the performance of the protected material or component.

Ceiling Outlet: A round, square, rectangular, or linear air diffuser located in the ceiling which provides a horizontal distribution pattern of primary and secondary air over the occupied zone and induces low velocity secondary air motion through the occupied zone.

Celsius (Formerly Centigrade): A thermometric scale in which the freezing point of water is called 0°C and its boiling point is 100°C at normal atmospheric pressure (14.696 psi).

Change of State: Change from one phase, such as solid, liquid or gas, to another.

Changeover: The process of switching an air -conditioning system from heating to cooling, or vice versa.

Channel: Term used to describe output of a load management system. Usually corresponds to a specific relay.

Chemical Compatibility: The ability of materials and components in contact with each other to resist mutual chemical degradation, such as that caused by electrolytic action.

Circuit: An electrical arrangement requiring a source of voltage, a closed loop of wiring, an electric load and some means for opening and closing it.

Circuit Breaker: A switch-type mechanism that opens automatically when it senses an overload (excess current).

Clearing a Fault: Eliminating a fault condition by some means. Generally taken to mean operation of the over-circuit device that opens the circuit and clears the fault.

Clo Value: A numerical representation of a clothing ensemble's thermal resistance. 1 Clo = 0.88 sq. ft. h°F/Btu.

Coefficient of Discharge: For an air diffuser, the ratio of net area or effective area at vena contracta of an orificed air-stream to the free area of the opening.

Coefficient of Expansion: The change in length per unit length or the change in volume, per deg. change in temperature.

Coefficient of Performance (COP), Heat Pump: The ratio of the compressor heating effect (heat pump) to the rate of energy input to the shaft of the compressor, in consistent units, in a complete heat pump, under designated operating conditions.

Coil: A cooling or heating element made of pipe or tubing.

Cold Deck: The cooling section of a mixed air zoning system.

Collector Azimuth: The horizontal angle between true south and a line which is perpendicular to the plane of the collector that is projected on a horizontal plane.

Collector Plate: The component of a solar collector which transfers the heat from solar energy to a circulating fluid.

Collector (Solar): An assembly of components intended to capture usable solar energy.

Combustion: The act of process of burning.

Comfort Chart: A chart showing effective temperatures with dry-bulb temperatures and humidities (and sometimes air motion) by which the effects of various air conditions on human comfort may be compared.

Comfort Cooling: Refrigeration for comfort as opposed to refrigeration for storage or manufacture.

Comfort Zone: (Average) the range of effective temperatures over which the majority (50 percent or more) of adults feel comfortable; (extreme) the range of effective temperatures over which one or more adults feel comfortable.

Common Neutral: A neutral conductor that is common to, or serves, more than one circuit.

Compressibility: The ease with which a fluid may be reduced in volume by the application of pressure, depends upon the state of the fluid as well as the type of fluid itself. In TAB work, consider that water may not be compressed. Air is a compressible gas, but that factor is usually not considered during normal testing and balancing procedures.

Compressor: The pump which provides the pressure differential to cause fluid to flow and in the pumping process increases pressure of the refrigerant to the high side condition. The compressor is the separation between low side and high side.

Concentrator: A reflective surface or refracting lens for directing insolation onto the absorber surface.

Condensate: The liquid formed by condensation of a vapour. In steam heating, water condensed from steam; in air - conditioning, water extracted from air, as by condensation on the cooling of refrigeration machine.

Condensation: Process of changing a vapour into liquid by extracting heat. Condensation of steam or water vapor is effected in either steam condensers or dehumidifying coils, and the resulting water is called condensate.

Condenser: The heat exchanger in which the heat absorbed by the evaporator and some of the heat of compression introduced by the compressor are removed from the system. The gaseous refrigerant changes to a liquid, again taking advantage of the relatively large heat transfer by the change of state in the condensing process.

Condenser: Electrical - see "Capacitor"

Condensing Unit, Refrigerant: An assembly of refrigerating components designed to compress and liquify a specific refrigerant, consisting of one or more refrigerant compressors, refrigerant condensers, liquid receivers (when required) and regularly furnished accessories.

Conditioned Space: Space within a building which is provided with heated and/or cooled air or surface and, where required, with humidification or dehumidification means so as to maintain a space condition falling within the "comfort zone".

Conditions, Standard: A set of physical, chemical, or other parameters of a substance or system which defines an accepted reference state or forms a basis for comparison.

Conductance, Electrical: The reciprocal (opposite) of resistance and the current carrying ability of any wire or electrical component. Resistance is the ability to oppose the flow of current.

Conductance, Surface Film: Time rate of heat flow per unit area under steady conditions between a surface and a fluid for unit temperature difference between the surface and fluid.

Conductance, Thermal: Time rate of heat flow through a body (frequently per unit area) from one of its bounding surfaces to the other for a unit temperature difference between the two surfaces, under steady conditions.

Conductivity, Thermal: The time rate of heat flow through the unit area and unit thickness of a homogeneous material under steady conditions when a unit temperature gradient is maintained in the direction perpendicular to the area. Materials are considered homogeneous when the value of the thermal conductivity is not affected by valuation in thickness or in size of sample within the range normally used in construction.

Conductor, Thermal: A material which readily transmits heat by means of conduction.

Conduit: A round cross-section electrical raceway, of metal or plastic.

Connected Load: The sum of all loads on a circuit.

Connection in Parallel: System whereby flow is divided among two or more channels from a common starting point or header.

Connection in Series: System whereby flow through two or more channels is in a single path entering each succeeding channel only after leaving the first or previous channel.

Contactor: Electromagnetic switching device.

Control: A device for regulation of a system or component in normal operation, manual or automatic. If automatic, the implication is that it is responsive to changes of pressure, temperature or other property whose magnitude is to be regulated.

Control Diagram (ladder diagram): A diagram that shows the control scheme only. Power wiring is not shown. The control items are shown between two vertical lines; hence, the name - ladder diagram.

Control Point: The value of the controlled variable which the controller operates to maintain.

Controlled Device: One which receives the converted signal from the transmission system and translates it into the appropriate action in the environmental system. For example: a valve opens or closes to regulate fluid flow in the system.

Controller: An instrument which receives the signal from the sensing device and translates that signal into the appropriate corrective measure. The correction is then sent to the system controlled devices through the transmission system.

Convection: Transfer of heat by movement of fluid.

Convection, Forced: Convection resulting from forced circulation of a fluid, as by a fan, jet or pump.

Convection, Natural: Circulation of gas or liquid (usually air or water) due to differences in density resulting from temperature changes.

Cooling, Evaporative: Involves the adiabatic exchange of heat between air and water spray or wetted surface. The water assumes the wet-bulb temperature of the air, which remains constant during its traverse of the exchanger.

Cooling, Regenerative: Process of utilizing heat which must be rejected or absorbed in one part of the cycle to function usefully in another part of the cycle by heat transfer.

Cooling Coil: An arrangement of pipe or tubing which transfers heat from air to a refrigerant or brine.

Cooling Effect, Sensible: Difference between the total cooling effect and the dehumidifying.

Counterflow: In heat exchange between two fluids, opposite direction of flow, coldest portion of one meeting coldest portion of the other.

Critical Velocity: The velocity above which fluid flow is turbulent.

Cross Connection: Any physical connection or arrangement between two otherwise separate piping systems, one of which contains potable water and the other either water of unknown or questionable fluid or steam, gas, chemical, or other substances whereby there may be a flow from one system to the other, the direction of flow depending on the pressure differential between the two systems.

Crystal Formation, Zone of Maximum: Temperature range in freezing in which most freezing takes place, i.e., about 25°F to 30°F for water.

Curb Box: Access to an underground valve at the street curb. It controls water service to a house or building.

Current (I): The electrical flow in an electric circuit, which is expressed in amperes (amps).

Cycle: A complete course of operation of working fluid back to a starting point, measured in thermodynamic terms (functions). Also, in general for any repeated process on any system.

Cycle Reversible: Theoretical thermodynamic cycle, composed of a series of processes, which can be completely reversed.

D

DMV: Drainage, waste and vent.

Dalton's Law of Partial pressure: Each constituent of a mixture of gases behaves thermodynamically as if it alone occupied the space. The sum of the individual pressures of the constituents equals the total pressure of the mixture.

Damper: A device used to vary the volume of air passing through an air outlet, air inlet or duct.

Deadband: In HVAC, a temperature range in which neither heating nor cooling is turned on; in load management; a kilowatt range in which load is neither shed nor restored.

Decay Rate: The rate at which the sound pressure level in an enclosed space decreases after the sound source has stopped. It is measured in decibels per second.

Decible (dB): A decibel is a division of a logarithmic scale for expressing the ratio of two quantities proportional to power or energy. The number of decibels denoting such a ratio is ten times the logarithm of the ratio.

Degree Day: A unit, based upon temperature difference and time, used in estimating fuel consumption and specifying nominal heating load of a building in winter. For any one day, when the mean temperature is less than 65°F, there exists as many degree days as there are Fahrenheit degrees difference in temperature between the mean temperature for the day and 65°F.

Dehumidification: The condensation of water vapor from air by cooling below the dewpoint or removal of water vapor from air by chemical or physical methods.

Dehumidifier: (1) An air cooler or washer used for lowering the moisture content of the air passing through it; (2) An absorption or adsorption device for removing moisture from air.

Dehydration: (1) removal of water vapor from air by the use of absorbing or adsorbing materials; (2) removal of water from stored goods.

Delta Service: An arrangement of the utility transformers. Commonly shown as "D".

Demand: The probable maximum rate of water flow as determined by the number of water supply fixture units.

Demand Charge: That part of an electric bill based on kW demand and the demand interval, expressed in dollars per kilo-watt. Demand charges offset construction and maintenance of a utility's need for a large generating capacity.

Demand Control: A device which controls the kW demand level by shedding loads when the kW demand exceeds a predetermined set point.

Demand Interval: The period of time during which kW demand is monitored by a utility service 15 or 30 minutes long.

Demand Load: The actual amount of load on a circuit at any time. The sum of all the loads which are ON. Equal to the connected load minus the loads that are OFF.

Demand Reading: Highest or maximum demand for electricity an individual customer registers in a given interval, example, 15 minute interval. The metered demand reading sets the demand charge for the month.

Density: The ratio of the mass of a specimen of substance to the volume of the specimen. The mass of a unit volume of a substance. When weight can be used without confusion, as synonymous with mass, density is the weight per unit volume.

Desiccant: Any absorbent or adsorbent, liquid or solid, that will remove water or water vapor from a material. In a refrigeration circuit, the desiccant should be insoluble in the refrigerant.

Design Working Pressure: The maximum allowable working pressure for which a specific part of a system is designed.

Dewpoint, Apparatus: That temperature which would result if the psychrometric process occurring in a dehumidifier, humidifier of surface-cooler were carried to the saturation condition of the leaving air while maintaining the same ratio of sensible to total heat load in the process.

Dew Point Depression: The difference between dry bulb and dew point temperatures (°F DB-°F DP).

Dew Point Temperature: (idp) The temperature at which moist air becomes saturated (100% relative humidity) with water vapor when cooled at constant pressure.

Dielectric Fitting: An insulating or nonconducting fitting used to isolate electrochemically dissimilar materials.

Differential: The difference between the points where a controller turns "on" and "off". If a thermostat turns a furnace on at 68° and the differential is 3°, the burner will be turned off at 71°.

Diffuse Sound Field: A diffuse sound field is a space in which at every point the flow of sound energy in all directions is equally probable. (It is often assumed that in a diffuse field, the sound pressure level, averaged through time, is everywhere the same).

Diffuser: A circular, square, or rectangular air distribution outlet, generally located in the ceiling and comprised of deflecting members discharging supply air in various directions and planes, and arranged to promote mixing of primary air with secondary room air.

Direct Acting: Instruments that increase control pressure as the controlled variable (such as temperature of pressure) increases; while reverse acting instruments increase control pressure as the controlled variable decreases.

Direct Current (DC): A source of power for electrical circuit which does not reverse the polarity of its charge.

Direct Field: The sound in a region in which all or most of the sound arrives directly from the source without reflection.

Directivity Factor: The ratio of the sound pressure squared at some fixed distance and on the axis of maximum response to the mean square sound pressure at the same distance averaged over all directions from the source.

Discharge Stop Valve: The manual service valve at the leaving connection of the compressor.

Discrete Logic: Electronic circuitry composed of standard transistors, resistors, capacitors, etc., as compared to micro-processor circuits where the logic is condensed on a single chip (integrated circuit).

Domestic Hot Water: Potable hot water as distinguished from hot water used for house heating.

Draft: a) A current of air, when referring to the pressure difference which causes a current of air or gases to flow through a flue, chimney, heater, or space; or b) to a localized effect caused by one or more factors of high air velocity, low ambient temperature, or direction of air flow, whereby more heat is withdrawn from a person's skin than is normally dissipated.

Drier: A manufactured device containing a desiccant placed in the refrigerant circuit. Its primary purpose is to collect and hold within the desiccant, all water in the system in excess of the amount which can be tolerated in the circulating refrigerant.

Drift: Term used to describe the difference between the set point and the actual operating or control point.

Drip: A pipe, or a steam trap and a pipe considered as a unit, which conducts condensation from steam side of a piping system to the water or return side of the system.

Droop: Terms used to describe the difference between the set point and the actual operating or control point.

Drop: The vertical distance that the lower edge of a horizontally projected airstream drops between the outlet and the end of its throw.

Dry bulb, Room: The dry bulb (dewpoint, etc.) temperature of the conditioned room or space.

Dry Bulb Temperature: The temperature registered by an ordinary thermometer. The dry bulb temperature represents the measure of sensible heat, or the intensity of heat.

Dry, Bulb Temperature Adjusted (tadb): The average of the air temperature (ta) and the mean radiant temperature (tr) at a given location. The adjusted dry bulb temperature (iac/b) is approximately equivalent to operative temperature (t0) at air motions less than 80 fpm when it is less than 12°F.

Duct: A passageway made of sheet, metal or other suitable material, not necessarily leaktight, used for conveying air or other gas at low pressures.

Dust: An air suspension (aerosol) or particles of any solid material, usually with particle size less than 100 microns.

Dynamic Discharge Head: Static discharge head plus friction head plus velocity head.

Dynamic Insertion Loss: The dynamic insertion loss of a silencer, duct lining or other attenuating device is the performance measured in accordance with ASTME 477 when handling the rated airflow. It is the reduction in sound power level, expressed in decibels, due solely to the placement of the sound attenuating device in the duct system.

Dynamic Suction Head: Positive static suction head minus friction head and minus velocity head.

Dynamic Suction Lift: The sum of suction lift and velocity head at the pump suction when the source is below pump centreline.

E

Economizer: A system of dampers, temperature and humidity sensors and motors which maximizes the use of outdoor air for cooling.

Effect, Humidifying: Latent heat of water vaporization at the average evaporating temperature times the number of pounds of water evaporated per hour in Btuh.

Effect, Sun: Solar energy transmitted into space through windows and building materials.

Effect, Total Cooling: The difference between the total enthalpy of the dry air and water vapour mixture entering a unit per hour and the total enthalpy of the dry air and water vapour (and water) mixture leaving the unit per hour, expressed in Btu per hour.

Effective Area: The net area of an outlet or inlet device through which air can pass, equal to the free area times the coefficient of discharge.

Effectiveness (Efficiency): The ratio of the actual amount of heat transferred by a heat recovery device to the maximum heat transfer possible between the airstreams (sensible heat/sensible heat, sensible heat/total heat, or total heat/total heat).

Elasticity of Demand: The change in quantity of electricity (or other commodity) purchased as a result of a change in its price. Demand for electricity is "elastic" when it increases or decreases in response to decreases or increases, respectively, in the price for the electricity.

Electrical Circuit: A power supply, a load, and a path for current flow are the minimum requirements for an electrical circuit.

Electromechanical: Converting electrical input into mechanical action. A relay is an electromechanical switch.

Electro-Pneumatic (EP) Switches: Switches that open or close an air line valve from an electrical impulse.

Emissivity: The property of a surface that determines its ability to give off radiant energy.

Emittance: The ratio of the radiant energy emitted by a body to the energy emitted by a black body at the same temperature.

Energy: Expressed in Kilowatt-hours (kWh) or Watt-hours (Wh), and is equal to the product and time.

energy = power x time

kilowatt-hours = kilowatts hours

watt-hours = watts hour

Energy (Consumption) Charge: That part of an electric bill based on kWh consumption (expressed in cents power kWh). Energy charge covers cost of utility fuel, general operating costs, and part of the amortization of the utility's equipment.

Energy Efficient Ratio (EER), Cooling: The ratio of net cooling capacity in Btuh to total electric input in watts under designated operating conditions.

Engine: Prime mover, device for transforming fuel or heat energy into mechanical energy.

Enthalpy: The total quantity of heat energy contained in a substance, also called total heat; the thermodynamic property of a substance defined as the sum of its internal energy plus the quantity FV/J, where P = pressure of the substance, v = its volume and J = the mechanical equivalent of heat.

Enthalpy, Specific: A term sometimes applied to enthalpy per unit weight.

Entrainment: The capture of part of the surrounding air by the airstream discharged from an outlet (sometimes called secondary air motion).

Entropy: The ratio of the heat added to a substance to the absolute temperature at which it is added.

Entropy, Specific: A term sometimes applied to entropy per unit weight.

Equal Friction Method: A method of duct sizing wherein the selected duct friction loss value is used constantly throughout the design of a low pressure duct system.

Equivalent Duct Diameter: The equivalent duct diameter for a rectangular duct with sides of dimensions a and b is $4 \times ab \div [2 \times (a+b)]$.

Evaporation: Change of state from liquid to vapor.

Evaporative Cooling: The adiabatic exchange of heat between air and a water spray or wetted surface. The heater approaches the wet-bulb temperature of the air, which remains constant during its traverse of the exchanger.

Evaporator: The heat exchanger in which the medium being cooled, usually air or water, gives up heat to the refrigerant through the exchanger transfer surface. The liquid refrigerant boils into a gas in the process of heat absorption.

Exfiltration: Air flow outward through a wall, leak, membrance, etc.

Extended Surface: Heat transfer surface, one or both sides of which are increased in area by the addition of fins, discs, or other means.

F

Face Area: The total plane area of the portion of a grille, coil, or other items bounded by a line tangent to the outer edges of the openings through which air can pass.

Face Velocity: The velocity obtained by dividing the air quantity by the component face area.

Fahrenheit: A thermometric scale in which 32 (°F) denotes freezing and 212 (°F) the boiling point of water under normal pressure at sea level (14.696psi).

Fail Safe: In load management, returning all loads to conventional control during a power failure. Accomplished by a relay whose contacts are normally closed.

Fan, Centrifugal: A fan rotor or wheel within a scroll type housing and including driving mechanism supports for either belt drive or direct connection.

Fan Performance Curve: Fan performance curve refers to the constant speed performance curve. This is a graphical presentation of static or total pressure and power input over a range of air volume flow rate at a stated inlet density and fan speed. It may include static and mechanical efficiency curves. The range of air volume flow rate which is covered generally extends from shutoff (zero air volume flow rate) to free delivery (zero fan static pressure). The pressure curves are generally referred to as the pressure-volume curves.

Fan Propeller: A propeller or disc type wheel within a mounting ring or plate and including driving mechanism supports for either belt drive or direct connection.

Fan, Tubeaxial: A propeller or disc type wheel within a cylinder and including driving mechanism supports for either belt drive or direct connection.

Fan Vaneaxial: A disc type wheel within a cylinder, a set of air guide vanes located either before or after the wheel and including driving mechanism supports for either belt drive or direct connection.

Fault: A short circuit - either line to line, or line to ground.

Feed Line: A pipe that supplies water to items such as a boiler or a domestic hot water tank.

Filter: A device to remove solid material from a fluid.

Filter-Drier: A combination device used as a strainer and moisture remover.

Fin: An extended surface to increase the heat transfer area, as metal sheets attached to tubes.

Fixed Collector: A permanently oriented collector that has no provision for seasonal adjustment or tracking of the sun.

Flanking Transmission (Sound): The reduction in apparent transmission loss of a wall caused by sound being carried around the wall by other paths. (Structure-borne sound, leaks, etc.)

Flat-Plate Collector: A collector without external concentrators or focusing devices, usually consisting of an absorber plate, cover plates, back and side insulation and a container.

Floating Action Controllers: Essentially two position type controllers which vary the position of the controlled devices but which are arranged to stop before reaching a maximum or minimum position.

Flow, Laminar or Streamline: Fluid flow in which each fluid particle moves in a smooth path substantially parallel to the paths followed by all other particles.

Flow, Turbulent: Fluid flow in which the fluid moves transversely as well as in the direction of the tube or pipe axis, as opposed to streamline or viscous flow.

Flue: A special enclosure incorporated into a building for the removal of products of combustion.

Type "A": A flue listed for use with oil, gas, or coal burning equipment.

Type "B": A manufactured flue listed for use with gas burning equipment.

Fluid: Gas, vapour, or liquid.

Fluid Head: The static pressure of fluid expressed in terms of the height of a column of the fluid, or of some manometric fluid, which it would support.

Fluid, Heat Transfer: Any gas, vapor, or liquid used to absorb heat from a source at a high temperature and reject it to a lower temperature substance.

Fluid Dynamics: Fluid Dynamics is used to describe the condition of motion of a fluid within a system. The velocity of a fluid is based upon the cross-sectional area and the volume of a fluid passing through it. The importance of this property is that volume may be determined for air or water systems when the area and velocity are known.

Fluid Statics: Fluid Statics as applied to TAB work, refers to a condition of a quantity of fluid at rest. It is the direct result of gravity and weight. Static pressure is used in both air and water testing to determine the potential for the movement of fluid within a system. Pressures in air systems are normally measured in units of inches of water (in. W.g.). A pressure unit of one inch of water is equivalent to the static pressure found at the base of a column of water one inch high. Pressures in water systems are normally measured in pounds per square inch (psi), but are converted to feet of water (ft. W.g.) for the purpose of evaluating pump and equipment performance.

Focusing Collector: A collector using some type of focusing device (parabolic mirror, Fresnel lens, etc.) to concentrate the insolation on an absorbing element.

Force: The action on a body which tends to change its relative condition as to rest or motion.

Forced Circulation: Circulation of heat transfer fluid by a pump or fan.

Free Area: The total minimum area of the openings in the air outlet or inlet through which air can pass.

Free Delivery-Type Unit: A device which takes in air and discharges it directly to the space to be treated without external elements which impose air resistance.

Free Sound Field (Free Field): A free sound field is a field in a homogenous, isotropic medium free from boundaries. In practice, it is a field in which the effect of the boundaries are negligible over the region of interest. In the free field, the sound pressure level decreases 6dB for a doubling of distance from a point source.

Freezing Point: Temperature at which a given liquid substance will solidify or freeze on removal of heat. Freezing point of water is 32°F.

Frequency: The number of vibrations, waves, or cycles of any periodic phenomenon per second. In architectural acoustics, the interest lies in the audible frequency range of 20 to 20,000 cps Hertz (cycles per second).

Frequency Spectrum: Usually a visual representation of a complex sound or noise which has been resolved into frequency components. The detailed nature of a complex sound may be studied by obtaining its frequency spectrum. Frequency spectra are commonly obtained in octave bands, 1/3 octave bands, and various narrow bands.

Friction: Friction is the resistance found at the duct and piping walls. Resistance creates a static pressure loss in systems. The primary purpose of a fan or pump is to produce a design volume and the other dynamic pressure losses of the components.

Friction Head: The pressure in psi or feet of the liquid pumped which represents system resistance that must be overcome.

Full Load Current: See Running Current.

Fumes: Solid particles are commonly formed by the condensation of vapors from normally solid materials such as molten metals. Fumes may also be formed by sublimation, distillation, calcination, or chemical reaction wherever such processes create airborne particles predominantly below one micron in size. Such solid particles sometimes serve as condensation nuclei for water vapor to form smog.

G

GFI, GFCI: Ground fault (circuit) interrupter - a device that senses ground faults and reacts by opening the circuit.

Gang: One wiring device position in a box.

Gas: Usually a highly superheated vapor which, within acceptable limits of accuracy, satisfies the perfect gas laws.

Gas, Inert: A gas that neither experiences nor causes chemical reaction nor undergoes a change of state in a system or process; e.g. nitrogen or helium mixed with a volatile refrigerant.

Gas Constant: The coefficient “R” in the perfect gas equation

$PV = MRT$.

Gradual Switches: Manual adjustment devices which proportion the control condition in accordance with the position of the switch.

Grains of Moisture: The unit of measurement of actual moisture contained in a sample of air. (7000 grains = one pound of water).

Gravity, Specific: Density compared to density of standard material; reference usually to water or to air.

Grille: A louvered or perforated covering for an air passage opening which can be located on a wall, ceiling or floor.

Ground: Zero voltage, or any point connected to the earth or “ground”.

Ground Bus: A busbar in a panel or elsewhere, deliberately connected to the ground.

Ground Conductor: Conductor run in an electrical system, which is deliberately connected to the ground electrode. Purpose is to provide a ground point throughout the system. Insulation color - green. Also called “green ground”.

Ground Fault: An unintentional connection to the ground.

H

Head, Dynamic or Total: In flowing fluid, the sum of the static and velocity heads at the point of measurement.

Head, Static: The static pressure of fluid expressed in terms of the height of a column of the fluid, or of some manometric fluid, which it would support.

Head, Velocity: In a flowing fluid, the height of the fluid or of some manometric fluid equivalent to its velocity pressure.

Heat: The form of energy that is transferred by virtue of a temperature difference.

Heat, Latent: Change of enthalpy during a change of state, usually expressed in Btu per lb. With pure substances, latent heat is absorbed or rejected at a constant temperature.

Heat, Sensible: Heat which is associated with a change in temperature; specific heat exchange of temperature; in contrast to a heat interchange in which a change of state (latent heat) occurs.

Heat, Specific: The ratio of the quantity of heat required to raise the temperature of a given mass of any substance by one degree to the quantity

required to raise the temperature of an equal mass of a standard substance (usually water at 59°F) by one degree.

Heat, Total (Enthalpy): The sum of sensible heat and latent heat between an arbitrary datum point and the temperature and state under consideration.

Heat Capacity: The amount of heat necessary to raise the temperature of a given mass by one degree. Numerically, the mass multiplied by the specific heat.

Heat Conductor: A material capable of readily conducting heat. The opposite of an insulator or insulation.

Heat Exchanger: A device specifically designed to transfer heat between two physically separated fluids.

Heat of Fusion: Latent heat involved in changing between the solid and the liquid states.

Heat of Vaporization: Latent heat involved in the change between liquid and vapor states.

Heat Pump: A refrigerating system employed to transfer heat into a space or substance. The condenser provides the heat while the evaporator is arranged to pick up heat from air, water, etc. By shifting the flow of air or other fluid, a heat pump system may also be used to cool the space.

Heat Transfer Medium: A fluid used in the transport of thermal energy.

Heat Transmission: Any time-rate of heat flow; usually refers to conduction, convection and radiation combined.

Heat Transmission Coefficient: Any one of a number of coefficients used in the calculation of heat transmission by conduction, convection, and radiation, through various materials and structures.

Heating, Regenerative (or Cooling): Process of utilizing heat, which must be rejected or absorbed in one part of the cycle, to perform a useful function in another part of the cycle by heat transfer.

Hidden Demand Charge: Electric bill charges that are based on cents per kWh per kW demand contain a hidden demand charge. A low load factor for a building then penalizes the energy used through this “hidden” charge.

High Limit Control: A device which normally monitors the condition of the controlled medium and interrupts system operation if the monitored condition becomes excessive.

High Pressure Cutout: A pressure actuated switch to protect the compressor from pressure often caused by high condenser temperatures and pressure due to fouling and lack of water or air.

High Side: Parts of the refrigerating system subjected to condenser pressure or higher; the system from the compression side of the compressor through the condenser to the expansion point of the evaporator.

Horsepower: Unit of power in foot-pound-second system; work done at the rate of 550 ft-lb per sec, or 33,000 ft-lb per min.

Hot Deck: The heating section of a multizone system.

Hot Gas Bypass: The piping and manual, but more often automatic, valve used to introduce compressor discharge gas directly into the evaporator. This type of arrangement will maintain compressor operation at light loads down to zero by falsely loading the evaporator and compressor.

Hot Gas Piping: The compressor discharge piping which carries the hot refrigerant gas from the compressor to the condenser. Velocities must be high enough to carry entrained oil.

Humidifier: A device to add moisture to air.

Humidifying Effect: The latent heat of vaporization of water at the average evaporating temperature times the weight of water evaporated per unit of time.

Humidistat: A regulatory device, actuated by changes in humidity, used for the automatic control of relative humidity.

Humidity: Water vapor within a given space.

Humidity, Absolute: The weight of water vapour per unit volume.

Humidity, Percentage: The ratio of the specific humidity of humid air to that of saturated air at the same temperature and pressure, usually expressed as a percentage (degree of saturation; saturation ratio).

Humidity, Ratio: The ratio of the mass of the water vapour to the mass of dry air contained in the sample.

Humidity, Relative: The ratio of the moist fraction of water vapor present in the air, to the moist fraction of water vapor present in saturated air at the same temperature and barometric pressure; approximately, it equals the ratio of the partial pressure or density of the water vapour in the air, to the saturation pressure or density, respectively, of water at the same temperature.

Humidity, Specific: Weight of water vapor (steam) associated with 1 lb. weight of dry air, also called humidity.

Hunting: A condition which occurs when the desired condition cannot be maintained. The controller, controlled device and system, individually or

collectively, continuously override or “overshoot” the control point with a resulting fluctuation and loss of control of the condition to be maintained.

Hydrostatic Pressure: The pressure at any point in a liquid at rest; equal to the depth of the liquid multiplied by its density.

Hygroscopic: Absorptive of moisture, readily absorbing and retaining moisture.

I

Impedance (Z): The quantity in an AC circuit that is equivalent to resistance in a DC circuit, in as much as it relates to current and voltage. It is composed of resistance plus a purely AC concept called reactance and is expressed, like resistance, in Ohms.

“In” Contacts: Those relay contacts which complete circuits when the relay armature is energized. Also referred to as Normally Open Contacts.

Inch of Water (in. w.g.): A unit of pressure equal to the pressure exerted by a column of liquid water 1 inch high at a temperature of 39.2°F.

Incidence, Angle of: The angle at which insolation strikes a surface.

Indicator: A term used to describe any device such as a thermometer or pressure gauge which is used to indicate the condition at a point in the system but which does not provide any controlling action or effect on the system operation.

Inductance: The process when a second conductor is placed next to a conductor carrying AC current (but not touching it), the everchanging magnetic field will induce a current in the second conductor.

Induction: The capture of part of the ambient air by the jet action of the primary airstream discharging from a controlled device.

Inductive Loads: Loads whose voltage and current are out-of-phase. True power consumption for inductive loads is calculated by multiplying its voltage, current, and the power factor of the load.

Infiltration: Air flowing into a building as through a wall, crack, etc.

Input Override Relay: A relay that allows the duty cycle to be inhibited on specific channels because of inputs from outdoor temperature, space temperature, case temperature, time-of-day, etc. Sometimes called “duty cycle control relay”.

Inrush Current: The current that flows the instant after the switch controlling current flow to a load is closed. Also called “locked rotor current”.

Insertion Loss: The insertion loss of an element of an acoustic transmission system is the positive or negative change in acoustic power transmission that results when the element is introduced.

Insolation: The total amount of solar energy reaching a surface per unit of time.

Instantaneous Rate: Method for determining when load shedding should occur. Actual energy usage is measured and compared to a present kilowatt level. If the actual kilowatt level exceeds a designated set point, loads will be shed until the actual rate drops below the set point.

Insulation, Thermal: A material having a relatively high resistance to heat flow and used principally to retard heat flow.

Interstage Differential: In a multistage HVAC system, the change in temperature at the thermostat needed to turn additional heating or cooling equipment on.

Isentropic: An adjective describing a reversible adiabatic process; a change taking place at constant entropy.

Isobaric: An adjective used to indicate a change taking place at constant pressure.

Isothermal: An adjective used to indicate a change taking place at constant temperature.

J

Junction Box: Metal box in which tap to circuit conductors is made. Junction is not an outlet, since no load is fed from it directly.

K

Kilovolt Ampere: Product of the voltage times the current. Different from kilowatts because of inductive loads in an electrical system. Abbreviated: KVA kilowatts is equal to KVA times power factor.

Kilowatt: 1000 watts. Abbreviated: kW.

Kilowatt-Hour: A measure of electrical energy consumption, 1000 watts being consumed per hour. Abbreviated: kWh.

kW Demand: The maximum rate of electric power usage required to operate a facility during a period of time, usually a month or billing period. Often called “demand”.

kWh Consumption: The amount of electric energy used over a period of time; the number of kWh used per month. Often called “consumption”.

L

Lag: A delay in the effect of a changed condition at one point in the system, on some other condition to which it is related. Also, the delay in action of the sensing element of a control, due to the time required

for the sensing element to reach equilibrium with the property being controlled; i.e. temperature lag, flow lag, etc.

Langley: Standard unit of insolation measurements, 1 langley = 1 cal/sq.cm. (1 langley/min. = 221 Btuh/sq.ft.).

Latent Heat of Fusion: The heat required to change a solid to a liquid at the same temperature; i.e. ice to water.

Latent Heat of Vaporization: The amount of heat necessary to change a quantity of water to water vapour without changing either temperature or pressure. When water is vaporized and passes into the air, the latent heat of vaporization passes into the air along with the vapour. Likewise, latent heat is removed when water vapour is condensed.

Law of Partial Pressure, Dalton's: Each constituent of a mixture of gases behaves thermodynamically as if it alone occupied the space. The sum of the individual pressures of the constituents equals the total pressure of the mixture.

Level (L): The ratio expressed in decibels of two quantities proportioned to power or energy the second of which is a standard reference quantity.

Light Emitting Diode: A low current and voltage light used as an indicator on load management equipment. Abbreviated: LED.

Limit: Control applied in the line or low voltage control circuit to break the circuit of conditions that move outside a present range. In a motor, a switch which cuts off power to the motor windings when the motor reaches its full open position.

Limit Control: A temperature, pressure, humidity, dew point or other control that overrides the demand control and/or duty cycle to prevent any affect on the business operation from load management, malfunction, or abnormal conditions. Also called "load override".

Line Side: The side of a device electrically closest to the source of current.

Line Voltage: In the control industry, the normal electric supply voltages, which are usually 120 or 240 volts.

Liquefaction: A change of state to liquid; generally used instead of condensation in cases of substances ordinarily gaseous.

Liquid Sight Glass: The glass ported fitting in the liquid line used to indicate adequate refrigerant charge. When bubbles appear in the glass, there is insufficient refrigerant in the system.

Liquid Solenoid Valve: The electrically operated automatic shutoff valve in the liquid piping which closes on system shut-down to close off receiver discharge when used in pump down cycle and which prevents refrigerant migration in any system.

Load: The amount of heat per unit time imposed on a refrigerant system, or the required rate of heat removal.

Load Factor: This is a ratio expressing a customer's average actual use of the utility's capacity provided versus the maximum amount used.

Load Management: The control of electrical loads to reduce kW demand and kWh consumption.

Load Programmer: Any device which turns loads on and off on a real time, time interval or kW demand basis.

Load Side: The side of a device electrically farthest from the current source.

Locked Rotor Current: See "Inrush Current".

Loudness: The subjective human definition of the intensity of a sound. Human reaction to sound is highly dependent on the sound pressure and frequency.

Loudness Level: A subjective method of rating loudness in which a 1000 Hz tone is varied in intensity until it is judged by listeners to be equally as loud as a given sound sample. The loudness level in "phons" is taken as the sound pressure level, in decibels, of the 1000 Hz tone.

Louver: An assembly of sloping vanes intended to permit air to pass through and to inhibit transfer of water droplets.

Low Limit Control: A device which normally monitors the condition of the controlled medium and interrupts system operation if the monitored condition drops below the desired minimum value.

Low Side: The refrigerating system from the expansion point to the point where the refrigerant vapor is compressed; where the system is at or below evaporated pressure.

Low Temperature Cutout: A pressure or temperature actuated device with sensing element in the evaporator, which will shut the system down at its control setting to prevent freezing chilled water or to prevent coil frosting. Direct expansion equipment may not use this device.

Low Voltage: In the control industry, a power supply of 25 volts or less.

M

MCM: Thousand circular mil - used to describe large wire sizes.

Manometer: An instrument for measuring pressures: especially a U-tube partially filled with a liquid, usually water, mercury, or a light oil, so constructed that the amount of displacement of the liquid indicates the pressure being exerted on the instrument.

Mass: The quantity of matter in a body as measured by the ratio of the force required to produce given acceleration, to the acceleration.

Mass Law (Sound): The law relating to the transmission loss of sound barriers which says that in a part of the frequency range, the magnitude of the loss is controlled entirely by the mass per unit area of the barrier. The law also says that the transmission loss increases 6 decibels for each doubling of frequency or each doubling of the barrier mass per unit area.

Master (Central) Control: Control of all outlets from one point.

Maximum "No-Flow" Temperature: The maximum temperature that will be obtained in a component when the heat transfer fluid is not flowing through the system.

Media: The heat transfer material used in rotary heat exchangers, also referred to as matrix.

Melting Point: For a given pressure, the temperature at which the solid and liquid phases of the substance are in equilibrium.

Microbar: A unit of pressure equal to 1 dyne/cm^2 (one millionth of the pressure of the atmosphere)

Micron: A unit of length, the thousandth part of 1 mm of the millionth of a meter.

Microprocessor: A small computer used in load management to analyze energy demand and consumption such that loads are turned on and off according to a predetermined program.

Modulation: Of a control, tending to adjust by increments and decrements.

Modulating Control: A mode of automatic control in which the action of the final control element is proportional to the deviation, from set point, of the controlled medium.

Modulating Controllers: Constantly reposition themselves in proportion to the requirements of the system, theoretically being able to maintain an accurately constant condition.

Motor Control Center: A single metal enclosed assembly containing a number of motor controllers and possibly other devices such as switches and control devices.

Multipole: Connects to more than 1 pole such as a 2-pole circuit breaker.

Multistage Thermostat: A thermostat which controls auxiliary equipment for heating or cooling in response to a greater demand for heating or cooling.

N

N.C: Normally closed contacts of a relay. Contacts are close circuited when the relay is de-energized.

N.O.: Normally open contacts of a relay. Contacts are open circuited when relay is de-energized.

Neutral: The circuit conductor that is normally grounded at zero voltage difference to the ground.

Nocturnal Radiation: Loss of energy by radiation to the night sky.

Noise: Any undesired sounds, usually of different frequencies, resulting in an objectionable or irritating sensation.

Noise Criteria Curves (NC Curve): Curves that define the limits which the octave band spectrum of a noise source must not exceed if a certain level of occupant acceptance is to be achieved.

Noise Reduction (NR): The difference between the average sound pressure levels of two spaces. Usually these two spaces are two adjacent rooms called, respectively, the source room and the receiving room.

Normally open (or Normally closed): The position of a valve, damper, relay contacts, or switch when external power or pressure is not being applied to the device. Valves and dampers are returned usually to a "normal" position by a spring.

0

Octave Band (O.B): A range of frequency where the highest frequency of the band is double the lowest frequency of the band. The band is usually specified by the center frequency.

Offset: Term used to describe the difference between the set point and the actual operating or control point.

Ohm (R) or (V): A measure of pure resistance of an electrical circuit.

Ohm's Law: The relationship between current and voltage in a circuit. It states that current is proportional to voltage and inversely proportional to resistance. Expressed algebraically, in DC circuits / = E/R; in AC, circuits / = E/Z. .

"On-off" Control: A two position action which allows operation at either maximum or minimum condition, or on or off, depending on the position of the controller.

Opaque: Not permitting transmission of radiant energy.

Open Circuit: The condition when either deliberately or accidentally, an electrical conductor or connection is broken or open with a switch.

Operating Point: The value of the controlled condition at which the controller actually operates. Also called control point.

Optimum Operative Temperature: Temperature that satisfies the greatest possible number of people at a given clothing and activity level.

Out Contacts: Those relay contacts which complete circuits when the relay coil is deenergized. Also referred to as "normally closed contacts".

Outgassing: The emission of gases by materials and components, usually during exposure to elevated temperature, or reduced pressure.

Outlet, Ceiling: A round, square, rectangular, or linear air diffuser located in the ceiling, which provides a horizontal distribution pattern of primary and secondary air over the occupied zone and induces low velocity secondary air motion through the occupied zone.

Outlet, Slotted: A long, narrow air distribution outlet, comprised of deflecting members, located in the ceiling sidewall, or sill, with an aspect ratio greater than 10, designed to distribute supply air in varying directions and planes, and arranged to promote mixing of primary air and secondary room air.

Outlet, Vaned: A register or grille equipped with vertical and / or horizontal adjustable vanes.

Outlet Velocity: The average velocity of air emerging from an opening, fan or outlet, measured in the plane of the opening.

Output: Capacity, duty, performance, net refrigeration produced by system.

Outside Air Opening: Any opening used as an entry for air from outdoors.

Overall Coefficient of Heat Transfer (thermal transmittance): The time rate of heat flow through a body per unit area, under steady conditions, for a unit temperature difference between the fluids on the two sides of the body.

Overcurrent Device: A device such as a fuse or a circuit breaker designed to protect a circuit against excessive current by opening the circuit.

Overload: A condition of excess current; more current flowing than the circuit was designed to carry.

Override: A manual or automatic action taken to bypass the normal operation of a device or system.

P

Package A/C unit: Consists of a factory-made assembly which normally includes an indoor conditioning coil, compressor(s), condensing coil, and may include a heating function as well.

Parallel Circuit: One where all the elements are connected across the voltage source. Therefore, the voltage on each element is the same but the current through each may be different.

Passive Solar System: An assembly of collectors, thermal storage device(s), and transfer media which converts solar energy into thermal energy and in which no energy in addition to solar is used to accomplish the transfer of thermal energy. The prime element in a passive solar system is usually some form of thermal capacitance.

Peak Demand: The greatest amount of kilowatts needed during a demand interval.

Peak Load pricing: A pricing principle that charges more for purchases that contribute to the peak demand and, thereby, cause the expansion of productive capacity when the peak demand exceeds the peak power capacity (less minimum excess capacity). In the electric power industry, this means charging more for electricity bought on or near the seasonal peak of the utility or on or near the daily peak of the utility. The latter requires special meters; the former does not.

Performance Factor: Ratio of the useful output capacity of a system to the input required to obtain it. Units of capacity and input need not be consistent.

Phase: Part of an AC voltage cycle. Residential electrical service is 2-phase; commercial facilities are usually 3-phase AC voltage.

Phon: A measurement of loudness level. The loudness level in phons of any sound is the sound pressure level of the 1000-Hz reference tone which is equally loud to the sound being rated. The loudness of 1 sone corresponds to a loudness level of 40 phons in accordance with the definition of the sone; a two fold change of loudness in sones is associated with a 10-phon change in loudness level.

Photovoltaic Conversion: Use of semiconductor or other photovoltaic devices that convert solar radiation directly to electricity.

Pilot Duty Relay: A relay used for switching loads such as another relay or solenoid valve coils. The pilot duty relay contacts are located in a second control circuit. Pilot duty relays are rated in volt-amperes (VA).

Pitch: The pitch of a sound depends primarily on its frequency. In music, sounds of higher frequencies are referred to as treble notes, while those of lower frequencies are referred to as bass notes.

Planting Screen: Bushes or other planting that hides a refrigerant compressor.

Plenum: An air compartment connected to one or more distributing ducts.

Plug-in-Bus Duct: Bus duct with built-in power tap-off points. Tap-off is made with a plug-in switch, circuit breaker, or other fitting.

Pneumatic: Operated by air pressure.

Pneumatic-Electric (PE) Switches: Device that operates an electric switch from a change of air pressure.

Point, Critical: Of a substance, state point at which liquid and vapour have identical properties; critical temperature, critical pressure and critical volume are the terms given to the temperature, pressure, and volume at the critical point. Above the critical temperature or pressure, there is no demarcation line between liquid and gaseous phases.

Point of Duty: A statement of air volume flow rate and static or total pressure at a stated density and is used to specify the point on the system curve at which a fan is to operate.

Point of Operation: Used to designate the single set fan performance values which correspond to the point of intersection of the system curve and the fan pressure-volume curve.

Point of rating: A statement of fan performance values which relate to one specific point on the fan pressure-volume curve.

Polarity: The direction of current flow in a DC circuit. By convention, current flows from plus to minus. Electron flow is actually in the opposite direction.

Pole: An electrical connection point. In a panel, the point of connection. On a device, the terminal that connects to the power.

Potable Water: Water that is safe to drink.

Potential Transformer: A voltage transformer. The voltage supplied to a primary coil induces a voltage in a secondary coil according to the ratio of the wire windings in each of the coils.

Potentiometer: An elecromechanical device having a terminal connected to each and to the resistive element, and a third terminal connected to the wiper contact. The electrical input is divided as the contact moves over the element, thus making it possible to mechanically change the resistance.

Power (P): Expressed in watts (W) or kilowatts (kW), and is equal to:

in DC circuit, P = EI and P = I2R in AC circuit, P = EI x Power factor

Power Factor (pf): A quantity that relates the volt-amperes of an AC circuit to the wattage (power = volt-amperes x power factor). Power factor is also is the ratio of the circuit resistance (R) to the impedance (Z) expressed as a decimal between zero and one (p.f. = R/Z). When the power factor equals one, all consumed power provides useful work.

Power Factor Charge: A utility charge for “poor” power factor. It is more expensive to provide power to a facility with a poor power factor (usually less than 0.8).

Power factor Correction: Installing capacitors on the utility service’s supply line to improve the power factor of a building.

Power Supply: The voltage and current source for an electrical circuit. A battery, a utility service, and a transformer are power supplies.

Predicting Method: Method of determining when load shedding should occur. A formula is used to arrive at a preset kilowatt limit. Then the actual amount of energy accumulated during the utility’s demand intervals is measured. A projection is made of the actual rate of energy usage during the rest of the interval. If the predicted value exceeds the present limit, loads will be shed.

Preheating: In air conditioning, to heat the air ahead of other processes.

Pressure: The normal force exerted by a homogeneous liquid or gas, per unit of area, on the wall of its container.

Pressure, Absolute: Pressure referred to that of a perfect vacuum. It is the sum of gauge pressure and atmospheric pressure.

Pressure, Atmospheric: It is the pressure indicated by a barometer. Standard atmosphere is the pressure equivalent to 14.696 psi or 29.921 in. of mercury at 32°F.

Pressure, Critical: Vapor pressure corresponding to the substance’s critical state at which the liquid and vapor have identical properties.

Pressure, Gauge: Pressure above atmospheric.

Pressure, Hydrostatic: The normal force per unit area that would be exerted by a moving fluid on an infinitesimally small body immersed in it if the body were carried along with the fluid.

Pressure, Partial: Portion of total gas pressure of a mixture attributable to one component.

Pressure, Static (SP): The normal force per unit area that would be exerted by a moving fluid on a small body immersed in it if the body were carried along with the fluid. Practically, it is the normal force per unit area at a small hole in a wall of the duct through which the fluid flows (piezometer) or on the surface of a stationary tube at a point where the disturbances, created by inserting the tube, are cancelled. It is supposed that the thermodynamic properties of a moving fluid depend on static pressure in exactly the same manner as those of the same fluid at rest depend upon its uniform, hydrostatic pressure.

Pressure, Total (TP): In the theory of flow of fluids, the sum of the static pressure and the velocity pressure at the point of measurement. Also called dynamic pressure.

Pressure, Vapour: The partial pressure exerted by the water vapour contained in air.

Pressure, Velocity (Vp): In moving fluid, the pressure capable of causing an equivalent velocity, if applied to move the same fluid through an orifice such that all pressure energy expended is converted into kinetic energy.

Pressure Drop: Pressure loss in fluid pressure, as from one end of a duct to the other, due to friction, dynamic losses, and changes in velocity pressure.

Pressure Regulator: Automatic valve between the evaporator outlet and compressor inlet that is responsive to pressure or temperature; it functions to throttle the vapor flow when necessary to prevent the evaporator pressure from falling below a preset level.

Primary Air: The initial airstream discharged by an air outlet (the air being supplied by a fan or supply duct) prior to any entrainment of the ambient air.

Primary Control: A device which directly or indirectly controls the control agent in response to needs indicated by the controller. Typically a motor, valve, relay, etc.

Primary Element: The portion of the controller which first uses energy derived from the controlled medium to produce a condition representing the value of the controlled variable; for example, a thermostat bimetal.

Primary Service: High voltage service, above 600 volts.

"Process" Hot Water: Hot water needed for manufacturing processes over and above the "domestic hot water" that is for the personal use of industrial workers.

Properties, Thermodynamic: Basic qualities used in defining the condition of a substance, such as temperature, pressure, volume, enthalpy, entropy.

Proportional Band: The range of values of a proportional positioning controller through which the controlled variable must pass to move the final control element through its full operating range. Commonly used equivalents are "throttling range" and "modulating range".

Proportional Control: See Modulating Control.

Psychrometer: An instrument for ascertaining the humidity or hygrometric state of the atmosphere.

Psychrometric Chart: A graphical representation of the thermodynamic properties of moist air.

Pull Box: A metal cabinet inserted into a conduit run for the purpose of providing a cable pulling point. Cable may be spliced in these boxes.

Pulsing Demand Meter: A meter which generates a pulse in correspondence with each revolution of kWh meter. Pulses are recorded on paper or magnetic tape. Pulse can also be the signal to demand control equipment.

Pure Tone: A pure tone sound that has a unique pitch and is characterized by a sinusoidal variation in sound pressure with time. The frequency spectrum of a pure tone shows a single line at a discrete frequency.

Pyranometer: A measurement device to determine local values of total (direct and diffuse) isolation.

Pyrometer: An instrument for measuring high temperatures.

Pyrheliometer: A measurement device to determine local values of direct insolation.

R

Raceway: Any support system, open or closed, for carrying electric waves.

Radiation (Acoustic): The process of turning structure-borne noise into airborne (or some other fluid-borne) noise.

Radiation, Thermal: The transmission of heat through space by wave motion; the passage of heat from one object to another without warming the space between.

Radius of Diffusion: The horizontal axial distance an airstream travels after leaving an air outlet before the maximum stream velocity is reduced to a specified terminal level; e.g. 200, 150 or 100 fpm.

Random Incidence: If an object is in a diffuse sound field, the sound is said to strike the object at random incidence.

Real Time: Time measured according to the time of day (1PM, 2 PM, etc.). Different from the “electronic time” of a cycling device.

Receiver: An auxiliary storage receptacle for refrigerant when the system is pumped down and shut down.

Reflected Isolation: The portion of the total solar energy reaching a surface (windows, wall, collector) which has been reflected by an adjoining surface.

Reflectivity: The property of a material that determines its ability to reflect radiant energy.

Refrigerant: The fluid used for heat transfer in a refrigerating system, which absorbs heat at a low temperature and a low pressure of the fluid and rejects heat at a higher temperature and a higher pressure of the fluid, usually involving changes of state of the fluid.

Regenerated Noise: Duct noise, which is generated by air turbulence in the duct or fittings.

Register: A grille equipped with an integral damper or control valve.

Relative Humidity (RH): The ratio of water vapor in the air as compared to the maximum amount of water vapor that may be contained.

Relay: An electomechanical switch that opens or closes contacts in response to some controlled action. Relay contacts can be normally open (N.O.) and/or normally closed (N.C.). Relays may be electric, pneumatic, or a combination of both. PE and EP switches are relays.

Relay, Thermal: A switching relay in which a small heater warms a bimetal element which bends to provide the switching force.

Remote Temperature Set Point: Ability to set a temperature control point for a space from outside the space. Often used in public areas.

Reset: A process of automatically adjusting the control point of a given controller to compensate for changes in outdoor temperature. The hot deck control point is normally reset upward as the outdoor temperature drops. The cold deck control point is normally reset downward as the outdoor temperature increases.

Reset Controllers: Two controllers operating together; one sensing a condition other than that of the controlled space and changing the set point of the second controller, which is directly responsible for the result in the controlled space. The resetting controller is commonly called the master, and the controller being reset is commonly called the submaster (slave).

Reset Ratio: The ratio of change in outdoor temperature to the change in control point temperature. For example, a 2:1 reset ratio means that the control point will increase 1 degree for every 2 degrees change in outdoor temperature.

Resistance (w): The opposition which limits the amount of current that can be produced by an applied voltage in an electrical circuit, measured in ohms.

Resistance, Thermal: The reciprocal of thermal conductance.

Return Air: Air returned from conditioned or refrigerated space.

Reverberant Sound Field: A space in which sound persists because of continuous reflections. A reverberant field is not necessarily diffuse.

Reverberation: The persistence of sound in an enclosed space after the sound source has stopped. In a reverberation room, it is characterized by the decay or dying away of the sound.

Reverberation Room: A highly sound reflective room in which special care has been taken to make the sound field as diffuse as possible.

Reverberation Time: The reverberation time of an enclosed space is the number of seconds required, or that would be required were the decay rate to remain constant, for the sound pressure level to decrease by 60 seconds.

Riser Diagram: Electrical block-type diagram showing connection of major items of equipment. It is also applied to signal equipment connections. Also generally applied to multi-storey buildings for vertical hydronic piping and duct work.

Riser Shaft: A vertical shaft designed to house electric cables, piping and ductwork.

Room Criteria Curves (RC Curves): Curves similar to NC curves that represent a close approximation to a well balanced, bland-sounding spectrum.

Room Dry Bulb: The actual temperature of the conditioned room or space as measured with an accurate thermometer.

Room Effect: The difference between the sound power level discharged by a duct (through a diffuser or other termination device) and the sound pressure level heard by an occupant of a room is called the Room Effect. The magnitude of the Room Effect depends upon the amount of sound absorption in the room (unit of sound abrorption, Sabins), the distance between the termination of the duct and the nearest observer and the ratio of directivity factor of the duct, to the nearest observer, to the directivity factor of the source.

S

Sabin: The unit of acoustic absorption. One sabin is one square foot of perfect sound-absorbing material.

Saturation Degree of: The ratio of the weight of water vapor associated with a pound of dry air to the weight of water vapor associated with a pound of dry air saturated at the same temperature.

Seasonal Energy Efficiency Ratio (SEER): The total quantity of heat delivered or removed by heating or cooling equipment in Btu divided by the total electrical energy input in kilowatt hours over an entire season.

Seasonal Performance Factor: The ratio of the total quantity of heat delivered by a heat pump, (including supplement resistance heaters) to the total quantity of energy input (including supplementary resistance heaters) for the total annual heating hours below 69°F.

Secondary Air: The air surrounding an outlet that is captured or entrained by the initial outlet discharge airstream (furnished by a supply duct or fan).

Secondary Service: Voltage service up to 600 volts.

Seismic: Subject to or caused by an earthquake.

Semi-Extended Plenum: A trunk duct that is extended as a plenum from a fan or HVAC unit to serve multiple outlets and/or branch ducts.

Sensible Heat: Sensible heat is any heat transfer that causes a change in temperature. Heating and cooling of air and water that may be measured with a thermometer is sensible heat. Heating or cooling coils that simply increase or decrease the air temperature without a change in moisture content are examples of sensible heat.

Sensible Heat Factor: The ratio of sensible heat to total heat.

Sensible Heat Ratio, Air cooler: The ratio of sensible cooling effect to total cooling effect of an air cooler.

Sensing Device: A device that keeps track of the measured condition and its fluctuations so that when sufficient variation occurs it will originate the signal to revise the operation of the system and offset the change. Example: a thermostat “bulb”. A sensing device may be an integral part of a controller.

Sensing Element: The first system element or group of elements. The sensing element performs the initial measurement operation.

Sensitivity: The ability of a control instrument to measure and act upon variations of the measure condition.

Sensor: A sensing element.

Sequencer: A mechanical or electrical device that may be set to initiate a series of events and to make the events follow in sequence.

Sequencing Control: A control which energizes successive stages of heating or cooling equipment as its sensor detects the need for increased heating or cooling capacity. May be electronic or electromechanical.

Series Circuit: One with all the elements connected end to end. The current is the same throughout but the voltage can be different across each element.

Service Drop: The overhead service wires that serve a building.

Service Switch: One to six disconnecting switches or circuit breakers. Purpose is to completely disconnect the building from the electric service.

Set Point: The value of the controlled condition at which the instrument is set to operate. The set point in the example in “differential” might be 69 1/2°, the mid-point of the differential.

Shading Loss: The loss of collector efficiency caused by the shading of the absorber plate by collector edges or components. The shading loss usually varies with the angle of incidence of the isolation.

Shall or Will: Where shall or will is used as a provision specified, that provision is mandatory if compliance with the standard is claimed.

Shed: To de-energize a load in order to maintain a kW demand set point.

Shed Mode: A method of demand control that reduces kW demand through shedding and restoring loads.

Shielded Cable: Special cable used with equipment that generates a low voltage output. Used to minimize the effects of frequency “noise” on the output signal.

Short Circuit: An electric circuit with zero load; an electrical fault.

Short Cycling: Unit runs and then stops at short intervals; generally this excessive cycling rate is hard on the system equipment.

Should or It is Recommended: Term used to indicate provisions which are desirable as good practice.

Single-phasing: The condition when one phase of a multiphase (polyphase) motor circuit is broken or opened. Motors running when this occurs may continue to run but with lower power output and overheating.

Solar Altitude: The angular elevation of the sun above the horizon.

Solar Azimuth: Angle between true south and projection of earth-sun line on a horizontal plane.

Solar Collector: Any device which collects solar energy and transforms it to another usable form of energy.

Solar Energy: The photon energy originating from the sun's radiation in the wavelength region from 0.3 to 2.4 micrometers; the radiation energy of the sun, whether it be direct diffuse, or reflected radiation.

Solar Time: The time of day based on the relative position of the sun with respect to a position on the earth's surface. Solar noon is that instant on any day at which the sun reaches its maximum altitude for that day.

Solenoid Air Valves: EP switches with an electromagnetic coil in the valve topworks that opens or closes the valve from normal position. A spring returns the valve to the normal position when the coil is de-energized.

Sone: One sone is defined as the loudness of a 1000 Hz tone having a sound pressure of 40 dB. Two sones is twice as loud as the 40 dB reference sound of one sone, etc.

Sorbent: See absorbent.

Sound Absorption: (1) The process of dissipating or removing sound energy. (2) The property possessed by materials, objects, and structures, such as rooms, of absorbing sound energy. (3) The measure of the magnitude of the absorptive property of a material, an object, or a structure, such as a room.

Sound Attenuator: A device or equipment that prevents, reduces or absorbs sound.

Sound Power Level of a Source (Lw): The ratio, expressed in decibels, of its sound power to the reference sound power which, by divided agreement, is either 10∼13 or 10∼12 watts. The reference power should always be stated.

Sound Power of a Source (W): The rate at which sound energy is radiated by the source. Without qualification, overall sound power is meant but often sound power in a specific frequency band is indicated.

Sound Pressure (p): An alternating pressure superimposed on the static or barometric pressure by sound. In analogy to alternating voltage, it can be measured or expressed in several ways, such as maximum sound pressure or instantaneous sound pressure. Unless such a qualifying word is used, it is the effective or root-mean-square pressure which is meant.

Sound Pressure Level (Lp): The squared ratio, expressed in decibels, of the sound pressure under consideration to the reference pressure which, by agreement, is 0.0002 dynes per square centimetre. The reference pressure should be stated if it is not implied.

This concept is more properly, but more cumbersomely, called "effective-sound-pressure-squared level", since effective pressures are implied and it is pressure-squared which is proportional to power to energy.

Sound Transmission Class: The preferred single figure rating designed to give a preliminary estimate of the sound insulation properties of a partition. A standard contour which defines transmission loss as a function of frequency is fitted to the transmission loss curve according to the rules outlined in ASTM E413-73, "Standard Classification For Determination of Sound Transmission Class".

Sound Transmission Coefficient: The sound transmission coefficient of a partition is the fraction of the incident sound power transmitted through it when the sound fields on both sides of the partition are diffuse.

Sound Transmission Loss of a Partition (TL):

The ratio, expressed in decibels, of the incident sound power on the source side of the specimen to the transmitted sound power on the receiving side when the sound fields on both sides of the specimen are diffuse. When the sound fields are not diffuse, a qualifying word is necessary, such as normal incidence sound transmission loss, or field transmission loss.

Specific Heat: Specific heat (Cp) is the amount of heat energy in Btu's required to raise the temperature of one pound of substance by one degree Fahrenheit. The following are specific heat values at standard conditions:

water - Cp = 1.00 Btu/lb/°F air-Cp = 0.24 Btu/lb/°F

Using these values in simple equations, gallons per minute or cubic feet per minute may be determined in a system if the Btu per hour and the temperature difference are known.

Specific Volume: The reciprocal of density and is used to determine the cubic feet of volume, if the pounds of weight are known. Both density and specific volume are affected by temperature and pressure. The specific volume of air under standard condition is 13.33 cubic feet per pound and the specific volume of water at standard conditions is 0.016 feet per pound.

Spread: The divergence of the airstream in a horizontal or vertical plane after it leaves the outlet.

Stage Differential: Change in temperature at the thermostat needed to turn heating or cooling equipment off once it is turned on.

Staging Interval: The minimum time period for shedding or restoring two sequential loads.

Stagnant Air Area: An area within a space where the air velocity is less than 25 fpm.

Standard Air Density (d): Standard air density has been set at 0.075 lb/cu.ft. This corresponds approximately to dry air at 70°F and 29.92 in. Hg in metric units, the standard air density is 1.2041kg3/m at 20°C and at 101.325 kPa.

Standard Conditions: The standard conditions referred to in environmental system work for air are: dry air at 70°F, and at an atmospheric pressure of 29.92 inches mercury (in.Hg.). For water, standard conditions are 68°F at the same barometric pressure. At these standard conditions, the density of air is 0.075 pounds per cubic feet and the density of water is 62.4 pounds per cubic foot.

Standard Rating: An interpolated assessment based on tests performed at Standard Rating Conditions.

Starter: Basic contactor with motor overloads, etc., added - a motor starter is an adaption of the basic contactor which includes overload relays. Starters for large motors may include reactors, step resistors, disconnects, or other features required in a more sophisticated starter package.

State: Refers to the form of a fluid, either liquid, gas or solid. Liquids used in environmental systems are water, thermal fluids such as ethylene glycol solutions, and refrigerants in the liquid state. Gases are steam, evaporated refrigerants and the air-water vapour mixture found in the atmosphere. Some substances, including commonly used refrigerants, may exist in any of three states. A simple example is water, which may be solid (ice), liquid (water), or gas (steam or water vapour).

Static Head: The pressure due to the weight of a fluid above the point of measurement.

Static Regain Method: A method of duct sizing wherein the duct velocities are systematically reduced, allowing a portion of the velocity pressure to convert to static pressure offsetting the duct friction losses.

Static Suction Head: The positive vertical height in feet from the pump centreline to the top of the level of the liquid source.

Static Suction Lift: The distance in feet between the pump centreline and the source of liquid below the pump centreline.

Step Controller: See Sequencer.

Stratified Air: Unmixed air in a duct that is in thermal layers that have temperature variations of more than five degrees.

Structure-Borne Noise: A condition when the sound waves are being carried by a solid material. Sound waves in this state are inaudible to the human ear, since they cannot carry energy to it. Airborne noise can be created from the radiation of structure-borne noise into air. Structure-borne noise may be propagated by shear waves, tension-compression waves, bending waves, or complicated combination of waves.

Subcooling: The difference between the temperature of a pure condensable fluid below saturation and the temperature at the liquid saturated state, at the same pressure.

Sublimation: A change of state directly from solid to gas without appearance of liquid.

Suction Head: The positive pressure on the pump inlet when the source of liquid supply is above the pump centreline.

Suction Lift: The combination of static suction lift and friction head in the suction piping when the source of liquid is below the pump centreline.

Suction Piping: The piping which returns gaseous refrigerant to the compressor. Sizes must be large enough to maintain minimum friction to prevent reduced compressor and system capacity but must be small enough to produce adequate velocity to return oil to the compressor.

Sun Effect: Solar energy transmitted into space through windows and building materials.

Sun Rights (Solar Rights): A legal question concerning the rights to non-interrupted use of the sun's radiant energy, such as shading of solar collectors by a neighbors' building.

Superheat: The difference between the temperature of a pure condensable fluid above saturation and the temperature at the dry saturated state, at the same pressure.

Superheat, Specific: The difference between specific enthalpies of a pure condensable fluid between vapor at a given temperature above saturation and vapor at dry saturation, at the same pressure.

Surface, Heating: The exterior surface of a heating unit. Extended heating surface (or extended surface); consisting of fins, pins, or ribs which receive heat by

conduction from the prime surface. Prime surface: heating surface having the heating medium on one side and air (or extended surface) on the other.

Surge Suppressor: A device that reduces harmonic distortion in line voltage circuits by clipping off transient voltages which are fed through the power lines from operating equipment.

Switching Relays: Relays are devices which operate by a variation in the conditions of one electrical circuit to affect the operation of devices in the same or another circuit. General purpose switching relays are used to increase switching capability and isolate electrical circuit, such as in a system where the heating and cooling equipment have separate power supplies, and provide electrical interlocks within the system.

System: A series of ducts, conduits, elbows, branch piping, etc. designed to guide the flow of air, gas or vapor to and from one or more locations. A fan provides the necessary energy to overcome the resistance to flow of the system and causes air or gas flow through the system. Some components of a typical system are louvers, grilles, diffusers, filters, heating and cooling coils, air pollution control devices, burner assemblies, volume flow control dampers, mixing boxes, sound attenuators, the ductwork and related fittings.

System, Central Fan: A mechanical, indirect system of heating, ventilating, or air-conditioning, in which the air is treated or handled by equipment located outside the rooms served, usually at a central location, and conveyed to and from the rooms by means of a fan and a system of distributing ducts.

System Closed: A heating or refrigerating piping system in which circulating water or brine is completely enclosed, under pressure above atmospheric, and shut off from the atmosphere except for an expansion tank.

System, Duct: A series of ducts, conduits, elbows, branch piping, etc. designed to guide the flow of air, gas or vapor to and from one or more locations. A fan provides the necessary energy to overcome the resistance to flow of the system and causes air or gas flow through the system. Some components of a typical system are louvers, grilles, diffusers, filters, heating and cooling coils, energy recovery devices, burner assemblies, volume dampers, mixing boxes, sound attenuators, the ductwork and related fittings.

System Flooded: A system in which only part of the refrigerant passing over the heat transfer surface is evaporated, and the portion not evaporated is separated from the vapor and recirculated.

System, Gravity Circulation: A heating or refrigerating system in which the heating or cooling fluid circulation is effected by the motive head due to difference in densities of cooler and warmer fluids in the two sides of the system.

System, Run-around: A regenerative-type, closed, secondary system in which a continuously circulated fluid abstracts heat from the primary system fluid at one place, returning this heat to the primary system fluid at another place.

System, Unitary: A complete, factory-assembled and factory-tested refrigerating system comprising one or more assemblies which may be shipped as one unit or separately but which are designed to be used together.

System Curve: A graphic presentation of the pressure vs. volume flow rate characteristics of a particular system.

System Effect Factor: A pressure loss factor which recognizes the effect of fan inlet restrictions, fan outlet restrictions, or other conditions influencing fan performance when installed in the system.

T

Temperature, Absolute Zero: The zero point on the absolute temperature scale, 459.69 degrees below the zero of the Fahrenheit scale, 273.16 degrees below the zero of the Celsius scale.

Temperature, Critical: The saturation temperature corresponding to the critical state of the substance at which the properties of the liquid and vapor are identical.

Temperature, Dewpoint: The temperature at which the condensation of water vapor in space begins for a given state of humidity and pressure as the temperature of the vapor is reduced. The temperature corresponding to saturation (100 percent relative humidity) for a given absolute humidity at constant pressure.

Temperature, Dry bulb: The temperature of a gas or mixture of gases indicated by an accurate thermometer after correction for radiation.

Temperature, Effective: An arbitrary index which combines into a single value the effect of temperature, humidity, and air movement on the sensation of warmth or cold felt by the human body. The numerical value is that of the temperature of still, saturated air which would induce an identical sensation.

Temperature, Mean Radiant (MRT) : The temperature of a uniform black enclosure is which a solid body or occupant would exchange the same amount of radiant heat as in the existing non-uniform environment.

Temperature, Saturation: The temperature at which no further moisture can be added to the air-water vapor mixture. Equals dew point temperature.

Temperature, Wet-bulb: Thermodynamic wet bulb temperature is the temperature at which liquid or solid water, by evaporating into air, can bring the air to saturation adiabatically at the same temperature. Wet bulb temperature (without qualification) is the temperature indicated by a wet bulb psychrometer constructed and used according to specifications.

Temperature, Wet Bulb Depression: Difference between dry bulb and wet bulb temperatures.

Temperature Difference, Mean: Mean of difference between temperatures of a fluid receiving and a fluid yielding heat.

Terminal Velocity: The maximum airstream velocity at the end of the throw.

Therm: Measurement used by gas utilities for billing purposes. 1 Therm = 100 cubic feet of gas = 100,000 Btu.

Thermal Capacity: The ability of a medium to hold heat.

Thermal Expansion Valve: The metering device or flow control which regulates the amount of liquid refrigerant which is allowed to enter the evaporator.

Thermistor: Semiconductor material that responds to temperature changes by changing its resistance.

Thermocouple: Device for measuring temperature utilizing the fact that an electromotive force is generated whenever two junctions of two dissimilar metals in an electric circuit are at different temperature levels.

Thermodynamics, Laws of: Two laws upon which rest the classical theory of thermodynamics. These law have been stated in many different, but equivalent ways.

The First Law: (1) When work is expanded in generating heat, the quantity of heat produced is proportional to the work expended; and, conversely, when heat is employed in the performance of work, the quantity of heat which disappears is proportional to the work done (Joule); (2) If a system is caused to change from an initial state to a final state by adiabatic means only, the work done is the same for all adiabatic -paths connecting the two states (Zemansky); (3) In any power cycle or refrigeration cycle, the net heat absorbed by the working substance is exactly equal to the net work done.

The Second Law: (1) It is impossible for a self-acting machine, unaided by any external agency, to convey heat from a body of lower temperature to one of higher temperature (Clausius); (2) It is impossible to derive mechanical work from heat taken from a body unless there is available a body of lower temperature into which the residue not so used may be discharged (Kelvin); (3) It is impossible to construct an engine that, operating in a cycle, will produce no effect other than the extraction of heat from a reservoir and the performance of an equivalent amount of work (Zemansky).

Thermodynamic Wet Bulb Temperature: The temperature at which water, by evaporating into air, can bring the air to saturation adiabatically at the same temperature. The wet bulb temperature measured with an appropriate psychrometer can approach the thermodynamic wet bulb temperature (also called the Adiabatic Saturation Temperature).

Thermostat: An instrument which responds to changes in temperature and which directly or indirectly controls temperature.

Thermosyphon: Circulation of a fluid by making use of the change in density of a material when it is heated and cooled. Also called Natural Circulation.

Throttling Range: The amount of change in the variable being controlled to make the controlled device move through the full length of its stroke.

Throw: The horizontal or vertical axial distance an airstream travels after leaving an air outlet before the maximum stream velocity is reduced to a specified terminal level; e.g., 200, 150, 100 or 50 fpm.

Ton (of Refrigeration): A useful refrigerating effect equal to 12,000 Btuh; 200 Btu/miin.

Total Dynamic Head: Dynamic discharge head (static discharge head, plus friction head, plus velocity head) plus dynamic suction lift, or dynamic discharge head minus dynamic suction head.

Total Heat (Enthalpy): Total heat is the sum of the sensible heat and latent heat in an exchange process. In many cases, the addition or subtraction of latent and sensible heat at terminal coils appears simultaneously. Total heat is also called enthalpy, both of which can be defined as the quantity of heat energy contained in that substance.

Total Pressure Method: A method of duct sizing which allows the designer to determine all friction and dynamic losses in each section of a duct system (including the total system).

Toxic Fluids: Gases or liquids which are poisonous, irritating and/or suffocating.

Tracking Collector: A solar energy collector that constantly positions itself perpendicular to the sun as the earth rotates.

Transducer: The means by which the controller converts the signal from the sensing device into the means necessary to have the appropriate effect on the controlled device. For example, a change in air pressure in the pneumatic transmission piping.

Transformer: The system power supply - a transformer is an inductive stationary device which transfers electrical energy from one circuit to another. The transformer has two windings, primary and secondary. A changing voltage applied to one of these, usually the primary, induces a current to flow in the other winding. A coupling transformer transfers energy at the same voltage, a step-down transformer transfers energy at a lower voltage, and a step-up transformer transfers energy at a higher voltage.

Transmission: The means by which a signal is moved from one point of origin to the point of action.

Transmission, Coefficient of Heat: Any one of a number of coefficients used in the calculation of heat transmission by conduction, convection, and radiation, through various materials and structures.

Transmittance, Thermal (U-factor): The time rate of heat flow per unit area under steady conditions from the fluid on the warm side of a barrier to the fluid on the cold side, per unit temperature difference between the two fluids.

U

Utility Service: The utility company. Also, the amount and configuration of voltage supplied by a utility company. There are four main types of commercial utility services: 208V AC wye, 480 V AC wye, 240 V AC delta, and 480 V AC delta.

Utility Transformer: Primary and secondary coils of wire which reduce (step down) the utility supply voltage for use within a facility.

Unitary System: A room unit which performs part or all of the air - conditioning functions. It may or may not be used with a central fan system.

Unloader: A device on or in a compressor for equalizing the high and low side pressures for a brief period during starting, in order to decrease the starting load on the motor; also a device for controlling compressor capacity by rendering one or more cylinders ineffective.

V

Vacuum: Any pressure less than that exerted by the atmosphere.

Vacuum, Breaker: A device to prevent a suction in a water pipe.

Valve, Modulating: A valve which can be positioned anywhere between fully on and fully off to proportion the rate of flow in response to a modulating controller (see modulating control).

Valve, Two-Position: A valve which is either fully on or fully off with no position between. Also called an “on-off valve”.

Vane Ratio: In air distributing devices, the ratio of depth of vane to shortest opening width between two adjacent grille bars.

Vapor: A gas, particularly one near to equilibrium with the liquid phase of the substance and which does not follow the gas laws. Usually used instead of gas for a refrigerant, and, in general, for any gas below the critical temperature.

Vapor, Saturated: Vapor in equilibrium with its liquid; i.e. when the numbers per unit time of molecules passing in two directions through the surface dividing the two phases are equal.

Vapor, Superheated: Vapor at a temperature which is higher than the saturation temperature (i.e. boiling point) at the existing pressure.

Vapor, Water: Used commonly in air-conditioning parlance to refer to steam in the atmosphere.

Vapor Barrier: A moisture-impervious layer applied to the surfaces enclosing a humid space to prevent moisture travel to a point where it may condense due to lower temperature.

Vapor Pressure: Vapor Pressure denotes the lowest absolute pressure at which a given liquid at a given temperature will remain liquid before evaporating into its gaseous form or state.

Velocity: A vector quantity which denotes, at once, the time rate and the direction of a linear motion.

Velocity Head: The pressure needed to accelerate the fluid being pumped.

Velocity Reduction Method: A method of duct sizing where arbitrary reductions are made in velocity after each branch or outlet.

Velocity, Outlet: The average discharge velocity of primary air being discharged from the outlet, normally measured in the plane of the opening.

Velocity, Room: The average sustained, residual air velocity level in the occupied zone of the conditioned space; e.g., 65, 50, 35fpm.

Velocity, Terminal: The highest sustained airstream velocity existing in the mixed air path at the end of the throw.

Ventilation: The process of supplying or removing air, by natural or mechanical means, to or from any space. Such air may or may not have been conditioned.

Vernal Equinox: The position of the sun midway between its lowest and highest altitude; during the spring it occurs on March 21. The sunlit period is approximately the same length as the autumnal equinox.

(see also AUTUMNAL EQUINOX)

Viscosity: That property of semifluids, fluids, and gases by the virtue of which they resist an instantaneous change of shape or arrangement of parts. It is the cause of fluid friction whenever adjacent layers of fluid move with relation to each other.

Volatility: Volatility surface tension and capillary action of a fluid are incidental to environmental systems. Volatility is the rapidity with which liquids evaporate extremely rapidly and therefore is highly volatile.

Voltage (E) : The electromotive force in an electrical circuit. The difference in potential between two unlike charges in an electrical circuit is its voltage measured in Volts: (V).

Voltage Drop: The voltage drop around a circuit including wiring and loads must equal the supply voltage.

Volume: Cubic feet per pound of dry air in the air-water vapor mixture as used in psychrometrics.

Volume, Specific: The volume of a substance per unit mass; the reciprocal of density.

W

Water Hammer: Banging of pipes caused by the shock of closing valves (faucets).

Watt (W): A measure of electric power equal to a current flow of one ampere under one volt of pressure; or one joule per second in SI units.

Watt Transducer: A device which converts a current signal into a proportional millivolt signal. Used to interface between current transformers and a load management panel.

Wavelength: The distance between two similar and successive points on an alternating wave. The wavelength is equal to the velocity of the propagation divided by the frequency of the alternations.

Weight: The amount of force a substance exerts under pull by the earth's gravitational field and that force is measured in pounds in United States.

Wet Bulb Temperature (WB): The temperature registered by a thermometer whose bulb is covered by a saturated wick and exposed to a current of rapidly moving air. The wet bulb temperature also represents the dew point temperature of the air, where the moisture of the air condenses on a cold surface.

Wet Bulb Depression: Difference between dry bulb and wet bulb temperatures.

Winter Solstice: The shortest sunlit day of the year at which the sun is at the lowest altitude; it occurs on December 21.

Wye Service: An arrangement of the utility transformers. Abbreviated: Y.

Z

Zoning: The practice of dividing a building into small sections for heating and cooling control. Each section is selected so that one thermostat can be used to determine its requirement.

SECTION 15

ABOUT ISHRAE

The Indian Society of Heating, Refrigerating and Air-Conditioning Engineers (ISHRAE), was founded in 1981 at New Delhi by a group of eminent HVAC&R professionals. ISHRAE today has more than 10,000 HVAC&R professionals and 3,000 students as members with 40 chapters and sub-chapters across India.

ISHRAE's primary objective is the advancement of the art and sciences of Heating, Ventilation, Air-Conditioning, Refrigeration Engineering & other related Building Services. ISHRAE engages in a broad spectrum of activities to attain its objectives.

ISHRAE conducts conferences, seminars, workshops and catalogue shows throughout the country with both national and international participation on the latest in terms of technologies, systems and services.

ISHRAE organizes ACREX, the largest international exposition in South Asia on the air - conditioning, refrigeration, ventilation and building service industry. Held annually, ACREX is considered to be a major platform to display the latest technologies and innovations and to also find buyers for existing products and services.

ISHRAE publications strive to help its members keep up to date with the happenings, learn new techniques, improve old designs and adopt the use of new devices to improve indoor air quality in our buildings. The ISHRAE standards, the guide books, the fundamentals booklets, the HVAC, refrigeration and ventilation handbooks and the ISHRAE journal are a few such initiatives.

ISHARE promotes research in the field of products or techniques/technology aimed at specific end use. It envisages active user involvement and association in the development effort.

ISHRAE Institute of Excellence (IIE), the education arm of the Society, is working towards human resource development in the HVAC&R industry in the country through its classroom and distance learning programs.

ISHRAE students chapters in more than 150 engineering colleges is promoting careers in the HVAC&R industry amongst the students through seminars, quizzes, plant and site visits.

The K-12 initiative of ISHRAE is focused on school students, in making them aware of the energy conservation and environmental concerns through sit and draw competition, poster design, quizzes and planting of trees.

ISHRAE is also working in close co-operation with other similar bodies, both national and international, and government agencies for the promotion and development of green and net zero energy buildings in the country.

ISHRAE has recently embarked on a program, called the Integrated Approach towards Product Delivery (IAPD), to ensure that all the stakeholders in the building industry can meet their respective roles and deliver systems that meet the requirement and expectation of the end users.

ISHRAE is committed towards building a safe environment for the future.

ISHRAE CHAPTERS / SUB CHAPTERS, NAME & MAIL ID'S

CHAPTER	Mail ID'
DELHI Chapter	sinfo@dcishrae.org
MEERUT Sub-Chapter	meerut@ishraehq.in
AGRA Sub-Chapter	agra@ishraehq.in
LUCKNOW Sub-Chapter	lucknow@ishraehq.in
DEHRADUN Sub-Chapter	dehradun@ishraehq.in
CHANDIGARH Chapter	ccishrae@gmail.com
LUDHIANA Sub-Chapter	ishraeldh@gmail.com
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RAIPUR Sub-Chapter	ishraeraipur@yahoo.in
AHMEDABAD Chapter	ishraeahd@gmail.com
SURAT Chapter Vapi Sub-Chapter	ishraesurat@gmail.com & ishrae.vapi@gmail.com
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KOCHI Chapter	ishrae.cochin@gmail.com
TRIVANDRUM Sub-Chapter	ishraetvm@gmail.com
CHENNAI Chapter	ishraechennai@yahoo.com
KALPAKKAM Sub-Chapter	kalpakkam@ishraehq.in
MADURAI Sub-chapter	madurai@ishraehq.in
DECCAN Chapter	ishraehc@gmail.com
VIJAYWADA Sub-Chapter	ishraevjasub@gmail.com
VISAKHAPATNAM Chapter	ishraevizag@gmail.com

ISHRAE INSTITUTE OF EXCELLENCE

ISHRAE INSTITUTE OF EXCELLENCE (IIE) is the educational arm of ISHRAE. Its main objective is to impart education in the field of air-conditioning, refrigeration, heating and ventilation for the benefit of ISHRAE members as well as industry professionals. At present IIE is functioning from Delhi, Bangalore, Chennai, Hyderabad, Mumbai and Ahmedabad. During the last seven years many ISHRAE members, professionals and young engineering students have been benefited by the IIE.

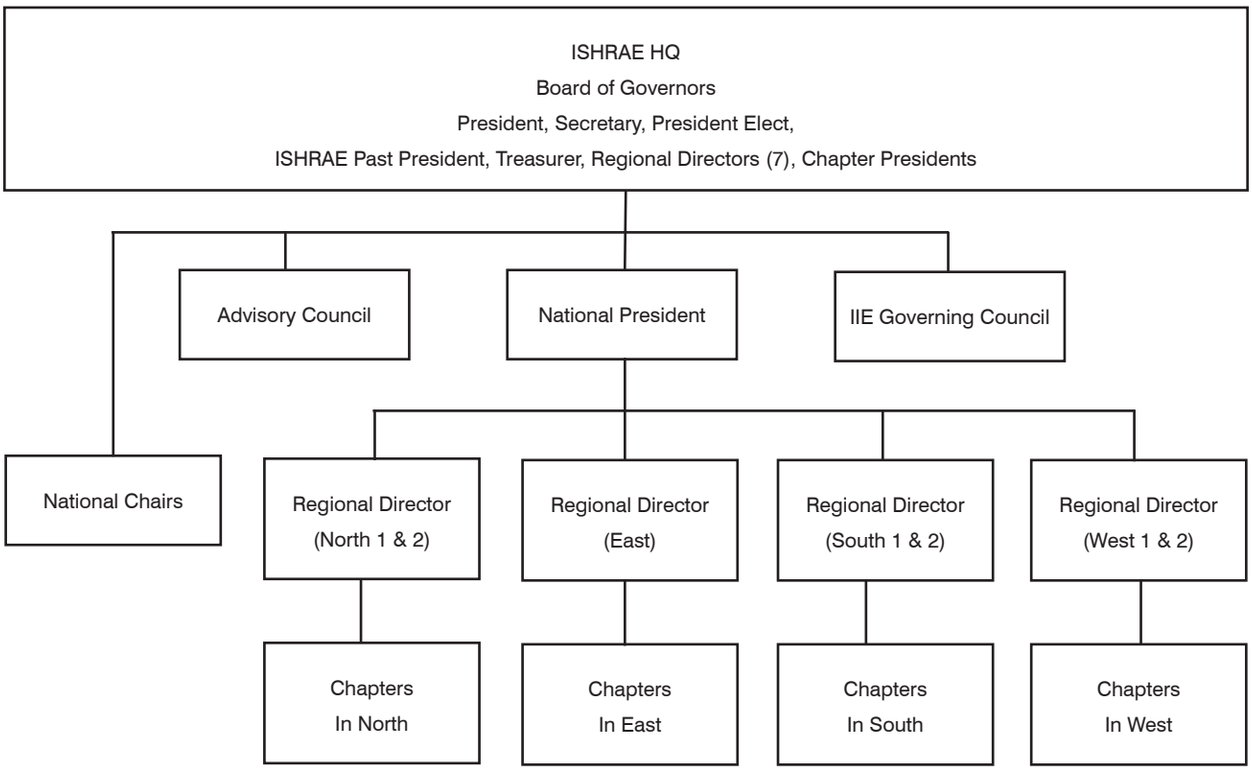
LARGEST EXHIBITIONS OF ASIA FOR HVAC & R INDUSTRIES



MAJOR EVENTS OF ISHRAE

- ACRECONF
- ACR TRENDZ
- ACRESERVE
- ACRETECH
- CONFLUENCE
- EEHVAC&R
- REFCONF
- RACON
- SYMPOSIA
- TECHFEST
- URJAVARAN
- VENTCONF

ISHRAE Organization Structure



Present National Chairs are for Membership Promotion, Student Activities, Programs, K-12 & Advocacy.

ISHRAE's Affiliation with other Organizations

National

S. No	Society/Organization
1	RAMA
2	IGBC
3	AIACRA
4	I PA
5	FSAI
6	Emerson e-Learning
7	Danfoss e-Learning

International

S. No	Society/Organization
1	ASHRAE
2	REHVA
3	AHRI
4	AMCA
5	EUROVENT
6	CAR
7	IFMA

ASHRAE Affiliation : ISHRAE is an international associate of ASHRAE. This association provides several key benefits to ISHRAE and its members.

- ISHRAE Members can purchase ASHRAE Publications at 33% discount as applicable to ASHRAE members.
- ISHRAE has easy access to ASHRAE Technical Papers.
- ISHRAE Library will receive all ASHRAE Journals & Transactions.
- ISHRAE members can apply for ASHRAE membership without reference requirement.

Why Join ISHRAE?

- A premiere technical society exclusively for the HVAC & R community.
- A well - organized and professionally run technical society.
- The best platform to learn about the latest in technological developments. Membership for individuals only. No corporate membership. Easy access to all ISHRAE Technical Publications.
- Excellent opportunities to interact with other professionals, industry leaders and key decision makers in the industry.
- International exposure through ASHRAE association.
- An excellent forum for professional development and continuous training & re-training.

SECTION - 16

ANNEXURE - CLTD CALCULATOR

SOURCE : ISHRAE

PROCEDURE TO USE CLTD PROGRAMME

1. Copy the XL Sheet to a directory or Folder as desired.
2. Double click on XL Sheet.
3. The XL Sheet will open, click “Enable Content”.
4. Go to Worksheet.

DATA ENTERING:

1. **PROJECT DATA :** in the spaces **ENTER**
Date :
Sheet No :
Of (Total Sheets of a project)
Client Name :
Job No : (If any)
Drg No : (For reference)
Computed by :
Checked by :
Approved by :

2. **DESIGN CONDITIONS:**

OUTDOOR CONDITIONS:

SELECT Season for Calculation from Dropdown List in Top RHS Corner.
Based on Season double click the DB field.
“Climate Conditions” sheet will pop – up.
Based on City and % double click on DBT field.
The cell will automatically shift to WBT field. Double click and then click the Return Button next to ISHRAE ICON.
All properties will then get transferred to Main Sheet.
Use different sheet for each Season.

INDOOR CONDITIONS:

Double click the appropriate field for DBT in Indoor Condition.
The Psychometric Calculation will pop up.
Enter Elevation manually.
Enter DBT manually.
Enter RH manually & click.
The properties will be automatically calculated.
Click Return Button next to ISHRAE LOGO to return to Main Sheet.

3. **DIMENSIONAL DETAILS,CONDUCTION, AREAS, U FACTORS ETC.:**

ENTER the Hour for Heat Load Calculation (3 Choices) of hrs. you want to calculate loads for.

ENTER manually “u” factors & Areas for Roofs & each orientation for walls. Enter Area of wall without deducting Glass Area.

ENTER Glass Conduction Areas, for each orientation. [Other than in walls above]

For Conduction, CLTD values double click to go to appropriate Table.
Select & Double click from the required construction or the nearest u&Wt Values.

For Latitude / Month Correction, select field & double click.

Select Appropriate Latitude &Month & double click.

If exact Latitudes are not available, choose the nearest lower value.

ENTER u & Areas for Partitions, Ceiling, Roof & Floors.
Choose Colour Correction Factor from Drop down List. Light / Medium / Dark.
Double Click on Field for “Inside Temp Correction”, Select correction Factor and
Double click field for “Outside Temp Adjustment”, select based on Design Outdor & Daily Range. Double click.

4. SOLAR

ENTER Areas in appropriate orientation & shaded / unshaded the Areas.
For Shading Coefficients, double click cell & select from the various charts available.

Max SHG Factors : Double click on cell, and select the appropriate orientation & Latitude.

5. SHADING MULTIPLIERS

Use only with external Shading Devices. Double click cell to go to appropriate chart.
Select from Horizontal (Left Chart) or Vertical projection (Right Chart), go to correct Latitude , Month, Time & Orientation.
Note Value, then from 1st table select the Shading Coefficient Multipliers, based on value in Chart & double click.
If there are no external shades enter value as "1".

6. INTERNAL LOADS

Lights / People / Equipment / Misc : ENTER values for type of lights [Not necessary]
Total Hours of usage
Starting Time
Ballast Factor
& Wattage / No of People
The appropriate column will be highlighted
For CLF double click & select.

7. OTHER LOADS

ENTER value of Infiltration Air and ΔT between Indoor & Outdoor at that hour.
ENTER perimeter of Room in Ft.
If lights are in false Ceiling Enter, fraction to Area above F.C.
ENTER Ventilation Air & ΔT at the appropriate Hour.

8. LATENT LOADS

Latent Load Factor can be selected by double clicking & choosing appropriate value.

ENTER manually other cells
ENTER % of Return Duct Heat Gain
ENTER % of Safety for both Sensible Loads & Latent Loads
ENTER % of Supply Duct Leakage
ENTER % of Heat Gain
ENTER % of Latent Duct leakage Loss.
ENTER % of Supply Air Temperature

9. WINTER CALCULATIONS

ENTER Value of Ventilation / Infiltration
ENTER Supply Factor Safety %
Pickup Factor : use default Value as " 1" if Heat pick up factors are not known.

ENTER Supply CFM to work out Latent Loads for Winter.

10. PRINTING & SAVING

Press Ctrl P for Printing, and use settings as per Printer / Paper size.
For saving follow the standard procedure, for saving in WINDOWS.

Table 16.1.1 : Climate conditions for Cities in Deg. C.

City or STN Name	Longi-tude	Lati-tude	Eleva-tion	Cooling DB/MCWB of						Cooling WB/ MCDB of						Heating DB / MCWB of			
				0.40%		1.00%		2.00%		0.40%		1%		2%		99.60%		99%	
				DB	MCWB	DB	MCWB	DB	MCWB	WB	MCDB	WB	MCDB	WB	MCDB	DB	MCWB	DB	MCWB
Ahmedabad	72° 37'	23° 4'	55	42.00	20.82	41.20	22.88	40.20	23.31	28.80	33.90	28.20	33.50	27.70	31.30	11.40	9.15	12.50	9.76
Akola	77° 1'	20° 42'	282	42.90	22.97	42.00	22.25	41.00	22.80	27.30	34.87	26.50	37.68	25.70	35.52	12.90	9.30	14.10	11.04
Allahabad	81° 43'	25° 27'	98	43.20	24.09	42.20	24.61	41.00	22.95	30.50	33.76	29.60	33.10	29.00	33.29	8.30	5.35	9.70	8.70
Amritsar	74° 52'	31° 37'	234	41.80	23.95	40.50	27.92	39.20	21.97	30.30	34.02	29.60	33.30	29.00	33.59	4.30	3.07	5.40	4.06
Aurangabad	75° 24'	19° 51'	579	40.40	25.94	39.00	22.47	38.00	23.11	26.60	31.95	26.00	33.83	25.60	31.32	10.20	8.85	11.40	9.12
Barmer	71° 22'	25° 45'	194	43.00	23.90	41.90	22.89	40.80	24.42	28.90	35.98	28.00	35.07	27.20	32.58	9.50	7.77	10.50	6.29
Belgaum	74° 37'	15° 51'	747	37.00	18.97	36.30	18.94	35.20	20.77	24.40	28.43	23.80	27.42	23.30	26.76	12.40	11.01	14.00	12.58
Bangalore	77° 34'	12° 58'	921	34.70	21.14	33.90	20.43	32.90	20.70	24.00	29.30	23.40	29.31	22.90	27.30	15.00	14.45	15.70	14.90
Bhagalpur	86° 56'	25° 13'	49	40.00	29.19	38.60	26.56	37.40	26.89	30.60	35.60	29.80	36.29	29.30	34.68	11.70	10.46	12.50	11.39
Bhopal-Bairagarh	77° 20'	23° 16'	523	41.90	26.54	40.90	24.07	39.40	22.23	27.20	40.76	26.30	32.34	25.70	32.36	9.80	6.17	10.80	8.48
Bhubaneshwar	85° 49'	20° 15'	46	38.60	28.81	37.50	28.46	36.60	28.32	29.70	35.52	29.30	35.40	28.90	34.05	13.70	12.45	14.90	13.51
Bhuj	69° 40'	23° 15'	80	40.70	21.62	39.50	22.79	38.30	25.69	29.00	36.11	28.50	35.84	28.00	34.33	9.90	7.06	10.90	9.49
Bikaner	73° 18'	28° 0'	224	44.60	22.23	43.10	21.60	41.80	23.45	28.60	34.18	28.20	33.89	27.80	32.98	4.20	3.45	6.00	3.96
Chennai-Minambakkam	80° 10'	13° 0'	16	39.80	26.92	37.90	24.70	36.60	25.67	29.00	33.12	28.60	33.12	28.00	32.83	20.40	19.68	21.00	20.07
Chitradurga	76° 25'	14° 13'	733	36.30	20.42	35.60	20.48	34.80	21.15	24.60	33.88	24.10	26.71	23.70	28.21	16.20	13.55	17.00	14.40
Dehradun	78° 1'	30° 19'	682	36.40	18.96	35.50	20.18	34.40	23.13	27.00	30.46	26.60	29.21	26.20	30.35	6.00	5.20	6.80	5.90
Dibrugarh	95° 1'	27° 28'	111	34.30	27.47	33.40	27.34	32.40	26.88	28.30	33.30	27.80	32.58	27.40	31.24	8.00	7.53	9.30	8.82
Gorakhpur	83° 22'	26° 45'	77	39.70	24.60	38.70	26.34	37.40	25.63	29.70	33.08	29.20	32.82	28.90	32.21	8.50	7.25	10.20	8.76
Guwahati	91° 34'	26° 6'	54	34.60	26.05	33.40	26.68	32.50	27.47	28.60	31.34	27.90	31.87	27.60	31.30	9.50	9.00	11.20	10.91
Gwalior	78° 15'	26° 13'	207	43.60	23.36	42.10	22.66	40.90	24.27	27.80	35.82	27.40	33.85	26.90	32.84	4.90	3.42	5.90	4.51
Hissar	75° 43'	29° 10'	221	44.60	25.64	43.60	23.70	42.60	23.29	30.10	34.06	29.60	34.30	29.10	33.74	6.70	6.64	7.90	7.28
Hyderabad-AP	78° 28'	17° 27'	545	39.40	22.18	38.10	22.64	37.30	22.49	25.60	33.86	25.10	31.13	24.60	30.44	13.80	11.58	15.10	13.01
Imphal	93° 54'	24° 46'	781	31.20	23.68	30.40	23.86	29.80	23.20	25.00	29.51	24.70	29.20	24.30	28.59	3.20	2.78	4.30	3.82
Indore	75° 48'	22° 43'	567	40.20	21.26	39.50	20.14	38.50	18.63	25.30	31.44	25.00	29.94	24.60	29.95	9.50	7.60	10.40	7.76
Jabalpur	79° 56'	23° 12'	393	40.70	22.22	39.80	22.24	38.60	22.23	26.70	34.46	26.40	33.32	26.00	31.70	8.70	8.14	9.70	8.15
Jagdalpur	82° 1'	19° 4'	553	38.60	21.63	37.80	23.65	36.40	21.63	26.00	32.86	25.50	32.15	25.20	30.59	8.40	7.57	9.90	8.57
Jaipur-Sanganer	75° 48'	26° 49'	390	42.00	21.70	41.20	22.39	40.20	22.54	27.70	31.98	27.20	32.93	26.70	31.90	7.40	4.60	8.60	5.83
Jaisalmer	70° 55'	26° 53'	231	43.50	23.36	42.50	25.04	41.30	24.86	29.30	36.78	28.40	37.53	27.90	37.12	9.00	2.23	10.50	5.20
Jamnagar	70° 1'	22° 28'	20	36.50	24.54	35.80	25.36	35.00	24.59	27.70	32.17	27.30	32.97	27.00	32.46	9.20	7.61	10.60	9.35
Jodhpur	73° 1'	26° 17'	224	42.70	20.58	41.50	22.39	40.40	22.66	28.20	34.07	27.40	33.43	26.80	31.94	10.20	7.18	11.10	8.20
Jorhat	94° 10'	26° 43'	90	34.40	28.20	33.70	27.62	32.80	27.49	28.60	33.30	28.10	32.49	27.80	32.28	9.20	8.60	10.00	9.43
Kodaikanal	77° 47'	10° 23'	2343	22.00	13.80	21.30	15.94	20.80	14.22	18.00	20.50	17.50	19.77	17.00	19.33	7.10	4.74	8.00	6.07
Kolkata-Dum Dum	88° 26'	22° 38'	6	37.50	30.75	36.60	27.57	35.80	26.97	30.90	36.77	30.00	34.78	29.30	33.62	12.10	10.52	13.20	11.80
Kota	75° 50'	25° 8'	274	43.60	24.53	42.60	22.16	41.30	23.19	27.40	33.22	27.10	34.92	26.50	33.89	10.00	6.96	11.00	7.52

Table 16. 1.1 : Climate conditions for Cities in Deg. C. (Contd.)

City or STN Name	Longi-tude	Lati-tude	Eleva-tion	Cooling DB/MCWB of						Cooling WB/ MCDB of						Heating DB / MCWB of			
				0.40%		1.00%		2.00%		0.40%		1%		2%		99.60%		99%	
				DB	MCWB	DB	MCWB	DB	MCWB	WB	MCDB	WB	MCDB	WB	MCDB	DB	MCWB	DB	MCWB
Kurnool	78° 4'	15° 48'	281	41.70	22.28	40.80	23.08	39.70	23.17	25.90	33.81	25.50	32.66	25.20	32.96	16.90	15.87	17.80	16.09
Lucknow-Amausi	80° 52'	26° 45'	128	41.30	21.53	40.00	22.92	38.90	21.98	29.90	33.46	29.20	32.55	28.70	32.84	7.00	6.23	8.90	7.70
Mangalore	74° 31'	12° 31'	22	34.60	24.11	34.20	23.16	33.70	23.00	26.80	31.22	26.50	31.88	26.20	31.17	20.10	17.98	20.90	19.23
Mumbai-SantaCruz	72° 50'	19° 7'	14	35.10	23.28	34.20	22.62	33.50	23.06	27.90	31.45	27.60	30.62	27.30	30.79	15.40	13.52	16.70	14.51
Nagpur-Sonegaon	79° 3'	21° 6'	310	42.90	24.55	42.00	26.11	41.00	24.42	27.90	38.05	26.90	32.00	26.40	31.61	11.80	9.58	13.20	11.18
Nellore	79° 58'	14° 26'	20	40.30	26.88	39.10	26.95	37.70	26.12	28.90	35.31	28.40	35.99	27.90	33.21	19.90	18.53	20.50	18.37
New Delhi-Safdarjun	77° 11	28° 34'	216	42.10	21.55	40.80	22.54	39.30	23.76	28.90	33.43	28.30	31.65	27.90	31.70	6.10	5.41	7.10	6.48
Panjim	73° 49'	15° 28'	60	34.20	21.71	33.60	25.09	33.20	25.30	27.90	32.27	27.60	31.00	27.30	30.51	19.50	17.86	20.10	18.39
Patna	85° 10'	25° 16'	53	41.00	22.39	40.10	22.97	38.70	23.54	28.80	32.27	28.50	31.81	28.20	31.52	8.20	7.65	9.10	8.03
Port Blair	92° 72'	11° 67'	79	32.50	26.71	32.10	25.88	31.40	25.69	26.90	30.51	26.60	30.02	26.40	29.91	21.90	20.21	22.70	20.97
Pune	73° 50'	18° 31'	559	38.20	21.98	37.20	19.19	36.40	19.12	25.20	30.88	24.80	29.99	24.40	29.57	9.00	8.12	10.10	9.21
Raipur	81° 39'	21° 13'	298	43.20	22.96	42.00	22.59	40.90	23.37	27.00	31.24	26.70	30.83	26.40	30.55	10.60	8.64	12.00	9.11
Rajkot	70° 46'	22° 17'	138	41.40	21.88	40.50	19.08	39.50	19.85	27.70	31.70	27.30	31.35	26.90	30.73	11.90	7.22	13.60	8.18
Ramagundam	79° 25	18° 46'	156	43.40	26.40	42.30	27.08	40.90	25.47	28.20	37.51	27.60	34.57	27.10	35.10	12.90	11.90	14.10	12.67
Ranchi	85° 19'	23° 22'	655	39.00	21.64	37.20	21.15	36.00	21.80	25.70	30.31	25.20	30.36	24.90	29.14	9.00	7.54	10.30	8.95
Ratnagiri	73° 19'	16° 58'	67	33.80	22.17	33.20	21.00	32.50	22.67	27.30	30.12	27.00	30.06	26.60	29.74	17.70	14.11	19.30	17.12
Raxaul	84° 31'	26° 34'	1350	36.50	26.37	35.50	26.03	34.40	25.67	28.70	31.72	28.30	32.82	28.00	32.24	7.30	7.09	8.30	7.90
Saharanpur	77° 52'	29° 51'	274	38.70	23.59	37.40	23.62	36.60	23.74	28.20	32.75	27.90	32.51	27.50	32.64	1.40	1.12	2.50	2.03
Shillong	91° 52'	25° 34'	1500	24.80	19.44	23.60	19.67	22.70	18.37	20.60	23.22	20.10	22.57	19.80	22.15	0.30	0.29	0.60	0.59
Sholapur	75° 54'	17° 40'	479	40.80	24.33	39.60	23.46	38.50	22.99	26.90	33.80	26.40	30.10	25.90	31.79	15.40	10.93	16.40	12.04
Srinagar	74° 83'	34° 08'	1587	32.40	20.77	31.50	21.47	30.30	20.38	23.60	29.80	22.90	28.51	22.20	27.89	-2.00	-2.51	-1.10	-1.91
Surat	72° 49'	21° 12'	12	38.10	25.15	36.60	23.72	35.20	23.68	27.90	31.94	27.60	31.10	27.40	30.88	15.40	12.40	16.40	13.01
Tezpur	92° 46'	26° 37'	79	34.10	28.19	33.20	26.99	32.50	28.19	29.20	32.66	28.60	32.23	28.10	31.41	10.90	10.44	11.70	11.24
Thiruvanan-thapuram	76° 56'	8° 28'	64	33.20	27.42	32.70	26.24	32.30	25.64	27.70	31.53	27.30	31.22	27.00	30.90	22.80	22.05	23.20	22.32
Tiruchirappalli	78° 43'	10° 46'	88	38.40	25.84	37.90	26.54	37.00	25.04	27.60	33.36	27.20	31.48	27.00	35.13	20.00	18.78	20.60	19.68
Varanasi	82° 52'	25° 27'	85	41.90	25.73	40.70	20.53	39.20	20.62	30.30	34.26	29.60	34.69	29.00	33.31	6.30	4.90	8.80	7.29
Veraval	70° 22'	20° 53'	8	34.90	21.41	33.60	25.10	32.80	26.14	29.20	31.65	28.80	31.62	28.40	30.95	15.90	10.08	17.00	11.60
Visakhapatnam	83° 13'	17° 43'	3	36.00	27.46	35.40	25.97	34.80	26.76	28.90	33.19	28.50	32.53	28.30	32.77	15.40	14.14	17.30	16.23

Source : ISHRAE WEATHER DATA in Deg. F also.

Table 16.1.2 : Monthly Mean, Maximum and Range - DB °F

Month			JAN	FEB	MAR	APR	MAY	JUN	JULY	AUG	SEP	OCT	NOV	DEC
Ahmedabad		Mean	68.9	73.38	81.96	89.42	92.94	90.78	85.04	82.83	85.24	82.54	76.80	70.03
LatN	23.07	Max.	92.84	97.21	105.6	109.8	113.1	109.7	96.51	92.19	98.60	97.7	92.17	89.79
Alt Ft.	180	Range	59.36	60.26	59.01	57.88	56.48	49.96	44.20	42.89	47.31	52.70	59.46	57.52
Allahabad		Mean	57.2	66.07	75.86	87.58	92.19	92.46	84.99	84.72	83.22	78.29	70.50	61.97
LatN	25.45	Max.	73.86	88.52	100.4	109.20	112.40	113.1	98.99	96.72	96.72	95.46	91.11	82.94
Alt Ft.	322	Range	52.16	57.38	60.85	62.69	58.31	51.45	44.31	44.27	44.85	53.76	58.60	56.17
Amritsar		Mean	52.95	56.40	64.7	76.24	86.52	89.45	85.98	84.27	82.47	73.2	62.69	54.24
LatN	31.38	Max.	66.05	69.38	77.81	91.02	101.4	101.8	93.43	91.74	91.97	89.11	79.48	69.13
Alt Ft.	768	Range	57.38	57.81	57.95	62.81	63.77	57.7	47.51	47.1	50.77	61.48	62.27	59.48
Akola		Mean	72.50	76.9	84.45	91.79	94.74	86.86	81.39	79.59	82.32	79.95	75.36	70.64
LatN	20.7	Max.	86.0	90.98	98.09	104.4	106.9	96.9	88.08	85.62	91.63	92.04	88.35	83.78
Alt Ft.	925	Range	58.82	60.36	60.20	58.22	56.69	51.11	44.61	43.14	49.2	55.85	57.97	58.20
Aurangabad		Mean	70.34	74.01	81.93	88.37	89.47	81.69	77.43	76.08	78.0	76.87	72.77	68.50
LatN	19.88	Max.	90.15	93.43	100.8	107.8	107.5	100.6	91.6	87.96	92.64	93.25	89.88	87.49
Alt Ft.	1906	Range	60.98	61.07	59.46	59.03	57.43	50.3	45.37	44.29	48.5	54.15	58.20	60.58
Bhagalpur		Mean	64.76	68.99	79.39	87	88.21	87.02	85.20	85.65	84.9	81.82	75.05	66.77
LatN	25.23	Max.	84.68	89.96	103.4	108.9	110.1	105.7	100.6	97.84	98.11	95.3	92.66	84.56
Alt Ft.	161	Range	53.6	55.20	57.63	57.23	54.91	46.67	43.82	43.3	45.06	47.71	53.13	53.13
Bikaner		Mean	57.74	64.02	76.87	87.45	94.76	95.43	90.78	89.24	88.43	81.44	70.16	59.3
LatN	28	Max.	84.79	89.11	100.1	109.3	115.1	114.4	108.3	104.9	104.1	102.8	96.94	88.34
Alt Ft.	73.5	Range	62.60	62.79	61.79	60.87	59.18	53.79	49.13	49.46	52.37	61.5	64.34	63.05
Bangalore		Mean	69.44	74.13	79.07	81.68	80.06	75.2	73.74	72.87	741.7	73.22	71.38	68.95
LatN	12.97	Max.	85.65	90.32	94.8	97.1	96.27	90.33	87.72	85.71	86.34	84.75	84.16	82.7
Alt Ft.	3022	Range	52.7	54.59	54.14	53.27	52.1	47.22	45.91	44.70	46.43	45.46	47.13	48.43
Belgaum		Mean	71.65	74.26	78.78	80.87	80.11	75.03	72.8	72,12	73.49	74.58	73.02	70.08
LatN	15.51	Max.	85.26	89.4	93.92	95.77	93.7	82.25	77.75	77.34	81.89	84.72	83.78	81.77
Alt Ft.	2470	Range	58.19	61.61	61.25	58.58	55.43	44.2	40.38	40.53	46.29	50.95	52.91	54.14
Bhopal		Mean	64.76	69.06	78.04	87.53	92.17	86.32	79.73	77.55	79.30	78.04	71.63	65.84
LatN	23.28	Max.	86.90	91.04	97.93	106.1	108.8	102.6	94.28	88.88	93.61	93.43	88.34	84.43
Alt Ft.	1716	Range	56.48	57.56	57.38	58.35	56.93	48	43.7	42.5	46.81	53.9	55.67	55.61
Bhubaneshwar		Mean	71.60	76.5	82.29	85.89	87.18	85.37	82.47	82.63	82.56	80.2	75.84	70.98
LatN	20.25	Max.	89.94	94.76	103.5	105.8	104.5	103.8	95.72	94.17	97.05	92.31	90.75	89.78
Alt Ft.	151	Range	54.32	53.54	53.52	52.05	49.65	46.27	42.60	42.26	43.68	46.68	50.79	54.30
Barmer		Mean	63.68	69.51	80.83	89.69	94.08	93.25	88.37	85.78	87.62	85.82	75.95	66.47
LatN	25.75	Max.	86.36	93.14	101.8	109.9	111.80	110.70	106.3	101.30	103.8	103.8	92.80	85.58
Alt Ft.	636	Range	56.66	57.52	56.01	55.9	56.58	53.78	48.65	46.92	50.57	53.42	55.7	55.70
Chennai		Mean	75.92	78.42	82.38	86.18	88.88	88.32	86.45	85.1	84.61	81.98	78.13	76.92
LatN	13	Max.	90.30	91.86	97.30	101.8	105.1	102.5	99.86	98.61	97.71	95.79	87.89	87.31
Alt Ft.	52	Range	46.86	48.29	48.45	48.05	48.30	48.03	47.22	46.92	46.74	44.27	41.68	43.82
Chitradurga		Mean	73.11	78.09	82.92	84.47	82.79	77.09	74.89	73.7	75.61	76.10	73.4	71.0
LatN	14.14	Max.	83.66	89.18	94.19	95.95	93.97	84.59	81.44	80.02	83.58	84.20	81.51	79.97
Alt Ft.	2405	Range	52.55	54.06	55.13	54.53	53.06	45.35	43.19	42.56	46.20	47.94	48.63	49.69
Dibrugarh		Mean	57.38	62.81	68.75	72.51	77.73	81.62	80.52	81.89	79.64	75.48	67.35	60.44
LatN	27.48	Max.	73.59	82.76	86.27	89.69	93.41	95.68	94.06	95.68	93.79	89.96	84.61	78.04
Alt Ft.	364	Range	53.24	51.60	48.38	46.13	46	43.88	42	42.99	42.47	46.56	53.36	56.69
Dehradun		Mean	52.34	57.74	66.57	75.66	80.76	83.39	79.80	78.72	76.72	69.78	62.49	55.95
LatN	30.32	Max.	70.10	77.05	87.74	96.47	101.5	103.3	94.69	92.44	89.56	83.21	80.74	79.01
Alt Ft.	2238	Range	50.72	53.97	55.45	57.57	56.8	52.46	44.65	43.57	46.74	49.73	54.60	54.78
Gorakhpur		Mean	.59.0	65.84	74.44	84.81	88.57	87.9	84.57	84.77	83.3	78.85	69.78	61.77
LatN	26.76	Max.	81.41	87.89	98.42	106.4	108.20	102.9	100.6	97.3	97.64	95.54	93.05	84.02
Alt Ft.	256	Range	55.85	57.20	60.24	62.06	57.79	48.29	43.03	44.20	55.58	53.43	59.20	57.30
Guwahati		Mean	61.70	65.80	71.97	76.94	80.15	82.85	82.81	83.19	81.82	78.15	71.43	63.75
LatN	26.1	Max.	76.31	81.93	92.48	97.59	94.92	95.21	93.63	96.8	93.41	94.10	85.35	78.94
Alt Ft.	177	Range	50.54	54.84	53.43	50.34	46.45	42.9	41.36	42.47	42.45	44.69	49.38	52.82
Gwalior		Mean	58.46	65.15	75.05	86.55	93.65	92.64	87.08	84.99	84.56	78.42	68.25	57.77
LatN	26.23	Max.	82.49	89.09	99.8	109.9	113	109.4	102.2	98.81	101.5	98.99	92.30	78.58
Alt Ft.	679	Range	60.62	59.61	61.98	64.05	59.66	50.16	45.75	44.36	48.3	59.99	62.58	56.35

SOURCE : WEDCO, ISHRAE

Table 16.1.2 : Monthly Mean, Maximum and Range - DB °F (Contd...)

Month			JAN	FEB	MAR	APR	MAY	JUN	JULY	AUG	SEP	OCT	NOV	DEC
Hissar		Mean	55.58	61.1	72.44	82.43	3.43	91.47	87.47	86.48	84.72	77.12	66.84	58.37
LatN	29.17	Max.	75.45	86.5	96.65	108.4	115	108.4	105.7	103.3	101.8	100.1	92.73	80.88
Alt Ft.	725	Range	58.10	60.36	60.44	61.73	62.09	51.18	48.23	47.42	50.73	60.64	62.40	57.79
Hyderabad		Mean	1.6°C	77.61	83.87	89.06	90.95	83.46	79.7	78.11	79.91	78.81	74.62	71.22
LatN	17.45	Max.	1.6°C	93.63	100.6	104.1	106.3	101.7	92.4	90.14	91.68	91.22	87.85	84.27
Alt Ft.	1788	Range	1.6°C	54.55	54.48	54.14	52.7	48.18	44.16	43.21	45.55	49.10	49.56	51.44
Imphal		Mean	54.32	58.47	66.11	70.46	73.99	76.74	77.05	77.34	75.38	71.92	62.87	55.49
LatN	24.77	Max.	75.48	79.12	84.74	86.75	92.51	89.56	90.1	88.88	88.3	88.19	82.94	76.42
Alt Ft.	2562	Range	60.26	58.98	56.58	50.79	48.79	43.53	42.63	43.7	45.03	50.95	56.39	59.43
Indore		Mean	64.76	68.68	78.22	85.96	90.33	85.01	78.85	76.26	77.88	76.74	70.68	65.19
LatN	22.72	Max.	88.41	92.73	101.1	106.6	109.1	105.8	93.25	89.20	94.38	94.53	89.99	85.87
Alt Ft.	1860	Range	61.52	62.06	62.96	61.64	58.83	52.17	44.67	42.27	48.68	57	60	60.31
Jabalapur		Mean	63.50	68.88	77.05	84.05	92.21	87.99	80.58	79.26	80.52	77.36	69.62	62.29
LatN	23.2	Max.	82.34	91.22	99.68	101.3	110.5	105.6	94.37	88.61	93.7	93.09	88.44	82.83
Alt Ft.	1289	Range	55.40	58.37	59.64	55.88	57.03	47.6	43.03	40.38	44.63	52.8	57.11	56.93
Jagdalpur		Mean	67.1	72.08	79.08	85.51	85.60	80.54	76.94	76.87	77.61	74.91	70.21	36.34
LatN	19.08	Max.	87.40	93.30	86	103.4	103.8	100.2	89.63	88.26	90.17	88.48	87.15	36
Alt Ft.	1814	Range	61.7	62.49	60.26	59.52	56.58	47.67	42.13	42.18	45.05	50.30	55.59	59.28
Jaipur		Mean	60.26	65.04	74.75	86.52	92.17	,92.15	86.14	83.67	84.25	60.61	71.61	61.23
LatN	26.82	Max.	80.74	86.28	97.80	107.8	111.0	110.0	101.7	98.25	100.2	98.70	88.7	83.12
Alt Ft.	1280	Range	57.02	56.54	57.30	58.78	57.03	' 53.22	46.65	46.27	50.16	56.82	55.70	56.78
Jaisalmer		Mean	59.54	65.60	76.24	87.76	98.21	91.72	88.12	86.48	83.34	84.30	73.88	62.88
Lat N	26.9	Max.	84.56	90.68	98.78	109.1	111.6	107.4	106.5	104.0	102.7	102.0	96.5	85.64
Aft Ft.	794	Range	49.42	52.7	52.12	47.39	45.20	44.69	43.21	43.7	43.84	45.05	53.25	49.60
Kolkata		Mean	63.14	73.59	79.91	84.66	85.51	86.36	83.24	84.38	83.22	80.34	75.86	68.73
Lat N	22.65	Max.	75.74	90.73	100.0	101.3	101.1	102.3	95.23	94.94	94.94	93.32	90.01	64.57
Alt Ft.	20	Range	47.57	53.24	52.46	49.47	50.01	45.32	41.84	41.84	42.56	46.00	48.68	62.16
Kota		Mean	62.42	66.77	77.87	89.42	95.78	93.77	85.74	42.31	64.39	82.29	70.92	65.22
LatN	25.15	Max.	81.77	90.50	100.2	108.6	112.1	111.3	99.91	95.03	97.34	89.45	89.65	31.53
Alt Ft.	899	Range	51.82	52.79	65.38	55.16	53.43	50.13	44.34	41.81	46.00	51.72	53.47	53.38
Kurnool		Mean	75.74	80.36	87.65	90.77	91.95	85.89	81.66	80.96	82.02	81.23	77.34	74.46
LatN	15.5	Max.	87.98	94.40	98.98	103.8	103.2	95.14	89.48	88.21	89.67	90.23	86.68	84.66
Alt Ft.	922	Range	56.33	58.20	56.56	55.68	54.05	49.69	46.50	45.50	48.56	49.49	50.84	52.64
Lucknow		Mean	55.76	63.53	73.27	84.16	89.06	89.87	85.19	84.25	82.25	76.58	67.74	60.58
LatN	26.87	Max.	67.56	87.92	96.13	106.9	110.20	110.5	104.8	96.20	96.13	92.71	86.72	85.59
Alt Ft.	364	Range	47.03	59.28	61.05	61.70	58.22	52.82	43.91	43.73	45.42	53.00	56.48	53.47
Mangalore		Mean	79.12	80.18	82.38	84.48	84.83	78.18	78.24	77.66	78.21	80.13	80.29	79.50
LatN	12.52	Max.	90.93	90.59	91.65	92.39	92.28	84.36	82.86	82.32	85.42	87.60	89.69	90.32
Alt Ft.	72	Range	53.29	50.90	48.92	47.24	42.15	41.81	40.65	40.24	42.85	45.66	49.02	51.92
Mumbai		Mean		76.46	80.06	83.80	86.18	84.16	82.37	80.33	87.68	82.58	80.83	76.92
LatN	18.9	Max	94.1	95.88	98.42	100.4	87.08	93.54	88.32	87.38	91.09	96.78	95.30	94.20
Alt Ft.	36	Range	25.02	53.58	50.59	46.56	42.33	40.74	38.78	38.73	41.32	47.93	52.52	54.26
Nagpur		Mean	69.62	74.57	83.06	91.49	95.10	88.14	81.08	80.08	81.48	78.11	71.83	68.03
LatN	21.1	Max.	90.05	96.33	104.3	110.3	112.5	104.9	94.53	92.35	95.34	94.58	87.63	87.65
Alt Ft.	1017	Range	57.79	59.72	60.27	60.31	57.34	47.28	43.73	43.17	43.85	54.42	54.06	57.57
Nellore		Mean	76.46	79.79	83.49	87.42	90.77	89.70	86.45	85.76	85.69	83.55	78.69	76.19
LatN	14.45	Max.	80.20	96.20	102.8	107.4	107.5	103.5	100.7	98.38	96.63	96.36	89.85	86.32
Alt Ft.	66	Range	48.36	50.73	51.65	52.21	51.44	48.43	46.68	45.64	45.96	45.03	43.05	44.81
New Delhi		Mean	57.02	61.79	71.78	82.81	89.36	91.92	98.08	85.73	84.75	77.59	67.06	58.40
LatN	28.58	Max.	79.53	82.74	93.39	105.2	108.2	110.3	102.0	99.12	96.79	96.06	69.18	78.99
Alt Ft.	709	Range	64.22	65.93	65.80	63.46	57.09	45.96	41.10	41.10	46.61	54.75	59.75	62.31
Raipur		Mean	68.54	74.55	81.78	90.14	94.01	86.95	80.96	80.70	81.78	78.08	73.22	67.67
LatN	21.23	Max.	87.83	93.77	103.0	108.5	112.8	109.4	94.64	92.21	93.77	93.11	89.78	85.33
Alt Ft.	978	Range	56.84	57.59	57.34	59.19	56.82	49.38	43.03	42.27	44.65	50.14	54.17	56.03

SOURCE : WEDCO, ISHRAE

Table 16.1.2 : Monthly Mean, Maximum and Range - DB °F (Contd...)

Month			JAN	FEB	MAR	APR	MAY	JUN	JULY	AUG	SEP	OCT	NOV	DEC
Rajkot		Mean	68.18	71.81	79.77	85.67	89.25	87.82	83.55	81.24	82.50	63.96	78.60	70.82
LatN	22.3	Max.	90.37	95.12	101.2	107.8	108.8	104.8	96.56	94.04	99.08	101.2	96.38	90.69
Alt Ft.	453	Range	59.36	59.25	60.38	50.17	58.26	50.10	44.47	43.54	49.37	55.68	67.21	57.65
Ramagundam		Mean	72.69	77.48	84.29	90.95	94.49	87.90	82.50	81.5	83.04	80.25	75.63	70.93
LatN	18.77	Max.	91.32	97.23	104.4	110.8	112.5	108.8	97.64	94.08	95.84	94.82	91.70	87.8
Alt Ft.	512	Range	57.74	58.92	56.04	58.15	56.12	48.65	44.42	43.23	46.77	51.98	34.31	37.63
Ranchi		Mean	60.98	85.96	75.23	83.40	85.82	82.05	78.35	77.41	77.39	74.13	68.23	62.06
LatN	23.38	Max.	75.54	84.74	95.43	102.05	104.0	100.5	90.21	87.90	88.57	86.72	92.94	78.33
Alt Ft.	2149	Range	49.22	53.49	55.32	55.72	54.33	47.57	41.59	40.91	43.58	48.00	50.20	53.04
Ratnagiri		Mean	77.36	77.43	78.94	82.41	84.57	81.10	79.62	78.65	79.39	80.73	80.79	78.33
LatN	16.98	Max.	95.46	94.85	90.60	98.20	82.48	90.85	85.71	84.74	47.96	95.54	94.71	93.12
Alt Ft.	220	Range	83.24	51.89	47.22	44.04	42.13	40.85	38.53	38.42	41.10	47.29	50.79	50.81
Raxaul		Mean	50.84	62.69	71.30	81.66	85.13	85.62	83.75	84.11	82.59	77.90	69.96	60.88
LatN	26.58	Max.	77.82	83.52	93.30	90.38	102.4	102.3	95.61	95.14	94.1	90.82	96.97	90.38
Alt Ft.	4429	Range	55.58	57.36	61.23	39.03	54.37	47.22	42.26	42.60	42.80	44.24	50.61	54.59
Saharanpur		Mean	52.34	57.48	66.75	77.09	81.24	84.79	85.01	82.85	79.97	71.47	59.72	53.90
LatN	29.85	Max.	76.13	81.60	90.68	103.1	103.3	105.3	102.8	95.36	92.80	93.38	82.38	79.98
Alt Ft.	899	Range	61.52	62.70	63.23	67.55	61.98	56.28	48.32	44.43	49.24	63.60	63.26	64.63
Shillong		Mean	44.38	48.11	52.86	60.96	62.79	66.07	56.02	66.81	64.49	60.63	52.71	47.10
LatN	25.57	Max.	60.67	65.22	66.38	73.94	76.92	77.28	76.89	78	76.28	78.62	73.54	70.77
Alt Ft.	4921	Range	52.18	54.68	49.49	49.40	46.86	43.19	49.09	42.47	43.32	51.72	67.25	56.58
Sholapur		Mean	75.58	77.92	85.78	91	90.03	82.27	79.50	78.40	79.86	80.25	77.32	74.13
LatN	17.67	Max.	91.99	82.80	103.6	107.5	108.7	101.7	92.48	91.58	93.29	94.51	81.40	88.89
Alt Ft.	1572	Range	54.5	53.18	56.48	56.71	55.47	48.74	45.24	44.76	47.26	50.50	52.43	52.73
Srinagar		Mean	49.13	52.68	58.73	69.02	77.03	79.45	77.79	76.55	74.26	66.21	56.96	49.67
LatN	31.32	Max.	77.39	73.83	68.05	95	101.2	99.57	93.56	88.73	88.59	86.90	79.52	71.42
Alt Ft.	2869	Range	54.53	53.78	55.38	60.88	80.92	56.63	46.91	45.39	45.58	59.77	59.77	56.28
Surat		Mean	72.68	75.18	80.15	85.60	87.71	85.25	82.0	81.75	82.77	83.75	78.98	72.34
LatN	21.2	Max.	92.08	93.50	96.85	103.9	105.6	95.24	91.59	89.22	95.37	96.6	94.94	92.53
Alt Ft.	39	Range	55.14	53	51.76	50.01	45.54	40.91	39.25	38.49	41.72	48.09	51.78	53.15
Tezpur		Mean	62.06	65.42	72.96	75.07	79.12	82.47	81.68	63.21	80.52	77.75	69.90	63.39
LatN	26.62	Max.	80.15	83.71	92.06	92.44	94.94	95.45	92.71	96.11	92.44	91.13	87.26	80.47
Alt Ft.	259	Range	53.24	52.79	53.33	48.50	46.95	43.66	40.91	42.40	42.04	47.10	52.91	52.23
Tiruchirapalli		Mean	77.18	80.70	85.49	89.02	90.33	88.07	86.59	86.46	84.79	82.90	79.41	77.30
LatN	10.77	Max.	90.75	96.62	102.9	105.8	106.9	102.5	101.7	100.5	99.14	96.29	91.50	88.55
Alt Ft.	289	Range	49.04	52.97	53.87	52.43	51.83	49.56	48.36	48.92	49.40	46.14	44.63	46.13
Trivandrum		Mean	80.06	81.12	83.10	84.32	83.19	79.61	78.54	79.19	80.36	79.35Q	79.84	80.63
LatN	8.48	Max.	91.79	93.56	94.46	94.76	94.42	88.39	88.66	89.75	90.89	90.08	90.23	92.08
Alt Ft.	210	Range	48.2	48.36	47.17	45.37	44.06	41.39	42.33	42.47	44.13	43.14	44.24	47.17
Veraval		Mean	72.14	73.47	76.94	80.78	84.21	85.92	83.59	81.77	82.50	82.14	89.62	73.94
LatN	20.9	Max.	90.35	93.59	97.43	99.14	93.88	82.78	89.92	87.74	90.91	99.53	97.48	92.80
Alt Ft.	26	Range	56.3	54.55	50.99	45.60	41.73	38.71	37.05	37.43	40.78	49.83	54.19	55.00
Visakhapatnam		Mean	73.58	78.17	81.89	85.71	87.27	86.45	84.09	83.85	63.17	81.59	77.82	73.05
LatN	17.72	Max.	91.22	93.11	96.85	100.0	98.99	1006	96.62	96.58	95.05	92.69	89.99	86
Alt Ft.	10	Range	52.26	50.55	47.66	45.59	44.38	42.92	43.30	44.25	45.17	43.17	46.77	50.63

SOURCE : WEDCO, ISHRAE

Table 16.1.3 : Typical Inside Design Conditions - Industrial

(Listed conditions are only typical; final design conditions are established by customer requirement)

INDUSTRY	PROCESS	DRY BULB (F)	RH (%)
PHARMACEUTICALS	Powder Storage		
	Before Mfg	70-80	30-35
	After Mfg	75-80	15-35
	Milling Room	80	35
	Tablet Compressing	70-80	40
	Tablet Coating	80	35
	Effervescent Tablet & Powder	90	15
	Hypodermic Tablet	75-80	30
	Colloids	70	30-50
	Cough Syrup	80	40
	Glandular Prod.	78-80	5-10
	Ampule Mfg.	80	35
	Gelatin Capsule	78	40-50
	Capsule Storage	75	35-40
	Microanalysis	Comfort	
	Biological Mfg.	80	35
	Liver Extract	70-80	20-30
	Serums	Comfort	
	Animal	Comfort	
PHOTO MATERIAL	Drying		
	Cutting & Packing		
	Storage Film Base, Film Paper Coated Paper	70-75	40-65
	Safety Film	60-80	45-50
	Nitrate Film	40-50	40-50
PLASTIC	Mfg. Thermo Setting Compounds	80	25-30
	Cellophane	75-80	45-65
PLYWOOD	Hot Press Resin	90	25-30
	Cold Press	90	15-25
PRECISION MACHINING	Spectrographic Anal.	Comfort	35-40
	Gear Matching & Assem	75-80	
	Storage		
	Gasket	100	50
	Cement & Glue	65	40
	Machine	Comfort	
	Gaging. Assem		
	Adjusting Precision		
	Parts Honing	75-80	3545
PRINTING	Multicolour Litho		
	Press room	75-80	46-48
	Stock room	73-80	49-51
	Sheet & Web Print	Comfort	
	Storage, Folding Etc	Comfort	
REFRIGERATION EQUIPMENT	Valve Mfg.	75	40
	Compressor Assem.	70-76	30-45
	Refrigerator Assem.	Comfort	
	Testing	65-82	47
RUBBER DIPPED GOODS	Mfg.	90	-
	Cementing	80	25-30
	Surgical Articles	75-90	25-30
	Storage Before Mfg.	60-75	40-50
	Lab. (ASTM Std.)	73.4	50

INDUSTRY	PROCESS	DRY BULB (F)	RH (%)
TEXTILES	Cotton		
	Opening & Packing	70-75	55-70
	Carding	83-87	50-55
	Drawing & Roving	80	65-60
	Ring Spinning		
	Conventional	80-85	60-70
	Long Draft	80-85	-
	Frame Spinning	80-85	55-60
	Spooling, Warping	78-80	60-65
	Weaving	78-80	70-85
	Cloth Room	75	65-70
	Combing	75	55-65
	Linen		
	Carding, Spinning	75-80	62
	Weaving	80	80
	Woolens		
	Pickers	80-85	60
	Carding	80-85	65-70
	Spinning	80-85	50-60
	Dressing	75-80	50-60
	Weaving		
	Light Goods	80-85	55-70
	Heavy	80-85	60-65
	Drawing	75	50-60
	Worsteds		
	Carding Combing and Ginning	80-85	60-70
	Storage	70-85	75-80
	Drawing	80-85	50-70
	Cap Spinning	80-85	50-65
	Spooling, Winding	75-80	55-60
	Weaving	80	50-60
	Finishing	75-80	60
	Silk		
	Prep. & Dressing	80	60-65
	Weaving & Spinning	80	65-70
	Throwing	80	60
	Rayon		
	Spinning	80-90	50-60
	Throwing	80	55-60
	Weaving	-	-
	Regenerated	80	50-60
	Acetate	80	55-60
	Spun Rayon	80	80
	Picking	75-80	50-60
	Carding, Roving	-	-
	Drawing	80-90	50-60
	Knitting		
	Viscose or Cuprammonium Synthetic Fiber	80-85	65
	Prep. & Weaving		
	Viscose	80	60
	Celanese	80	70
	Nylon	80	50-60
TOBACCO	Cigar & Cigarette		
	Mfg.	70-75	55-65
	Softening	90	85-88
	Stemming & Stripping	75-80	75
	Storage & Prep.	78	70
	Conditioning	75	75
	Packing & Shipping	75	60

Table 16.2.1 : Cooling Load Temperature Differences for Calculating Cooling Load From Flat Roof

Roof No	"Description of Construction"	"Weight lb/ft2"	"U-value Btu/(h ft2.oF)"	Solar Time , hr																								"Hour of Maxi-mum in a day"	Mini-mum	Maxi-mum	Dif-fer-ence	"Heat Capacity Btu/(ft2-oF)"
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	CLTD	CLTD	CLTD	CLTD	
		Without Suspended Ceiling °F																														
1	"Steel sheet with 1-in. (or 2 in) insulation"	"7 (8)"	"0.213 (0.214)"	1	-2	-3	-3	-5	-3	6	19	34	49	61	71	78	79	77	70	59	45	30	18	12	8	5	3	14	-5	79	84	2.13
2	"1 in wood with 1 in insulation"	8	0.17	6	3	0	-1	-3	-3	-2	4	14	27	39	52	62	70	74	74	70	62	51	38	28	20	14	9	16	-3	74	77	3.73
3	4 in 1 w concrete	18	0.213	9	5	2	0	-2	-3	-3	1	9	20	32	44	55	64	70	73	71	66	57	45	34	25	18	13	16	-3	73	76	4.45
4	"2 in h.w concerete with 1 in (or 2 in) insulation"	29	"0.206 (0.122)"	12	8	5	3	0	-1	-1	3	11	20	30	41	51	59	65	66	66	62	54	45	36	29	22	17	16	-1	67	68	6.57
5	"1 in wood with 2 in insulation"	19	0.109	3	0	-3	-4	-5	-7	-6	-3	5	16	27	39	49	57	63	64	62	57	48	37	26	18	11	7	16	-7	64	71	3.83
6	6 in 1 w concrete	24	0.158	22	17	13	9	6	3	1	1	3	7	15	23	33	43	51	58	62	64	62	57	50	42	35	28	18	1	64	63	5.79
7	"2.5 in wood with 1 in insulation"	13	0.13	29	24	20	16	13	10	7	6	6	9	13	20	27	34	42	48	53	55	56	54	59	44	39	34	19	6	56	50	6.51
8	8 in 1 w concrete	31	0.126	35	30	26	22	18	14	11	9	7	7	9	13	19	25	33	39	46	50	53	54	53	49	45	40	20	7	54	47	7.13
9	"4 in h.w concrete with 1 in (or 2 in) insulation"	"52 (52)"	"0.2 (0.12)"	25	22	18	15	12	9	8	8	10	14	20	26	33	40	46	50	53	53	52	48	43	38	34	30	18	8	53	45	11.21
10	"2.5 in wood with 2 in insulation"	13	0.093	30	26	23	19	16	13	10	9	8	9	13	17	23	29	36	41	46	49	51	50	47	43	39	35	19	8	51	43	6.61
11	Roof terrace system	75	0.106	34	31	28	25	22	19	16	14	13	13	15	18	22	26	31	36	40	44	45	46	45	43	40	37	20	13	46	33	15.98
12	"6 in h.w concrete with 1 in (or 2 in) insulation"	"75 (75)"	"0.192 (0.117)"	31	28	25	22	20	17	15	14	14	16	18	22	26	31	36	40	43	45	45	44	42	40	37	34	19	14	45	31	15.89
13	"4 in wood with 1 in (or 2 in) insulation"	"17 (18)"	"0.106 (0.078)"	38	36	33	30	28	25	22	20	18	17	16	17	18	21	24	28	32	36	39	41	43	43	42	40	22	16	43	27	9.27

Table 16.2.1 : Cooling Load Teperature Differences for Calculating Cooling Load From Flat Roof (Contd.)

Roof No	"Description of Construction"	"Weight lb/ft2"	"U-value Btu/(h ft2.oF)"	Solar Time , hr																								"Hour of Maxi-mum in a day"	Mini-mum	Maxi-mum	Dif-fer-ence	"Heat Capacity Btu/(ft2-oF)"
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	CLTD	CLTD	CLTD	CLTD	
		With Suspended Ceiling °F																														
1	"Steel sheet with 1-in. (or 2 in) insulation"	"9 (10)"	"0.134 (0.092)"	2	0	-2	-3	-4	-4	-1	9	23	37	50	62	71	77	78	74	67	56	42	28	18	12	8	5	15	-4	78	82	2.5
2	"1 in wood with 1 in insulation"	10	0.115	20	15	11	8	5	3	2	3	7	13	21	30	40	48	55	60	62	61	58	51	44	37	30	25	17	2	62	60	4.11
3	4 in 1 w concrete	20	0.134	19	14	10	7	4	2	0	0	4	10	19	29	39	48	56	62	65	64	61	54	46	38	30	24	17	0	65	65	4.83
4	"2 in h.w concerete with 1 in (or 2 in) insulation"	30	0.131	28	25	23	20	17	15	13	13	14	16	20	25	30	35	39	43	46	47	46	44	41	38	35	32	18	13	47	34	6.94
5	"1 in wood with 2 in insulation"	10	0.083	25	20	16	13	10	7	5	5	7	12	18	25	33	41	48	53	57	57	56	52	46	40	34	29	18	5	57	52	4.21
6	6 in 1 w concrete	26	0.109	32	28	23	19	16	13	10	8	7	8	11	16	22	29	36	42	48	52	54	54	51	47	42	37	20	7	54	47	6.17
7	"2.5 in wood with 1 in insulation"	15	0.096	34	31	29	26	23	21	18	16	15	15	16	18	21	25	30	34	38	41	43	44	44	42	40	37	21	15	44	29	6.89
8	8 in 1 w concrete	33	0.093	39	36	33	29	26	23	20	18	15	14	14	15	17	20	25	29	34	38	42	45	46	45	44	42	21	14	46	32	7.51
9	"4 in h.w concrete with 1 in (or 2 in) insulation"	"53 (54)"	"0.128 (0.090)"	30	29	27	26	24	22	21	20	20	21	22	24	27	29	32	34	36	38	38	38	37	36	34	33	19	20	38	18	11.58
10	"2.5 in wood with 2 in insulation"	15	0.072	35	33	30	28	26	24	22	20	18	18	18	20	22	25	28	32	35	38	40	41	41	40	39	37	21	18	41	23	6.98
11	Roof terrace system	77	0.082	30	29	28	27	26	25	24	23	22	22	22	23	23	25	26	28	29	31	32	33	33	33	33	32	22	22	33	11	16.36
12	"6 in h.w concrete with 1 in (or 2 in) insulation"	"77 (77)"	"0.125 (0.088)"	29	28	27	26	25	24	23	22	21	21	22	23	25	26	28	30	32	33	34	34	34	33	32	31	20	21	34	13	16.26
13	"4 in wood with 1 in (or 2 in) insulation"	"19 (20)"	"0.082 (0.064)"	35	34	33	32	31	29	27	26	24	23	22	21	22	22	24	25	27	30	32	34	35	36	37	36	23	21	37	16	9.64

Table 16.2.2 : Typical Wall Construction

GROUP A			
Description of Construction	**"Weight (lb/ft2)"**	**"U-Value Btu/(hr.ft2.F)"**	**"Heat Capacity Btu/(ft2.F)"**
4-in. Face Brick + Insulation of Air space + 8-in. Common Brick	130	0.154-0.243	26.4
4-in. Face Brick + Air space or Insulation + 8-in. or more Concrete	143-190	0.110-0.112	29.1-38.4
4-in. Face Brick + 2-in. Insulation + 8-in. Tile	97	0.097	19.8
H.W. Concrete Wall + 2-in. Insulation + 8-in. Concrete	110	0.115	21.9
H.W. Concrete Wall + 12-in. Concrete + Insulation	156	0.113	31.3
GROUP B			
Description of Construction	**"Weight (lb/ft2)"**	**"U-Value Btu/(hr.ft2.F)"**	**"Heat Capacity Btu/(ft2.F)"**
4-in. Face Brick + 2-in. Insulation + 4-in. Common Brick	88	0.111	18.5
4-in. Face Brick + 8-in. Common Brick	130	0.302	26.4
4-in. Face Brick + 2-in. Insulation + 4-in. Concrete	97	0.116	19.8
4-in. Face Brick + 2-in. Insulation + 8-in. Block	89	0.096-0.107	15.5-18.6
4-in. Face Brick + Air Space or 1-in. Insulation + 8-in. Tile	96	0.142-0.221	19.7
H.W. Concrete Wall + 8-in. Concrete + 1-in. or 2-in. Insulation	110	0.115-0.187	22
H.W. Concrete Wall + 12-in. Concrete	156	0.421	31.2
Clay Tile + 2-in. Insulation + 8-in. Tile	63	0.099	12.6
GROUP C			
Description of Construction	**"Weight (lb/ft2)"**	**"U-Value Btu/(hr.ft2.F)"**	**"Heat Capacity Btu/(ft2.F)"**
4-in. Face Brick + Air Space + 4-in. Face Brick	83	0.358	18.3
4-in. Face Brick + 1-in. Insulation or Air Space + 4-in. Common Brick	90	0.74-0.301	18.4
4-in. Face Brick + Air Space + 2-in. Concrete	94	0.35	19.7
4-in. Face Brick + Air Space or 1-in. Insulation + 6-in. or 8-in. Block	73-89	0.221-0.275	15.5-18.5
4-in. Face Brick + Insulation + 4-in. Tile	71	0.169	15.1
4-in. Face Brick + 8-in. Tile	96	0.275	19.7
H.W. Concrete Wall + 2-in. Insulation + 4-in. Concrete	63	0.119	12.7
H.W. Concrete Wall + 8-in. Concrete	109	0.49	21.9
Clay Tile + 8-in. Tile + Air Space / 1-in. Insulation	63	0.151-0.231	12.6
GROUP D			
Description of Construction	**"Weight (lb/ft2)"**	**"U-Value Btu/(hr.ft2.F)"**	**"Heat Capacity Btu/(ft2.F)"**
4-in. Face Brick + 4-in. Common Brick	90	0.415	18.4
4-in. Face Brick + Air Space or Insulation + 4-in. Block	62	0.153-0.246	12.9
4-in. Face Brick + 8-in. Block	70	0.274	15.1
4-in. Face Brick + 4-in. Tile	71	0.381	15.1
4-in. Face Brick + Air Space + 4-in. Tile	71	0.281	15.1
H.W. Concrete Wall + 4-in. Concrete + 2-in. Insulation	63	0.119-0.200	12.5
L.W. and H.W. Concrete Block + 8-in. Block + Air Space / Insulation	41-57	0.149-0.173	8.3-11.3
Clay Tile + 2-in. Insulation + 4-in. Tile	40	0.11	7.9
Clay Tile + 8-in. Tile	63	0.296	12.5

Table 16.2.2 : Typical Wall Construction (Contd.)

GROUP E			
Description of Construction	**"Weight (lb/ft2)"**	**"U-Value Btu/(hr.ft2.F)"**	**"Heat Capacity Btu/(ft2.F)"**
4-in. Face Brick + 4-in. Block	62	0.319	12.9
H.W. Concrete Wall + 4-in. Concrete	63	0.585	12.5
L.W. and H.W. Concrete Block + 2-in. Insulation + 4-in. Block	29-37	0.105-0.114	5.8-7.3
L.W. and H.W. Concrete Block + 8-in. Block	41-57	0.294-0.402	6.3-11.3
Clay Tile + 4-in. Tile + 1-in. Insulation	39	0.175	7.9
GROUP F			
Description of Construction	**"Weight (lb/ft2)"**	**"U-Value Btu/(hr.ft2.F)"**	**"Heat Capacity Btu/(ft2.F)"**
L.W. and H.W. Concrete Block + 4-in. Block + Air Space / Insulation	29-36	0.161-0.263	5.7-7.2
Clay Tile + 4-in. Tile	39	0.419	7.8
Clay Tile + 4-in. Tile + Air Space	39	0.303	7.8
GROUP G			
Description of Construction	**"Weight (lb/ft2)"**	**"U-Value Btu/(hr.ft2.F)"**	**"Heat Capacity Btu/(ft2.F)"**
Metal Curtain Wall + With/without Air Space + 1-in./2-in./3-in. Insulation	5-6	0.091-0.230	0.7
Frame Wall + 1-in. to 3-in. Insulation	16	0.081-0.178	3.2

Table 16.2.3 : Cooling Load Temperature Differences for Calculating Cooling Load From Sunlit Walls

"North Latitude Wall Facing"	Solar Time , Hr																								"Hr of Maximum CLTD"	"Mini-mum CLTD"	"Maxi-mum CLTD"	"Differ-ence CLTD"
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24				
								Heavier Than Group A Walls																				
								N	NE	E	SE	S	SW	W	NW													
								11	17	22	21	17	21	22	17													
	Group A Walls																											
N	14	14	14	13	13	13	12	12	11	11	10	10	10	10	10	10	11	11	12	12	13	13	14	14	2	10	14	4
NE	19	19	19	18	17	17	16	15	15	15	15	15	16	16	17	18	18	18	19	19	20	20	20	20	22	15	20	5
E	24	24	23	23	22	21	20	19	19	18	19	19	20	21	22	23	24	24	25	25	25	25	25	25	22	18	25	7
SE	24	23	23	22	21	20	19	18	18	18	18	18	19	20	21	22	23	23	24	24	24	24	24	24	22	18	24	6
S	20	20	20	24	21	18	15	196	15	14	14	14	14	14	14	14	14	15	18	14	16	18	19	19	23	14	20	6
SW	25	25	25	24	24	23	22	21	20	19	19	18	17	17	17	17	18	19	20	22	23	24	25	25	24	17	25	8
W	27	26	26	25	24	24	23	22	21	20	19	19	18	18	18	18	19	20	22	23	25	26	26	25	1	18	27	9
NW	21	21	21	20	20	29	27	18	14	169	15	185	24	14	14	15	15	16	17	18	19	20	21	22	1	14	21	7
	Group B Walls																											
N	15	14	14	13	12	11	11	10	9	9	9	8	9	9	9	10	11	12	13	14	14	15	15	15	24	8	15	7
NE	19	18	17	16	15	14	13	12	12	13	14	15	16	17	18	19	19	20	20	21	21	21	20	20	21	12	21	9
E	23	22	21	20	18	17	16	15	15	15	17	19	21	22	24	25	26	26	27	27	26	26	25	24	20	15	27	12
SE	23	22	21	20	18	17	16	15	14	14	15	16	18	20	21	23	24	25	26	26	26	26	25	24	21	14	26	12
S	21	20	19	18	17	15	14	13	12	11	11	11	11	12	14	15	17	19	20	21	22	22	22	21	23	11	22	11
SW	27	26	25	24	22	21	19	18	16	15	14	14	13	13	14	15	17	20	22	25	27	28	28	28	24	13	28	15
W	29	28	27	26	24	23	21	19	18	17	16	15	14	14	14	15	17	19	22	25	27	29	29	30	24	14	30	16
NW	23	22	21	20	19	18	17	15	14	13	12	12	12	11	12	12	13	15	17	19	21	22	23	23	24	11	23	12
	Group C Walls																											
N	15	14	13	12	11	10	9	8	8	7	7	8	8	9	9	12	13	14	15	16	17	17	17	16	22	7	17	10
NE	19	17	16	14	13	11	10	10	11	13	15	17	19	20	21	22	22	23	23	23	23	22	21	20	20	10	23	13
E	22	21	19	17	15	14	12	12	14	16	19	22	25	27	29	29	30	30	30	29	28	27	26	24	18	12	30	18
SE	22	21	19	17	15	14	12	12	12	13	16	19	22	24	26	28	29	29	29	29	28	27	26	24	19	12	29	17
S	21	19	18	16	15	13	12	10	9	9	9	10	11	14	17	20	22	24	25	26	25	25	24	22	20	9	26	17
SW	29	27	25	22	20	18	16	15	13	12	11	11	11	13	15	18	22	26	29	32	33	33	32	31	22	11	33	22
W	13	29	27	25	22	20	18	16	14	13	12	12	12	13	14	16	20	24	29	32	35	35	35	33	22	12	35	23
NW	25	23	21	20	18	16	14	13	11	10	10	10	10	11	12	13	15	18	22	25	27	27	27	26	22	10	27	17

Table 16.2.3 : Cooling Load Temperature Differences for Calculating Cooling Load From Sunlit Walls (Contd.)

	Group D Walls																											
N	15	13	12	10	9	7	6	6	6	6	6	7	8	10	12	13	15	17	18	19	19	19	18	16	21	6	19	13
NE	17	15	13	11	10	8	7	8	10	14	17	20	22	23	23	24	24	25	25	24	23	22	20	18	19	7	25	18
E	19	17	15	13	11	9	8	9	12	17	22	27	30	32	33	33	32	32	31	30	28	26	24	22	16	8	33	25
SE	20	17	15	13	11	10	8	8	10	13	17	22	26	29	31	32	32	32	31	30	28	26	24	22	17	8	32	24
S	19	17	15	13	11	9	8	7	6	6	7	9	12	16	20	24	27	29	29	29	27	26	24	22	19	6	29	23
SW	28	25	22	19	16	14	12	10	9	8	8	8	10	12	16	21	27	32	36	38	38	37	34	31	21	8	38	30
W	31	27	24	21	18	15	13	11	10	9	9	9	10	11	14	18	24	30	36	40	41	40	38	34	21	9	41	32
NW	25	22	19	17	14	12	10	9	8	7	7	8	9	10	12	14	18	22	27	31	32	32	30	27	22	7	32	25
	Group E Walls																											
N	12	10	8	7	5	4	3	4	5	6	7	9	11	13	15	17	19	20	21	23	20	18	16	14	20	3	22	19
NE	13	11	9	7	6	4	5	9	15	20	24	25	25	26	26	26	26	26	25	24	22	19	17	15	16	4	26	22
E	14	12	10	8	6	5	6	11	18	26	33	36	38	37	36	34	33	32	30	28	25	22	20	17	13	5	38	33
SE	15	12	10	8	7	5	5	8	12	19	25	31	35	37	37	36	34	33	31	28	27	23	20	17	15	5	37	32
S	15	12	10	8	7	5	4	3	4	5	9	13	19	24	29	32	34	33	31	29	26	23	20	17	17	3	34	31
SW	22	18	15	12	10	8	6	5	5	6	7	9	12	18	24	32	38	43	45	44	40	35	30	26	19	5	45	40
W	25	21	17	14	11	9	7	6	6	6	7	9	11	14	20	27	36	43	49	49	45	40	34	29	20	6	49	43
NW	20	17	14	11	9	7	6	5	5	5	6	8	10	13	16	20	26	32	37	38	36	32	28	24	20	5	38	33
	Group F Walls																											
N	8	6	5	3	2	1	2	4	6	7	9	11	14	17	19	21	22	23	24	23	20	16	13	11	19	1	24	23
NE	9	7	5	3	2	1	5	14	23	28	30	29	28	27	27	27	27	27	24	22	19	16	13	11	11	1	30	29
E	10	7	6	4	3	2	6	17	28	38	44	45	43	39	36	34	32	30	27	24	21	17	15	12	12	2	45	43
SE	10	7	6	4	3	2	4	10	19	28	36	41	43	42	39	36	34	31	28	25	21	18	15	12	13	2	43	41
S	10	8	6	4	3	2	1	1	3	7	13	20	27	34	38	39	38	35	31	26	22	18	15	12	16	1	39	38
SW	15	11	9	6	5	3	2	2	4	5	8	11	17	26	35	44	50	53	52	45	37	28	23	18	18	2	53	51
W	17	13	10	7	5	4	3	3	4	6	8	11	14	20	28	39	49	57	60	54	43	34	27	21	19	3	60	57
NW	14	10	8	6	4	3	2	2	3	5	8	10	13	15	21	27	35	42	46	43	35	28	22	18	19	2	46	44
	Group G Walls																											
N	3	2	1	0	-1	2	7	8	9	12	15	18	21	23	24	24	25	26	22	15	11	9	7	5	18	-1	26	27
NE	3	2	1	0	-1	9	27	36	39	35	30	26	26	27	27	26	25	22	18	14	11	9	7	5	9	-1	39	40
E	4	2	1	0	-1	11	31	47	54	55	50	40	33	31	30	29	27	24	19	15	12	10	8	6	10	-1	55	56
SE	4	2	1	0	-1	5	18	32	42	49	51	48	42	36	32	30	27	24	19	15	12	10	8	6	11	-1	51	52
S	4	2	1	0	-1	0	1	5	12	22	31	39	45	46	43	37	31	25	20	15	12	10	8	5	14	-1	46	47
SW	5	4	3	1	0	0	2	5	8	12	16	26	38	50	59	63	61	52	37	24	17	13	10	8	16	0	63	63
W	6	5	3	2	1	1	2	5	8	11	15	19	27	41	56	67	72	67	48	29	20	15	11	8	17	1	72	71
NW	5	3	2	1	0	0	2	5	8	11	15	18	21	27	37	47	55	55	41	25	17	13	10	7	18	0	55	55

Table 16.2.4 : Cooling Load Temperature differences for conduction through glass and conduction through wall °F

Solar Time , hr																							
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
CLTD , F																							
1	0	-1	-2	-2	-2	-2	0	2	4	7	9	12	13	14	14	13	12	10	8	6	4	3	2

Table 16.3 : CLTD Corrections For Latitude And Months Applied To Walls And Roofs, North Latitude °F

Lat.	Month	N	"NNE NNW"	"NE NW"	"ENE WNW"	"E W"	"ESE WSW"	"SE SW"	"SSE SSW"	S	HOR
0	Dec	-3	-5	-5	-5	-2	0	3	6	9	-1
0	Jan / Nov	-3	-5	-4	-4	-1	0	2	4	7	-1
0	Feb / Oct	-3	-2	-2	-2	-1	-1	0	-1	0	0
0	Mar / Sept	-3	0	1	-1	-1	-3	-3	-5	-8	0
0	Apr / Aug	5	4	3	0	-2	-5	-6	-8	-8	-2
0	May / Jul	10	7	5	0	-3	-7	-8	-9	-8	-4
0	Jun	12	9	5	0	-3	-7	-9	-10	-8	-5
8	Dec	-4	-6	-6	-6	-3	0	4	8	12	-5
8	Jan / Nov	-3	-5	-6	-5	-2	0	3	6	10	-4
8	Feb / Oct	-3	-4	-3	-3	-1	-1	1	2	4	-1
8	Mar / Sept	-3	-2	-1	-1	-1	-2	-2	-3	-4	0
8	Apr / Aug	2	2	2	0	-1	-4	-5	-7	-7	-1
8	May / Jul	7	5	4	0	-2	-5	-7	-9	-7	-2
8	Jun	9	6	4	0	-2	-6	-8	-9	-7	-2
16	Dec	-4	-6	-8	-8	-4	-1	4	9	13	-9
16	Jan / Nov	-4	-6	-7	-7	-4	-1	4	8	12	-7
16	Feb / Oct	-3	-5	-4	-4	-2	0	2	5	7	-4
16	Mar / Sept	-3	-3	-2	-2	-1	-1	0	0	0	-1
16	Apr / Aug	-1	0	-1	-1	-1	-3	-3	-5	-6	0
16	May / Jul	4	3	0	0	-1	-4	-5	-7	-7	0
16	Jun	6	4	1	1	-1	-4	-6	-8	-7	0
24	Dec	-5	-7	-9	-10	-7	-3	3	9	13	-13
24	Jan / Nov	-4	-6	-8	-9	-6	-3	3	9	13	-11
24	Feb / Oct	-4	-5	-6	-6	-3	-1	3	7	10	-7
24	Mar / Sept	-3	-4	-3	-3	-1	-1	1	2	4	-3
24	Apr / Aug	-2	-1	0	-1	-1	-2	-1	-2	-3	0
24	May / Jul	1	2	2	0	0	-3	-3	-5	-6	1
24	Jun	3	3	3	1	0	-3	-4	-6	-6	1
32	Dec	-5	-7	-10	-11	-8	-5	2	9	12	-17
32	Jan / Nov	-5	-7	-9	-11	-8	-4	2	9	12	-15
32	Feb / Oct	-4	-6	-7	-8	-4	-2	4	8	11	-10
32	Mar / Sept	-3	-4	-4	-4	-2	-1	3	5	7	-5
32	Apr / Aug	-2	-2	-1	-2	0	-1	0	1	1	-1
32	May / Jul	1	1	1	0	0	-1	-1	-3	-3	1
32	Jun	1	2	2	1	0	-2	-2	-4	-4	2

Table 16.3 : CLTD Corrections For Latitude And Months Applied To Walls And Roofs, North Latitude °F (Contd.)

Lat.	Month	N	"NNE NNW"	"NE NW"	"ENE WNW"	"E W"	"ESE WSW"	"SE SW"	"SSE SSW"	S	HOR
40	Dec	-6	-8	-10	-13	-10	-7	0	7	10	-21
40	Jan / Nov	-5	-7	-10	-12	-9	-6	1	8	11	-19
40	Feb / Oct	-5	-7	-8	-9	-6	-3	3	8	12	-14
40	Mar / Sept	-4	-5	-5	-6	-3	-1	4	7	10	-8
40	Apr / Aug	-2	-3	-2	-2	0	0	2	3	4	-3
40	May / Jul	0	0	0	0	0	0	0	0	1	1
40	Jun	1	1	1	0	1	0	0	-1	-1	2
48	Dec	-6	-8	-11	-14	-13	-10	-3	2	6	-25
48	Jan / Nov	-6	-8	-11	-13	-11	-8	-1	5	8	-24
48	Feb / Oct	-5	-7	-10	-11	-8	-5	1	8	11	-18
48	Mar / Sept	-4	-6	-6	-7	-4	-1	4	8	11	-11
48	Apr / Aug	-3	-3	-3	-3	-1	0	4	6	7	-5
48	May / Jul	0	-1	0	0	1	1	3	3	4	0
48	Jun	1	1	2	1	2	1	2	2	3	2
56	Dec	-7	-9	-12	-16	-16	-14	-9	-5	-3	-28
56	Jan / Nov	-6	-8	-11	-15	-14	-12	-6	-1	2	-27
56	Feb / Oct	-6	-8	-10	-12	-10	-7	0	6	9	-22
56	Mar / Sept	-5	-6	-7	-8	-5	-2	4	8	12	-15
56	Apr / Aug	-3	-4	-4	-4	-1	1	5	7	9	-8
56	May / Jul	0	0	0	0	2	2	5	6	7	-2
56	Jun	2	1	1	1	3	3	4	5	6	1
64	Dec	-7	-9	-12	-16	-17	-18	-16	-14	-12	-30
64	Jan / Nov	-7	-9	-12	-16	-16	16	-13	-10	-8	-29
64	Feb / Oct	-6	-8	-11	-14	-13	-10	-4	1	4	-26
64	Mar / Sept	-5	-7	-9	-10	-7	-4	2	7	11	-20
64	Apr / Aug	-3	-4	-4	-4	-1	1	5	9	11	-11
64	May / Jul	1	0	1	0	3	4	6	8	10	-3
64	Jun	2	2	2	2	4	4	6	7	9	0

(1) Corrections in this table are in degrees F. The correction is applied directly to the CLTD for a wall or roof as given in Tables 2.3 and 2.1.

(2) The CLTD correction given in this table is not applicable to Table 2.4, Cooling Load Temperature Differences for Conduction through glass and conduction through wall.

(3) For South latitudes, replace Jan. through Dec. by July through June.

Table 16.4 : Adjust for Inside / Outside temperature

a) Correction for inside design temperature, °F (See Note 1)									
Inside db, F	72	73	74	75	76	77	78	79	80
Correction, F	6	5	4	3	2	1	0	-1	-2

b) Correction for outside design conditions, °F (See Note 2)														
"Design Outside db, F"	Daily range, F													
	10	12	14	16	18	20	22	24	26	28	30	32	34	36
88	-2	-3	-4	-5	-6	-7	-8	-9	-10	-11	-12	-13	-14	-15
90	0	-1	-2	-3	-4	-5	-6	-7	-8	-9	-10	-11	-12	-13
92	2	1	0	-1	-2	-3	-4	-5	-6	-7	-8	-9	-10	-11
94	4	3	2	1	0	-1	-2	-3	-4	-5	-6	-7	-8	-9
96	6	5	4	3	2	1	0	-1	-2	-3	-4	-5	-6	-7
98	8	7	6	5	4	3	2	1	0	-1	-2	-3	-4	-5
100	10	9	8	7	6	5	4	3	2	1	0	-1	-2	-3
102	12	11	10	9	8	7	6	5	4	3	2	1	0	-1
104	14	13	12	11	10	9	8	7	6	5	4	3	2	1
106	16	15	14	13	12	11	10	9	8	7	6	5	4	3

Note:

(1) Correction for inside design = (78 - T_R), where TR is inside design db temperature, F.

(2) Correction for outside conditions = (T_o - 85), where T_o is outside mean temperature given by,

T_o = Design outside db - 1/2 X Daily Range

Table 16.5.1 : Shading Coefficient for Single and Insulating Glass with Draperies

Glazing	Glass Trans.	Glass SC*	SC for Index Letters in Fig. 3.1**									
			A	B	C	D	E	F	G	H	I	J
Single Glass												
1/4 in. Clear	0.80	0.95	0.80	0.75	0.70	0.65	0.60	0.55	0.50	0.45	0.40	0.35
1/2 in. Clear	0.71	0.88	0.74	0.70	0.66	0.61	0.56	0.52	0.48	0.43	0.39	0.35
1/4 in. Heat Abs.	0.46	0.67	0.57	0.54	0.52	0.49	0.46	0.44	0.41	0.38	0.36	0.33
1/2 in. Heat Abs.	0.24	0.50	0.43	0.42	0.40	0.39	0.38	0.36	0.34	0.33	0.32	0.30
Reflective Coated (See Manufacturers literature for exact values)	–	0.60	0.57	0.54	0.51	0.49	0.46	0.43	0.41	0.38	0.36	0.33
	–	0.50	0.46	0.44	0.42	0.41	0.39	0.38	0.36	0.34	0.33	0.31
	–	0.40	0.36	0.35	0.34	0.33	0.32	0.30	0.29	0.28	0.27	0.26
	–	0.30	0.25	0.24	0.24	0.23	0.23	0.23	0.22	0.21	0.21	0.20
Insulating Glass (1/2 in. Air Space)												
Clear Out and Clear In	0.64	0.83	0.66	0.62	0.58	0.56	0.52	0.48	0.45	0.42	0.37	0.35
Heat Abs. Out and Clear In	0.37	0.56	0.49	0.47	0.45	0.43	0.41	0.39	0.37	0.35	0.33	0.32
Reflective Coated (See Manufacturers literature for exact values)	–	0.40	0.38	0.37	0.37	0.36	0.34	0.32	0.31	0.29	0.28	0.28
	–	0.30	0.29	0.28	0.27	0.27	0.26	0.26	0.25	0.25	0.24	0.24
	–	0.20	0.19	0.19	0.18	0.18	0.17	0.17	0.16	0.16	0.15	0.15

*For glass alone, with no drapery.
** Shading Coefficient values for the SC lines in Fig. 3.1 for representative glazings. Substitute for SC index letters in Fig. 3.1 values on the line of the glazings selected.

Notes :
1. Shading coefficients are for draped fabrics.
2. Other properties are for fabrics in flat orientation.
3. Use Fabric Reflectance and Transmittance to obtain accurate Shading Coefficients.
4. Use Openness and Yarn Reflectance or Openness and Fabric Reflectance to obtain the Various Environmental Characteristics, or to obtain Approximate Shading Coefficients.

CLASSIFICATION OF FABRICS
I = Open Weave
II = Semi-open Weave
II = Closed Weave
IV = Dark "Color"
V = Medium "Color"
VI = Light "Color"

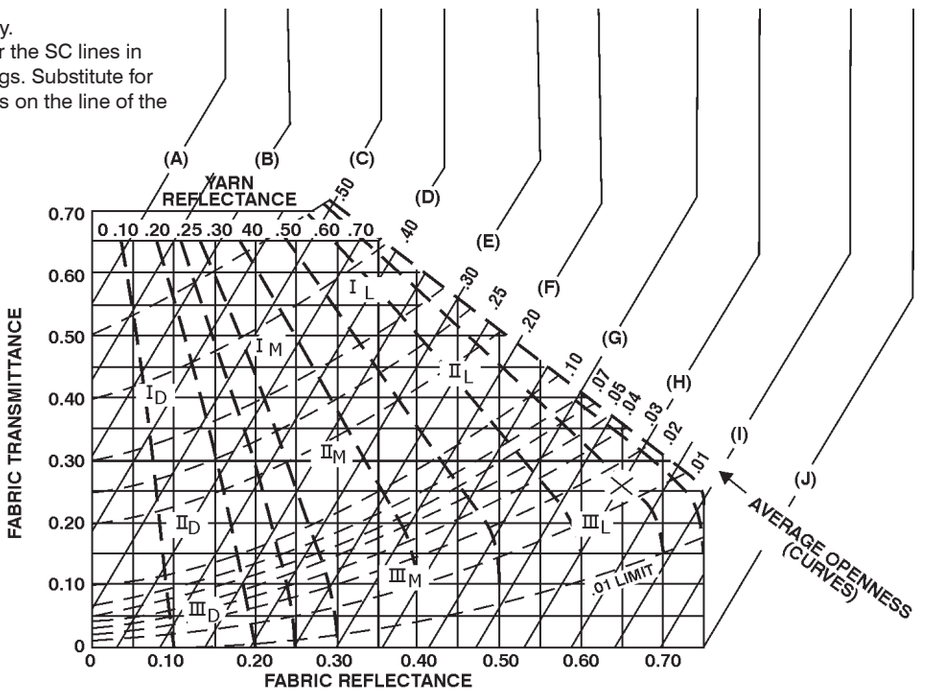


Figure 16.3.1 Indoor Shading properties of Drapery Fabrics

To obtain Fabric Designator (III_1, I_M, etc.) Using Coordinates (1) Fabric Transmittance and Fabric Reflectance or (2) Openness and Yarn Reflectance, find point on chart and note designator for that area. If properties are not known, classification may be approximated by eye using Fig. 3.2, Note 2.

To obtain Shading Coefficient (SC) : (1) Locate drapery fabric as a point using its known properties, or approximate using fabric classification designator for greatest accuracy. Fabric Transmittance and Fabric Reflectance. (2) Follow diagonal SC lines to lettered columns in Table 5.1 (3) Find on line with the glazing used. Example : SC of point "X" is -- with 0.25 in. Clear Single Glass (Column H). Note : SC are for 45 deg incident angle. For 30 deg or less, 5% to number found in Table 5.1.

Table 16.5.2 : Shading Coefficient for Louvered Sun Screens

Profile Angle, Deg	Sn/P*	Group 1		Group 2	
		Transmi-ttance	SC	Trans-mittance	SC
10	0.176	0.23	0.35	0.25	0.33
20	0.314	0.06	0.17	0.14	0.23
30	0.577	0.04	0.15	0.12	0.21
40	0.839	0.04	0.15	0.11	0.20
& above	& above				
Profile Angle, Deg	Sn/P*	Group 3		Group 4	
		Transmi-ttance	SC	Transmi-ttance	SC
10	0.176	0.40	0.51	0.48	0.59
20	0.314	0.32	0.42	0.39	0.50
30	0.577	0.21	0.31	0.28	0.38
40	0.839	0.07	0.18	0.20	0.30
& above	& above				
Profile Angle, Deg	Sn/P*	Group 5		Group 6	
		Transmi-ttance	SC	Transmi-ttance	SC
10	0.176	0.15	0.27	0.26	0.45
20	0.314	0.04	0.11	0.20	0.35
30	0.577	0.03	0.10	0.13	0.26
40	0.839	0.03	0.10	0.04	0.13
& above	& above				

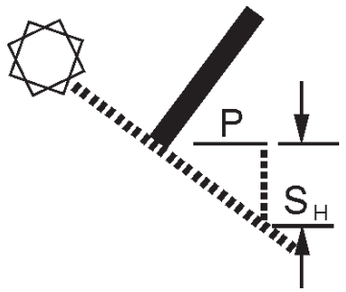


Figure 16.3.2

Table 16.5.3 : Shading Coefficient for Domed Skylights

Curb (See Fig. 3.3)						
Dome	**Light Diffuser (Translu-cent)**		**"Height, in."**	**Width to Height Ratio**	**Shad-ing Coef-ficient**	**U-Factor**
Clear		yes	0	∞	0.61	0.46
	$\tau = 0.86$	$\tau = 0.58$	9	5	0.58	0.43
			18	2.5	0.50	0.40
Clear			0	∞	0.99	0.80
	$\tau = 0.86$	None	9	5	0.88	0.75
			18	2.5	0.80	0.70
Translucent			0	∞	0.57	0.80
	$\tau = 0.52$	None	18	2.5	0.46	0.70
Translucent			0	∞	0.34	0.80
	$\tau = 0.27$	None	9	5	0.30	0.75
			18	2.5	0.28	0.70

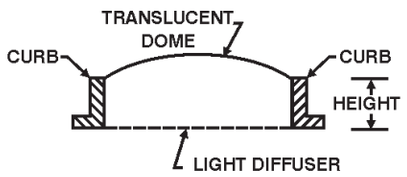


Figure 16.3.3 : Terminology for Deomed skylights

Table 16.5.4 : Solar Optical Properties and Shading Coefficients of Transparent Plastic Sheeting

Type of Plastic	Transmittance		SC
	Visible	Solar	
Acrylic			
Clear	0.92	0.85	0.98
Gray Tint	0.16	0.27	0.52
"	0.33	0.41	0.63
"	0.45	0.55	0.74
"	0.59	0.62	0.80
"	0.76	0.74	0.89
Bronze Tint	0.10	0.20	0.46
"	0.27	0.35	0.58
"	0.61	0.62	0.80
"	0.75	0.75	0.90
Reflective*	0.14	0.12	0.21
Polycarbonate			
Clear (0.125 in.)	0.88	0.82	0.98
Gray (0.125 in)	0.50	0.57	0.74
Bronze (0.125 in)	0.50	0.57	0.74
* Aluminum metalized polyster film on plastic			

Table 16.5.5 : Shading Coefficients for Double Glazing with Between-Glass Shading

Type of Glass	"Nominal Each Pane, in."	Solar Trans.a		Description of Air Space	Type of Shading		
		"Outer Pane"	"Inner Pane"		Venetian Blinds		"Louvered Sun Screen"
					Light	Medium	
Clear Out Clear In	3/32, 1/8	0.87	0.87	Shade in contact with glass or shade separated from glass by air space.	0.33	0.36	0.43
Clear Out Clear In	1/4	0.80	0.80	Shade in contact with glass-voids filled with plastic.	-	-	0.49
Heat-Abs. b Out Clear In	1/4	0.46	0.80	Shade in contact with glass or shade separated from glass by air space. Shade in contact with glass-voids filled with plastic.	0.28 -	0.30 -	0.37 0.41

[a] Refer to manufacturer's literature for exact values.
[b] Refers to grey, bronze, and green tinted heat-absorbing glass

Table 16.5.6 : Shading Coefficients for Glass Without or With Interior Shading by Venetian Blinds or Roller Shades

	Type of Glass	"Nominal Thickness Each Light a"	"Solar Trans.b"	No Interior Shading		Type of Interior Shading				
						"Venetian Blinds"		Roller Shades		
								Opaque		Translucent
				ho = 4.0	ho = 3.0	Medium	Light	Dark	Light	Light
SINGLE GLASS	Single									
	Clear	3/32 to 1/4	0.87-0.80	1.00	1.00					
	Clear	1/4 to 1/2	0.80-0.71	0.94	0.95					
	Clear	3/8	0.72	0.90	0.92	0.64	0.55	0.59	0.25	0.39
	Clear	1/2	0.67	0.87	0.88					
	Clear Pattern	1/8 to 9/32	0.87-0.79	0.83	0.85					
	Heat Absorbing Pattern	1/8		0.83	0.85					
	Heat Absorbing c	3/16 to 1/4	0.46	0.69	0.73	0.57	0.53	0.45	0.30	0.36
	Heat Absorbing Pattern	3/16 to 1/4		0.69	0.73					
	Tinted	1/8 to 7/32	0.59-0.45	0.69	0.73					
	Heat Absorbing Pattern		0.44-0.30	0.60	0.64					
	Heat Absorbing c	3/8	0.34	0.60	0.64					
	Heat Absorbing Pattern	1/2	0.44-0.30 0.24	0.53	0.58	0.42	0.40	0.36	0.28	0.31
	Reflective Coated Glass			0.30		0.25	0.23			
				0.40		0.33	0.29			
				0.50		0.42	0.38			
				0.60		0.50	0.44			
INSULATING GLASS	Double d									
	Clear Out Clear In	3/32. 1/8	0.71a	0.88	0.88	0.57	0.51	0.60	0.25	0.37
	Clear Out Clear In	1/4	0.61a	0.81	0.82					
	Heat Absorbing Out Clear In	1/4	0.36a	0.55	0.58	0.39	0.36	0.40	0.22	0.30
	Reflective Coated Glass			0.20		0.19	0.18			
				0.30		0.27	0.26			
				0.40		0.34	0.33			
	Triple									
	Clear	1/4		0.71						
	Clear	1/8		0.80						

[a] Refer to manufacturer's literature for values.
[b] For vertical blinds with opaque white and beige louvers in the tightly closed position, SC is 0.25 and 0.29 when used with glass of 0.71 to 0.80 transmittance.
[c] Refers to grey, bronze and green tinted heat-absorbing glass.
[d] Refers to factory-fabricated units with 3/16, 1/4 or 1/2 in. air space between prime windows and storm windows.

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Table 16.6 : Maximum Solar Heat Gain Factor BTU/hr - sq.ft.

0 Deg										
Column1	N	"NNE/ NNW"	"NE/ NW"	"ENE/ WNW"	"E/ W"	"ESE/ WSW"	"SE/ SW"	"SSE/ SSW"	S	HOR
Jan.	34	34	88	177	234	254	235	182	118	296
Feb.	36	39	132	205	245	247	210	141	67	306
Mar.	38	87	170	223	242	223	170	87	38	303
Apr.	71	134	193	224	221	184	118	38	37	284
May	113	164	203	218	201	154	80	37	37	265
June	129	173	206	212	191	140	66	37	37	255
July	115	164	201	213	195	149	77	38	38	260
Aug.	75	134	187	216	212	175	112	39	38	276
Sep.	40	84	163	213	231	213	163	84	40	293
Oct.	37	40	129	199	236	238	202	135	66	299
Nov.	35	35	88	175	230	250	230	179	117	293
Dec.	34	34	71	164	226	253	240	196	138	288

4 Deg										
Column1	N	"NNE/ NNW"	"NE/ NW"	"ENE/ WNW"	"E/ W"	"ESE/ WSW"	"SE/ SW"	"SSE/ SSW"	S	HOR
Jan.	33	33	79	170	229	252	237	193	141	286
Feb.	35	35	123	199	242	248	215	152	88	301
Mar.	38	77	163	219	242	227	177	96	43	302
Apr.	55	125	189	223	223	190	126	43	38	287
May	93	154	200	220	206	161	89	38	38	272
June	110	164	202	215	196	147	73	38	38	263
July	96	154	197	215	200	156	85	39	38	267
Aug.	59	124	184	215	214	181	120	42	40	279
Sep.	39	75	156	209	231	216	170	93	44	293
Oct.	36	36	120	193	234	239	207	148	86	294
Nov.	34	34	79	168	226	248	232	190	139	284
Dec.	33	33	62	157	221	250	242	206	160	277

8 Deg										
Column1	N	"NNE/ NNW"	"NE/ NW"	"ENE/ WNW"	"E/ W"	"ESE/ WSW"	"SE/ SW"	"SSE/ SSW"	S	HOR
Jan.	32	32	71	163	224	250	242	203	162	275
Feb.	34	34	114	193	239	248	219	165	110	294
Mar.	37	67	156	215	241	230	184	110	55	300
Apr.	44	117	184	221	225	195	134	53	39	289
May	74	146	198	220	209	167	97	39	38	277
June	90	155	200	217	200	141	82	39	39	269
July	77	145	195	215	204	162	93	40	39	272
Aug.	47	117	179	214	216	186	128	51	41	282
Sep.	38	66	149	205	230	219	176	107	56	290
Oct.	35	35	112	187	231	239	211	160	108	288
Nov.	33	33	71	161	220	245	233	200	160	273
Dec.	31	31	55	149	215	246	247	215	179	265

Table 16.6 : Maximum Solar Heat Gain Factor BTU/hr - sq.ft. (Contd.)

12 Deg										
Column1	N	"NNE/ NNW"	"NE/ NW"	"ENE/ WNW"	"E/ W"	"ESE/ WSW"	"SE/ SW"	"SSE/ SSW"	S	HOR
Jan.	31	31	63	155	217	246	247	212	182	262
Feb.	34	34	105	186	235	248	226	177	133	286
Mar.	36	58	148	210	240	233	190	124	73	297
Apr.	40	108	178	219	227	200	142	64	40	290
May	60	139	194	220	212	173	106	40	40	280
June	75	149	198	217	204	161	90	40	40	274
July	63	139	191	215	207	168	102	41	41	275
Aug.	42	109	174	212	218	191	135	62	142	282
Sep.	37	57	142	201	229	222	182	121	73	287
Oct.	34	34	103	180	227	238	219	172	130	280
Nov.	32	32	63	153	214	241	243	209	179	260
Dec.	30	30	47	141	207	242	251	223	197	250

16 Deg										
Column1	N	"NNE/ NNW"	"NE/ NW"	"ENE/ WNW"	"E/ W"	"ESE/ WSW"	"SE/ SW"	"SSE/ SSW"	S	HOR
Jan.	30	30	55	147	210	244	251	223	199	248
Feb.	33	33	96	180	231	247	233	188	154	275
Mar.	35	53	140	205	239	235	197	138	93	291
Apr.	39	99	172	216	227	204	150	77	45	289
May	52	132	189	218	215	179	115	45	41	282
June	66	142	194	217	207	167	99	41	41	277
July	55	132	187	214	210	174	111	44	42	277
Aug.	41	100	168	209	219	196	143	74	46	282
Sep.	36	50	134	196	227	224	191	134	93	282
Oct.	33	33	95	174	223	237	225	183	150	270
Nov.	30	30	55	145	206	241	247	220	196	246
Dec.	29	29	41	132	198	241	254	233	212	234

20 Deg										
Column1	N	"NNE/ NNW"	"NE/ NW"	"ENE/ WNW"	"E/ W"	"ESE/ WSW"	"SE/ SW"	"SSE/ SSW"	S	HOR
Jan.	29	29	48	138	201	243	253	233	214	232
Feb.	31	31	88	173	226	244	238	201	174	263
Mar.	34	49	132	200	237	236	206	152	115	284
Apr.	38	92	166	213	228	208	158	91	58	287
May	47	123	184	217	217	184	124	54	42	283
June	59	135	189	216	210	173	108	45	42	279
July	48	124	182	213	212	179	119	53	43	278
Aug.	40	91	162	206	220	200	152	88	57	280
Sep.	36	46	127	191	225	225	199	148	114	275
Oct.	32	32	87	167	217	236	231	196	170	258
Nov.	29	29	48	136	197	239	249	229	211	230
Dec.	27	27	35	122	187	238	254	241	226	217

Table 16.6 : Maximum Solar Heat Gain Factor BTU/hr - sq.ft. (Contd.)

24 Deg										
Column1	N	"NNE/ NNW"	"NE/ NW"	"ENE/ WNW"	"E/ W"	"ESE/ WSW"	"SE/ SW"	"SSE/ SSW"	S	HOR
Jan.	27	27	41	128	190	240	253	241	227	214
Feb.	30	30	80	165	220	244	243	213	192	249
Mar.	34	45	124	195	234	237	214	168	137	275
Apr.	37	88	159	209	228	212	169	107	75	283
May	43	117	178	214	218	190	132	67	46	282
June	55	127	184	214	212	179	117	55	43	279
July	45	116	176	210	213	185	129	65	46	278
Aug.	38	87	156	203	220	204	162	103	72	277
Sep.	35	42	119	185	222	225	206	163	134	266
Oct.	31	31	79	159	211	237	235	207	187	244
Nov.	27	27	42	126	187	236	249	237	224	213
Dec.	26	26	29	112	180	234	247	247	237	199

28 Deg										
Column1	N	"NNE/ NNW"	"NE/ NW"	"ENE/ WNW"	"E/ W"	"ESE/ WSW"	"SE/ SW"	"SSE/ SSW"	S	HOR
Jan.	25	25	35	117	183	235	251	247	238	196
Feb.	29	29	72	157	213	244	246	224	207	234
Mar.	33	41	116	189	231	237	221	182	157	265
Apr.	36	84	151	205	228	216	178	124	94	278
May	40	115	172	211	219	195	144	83	58	280
June	51	125	178	211	213	184	128	68	49	278
July	41	114	170	208	215	190	140	80	57	276
Aug.	38	83	149	199	220	207	172	120	91	272
Sep.	34	38	111	179	219	226	213	177	154	256
Oct.	30	30	71	151	204	236	238	217	202	229
Nov.	26	26	35	115	181	232	247	243	235	195
Dec.	24	24	24	99	172	227	248	251	246	179

32 Deg										
Column1	N	"NNE/ NNW"	"NE/ NW"	"ENE/ WNW"	"E/ W"	"ESE/ WSW"	"SE/ SW"	"SSE/ SSW"	S	HOR
Jan.	24	24	29	105	175	229	249	250	246	176
Feb.	27	27	65	149	205	242	248	232	221	217
Mar.	32	37	107	183	227	237	227	195	176	252
Apr.	36	80	146	200	227	219	187	141	115	271
May	38	111	170	208	220	199	155	99	74	277
June	44	122	176	208	214	189	139	83	60	276
July	40	111	167	204	215	164	150	96	72	273
Aug.	37	79	141	195	219	210	181	136	111	265
Sep.	33	35	103	173	215	227	218	189	171	244
Oct.	28	28	63	143	195	234	239	225	215	213
Nov.	24	24	29	103	173	225	245	246	243	175
Dec.	22	22	22	84	162	218	246	252	252	158

Table 16.6 : Maximum Solar Heat Gain Factor BTU/hr - sq.ft. (Contd.)

36 Deg										
Column1	N	"NNE/ NNW"	"NE/ NW"	"ENE/ WNW"	"E/ W"	"ESE/ WSW"	"SE/ SW"	"SSE/ SSW"	S	HOR
Jan.	22	22	24	90	166	219	247	252	252	155
Feb.	26	26	57	139	195	239	248	239	232	199
Mar.	30	33	99	176	223	238	232	206	192	238
Apr.	35	76	144	196	225	221	196	156	135	262
May	38	107	168	204	220	204	165	116	93	272
June	47	118	175	205	215	194	150	99	77	273
July	39	107	165	201	216	199	161	113	90	268
Aug.	36	75	138	190	218	212	189	151	131	257
Sep.	31	31	95	167	210	228	223	200	187	230
Oct.	27	27	56	133	187	230	239	231	225	195
Nov.	22	22	24	87	163	215	243	248	248	154
Dec.	20	20	20	69	151	204	241	253	254	136

40 Deg										
Column1	N	"NNE/ NNW"	"NE/ NW"	"ENE/ WNW"	"E/ W"	"ESE/ WSW"	"SE/ SW"	"SSE/ SSW"	S	HOR
Jan.	20	20	20	74	154	205	241	252	254	133
Feb.	24	24	50	129	186	234	246	244	241	180
Mar.	29	29	93	169	218	238	236	216	206	223
Apr.	34	71	140	190	224	223	203	170	154	252
May	37	102	165	202	220	208	175	133	113	265
June	48	113	172	205	216	199	161	116	95	267
July	38	102	163	198	216	203	170	129	109	262
Aug.	35	71	135	185	216	214	196	165	149	247
Sep.	20	30	87	160	203	227	226	209	200	215
Oct.	25	25	49	123	180	225	238	236	234	177
Nov.	20	20	20	73	151	201	237	248	250	132
Dec.	18	18	18	60	135	188	232	249	253	113

44 Deg										
Column1	N	"NNE/ NNW"	"NE/ NW"	"ENE/ WNW"	"E/ W"	"ESE/ WSW"	"SE/ SW"	"SSE/ SSW"	S	HOR
Jan.	17	17	17	64	138	189	232	248	252	109
Feb.	22	22	43	117	178	227	246	248	247	160
Mar.	27	27	87	162	211	236	238	224	218	206
Apr.	33	66	136	185	221	224	210	183	171	240
May	36	96	162	201	219	211	183	148	132	257
June	47	108	169	205	215	203	171	132	115	261
July	37	96	159	198	215	206	179	144	128	254
Aug.	34	66	132	180	214	215	202	177	165	236
Sep.	28	28	80	152	198	226	227	216	211	199
Oct.	23	23	42	111	171	217	237	240	239	157
Nov.	18	18	18	64	135	186	227	244	248	109
Dec.	15	15	15	49	115	175	217	240	246	89

Table 16.6 : Maximum Solar Heat Gain Factor BTU/hr - sq.ft. (Contd.)

48 Deg										
Column1	N	"NNE/ NNW"	"NE/ NW"	"ENE/ WNW"	"E/ W"	"ESE/ WSW"	"SE/ SW"	"SSE/ SSW"	S	HOR
Jan.	15	15	15	53	118	175	216	239	245	85
Feb.	20	20	36	103	168	216	242	249	250	138
Mar.	26	26	80	154	204	234	239	232	228	188
Apr.	31	61	132	180	219	225	215	194	186	226
May	35	97	158	200	218	214	192	163	150	247
June	46	110	165	204	215	206	180	148	134	252
July	37	96	156	196	214	209	187	158	146	244
Aug.	33	61	128	174	211	216	208	188	180	223
Sep.	27	27	72	144	191	223	228	223	220	182
Oct.	21	21	35	96	161	207	233	241	242	136
Nov.	15	15	15	52	115	172	212	234	240	85
Dec.	13	13	13	36	91	156	195	225	233	65

52 Deg										
Column1	N	"NNE/ NNW"	"NE/ NW"	"ENE/ WNW"	"E/ W"	"ESE/ WSW"	"SE/ SW"	"SSE/ SSW"	S	HOR
Jan.	13	13	13	39	92	155	193	222	230	62
Feb.	18	18	29	85	156	202	235	247	250	115
Mar.	24	24	73	145	196	230	239	238	236	169
Apr.	30	56	128	177	215	224	220	204	199	211
May	34	98	154	198	217	217	199	175	167	235
June	45	111	161	202	214	210	188	162	152	242
July	36	97	152	194	213	212	195	171	163	233
Aug.	32	56	124	169	208	216	212	197	193	208
Sep.	25	25	65	136	182	218	228	228	227	163
Oct.	19	19	28	80	148	192	225	238	240	114
Nov.	13	13	13	39	90	152	189	217	225	62
Dec.	10	10	10	19	73	127	172	199	209	42

56 Deg										
Column1	N	"NNE/ NNW"	"NE/ NW"	"ENE/ WNW"	"E/ W"	"ESE/ WSW"	"SE/ SW"	"SSE/ SSW"	S	HOR
Jan.	10	10	10	21	74	126	169	194	205	40
Feb.	16	16	21	71	139	184	223	239	244	91
Mar.	22	22	65	136	185	224	238	241	241	149
Apr.	28	58	123	173	211	223	223	213	210	195
May	36	99	149	195	215	218	206	187	181	222
June	53	111	160	199	213	213	196	174	168	231
July	37	98	147	192	211	214	201	183	177	221
Aug.	30	56	119	165	203	216	215	206	203	193
Sep.	23	23	58	126	171	211	227	230	231	144
Oct.	16	16	20	68	132	176	213	229	234	91
Nov.	10	10	10	21	72	122	165	190	200	40
Dec.	7	7	7	7	47	92	135	159	171	23

Table 16.6 : Maximum Solar Heat Gain Factor BTU/hr - sq.ft. (Contd.)

60 Deg										
Column1	N	"NNE/ NNW"	"NE/ NW"	"ENE/ WNW"	"E/ W"	"ESE/ WSW"	"SE/ SW"	"SSE/ SSW"	S	HOR
Jan.	7	7	7	7	46	88	130	152	164	21
Feb.	13	13	13	58	118	168	204	225	231	68
Mar.	20	20	56	125	173	215	234	241	242	128
Apr.	27	59	118	168	206	222	225	220	218	178
May	43	98	149	192	212	220	211	198	194	208
June	58	110	162	197	213	215	202	186	181	217
July	44	97	147	189	208	215	206	193	190	207
Aug.	28	57	114	161	199	214	217	213	211	176
Sep.	21	21	50	115	160	202	222	229	231	123
Oct.	14	14	14	56	111	159	193	215	221	67
Nov.	7	7	7	7	45	86	127	148	160	22
Dec.	4	4	4	4	16	51	76	100	107	9

64 Deg										
Column1	N	"NNE/ NNW"	"NE/ NW"	"ENE/ WNW"	"E/ W"	"ESE/ WSW"	"SE/ SW"	"SSE/ SSW"	S	HOR
Jan.	3	3	3	3	15	45	67	89	96	8
Feb.	11	11	11	43	89	144	177	202	210	45
Mar.	18	18	47	113	159	203	226	236	239	105
Apr.	25	59	113	163	201	219	225	225	224	160
May	48	97	150	186	211	220	215	207	204	192
June	62	114	162	193	213	216	208	196	193	230
July	49	96	148	186	207	215	211	202	200	192
Aug.	27	58	109	157	193	211	217	217	217	159
Sep.	19	19	43	103	148	189	213	224	227	101
Oct.	11	11	11	40	83	135	167	191	199	46
Nov.	4	4	4	4	15	44	66	87	93	8
Dec.	0	0	0	0	1	5	11	14	15	1

Max SHG for externally shaded glass (Based on Ground Reflectance of 0.2)										
Column1	N	"NNE/ NNW"	"NE/ NW"	"ENE/ WNW"	"E/ W"	"ESE/ WSW"	"SE/ SW"	"SSE/ SSW"	S	HOR
Jan.	31	31	31	32	34	36	37	37	38	16
Feb.	34	34	34	35	36	37	38	38	39	16
Mar.	36	36	37	38	39	40	40	39	39	19
Apr.	40	40	41	42	42	42	41	40	40	24
May	43	44	45	46	45	43	41	40	40	28
June	45	46	47	47	46	44	41	40	40	31
July	45	45	46	47	47	45	42	41	41	31
Aug.	42	42	43	45	46	45	43	42	42	28
Sep.	37	37	38	40	41	42	42	41	41	23
Oct.	34	34	34	36	38	39	40	40	40	19
Nov.	32	32	32	32	34	36	38	38	39	17
Dec.	30	30	30	31	32	34	36	37	37	15

Table 16.7.1 : CLF For Glass Without Interior Shading

Cooling Load Factors for Glass Without Interior Shading, North Latitudes																									
Fenestration Facing	Room Construction	Solar Time , hr																							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
"N (Shaded)"	L	0.17	0.14	0.11	0.09	0.08	0.33	0.42	0.48	0.56	0.63	0.71	0.76	0.8	0.82	0.82	0.79	0.79	0.84	0.61	0.48	0.38	0.31	0.25	0.2
	M	0.23	0.2	0.18	0.16	0.14	0.34	0.41	0.46	0.53	0.59	0.65	0.7	0.74	0.75	0.76	0.74	0.75	0.79	0.61	50	0.42	0.36	0.31	0.27
	H	0.25	0.23	0.21	0.2	0.19	0.38	0.45	0.49	0.55	0.6	0.65	0.69	0.72	0.72	0.72	0.7	0.7	0.75	0.57	0.46	0.39	0.34	0.31	0.28
NNE	L	0.06	0.05	0.04	0.03	0.03	0.26	0.43	0.47	0.44	0.41	0.4	0.39	0.39	0.38	0.36	0.33	0.3	0.26	0.2	0.16	0.13	0.1	0.08	0.07
	M	0.09	0.08	0.07	0.06	0.06	0.24	0.38	0.42	0.39	0.37	0.37	0.36	0.36	0.36	0.34	0.33	0.3	0.27	0.22	0.18	0.16	0.14	0.12	0.1
	H	0.11	0.1	0.09	0.09	0.08	0.26	0.39	0.42	0.39	0.36	0.35	0.34	0.34	0.33	0.32	0.31	0.28	0.25	0.21	0.18	0.16	0.14	0.13	0.12
NE	L	0.04	0.04	0.03	0.02	0.02	0.23	0.41	0.51	0.51	0.45	0.39	0.36	0.33	0.31	0.28	0.26	0.23	0.19	0.15	0.12	0.1	0.08	0.06	0.05
	M	0.07	0.06	0.06	0.05	0.04	0.21	0.36	0.44	0.45	0.4	0.36	0.33	0.31	0.3	0.28	0.26	0.24	0.21	0.17	0.15	0.13	0.11	0.09	0.08
	H	0.09	0.08	0.08	0.07	0.07	0.23	0.37	0.44	0.44	0.39	0.34	0.31	0.29	0.27	0.26	0.24	0.22	0.2	0.17	0.14	0.13	0.12	0.11	0.1
ENE	L	0.04	0.03	0.03	0.02	0.02	0.21	0.4	0.52	0.57	0.53	0.45	0.39	0.34	0.31	0.28	0.25	0.22	0.18	0.14	0.12	0.09	0.08	0.06	0.05
	M	0.07	0.06	0.05	0.05	0.04	0.2	0.35	0.45	0.49	0.47	0.41	0.36	0.33	0.3	0.28	0.26	0.23	0.2	0.17	0.14	0.12	0.11	0.09	0.08
	H	0.09	0.09	0.08	0.07	0.07	0.22	0.36	0.46	0.49	0.45	0.38	33	0.3	0.27	0.25	0.23	0.21	0.19	0.16	0.14	0.13	0.12	0.11	0.1
E	L	0.04	0.03	0.03	0.02	0.02	0.19	0.37	0.51	0.57	0.57	0.5	0.42	0.37	0.32	0.29	0.25	0.22	0.19	0.15	0.12	0.1	0.08	0.06	0.05
	M	0.07	0.06	0.06	0.05	0.05	0.18	0.33	0.44	0.5	0.51	0.46	0.39	0.35	0.31	0.29	0.26	0.23	0.21	0.17	0.15	0.13	0.11	0.1	0.08
	H	0.09	0.09	0.08	0.08	0.07	0.2	0.34	0.45	0.49	0.49	0.43	0.36	0.32	0.29	0.26	0.24	0.22	0.19	0.17	0.15	0.13	0.12	0.11	0.1
ESE	L	0.05	0.04	0.03	0.03	0.02	0.17	0.34	0.49	0.58	0.61	0.57	0.48	0.41	0.36	0.32	0.28	0.24	0.2	0.16	0.13	0.1	0.09	0.07	0.06
	M	0.08	0.07	0.06	0.05	0.05	0.16	0.31	0.43	0.51	0.54	0.51	0.44	0.39	0.35	0.32	0.29	0.26	0.22	0.19	0.16	0.14	0.12	0.11	0.09
	H	0.1	0.09	0.09	0.08	0.08	0.19	0.32	0.43	0.5	0.52	0.49	0.41	0.36	0.32	0.29	0.26	0.24	0.21	0.18	0.16	0.14	0.13	0.12	0.11
SE	L	0.05	0.04	0.04	0.03	0.03	0.13	0.28	0.43	0.55	0.62	0.63	0.57	0.48	0.42	0.37	0.33	0.28	0.24	0.19	0.15	0.12	0.1	0.08	0.07
	M	0.09	0.08	0.07	0.06	0.05	0.14	0.26	0.38	0.48	0.54	0.56	0.51	0.45	0.4	0.36	0.33	0.29	0.25	0.21	0.18	0.16	0.14	0.12	0.1
	H	0.11	0.1	0.1	0.09	0.08	0.17	0.28	0.4	0.49	0.53	0.53	0.48	0.41	0.36	0.33	0.3	0.27	0.24	0.2	0.18	0.16	0.14	0.13	0.12
SSE	L	0.07	0.05	0.04	0.04	0.03	0.06	0.15	0.29	0.43	0.55	0.63	0.64	0.6	0.52	0.45	0.4	0.35	0.29	0.23	0.18	0.15	0.12	0.1	0.08
	M	0.11	0.09	0.08	0.07	0.06	0.08	0.16	0.26	0.38	0.48	0.55	0.57	0.54	0.48	0.43	0.39	0.35	0.3	0.25	0.21	0.18	0.16	0.14	0.12
	H	0.12	0.11	0.11	0.1	0.09	0.12	0.19	0.29	0.4	0.49	0.54	0.55	0.51	0.44	0.39	0.35	0.31	0.27	0.23	0.2	0.18	0.16	0.15	0.13
S	L	0.08	0.07	0.05	0.04	0.04	0.06	0.09	0.14	0.22	0.34	0.48	0.59	0.65	0.65	0.59	0.5	0.43	0.36	0.28	0.22	0.18	0.15	0.12	0.1
	M	0.12	0.11	0.09	0.08	0.07	0.08	0.11	0.14	0.21	0.31	0.42	0.52	0.57	0.58	0.53	0.47	0.41	0.35	0.29	0.25	0.21	0.18	0.16	0.14
	H	0.13	0.12	0.12	0.11	0.1	0.11	0.14	0.17	0.24	0.33	0.43	0.51	0.56	0.55	0.5	0.43	0.37	0.32	0.26	0.22	0.2	0.18	0.16	0.15
SSW	L	0.1	0.08	0.07	0.06	0.05	0.06	0.09	0.11	0.15	0.19	0.27	0.39	0.52	0.62	0.67	0.65	0.58	0.46	0.36	0.28	0.23	0.19	0.15	0.12
	M	0.14	0.12	0.11	0.09	0.08	0.09	0.11	0.13	0.15	0.18	0.25	0.37	0.46	0.55	0.59	0.59	0.53	0.44	0.35	0.3	0.25	0.22	0.19	0.16
	H	0.15	0.14	0.13	0.12	0.11	0.12	0.14	0.16	0.18	0.21	0.27	0.35	0.46	0.53	0.57	0.55	0.49	0.4	0.32	0.26	0.23	0.2	0.18	0.16
SW	L	0.12	0.1	0.08	0.06	0.05	0.06	0.08	0.1	0.12	0.14	0.16	0.24	0.36	0.49	0.6	0.66	0.66	0.58	0.43	0.33	0.27	0.22	0.18	0.14
	M	0.15	0.14	0.12	0.1	0.09	0.09	0.1	0.12	0.13	0.15	0.17	0.23	0.33	0.44	0.53	0.58	0.59	0.53	0.41	0.33	0.28	0.24	0.21	0.18
	H	0.15	0.14	0.13	0.12	0.11	0.12	0.13	0.14	0.16	0.17	0.19	0.25	0.34	0.44	0.52	0.56	0.56	0.49	0.37	0.3	0.25	0.21	0.19	0.17
WSW	L	0.12	0.1	0.08	0.07	0.05	0.06	0.07	0.09	0.1	0.12	0.13	0.17	0.26	0.4	0.52	0.62	0.66	0.61	0.44	0.34	0.27	0.22	0.18	0.15
	M	0.15	0.13	0.12	0.1	0.09	0.09	0.1	0.11	0.12	0.13	0.14	0.17	0.24	0.35	0.46	0.54	0.58	0.55	0.42	0.34	0.28	0.24	0.21	0.18
	H	0.15	0.14	0.13	0.12	0.11	0.11	0.12	0.13	0.14	0.15	0.16	0.19	0.26	0.36	0.46	0.53	0.56	0.51	0.38	0.3	0.25	0.21	0.19	0.17
W	L	0.12	0.1	0.08	0.06	0.05	0.06	0.07	0.08	0.1	0.11	0.12	0.14	0.2	0.32	0.45	0.57	0.64	0.61	0.44	0.34	0.27	0.22	0.18	0.14
	M	0.15	0.13	0.11	0.1	0.09	0.09	0.09	0.1	0.11	0.12	0.13	0.14	0.19	0.29	0.4	0.5	0.56	0.55	0.41	0.33	0.27	0.23	0.2	0.17
	H	0.14	0.13	0.12	0.11	0.1	0.11	0.12	0.13	0.14	0.14	0.15	0.16	0.21	0.3	0.4	0.49	0.54	0.52	0.38	0.3	0.24	0.21	0.18	0.16
WNW	L	0.12	0.1	0.08	0.06	0.05	0.06	0.07	0.09	0.1	0.12	0.13	0.15	0.17	0.26	0.4	0.53	0.63	0.62	0.44	0.34	0.27	0.22	0.18	0.14
	M	0.15	0.13	0.11	0.1	0.09	0.09	0.1	0.11	0.12	0.13	0.14	0.15	0.17	0.24	0.35	0.47	0.53	0.55	0.41	0.33	0.27	0.23	0.2	0.17
	H	0.14	0.13	0.12	0.11	0.1	0.11	0.12	0.13	0.14	0.15	0.16	0.17	0.18	0.25	0.36	0.46	0.53	0.52	0.38	0.3	0.24	0.2	0.18	0.16
NW	L	0.11	0.09	0.08	0.06	0.05	0.06	0.08	0.1	0.12	0.14	0.16	0.17	0.19	0.23	0.33	0.47	0.59	0.6	0.42	0.33	0.26	0.21	0.17	0.14
	M	0.14	0.12	0.11	0.09	0.08	0.09	0.1	0.11	0.13	0.15	0.16	0.17	0.18	0.21	0.3	0.42	0.51	0.54	0.39	0.32	0.26	0.22	0.19	0.16
	H	0.14	0.12	0.11	0.1	0.1	0.1	0.12	0.13	0.15	0.16	0.18	0.18	0.19	0.22	0.3	0.41	0.5	0.51	0.36	0.29	0.23	0.2	0.17	0.15
NNW	L	0.12	0.09	0.08	0.06	0.05	0.07	0.11	0.14	0.18	0.22	0.25	0.27	0.29	0.3	0.33	0.44	0.57	0.62	0.44	0.33	0.26	0.21	0.17	0.14
	M	0.15	0.13	0.11	0.1	0.09	0.1	0.12	0.15	0.18	0.21	0.23	0.27	0.27	0.28	0.31	0.39	0.51	0.56	0.41	0.33	0.27	0.23	0.2	0.17
	H	0.14	0.13	0.12	0.11	0.1	0.12	0.15	0.17	0.2	0.23	0.25	0.26	0.28	0.28	0.31	0.38	0.49	0.53	0.38	0.3	0.25	0.21	0.18	0.16
HOR.	L	0.11	0.09	0.07	0.06	0.05	0.07	0.14	0.24	0.36	0.48	0.58	0.66	0.72	0.74	0.73	0.67	0.59	0.47	0.37	0.29	0.24	0.19	0.16	0.13
	M	0.16	0.14	0.12	0.11	0.09	0.11	0.16	0.24	0.33	0.43	0.52	0.59	0.64	0.67	0.66	0.62	0.56	0.47	0.38	0.32	0.28	0.24	0.21	0.18
	H	0.17	0.16	0.15	0.14	0.13	0.15	0.2	0.28	0.36	0.45	0.52	0.59	0.62	0.64	0.62	0.58	0.51	0.42	0.35	0.29	0.26	0.23	0.21	0.19

Table 16.7.2 Cooling Load Factors for Glass with Interior Shading, North Latitudes (All Room Constructions)

Fenestration Facing	Solar Time, hr																							
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
N	0.08	0.07	0.06	0.06	0.07	0.73	0.66	0.65	0.73	0.8	0.86	0.89	0.89	0.86	0.82	0.75	0.78	0.91	0.24	0.18	0.15	0.13	0.11	0.1
NNE	0.03	0.03	0.02	0.02	0.03	0.64	0.77	0.62	0.42	0.37	0.37	0.37	0.36	0.35	0.32	0.28	0.23	0.17	0.08	0.07	0.06	0.05	0.04	0.04
NE	0.03	0.02	0.02	0.02	0.02	0.56	0.76	0.74	0.58	0.37	0.29	0.27	0.26	0.24	0.22	0.2	0.16	0.12	0.06	0.05	0.04	0.04	0.03	0.03
ENE	0.03	0.02	0.02	0.02	0.02	0.52	0.76	0.8	0.71	0.52	0.31	0.26	0.24	0.22	0.2	0.18	0.15	0.11	0.06	0.05	0.04	0.04	0.03	0.03
E	0.03	0.02	0.02	0.02	0.02	0.47	0.72	0.8	0.76	0.62	0.41	0.27	0.24	0.22	0.2	0.17	0.14	0.11	0.06	0.05	0.05	0.04	0.03	0.03
ESE	0.03	0.03	0.02	0.02	0.02	0.41	0.67	0.79	0.8	0.72	0.54	0.34	0.27	0.24	0.21	0.19	0.15	0.12	0.07	0.06	0.05	0.04	0.04	0.03
SE	0.03	0.03	0.02	0.02	0.02	0.3	0.57	0.74	0.81	0.79	0.68	0.49	0.33	0.28	0.25	0.22	0.18	0.13	0.08	0.07	0.06	0.05	0.04	0.04
SSE	0.04	0.03	0.03	0.03	0.02	0.12	0.31	0.54	0.72	0.81	0.81	0.71	0.54	0.38	0.32	0.27	0.22	0.16	0.09	0.08	0.07	0.06	0.05	0.04
S	0.04	0.04	0.03	0.03	0.03	0.09	0.16	0.23	0.38	0.58	0.75	0.83	0.8	0.68	0.5	0.35	0.27	0.19	0.11	0.09	0.08	0.07	0.06	0.05
SSW	0.05	0.04	0.04	0.03	0.03	0.09	0.14	0.18	0.22	0.27	0.43	0.63	0.78	0.84	0.8	0.66	0.46	0.25	0.13	0.11	0.09	0.08	0.07	0.06
SW	0.05	0.05	0.04	0.04	0.03	0.07	0.11	0.14	0.16	0.19	0.22	0.38	0.59	0.75	0.83	0.81	0.69	0.45	0.16	0.12	0.1	0.09	0.07	0.06
WSW	0.05	0.05	0.04	0.04	0.03	0.07	0.1	0.12	0.14	0.16	0.17	0.23	0.44	0.64	0.78	0.84	0.78	0.55	0.16	0.12	0.1	0.09	0.07	0.06
W	0.05	0.05	0.04	0.04	0.03	0.06	0.09	0.11	0.13	0.15	0.16	0.17	0.31	0.53	0.72	0.82	0.81	0.61	0.16	0.12	0.1	0.08	0.07	0.06
WNW	0.05	0.05	0.04	0.03	0.03	0.07	0.1	0.12	0.14	0.16	0.17	0.18	0.22	0.43	0.65	0.8	0.84	0.66	0.16	0.12	0.1	0.08	0.07	0.06
NW	0.05	0.04	0.04	0.03	0.03	0.07	0.11	0.14	0.17	0.19	0.2	0.21	0.22	0.3	0.52	0.73	0.82	0.69	0.16	0.12	0.1	0.08	0.07	0.06
NNW	0.05	0.05	0.04	0.03	0.03	0.11	0.17	0.22	0.26	0.3	0.32	0.33	0.34	0.34	0.39	0.61	0.82	0.76	0.17	0.12	0.1	0.08	0.07	0.06
HOR.	0.06	0.05	0.04	0.04	0.03	0.12	0.27	0.44	0.59	0.72	0.81	0.85	0.85	0.81	0.71	0.58	0.42	0.25	0.14	0.12	0.1	0.08	0.07	0.06

Table 16.8 : Cooling Load Factors for Lights

“a” Classification for Lights

This table is based on rooms having an average amount of furnishings

"a"	Light Fixture and Ventilation Arrangements
0.45	"Recessed lights which are not vented Low air supply rate - less than 0.5 cfm/ft2 of floor area supply and return diffusers below ceiling"
0.55	"Recessed lights which are not vented Medium to high air supply rate - more than 0.5 cfm/ft2 of floor area Supply and return diffusers below ceiling or through ceiling space and grill"
0.65	"Vented light fixtures Medium to high air supply rate - more than 0.5 cfrn/ft2 of floor area Supply air jhrough ceiling or wall but return air flows around light fixtures and through ceiling space"
0.75	"Vented or free hanging lights Supply air through ceiling or wall but return air flows around light fixtures and through a ducted return"

“b” Classification for Lights

This table is based on floor covered with carpet and rubber pad. For floor covered with floor tile use letter designation in next row down with the same floor weight.

	Floor Construction and Floor Weight in-Pounds Per Square Foot of Floor Area				
Room Air Circulation and Type of Supply and Return	"2 in. Wooden floor 10 lb/ft2"	"3 in. Concrete floor 40 lb/ft2"	"6 in. Concrete floor 75 lb/ft2"	"8 in. Concrete floor 120 lb/ ft2"	"12 in. Concrete floor 160 lb/ ft2"
Low ventilation rate minimum required to handle cooling load. Supply through floor, wall or ceiling diffuser. Ceiling space not vented.	B	B	C	D	D
Medium ventilation rate. Supply through floor, wall or ceiling diffuser. Ceiling space not vented.	A	B	C	D	D
High room air circulation induced by primary air of induction unit or by fan coil unit. Return through ceiling space.	A	B	C	C	D
Very high room air circulation used to minimize room temperature gradients. Return through ceiling space.	A	A	B	C	D

Table 16.8.1 : Cooling Load Factors when Lights are on for 8 Hours

"a" Classification	"b" Classification	Number of hours after lights are turned on																							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
0.45	A	0.02	0.46	0.57	0.65	0.72	0.77	0.82	0.85	0.88	0.46	0.37	0.3	0.24	0.19	0.15	0.12	0.1	0.08	0.06	0.05	0.04	0.03	0.03	0.02
	B	0.07	0.51	0.56	0.61	0.65	0.68	0.71	0.74	0.77	0.34	0.31	0.28	0.25	0.22	0.2	0.18	0.16	0.15	0.13	0.12	0.11	0.1	0.09	0.08
	C	0.11	0.55	0.58	0.6	0.63	0.65	0.67	0.69	0.71	0.28	0.26	0.25	0.23	0.22	0.2	0.19	0.18	0.17	0.16	0.15	0.14	0.13	0.12	0.12
	D	0.14	0.58	0.6	0.61	0.62	0.63	0.64	0.65	0.66	0.22	0.22	0.21	0.2	0.2	0.19	0.19	0.18	0.18	0.17	0.16	0.16	0.16	0.15	0.15
0.55	A	0.01	0.56	0.65	0.72	0.77	0.85	0.85	0.88	0.9	0.37	0.3	0.24	0.19	0.16	0.13	0.1	0.08	0.07	0.05	0.04	0.03	0.03	0.02	0.02
	B	0.06	0.6	0.64	0.68	0.71	0.74	0.76	0.79	0.81	0.28	0.25	0.23	0.2	0.18	0.16	0.15	0.13	0.12	0.11	0.1	0.09	0.08	0.07	0.06
	C	0.09	0.63	0.66	0.68	0.7	0.71	0.73	0.75	0.76	0.23	0.21	0.2	0.19	0.18	0.17	0.16	0.15	0.14	0.13	0.12	0.11	0.11	0.1	0.1
	D	0.11	0.66	0.67	0.68	0.69	0.7	0.71	0.72	0.72	0.18	0.18	0.17	0.17	0.16	0.16	0.15	0.15	0.14	0.14	0.13	0.13	0.13	0.12	0.12
0.65	A	0.01	0.66	0.73	0.78	0.82	0.86	0.88	0.91	0.93	0.29	0.23	0.19	0.15	0.12	0.1	0.08	0.06	0.05	0.04	0.03	0.03	0.02	0.02	0.01
	B	0.04	0.69	0.72	0.75	0.77	0.8	0.82	0.84	0.85	0.22	0.19	0.18	0.16	0.14	0.13	0.12	0.1	0.09	0.08	0.08	0.07	0.06	0.06	0.05
	C	0.07	0.72	0.73	0.75	0.76	0.78	0.79	0.8	0.82	0.18	0.17	0.16	0.15	0.14	0.13	0.12	0.11	0.11	0.1	0.1	0.09	0.08	0.08	0.07
	D	0.09	0.73	0.74	0.75	0.76	0.77	0.77	0.78	0.79	0.14	0.14	0.13	0.13	0.13	0.12	0.12	0.11	0.11	0.11	0.1	0.1	0.1	0.1	0.09
0.75	A	0.01	0.76	0.8	0.84	0.87	0.9	0.92	0.93	0.95	0.21	0.17	0.13	0.11	0.09	0.07	0.06	0.05	0.04	0.03	0.02	0.02	0.02	0.01	0.01
	B	0.03	0.78	0.8	0.82	0.84	0.85	0.87	0.88	0.89	0.15	0.14	0.13	0.11	0.1	0.09	0.08	0.07	0.07	0.06	0.05	0.05	0.04	0.04	0.04
	C	0.05	0.8	0.81	0.82	0.83	0.84	0.85	0.86	0.87	0.13	0.12	0.11	0.1	0.1	0.09	0.09	0.08	0.08	0.07	0.07	0.06	0.06	0.06	0.05
	D	0.06	0.81	0.82	0.82	0.83	0.83	0.84	0.84	0.85	0.1	0.1	0.1	0.09	0.09	0.09	0.08	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.07

Table 16.8.2 : Cooling Load Factors when Lights are on for 10 Hours

"a" Classification	"b" Classification	Number of hours after lights are turned on																							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
0.45	A	0.03	0.47	0.58	0.66	0.73	0.78	0.82	0.86	0.88	0.91	0.93	0.49	0.39	0.32	0.26	0.21	0.17	0.13	0.11	0.09	0.07	0.06	0.05	0.04
	B	0.1	0.54	0.59	0.63	0.66	0.7	0.73	0.76	0.78	0.8	0.82	0.39	0.35	0.32	0.28	0.26	0.23	0.21	0.19	0.17	0.15	0.14	0.12	0.11
	C	0.15	0.59	0.61	0.64	0.66	0.68	0.7	0.72	0.73	0.75	0.76	0.33	0.31	0.29	0.27	0.26	0.24	0.23	0.21	0.2	0.19	0.18	0.17	0.16
	D	0.18	0.62	0.63	0.64	0.66	0.67	0.68	0.69	0.69	0.7	0.71	0.27	0.26	0.26	0.25	0.24	0.23	0.23	0.22	0.21	0.21	0.2	0.19	0.19
0.55	A	0.02	0.57	0.65	0.72	0.78	0.82	0.85	0.88	0.91	0.92	0.94	0.4	0.32	0.26	0.21	0.17	0.14	0.11	0.09	0.07	0.06	0.05	0.04	0.03
	B	0.08	0.62	0.66	0.69	0.73	0.75	0.78	0.8	0.82	0.84	0.85	0.32	0.29	0.26	0.23	0.21	0.19	0.17	0.15	0.14	0.12	0.11	0.1	0.09
	C	0.12	0.66	0.68	0.7	0.72	0.74	0.75	0.77	0.78	0.79	0.81	0.27	0.25	0.24	0.22	0.21	0.2	0.19	0.17	0.16	0.15	0.14	0.14	0.13
	D	0.15	0.69	0.7	0.71	0.72	0.73	0.73	0.74	0.75	0.76	0.76	0.22	0.22	0.21	0.2	0.2	0.19	0.18	0.18	0.17	0.17	0.16	0.16	0.15
0.65	A	0.02	0.66	0.73	0.78	0.83	0.86	0.89	0.91	0.93	0.94	0.95	0.31	0.25	0.2	0.16	0.13	0.11	0.08	0.07	0.05	0.04	0.04	0.03	0.02
	B	0.06	0.71	0.74	0.76	0.79	0.81	0.83	0.84	0.86	0.87	0.89	0.25	0.22	0.2	0.18	0.16	0.15	0.13	0.12	0.11	0.1	0.09	0.08	0.07
	C	0.09	0.74	0.75	0.77	0.78	0.8	0.81	0.82	0.83	0.84	0.85	0.21	0.2	0.18	0.17	0.16	0.15	0.14	0.14	0.13	0.12	0.11	0.11	0.1
	D	0.11	0.76	0.77	0.77	0.78	0.79	0.79	0.8	0.81	0.81	0.82	0.17	0.17	0.16	0.16	0.15	0.15	0.14	0.14	0.14	0.13	0.13	0.12	0.12
0.75	A	0.01	0.76	0.81	0.84	0.88	0.9	0.92	0.93	0.95	0.96	0.97	0.22	0.18	0.14	0.12	0.09	0.08	0.06	0.05	0.04	0.03	0.03	0.02	0.02
	B	0.04	0.79	0.81	0.83	0.85	0.86	0.88	0.89	0.9	0.91	0.92	0.18	0.16	0.14	0.13	0.12	0.1	0.09	0.08	0.08	0.07	0.06	0.06	0.05
	C	0.07	0.81	0.82	0.83	0.84	0.85	0.86	0.87	0.88	0.89	0.89	0.15	0.14	0.13	0.12	0.12	0.11	0.1	0.1	0.09	0.09	0.08	0.08	0.07
	D	0.08	0.83	0.83	0.84	0.84	0.85	0.85	0.86	0.86	0.87	0.87	0.12	0.12	0.12	0.11	0.11	0.11	0.1	0.1	0.1	0.09	0.09	0.09	0.09

Table 16.8.3 : Cooling Load Factors when Lights Are on for 12 Hours

"a" Classification	"b" Classification	Number of hours after lights are turned on																							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
0.45	A	0.05	0.49	0.59	0.67	0.73	0.78	0.83	0.86	0.89	0.91	0.93	0.94	0.95	0.51	0.41	0.33	0.27	0.22	0.17	0.14	0.11	0.09	0.07	0.06
	B	0.13	0.57	0.61	0.65	0.69	0.72	0.75	0.77	0.79	0.82	0.83	0.85	0.87	0.43	0.39	0.35	0.31	0.28	0.25	0.23	0.21	0.18	0.17	0.15
	C	0.19	0.63	0.65	0.67	0.69	0.71	0.73	0.74	0.76	0.77	0.79	0.8	0.81	0.37	0.35	0.33	0.31	0.29	0.27	0.26	0.24	0.23	0.21	0.2
	D	0.22	0.66	0.67	0.68	0.69	0.7	0.71	0.72	0.73	0.74	0.74	0.75	0.76	0.32	0.31	0.3	0.29	0.28	0.27	0.26	0.26	0.25	0.24	0.23
0.55	A	0.04	0.58	0.66	0.73	0.78	0.82	0.86	0.89	0.91	0.93	0.94	0.95	0.96	0.42	0.34	0.27	0.22	0.18	0.14	0.11	0.09	0.07	0.06	0.05
	B	0.11	0.65	0.68	0.72	0.74	0.77	0.79	0.81	0.83	0.85	0.86	0.88	0.89	0.35	0.32	0.28	0.26	0.23	0.21	0.19	0.17	0.15	0.14	0.12
	C	0.15	0.69	0.71	0.73	0.75	0.76	0.78	0.79	0.8	0.81	0.83	0.84	0.85	0.3	0.29	0.27	0.25	0.24	0.22	0.21	0.2	0.19	0.17	0.16
	D	0.18	0.72	0.73	0.74	0.75	0.76	0.76	0.77	0.78	0.78	0.79	0.8	0.8	0.26	0.25	0.24	0.24	0.23	0.22	0.22	0.21	0.2	0.2	0.19
0.65	A	0.03	0.67	0.74	0.79	0.83	0.86	0.89	0.91	0.93	0.94	0.95	0.96	0.97	0.33	0.26	0.21	0.17	0.14	0.11	0.09	0.07	0.06	0.05	0.04
	B	0.09	0.73	0.75	0.78	0.8	0.82	0.84	0.85	0.87	0.88	0.89	0.9	0.91	0.27	0.25	0.22	0.2	0.18	0.16	0.15	0.13	0.12	0.11	0.1
	C	0.12	0.76	0.78	0.79	0.8	0.81	0.83	0.84	0.85	0.86	0.86	0.87	0.88	0.24	0.22	0.21	0.2	0.19	0.17	0.16	0.15	0.14	0.14	0.13
	D	0.14	0.79	0.79	0.8	0.8	0.81	0.82	0.82	0.83	0.83	0.84	0.84	0.85	0.2	0.2	0.19	0.18	0.18	0.17	0.17	0.16	0.16	0.15	0.15
0.75	A	0.02	0.77	0.81	0.85	0.88	0.9	0.92	0.94	0.95	0.96	0.97	0.97	0.98	0.23	0.19	0.15	0.12	0.1	0.08	0.06	0.06	0.04	0.03	0.03
	B	0.06	0.81	0.82	0.84	0.86	0.87	0.88	0.9	0.91	0.92	0.92	0.93	0.94	0.19	0.18	0.16	0.14	0.13	0.12	0.1	0.1	0.08	0.08	0.07
	C	0.09	0.83	0.84	0.85	0.86	0.87	0.88	0.88	0.89	0.9	0.9	0.91	0.91	0.17	0.16	0.15	0.14	0.13	0.12	0.12	0.12	0.1	0.1	0.09
	D	0.1	0.85	0.85	0.86	0.86	0.86	0.87	0.87	0.88	0.88	0.88	0.89	0.89	0.14	0.14	0.14	0.13	0.13	0.12	0.12	0.12	0.11	0.11	0.11

Table 16.8.4 : Cooling Load Factors when Lights Are on for 14 Hours

"a" Class-ification	"b" Class-ification	Number of hours after lights are turned on																							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
0.45	A	0.07	0.51	0.61	0.68	0.74	0.79	0.83	0.87	0.89	0.91	0.93	0.94	0.95	0.96	0.97	0.53	0.42	0.34	0.27	0.22	0.18	0.14	0.12	0.09
	B	0.18	0.61	0.65	0.68	0.72	0.74	0.77	0.79	0.81	0.83	0.85	0.86	0.88	0.89	0.9	0.46	0.41	0.37	0.34	0.3	0.27	0.24	0.22	0.2
	C	0.24	0.67	0.69	0.71	0.73	0.74	0.76	0.77	0.79	0.8	0.81	0.82	0.83	0.84	0.85	0.41	0.39	0.36	0.34	0.32	0.3	0.28	0.27	0.25
	D	0.26	0.71	0.72	0.72	0.73	0.74	0.75	0.76	0.77	0.78	0.78	0.79	0.8	0.8	0.8	0.36	0.35	0.34	0.33	0.32	0.31	0.3	0.29	0.28
0.55	A	0.06	0.69	0.68	0.74	0.79	0.83	0.86	0.89	0.91	0.93	0.94	0.95	0.96	0.97	0.98	0.43	0.35	0.28	0.22	0.18	0.15	0.12	0.09	0.08
	B	0.15	0.68	0.71	0.74	0.77	0.79	0.81	0.83	0.85	0.86	0.88	0.89	0.9	0.91	0.92	0.38	0.34	0.31	0.27	0.25	0.22	0.2	0.18	0.16
	C	0.19	0.73	0.75	0.76	0.78	0.79	0.8	0.81	0.83	0.84	0.85	0.86	0.86	0.87	0.88	0.34	0.32	0.3	0.28	0.26	0.25	0.23	0.22	0.21
	D	0.22	0.76	0.77	0.77	0.78	0.79	0.79	0.8	0.81	0.81	0.82	0.82	0.83	0.83	0.84	0.29	0.28	0.28	0.27	0.26	0.25	0.24	0.24	0.23
0.65	A	0.05	0.69	0.75	0.8	0.84	0.87	0.89	0.92	0.93	0.95	0.96	0.96	0.97	0.98	0.98	0.34	0.27	0.22	0.17	0.14	0.11	0.09	0.07	0.06
	B	0.11	0.75	0.78	0.8	0.82	0.64	0.85	0.87	0.88	0.89	0.9	0.91	0.92	0.93	0.94	0.29	0.26	0.24	0.21	0.19	0.17	0.16	0.14	0.13
	C	0.15	0.79	0.8	0.82	0.83	0.84	0.85	0.86	0.86	0.87	0.88	0.89	0.89	0.9	0.91	0.26	0.25	0.23	0.22	0.2	0.19	0.18	0.17	0.16
	D	0.17	0.81	0.82	0.82	0.83	0.83	0.84	0.84	0.85	0.85	0.86	0.86	0.87	0.87	0.87	0.23	0.22	0.21	0.21	0.2	0.2	0.19	0.18	0.18
0.75	A	0.03	0.78	0.82	0.86	0.88	0.91	0.92	0.94	0.95	0.96	0.97	0.97	0.98	0.98	0.99	0.24	0.19	0.16	0.12	0.1	0.08	0.07	0.05	0.04
	B	0.08	0.82	0.84	0.86	0.87	0.88	0.9	0.91	0.92	0.92	0.93	0.94	0.94	0.95	0.96	0.21	0.19	0.17	0.15	0.14	0.12	0.11	0.1	0.09
	C	0.11	0.85	0.86	0.87	0.88	0.88	0.89	0.9	0.9	0.91	0.91	0.92	0.92	0.93	0.93	0.19	0.18	0.17	0.16	0.15	0.14	0.13	0.12	0.11
	D	0.12	0.87	0.87	0.87	0.88	0.88	0.89	0.89	0.89	0.9	0.9	0.9	0.9	0.91	0.91	0.16	0.16	0.15	0.15	0.14	0.14	0.14	0.13	0.13

Table 16.8.5 : Cooling Load Factors when Lights Are on for 16 Hours

"a" Class-ification	"b" Class-ification	Number of hours after lights are turned on																							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
0.45	A	0.12	0.54	0.63	0.7	0.76	0.81	0.85	0.88	0.9	0.92	0.94	0.95	0.96	0.97	0.97	0.98	0.98	0.54	0.43	0.35	0.28	0.23	0.18	0.15
	B	0.23	0.66	0.69	0.72	0.75	0.78	0.8	0.82	0.84	0.85	0.87	0.88	0.89	0.9	0.91	0.92	0.93	0.49	0.44	0.39	0.35	0.32	0.29	0.26
	C	0.29	0.72	0.74	0.75	0.77	0.78	0.8	0.81	0.82	0.83	0.84	0.85	0.86	0.87	0.88	0.88	0.89	0.45	0.42	0.39	0.37	0.35	0.33	0.31
	D	0.31	0.75	0.76	0.77	0.77	0.78	0.79	0.79	0.8	0.81	0.81	0.82	0.82	0.83	0.83	0.84	0.84	0.4	0.39	0.37	0.36	0.35	0.34	0.33
0.55	A	0.1	0.63	0.7	0.76	0.81	0.84	0.87	0.9	0.92	0.93	0.95	0.96	0.97	0.97	0.98	0.98	0.99	0.44	0.35	0.28	0.23	0.18	0.15	0.12
	B	0.19	0.72	0.75	0.77	0.8	0.82	0.84	0.85	0.87	0.88	0.89	0.9	0.91	0.92	0.93	0.94	0.94	0.4	0.36	0.32	0.29	0.26	0.24	0.21
	C	0.24	0.77	0.79	0.8	0.81	0.82	0.83	0.84	0.85	0.86	0.87	0.88	0.88	0.89	0.9	0.9	0.91	0.37	0.34	0.32	0.3	0.29	0.27	0.25
	D	0.26	0.8	0.8	0.81	0.82	0.82	0.83	0.83	0.84	0.84	0.85	0.85	0.86	0.86	0.86	0.87	0.97	0.33	0.32	0.31	0.3	0.29	0.28	0.27
0.65	A	0.07	0.71	0.77	0.81	0.85	0.88	0.9	0.92	0.94	0.95	0.96	0.97	0.97	0.98	0.98	0.99	0.99	0.34	0.27	0.22	0.18	0.14	0.12	0.09
	B	0.15	0.78	0.81	0.82	0.84	0.86	0.87	0.88	0.9	0.91	0.92	0.92	0.93	0.94	0.94	0.95	0.96	0.31	0.28	0.25	0.23	0.2	0.18	0.16
	C	0.18	0.82	0.83	0.84	0.85	0.86	0.87	0.88	0.89	0.89	0.9	0.9	0.91	0.92	0.92	0.93	0.93	0.28	0.27	0.25	0.24	0.22	0.21	0.2
	D	0.2	0.84	0.85	0.85	0.86	0.86	0.87	0.87	0.87	0.88	0.88	0.88	0.89	0.89	0.89	0.9	0.9	0.25	0.25	0.24	0.23	0.22	0.22	0.21
0.75	A	0.05	0.79	0.83	0.87	0.89	0.91	0.93	0.94	0.95	0.96	0.97	0.98	0.98	0.98	0.99	0.99	0.99	0.24	0.2	0.16	0.13	0.1	0.08	0.07
	B	0.11	0.85	0.86	0.87	0.89	0.9	0.91	0.92	0.93	0.93	0.94	0.95	0.95	0.96	0.96	0.96	0.97	0.22	0.2	0.18	0.16	0.15	0.13	0.12
	C	0.13	0.87	0.88	0.89	0.89	0.9	0.91	0.91	0.92	0.92	0.93	0.93	0.94	0.94	0.94	0.95	0.95	0.2	0.19	0.18	0.17	0.16	0.15	0.14
	D	0.14	0.89	0.89	0.89	0.9	0.9	0.9	0.91	0.91	0.91	0.91	0.92	0.92	0.92	0.92	0.93	0.93	0.18	0.18	0.17	0.17	0.16	0.16	0.15

Table 16.8.6 : Sensible Heat Cooling Load Factor for people

Total Hours In Space	Hours after Each Entry Into Space																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
2	0.49	0.58	0.17	0.13	0.1	0.08	0.07	0.06	0.05	0.04	0.04	0.03	0.03	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
4	0.49	0.59	0.66	0.71	0.27	0.21	0.16	0.14	0.11	0.1	0.08	0.07	0.06	0.06	0.05	0.04	0.04	0.03	0.03	0.03	0.02	0.02	0.02	0.01
6	0.5	0.6	0.67	0.72	0.76	0.79	0.34	0.26	0.21	0.18	0.15	0.13	0.11	0.1	0.08	0.07	0.06	0.06	0.05	0.04	0.04	0.03	0.03	0.03
8	0.51	0.61	0.67	0.72	0.76	0.8	0.82	0.84	0.38	0.3	0.25	0.21	0.18	0.15	0.13	0.12	0.1	0.09	0.08	0.07	0.06	0.05	0.05	0.04
10	0.53	0.62	0.69	0.74	0.77	0.8	0.83	0.85	0.87	0.89	0.42	0.34	0.28	0.23	0.2	0.17	0.15	0.13	0.11	0.1	0.09	0.08	0.07	0.06
12	0.55	0.64	0.7	0.75	0.79	0.81	0.84	0.86	0.88	0.89	0.91	0.92	0.45	0.36	0.3	0.25	0.21	0.19	0.16	0.14	0.12	0.11	0.09	0.08
14	0.58	0.66	0.72	0.77	0.8	0.83	0.85	0.87	0.89	0.9	0.91	0.92	0.93	0.94	0.47	0.38	0.31	0.26	0.23	0.2	0.17	0.15	0.13	0.11
16	0.62	0.7	0.75	0.79	0.82	0.85	0.87	0.88	0.9	0.91	0.92	0.93	0.94	0.95	0.95	0.96	0.49	0.39	0.33	0.28	0.24	0.2	0.18	0.16
18	0.66	0.74	0.79	0.82	0.85	0.87	0.89	0.9	0.92	0.93	0.94	0.94	0.95	0.96	0.96	0.97	0.97	0.97	0.5	0.4	0.33	0.28	0.24	0.21

Table 16.9 : Rate of Heat Gain from occupants of conditioned spaces

Degree of Activity	Typical Application	"ADULT MALE Total ($q_{s/person}+q_{l/person}$)"		"ADJUSTED GROUP Total ($q_{s/person}+q_{l/person}$)"		"ADJUSTED GROUP Sensible $q_{s/person}$"		"ADJUSTED GROUP Latent $q_{l/person}$"	
		Watts	Btu/hr	Watts	Btu/hr	Watts	Btu/hr	Watts	Btu/hr
Seated at rest	Theatre, movie	115	400	100	350	60	210	40	140
Seated, very light work (writing)	Offices, hotels, apts	140	480	120	420	65	230	55	190
Seated, eating	Restaurant	150	520	170	580	75	255	95	325
Seated, light work, typing	Offices, hotels, apts	185	640	150	510	75	255	75	255
Standing, light work or walking slowly	Retail store, bank	235	800	185	640	90	315	95	325
Light bench work	Factory	255	880	230	780	100	345	130	435
Walking, 3 mph, light machine work	Factory	305	1040	305	1040	100	345	205	695
Bowling	Bowling alley	350	1200	280	960	100	345	180	615
Moderate dancing	Dance hall	400	1360	375	1280	120	405	255	875
Heavy work, heavy machine work, lifting	Factory	470	1600	470	1600	165	565	300	1035
Heavy work, athletics	Gymnasium	585	2000	525	1800	185	635	340	1165

NOTE: Refer tables from 10 and select accordingly from this Table

Shading ratio from A-3I	Shading Coefficient Multiples
From 0 to 0.176	0.51
From 0.176 to 0.314	0.42
From 0.314 to 0.577	0.31
From 0.577 and above	0.18

Table 16.10 : Shadow Lengths and Shadow Widths for Building Exterior Projections

DATE	"SOLAR TIME AM"	"HORIZONTAL PROJECTION SHADOW LENGTH, FOOT PER FOOT PROJECTION" 0.0 DEG NORTH LATITUDE												"SIDE PROJECTION SHADOW WIDTH, FOOT PER FOOT PROJECTION" 0.0 DEG NORTH LATITUDE											TIME
		N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	PM
DEC	7			0.7	0.4	0.3	0.2	0.3	0.3	0.6	8.1					2.6	1.1	0.4	0	0.4	0.9	2.2	34			5
	8			1.7	0.8	0.6	0.5	0.6	0.7	1.2	7.1					3	1.2	0.5	0.1	0.3	0.9	2	13.9			4
	9			3.7	1.4	1	0.9	0.9	1	1.6	5.7					4.2	1.4	0.6	0.2	0.2	0.7	1.6	6.3			3
	10			19.1	2.9	1.7	1.4	1.3	1.5	2	4					14.1	2	0.9	0.3	0.1	0.5	1.2	2			2
	11				14.3	3.7	2.4	2	2	2.2	3.3	8.1					6.8	1.7	0.7	0.3	0.1	0.6	1.3	4		1
	12						6.3	3.3	2.5	2.4	2.5	3.3	6.3						2.4	1	0.4	0	0.4	1	2.4	12
JAN/ NOV	7		8.1	0.6	0.3	0.3	0.2	0.3	0.4	0.7					30.9	2.2	0.9	0.4	0	0.5	1	2.7				5
	8			1.4	0.8	0.6	0.5	0.6	0.8	1.4	57.3					2.4	1	0.4	0	0.4	1	2.4				4
	9			2.9	1.4	1	0.9	0.9	1.2	2	11.4					3.1	1.2	0.5	0.1	0.3	0.8	1.9	12.1			3
	10			9.5	2.7	1.7	1.4	1.4	1.7	2.4	6.3					6.4	1.6	0.7	0.2	0.2	0.6	1.4	4.1			2
	11				9.5	3.7	2.6	2.1	2.2	2.6	4	14.3					4.4	1.4	0.6	0.2	0.2	0.7	1.6	5.9		1
	12						7.1	4	2.9	2.7	2.9	4.4	7.1						2.4	1	0.4	0	0.4	1	2.4	12
FEB/ OCT	7		1.3	0.5	0.3	0.3	0.3	0.3	0.5	1.4					5	1.5	0.7	0.2	0.2	0.7	1.5	5.1				5
	8		3.3	1	0.7	0.6	0.6	0.7	1	2.6					5.6	1.6	0.7	0.2	0.2	0.6	1.4	4.5				4
	9		7.1	2	1.2	1	1	1.1	1.6	3.7					7.7	1.7	0.8	0.3	0.1	0.6	1.3	3.7				3
	10		57.3	4	2.2	1.7	1.6	1.8	2.4	4.7					35.4	2.2	0.9	0.4	0	0.4	1.1	2.6				2
	11			19.1	5.7	3.7	3.1	3.1	3.5	5.1	11.4					6.6	1.7	0.7	0.2	0.2	0.6	1.4	4			1
	12						14.3	7.1	5.7	5.1	5.7	7.1	14.3						2.4	1	0.4	0	0.4	1	2.4	12
MAR/ SEP	7		0.7	0.4	0.3	0.3	0.3	0.4	0.7						2.4	1	0.4	0	0.4	1	2.4					5
	8		1.5	0.8	0.6	0.6	0.6	0.8	1.5						2.4	1	0.4	0	0.4	1	2.4					4
	9		2.6	1.4	1.1	1	1.1	1.4	2.6						2.4	1	0.4	0	0.4	1	2.4					3
	10		4.7	2.5	1.9	1.7	1.9	2.5	4.7						2.4	1	0.4	0	0.4	1	2.4					2
	11		9.5	5.1	4	3.7	4	5.1	9.5						2.4	1	0.4	0	0.4	1	2.4					1
	12														2.4	1	0.4	0	0.4	1	2.4					12
APR/ AUG	7	1.3	0.5	0.3	0.3	0.3	0.3	0.5	1.4					4.7	1.5	0.6	0.2	0.2	0.7	1.5	5.4					5
	8	2.5	1	0.6	0.6	0.6	0.7	1.1	3.5					4.2	1.4	0.6	0.2	0.2	0.7	1.6	6.2					4
	9	3.5	1.5	1.1	1	1	1.2	2	8.1					3.4	1.2	0.6	0.1	0.3	0.8	1.8	9					3
	10	4.3	2.2	1.7	1.6	1.7	2.2	4						2.4	1	0.4	0	0.4	1	2.4						2
	11	4.7	3.3	2.9	3.1	3.7	6.3	28.6						1.3	0.6	0.1	0.3	0.8	1.8	8.7						1
	12	4.7	5.1	7.1	14.3									0	0.4	1	2.4									12
MAY/ JUL	7	0.7	0.4	0.3	0.2	0.3	0.3	0.6	8.1					2.7	1.1	0.5	0	0.4	0.9	2.2	30.9					5
	8	1.4	0.8	0.6	0.5	0.6	0.8	1.4						2.4	1	0.4	0	0.4	1	2.4						4
	9	2	1.2	0.9	0.9	1	1.4	2.9						1.9	0.8	0.3	0.1	0.5	1.2	3.1						3
	10	2.4	1.7	1.4	1.4	1.7	2.7	9.5						1.4	0.6	0.2	0.2	0.7	1.6	6.4						2
	11	2.6	2.2	2.1	2.6	3.7	9.5							0.7	0.2	0.2	0.6	1.4	4.4							1
	12	2.7	2.9	4	7.1									0	0.4	1	2.4									12
JUN	7	0.6	0.3	0.3	0.2	0.3	0.4	0.7						2.2	0.9	0.4	0	0.4	1.1	2.6						5
	8	1.2	0.7	0.6	0.5	0.6	0.8	1.7						2	0.9	0.3	0.1	0.5	1.2	3						4
	9	1.6	1	0.9	0.9	1	1.4	3.7						1.6	0.7	0.2	0.2	0.6	1.4	4.2						3
	10	2	1.5	1.3	1.4	1.7	2.9	19.1						1.2	0.5	0.1	0.3	0.9	2	14.1						2
	11	2.2	2	2	2.4	3.7	14.3							0.6	0.1	0.3	0.7	1.7	6.8							1
	12	2.4	2.5	3.3	6.3									0	0.4	1	2.4									12
		N	NNW	NW	WNW	W	WSW	SW	SSW	S	SSE	SE	ESE	N	NNW	NW	WNW	W	WSW	SW	SSW	S	SSE	SE	ESE	PM

Table 16.10 : Shadow Lengths and Shadow Widths for Building Exterior Projections(contd.)

DATE	"SOLAR TIME AM"	"HORIZONTAL PROJECTION 8.0 DEG NORTH LATITUDE SHADOW LENGTH, FOOT PER FOOT PROJECTION"												"SIDE PROJECTION 8.0 DEG NORTH LATITUDE SHADOW WIDTH, FOOT PER FOOT PROJECTION"											"TIME PM"
		N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	
DEC	7			0.6	0.3	0.2	0.2	0.2	0.2	0.4	3.3					2.9	1.1	0.5	0.1	0.3	0.9	2.1	17.7			5
	8			1.7	0.7	0.5	0.4	0.4	0.6	0.9	3.3					3.7	1.3	0.6	0.1	0.3	0.8	1.7	7.6			4
	9			5.1	1.4	0.9	0.8	0.7	0.8	1.2	2.9					6.9	1.7	0.7	0.3	0.1	0.6	1.3	3.9			3
	10				3.1	1.6	1.2	1.1	1.2	1.4	2.5	19.1					2.8	1.1	0.5	0	0.4	0.9	2.1	21		2
	11				57.3	3.5	2	1.5	1.4	1.6	2.1	4					26.6	2.2	0.9	0.4	0	0.5	1.1	2.7		1
	12						4.3	2.4	1.8	1.7	1.8	2.4	4.3						2.4	1	0.4	0	0.4	1	2.4	12
JAN/ NOV	7		57.3	0.5	0.3	0.2	0.2	0.2	0.3	0.5						2.4	1	0.4	0	0.4	1	2.4				5
	8			1.4	0.7	0.5	0.5	0.5	0.6	1	7.1					3	1.1	0.5	0.1	0.3	0.9	2	14.6			4
	9			3.7	1.4	0.9	0.8	0.8	0.9	1.4	4.3					4.7	1.5	0.6	0.2	0.2	0.7	1.5	5.4			3
	10			57.3	2.9	1.6	1.2	1.2	1.3	1.7	3.3					51.5	2.3	1	0.4	0	0.4	1	2.6			2
	11				19.1	3.5	2.1	1.7	1.6	1.8	2.5	5.7					11.2	1.9	0.8	0.3	0.1	0.5	1.2	3.2		1
	12						4.7	2.6	2.1	1.9	2.1	2.6	4.7						2.4	1	0.4	0	0.4	1	2.4	12
FEB/ OCT	7		1.4	0.4	0.3	0.2	0.2	0.3	0.4	1					6	1.6	0.7	0.2	0.2	0.6	1.4	4.3				5
	8		5.1	1.1	0.7	0.5	0.5	0.6	0.8	1.8					9.7	1.9	0.8	0.3	0.1	0.5	1.2	3.4				4
	9			2.2	1.2	1	0.9	1	1.2	2.4						2.4	1	0.4	0	0.4	1	2.5				3
	10			6.3	2.5	1.7	1.4	1.4	1.7	2.7	9.5					4.2	1.4	0.6	0.2	0.2	0.7	1.6	6.1			2
	11				8.1	3.5	2.6	2.2	2.4	2.9	4.7	19.1					3.4	1.2	0.6	0.1	0.3	0.8	1.8	9		1
	12						8.1	4	3.3	2.9	3.3	4	8.1						2.4	1	0.4	0	0.4	1	2.4	12
MAR/ SEP	7		0.8	0.4	0.3	0.3	0.3	0.4	0.6	7.1					2.7	1.1	0.5	0	0.4	0.9	2.2	26.8				5
	8		1.9	0.9	0.6	0.6	0.6	0.8	1.2	7.1					3.1	1.2	0.5	0.1	0.3	0.9	2	12.4				4
	9		4	1.6	1.2	1	1	1.2	2	7.1					3.8	1.3	0.6	0.1	0.3	0.8	1.7	7.2				3
	10		11.4	3.3	2.1	1.7	1.7	2	2.9	7.1					6.4	1.6	0.7	0.2	0.2	0.6	1.4	4.1				2
	11			11.4	5.1	3.7	3.3	3.5	4.3	7.1	28.6					3.2	1.2	0.5	0.1	0.3	0.8	1.9	11.6			1
	12						19.1	9.5	8.1	7.1	8.1	9.5	19.1						2.4	1	0.4	0	0.4	1	2.4	12
APR/ AUG	6	0.1	0.1	0	0	0	0	0.1	0.1					4.9	1.5	0.7	0.2	0.2	0.7	1.5	5.1					6
	7	1.7	0.6	0.4	0.3	0.3	0.3	0.5	1.3					5.8	1.6	0.7	0.2	0.2	0.6	1.4	4.4					5
	8	4	1.2	0.8	0.6	0.6	0.7	1	2.5					6.5	1.6	0.7	0.2	0.2	0.6	1.4	4.1					4
	9	7.1	2	1.3	1	1	1.2	1.7	4.3					6.7	1.7	0.7	0.3	0.1	0.6	1.3	4					3
	10	11.4	3.3	2.1	1.8	1.8	2.1	3.1	8.1					6	1.6	0.7	0.2	0.2	0.6	1.4	4.3					2
	11	14.3	6.3	4.3	3.7	3.7	4.7	7.1	28.6					3.8	1.3	0.6	0.1	0.3	0.8	1.7	7.5					1
	12	14.3	19.1	19.1	57.3									0	0.4	1	2.4									12
MAY/ JUL	6	0.1	0.1	0.1	0.1	0.1	0.1	0.1	1					2.8	1.1	0.5	0	0.4	0.9	2.1	21.4					6
	7	0.9	0.5	0.3	0.3	0.3	0.4	0.7	4.3					3	1.1	0.5	0.1	0.3	0.9	2	14.5					5
	8	1.9	0.9	0.7	0.6	0.6	0.8	1.3	8.1					3	1.1	0.5	0.1	0.3	0.9	2	14.5					4
	9	2.9	1.5	1.1	1	1.1	1.4	2.4	28.6					2.7	1.1	0.5	0	0.4	0.9	2.2	26.4					3
	10	3.7	2.2	1.7	1.7	1.8	2.5	5.1						2.1	0.9	0.4	0.1	0.5	1.1	2.8						2
	11	4.3	3.3	2.9	3.1	4	6.3	57.3						1.1	0.5	0.1	0.3	0.9	2	14.8						1
	12	4.7	5.1	6.3	11.4									0	0.4	1	2.4									12
JUN	6	0.1	0.1	0.1	0.1	0.1	0.1	0.2						2.3	1	0.4	0	0.4	1	2.5						6
	7	0.8	0.4	0.3	0.3	0.3	0.4	0.8	57.3					2.5	1	0.4	0	0.4	1	2.4						5
	8	1.5	0.8	0.6	0.6	0.6	0.8	1.5						2.4	1	0.4	0	0.4	1	2.4						4
	9	2.2	1.3	1	1	1.1	1.4	2.9						2.1	0.9	0.4	0	0.5	1.1	2.8						3
	10	2.9	2	1.6	1.6	1.8	2.6	7.1						1.6	0.7	0.2	0.2	0.6	1.4	4.2						2
	11	3.5	2.7	2.6	2.9	4	8.1							0.9	0.3	0.1	0.5	1.1	2.9							1
	12	3.7	4	5.1	9.5									0	0.4	1	2.4									12
		N	NNW	NW	WNW	W	WSW	SW	SSW	S	SSE	SE	ESE	N	NNW	NW	WNW	W	WSW	SW	SSW	S	SSE	SE	ESE	PM

Table 16.10 : Shadow Lengths and Shadow Widths for Building Exterior Projections(contd.)

DATE	"SOLAR TIME AM"	"HORIZONTAL PROJECTION 16.0 DEG NORTH LATITUDE SHADOW LENGTH, FOOT PER FOOT PROJECTION"												"SIDE PROJECTION 16.0 DEG NORTH LATITUDE SHADOW WIDTH, FOOT PER FOOT PROJECTION"											"TIME PM"
		N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	
DEC	7			0.4	0.2	0.1	0.1	0.1	0.2	0.3	1.6					3	1.2	0.5	0.1	0.3	0.9	2	13.2			5
	8			1.7	0.6	0.4	0.4	0.4	0.4	0.6	2					4.6	1.4	0.6	0.2	0.2	0.7	1.6	5.6			4
	9			8.1	1.3	0.8	0.6	0.6	0.7	0.9	1.9					13.9	2	0.9	0.3	0.1	0.5	1.2	3			3
	10				3.5	1.4	1	0.9	0.9	1.1	1.7	6.3					3.8	1.3	0.6	0.1	0.3	0.8	1.7	7.4		2
	11					3.1	1.6	1.2	1.1	1.2	1.5	2.7	28.6					2.6	1.1	0.5	0	0.4	0.9	2.2	32.7	1
	12						3.3	1.7	1.3	1.2	1.3	1.7	3.3						2.4	1	0.4	0	0.4	1	2.4	12
JAN/ NOV	7			2.4	0.2	0.2	0.1	0.2	0.2	0.3	8.1					2.5	1	0.4	0	0.4	1	2.3	54			5
	8			1.4	0.6	0.4	0.4	0.4	0.5	0.8	3.3					3.6	1.3	0.6	0.1	0.3	0.8	1.8	8.3			4
	9			5.1	1.3	0.8	0.7	0.6	0.8	1.1	2.5					7.7	1.7	0.8	0.3	0.1	0.6	1.3	3.7			3
	10				3.1	1.5	1.1	1	1	1.2	2.1	11.4					3.1	1.2	0.5	0.1	0.3	0.8	1.9	12.3		2
	11					3.3	1.7	1.3	1.2	1.3	1.7	3.3						2.4	1	0.4	0	0.4	1	2.4		1
	12						3.5	2	1.5	1.4	1.5	2	3.5						2.4	1	0.4	0	0.4	1	2.4	12
FEB/ OCT	7		1.5	0.4	0.2	0.2	0.2	0.2	0.3	0.8					7.4	1.7	0.8	0.3	0.1	0.6	1.3	3.8				5
	8		11.4	1.1	0.6	0.5	0.5	0.5	0.7	1.3					26.6	2.2	0.9	0.4	0	0.5	1.1	2.7				4
	9			2.7	1.2	0.9	0.8	0.8	1	1.7	8.1					3.3	1.2	0.5	0.1	0.3	0.8	1.9	10.1			3
	10			14.3	2.6	1.5	1.2	1.2	1.3	1.9	4					11.8	1.9	0.8	0.3	0.1	0.5	1.2	3.1			2
	11				14.3	3.5	2.1	1.7	1.7	2	2.7	6.3					7.7	1.7	0.8	0.3	0.1	0.6	1.3	3.7		1
	12						5.1	2.7	2.1	2	2.1	2.7	5.1						2.4	1	0.4	0	0.4	1	2.4	12
MAR/ SEP	7		0.8	0.4	0.3	0.2	0.3	0.3	0.6	3.5					3	1.2	0.5	0.1	0.3	0.9	2	13.5				5
	8		2.4	0.9	0.6	0.6	0.6	0.7	1	3.5					4.2	1.4	0.6	0.2	0.2	0.7	1.6	6.3				4
	9		7.1	1.9	1.2	1	0.9	1.1	1.5	3.5					8	1.8	0.8	0.3	0.1	0.6	1.3	3.6				3
	10			4.3	2.2	1.7	1.5	1.6	2.1	3.5	28.6					2.8	1.1	0.5	0.1	0.4	0.9	2.1	19			2
	11				7.1	3.5	2.7	2.5	2.7	3.5	6.3						2.5	1	0.4	0	0.4	1	2.3	70.7		1
	12						9.5	5.1	3.7	3.5	3.7	5.1	9.5						2.4	1	0.4	0	0.4	1	2.4	12
APR/ AUG	6	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.3					5.1	1.5	0.7	0.2	0.2	0.7	1.5	5					6
	7	2.5	0.6	0.4	0.3	0.3	0.4	0.5	1.2					7.7	1.7	0.8	0.3	0.1	0.6	1.3	3.7					5
	8	9.5	1.4	0.8	0.6	0.6	0.7	0.9	2					14.6	2	0.9	0.3	0.1	0.5	1.1	3					4
	9		2.7	1.5	1.1	1	1.1	1.5	2.7						2.4	1	0.4	0	0.4	1	2.4					3
	10		5.7	2.7	2	1.8	1.9	2.4	4	19.1					3.1	1.2	0.5	0.1	0.3	0.8	1.9	12.1				2
	11		28.6	7.1	4.7	3.7	3.7	4.3	6.3	14.3					7.5	1.7	0.8	0.3	0.1	0.6	1.3	3.8				1
	12						28.6	19.1	14.3	14.3	14.3	19.1	28.6						2.4	1	0.4	0	0.4	1	2.4	12
MAY/ JUL	6	0.3	0.1	0.1	0.1	0.1	0.1	0.2	1.7					2.9	1.1	0.5	0.1	0.3	0.9	2.1	17.8					6
	7	1.2	0.6	0.4	0.3	0.4	0.4	0.7	3.1					3.5	1.3	0.6	0.1	0.3	0.8	1.8	8.9					5
	8	2.7	1.1	0.8	0.6	0.7	0.8	1.2	4.3					4.1	1.4	0.6	0.2	0.2	0.7	1.6	6.5					4
	9	5.1	1.9	1.3	1.1	1.1	1.3	2	6.3					4.6	1.4	0.6	0.2	0.2	0.7	1.6	5.6					3
	10	8.1	3.3	2.1	1.9	1.9	2.2	3.5	11.4					4.5	1.4	0.6	0.2	0.2	0.7	1.6	5.7					2
	11	11.4	5.7	4.3	3.7	4	5.1	8.1	57.3					3.1	1.2	0.5	0.1	0.3	0.9	2	12.4					1
	12	14.3	14.3	19.1	28.6									0	0.4	1	2.4									12
JUN	6	0.3	0.2	0.1	0.1	0.1	0.2	0.3						2.4	1	0.4	0	0.4	1	2.4						6
	7	1.1	0.5	0.4	0.4	0.4	0.5	0.8	7.1					2.8	1.1	0.5	0	0.4	0.9	2.1	20.4					5
	8	2.1	1	0.8	0.6	0.7	0.9	1.4	8.1					3.1	1.2	0.5	0.1	0.3	0.9	2	12.3					4
	9	3.5	1.7	1.2	1.1	1.2	1.4	2.4	11.4					3.2	1.2	0.5	0.1	0.3	0.8	1.9	11.3					3
	10	5.1	2.6	2	1.8	1.9	2.5	4.3	28.6					2.8	1.1	0.5	0.1	0.4	0.9	2.1	19.9					2
	11	7.1	4.3	3.7	3.5	4	5.7	14.3						1.7	0.8	0.3	0.1	0.6	1.3	3.8						1
	12	8.1	8.1	11.4	19.1									0	0.4	1	2.4									12
		N	NNW	NW	WNW	W	WSW	SW	SSW	S	SSE	SE	ESE	N	NNW	NW	WNW	W	WSW	SW	SSW	S	SSE	SE	ESE	PM

Table 16.10 : Shadow Lengths and Shadow Widths for Building Exterior Projections(contd.)

DATE	"SOLAR TIME AM"	"HORIZONTAL PROJECTION 24.0 DEG NORTH LATITUDE SHADOW LENGTH, FOOT PER FOOT PROJECTION"												"SIDE PROJECTION 24.0 DEG NORTH LATITUDE SHADOW WIDTH, FOOT PER FOOT PROJECTION"											"TIME PM"
		N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	
DEC	7			0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.6					3.2	1.2	0.5	0.1	0.3	0.8	1.9	11.6			5
	8			1.5	0.5	0.3	0.3	0.3	0.3	0.5	1.3					5.5	1.6	0.7	0.2	0.2	0.6	1.4	4.6			4
	9			28.6	1.2	0.7	0.5	0.5	0.5	0.7	1.3					59.9	2.3	1	0.4	0	0.4	1	2.5			3
	10				3.5	1.2	0.8	0.7	0.7	0.8	1.2	3.5					5	1.5	0.7	0.2	0.2	0.7	1.5	5		2
	11					2.7	1.3	1	0.8	0.9	1.1	1.9	11.4					3	1.2	0.5	0.1	0.3	0.9	2	13.2	1
	12						2.4	1.3	1	0.9	1	1.3	2.4						2.4	1	0.4	0	0.4	1	2.4	12
JAN/ NOV	7			0.2	0.1	0.1	0.1	0.1	0.1	0.2	2.6					2.7	1.1	0.5	0	0.4	0.9	2.2	30.5			5
	8			1.3	0.5	0.4	0.3	0.3	0.4	0.6	1.9					4.2	1.4	0.6	0.2	0.2	0.7	1.6	6.1			4
	9			8.1	1.2	0.7	0.6	0.5	0.6	0.8	1.7					15.3	2	0.9	0.3	0.1	0.5	1.1	2.9			3
	10				3.3	1.3	0.9	0.8	0.8	0.9	1.5	5.1					4.1	1.4	0.6	0.2	0.2	0.7	1.6	6.4		2
	11					2.9	1.4	1.1	1	1	1.3	2.2	19.1					2.8	1.1	0.5	0.1	0.4	0.9	2.1	20	1
	12						2.7	1.5	1.1	1	1.1	1.5	2.7						2.4	1	0.4	0	0.4	1	2.4	12
FEB/ OCT	7		1.4	0.3	0.2	0.2	0.2	0.2	0.2	0.6					9	1.8	0.8	0.3	0.1	0.6	1.3	3.5				5
	8			1.1	0.6	0.4	0.4	0.4	0.6	1	19.1					2.5	1	0.4	0	0.4	1	2.3	54			4
	9			3.3	1.2	0.8	0.7	0.7	0.8	1.2	3.7					4.8	1.5	0.7	0.2	0.2	0.7	1.5	5.3			3
	10				2.7	1.4	1.1	1	1	1.4	2.5	28.6					2.6	1.1	0.4	0	0.4	0.9	2.2	38.7		2
	11				28.6	3.1	1.7	1.4	1.3	1.4	1.9	3.7					28.2	2.2	0.9	0.4	0	0.5	1.1	2.7		1
	12						3.7	2.1	1.5	1.4	1.5	2.1	3.7						2.4	1	0.4	0	0.4	1	2.4	12
MAR/ SEP	7		0.9	0.4	0.3	0.2	0.2	0.3	0.5	2.2					3.4	1.2	0.5	0.1	0.3	0.8	1.8	9.2				5
	8		3.3	1	0.6	0.5	0.5	0.6	0.9	2.2					6.1	1.6	0.7	0.2	0.2	0.6	1.4	4.3				4
	9			2.1	1.2	0.9	0.8	0.9	1.2	2.2						2.4	1	0.4	0	0.4	1	2.5				3
	10			7.1	2.5	1.6	1.3	1.3	1.5	2.2	5.7					5.8	1.6	0.7	0.2	0.2	0.6	1.4	4.5			2
	11				9.5	3.5	2.2	1.9	1.9	2.2	3.3	9.5					5.2	1.5	0.7	0.2	0.2	0.7	1.5	4.9		1
	12						5.7	3.3	2.5	2.2	2.5	3.3	5.7						2.4	1	0.4	0	0.4	1	2.4	12
APR/ AUG	6	0.4	0.2	0.1	0.1	0.1	0.1	0.1	0.4					5.3	1.5	0.7	0.2	0.2	0.7	1.5	4.8					6
	7	4	0.7	0.4	0.3	0.3	0.4	0.5	1.1					11.7	1.9	0.8	0.3	0.1	0.5	1.2	3.1					5
	8		1.7	0.9	0.7	0.6	0.7	0.9	1.5	28.6					2.5	1	0.4	0	0.4	1	2.3	54.7				4
	9		4	1.7	1.2	1	1.1	1.3	2.1	7.1					3.9	1.3	0.6	0.1	0.3	0.8	1.7	7.1				3
	10		19.1	3.7	2.1	1.7	1.7	1.9	2.6	5.1					13.4	2	0.9	0.3	0.1	0.5	1.2	3				2
	11			28.6	6.3	3.7	3.1	2.9	3.3	4.7	11.4					8.7	1.8	0.8	0.3	0.1	0.6	1.3	3.5			1
	12						11.4	6.3	5.1	4.7	5.1	6.3	11.4						2.4	1	0.4	0	0.4	1	2.4	12
MAY/ JUL	6	0.4	0.2	0.2	0.1	0.1	0.2	0.3	2					3	1.2	0.5	0.1	0.3	0.9	2	13.9					6
	7	1.7	0.7	0.4	0.4	0.4	0.5	0.7	2.4					4.3	1.4	0.6	0.2	0.2	0.7	1.6	6.1					5
	8	4.7	1.3	0.9	0.7	0.7	0.8	1.2	2.9					6.7	1.7	0.7	0.2	0.1	0.6	1.4	4					4
	9	19.1	2.6	1.5	1.2	1.1	1.2	1.7	3.5					15.7	2	0.9	0.3	0.1	0.5	1.1	2.9					3
	10		5.7	2.7	2.1	1.9	2	2.6	4.3	57.3					2.7	1.1	0.5	0	0.4	0.9	2.2	25.3				2
	11		28.6	7.1	4.7	4	4	4.7	6.3	19.1					6.1	1.6	0.7	0.2	0.2	0.6	1.4	4.3				1
	12						28.6	19.1	14.3	14.3	14.3	19.1	28.6						2.4	1	0.4	0	0.4	1	2.4	12
JUN	6	0.4	0.2	0.2	0.2	0.2	0.2	0.4	11.4					2.5	1	0.4	0	0.4	1	2.3	64.9					6
	7	1.4	0.6	0.5	0.4	0.4	0.5	0.9	4					3.3	1.2	0.5	0.1	0.3	0.8	1.9	10					5
	8	3.3	1.2	0.8	0.7	0.7	0.9	1.3	4					4.5	1.4	0.6	0.2	0.2	0.7	1.6	5.7					4
	9	7.1	2.2	1.4	1.2	1.2	1.3	2	4.7					6.5	1.6	0.7	0.2	0.2	0.6	1.4	4.1					3
	10	19.1	4.3	2.5	2.1	2	2.1	3.1	6.3					11.4	1.9	0.8	0.3	0.1	0.5	1.2	3.2					2
	11		9.5	5.7	4.3	4	4.3	5.7	11.4					76.2	2.3	1	0.4	0	0.4	1	2.5					1
	12								57.3	57.3	57.3								2.4	1	0.4	0	0.4	1	2.4	12
		N	NNW	NW	WNW	W	WSW	SW	SSW	S	SSE	SE	ESE	N	NNW	NW	WNW	W	WSW	SW	SSW	S	SSE	SE	ESE	PM

Table 16.10 : Shadow Lengths and Shadow Widths for Building Exterior Projections(contd.)

DATE	"SOLAR TIME AM"	"HORIZONTAL PROJECTION 32.0 DEG NORTH LATITUDE SHADOW LENGTH, FOOT PER FOOT PROJECTION"												"SIDE PROJECTION 32.0 DEG NORTH LATITUDE SHADOW WIDTH, FOOT PER FOOT PROJECTION"											"TIME PM"
		N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	
DEC	8			1.2	0.3	0.2	0.2	0.2	0.2	0.3	0.8					6.4	1.6	0.7	0.2	0.2	0.6	1.4	4.1			4
	9				1	0.5	0.4	0.4	0.4	0.5	0.9	14.3					2.6	1.1	0.4	0	0.4	1	2.3	40.9		3
	10				3.5	1	0.6	0.5	0.5	0.6	0.9	2.1					6.6	1.7	0.7	0.2	0.2	0.6	1.4	4.1		2
	11					2.2	1	0.7	0.6	0.7	0.8	1.3	6.3					3.4	1.2	0.5	0.1	0.3	0.8	1.8	9.3	1
	12						1.8	1	0.8	0.7	0.8	1	1.8						2.4	1.0	0.4	0	0.4	1	2.4	12
JAN/ NOV	7			0.1	0	0	0	0	0	0.1	0.6					2.7	1.1	0.5	0	0.4	0.9	2.2	25.2			5
	8			1.1	0.4	0.3	0.2	0.2	0.3	0.4	1.2					4.9	1.5	0.7	0.2	0.2	0.7	1.5	5.1			4
	9			28.6	1	0.6	0.4	0.4	0.4	0.6	1.1					58.6	2.3	1	0.4	0	0.4	1	2.5			3
	10				3.3	1.1	0.7	0.6	0.6	0.7	1	2.9					5.4	1.5	0.7	0.2	0.2	0.7	1.5	4.7		2
	11					2.5	1.2	0.8	0.7	0.8	1	1.6	8.1					3.2	1.2	0.5	0.1	0.3	0.8	1.9	11.4	1
	12						2.1	1.1	0.8	0.8	0.8	1.1	2.1						2.4	1	0.4	0	0.4	1	2.4	12
FEB/ OCT	7		1.3	0.2	0.2	0.1	0.1	0.1	0.2	0.4					10.8	1.9	0.8	0.3	0.1	0.5	1.2	3.2				5
	8			1	0.5	0.4	0.3	0.3	0.4	0.8	5.1					2.9	1.1	0.5	0.1	0.3	0.9	2	15.3			4
	9			4	1.1	0.7	0.6	0.6	0.6	0.9	2.2					7.3	1.7	0.8	0.3	0.1	0.6	1.3	3.8			3
	10				2.7	1.3	0.9	0.8	0.8	1	1.7	7.1					3.4	1.2	0.5	0.1	0.3	0.8	1.8	9.3		2
	11					2.7	1.4	1.1	1	1.1	1.4	2.5	57.3					2.6	1.1	0.4	0	0.4	0.9	2.2	38.6	1
	12						2.7	1.5	1.2	1.1	1.2	1.5	2.7						2.4	1	0.4	0	0.4	1	2.4	12
MAR/ SEP	7		0.9	0.4	0.3	0.2	0.2	0.3	0.4	1.6					3.9	1.3	0.6	0.1	0.3	0.8	1.7	7				5
	8		4.7	1	0.6	0.5	0.5	0.5	0.7	1.6					10.4	1.9	0.8	0.3	0.1	0.5	1.2	3.3				4
	9			2.6	1.2	0.8	0.8	0.8	1	1.6	8.1					3.3	1.2	0.5	0.1	0.3	0.8	1.9	10.5			3
	10			28.6	2.6	1.5	1.2	1.1	1.2	1.6	3.1					23.3	2.1	0.9	0.4	0	0.5	1.1	2.7			2
	11				19.1	3.1	1.9	1.5	1.4	1.6	2.1	4.7					13.2	2	0.9	0.3	0.1	0.5	1.2	3		1
	12						4.3	2.2	1.7	1.6	1.7	2.2	4.3						2.4	1	0.4	0	0.4	1	2.4	12
APR/ AUG	6	0.6	0.2	0.1	0.1	0.1	0.1	0.2	0.5					5.7	1.6	0.7	0.2	0.2	0.6	1.4	4.5					6
	7	4.7	0.8	0.5	0.4	0.3	0.4	0.5	1					26.2	2.2	0.9	0.4	0	0.5	1.1	2.7					5
	8		2.1	1	0.7	0.6	0.6	0.8	1.3	5.7					3.4	1.2	0.5	0.1	0.3	0.8	1.8	9.5				4
	9		8.1	2	1.2	1	1	1.1	1.5	3.5					8.6	1.8	0.8	0.3	0.1	0.6	1.3	3.5				3
	10			5.7	2.4	1.7	1.5	1.5	1.9	2.9	11.4					3.6	1.3	0.6	0.1	0.3	0.8	1.8	7.9			2
	11				8.1	3.5	2.5	2.2	2.2	2.7	4.3	19.1					3.7	1.3	0.6	0.1	0.3	0.8	1.7	7.6		1
	12						7.1	3.7	2.9	2.7	2.9	3.7	7.1						2.4	1	0.4	0	0.4	1	2.4	12
MAY/ JUL	6	0.6	0.3	0.2	0.2	0.2	0.2	0.4	2					3.2	1.2	0.5	0.1	0.3	0.8	1.9	10.7					6
	7	2.4	0.8	0.5	0.4	0.4	0.5	0.7	2					5.6	1.6	0.7	0.2	0.2	0.6	1.4	4.5					5
	8	14.3	1.7	1	0.8	0.7	0.8	1.1	2.1					19.8	2.1	0.9	0.4	0.1	0.5	1.1	2.8					4
	9		3.7	1.7	1.3	1.1	1.2	1.4	2.4	11.4					3.2	1.2	0.5	0.1	0.3	0.8	1.9	10.7				3
	10		19.1	3.7	2.2	1.9	1.8	2.1	2.7	6.3					9.9	1.9	0.8	0.3	0.1	0.5	1.2	3.3				2
	11			28.6	6.3	4	3.3	3.1	3.5	5.1	11.4					8.3	1.8	0.8	0.3	0.1	0.6	1.3	3.6			1
	12						11.4	6.3	5.1	4.7	5.1	6.3	11.4						2.4	1	0.4	0	0.4	1	2.4	12
JUN	5	0	0	0	0	0	0	0						1.9	0.8	0.3	0.1	0.5	1.2	3.2						7
	6	0.6	0.3	0.2	0.2	0.2	0.3	0.5	5.1					2.7	1.1	0.5	0	0.4	0.9	2.2	24.9					6
	7	2	0.8	0.5	0.5	0.5	0.6	0.9	2.9					4.2	1.4	0.6	0.2	0.2	0.7	1.6	6.3					5
	8	6.3	1.5	1	0.8	0.8	0.9	1.2	2.7					8.4	1.8	0.8	0.3	0.1	0.6	1.3	3.6					4
	9		3.1	1.7	1.3	1.2	1.3	1.7	3.1						2.5	1	0.4	0	0.4	1	2.3					3
	10		9.5	3.3	2.2	2	2	2.4	3.5	11.4					4.6	1.4	0.6	0.2	0.2	0.7	1.6	5.5				2
	11			14.3	5.7	4	3.5	3.7	4.7	7.1	28.6					3.5	1.3	0.6	0.1	0.3	0.8	1.8	8.7			1
	12						19.1	9.5	7.1	6.3	7.1	9.5	19.1						2.4	1	0.4	0	0.4	1	2.4	12
		N	NNW	NW	WNW	W	WSW	SW	SSW	S	SSE	SE	ESE	N	NNW	NW	WNW	W	WSW	SW	SSW	S	SSE	SE	ESE	PM

Table 16.10 : Shadow Lengths and Shadow Widths for Building Exterior Projections(contd.)

DATE	"SOLAR TIME AM"	"HORIZONTAL PROJECTION 40.0 DEG NORTH LATITUDE SHADOW LENGTH, FOOT PER FOOT PROJECTION"												"SIDE PROJECTION 40.0 DEG NORTH LATITUDE SHADOW WIDTH, FOOT PER FOOT PROJECTION"											"TIME PM"
		N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	
DEC	8			0.7	0.2	0.1	0.1	0.1	0.1	0.2	0.4					7.2	1.7	0.8	0.3	0.1	0.6	1.3	3.9			4
	9				0.8	0.4	0.3	0.2	0.3	0.3	0.6	4.7					2.8	1.1	0.5	0.1	0.4	0.9	2.1	18.7		3
	10				3.1	0.8	0.5	0.4	0.4	0.4	0.6	1.4					8.3	1.8	0.8	0.3	0.1	0.6	1.3	3.6		2
	11					1.8	0.8	0.5	0.5	0.5	0.6	0.9	3.7					3.7	1.3	0.6	0.1	0.3	0.8	1.7	7.8	1
	12						1.3	0.7	0.5	0.5	0.5	0.7	1.3						2.4	1.0	0.4	0	0.4	1	2.4	12
JAN/ NOV	8			0.8	0.3	0.2	0.1	0.1	0.2	0.2	0.7					5.5	1.6	0.7	0.2	0.2	0.6	1.4	4.6			5
	9				0.8	0.4	0.3	0.3	0.3	0.4	0.8	19.1					2.5	1	0.4	0	0.4	1	2.3	54.9		4
	10				3.1	0.9	0.6	0.4	0.4	0.5	0.7	1.8					6.8	1.7	0.7	0.3	0.1	0.6	1.3	4		3
	11					2	0.9	0.6	0.6	0.6	0.7	1.1	4.7					3.5	1.3	0.6	0.1	0.3	0.8	1.8	8.8	2
	12						1.5	0.8	0.6	0.6	0.6	0.8	1.5						2.4	1	0.4	0	0.4	1	2.4	1
FEB/ OCT	7		0.9	0.2	0.1	0.1	0.1	0.1	0.1	0.2					12.5	2	0.9	0.3	0.1	0.5	1.2	3.1			5
	8			0.9	0.4	0.3	0.3	0.3	0.3	0.6	2.6					3.3	1.2	0.5	0.1	0.3	0.8	1.9	9.7		4
	9			5.7	1	0.6	0.5	0.4	0.5	0.7	1.5					12.3	1.9	0.8	0.3	0.1	0.5	1.2	3.1		3
	10				2.7	1.1	0.7	0.6	0.6	0.8	1.2	3.7					4.4	1.4	0.6	0.2	0.2	0.7	1.6	5.9		2
	11					2.4	1.2	0.8	0.8	0.8	1	1.7	11.4					3	1.1	0.5	0.1	0.3	0.9	2	14.8	1
	12						2.1	1.2	0.9	0.8	0.9	1.2	2.1						2.4	1	0.4	0	0.4	1	2.4	12
MAR/ SEP	7		0.9	0.3	0.2	0.2	0.2	0.2	0.4	1.2					4.4	1.4	0.6	0.2	0.2	0.7	1.6	5.8				5
	8		11.4	1	0.6	0.4	0.4	0.5	0.6	1.2					26.8	2.2	0.9	0.4	0	0.5	1.1	2.7				4
	9			3.1	1.1	0.8	0.6	0.6	0.8	1.2	3.7					4.6	1.4	0.6	0.2	0.2	0.7	1.6	5.5			3
	10				2.6	1.3	1	0.9	0.9	1.2	2.1	19.1					2.8	1.1	0.5	0.1	0.4	0.9	2.1	18.6		2
	11					2.9	1.5	1.2	1.1	1.2	1.5	2.9						2.4	1	0.4	0	0.4	1	2.4		1
	12						3.1	1.7	1.3	1.2	1.3	1.7	3.1						2.4	1	0.4	0	0.4	1	2.4	12
APR/ AUG	6	0.8	0.2	0.2	0.1	0.1	0.2	0.2	0.6					6.4	1.6	0.7	0.2	0.2	0.6	1.4	4.1					6
	7		0.9	0.5	0.4	0.3	0.4	0.5	0.9	28.6					2.5	1	0.4	0	0.4	1	2.4					5
	8		2.9	1	0.7	0.6	0.6	0.7	1.1	3.1					4.8	1.5	0.7	0.2	0.2	0.7	1.5	5.3				4
	9			2.4	1.2	1	0.9	0.9	1.2	2.2						2.5	1	0.4	0	0.4	1	2.4				3
	10			11.4	2.6	1.6	1.3	1.2	1.4	2	4.3					8.9	1.8	0.8	0.3	0.1	0.6	1.3	3.5			2
	11				14.3	3.3	2.1	1.7	1.7	1.9	2.6	6.3					8.5	1.8	0.8	0.3	0.1	0.6	1.3	3.5		1
	12						4.7	2.6	2	1.9	2	2.6	4.7						2.4	1	0.4	0	0.4	1	2.4	12
MAY/ JUL	5	0.1	0.1	0	0	0	0.1	0.1						2.2	0.9	0.4	0	0.5	1.1	2.7						6
	6	0.8	0.4	0.3	0.2	0.2	0.3	0.5	1.9					3.6	1.3	0.6	0.1	0.3	0.8	1.8	8.2					
	7	3.7	0.9	0.6	0.5	0.4	0.5	0.7	1.6					8.6	1.8	0.8	0.3	0.1	0.6	1.3	3.5					5
	8		2.1	1.1	0.8	0.7	0.8	1	1.7	14.3					2.8	1.1	0.5	0	0.4	0.9	2.1	20.3				4
	9		7.1	2.1	1.3	1.1	1.1	1.2	1.8	4.3					6.7	1.7	0.7	0.2	0.2	0.6	1.4	4				3
	10			5.7	2.5	1.8	1.6	1.6	2	3.3	14.3					3.5	1.3	0.6	0.1	0.3	0.8	1.8	8.7			2
	11				9.5	3.7	2.6	2.2	2.4	2.9	4.3	19.1					3.8	1.3	0.6	0.1	0.3	0.8	1.7	7.2		1
	12						7.1	4	2.9	2.7	2.9	4	7						2.4	1	0.4	0	0.4	1	2.4	12
JUN	5	0.2	0.1	0.1	0.1	0.1	0.1	0.2						1.9	0.8	0.3	0.1	0.5	1.2	3.1						7
	6	0.8	0.4	0.3	0.3	0.3	0.3	0.6	3.7					3	1.2	0.5	0.1	0.3	0.9	2	13.9					6
	7	2.9	0.9	0.6	0.5	0.5	0.6	0.8	2.2					5.8	1.6	0.7	0.2	0.2	0.6	1.4	4.4					5
	8	57.3	2	1.1	0.8	0.8	0.8	1.1	2.1					79.5	2.3	1	0.4	0	0.4	1	2.5					4
	9		5.1	2	1.4	1.2	1.2	1.4	2.1	7.1					4.4	1.4	0.6	0.2	0.2	0.7	1.6	5.8				3
	10			4.7	2.5	1.9	1.7	1.8	2.4	4.3	57.3					2.6	1.1	0.4	0	0.4	0.9	2.2	34.3			2
	11				8.1	4	2.9	2.6	2.7	3.5	6.3	57.3					2.8	1.1	0.5	0.1	0.4	0.9	2.1	18.4		1
	12						9.5	4.7	3.7	3.3	3.7	4.7	9.5						2.4	1	0.4	0	0.4	1	2.4	12
		N	NNW	NW	WNW	W	WSW	SW	SSW	S	SSE	SE	ESE	N	NNW	NW	WNW	W	WSW	SW	SSW	S	SSE	SE	ESE	PM

Table 16.10 : Shadow Lengths and Shadow Widths for Building Exterior Projections(contd.)

DATE	"SOLAR TIME AM"	"HORIZONTAL PROJECTION 48.0 DEG NORTH LATITUDE SHADOW LENGTH, FOOT PER FOOT PROJECTION"												"SIDE PROJECTION 48.0 DEG NORTH LATITUDE SHADOW WIDTH, FOOT PER FOOT PROJECTION"											"TIME PM"
		N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	
DEC	8			0.1	0	0	0	0	0	0	0					7.5	1.7	0.8	0.3	0.1	0.6	1.3	3.8			4
	9				0.4	0.2	0.2	0.1	0.1	0.2	0.3	2					3	1.2	0.5	0.1	0.3	0.9	2	14		3
	10				2.5	0.5	0.3	0.2	0.2	0.3	0.4	0.8					10.1	1.9	0.8	0.3	0.1	0.5	1.2	3.3		2
	11					1.2	0.5	0.4	0.3	0.3	0.4	0.6	2.2					3.9	1.3	0.6	0.1	0.3	0.8	1.7	7	1
	12						0.9	0.5	0.4	0.3	0.4	0.5	0.9						2.4	1	0.4	0	0.4	1	2.4	12
JAN/ NOV	8			0.4	0.1	0.1	0.1	0.1	0.1	0.1	0.3					5.9	1.6	0.7	0.2	0.2	0.6	1.4	4.4			4
	9				0.6	0.3	0.2	0.2	0.2	0.3	0.5	4.7					2.7	1.1	0.5	0	0.4	0.9	2.2	23.8		3
	10				2.5	0.6	0.4	0.3	0.3	0.3	0.5	1.1					8.3	1.8	0.8	0.3	0.1	0.6	1.3	3.6		2
	11					1.4	0.6	0.4	0.4	0.4	0.5	0.8	2.9					3.7	1.3	0.6	0.1	0.3	0.8	1.7	7.7	1
	12						1.1	0.6	0.4	0.4	0.4	0.6	1.1						2.4	1	0.4	0	0.4	1	2.4	12
FEB/ OCT	7		0.4	0.1	0	0	0	0	0.1	0.1					13.7	2	0.9	0.3	0.1	0.5	1.2	3				5
	8			0.8	0.3	0.2	0.2	0.2	0.2	0.4	1.5					3.7	1.3	0.6	0.1	0.3	0.8	1.7	7.6			4
	9			8.1	0.8	0.5	0.4	0.3	0.4	0.5	1					25.2	2.2	0.9	0.4	0	0.5	1.1	2.7			3
	10				2.6	0.9	0.6	0.5	0.5	0.6	0.8	2.2					5.4	1.5	0.7	0.2	0.2	0.6	1.5	4.7		2
	11					2	0.9	0.6	0.6	0.6	0.7	1.2	6.3					3.3	1.2	0.5	0.1	0.3	0.8	1.9	10.4	1
	12						1.6	0.9	0.6	0.6	0.6	0.9	1.6						2.4	1	0.4	0	0.4	1	2.4	12
MAR/ SEP	7		0.9	0.3	0.2	0.2	0.2	0.2	0.3	0.9					5	1.5	0.7	0.2	0.2	0.7	1.5	5				5
	8			1	0.5	0.4	0.4	0.4	0.5	0.9	28.6					2.5	1	0.4	0	0.4	1	2.3	79.4			4
	9			3.7	1	0.7	0.6	0.5	0.6	0.9	2.2					6.8	1.7	0.7	0.3	0.1	0.6	1.3	4			3
	10				2.7	1.2	0.8	0.7	0.7	0.9	1.4	5.7					3.6	1.3	0.6	0.1	0.3	0.8	1.8	8		2
	11					2.5	1.3	0.9	0.8	0.9	1.2	2	19.1					2.8	1.1	0.5	0	0.4	0.9	2.1	21.4	1
	12						2.4	1.3	1	0.9	1	1.3	2.4						2.4	1	0.4	0	0.4	1	2.4	12
APR/ AUG	6	1.1	0.3	0.2	0.2	0.2	0.2	0.2	0.6					7.3	1.7	0.8	0.3	0.1	0.6	1.3	3.8					6
	7		1	0.5	0.4	0.3	0.4	0.4	0.8	5.7					2.9	1.1	0.5	0.1	0.3	0.9	2.1	17.6				5
	8		4.3	1.1	0.7	0.6	0.6	0.6	0.9	2.1					7.7	1.7	0.8	0.3	0.1	0.6	1.3	3.7				4
	9			2.7	1.2	0.9	0.8	0.8	1	1.6	7.1					3.4	1.2	0.5	0.1	0.3	0.8	1.8	9.1			3
	10				2.7	1.5	1.1	1	1.1	1.4	2.6						2.5	1	0.4	0	0.4	1	2.4			2
	11				57.3	3.1	1.7	1.3	1.3	1.4	1.8	3.5					37.4	2.2	0.9	0.4	0	0.4	1.1	2.6		1
	12						3.5	1.9	1.5	1.4	1.5	1.9	3.5						2.4	1	0.4	0	0.4	1	2.4	12
MAY/ JUL	5	0.2	0.1	0.1	0.1	0.1	0.1	0.3						2.2	0.9	0.4	0	0.5	1.1	2.6						7
	6	1.1	0.4	0.3	0.3	0.3	0.3	0.5	1.7					4.1	1.4	0.6	0.2	0.2	0.7	1.6	6.5					6
	7	8.1	1.1	0.6	0.5	0.5	0.5	0.7	1.4					18.9	2.1	0.9	0.4	0.1	0.5	1.1	2.8					5
	8		2.9	1.2	0.8	0.7	0.7	0.9	1.3	4.7					4	1.3	0.6	0.1	0.3	0.7	1.7	6.8				4
	9		57.3	2.5	1.4	1	1	1.1	1.4	2.6					75.2	2.3	1	0.4	0	0.4	1	2.5				3
	10			11.4	2.7	1.7	1.4	1.3	1.5	2.1	4.7					9	1.8	0.8	0.3	0.1	0.6	1.2	3.5			2
	11				14.3	3.5	2.1	1.8	1.7	2	2.7	6.3					9.3	1.8	0.8	0.3	0.1	0.5	1.2	3.4		1
	12						4.7	2.6	2.1	1.9	2.1	2.6	4.7						2.4	1	0.4	0	0.4	1	2.4	12
JUN	5	0.3	0.2	0.1	0.1	0.2	0.2	0.4						2	0.9	0.3	0.1	0.5	1.2	3						7
	6	1.1	0.5	0.3	0.3	0.3	0.4	0.6	2.7					3.4	1.2	0.6	0.1	0.3	0.8	1.8	9					8
	7	5.1	1.1	0.6	0.5	0.5	0.6	0.8	1.8					9.9	1.9	0.8	0.3	0.1	0.5	1.2	3.3					5
	8		2.6	1.2	0.9	0.8	0.8	1	1.6	8.1					3.2	1.2	0.5	0.1	0.3	0.8	1.9	10.6				4
	9		14.3	2.4	1.4	1.1	1.1	1.2	1.6	3.5					14	2	0.9	0.3	0.1	0.5	1.2	3				3
	10			8.1	2.7	1.8	1.5	1.5	1.7	2.6	6.3					5.8	1.6	0.7	0.2	0.2	0.6	1.4	4.4			2
	11				14.3	3.7	2.4	2	2	2.2	3.3	8.1					6.5	1.7	0.7	0.2	0.2	0.6	1.4	4.1		1
	12						5.7	3.1	2.4	2.1	2.4	3.1	5.7						2.4	1	0.4	0	0.4	1	2.4	12
		N	NNW	NW	WNW	W	WSW	SW	SSW	S	SSE	SE	ESE	N	NNW	NW	WNW	W	WSW	SW	SSW	S	SSE	SE	ESE	PM

Table 16.10 : Shadow Lengths and Shadow Widths for Building Exterior Projections(contd.)

DATE	"SOLAR TIME AM"	"HORIZONTAL PROJECTION 56.0 DEG NORTH LATITUDE SHADOW LENGTH, FOOT PER FOOT PROJECTION"												"SIDE PROJECTION 56.0 DEG NORTH LATITUDE SHADOW WIDTH, FOOT PER FOOT PROJECTION"											"TIME PM"
		N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	
DEC	9				0.1	0.1	0	0	0	0	0.1	0.4					3.1	1.2	0.5	0.1	0.3	0.9	2	12.6		3
	10				1.3	0.2	0.2	0.1	0.1	0.1	0.2	0.4					11.4	1.9	0.8	0.3	0.1	0.5	1.2	3.2		2
	11					0.7	0.3	0.2	0.2	0.2	0.2	0.3	1.1					4	1.4	0.6	0.2	0.2	0.7	1.7	6.6	1
	12						0.5	0.3	0.2	0.2	0.2	0.3	0.5						2.4	1	0.4	0	0.4	1	2.4	12
JAN/ NOV	9				0.3	0.1	0.1	0.1	0.1	0.1	0.2	1.6					2.8	1.1	0.5	0.1	0.4	0.9	2.1	18.1		3
	10				1.7	0.4	0.2	0.2	0.2	0.2	0.3	0.6					9.5	1.8	0.8	0.3	0.1	0.5	1.2	3.4		2
	11					0.9	0.4	0.3	0.2	0.2	0.3	0.4	1.7					3.9	1.3	0.6	0.1	0.3	0.8	1.7	7.1	1
	12						0.6	0.3	0.3	0.2	0.3	0.3	0.6						2.4	1	0.4	0	0.4	1	2.4	12
FEB/ OCT	8			0.5	0.2	0.1	0.1	0.1	0.1	0.2	0.8					4	1.4	0.6	0.2	0.2	0.7	1.7	6.7			4
	9			28.6	0.6	0.3	0.2	0.2	0.3	0.3	0.6					98.5	2.3	1	0.4	0	0.4	1	2.5			3
	10				2.2	0.6	0.4	0.3	0.3	0.4	0.6	1.4					6.5	1.6	0.7	0.2	0.2	0.6	1.4	4.1		2
	11					1.5	0.6	0.5	0.4	0.4	0.5	0.8	3.5					3.5	1.3	0.6	0.1	0.3	0.8	1.8	8.7	1
	12						1.1	0.6	0.5	0.4	0.5	0.6	1.1						2.4	1	0.4	0	0.4	1	2.4	12
MAR/ SEP	7		0.8	0.3	0.2	0.2	0.1	0.2	0.2	0.7					5.7	1.6	0.7	0.2	0.2	0.6	1.4	4.5				5
	8			0.9	0.4	0.3	0.3	0.3	0.4	0.7	5.7					2.8	1.1	0.5	0.1	0.4	0.9	2.1	18.6			4
	9			4.7	0.9	0.6	0.4	0.4	0.5	0.7	1.5					10.7	1.9	0.8	0.3	0.1	0.5	1.2	3.2			3
	10				2.6	1	0.6	0.6	0.6	0.7	1	3.1					4.6	1.4	0.6	0.2	0.2	0.7	1.6	5.6		2
	11					2.1	1	0.7	0.6	0.7	0.8	1.4	8.1					3.1	1.2	0.5	0.1	0.3	0.9	2	12.5	1
	12						1.7	1	0.7	0.7	0.7	1	1.7						2.4	1	0.4	0	0.4	1	2.4	12
APR/ AUG	5	0.1	0	0	0	0	0	0.1	0.4					2.9	1.1	0.5	0.1	0.3	0.9	2	15.6					7
	6	1.5	0.3	0.2	0.2	0.2	0.2	0.3	0.6					8.7	1.8	0.8	0.3	0.1	0.6	1.3	3.5					6
	7		1.2	0.5	0.4	0.3	0.3	0.4	0.7	3.1					3.4	1.2	0.5	0.1	0.3	0.8	1.8	9.7				5
	8		8.1	1.1	0.6	0.5	0.5	0.6	0.7	1.5					16.8	2.1	0.9	0.3	0.1	0.5	1.1	2.9				4
	9			3.5	1.2	0.8	0.7	0.7	0.8	1.2	3.5					5	1.5	0.7	0.2	0.2	0.7	1.5	5.1			3
	10				2.9	1.3	0.9	0.8	0.9	1.1	1.8	9.5					3.2	1.2	0.5	0.1	0.3	0.8	1.9	10.7		2
	11					2.7	1.4	1.1	1	1	1.3	2.4	28.6					2.7	1.1	0.5	0	0.4	0.9	2.2	31.3	1
	12						2.6	1.4	1.1	1	1.1	1.4	2.6						2.4	1	0.4	0	0.4	1	2.4	12
MAY/ JUL	4	0	0	0	0	0	0	0.1						1.4	0.6	0.2	0.2	0.7	1.6	6						8
	5	0.4	0.2	0.2	0.1	0.2	0.2	0.4						2.3	1	0.4	0	0.4	1	2.5						7
	6	1.5	0.5	0.4	0.3	0.3	0.4	0.5	1.5					4.9	1.5	0.7	0.2	0.2	0.7	1.5	5.1					6
	7		1.2	0.6	0.5	0.5	0.5	0.6	1.2	57.3					2.5	1	0.4	0	0.4	1	2.3	87.5				5
	8		4.3	1.2	0.8	0.7	0.6	0.8	1.1	2.7					6.5	1.6	0.7	0.2	0.2	0.6	1.4	4.1				4
	9			3.1	1.4	1	0.9	0.9	1.1	1.8	8.1					3.4	1.2	0.5	0.1	0.3	0.8	1.8	9.6			3
	10				2.9	1.6	1.2	1.1	1.2	1.5	2.7	57.3					2.5	1	0.4	0	0.4	1	2.3	70.3		2
	11				57.3	3.3	1.8	1.4	1.3	1.4	1.9	3.5					61.7	2.3	1	0.4	0	0.4	1	2.5		1
	12						3.5	2	1.5	1.4	1.5	2	3.5						2.4	1	0.4	0	0.4	1	2.4	12
JUN	4	0.1	0.1	0.1	0.1	0.1	0.1	0.5						1.3	0.6	0.1	0.3	0.8	1.7	7.3						8
	5	0.5	0.3	0.2	0.2	0.2	0.3	0.6						2.1	0.9	0.4	0	0.5	1.1	2.8						7
	6	1.5	0.6	0.4	0.3	0.4	0.4	0.7	2.2					4.1	1.4	0.6	0.2	0.2	0.7	1.6	6.4					6
	7	19.1	1.3	0.7	0.6	0.5	0.6	0.8	1.5					34.5	2.2	0.9	0.4	0	0.4	1.1	2.6					5
	8		3.7	1.3	0.9	0.7	0.7	0.9	1.3	3.7					5	1.5	0.7	0.2	0.2	0.7	1.5	5				4
	9			2.9	1.4	1.1	1	1	1.3	2.2	14.3					2.9	1.1	0.5	0.1	0.3	0.9	2.1	16.7			3
	10			57.3	3.1	1.7	1.3	1.2	1.3	1.8	3.5					39.7	2.3	1	0.4	0	0.4	1.1	2.6			2
	11				28.6	3.5	2	1.5	1.5	1.6	2.1	4.3					24.1	2.2	0.9	0.4	0	0.5	1.1	2.7		1
	12						4	2.2	1.7	1.5	1.7	2.2	4						2.4	1	0.4	0	0.4	1	2.4	12
		N	NNW	NW	WNW	W	WSW	SW	SSW	S	SSE	SE	ESE	N	NNW	NW	WNW	W	WSW	SW	SSW	S	SSE	SE	ESE	PM

Table 16.10 : Shadow Lengths and Shadow Widths for Building Exterior Projections(contd.)

DATE	"SOLAR TIME AM"	"HORIZONTAL PROJECTION 64.0 DEG NORTH LATITUDE SHADOW LENGTH, FOOT PER FOOT PROJECTION"												"SIDE PROJECTION 64.0 DEG NORTH LATITUDE SHADOW WIDTH, FOOT PER FOOT PROJECTION"											"TIME PM"
		N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	
DEC	11					0.1	0.1	0	0	0	0	0.1	0.2					4.1	1.4	0.6	0.2	0.2	0.7	1.6	6.5	1
	12						0.1	0.1	0.1	0.1	0.1	0.1	0.1						2.4	1	0.4	0	0.4	1	2.4	12
JAN/ NOV	10				0.5	0.1	0.1	0.1	0.1	0.1	0.1	0.2					10.3	1.9	0.8	0.3	0.1	0.5	1.2	3.3		2
	11					0.4	0.2	0.1	0.1	0.1	0.1	0.2	0.6					4	1.3	0.6	0.1	0.3	0.7	1.7	6.8	1
	12						0.3	0.1	0.1	0.1	0.1	0.1	0.3						2.4	1	0.4	0	0.4	1	2.4	12
FEB/ OCT	8			0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.3					4.2	1.4	0.6	0.2	0.2	0.7	1.6	6.2			4
	9				0.4	0.2	0.1	0.1	0.1	0.2	0.3	14.3					2.5	1	0.4	0	0.4	1	2.4			3
	10				1.6	0.4	0.3	0.2	0.2	0.2	0.3	0.8					7.5	1.7	0.8	0.3	0.1	0.6	1.3	3.8		2
	11					1	0.4	0.3	0.2	0.3	0.3	0.5	2.1					3.7	1.3	0.6	0.1	0.3	0.8	1.7	7.8	1
	12						0.7	0.4	0.3	0.3	0.3	0.4	0.7						2.4	1	0.4	0	0.4	1	2.4	12
MAR/ SEP	7		0.7	0.2	0.1	0.1	0.1	0.1	0.2	0.5					6.3	1.6	0.7	0.2	0.2	0.6	1.4	4.2			5
	8			0.8	0.3	0.2	0.2	0.2	0.3	0.5	2.6					3.2	1.2	0.5	0.1	0.3	0.8	1.9	11.6		4
	9			6.3	0.8	0.4	0.3	0.3	0.4	0.5	1					18.8	2.1	0.9	0.4	0.1	0.5	1.1	2.8		3
	10				2.4	0.8	0.5	0.4	0.4	0.5	0.7	2					5.5	1.6	0.7	0.2	0.2	0.6	1.4	4.6		2
	11					1.7	0.8	0.5	0.5	0.5	0.6	1	4.7					3.4	1.2	0.5	0.1	0.3	0.8	1.8	9.7	1
	12						1.3	0.7	0.5	0.5	0.5	0.7	1.3						2.4	1	0.4	0	0.4	1	2.4	12
APR/ AUG	5	0.2	0.1	0.1	0.1	0.1	0.1	0.2	1					3	1.2	0.5	0.1	0.3	0.9	2	14.2					7
	6	2.1	0.4	0.2	0.2	0.2	0.2	0.3	0.6					11.1	1.9	0.8	0.3	0.1	0.5	1.2	3.2					6
	7		1.2	0.5	0.4	0.3	0.3	0.4	0.6	2.1					4	1.3	0.6	0.1	0.3	0.7	1.7	6.8				5
	8			1.1	0.6	0.5	0.4	0.5	0.6	1.1						2.4	1	0.4	0	0.4	1	2.4				4
	9			4.3	1.1	0.7	0.6	0.6	0.6	0.9	2.1					7.8	1.7	0.8	0.3	0.1	0.6	1.3	3.7			3
	10				2.9	1.1	0.8	0.7	0.7	0.8	1.3	4.3					4.2	1.4	0.6	0.2	0.2	0.7	1.6	6.3		2
	11					2.4	1.2	0.8	0.8	0.8	1	1.7	9.5					3	1.2	0.5	0.1	0.3	0.9	2	13.9	1
	12						2.1	1.1	0.8	0.8	0.8	1.1	2.1						2.4	1	0.4	0	0.4	1	2.4	12
MAY/ JUL	4	0.2	0.1	0.1	0.1	0.1	0.2	0.6						1.4	0.6	0.2	0.2	0.7	1.6	5.7						8
	5	0.6	0.3	0.2	0.2	0.2	0.3	0.5	28.6					2.5	1	0.4	0	0.4	1	2.4						7
	6	2.1	0.6	0.4	0.3	0.3	0.4	0.6	1.4					6.3	1.6	0.7	0.2	0.2	0.6	1.4	4.2					6
	7		1.5	0.7	0.5	0.5	0.5	0.6	1	6.3					3	1.2	0.5	0.1	0.3	0.9	2	13.2				5
	8		8.1	1.3	0.8	0.6	0.6	0.7	0.9	1.9					14.3	2	0.9	0.3	0.1	0.5	1.2	3				4
	9			4	1.4	0.9	0.8	0.8	0.9	1.3	3.7					5.1	1.5	0.7	0.2	0.2	0.7	1.5	4.9			3
	10				3.1	1.4	1	0.9	0.9	1.2	1.9	8.1					3.4	1.2	0.5	0.1	0.3	0.8	1.8	9.4		2
	11					2.9	1.5	1.1	1	1.1	1.3	2.4	28.6					2.7	1.1	0.5	0	0.4	0.9	2.2	23.5	1
	12						2.7	1.5	1.1	1	1.1	1.5	2.7						2.4	1	0.4	0	0.4	1	2.4	12
JUN	4	0.3	0.2	0.2	0.2	0.2	0.3	1.1						1.4	0.6	0.2	0.2	0.7	1.7	6.6						8
	5	0.6	0.4	0.3	0.3	0.3	0.4	0.7						2.3	1	0.4	0	0.4	1	2.6						7
	6	2.1	0.7	0.5	0.4	0.4	0.5	0.7	1.9					5.3	1.5	0.7	0.2	0.2	0.7	1.5	4.8					6
	7		1.5	0.8	0.6	0.5	0.6	0.7	1.2	11.4					2.8	1.1	0.5	0	0.4	0.9	2.1	22.7				5
	8		6.3	1.4	0.9	0.7	0.7	0.8	1.1	2.4					9.8	1.9	0.8	0.3	0.1	0.5	1.2	3.3				4
	9			3.7	1.4	1	0.8	0.9	1	1.6	5.1					4.4	1.4	0.6	0.2	0.2	0.7	1.6	5.8			3
	10				3.3	1.5	1.1	1	1	1.3	2.1	11.4					3.1	1.2	0.5	0.1	0.3	0.9	2	12.3		2
	11					3.1	1.6	1.2	1.1	1.2	1.5	2.7	57.3					2.6	1.1	0.4	0	0.4	0.9	2.2	35.7	1
	12						3.1	1.7	1.3	1.2	1.3	1.7	3.1						2.4	1	0.4	0	0.4	1	2.4	12
		N	NNW	NW	WNW	W	WSW	SW	SSW	S	SSE	SE	ESE	N	NNW	NW	WNW	W	WSW	SW	SSW	S	SSE	SE	ESE	PM
	11				28.6	3.5	2	1.5	1.5	1.6	2.1	4.3					24.1	2.2	0.9	0.4	0	0.5	1.1	2.7		1
	12						4	2.2	1.7	1.5	1.7	2.2	4						2.4	1	0.4	0	0.4	1	2.4	12
		N	NNW	NW	WNW	W	WSW	SW	SSW	S	SSE	SE	ESE	N	NNW	NW	WNW	W	WSW	SW	SSW	S	SSE	SE	ESE	PM

Table 16.11 : Heat Gain from equipment

Recommended Rate of Heat Gain from Commercial Cooking Appliances Located in the Air-Conditioned Area[a]

							Recommended Rate of Heat Gain,Btu/hr			
				Manufacturer's Input Rating			Without Hood		With Hood	
Appliance	Capacity	Overall Dim., Inches Width* Depth*Height	Miscellaneous Data (Dimensions in Inches)	Boiler hp or Watts	Btu/hr	Prob-able Max. Hourly Input Btu/hr	Sensible	Latent	Total	All Sensible
Electric, Floor Mounted Type										
Griddle		36*32*37	36*25 cooking surface	16,800	57,300					2,060
Broiler, no oven			23 wide*25 deep grid	12,000	40,900	20,500				6,500
with oven			23*27*12 oven	18,000	61,400	30,700				9,800
Broiler, single deck		36*36*54		16,000	54,600					10,800
Deep fat fryer	28 lb fat	20*38*36	14 wide*15 deep kettle	12,000	40,900	20,500				6,500
	60 lb fat	24*36*36	29 wide*20 deep kettle	18,000	61,400	30,700				9,800
Fryer		15*32*36	13*23 cooking surface	22,000	75,000					730
Oven,baking,per sq ft of herath			Compartment 8-in. high	500	1,700	850	Exhaust hood	Exhaust hood	Exhaust hood	270
Oven,roasting,per sq ft of hearth			Compartment 12-in. high	900	3,070	1,500	required	required	required	490
Range, heavy duty										
Top section		38*36*37	36*24 cooking surface	15,000	51,200					19,100
Oven				6,700	22,900					1,700
Range,medium duty		30*32*36								
Top section				8,000	27,300	13,600				4,300
Oven				3,600	12,300	6,200				1,900
Range,light duty		30*29*36								
Top section				6,600	22,500	11,200				3,600
Oven				3,000	10,200	5,100				1,600
Convection,Oven		38*36*55		11,000	37,500					1,540
Charbroiler		36*24*34	30*18 cooking surface	16,500	56,300					4,320
Steam cooker,two sections		36*29*64		24,000	81,900					3,140
Steam Heated										
Coffee urn	3 gal.			0.2	6,600	3,300	2,180	1,120	3,300	1,000
	5 gal.			0.3	10,000	5,000	3,300	1,700	5,000	1,600
	8 gal. twin			0.4	13,200	6,600	4,350	2,250	6,600	2,100
Steam table per sq ft of top			With insets	0.05	1,650	825	500	325	825	260
Bain-marie water bath per sq ft of top			Open Tank	0.1	3,300	1,650	825	825	1,650	520
Oyster steamer				0.5	16,500	8,250	5,000	3,250	8,250	2,600
Steam kettles per gal. capacity			Jacketed type	0.06	2,000	1,000	600	400	1,000	320
Compartment steamer per compartment		24*25*12 compartment	Floor mounted	1.2	40,000	20,000	12,000	8,000	20,000	6,400
Compartment steamer	3 pans 12*20*2.5		Single counter unit	0.5	16,500	8,250	5,000	3,250	8,250	2,600
Plate warmer per cu ft				0.05	1,650	825	550	275	825	260

Table 16.11 : Heat Gain from equipment (Contd.)

Recommended Rate of Heat Gain from Commercial Cooking Appliances Located in the Air-Conditioned Area[a]

							Recommended Rate of Heat Gain,Btu/hr			
				Manufacturer's Input Rating			Without Hood		With Hood	
Appliance	Capacity	Overall Dim., Inches Width* Depth*Height	Miscellaneous Data (Dimensions in Inches)	Boiler hp or Watts	Btu/hr	Prob-able Max. Hourly Input Btu/hr	Sensible	Latent	Total	All Sensible
Gas-burning, Counter Type										
Broiler-griddle		31*20*18			36,000	18,000	11,700	6,300	18,000	3,600
Coffee brewer										
per burner			With warm position		5,500	2,500	1,750	750	2,500	500
Water heater burner			With storage tank		11,000	5,000	3,850	1,650	5,500	1,100
Coffee urn	3 gal.	12-inch dia.			10,000	5,000	3,500	1,500	5,000	1,000
	5 gal.	14-inch dia.			15,000	7,500	5,250	2,250	7,500	1,500
	8 gal. twin	25-inch dia.			20,000	10,000	7,000	3,000	10,000	2,000
Deep fat fryer	15 lb fat	14*21*15			30,000	15,000	7,500	7,500	15,000	3,000
Dry food warmer per sq ft of top					1,400	700	560	140	700	140
Griddle,frying per sq ft of top					15,000	7,500	4,900	2,600	7,500	1,500
Short order stove,per burner			Open grates		10,000	5,000	3,200	1,800	5,000	1,000
Steam table per sq ft of top					2,500	1,250	750	500	1,250	250
Toaster,continuous	360 slices/ hr	19*16*30	2 slices wide		12,000	6,000	3,600	2,400	6,000	1,200
	720 slices/ hr	24*16*30	4 slices wide		20,000	10,000	6,000	4,000	10,000	2,000
Gas-burning, Floor Mounted Type										
Broiler,unit		24*26 grid	Same burner heats oven		70,000	35,000				7,000
Deep fat fryer	32 lb fat		14-in. kettle		65,000	32,500				6,500
	56 lb fat		18-in. kettle		100,000	50,000				10,000
Oven,deck,per sq ft			Same for 7 and 12							
of hearth area			high decks		4,000	2,000				400
Oven roasting		32*32*60	Two ovens-24-*28*15		80,000	40,000	Exhaust hood	Exhaust hood	Exhaust hood	8,000
							required	required	required	
Range,heavy duty		32*42*33								
Top section			32 wide*39 deep		64,000	32,000				6,400
Oven			25*28*15		40,000	20,000				4,000
Range, Junior heavy duty		31*35*33								
Top section			31 wide *32 deep		45,000	22,500				4,500
Oven			24*28*15		35,000	17,500				3,500
Range, restaurant type										
Per 2-burner sect.			12 wide * 28 deep		24,000	12,000				2,400
Per oven			24*22*14		30,000	15,000				3,000
Per broiler-griddle			24 wide * 26 deep		35,000	17,500				3,500

Table 16.11 : Heat Gain from equipment (Contd.)

Recommended Rate of Heat Gain from Commercial Cooking Appliances Located in the Air-Conditioned Area[a]

Appliance	Capacity	Overall Dim., Inches Width* Depth*Height	Miscellaneous Data (Dimensions in Inches)	Manufacturer's Input Rating		Prob-able Max. Hourly Input Btu/hr	Recommended Rate of Heat Gain,Btu/hr			
							Without Hood		With Hood	
				Boiler hp or Watts	Btu/hr		Sensible	Latent	Total	All Sensible
Electric, Counter Type										
Coffee brewer per burner				625	2,130	1,000	770	230	1,000	340
per warmer				160	545	300	230	70	300	90
automatic	240 cups per hr	27*21*22	4-burner+water htr.	5,000	17,000	8,500	6,500	2,000	8,500	1,700
Coffee urn	3 gal.			2,000	6,800	3,400	2,550	850	3,400	1,000
	5 gal.			3,000	10,200	5,100	3,850	1,250	5,100	1,600
	8 gal. twin			4,000	13,600	6,800	5,200	1,600	6,800	2,100
Deep fat fryer	14 lb fat	13*22*10		5,500	18,750	9,400	2,800	6,600	9,400	3,000
	21 lb fat	16*22*10		8,000	27,300	13,700	4,100	9,600	13,700	4,300
Dry food warmer,										
per sq ft of top				240	820	400	320	80	400	130
Egg boiler	2 cups	10*13*25		1,100	3,750	1,900	1,140	760	1,900	600
Griddle,frying,				2,700	9,200	4,600	3,000	1,600	4,600	1,500
per sq ft of top										
Griddle-Grill		18*20*13	Grid,200 sq in.	6,000	20,400	10,200	6,600	3,600	10,200	3,200
Hotplate		18*20*13	2 heating units	5,200	17,700	8,900	5,300	3,600	8,900	2,800
Roaster		18*20*13		1,650	5,620	2,800	1,700	1,100	2,800	900
Roll warmer		18*20*13		1,650	5,620	2,800	2,600	200	2,800	900
Toaster,continuous	360 slices/ hr	15*15*28	2 slices wide	2,200	7,500	3,700	1,960	1,740	3,700	1,200
	720 slices/ hr	20*15*28	4 slices wide	3,000	10,200	5,100	2,700	2,400	5,100	1,600
Toaster, pop-up	4 slices	12*11*9		2,540	8,350	4,200	2,230	1,970	4,200	1,300
Waffle iron		18*20*13	2 grids	1,650	5,620	2,800	1,680	1,120	2,800	900

Table 16.11a : Rate of Heat Gain from Miscellaneous Appliances

Appliance	"Miscellaneous Data"	"Manufacturer's Rating"		"Recommended Rate of Heat Gain"		
		Watts	Btu/hr	Sensible	Latent	Total
Electrical Appliances						
Hair Dryer	"Blower type"	1580	5400	2300	400	2700
Hair Dryer	"Helmet type"	705	2400	1870	330	2200
Permanent wave machine	"60 heaters @25 W in normal use"	1500	5000	850	150	1000
Neon sign	0.5 in.,dia			30		30
per linear ft of tube	0.375 in.,dia			60		60
Sterilizer, instrument		1100	3750	650	1200	1850
Magnetic Card Typewriter			690	350	0	350
Small	Running		6000	6000	0	6000
Copier	Standby		3000	3000	0	3000
Large	Running		12,000	12,000	0	12,000
Copier	Standby		6000	6000	0	6000
Gas-Burning Appliances						
Lab Burners						
Bunsen	"0.4375 in. barrel"		3000	1680	420	2100
Fishtail	"1.5 in. wide"		5000	2800	700	3500
Meeker	"1 in. diameter"		6000	3360	840	4200
Gas light, per burner	"Mantle type"		2000	1800	200	2000
Cigar lighter	"Continuous flame"		2500	900	100	1000

Table 16.12.1 : Sensible Heat Cooling Load Factors for Hooded Appliances

"Total Operational Hours"	Hours after appliances are on																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
2	0.27	0.4	0.25	0.18	0.14	0.11	0.09	0.08	0.07	0.06	0.05	0.04	0.04	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01
4	0.28	0.41	0.51	0.59	0.39	0.3	0.24	0.19	0.16	0.14	0.12	0.1	0.09	0.08	0.07	0.06	0.05	0.05	0.04	0.04	0.03	0.03	0.02	0.02
6	0.29	0.42	0.52	0.59	0.65	0.7	0.48	0.37	0.3	0.25	0.21	0.18	0.16	0.14	0.12	0.11	0.09	0.08	0.07	0.06	0.05	0.05	0.04	0.04
8	0.31	0.44	0.54	0.61	0.66	0.71	0.75	0.78	0.55	0.43	0.35	0.3	0.25	0.22	0.19	0.16	0.14	0.13	0.11	0.1	0.08	0.07	0.06	0.06
10	0.33	0.46	0.55	0.62	0.68	0.72	0.76	0.79	0.81	0.84	0.6	0.48	0.39	0.33	0.28	0.24	0.21	0.18	0.16	0.14	0.12	0.11	0.09	0.08
12	0.36	0.49	0.58	0.64	0.69	0.74	0.77	0.8	0.82	0.85	0.87	0.88	0.64	0.51	0.42	0.36	0.31	0.26	0.23	0.2	0.18	0.15	0.13	0.12
14	0.4	0.52	0.61	0.67	0.72	0.76	0.79	0.82	0.84	0.86	0.88	0.89	0.91	0.92	0.67	0.54	0.45	0.38	0.32	0.28	0.24	0.21	0.19	0.16
16	0.45	0.57	0.65	0.7	0.75	0.78	0.81	0.84	0.86	0.87	0.89	0.9	0.92	0.93	0.94	0.94	0.69	0.56	0.46	0.39	0.34	0.29	0.25	0.22
18	0.52	0.63	0.7	0.75	0.79	0.82	0.84	0.86	0.88	0.89	0.91	0.92	0.93	0.94	0.95	0.95	0.96	0.96	0.71	0.58	0.48	0.41	0.35	0.3

Table 16.12.2 : Sensible Heat Cooling Load Factors for Unhooded Appliances, Motors, etc.

"Total Operational Hours"	Hours after appliances are on																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
2	0.56	0.64	0.15	0.11	0.08	0.07	0.06	0.05	0.04	0.04	0.03	0.03	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
4	0.57	0.65	0.71	0.75	0.23	0.18	0.14	0.12	0.1	0.08	0.07	0.06	0.05	0.05	0.04	0.04	0.03	0.03	0.02	0.02	0.02	0.02	0.01	0.01
6	0.57	0.65	0.71	0.76	0.79	0.82	0.29	0.22	0.18	0.15	0.13	0.11	0.1	0.08	0.07	0.06	0.06	0.05	0.04	0.04	0.03	0.03	0.03	0.02
8	0.58	0.66	0.72	0.76	0.8	0.82	0.85	0.87	0.33	0.26	0.21	0.18	0.15	0.13	0.11	0.1	0.09	0.08	0.07	0.06	0.05	0.04	0.04	0.03
10	0.6	0.68	0.73	0.77	0.81	0.83	0.85	0.87	0.89	0.9	0.36	0.29	0.24	0.2	0.17	0.15	0.13	0.11	0.1	0.08	0.07	0.07	0.06	0.05
12	0.62	0.69	0.75	0.79	0.82	0.84	0.86	0.88	0.89	0.91	0.92	0.93	0.38	0.31	0.25	0.21	0.18	0.16	0.14	0.12	0.11	0.09	0.08	0.07
14	0.64	0.71	0.76	0.8	0.83	0.85	0.87	0.89	0.9	0.92	0.93	0.93	0.94	0.95	0.4	0.32	0.27	0.23	0.19	0.17	0.15	0.13	0.11	0.1
16	0.67	0.74	0.79	0.82	0.85	0.87	0.89	0.9	0.91	0.92	0.93	0.94	0.95	0.96	0.96	0.97	0.42	0.34	0.28	0.24	0.2	0.18	0.15	0.13
18	0.71	0.78	0.82	0.85	0.87	0.89	0.9	0.92	0.93	0.94	0.94	0.95	0.96	0.96	0.97	0.97	0.97	0.98	0.43	0.35	0.29	0.24	0.21	0.18

Table 16.13 : Monthwise Maximum, Minimum Temperatures and Daily Range

City Or Station Name	Longitude	Latitude	Elevation
Ahmedabad	**72° 37'**	**23° 4'**	**180.4**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	84.56	60.62	23.94
Feb	91.76	68	23.76
Mar	103.82	77.9	25.92
Apr	107.24	80.06	27.18
May	109.76	86.18	23.58
Jun	107.96	84.02	23.94
Jul	98.06	83.48	14.58
Aug	93.02	78.8	14.22
Sep	99.68	71.06	28.62
Oct	100.94	82.76	18.18
Nov	98.6	70.88	27.72
Dec	92.3	59.18	33.12

City Or Station Name	Longitude	Latitude	Elevation
Akola	**77° 1'**	**20° 42'**	**282.0**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	89.96	57.56	32.4
Feb	101.48	65.12	36.36
Mar	105.08	72.14	32.94
Apr	111.2	83.48	27.72
May	110.66	85.82	24.84
Jun	113	84.02	28.98
Jul	96.98	77.72	19.26
Aug	91.4	71.96	19.44
Sep	98.6	77	21.6
Oct	98.06	69.44	28.62
Nov	90.32	66.02	24.3
Dec	90.68	59.9	30.78

City Or Station Name	Longitude	Latitude	Elevation
Allahabad	**81° 43'**	**25° 27'**	**98**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	79.16	55.94	23.22
Feb	92.66	65.66	27
Mar	100.94	68.9	32.04
Apr	111.56	81.5	30.06
May	113	84.38	28.62
Jun	113	86	27
Jul	103.1	88.16	14.94
Aug	92.48	81.32	11.16
Sep	96.08	81.68	14.4
Oct	96.26	78.26	18
Nov	86.72	69.44	17.28
Dec	79.88	55.4	24.48

Table 16.13 : Monthwise Maximum, Minimum Temperatures and Daily Range (Cont.)

City Or Station Name	Longitude	Latitude	Elevation
Amritsar	**74° 52'**	**31° 37'**	**234**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	74.66	40.28	34.38
Feb	77.18	54.5	22.68
Mar	94.82	61.88	32.94
Apr	101.48	65.48	36
May	108.86	68.36	40.5
Jun	111.74	78.62	33.12
Jul	98.6	83.48	15.12
Aug	99.86	81.68	18.18
Sep	99.68	72.86	26.82
Oct	95.36	67.82	27.54
Nov	82.04	59.18	22.86
Dec	75.2	46.58	28.62

City Or Station Name	Longitude	Latitude	Elevation
Aurangabad	**75° 24'**	**19° 51'**	**579**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	90.68	56.84	33.84
Feb	91.76	56.12	35.64
Mar	100.4	81.68	18.72
Apr	103.28	79.7	23.58
May	107.96	83.84	24.12
Jun	106.7	85.1	21.6
Jul	93.02	75.92	17.1
Aug	87.8	69.98	17.82
Sep	88.88	72.5	16.38
Oct	93.74	66.92	26.82
Nov	91.04	61.52	29.52
Dec	85.64	52.7	32.94

City Or Station Name	Longitude	Latitude	Elevation
Barmer	**71° 22'**	**25° 45'**	**194**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	83.84	52.34	31.5
Feb	91.04	58.1	32.94
Mar	98.96	68.18	30.78
Apr	110.3	80.96	29.34
May	113.54	90.5	23.04
Jun	111.74	82.94	28.8
Jul	106.34	82.04	24.3
Aug	100.22	81.14	19.08
Sep	102.56	81.86	20.7
Oct	104.36	84.38	19.98
Nov	94.28	69.62	24.66
Dec	86	64.4	21.6

Table 16.13 : Monthwise Maximum, Minimum Temperatures and Daily Range (Cont.)

City Or Station Name	Longitude	Latitude	Elevation
Belgaum	**74° 37'**	**15° 51'**	**747**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	87.8	57.02	30.78
Feb	95.36	59.36	36
Mar	99.14	69.98	29.16
Apr	101.48	70.16	31.32
May	100.94	73.94	27
Jun	93.2	69.98	23.22
Jul	82.4	70.52	11.88
Aug	83.12	70.7	12.42
Sep	87.08	67.1	19.98
Oct	87.8	67.82	19.98
Nov	87.08	67.28	19.8
Dec	86	55.4	30.6

City Or Station Name	Longitude	Latitude	Elevation
Bangalore	**77° 34'**	**12° 58'**	**921**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	88.34	59.72	28.62
Feb	89.42	68.72	20.7
Mar	94.28	70.34	23.94
Apr	98.78	77	21.78
May	95.72	72.14	23.58
Jun	91.76	72.68	19.08
Jul	88.16	68.18	19.98
Aug	86.9	69.44	17.46
Sep	86.18	69.08	17.1
Oct	84.92	65.66	19.26
Nov	83.48	67.64	15.84
Dec	82.4	63.14	19.26

City Or Station Name	Longitude	Latitude	Elevation
Bhagalpur	**86° 56'**	**25° 13'**	**49**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	86.18	55.76	30.42
Feb	90.68	62.42	28.26
Mar	102.02	75.2	26.82
Apr	105.08	78.08	27
May	110.12	84.92	25.2
Jun	108.68	81.32	27.36
Jul	98.06	81.86	16.2
Aug	98.6	83.3	15.3
Sep	99.68	81.86	17.82
Oct	100.22	82.22	18
Nov	96.98	67.64	29.34
Dec	89.06	59.18	29.88

Table 16.13 : Monthwise Maximum, Minimum Temperatures and Daily Range (Cont.)

City Or Station Name	Longitude	Latitude	Elevation
Bhopal-Bairagarh	**77° 20'**	**23° 16'**	**523**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	82.76	56.84	25.92
Feb	92.48	71.42	21.06
Mar	102.2	68.72	33.48
Apr	106.34	79.52	26.82
May	111.02	84.56	26.46
Jun	108.5	86.72	21.78
Jul	100.76	77.54	23.22
Aug	90.68	77	13.68
Sep	91.4	73.58	17.82
Oct	95.54	68.36	27.18
Nov	87.8	68.72	19.08
Dec	87.08	56.48	30.6

City Or Station Name	Longitude	Latitude	Elevation
Bhubaneshwar	**85° 49'**	**20° 15'**	**46**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	94.46	65.66	28.8
Feb	95.9	70.34	25.56
Mar	99.5	74.12	25.38
Apr	102.2	82.04	20.16
May	104.72	77.18	27.54
Jun	106.7	84.92	21.78
Jul	97.34	82.94	14.4
Aug	91.94	80.42	11.52
Sep	95	80.6	14.4
Oct	92.3	78.08	14.22
Nov	89.06	66.92	22.14
Dec	86	64.4	21.6

City Or Station Name	Longitude	Latitude	Elevation
Bhuj	**69° 40'**	**23° 15'**	**80**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	86.36	55.76	30.6
Feb	96.98	65.12	31.86
Mar	105.98	64.58	41.4
Apr	105.98	75.56	30.42
May	107.6	77.36	30.24
Jun	104	80.96	23.04
Jul	102.02	82.22	19.8
Aug	95.9	79.7	16.2
Sep	102.02	75.02	27
Oct	102.02	80.42	21.6
Nov	98.96	74.48	24.48
Dec	89.06	54.14	34.92

Table 16.13 : Monthwise Maximum, Minimum Temperatures and Daily Range (Cont.)

City Or Station Name	Longitude	Latitude	Elevation
Bikaner	**73° 18'**	**28° 0'**	**224**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	82.76	42.62	40.14
Feb	90.68	58.28	32.4
Mar	98.6	63.68	34.92
Apr	110.48	72.32	38.16
May	115.88	81.5	34.38
Jun	112.28	84.92	27.36
Jul	106.88	88.7	18.18
Aug	104.18	80.78	23.4
Sep	103.82	80.24	23.58
Oct	99.86	68.72	31.14
Nov	103.28	55.04	48.24
Dec	83.3	47.66	35.64

City Or Station Name	Longitude	Latitude	Elevation
Chennai-Minambakkam	**80° 10'**	**13° 0'**	**16**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	86.54	70.16	16.38
Feb	95.18	75.38	19.8
Mar	97.7	77.54	20.16
Apr	100.58	83.3	17.28
May	110.12	87.62	22.5
Jun	105.44	85.64	19.8
Jul	99.86	79.7	20.16
Aug	97.88	81.32	16.56
Sep	97.7	78.8	18.9
Oct	94.1	79.16	14.94
Nov	91.22	77.72	13.5
Dec	86.36	74.84	11.52

City Or Station Name	Longitude	Latitude	Elevation
Chitradurga	**76° 25'**	**14° 13'**	**733**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	89.96	67.82	22.14
Feb	93.56	69.08	24.48
Mar	98.06	74.66	23.4
Apr	100.4	75.74	24.66
May	98.42	78.26	20.16
Jun	91.4	68	23.4
Jul	89.96	71.06	18.9
Aug	83.66	70.52	13.14
Sep	89.42	68.9	20.52
Oct	88.88	64.76	24.12
Nov	84.92	69.62	15.3
Dec	86.18	64.76	21.42

Table 16.13 : Monthwise Maximum, Minimum Temperatures and Daily Range (Cont.)

City Or Station Name	Longitude	Latitude	Elevation
Dehradun	**78° 1'**	**30° 19'**	**682**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	72.68	42.44	30.24
Feb	79.52	51.98	27.54
Mar	85.82	65.12	20.7
Apr	97.16	70.34	26.82
May	100.58	74.66	25.92
Jun	96.8	75.38	21.42
Jul	92.84	78.8	14.04
Aug	89.06	74.48	14.58
Sep	90.86	68	22.86
Oct	88.16	63.5	24.66
Nov	81.5	56.3	25.2
Dec	75.92	46.4	29.52

City Or Station Name	Longitude	Latitude	Elevation
Dibrugarh	**95° 1'**	**27° 28'**	**111**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	76.64	50.72	25.92
Feb	78.8	54.68	24.12
Mar	85.1	62.24	22.86
Apr	91.04	64.58	26.46
May	93.92	73.76	20.16
Jun	98.06	78.98	19.08
Jul	92.66	73.94	18.72
Aug	99.32	76.46	22.86
Sep	94.64	78.62	16.02
Oct	89.6	70.52	19.08
Nov	86.72	62.24	24.48
Dec	78.62	50	28.62

City Or Station Name	Longitude	Latitude	Elevation
Gorakhpur	**83° 22'**	**26° 45'**	**77**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	76.64	13.8	62.84
Feb	82.94	15.1	67.84
Mar	95.72	22.7	73.02
Apr	104.36	24.5	79.86
May	106.7	27.3	79.4
Jun	100.22	29.5	70.72
Jul	95.9	27	68.9
Aug	94.28	27.8	66.48
Sep	93.56	27	66.56
Oct	93.56	24.5	69.06
Nov	92.12	20.1	72.02
Dec	82.4	15.2	67.2

Table 16.13 : Monthwise Maximum, Minimum Temperatures and Daily Range (Cont.)

City Or Station Name	Longitude	Latitude	Elevation
Guwahati	**91° 34'**	**26° 6'**	**54**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	79.16	56.84	22.32
Feb	81.5	53.24	28.26
Mar	91.04	69.62	21.42
Apr	99.32	70.52	28.8
May	97.16	71.6	25.56
Jun	95.9	80.96	14.94
Jul	92.84	78.8	14.04
Aug	94.64	77.18	17.46
Sep	90.68	78.44	12.24
Oct	89.96	74.66	15.3
Nov	85.28	64.22	21.06
Dec	79.52	58.64	20.88

City Or Station Name	Longitude	Latitude	Elevation
Gwalior	**78° 15'**	**26° 13'**	**207**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	79.88	44.96	34.92
Feb	91.22	52.52	38.7
Mar	101.12	64.04	37.08
Apr	109.76	74.48	35.28
May	112.64	88.16	24.48
Jun	113.9	90.32	23.58
Jul	104	84.02	19.98
Aug	99.5	80.06	19.44
Sep	101.84	80.24	21.6
Oct	102.2	64.76	37.44
Nov	94.46	58.46	36
Dec	81.68	45.32	36.36

City Or Station Name	Longitude	Latitude	Elevation
Hissar	**75° 43'**	**29° 10'**	**221**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	75.38	49.46	25.92
Feb	81.5	57.2	24.3
Mar	98.06	66.56	31.5
Apr	112.82	84.2	28.62
May	112.82	90.14	22.68
Jun	115.52	91.94	23.58
Jul	110.66	89.42	21.24
Aug	100.22	82.4	17.82
Sep	98.96	84.56	14.4
Oct	100.04	80.24	19.8
Nov	94.82	62.6	32.22
Dec	83.3	57.38	25.92

Table 16.13 : Monthwise Maximum, Minimum Temperatures and Daily Range (Cont.)

City Or Station Name	Longitude	Latitude	Elevation
Hyderabad-AP	**78° 28'**	**17° 27'**	**545**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	90.32	63.14	27.18
Feb	96.8	68	28.8
Mar	102.38	70.34	32.04
Apr	106.34	85.28	21.06
May	107.06	84.02	23.04
Jun	105.26	74.84	30.42
Jul	95.36	76.82	18.54
Aug	90.32	75.38	14.94
Sep	90.68	72.5	18.18
Oct	88.52	68.36	20.16
Nov	86.54	66.02	20.52
Dec	86.72	62.96	23.76

City Or Station Name	Longitude	Latitude	Elevation
Imphal	**93° 54'**	**24° 46'**	**781**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	80.924	38.48	42.444
Feb	83.84	48.92	34.92
Mar	89.672	54.32	35.352
Apr	69.908	60.44	9.468
May	73.472	62.42	11.052
Jun	86.756	73.4	13.356
Jul	65.372	73.4	-8.028
Aug	58.892	73.4	-14.508
Sep	64.724	69.62	-4.896
Oct	68.288	64.76	3.528
Nov	68.936	57.02	11.916
Dec	74.768	42.98	31.788

City Or Station Name	Longitude	Latitude	Elevation
Indore	**75° 48'**	**22° 43'**	**567**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	85.46	53.96	31.5
Feb	92.3	57.74	34.56
Mar	100.76	61.88	38.88
Apr	105.8	75.92	29.88
May	107.24	76.1	31.14
Jun	104.72	80.78	23.94
Jul	93.2	72.86	20.34
Aug	87.98	73.04	14.94
Sep	95.36	69.8	25.56
Oct	93.56	66.2	27.36
Nov	89.6	58.28	31.32
Dec	84.74	48.38	36.36

Table 16.13 : Monthwise Maximum, Minimum Temperatures and Daily Range (Cont.)

City Or Station Name	Longitude	Latitude	Elevation
Jabalpur	**79° 56'**	**23° 12'**	**393**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	84.2	48.56	35.64
Feb	96.8	60.26	36.54
Mar	99.68	66.92	32.76
Apr	107.6	74.3	33.3
May	107.24	73.76	33.48
Jun	108.86	84.92	23.94
Jul	92.84	77.72	15.12
Aug	90.86	75.02	15.84
Sep	95.18	75.92	19.26
Oct	90.32	68	22.32
Nov	89.24	63.5	25.74
Dec	82.22	48.74	33.48

City Or Station Name	Longitude	Latitude	Elevation
Jagdalpur	**82° 1'**	**19° 4'**	**553**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	85.82	51.62	34.2
Feb	95.9	51.44	44.46
Mar	100.22	68	32.22
Apr	105.62	69.8	35.82
May	103.46	72.86	30.6
Jun	97.52	72.32	25.2
Jul	91.4	72.86	18.54
Aug	87.08	73.94	13.14
Sep	89.96	72.32	17.64
Oct	88.7	70.88	17.82
Nov	86.9	55.04	31.86
Dec	86.72	55.22	31.5

City Or Station Name	Longitude	Latitude	Elevation
Jaipur-Sanganer	**75° 48'**	**26° 49'**	**390**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	77.54	43.52	34.02
Feb	86.54	58.1	28.44
Mar	99.68	70.7	28.98
Apr	108.68	81.14	27.54
May	110.48	86.18	24.3
Jun	109.4	89.78	19.62
Jul	101.84	81.68	20.16
Aug	93.92	82.94	10.98
Sep	98.96	76.46	22.5
Oct	98.6	75.74	22.86
Nov	92.48	63.32	29.16
Dec	85.28	56.84	28.44

Table 16.13 : Monthwise Maximum, Minimum Temperatures and Daily Range (Cont.)

City Or Station Name	Longitude	Latitude	Elevation
Jaisalmer	**70° 55'**	**26° 53'**	**231**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	83.12	55.4	27.72
Feb	92.84	69.44	23.4
Mar	98.42	73.22	25.2
Apr	112.1	84.02	28.08
May	112.1	80.96	31.14
Jun	111.92	82.76	29.16
Jul	108.32	88.34	19.98
Aug	104	88.34	15.66
Sep	103.28	79.34	23.94
Oct	104.54	82.4	22.14
Nov	92.3	73.4	18.9
Dec	84.02	63.86	20.16

City Or Station Name	Longitude	Latitude	Elevation
Jamnagar	**70° 1'**	**22° 28'**	**20**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	89.96	52.34	37.62
Feb	94.46	55.94	38.52
Mar	102.02	69.8	32.22
Apr	99.68	72.5	27.18
May	100.22	73.94	26.28
Jun	98.24	81.14	17.1
Jul	98.06	80.42	17.64
Aug	90.68	77.36	13.32
Sep	97.16	75.92	21.24
Oct	96.98	70.88	26.1
Nov	91.4	61.16	30.24
Dec	89.06	60.8	28.26

City Or Station Name	Longitude	Latitude	Elevation
Jodhpur	**73° 1'**	**26° 17'**	**224**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	86	52.52	33.48
Feb	93.56	71.42	22.14
Mar	103.1	77.18	25.92
Apr	111.74	80.6	31.14
May	111.38	85.46	25.92
Jun	116.24	90.32	25.92
Jul	103.64	91.22	12.42
Aug	95.72	78.98	16.74
Sep	104.36	75.2	29.16
Oct	108.5	75.02	33.48
Nov	94.82	67.1	27.72
Dec	90.14	61.16	28.98

Table 16.13 : Monthwise Maximum, Minimum Temperatures and Daily Range (Cont.)

City Or Station Name	Longitude	Latitude	Elevation
Jorhat	**94° 10'**	**26° 43'**	**90**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	75.38	51.26	24.12
Feb	80.24	55.22	25.02
Mar	91.76	57.92	33.84
Apr	91.4	70.52	20.88
May	94.46	77.9	16.56
Jun	96.08	79.7	16.38
Jul	99.68	75.56	24.12
Aug	94.82	77.54	17.28
Sep	95	78.8	16.2
Oct	89.78	70.16	19.62
Nov	85.28	62.78	22.5
Dec	78.62	56.12	22.5

City Or Station Name	Longitude	Latitude	Elevation
Kodaikanal	**77° 47'**	**10° 23'**	**2343**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	71.6	46.94	24.66
Feb	71.78	50.54	21.24
Mar	74.66	53.78	20.88
Apr	74.3	54.68	19.62
May	74.3	57.38	16.92
Jun	69.62	51.26	18.36
Jul	67.28	53.24	14.04
Aug	67.64	52.34	15.3
Sep	70.7	51.26	19.44
Oct	68	49.28	18.72
Nov	68.18	52.88	15.3
Dec	71.6	46.76	24.84

City Or Station Name	Longitude	Latitude	Elevation
Kolkata-Dum Dum	**88° 26'**	**22° 38'**	**6**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	86	60.26	25.74
Feb	93.38	65.12	28.26
Mar	102.56	76.46	26.1
Apr	103.64	70.52	33.12
May	100.58	81.32	19.26
Jun	96.8	83.84	12.96
Jul	97.16	82.58	14.58
Aug	96.08	81.14	14.94
Sep	94.1	80.6	13.5
Oct	92.84	78.26	14.58
Nov	88.52	67.46	21.06
Dec	82.4	63.5	18.9

Table 16.13 : Monthwise Maximum, Minimum Temperatures and Daily Range (Cont.)

City Or Station Name	Longitude	Latitude	Elevation
Kota	**75° 50'**	**25° 8'**	**274**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	83.48	58.28	25.2
Feb	90.14	63.32	26.82
Mar	101.66	71.06	30.6
Apr	107.96	82.22	25.74
May	114.08	92.48	21.6
Jun	112.46	91.58	20.88
Jul	98.78	83.12	15.66
Aug	98.96	79.52	19.44
Sep	97.16	78.08	19.08
Oct	96.08	75.2	20.88
Nov	87.8	65.66	22.14
Dec	80.96	55.04	25.92

City Or Station Name	Longitude	Latitude	Elevation
Kurnool	**78° 4'**	**15° 48'**	**281**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	93.74	66.2	27.54
Feb	96.08	68.18	27.9
Mar	103.46	79.34	24.12
Apr	108.5	85.1	23.4
May	109.4	87.8	21.6
Jun	105.8	86	19.8
Jul	98.06	79.7	18.36
Aug	96.08	77	19.08
Sep	94.1	77	17.1
Oct	94.28	78.62	15.66
Nov	92.66	72.68	19.98
Dec	90.5	69.98	20.52

City Or Station Name	Longitude	Latitude	Elevation
Lucknow-Amausi	**80° 52'**	**26° 45'**	**128**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	80.6	54.86	25.74
Feb	89.6	59.18	30.42
Mar	98.24	70.88	27.36
Apr	107.6	76.64	30.96
May	110.12	86.18	23.94
Jun	105.44	80.96	24.48
Jul	100.58	81.14	19.44
Aug	92.66	82.76	9.9
Sep	95.72	76.46	19.26
Oct	92.66	72.68	19.98
Nov	88.88	66.38	22.5
Dec	79.16	55.22	23.94

Table 16.13 : Monthwise Maximum, Minimum Temperatures and Daily Range (Cont.)

City Or Station Name	Longitude	Latitude	Elevation
Mangalore	**74° 31'**	**12° 31'**	**22**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	95.54	69.62	25.92
Feb	94.82	72.14	22.68
Mar	94.82	76.46	18.36
Apr	95.36	77.72	17.64
May	97.52	76.1	21.42
Jun	93.74	76.82	16.92
Jul	87.98	74.66	13.32
Aug	87.62	75.02	12.6
Sep	87.62	74.12	13.5
Oct	93.56	73.76	19.8
Nov	93.2	73.4	19.8
Dec	94.1	71.96	22.14

City Or Station Name	Longitude	Latitude	Elevation
Mumbai-SantaCruz	**72° 50'**	**19° 7'**	**14**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	94.1	69.08	25.02
Feb	99.68	75.2	24.48
Mar	96.98	73.94	23.04
Apr	94.1	80.6	13.5
May	95.36	81.86	13.5
Jun	93.02	79.16	13.86
Jul	91.22	83.3	7.92
Aug	88.7	77.72	10.98
Sep	90.68	75.56	15.12
Oct	97.52	77.36	20.16
Nov	95.72	69.62	26.1
Dec	95.18	66.38	28.8

City Or Station Name	Longitude	Latitude	Elevation
Nagpur-Sonegaon	**79° 3'**	**21° 6'**	**310**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	89.42	60.26	29.16
Feb	91.94	71.42	20.52
Mar	100.4	71.78	28.62
Apr	105.62	82.94	22.68
May	111.92	84.92	27
Jun	113	92.12	20.88
Jul	98.42	81.68	16.74
Aug	92.3	78.26	14.04
Sep	93.02	74.66	18.36
Oct	91.04	75.56	15.48
Nov	87.8	69.44	18.36
Dec	86.18	53.78	32.4

Table 16.13 : Monthwise Maximum, Minimum Temperatures and Daily Range (Cont.)

City Or Station Name	Longitude	Latitude	Elevation
Nellore	**79° 58'**	**14° 26'**	**20**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	92.48	65.48	27
Feb	96.8	71.24	25.56
Mar	102.2	80.6	21.6
Apr	104.36	83.66	20.7
May	108.68	85.1	23.58
Jun	104.72	68	36.72
Jul	99.68	82.94	16.74
Aug	97.88	84.74	13.14
Sep	98.42	78.44	19.98
Oct	94.82	79.16	15.66
Nov	87.26	77.18	10.08
Dec	83.3	76.46	6.84

City Or Station Name	Longitude	Latitude	Elevation
New Delhi-Safdarjung	**77° 11**	**28° 34'**	**216**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	79.34	49.64	29.7
Feb	81.14	56.48	24.66
Mar	97.52	72.68	24.84
Apr	108.68	73.22	35.46
May	111.2	83.3	27.9
Jun	108.68	87.8	20.88
Jul	102.2	83.84	18.36
Aug	98.96	85.46	13.5
Sep	98.6	77.72	20.88
Oct	97.7	70.7	27
Nov	94.64	66.2	28.44
Dec	85.28	50	35.28

City Or Station Name	Longitude	Latitude	Elevation
Panjim	**73° 49'**	**15° 28'**	**60**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	95.36	68.54	26.82
Feb	95.54	73.76	21.78
Mar	95.18	70.88	24.3
Apr	93.2	75.74	17.46
May	93.38	79.16	14.22
Jun	91.76	74.84	16.92
Jul	87.26	76.28	10.98
Aug	85.46	77.18	8.28
Sep	89.06	76.46	12.6
Oct	92.84	78.44	14.4
Nov	95.72	75.38	20.34
Dec	95.54	71.6	23.94

Table 16.13 : Monthwise Maximum, Minimum Temperatures and Daily Range (Cont.)

City Or Station Name	Longitude	Latitude	Elevation
Patna	**85° 10'**	**25° 16'**	**53**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	78.44	54.32	24.12
Feb	86.36	54.14	32.22
Mar	103.82	67.28	36.54
Apr	106.88	74.3	32.58
May	109.4	79.52	29.88
Jun	108.32	81.5	26.82
Jul	100.76	82.94	17.82
Aug	97.16	76.46	20.7
Sep	93.56	81.32	12.24
Oct	92.12	76.64	15.48
Nov	84.92	64.04	20.88
Dec	82.04	50.18	31.86

City Or Station Name	Longitude	Latitude	Elevation
Port Blair	**92° 72'**	**11° 67'**	**79**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	85.82	75.02	10.8
Feb	87.44	73.94	13.5
Mar	90.68	74.3	16.38
Apr	92.66	79.88	12.78
May	91.76	83.48	8.28
Jun	89.06	77	12.06
Jul	86.54	77.18	9.36
Aug	87.08	79.16	7.92
Sep	86.36	77	9.36
Oct	86.18	75.92	10.26
Nov	86.72	79.52	7.2
Dec	87.62	77.72	9.9

City Or Station Name	Longitude	Latitude	Elevation
Pune	**73° 50'**	**18° 31'**	**559**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	88.7	55.22	33.48
Feb	92.48	53.24	39.24
Mar	101.12	58.28	42.84
Apr	102.92	66.02	36.9
May	105.8	68.9	36.9
Jun	102.74	72.68	30.06
Jul	88.7	73.04	15.66
Aug	85.28	70.52	14.76
Sep	87.26	70.52	16.74
Oct	91.76	68	23.76
Nov	88.16	56.12	32.04
Dec	85.64	55.04	30.6

Table 16.13 : Monthwise Maximum, Minimum Temperatures and Daily Range (Cont.)

City Or Station Name	Longitude	Latitude	Elevation
Raipur	**81° 39'**	**21° 13'**	**298**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	87.8	51.08	36.72
Feb	91.22	62.6	28.62
Mar	105.26	67.64	37.62
Apr	107.24	79.52	27.72
May	111.74	80.96	30.78
Jun	113.18	88.88	24.3
Jul	91.76	76.64	15.12
Aug	92.3	75.74	16.56
Sep	95.54	78.08	17.46
Oct	93.56	68.9	24.66
Nov	88.16	65.84	22.32
Dec	84.92	62.6	22.32

City Or Station Name	Longitude	Latitude	Elevation
Rajkot	**70° 46'**	**22° 17'**	**138**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	93.56	62.6	30.96
Feb	96.62	70.34	26.28
Mar	108.5	77.18	31.32
Apr	107.6	77.36	30.24
May	107.78	82.04	25.74
Jun	107.06	81.5	25.56
Jul	97.88	79.16	18.72
Aug	95.36	73.22	22.14
Sep	99.5	74.84	24.66
Oct	101.66	73.94	27.72
Nov	99.32	73.76	25.56
Dec	93.74	62.96	30.78

City Or Station Name	Longitude	Latitude	Elevation
Ramagundam	**79° 25**	**18° 46'**	**156**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	93.92	60.62	33.3
Feb	98.6	61.34	37.26
Mar	103.46	77	26.46
Apr	107.96	77	30.96
May	113.9	85.82	28.08
Jun	112.46	90.32	22.14
Jul	95.36	75.2	20.16
Aug	94.82	77.72	17.1
Sep	96.8	76.46	20.34
Oct	95	64.4	30.6
Nov	91.04	64.94	26.1
Dec	87.44	56.12	31.32

Table 16.13 : Monthwise Maximum, Minimum Temperatures and Daily Range (Cont.)

City Or Station Name	Longitude	Latitude	Elevation
Ranchi	**85° 19'**	**23° 22'**	**655**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	78.08	55.76	22.32
Feb	85.1	59.72	25.38
Mar	95.36	71.24	24.12
Apr	103.64	70.88	32.76
May	106.88	80.96	25.92
Jun	102.56	78.08	24.48
Jul	95	76.28	18.72
Aug	86.18	73.4	12.78
Sep	87.26	69.26	18
Oct	87.8	70.52	17.28
Nov	85.28	62.6	22.68
Dec	78.44	47.84	30.6

City Or Station Name	Longitude	Latitude	Elevation
Ratnagiri	**73° 19'**	**16° 58'**	**67**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	93.92	72.5	21.42
Feb	98.78	67.46	31.32
Mar	93.02	71.96	21.06
Apr	96.44	79.7	16.74
May	90.5	81.5	9
Jun	90.68	77	13.68
Jul	86.9	79.52	7.38
Aug	84.74	77.9	6.84
Sep	88.52	76.28	12.24
Oct	92.48	72.5	19.98
Nov	94.82	73.22	21.6
Dec	92.84	69.08	23.76

City Or Station Name	Longitude	Latitude	Elevation
Raxaul	**84° 31'**	**26° 34'**	**1350**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	79.16	52.88	26.28
Feb	85.28	52.52	32.76
Mar	91.04	52.7	38.34
Apr	99.32	62.78	36.54
May	102.56	78.62	23.94
Jun	102.56	78.62	23.94
Jul	94.46	79.88	14.58
Aug	94.28	78.44	15.84
Sep	93.92	76.82	17.1
Oct	89.6	68.72	20.88
Nov	87.44	58.64	28.8
Dec	81.5	52.88	28.62

Table 16.13 : Monthwise Maximum, Minimum Temperatures and Daily Range (Cont.)

City Or Station Name	Longitude	Latitude	Elevation
Saharanpur	**77° 52'**	**29° 51'**	**274**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	76.28	37.04	39.24
Feb	85.1	46.58	38.52
Mar	91.04	52.88	38.16
Apr	104.9	61.52	43.38
May	104.54	63.5	41.04
Jun	106.7	69.98	36.72
Jul	104.18	80.6	23.58
Aug	95	77.36	17.64
Sep	94.28	73.04	21.24
Oct	92.3	53.6	38.7
Nov	85.64	41	44.64
Dec	82.04	35.96	46.08

City Or Station Name	Longitude	Latitude	Elevation
Shillong	**91° 52'**	**25° 34'**	**1500**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	63.5	34.88	28.62
Feb	64.22	32.9	31.32
Mar	73.76	48.56	25.2
Apr	73.76	50	23.76
May	77.36	53.78	23.58
Jun	77.72	54.68	23.04
Jul	77.9	60.98	16.92
Aug	80.6	60.44	20.16
Sep	75.56	59.72	15.84
Oct	77.54	51.62	25.92
Nov	69.44	41.18	28.26
Dec	68	32.18	35.82

City Or Station Name	Longitude	Latitude	Elevation
Sholapur	**75° 54'**	**17° 40'**	**479**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	94.82	68.36	26.46
Feb	96.98	73.76	23.22
Mar	104.9	78.44	26.46
Apr	108.5	86	22.5
May	106.7	85.64	21.06
Jun	109.58	86.54	23.04
Jul	94.28	74.3	19.98
Aug	93.92	73.4	20.52
Sep	92.12	74.84	17.28
Oct	93.92	72.32	21.6
Nov	92.48	72.5	19.98
Dec	90.86	64.04	26.82

Table 16.13 : Monthwise Maximum, Minimum Temperatures and Daily Range (Cont.)

City Or Station Name	Longitude	Latitude	Elevation
Srinagar	**74° 83'**	**34° 08'**	**1587**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	51.26	38.84	12.42
Feb	56.66	31.28	25.38
Mar	70.88	46.4	24.48
Apr	81.5	52.52	28.98
May	89.24	56.3	32.94
Jun	95.18	63.5	31.68
Jul	93.38	70.88	22.5
Aug	90.86	68.72	22.14
Sep	90.14	61.7	28.44
Oct	78.98	51.62	27.36
Nov	71.24	39.92	31.32
Dec	57.02	27.14	29.88

City Or Station Name	Longitude	Latitude	Elevation
Surat	**72° 49'**	**21° 12'**	**12**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	92.48	62.6	29.88
Feb	96.26	66.2	30.06
Mar	108.5	77.54	30.96
Apr	99.86	74.66	25.2
May	103.64	78.44	25.2
Jun	95	82.4	12.6
Jul	92.48	80.42	12.06
Aug	89.24	81.32	7.92
Sep	91.4	77	14.4
Oct	96.62	76.1	20.52
Nov	94.64	76.28	18.36
Dec	91.4	65.3	26.1

City Or Station Name	Longitude	Latitude	Elevation
Tezpur	**92° 46'**	**26° 37'**	**79**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	80.6	52.34	28.26
Feb	82.76	57.92	24.84
Mar	88.88	64.76	24.12
Apr	92.12	64.58	27.54
May	93.2	76.1	17.1
Jun	95.36	78.44	16.92
Jul	95	79.16	15.84
Aug	95.18	80.96	14.22
Sep	91.4	76.64	14.76
Oct	91.22	66.92	24.3
Nov	86.54	64.04	22.5
Dec	80.06	56.48	23.58

Table 16.13 : Monthwise Maximum, Minimum Temperatures and Daily Range (Cont.)

City Or Station Name	Longitude	Latitude	Elevation
Thiruvananthapuram	**76° 56'**	**8° 28'**	**64**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	91.4	76.82	14.58
Feb	90.32	76.1	14.22
Mar	94.1	75.2	18.9
Apr	95.36	81.14	14.22
May	93.2	79.52	13.68
Jun	89.6	80.06	9.54
Jul	87.62	78.44	9.18
Aug	87.08	76.1	10.98
Sep	89.78	76.64	13.14
Oct	87.98	76.1	11.88
Nov	89.24	74.84	14.4
Dec	91.22	77	14.22

City Or Station Name	Longitude	Latitude	Elevation
Tiruchirapalli	**78° 43'**	**10° 46'**	**88**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	89.6	68.9	20.7
Feb	96.98	70.7	26.28
Mar	98.96	81.32	17.64
Apr	104.18	82.58	21.6
May	101.48	75.74	25.74
Jun	101.12	79.16	21.96
Jul	99.86	80.06	19.8
Aug	101.3	79.34	21.96
Sep	97.16	74.84	22.32
Oct	95.54	76.64	18.9
Nov	93.38	75.02	18.36
Dec	92.12	73.22	18.9

City Or Station Name	Longitude	Latitude	Elevation
Varanasi	**82° 52'**	**25° 27'**	**85**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	78.26	59.72	18.54
Feb	88.34	61.34	27
Mar	103.1	72.5	30.6
Apr	116.6	69.8	46.8
May	111.92	81.68	30.24
Jun	108.14	82.76	25.38
Jul	99.32	85.1	14.22
Aug	94.64	82.4	12.24
Sep	94.64	78.8	15.84
Oct	89.96	75.92	14.04
Nov	91.4	62.6	28.8
Dec	81.32	57.2	24.12

Table 16.13 : Monthwise Maximum, Minimum Temperatures and Daily Range (Cont.)

City Or Station Name	Longitude	Latitude	Elevation
Veraval	**70° 22'**	**20° 53'**	**8**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	95.9	75.2	20.7
Feb	91.04	69.8	21.24
Mar	98.6	70.52	28.08
Apr	104.36	78.98	25.38
May	93.2	79.88	13.32
Jun	98.24	79.88	18.36
Jul	88.7	82.94	5.76
Aug	90.86	80.06	10.8
Sep	95.54	80.42	15.12
Oct	99.5	75.02	24.48
Nov	98.06	75.92	22.14
Dec	91.22	69.44	21.78

City Or Station Name	Longitude	Latitude	Elevation
Visakhapatnam	**83° 13'**	**17° 43'**	**3**
Daily RANGE DBT's			
Months	**DB Deg F**		
	Max	**Min**	**Range**
Jan	92.84	57.2	35.64
Feb	89.06	71.78	17.28
Mar	98.78	72.68	26.1
Apr	98.6	79.52	19.08
May	97.88	77.36	20.52
Jun	99.14	80.96	18.18
Jul	96.08	83.48	12.6
Aug	96.44	80.78	15.66
Sep	96.08	78.26	17.82
Oct	93.02	73.04	19.98
Nov	90.32	75.2	15.12
Dec	85.46	74.12	11.34