SYLLABUS / 2014 BATCH

KARPAGAM ACADEMY OF HIGHER EDUCATION

(Deemed to be University Established Under Section 3 of UGC Act 1956)

Eachanari post, Coimbatore-641021. INDIA.

Faculty of Engineering

DEPARTMENT OF MECHANICAL ENGINEERING

SUBJECT NAME	**: REFRIGERATION AND AIR CONDITIONING**	**L**	**T**	**P**	**C**
SUBJECT CODE	**: 14BEMEE01**	**3**	**0**	**0**	**3**

INTENDED OUTCOMES:

- To integrate the thermodynamic concepts into the analysis of refrigeration cycles.
- To give awareness to students on parameter to be considered for designing Refrigeration and Air Conditioning.
- To enable the student to design air conditioning system for building

UNIT I REFRIGERATION CYCLE **9**

Review of thermodynamic principles of refrigeration. Concept of refrigeration system. Vapour compression refrigeration cycle – use of P–H charts – multistage and multiple evaporator systems – cascade system – COP comparison. Vapor absorption refrigeration system. Ammonia water and Lithium Bromide water systems. Steam jet refrigeration system

UNIT II REFRIGERANTS, SYSTEM COMPONENTS AND BALANCING **9**

Compressors – reciprocating and rotary (elementary treatment.) – Condensers – evaporators – cooling towers. Refrigerants – properties – selection of refrigerants, Alternate Refrigerants, Refrigeration plant controls – testing and charging of refrigeration units. Balancing of system components. Applications to refrigeration systems – ice plant – food storage plants – milk –chilling plants – refrigerated cargo ships.

UNIT III PSYCHROMETRY **9**

Psychrometric processes– use of psychrometric charts – – Grand and Room Sensible Heat Factors – bypass factor – requirements of comfort air conditioning – comfort charts – factors governing optimum effective temperature, recommended design conditions and ventilation standards

UNIT IV COOLING LOAD CALCULATIONS **9**

Types of load – design of space cooling load – heat transmission through building. Solar radiation – infiltration – internal heat sources (sensible and latent) – outside air and fresh air load – estimation of total load – Domestic, commercial and industrial systems – central air conditioning systems.

UNIT V AIRCONDITIONING **9**

Air conditioning equipments – air cleaning and air filters – humidifiers – dehumidifiers – air washers – condenser – cooling tower and spray ponds – elementary treatment of duct design – air distribution system. Thermal insulation of air conditioning systems. – Applications: car, industry, stores, and public buildings

TOTAL PERIODS: 45

TEXT BOOKS:

S.NO	AUTHOR(S) NAME	TITLE OF THE BOOK	PUBLISHER	YEAR OF PUBLICATION
1	Manohar Prasad	Refrigeration and Air Conditioning	New Age International Ltd, New Delhi.	2015
2	Arora. C.P.	Refrigeration and Air Conditioning	Tata McGraw–Hill, New Delhi.	2008

REFERENCES:

S.NO	AUTHOR(S) NAME	TITLE OF THE BOOK	PUBLISHER	YEAR OF PUBLICATION
1	Roy.J Dossat	Principles of Refrigeration	Pearson Education, New Delhi.	1997
2	Jordon and Prister	Refrigeration and Air Conditioning	Prentice Hall of India PVT Ltd., New Delhi.	1957
3	Stoecker N.F and Jerold W.Jones	Refrigeration and Air Conditioning	McGraw Hill, New Delhi.	1986

WEBSITES:

1. http://nptel.iitg.ernet.in/Mech_Engg/IIT%20Kharagpur/Refrigeration%20and%20Air%20Conditioning.htm
2. http://www.ashrae.org/
3. http://en.wikipedia.org/wiki/Thermal_comfort

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DEPARTMENT OF MECHANICAL ENGINEERING

LESSON PLAN

Subject Name : Refrigeration and Air Conditioning
Subject Code : 14BEMEE01
Branch : B.E. – Mechanical Engineering

Sl. No.	No. of Periods	Topics to be Covered	Support Materials
UNIT – I : REFRIGERATION CYCLE			
1.	1	Review of thermodynamic principles of refrigeration. Concept of refrigeration system	**T[1], R[4], T[2]**
2.	1	Vapour compression refrigeration cycle - use of P–H charts	**T[2], R[5], W[4]**
3.	2	Multistage and multiple evaporator systems	**T[1], T[2], R[1]**
4.	1	Cascade system – COP comparison	**T[1], T[2], R[5]**
5.	1	**Tutorial-1: Problems related to VCR System**	**T[1], T[2]**
6.	2	Vapor absorption refrigeration system. Ammonia water, Lithium Bromide water absorption refrigeration system	**R[4], T[2], W[4]**
7.	1	Steam jet refrigeration system	**R[5], R[3]**
8.	1	**Tutorial-2: Problems related to VCR System**	**T[1], T[2]**
9.	1	**Discussion on Competitive Examination related Questions / University previous year questions**	**GATE, ESE QP**
Total No. of Hours Planned for Unit - I			**11**

Sl. No.	No. of Periods	Topics to be Covered	Support Materials
UNIT – II : REFRIGERANTS, SYSTEM COMPONENTS AND BALANCING			
10.	2	Compressors – reciprocating and rotary (elementary treatment.) Condensers – evaporators – cooling towers	**T[1], T[2], R[4]**
11.	2	Refrigerants – properties – selection of refrigerants, Alternate Refrigerants.	**R[4], T[2], W[4]**
12.	1	Refrigeration plant controls – testing and charging of refrigeration units	**T[2], R[5]**
13.	1	**Tutorial-3: Problems Related to Refrigeration components**	**T[1], T[2]**
14.	1	Balancing of system components. Applications to refrigeration systems	**R[1], R[5], T[1]**

15.	2	Ice plant – food storage plants – milk –chilling plants – refrigerated cargo ships.	**T[1], T[2], R[4]**
16.	1	**Tutorial-4: Problems Related to Refrigeration components**	**T[1], T[2]**
17.	1	**Discussion on Competitive Examination related Questions / University previous year questions**	**GATE, ESE QP**
Total No. of Hours Planned for Unit - II			**11**

Sl. No.	No. of Periods	Topics to be Covered	Support Materials
UNIT – III : PSYCHROMETRY			
18.	2	Psychrometric processes– use of psychrometric charts	**T[1], T[2], R[4]**
19.	2	Grand and Room Sensible Heat Factors – bypass factor	**R[4], R[5], T[1]**
20.	1	Requirements of comfort air conditioning – comfort charts	**T[2], T[1], W[2]**
21.	1	**Tutorial-5: Problems Related to Psychrometric Processes**	**T[1], T[2]**
22.	1	Factors governing optimum effective temperature	**W[3], T[2], R[3]**
23.	2	Recommended design conditions and ventilation standards	**T[2], R[5], T[1]**
24.	1	**Tutorial-6: Problems Related to Psychrometric Processes**	**T[1], T[2]**
25.	1	**Discussion on Competitive Examination related Questions / University previous year questions**	**GATE, ESE QP**
Total No. of Hours Planned for Unit - III			**11**

Sl. No.	No. of Periods	Topics to be Covered	Support Materials
UNIT – IV : COOLING LOAD CALCULATIONS			
26.	1	Types of load – design of space cooling load	**R[5], R[4], T[1]**
27.	1	Heat transmission through building	**T[2], W[2], R[2]**
28.	1	Solar radiation – infiltration	**R[3], R[1]**
29.	1	Internal heat sources (sensible and latent)	**T[1], T[2], R[5]**
30.	1	**Tutorial-7: Problems Related to Cooling Load Calculations**	**T[1], T[2]**
31.	2	Outside air and fresh air load – estimation of total load	**T[1], T[2], R[2]**
32.	2	Domestic, commercial and industrial systems	**R[1], T[2], R[3]**
33.	1	Central air conditioning systems.	**R[5], T[1], T[2]**
34.	1	**Tutorial-8: Problems Related Cooling Load Calculations**	**T[1], T[2]**
35.	1	**Discussion on Competitive Examination related Questions / University previous year questions**	**GATE, ESE QP**
Total No. of Hours Planned for Unit - IV			**12**

Sl. No.	No. of Periods	Topics to be Covered	Support Materials
UNIT – V : AIR CONDITIONING			
36.	1	Air conditioning equipment	**T[1], R[5], R[4]**

37.	1	Air cleaning and air filters	**T[2], R[4], R[2]**
38.	1	Humidifiers – dehumidifiers – air washers	**T[1], T[2], R[1]**
39.	1	Condenser – cooling tower and spray ponds	**R[1], T[2], R[5]**
40.	1	**Tutorial-9: Problems Related to Refrigeration Systems**	**T[1], T[2]**
41.	2	Elementary treatment of duct design– air distribution system.	**R[5], R[4]**
42.	1	Thermal insulation of air conditioning systems.	**T[1], T[2], R[3]**
43.	1	Applications: car, industry, stores, and public buildings	**W[1], W[3], W[4]**
44.	1	**Tutorial-10: Problems Related to Air Conditioning Systems**	**T[1], T[2]**
45.	1	**Discussion on Competitive Examination related Questions / University previous year questions**	**GATE, ESE QP**
Total No. of Hours Planned for Unit - V			**11**

TOTAL PERIODS : 45

TEXT BOOKS

T [1] – Manohar Prasad, 2002, Refrigeration and Air Conditioning, New Age International Ltd, New Delhi.
T [2] – Arora C.P, 2000, Refrigeration and Air conditioning, Tata McGraw–Hill, New Delhi

REFERENCES

R [1] - Roy.J Dossat, 1997, Principles of Refrigeration, Pearson Education, New Delhi.
R [2] - Jordon and Prister,1948, Refrigeration and Air Conditioning, Prentice Hall of India PVT Ltd., New Delhi.
R [3] - Stoecker N.F and Jerold W.Jones, 1986, Refrigeration and Air Conditioning, McGraw Hill, New Delhi.
R [4] - R.S. Khurmi and J.K. Gupta, 2007, A Text Book of Refrigeration and Air conditioning, S. Chand Publication
R [5] - R.K. Rajput, 2003, A Text Book of Refrigeration and Air conditioning, S.K. Kataria & Sons Publication

WEBSITES

W'[1]- http://nptel.iitg.ernet.in/Mech_Engg/IIT%20Kharagpur/Refrigeration%20and%20Air%20Conditioning.htm
W [2] - http://www.ashrae.org/
W [3] - http://en.wikipedia.org/wiki/Thermal_comfort
W [4] - www.nptel.ac.in

UNIT – I

REFRIGERATION CYCLE

Introduction

Refrigeration may be defined as the process of achieving and maintaining a temperature below that of the surroundings, the aim being to cool some product or space to the required temperature. One of the most important applications of refrigeration has been the preservation of perishable food products by storing them at low temperatures. Refrigeration systems are also used extensively for providing thermal comfort to human beings by means of air conditioning. Air Conditioning refers to the treatment of air so as to simultaneously control its temperature, moisture content, cleanliness, odour and circulation, as required by occupants, a process, or products in the space. The subject of refrigeration and air conditioning has evolved out of human need for food and comfort, and its history dates back to centuries. The history of refrigeration is very interesting since every aspect of it, the availability of refrigerants, the prime movers and the developments in compressors and the methods of refrigeration all are a part of it. The French scientist Roger ThÝvenot has written an excellent book on the history of refrigeration throughout the world. Here we present only a brief history of the subject with special mention of the pioneers in the field and some important events.

Simple Vapour Compression Refrigeration System

A vapour compression refrigeration system is an improved type of air refrigeration system in which a suitable working substance, termed as refrigerant is used. It condensed and evaporates at temperatures and pressures close to the atmospheric conditions. The refrigerants usually used for this purpose are ammonia, carbon dioxide and sulphur dioxide.

Advantage and disadvantages of vapour compression refrigeration system:

Advantage:

1. It has smaller size for given capacity of refrigeration.
2. It has less running cost.
3. It can be employed over a large range of temperatures
4. The coefficient of performance is quite high

Disadvantages:

1. The initial cost is high
2. The prevention of leakage of refrigerant is the major problem in vapour compression system

Mechanism of simple vapour compression refrigeration system:

Compression refrigeration cycles take advantage of the fact that highly compressed fluids at a certain temperature tend to get colder when they are allowed to expand. If the pressure change is high enough, then the compressed gas will be hotter than our source of cooling (outside air, for instance) and the expanded gas will be cooler than our desired cold temperature. In this case, fluid is used to cool a low temperature environment and reject the heat to a high temperature environment. Vapour compression refrigeration cycles have two advantages. First, a large amount of thermal energy is required to change a liquid to a vapor, and therefore a lot of heat can be removed from the air-conditioned space. Second, the isothermal nature of the vaporization allows extraction of heat without raising the temperature of the working fluid to the temperature of whatever is being cooled. This means that the heat transfer rate remains high, because the closer the working fluid temperature approaches that of the surroundings, the lower the rate of heat transfer. The refrigeration cycle is shown in Figure below and can be broken down into the following stages:

1 – 2 Low-pressure liquid refrigerant

In the evaporator absorbs heat from its surroundings, usually air, water or some other process liquid. During this process it changes its state from a liquid to a gas, and at the evaporator exit is slightly superheated.

2 – 3 The superheated vapour

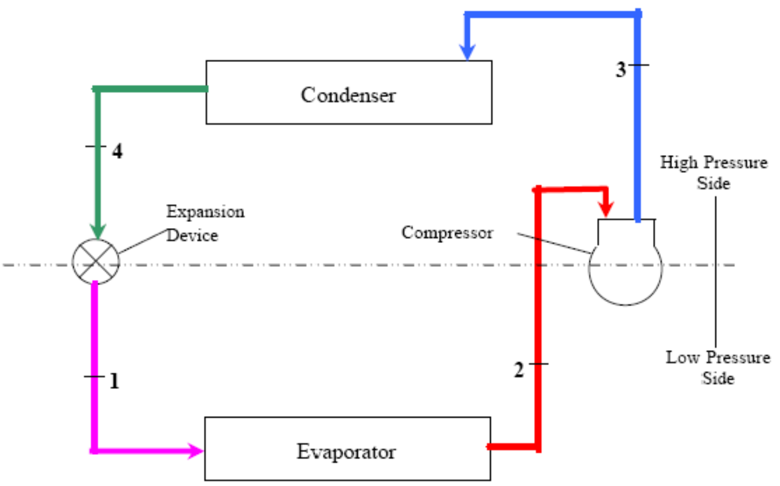
Enters the compressor where its pressure is raised. The temperature will also increase, because a proportion of the energy put into the compression process is transferred to the refrigerant.

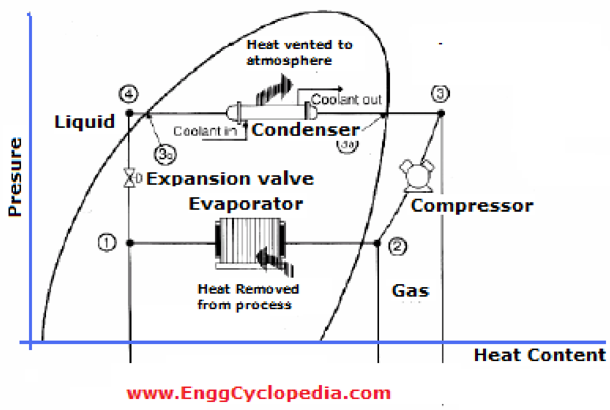
3 – 4 The high pressure superheated gas

Passes from the compressor into the condenser. The initial part of the cooling process (3-3a) superheats the gas before it is then turned back into liquid (3a-3b). The cooling for this process is usually achieved by using air or water. A further reduction in temperature happens in the pipe work and liquid receiver (3b - 4), so that the refrigerant liquid is sub-cooled as it enters the expansion device.

4 - 1 The high-pressure sub-cooled liquid

Passes through the expansion device, which both reduces its pressure and controls the flow into the evaporator.





Simple Vapour Absorption Refrigeration System

Vapour Absorption Refrigeration Systems (VARS) belong to the class of vapour cycles similar to vapour compression refrigeration systems. However, unlike vapour compression refrigeration systems, the required input to absorption systems is in the form of heat. Hence these systems are also called as heat operated or thermal energy driven systems. Since conventional absorption systems use liquids for absorption of refrigerant, these are also sometimes called as wet absorption systems. Similar to vapour compression refrigeration systems, vapour absorption refrigeration systems have also been commercialized and are widely used in various refrigeration and air conditioning applications. Since these systems run on low-grade thermal energy, they are preferred when low-grade energy such as waste heat or solar energy is available. Since conventional absorption systems use natural refrigerants such as water or ammonia they are environment friendly.

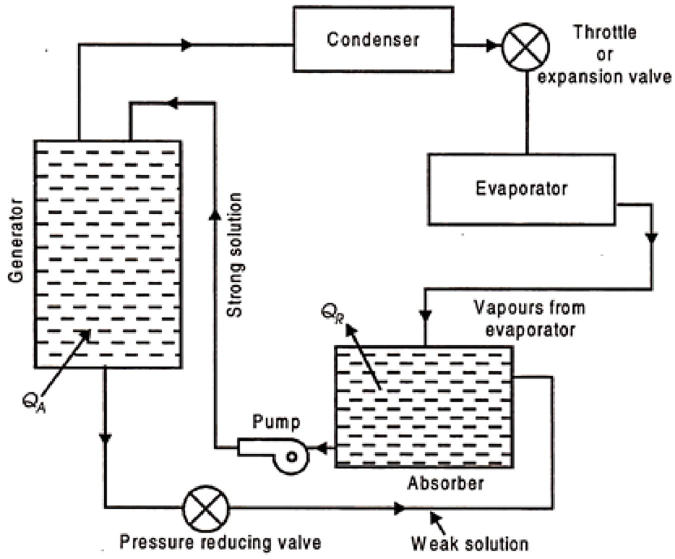


Fig. 36.32. *Equipment replacing the compressor* (*Simple vapour absorption system of refrigeration*)

Q_A = Heat added or supplied
Q_R = Heat rejected to coolant.

The most commonly used fluids in the absorption system are water as absorbent and ammonia as refrigerant. The vapour from the evaporator is allowed to be mixed and absorbed in the absorber. The heat of absorption generated in the process is rejected from the absorber to the circulating cold water in a heat exchanger dipped in the solution contained in the absorber.

The strong aqua-ammonia solution from the absorber is pumped upto the condenser pressure and fed to the generator which is the main energy consuming element of the system. Heat is supplied to the generator. The boiling point of refrigerant NH3, is lower than that of the absorbing liquid H2O, hence the vapours leaving the generator are predominantly those of refrigerant.

These vapours then pass on to the condenser. The liquid refrigerant from the condenser, then, passes through an expansion valve or throttle valve to the evaporator where it absorbs heat from the substances or bodies to be refrigerated. Liquid refrigerant is then evaporated and the vapours enter the absorber completing the cycle

The weak aqua-ammonia solution in the generator left due to separation of refrigerant vapour is drained back to the absorber for repeating the cycle.
The weak aqua-ammonia solution leaving the generator is at high pressure and the pressure in the absorber is the evaporator pressure which is less than the generator or condenser pressure, and hence a pressure reducing valve is provided in the weak solution line to the absorber.
The energy requirements of the system are at the generator and at the pump as compared to those at compressor in the vapour compression system. Since the volume of liquid handled by the pump is too small, the power required here is almost negligible as compared to that by the generator.

Practical Absorption Refrigeration Cycle:

The replacement of the compressor by the simple arrangement is not very economical in practice. In order to make improvements certain additional auxiliary items are provided in the system. They include analyzer, a rectifier, and two heat exchangers. The practical absorption cycles as developed after incorporating these auxiliaries.

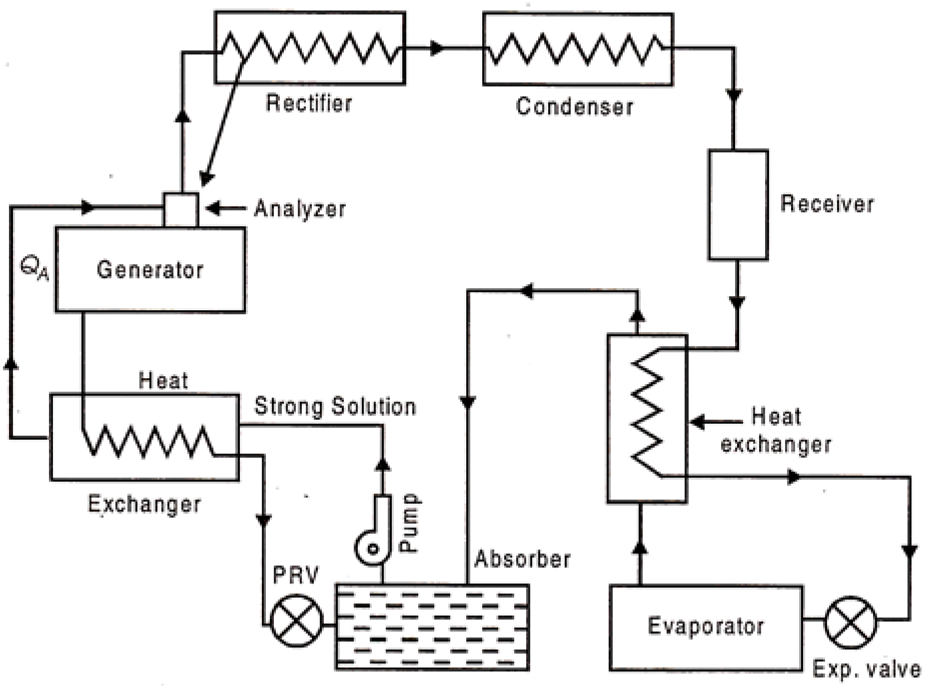


Fig. 36.33. *Practical absorption system*

(a) Analyzer:

The ammonia vapours leaving the generator may contain certain moisture, and therefore it should be freed from any trace of water vapour before passing on to the condenser and then to the expansion valve, otherwise the water vapour is likely to freeze in the small valve passage and choke the flow.
The function of the analyzer is to remove the moisture as far as possible. It is an open types of cooler and forms an integral part of the generator, mounted on its top. Both the strong aqua-ammonia solution from the absorber and the condensate removed in rectifier are introduced from the top and flow downwards.

The hot rising vapour of ammonia therefore comes in contact with the same and gets cooled. Thus most of the water vapour is condensed and drips back into the generator. This helps in salvaging a certain portion of heat in outgoing vapour which would otherwise have been rejected out through the condenser.

(b) Rectifier:

It is a closed type of cooler and is actually a miniature condenser where any traces of water vapour left in the ammonia vapour, are removed by condensation .The cooling is achieved by circulating water as is done in an ordinary condenser. The condensed aqua is drained back to the generator through the analyzer.

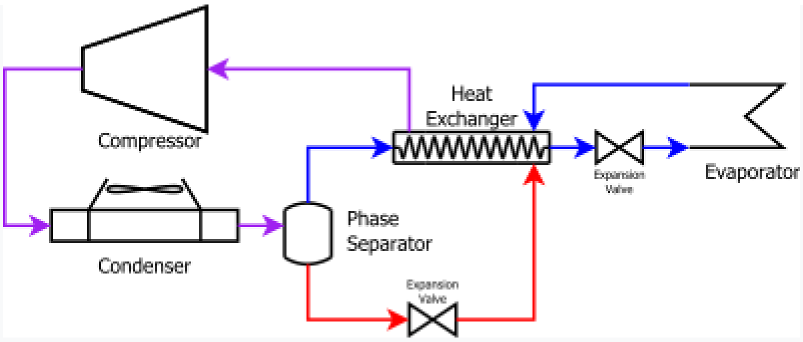
(c) Heat Exchangers:

Two heat exchangers are provided to internally exchange heat from the higher tempera-ture fluid to the lower temperature fluid so that one is cooled and the other is heated.
One heat exchanger is provided between liquid receiver and evaporator so that the liquid is sub-cooled and vapour is heated up. Another heat exchanger is located between generator and absorber so that the strong aqua is heated up before going on to the analyzer and weak aqua is cooled before entering the absorber.

Cascade Refrigeration

A cascade refrigeration cycle is a multi-stage thermodynamic cycle. An example two-stage process is shown at right. The cascade cycle is often employed for devices such as ULT freezers.

In a cascade refrigeration system, two or more vapor-compression cycles with different refrigerants are used. The evaporation-condensation temperatures of each cycle are sequentially lower with some overlap to cover the total temperature drop desired, with refrigerants selected to work efficiently in the temperature range they cover. The low temperature system removes heat from the space to be cooled using an evaporator, and transfers it to a heat exchanger that is cooled by the evaporation of the refrigerant of the high temperature system. Alternatively, a liquid to liquid or similar heat exchanger may be used instead. The high temperature system transfers heat to a conventional condenser that carries the entire heat output of the system and may be passively, fan, or water-cooled.



An auto-cascade process with two different refrigerants. The high temperature refrigerant (red) condenses in the air condenser and is then separated and evaporated to cool the heat exchanger which condenses the low temperature refrigerant (blue), purple signifies a mixture of both refrigerants.

Cascade cycles may be separated by either being sealed in separated loops, or in what is referred to as an "auto-cascade" where the gases are compressed as a mixture but separated as one refrigerant condenses into a liquid while the other continues as a gas through the rest of the cycle. Although an auto-cascade introduces several constraints on the design and operating conditions of the system that may reduce the efficiency it is often used in small systems due to only requiring a single compressor, or in cryogenic systems as it reduces the need for high efficiency heat exchangers to prevent the compressors leaking heat into the cryogenic cycles. Both types can be used in the same system, generally with the separate cycles being the first stage(s) and the auto-cascade being the last stage.

They may also use multi-stage peltier coolers. In these, one peltier element is cooled by a larger peltier cooler. For example, the hot side of the first peltier cooler is cooled by the cold side of the second peltier cooler, which is larger in size, whose hot side is in turn cooled by the cold side of an even larger peltier cooler, and so on. Efficiency drops very rapidly as more stages are added but for very low heat loads down to near-cryogenic temperatures this can often be the best solution, such as mid-range thermographic cameras.

Absorption system	Compression System
a) Uses low grade energy like heat. Therefore, may be worked on exhaust systems from I.C engines, etc.	a) Using high-grade energy like mechanical work.
b) Moving parts are only in the pump, which is a small element of the system. Hence operation is smooth.	b) Moving parts are in the compressor. Therefore, more wear, tear and noise.
c) The system can work on lower evaporator pressures also without affecting the COP. d) No effect of reducing the load on performance.	c) The COP decreases considerably with decrease in evaporator pressure. d) Performance is adversely affected at partial loads.
e) Liquid traces of refrigerant present in piping at the exit of evaporator	e) Liquid traces in suction line may damage the compressor.

Steam Jet Refrigeration System:

This system uses the principle of boiling the water below 1000 C. If the pressure on the surface of the water is reduced below atmospheric pressure, water can be made boil at low temperatures. Water boils at 60 C, when the pressure on the surface is 5 cm of Hg and at 100 C, when the pressure is 6.5 cms of Hg. The very low pressure or high vacuum on the surface of the water can be maintained by throttling the steam through jets or nozzles

Operation:

High pressure steam is supplied to the nozzle from the boiler and it is expanded. Here, the water vapor originated from the flash chamber is entrained with the high velocity steam jet and it is further compressed in the thermo compressor. The kinetic energy of the mixture is converted into static pressure and mass is discharged to the condenser. The condensate is usually returned to the boiler. Generally, 1% evaporation of water in the flash chamber is sufficient to decrease the temperature of chilled water to 60 C. The chilled water in the flash chamber is circulated by a pump to the point of application. The warm water from the load is returned to the flash chamber. The water is sprayed through the nozzles to provide maximum surface area for cooling. The water, which is splashed in the chamber and any loss of cold water at the application, must be replaced by makeup water added to the cold water circulating system.

Advantages:

a) It is flexible in operation; cooling capacity can be easily and quickly changed.
b) It has no moving parts as such it is vibration free.
c) It can be installed out of doors.
d) The weight of the system per ton of refrigerating capacity is less.
e) The system is very reliable and maintenance cost is less.
f) The system is particularly adapted to the processing of cold water used in rubber mills,, distilleries, paper mills, food processing plants, etc.
g) This system is particularly used in air-conditioning installations, because of the complete safety of water as refrigerant and ability to adjust quickly to load variations and no hazard from the leakage of the refrigerant.

Disadvantages:

a) The use of direct evaporation to produce chilled water is usually limited as tremendous volume of vapor is to be handled.
b) About twice as much heat must be removed in the condenser of steam jet per ton of refrigeration compared with the vapor compression system.
c) The system is useful for comfort air-conditioning, but it is not practically feasible for water temperature below 40 C.

MULTIPLE CHIOCE QUESTIONS

QUESTION	OPTION 1	OPTION 2	OPTION 3	OPTION 4	ANSWER
Air refrigeration operates on	Carnot cycle	Reversed Carnot cycle	Brayton cycle.	Rankine cycle	Brayton cycle.
Formation of frost on evaporator in refrigerator	results in loss of heat due to poor heat transfer	increases heat transfer rate	can be avoided by proper design	decreases compressor power.	results in loss of heat due to poor heat transfer
Refrigeration in aeroplanes usually employs the following refrigerant	C02	Freon-11	Freon-22	Air	Air
Highest temperature encountered in refrigeration cycle should be	near critical temperature of refrigerant	above critical temperature	much below critical temperature	could be anywhere	much below critical temperature
Accumulators should have adequate volume to store refrigerant charge at least	10%	25%	50%	100%	50%
Air refrigeration cycle is used in	domestic refrigerators	commercial refrigerators	air conditioning	gas liquefaction	gas liquefaction
Presence of moisture in a refrigerant affects the working of	compressor	condenser	evaparator	expansion valve.	expansion valve.
In a vapour compression cycle, the refrigerant immediately after expansion valve is	liquid	saturated liquid	wet vapour	dry vapour.	wet vapour
The bank of tubes at the back of domestic refrigerator are	condenser tubes	evaporator tubes	capillary tubes	throttling device	condenser tubes
The value of COP in vapour compression cycle is usually	always less than unity	always more than unity	equal to unity	any one of the above	always more than unity
Absorption system normally uses the following refrigerant	Freon-11	Freon-22	S02	ammonia.	ammonia.

One of the purposes of sub-cooling the liquid refrigerant is to	reduce compressor overheating	reduce compressor discharge tempera-ture	increase cooling effect	ensure that only liquid and not the vapour enters the expansion (throttling) valve	ensure that only liquid and not the vapour enters the expansion (throttling) valve
The domestic refrigerator uses following type of compressor	centrifugal	axial	miniature sealed unit	piston type reciprocating	piston type reciprocating
In a refrigeration system, heat absorbed in comparison to heat rejected is	more	less	less for small capacity and more for high capacity	more for small capacity and less for high capacity	less
For better COP of refrigerator, the pressure range corresponding to temperature in evaporator and condenser must be	small	high	equal	anything	small
The COP of a domestic refrigerator	is less than 1	is more than 1	is equal to 1	depends upon the make	is more than 1
Condensing temperature in a refrigerator is the temperature	of cooling medium	of freezing zone	at which refrigerant gas becomes liquid	condensing temperature of ice	condensing temperature of ice
The higher temperature in vapour compression cycle occurs at	receiver	expansion valve	evaporator	compressor discharge	compressor discharge
In a flooded evaporator refrigerator, an accumulator at suction of compressor is used to	collect liquid refrigerant and prevent it from going to compressor	detect liquid in vapour	superheat the vapour	collect vapours	collect liquid refrigerant and prevent it from going to compressor
Domestic refrigerator working on vapour compression cycle uses the following type of expansion device	electrically operated throttling valve	manually operated valve	capillary tube	expansion valve.	capillary tube
The vapour pressure of refrigerant should be	lower than atmospheric pressure	higher than atmospheric pressure	equal to atmospheric pressure	could be anything	higher than atmospheric pressure

At lower temperatures and pressures, the latent heat of vaporisation of a refrigerant	decreases	increases	remains same	depends on other factors	increases
The moisture in a refrigerant is removed by	evaporator	safety relief valve	dehumidifier	driers	driers
Ammonia-absorption refrigeration cycle requires	very little work input	maximum work input	nearly same work input as for vapour compression cycle	zero work input	very little work input
In vapour compression cycle, the condition of refrigerant is high pressure saturated liquid	after passing through the condenser	before passing through the condenser	after passing through the expansion or throttle valve	before entering the expansion valve	before entering the expansion valve
In vapour compression cycle, the condition of refrigerant is very wet vapour	after passing through the condenser	before passing through the condenser	before entering the compressor.	after passing through the expansion or throttle valve	before entering the compressor.
Critical temperature is' the temperature above which	a gas will never liquefy	a gas will immediately liquefy	water will evaporate	water will never evaporate	a gas will never liquefy
Clapeyron equation is a relation between	temperature, pressure and enthalpy	specific volume and enthalpy	temperature and enthalpy	temperature, pressure, specific value and enthalpy	temperature, pressure, specific value and enthalpy
In S.I. unit, one ton of refrigeration is equal to	210 kJ/min	21 kJ/min	420 kJ/min	105 kJ/min.	210 kJ/min
One ton of refrigeration is equal to the refrigeration effect corresponding to melting of 1000 kg of ice	in 1 hour	in 1 minute	in 12 hours	in 24 hours	in 24 hours
The boiling point of ammonia is	(-100)°C	(-50)°C	(-33.3)°C	0°C	(-33.3)°C
The vapour compression refrigerator employs the following cycle	Rankine	Reversed Carnot	Carnot	Reversed Rankine	Reversed Carnot
Allowable pressure on high-pressure side or ammonia absorption system is of the order of	atmospheric pressure	2-4 bars	5-6 bars	7-10 bars.	5-6 bars

The refrigerant for a refrigerator should have	high sensible heat	low sensible heat	high latent heat	low latent heat	high latent heat
The relative coefficient of performance is	actual COP/theoretical COP	theoretical COP/actual COP	actual COP x theoretical COP	1-actual COP x theoretical COP	actual COP/theoretical COP
One ton refrigeration corresponds to	50 kcal/min	50 kcal/hr	80 kcal/min	80 kcal/hr	50 kcal/min
An important characteristic of absorption system of refrigeration is	noisy operation	quiet operation	very little power consumption	its input only in the form of heating	quiet operation
In vapour compression cycle using NH3 as refrigerant, initial charge is filled at	suction of compressor	delivery of compressor	high pressure side colse to receiver	low pressure side near receiver	high pressure side colse to receiver
In vapour compression refrigeration system, refrigerant occurs as liquid between	condenser and expansion valve	compressor and evaporator	expansion valve and evaporator	compressor and condenser	expansion valve and evaporator
Freon group of refrigerants are	inflammable	toxic	non-inflammable and toxic	non-toxic and non-inflammable	non-toxic and non-inflammable
Super heating in a refrigeration cycle	increases COP	decreases COP	COP remains unaltered	other factors decide COP	decreases COP
A certain refrigerating system has a normal operating suction pressure of 10 kg/cm gauge and condensing pressure of about 67 kg/cm. The refrigerant used is	Ammonia	Carbon dioxide	Freon	Brine	Carbon dioxide
Efficiency of a Cornot engine is given as 80%. If the- cycle direction be reversed, what will be the value of COP of reversed Carnot cycle	1.25	0.8	0.5	0.25	0.25
Where does the lowest temperature occur in a vapour compression cycle ?	condenser	evaporator	compressor	expansion valve	expansion valve
Aqua ammonia is used as refrigerant in the following type of refrigeration system	compression	direct	indirect	absorption	absorption

Which of the following is not a desirable property of a refrigerant	high triiscibility with oil	low boiling point	good electrical conductor	large latent heat	good electrical conductor
Mass flow ratio of NH3 in comparison to Freon-12 for same refrigeration load and same temperature limits is of the order of	1:1	1:9	9:1	1:3	1:9
The COP of a vapour compression plant in comparison to vapour absorption plant is	more	less	same	unpredictable.	more
For obtaining high COP, the pressure range of compressor should be	high	low	optimum	any value	low
Which of the following refrigerants has lowest freezing point	Freon-12	NH3	C02	Freon-22	Freon-22
Under-cooling in a refrigeration cycle	increases COP	decreases COP	COP remains unaltered	other factors decide COP	increases COP
What is the amount of heat energy required to evaporate 1 pound of water?	370 btu	570 btu	770 btu	970 btu	970 btu
What btu of heat is required to raise 1 pound of ice 1 degree F when the temperature is below 32 degrees F?	0.25	0.5	1	1.5	0.5

UNIT – II

REFRIGERANTS, SYSTEM COMPONENTS AND BALANCING

Types of Compressors

◉ Positive displacement
  ○ Positive displacement compressors have chambers which decrease in volume during compression.
◉ Non-positive displacement (centrifugal).
  ○ Non-positive displacement compressors have fixed-volume chambers.
◉ Beyond this distinction, each type differs based on its specific mechanism for fluid compression.
◉ Open types have a separate housing for the compressor and the motor.
◉ They rely on lubricant in the system to splash on pump components and seals.
◉ If not operated frequently, the system can leak its operating gases.
◉ Open compressors can be driven by non-electric power sources such as combustion engines.

◉ Hermetic types seal the compressor and motor together in the same housing.
  ○ These compressors are leak-free and can sit for long periods unused, but cannot be maintained or repaired.
◉ Semi-hermetic types also contain the motor and compressor in one housing, but instead of a one-piece housing they incorporate gasketed/bolted covers.
  ○ These can be removed for maintenance and repair of the compressor or motor.

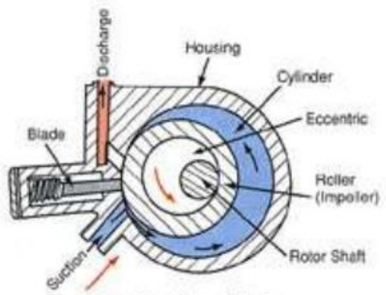
There are basically 5 types of air conditioner compressors that are commonly used in the HVAC industry:
  ○ Reciprocating
  ○ Scroll
  ○ Screw
  ○ Rotary
  ○ Centrifugal

Reciprocating/Piston Compressors

◉ Piston and cylinder arrangement to provide compressive force - like IC engines.
◉ Reciprocating motion of the piston due to external power compresses the refrigerant inside the cylinder.
◉ Low initial cost and a simple, easy to install design.
◉ Large power output range - can reach extremely high pressures. However, maintenance costs are high, potential vibrational issues.
◉ Not typically designed to run continuously at full capacity.
◉ Suction and discharge valves
◉ Valve position is controlled by the pressure difference across it
◉ Can be open, semi-hermetic or fully hermetic

Rotary Compressors

- ◉ Uses circular motion for compression (two rotating elements)
- ◉ Rotating blade (vane) type ○ Refrigerant is trapped by rotating vanes
    - ○ Refrigerant compresses as volume decreases
- ◉ Stationary blade (vane) type
    - ○ Equipped with only one blade or vane
- ◉ In general, rotary compressors are quite efficient
    - ○ Fewer moving parts
    - ○ Low rotational speeds, low initial and maintenance costs
    - ○ Limited to smaller volumes of the gas
    - ○ Produce less pressure than other types of compressors.
    - ○ Actions of taking in refrigerant and compressing refrigerant occurs simultaneously



Identification of Parts

Helical rotary (screw type compressors)

- ◉ Screw compressors use a pair of helical rotors or screws which mesh together to compress the refrigerant between them.
- ◉ The volume of the refrigerant decreases as it flows through the compressor
- ◉ A continuous, flowing output is produced
- ◉ Compressor capacity is controlled by a slide valve

Screw compressors

- ◉ They can produce high pressure for a small quantity of gas and consume less power than reciprocating compressors.
- ◉ They have low to medium initial and maintenance costs and few moving parts.
- ◉ However, they have difficulty in dirty environments, high rotational speeds, and shorter life expectancies than other designs.

Scroll type Compressors

- ◉ Utilizes two identically machined scrolls - one scroll is stationary, the other orbits
- ◉ The nesting of the scrolls traps vapour
- ◉ Gas is introduced from the outer edge refrigerant is discharged from the center
- ◉ Scroll compressors are quiet, smooth-operating units with few moving parts
- ◉ Highest efficiency ratio of all compressor types.
- ◉ However, as fully hermetic designs, they cannot be easily repaired. They also typically cannot rotate in both directions.

Centrifugal type compressors

- ◉ Rely on centrifugal force - utilizes an impeller
- ◉ No pistons, valves or cylinders
- ◉ Unlike other designs, centrifugal compressors do not operate on the positive displacement principle, but have fixed volume chambers.

◉ Well suited to compressing large volumes of refrigerant to relatively low pressures.

◉ Typically used for very large applications

◉ Capacity is controlled by inlet vanes

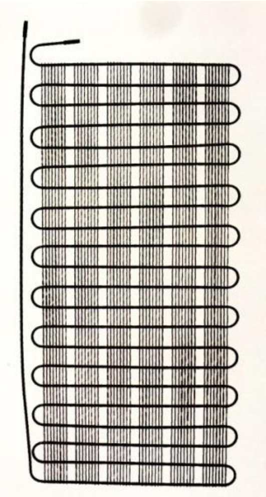
◉ The compressive force generated by an impeller wheel is small, so systems that use centrifugal compressors usually employ two or more stages (impellers wheels) in series to generate high compressive forces.

◉ Centrifugal compressors are desirable for their simple design, few moving parts, and energy efficiency when operating multiple stages.

Condenser

Function of Condenser

In a cooling cycle of a refrigeration system, heat is absorbed by the vapor refrigerant in the evaporator followed by the compression of the refrigerant by the compressor. The high pressure and high temperature state of the vapor refrigerant is then converted to liquid at the cond. It is designed to condense effectively the compressed refrigerant vapor.



There are basically three types of condensing unit depending on how the heat is removed by the condensing medium which is usually water, air or a combination of both.

- **Air-Cooled** types are usually used in the residential and small offices applications. They are used in small capacity systems below 20 tons. The advantages of using this design include not having to do water piping, not necessary to have water disposal system, saving in water costs and not much scaling problems caused by the mineral content of the water. It is also easier to install and has lower initial cost. There isn't much maintenance problems.The disadvantages are that it requires higher power per ton of refrigeration, has shorter compressor life and on days when most cooling is required, the least is available
- The circulation of air-cooled type can be by natural convection or by forced convection (usually using blower or fan). Due to its limited capacity, natural convection is used in smaller applications such as freezers and refrigerators. In forced convection, air is circulated by using a fan or blower that pulls the atmospheric air through the finned coils. Internally, the refrigerant circulates through the coil and air flows across the outside of the tubes.
- **Water-Cooled** There are 3 types commonly being used. They are shell and tube, shell and coil, and double tube. The most commonly used is the shell and tube type and are usually available from two tons up to couple of hundred tons. This design has lower power requirements per ton of refrigeration and the compressors can last longer compared to the air-cooled type. A water cooling tower is frequently used for higher capacity application.
- **Evaporative type** which is a combination of water and air-cooled.

Purpose of an evaporator

◉ The purpose of the evaporator is to receive low-pressure, low temperature fluid from the expansion valve and to bring it in close thermal contact with the load.

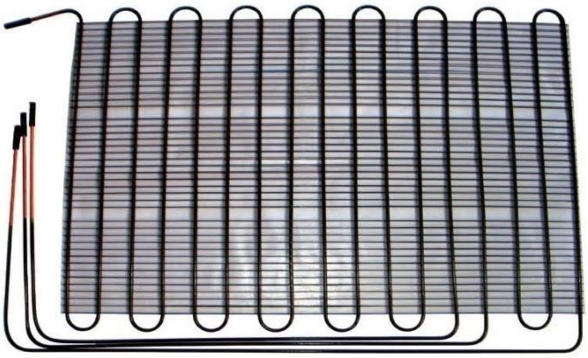
◉ The refrigerant takes up its latent heat from the load and leaves the evaporator as a dry gas.

◉ The function of the evaporator will be to cool gas, liquid or other product loads.

◉ In most cases air or a liquid is first cooled, and this is then used to cool the load. e.g., in a cold-room air is cooled and this air cools the stored produce and carries away heat leaking through the structure; in a water chiller, water is circulated to cool the load, etc.

Thermal path/ Resistances

◉ Heat has to pass from the hot water to cold refrigerant.
◉ The thermal resistances include:
  ○ Water side heat transfer coefficient
  ○ Water side fouling
  ○ Conduction in tube wall
  ○ Refrigerant side fouling (usually low/negligible)
  ○ Refrigerant side heat transfer coefficient



Classification of evaporators

◉ Evaporators are classified according to their refrigerant flow pattern, their function, geometrical features.
◉ Evaporators which cool water
◉ Evaporators with cool air

Defrosting of Evaporators

◉ Air cooling evaporators working below 0°C will accumulate frost which must be removed periodically, since it will obstruct heat transfer.
◉ Evaporators of suitable and robust construction can be defrosted by brushing, scraping or chipping.
◉ However, these methods are labour intensive and may lead to damage of the plant.
◉ Where the surrounding air is always at + 4°C or higher, it will be sufficient to stop the refrigerant for a period and allow the frost to melt off (as in the auto-defrost domestic refrigerator).
◉ This method can be used for cold-rooms, packaged airconditioners etc., where the service period can be interrupted.

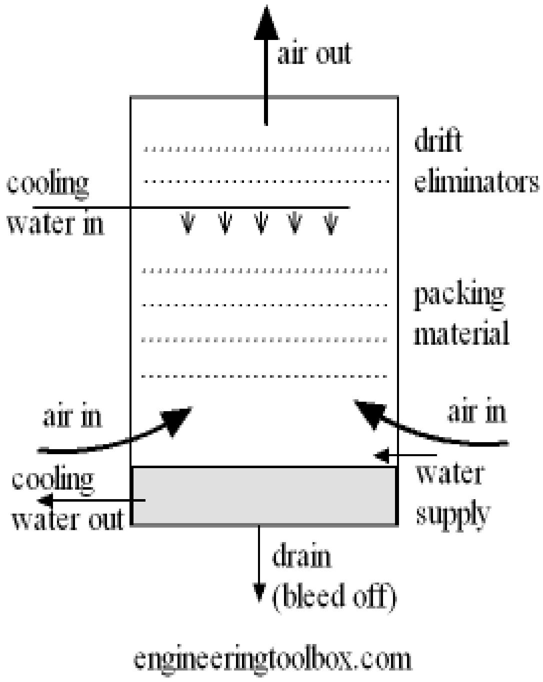
Cooling Tower

Cooling tower is a peripheral equipment that removes heat from the hot water that is pumped from the condenser to the tower. It is done by using the air from the surrounding to reduce the temperature of the water. The air can be natural or forced by the use of fan. The capacity to cool the water depends on the evaporation of the water when air comes in contact with the water.
his depends on the humidity of the surrounding air. Usually the tower should be able to cool the water by about 6°F to 7°F of the air wet bulb temperature. For example, if the wet bulb temperature of the air is 78°F and the hot water coming to the tower from the condenser is 95°F, then the cooled water that leaves the tower can be 85°F, about 7°F lower than the air wet bulb temperature.

Principles of Operation

An example of the application is the use of this equipment to cool the water-cooled condenser from a chiller system. The hot water from the chiller condenser which could be located in the building is piped to the cooling tower. Pumps are used to circulate the water from the condenser to the tower and back.

The hot water is sprayed through nozzle onto the thin films materials (also known as fill) which can be made of plastic, wood slats or metal fins. Their surfaces can be in the shape of honeycomb, corrugated sheet or flat sheet.



As the water flows through these materials, air from the surrounding which can be natural-draft or forced-draft rushed through it and in the process evaporates some of it. This cools the water which is then collected at the lower sump and through a filter to get rid of leaves and other materials before being circulated back to the condenser.

A drain is used to remove the hard water minerals from the system. As the amount of water will reduce due to evaporation and draining, a float valve is used to add the water to the system.

The tower should be located in an area where the ventilation is good and not located too close to the building. This is critical for the natural-draft tower where the cooling is done naturally.

Desirable Properties of Refrigerants

Refrigerants are widely used in Refrigeration cycle where cooling effect below the atmospheric temperatures are needed. Whenever we choose them for particular use Properties of Refrigerants also plays a vital role in economic and environmental friendly application. Here are some of the desirable properties of refrigerant explained in detail.

Physical Properties of Refrigerants

Low Freezing Point

Refrigerants should have low freezing point than the normal operating conditions. It should not freeze during application. Water for example cannot be used below 0 Deg C.

Low Condensing Pressure

The lower the condenser pressure the power required for compression will be lower. Higher condenser pressure will result in high operating costs. Refrigerants with low boiling points will have high condenser pressure and high vapor density. The condenser tubes have to be designed for higher pressures which also give raise to capital cost of the equipment.

If Boiling Point is Low, High Condenser Pressure – Reciprocating Compressor is used. Eg: Ammonia, R22, R12 etc. If Boiling Point is High, Low Condenser Pressure – Centrifugal Compressor is used. Eg: R11, R13 & R114 etc

High Evaporator Pressure

This is the most important property of refrigerant. In a negative pressure evaporator Atmospheric air or Moisture will Leak into the system. The moisture inside the system will starts freezing at low temperature zones and clogs and chokes the system.

Atmospheric air ingression into the system will occupy the heat transfer area and results in poor heat transfer rates. Presence of air will reduce the partial pressure of refrigerant and the condensation temperature will rise. It increasers the condenser pressures and thereby the power consumption for the compressor will also rise.

Atmospheric air ingression inside the system may sometime results in explosions if the flammability values of the refrigerants are in wide range.

Due to the above disadvantages, Positive evaporator pressure is preferred. Leak outside the system results in refrigerant loss and it can be identified easily and refrigerant loss can be topped up. Moderately high evaporator pressure boosts the compressor suction pressure thus reduces the power costs.

High Critical Pressure

Critical pressure of the refrigerant should be higher than the condenser pressures. Otherwise the zone of condensation decreases and the heat rejection occurs.

High Vapor Density

Refrigerants with High vapor density/ Low specific volume will require a smaller compressors and velocity can be kept small and so the condenser tubes used will also be in smaller diameter.

High Dielectric strength

In hermetically sealed compressors refrigerant vapor contacts with motor windings and may cause short circuits. Therefore dielectric strength should be high to avoid short circuits.

High Latent Heat of Vaporization

Higher latent heat of vaporization of the refrigerant will result in lower mass flow rates according to the Heat transfer equation. If the mass flow is very small it is difficult to control the flow rates. Therefore ammonia cannot be used for small refrigeration systems.

High Heat Transfer Coefficient

Higher heat transfer coefficient requires smaller area and lower pressure drop. This makes the equipments compact and reduced the operating cost.

Chemical Properties

Toxicity

Toxicity is the important properties of refrigerants. The refrigerants should be non poisonous to humans and food stuff. The toxicity depends upon the concentration and exposure limits.

Oil Solubility

The lubricating oils must be soluble in Refrigerants. If the oil is not miscible in the refrigerant used and it is heavier it will settle down in the evaporator and reduces the heat transfer. Therefore oil separators are to be employed. If the oil density is less than the refrigerant used and it if it is immiscible, the oil will float on the surface of the refrigerant. Therefore overflow drain is to be provided to remove oil. If the refrigerant velocity is not sufficient, then it cannot carry all oil back into the compressor. It may accumulate in evaporator. This phenomenon is called Oil logging.

Low Water Solubility

Most of the refrigerants form acids or bases in the presence of water. This will cause corrosion and deteriorates valves, Seals and Metallic parts. Insulation of windings in hermatic compressors will also get damaged. The free water apart from the dissolved water in refrigerant freezes below 0 Deg C and chokes the narrow orifice of expansion valve. This may also cause bursting of the tubes.

Reactivity

The refrigerants should not react with the materials used in refrigeration cycle like evaporators, condenser tubes, compressors, control valves etc. Ammonia reacts with Copper and Cuprous alloys and forms copper complexes. CH_3Cl reacts with Aluminium. Most of the refrigerants form acids with water.

CCl_2F_2, CH_4Cl can form HCL with water which dissolves the copper from condenser tubes and deposits them on compressor pistons and deteriorates the life of the machinery.

Types of Refrigerants

1. HaloCarbons
2. Azeotropic Refrigerants
3. Zeotropic Refrigerants
4. Inorganic Refrigerants
5. Hydrocarbon Refrigerants

Application of refrigeration in Food processing, preservation and distribution

Storage of Raw Fruits and Vegetables:

It is well-known that some bacteria are responsible for degradation of food, and enzymatic processing cause ripening of the fruits and vegetables. The growth of bacteria and the rate of enzymatic processes are reduced at low temperature. This helps in reducing the spoilage and improving the shelf life of the food.

Fish:

Icing of fish according to ASHRAE Handbook on Applications, started way back in 1938. In India, iced fish is still transported by rail and road, and retail stores store it for short periods by this method. Freezing of fish aboard the ship right after catch results in better quality than freezing it after the ship docks. In some ships, it is frozen along with seawater since it takes months before the ships return to dock. Long-term preservation of fish requires cleaning, processing and freezing.

Meat and poultry:

These items also require refrigeration right after slaughter during processing, packaging. Short-term storage is done at 0o C. Long-term storage requires freezing and storage at -25o C.

Dairy Products:

The important dairy products are milk, butter, buttermilk and ice cream. To maintain good quality, the milk is cooled in bulk milk coolers immediately after being taken from cow. Bulk milk cooler is a large refrigerated tank that cools it between 10 to 15o C. Then it is transported to dairy farms, where it is pasteurized. Pasteurization involves heating it to 73o C and holding it at this temperature for 20 seconds. Thereafter, it is cooled to 3 to 4o C. The dairies have to have a very large cooling capacity, since a large quantity of milk has to be immediately cooled after arrival. During the lean period, the refrigeration plants of dairies are used to produce ice that is used during peak periods to provide cooling by melting. This reduces the required peak capacity of the refrigeration plant. Ice cream manufacture requires pasteurization, thorough mixing, emulsification and stabilization and subsequently cooling to 4 to 5o C. Then it is cooled to temperature of about – 5 o C in a freezer where it stiffens but still remains in liquid state. It is packaged and hardened at –30 to –25o C until it becomes solid; and then it is stored at same temperature.

Buttermilk, curd and cottage cheese are stored at 4 to 10o C for increase of shelf life. Use of refrigeration during manufacture of these items also increases their shelf life. There are many varieties of cheese available these days. Adding cheese starter like lactic acid and several substances to the milk makes all of these. The whey is separated and solid part is cured for a long time at about 10OC to make good quality cheese.

Beverages:

Production of beer, wine and concentrated fruit juices require refrigeration. The taste of many drinks can be improved by serving them cold or by adding ice to them. This has been one of the favourite past time of aristocracy in all the countries. Natural or man-made ice for this purpose has been made available since a very long time. Fruit juice concentrates have been very popular because of low cost, good taste and nutritional qualities. Juices can be preserved for a longer period of time than the fruits. Also, fruit juice concentrates when frozen can be more easily shipped and transported by road. Orange and other citrus juices, apple juice, grape juice and pineapple juice are very popular. To preserve the taste and flavor of juice, the water is driven out of it by boiling it at low temperature under reduced pressure. The concentrate is frozen and transported at –20o C. Brewing and wine making requires fermentation reaction at controlled temperature, for example lager-type of beer requires 8 to12o C while wine requires 27- 30o C. Fermentation is an exothermic process; hence heat has to be rejected at controlled temperature.

Candy:

Use of chocolate in candy or its coating with chocolate requires setting at 5-10o C otherwise it becomes sticky. Further, it is recommended that it be stored at low temperature for best taste.

Processing and distribution of frozen food:

Many vegetables, meat, fish and poultry are frozen to sustain the taste, which nearly duplicates that of the fresh product. Freezing retains the sensory qualities of colour, texture and taste apart from nutritional qualities. The refrigeration systems for frozen food applications are very liberally designed, since the food items are frozen in shortest period of time. The sharp freezing with temperature often below –30o C, is done so that the ice crystals formed during freezing do not get sufficient time to grow and remain small and do not pierce the cell boundaries and damage them. Ready-to-eat frozen foods, packed dinners and bakery items are also frozen by this method and stored at temperatures of –25 to -20 oC for distribution to retail stores during peak demands or off-season demands. Vegetables in this list are beans, corn, peas, carrots, cauliflower and many others. Most of these are blanched before freezing. There are various processes of freezing. Blast freezers give a blast of high velocity air at – 30o C on the food container. In contact freezing, the food is placed between metal plates and metal surfaces that are cooled to −30o C or lower. Immersion freezing involves immersion of food in low temperature brine. Individual quick freezing (IQF) is done by chilled air at very high velocities like 5- 10 m/s that keeps the small vegetable particles or shrimp pieces floating in air without clumping, so that maximum area is available for heat transfer to individual particles. The frozen particles can be easily packaged and transported. The refrigeration capacities in all the freezers are very large since freezing of large quantities is done in a very short time. Liquid nitrogen and carbon dioxide are also used for freezing.

Of late supermarket refrigeration is gaining popularity all over the world. At present this constitutes the largest sector of refrigeration in developed countries. In a typical supermarket a large variety of products are stored and displayed for sale. Since a wide variety of products are stored, the required storage conditions vary widely. Refrigeration at temperatures greater than 0o C and less than 0o C is required, as both frozen and fresh food products are normally stored in the same supermarket. Figure 3.4 shows the photograph of a section of a typical supermarket. Refrigeration systems used for supermarkets have to be highly reliable due to the considerable value of the highly perishable products. To ensure proper refrigeration of all the stored products, a large of refrigerant tubing is used, leading to large refrigerant inventory.

MULTIPLE CHIOCE QUESTIONS

QUESTION	OPTION 1	OPTION 2	OPTION 3	OPTION 4	ANSWER
The heat rejection factor (HRF) is given by	1+C.O.P.	1-C.O.P.	1+1/C.O.P.	1-1/C.O.P.	1+1/C.O.P.
In actual air conditioning application for R-12 and R-22 and operating at a condensor temperature of 40°C and an evaporator temperature of 5°C, the heat rejection factor is about	1	1.25	2.15	5.12	1.25
Most air cooled condensers are designed to operate with a temperature difference of	5°C	8°C	14°C	22°C	14°C
The natural convection air-cooled condenser are used in	domestic refrigerators	water coolers	room air conditioners	all of these	domestic refrigerators
In shell and coil condenser,	water flows in the shell and the refrigerant in the coil	water flows in the coil and the refrigerant in the shell	only water flows through the shell as well as coil	only refrigerant flows through the shell as well as coil	water flows in the coil and the refrigerant in the shell
For ammonia refrigerating systems, the tubes of a shell and tube condenser are made of	copper	aluminium	steel	brass	steel
The condensiing medium used in evaporative condensers is	air only	water only	both air and water	oil	both air and water
An evaporator is also known as	freezing coil	cooling coil	chilling coil	all of these	all of these
The evaporator changes the low pressure liquid refrigerant from the expansion valve into	high pressure liquid refrigerant	low pressure liquid and vapour refrigerant	low pressure vapour refrigerant	non of the above	low pressure vapour refrigerant
The fluid side heat transfer coefficient (hf) when air flows through the evaporator shell is given by	$C\sqrt{m}$	C.m	$C (m)^2$	$C (m)^4$	$C\sqrt{m}$

The fluid side heat transfer coefficient when air flows over finned coil by convection is given by	$C (m)^{0.1}$	$C (m)^{0.2}$	$C (m)^{0.3}$	$C (m)^{0.4}$	$C (m)^{0.4}$
The evaporator generally used in home freezers, ice cream cabinets etc. is	plate evaporator	finned evaporator	shell and tube evaporator	shell and coil evaporator	plate evaporator
The evapoartor generally used for wine cooling and in petroleum industry for chilling oil is	plate evaporator	finned evaporator	tube-in-tube evaporator	shell and tube evaporator	plate evaporator
The evaporator used in house-hold refrigerators is	frosting evaporator	non-frosting evaporator	defrosting evaporator	none of these	frosting evaporator
The freon group of refrigerants are	halo - carbon refrigerants	azeotrope refrigerants	inorganic refrigerants	hydro-carbon refrigerants	halo - carbon refrigerants
Which of the following refrigerants has the lowest freezing point ?	R-11	R-12	R-22	ammonia	R-22
A refrigerant with the highest critical pressure is	R-11	R-12	R-22	ammonia	ammonia
Which of the following is an azeotrope refrigerant ?	R-11	R-40	R-114	R-502	R-502
The colour of the flame of halide torch, in case of leakage of freon refrigerant, will change to	bright green	yellow	red	orange	bright green
Which of the following refrigerants has the lowest boiling point?	ammonia	carbon dioxide	sulphur dioxide	R-12	carbon dioxide
which of the following refrigerants has the highest freezing point ?	ammonia	carbon dioxide	sulphur dioxide	R-12	carbon dioxide
Which of the following refrigerants is highly toxic and flammable ?	ammonia	carbon dioxide	sulphur dioxide	R-12	ammonia
The refrigerant widely used in domestic refrigerators is	ammonia	carbon dioxide	sulphur dioxide	R-12	R-12
In larger industrial and commercial reciprocating compression systems, the refrigerant widely use is	ammonia	carbon dioxide	sulphur dioxide	R-12	ammonia

R-12 is generally preferred over R-22 in deep freezers since	it has lower operating pressures	it gives higher coefficient of performance	it is miscible with oil over large range of temperatures	it is immiscible with oil over large range of temperatures	it is miscible with oil over large range of temperatures
Environmental protection agencies advice against the use of chloro-fluoro-carbon refrigerants since	these react with water vapour and cause acid rain	these react with plants and cause green house effect	these react with oxygen and cause its depletion	these react with ozone layer	these react with ozone layer
A refrigerant compressor is used to	raise pressure of the refrigerant	raise the temperature of the refrigerant	circulate the refrigerant through the refrigerating system	all of the above	all of the above
The refrigerant supplied to a compressor must be	superheated vapour refrigerant	dry saturated liquid refrigerant	a mixture of liquid and vapour refrigerant	none of the above	superheated vapour refrigerant
The pressure at the inlet of a refrigerant compressor is called	suction pressure	discharge pressure	critical pressure	back pressure	suction pressure
The pressure at the outlet of a refrigerator compressor is called	suction pressure	discharge pressure	critical pressure	back pressure	discharge pressure
In refrigerating system the expansion device is connected between the	compressor and condensor	condensor and reciever	reciever and evaporator	evaporator and compressor	reciever and evaporator
The capillary tube, as an expansion device, is used in	domestic refrigerators	water coolers	room air conditioners	all of these	all of these
For ammonia refrigerating systems, the tubes of a shell and tube condenser are made of	copper	aluminium	steel	brass	steel
The pressure in capillary tube decreases due to	frictional resistance offered by the tube wall	acceleration of refrigerator in the tube	heat transfer from the tube	both (a) and (b)	both (a) and (b)
Capillary tube is not used in larger capacity refrigeration system because	cost is too high	capacity control is not possible	it is made of copper	required pressure drop cannot be achieved	capacity control is not possible
The capillary tube used as expansion device in vapour compression system works on the principle of	isothermal expansion causing pressure drop	adiabatic expansion causing pressure drop	flow through pipe with friction causing pressure drop	throttle expansion causing pressure drop	flow through pipe with friction causing pressure drop

Thermostatic expansion valve is used in ………..type of evaporators.	flooded	DX coil	dry	all of these	dry
The thermostatic expansion valve operates on the changes in the	degree of superheat at exit from the evvaporator	temperature of the evaporator	pressure in the evaporator	none of these	degree of superheat at exit from the evvaporator
The thermostatic expansion valve is also called	constant pressure valve	constant temperature valve	constant superheat valve	none of these	constant superheat valve
Most thermostatic expansion valves are set for a superheat of	5°C	10°C	15°C	20°C	5°C
In shell and coil condenser,	water flows in the shell and the refrigerant in the coil	water flows in the coil and the refrigerant in the shell	only water flows through the shell as well as coil	only refrigerant flows through the shell as well as coil	water flows in the coil and the refrigerant in the shell
In compound compression refrigeration systems with intercooling the optimum intercooler or intermediate pressure p2, when the cooling ratio is fixed is given by	p2=p1/p3	p2=p3/p1	p2=p1×p3	p2=√p1×p3	p2=√p1×p3
The work requirement for a reciprocating compressor is minimum when the compressor process is	isothermal	isentropic	polytropic	adiabatic	isothermal
R-12 is generally preferred over R-22 in deep freezers since	it has lower operating pressures	it gives higher coefficient of performance	it is miscible with oil over large range of temperatures	it is immiscible with oil over large range of temperatures	it is miscible with oil over large range of temperatures
The centrifugal compressor are generally used for refrigerants that require	small displacements and low condensing pressures	large displacements and high condensing pressures	small displacement and high condensing pressures	large displacement and low condensing pressures	large displacement and low condensing pressures

UNIT – III

PSYCHROMETRY

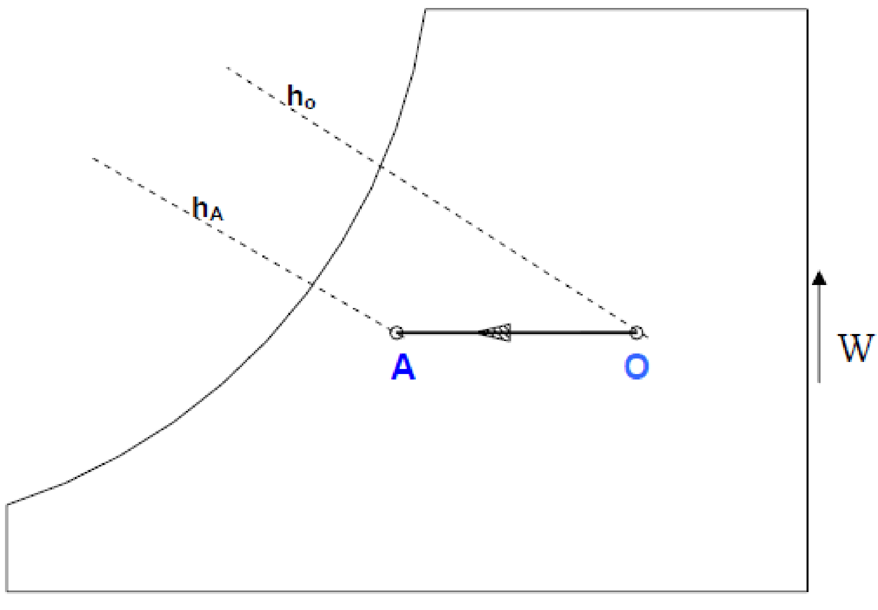
In the design and analysis of air conditioning plants, the fundamental requirement is to identify the various processes being performed on air. Once identified, the processes can be analyzed by applying the laws of conservation of mass and energy. All these processes can be plotted easily on a psychrometric chart. This is very useful for quick visualization and also for identifying the changes taking place in important properties such as temperature, humidity ratio, enthalpy etc. The important processes that air undergoes in a typical air conditioning plant are discussed below.

Important psychrometric processes:

a) Sensible cooling:

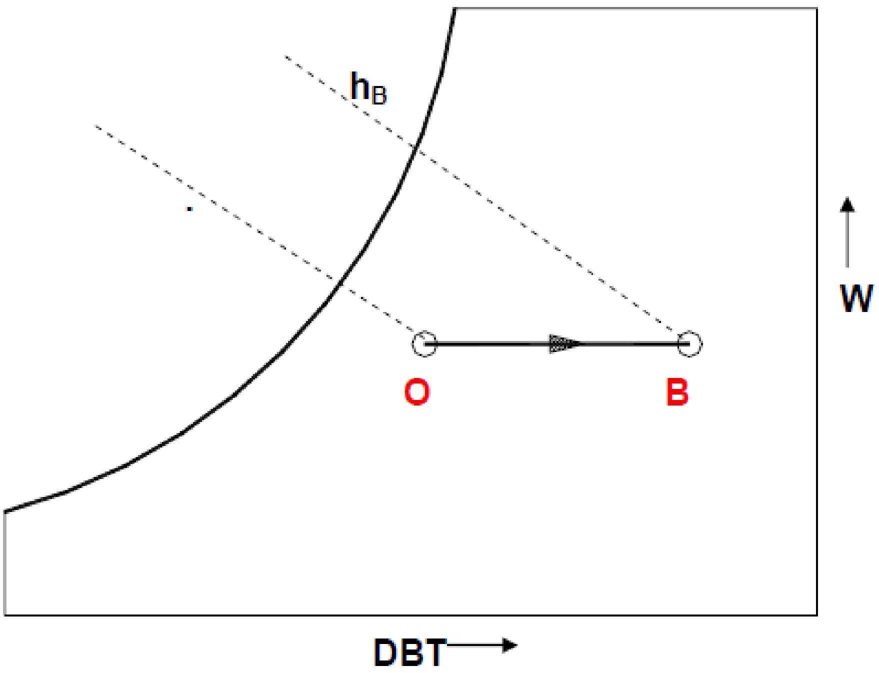
During this process, the moisture content of air remains constant but its temperature decreases as it flows over a cooling coil. For moisture content to remain constant, the surface of the cooling coil should be dry and its surface temperature should be greater than the dew point temperature of air. If the cooling coil is 100% effective, then the exit temperature of air will be equal to the coil temperature. However, in practice, the exit air temperature will be higher than the cooling coil temperature. Figure shows the sensible cooling process O-A on a psychrometric chart. The heat transfer rate during this process is given by:

$$Q_c = m_a(h_O - h_A) = m_a c_{pm}(T_O - T_A)$$



b) Sensible heating (Process O-B):

During this process, the moisture content of air remains constant and its temperature increases as it flows over a heating coil. The heat transfer rate during this process is given by: $Q_h = M_a (h_B - h_O) = M_a.C_{pm}(T_B - T_O)$ where cpm is the humid specific heat (≈1.0216 kJ/kg dry air) and ma is the mass flow rate of dry air (kg/s). Figure 28.2 shows the sensible heating process on a psychrometric chart.



c) Cooling and dehumidification:

When moist air is cooled below its dew-point by bringing it in contact with a cold surface as shown, some of the water vapor in the air condenses and leaves the air stream as liquid, as a result both the temperature and humidity ratio of air decreases as shown. This is the process air undergoes in a typical air conditioning system. Although the actual process path will vary depending upon the type of cold surface, the surface temperature, and flow conditions, for simplicity the process line is assumed to be a straight line. The heat and mass transfer rates can be expressed in terms of the initial and final conditions by applying the conservation of mass and conservation of energy equations as given below:

By applying mass balance for the water: ma.wo = ma.wC + mw

By applying energy balance: ma .hO = Qt + mw .hw + ma .hC

from the above two equations, the load on the cooling coil, Qt is given by: Qt = ma (hO − hC) −ma (wO − wC)hw

the 2nd term on the RHS of the above equation is normally small compared to the other terms, so it can be neglected. Hence,

Qt = ma (hO − hC)

It can be observed that the cooling and de-humidification process involves both latent and sensible heat transfer processes, hence, the total, latent and sensible heat transfer rates (Qt, Ql and Qs) can be written as

$$Q_t = Q_l + Q_s$$

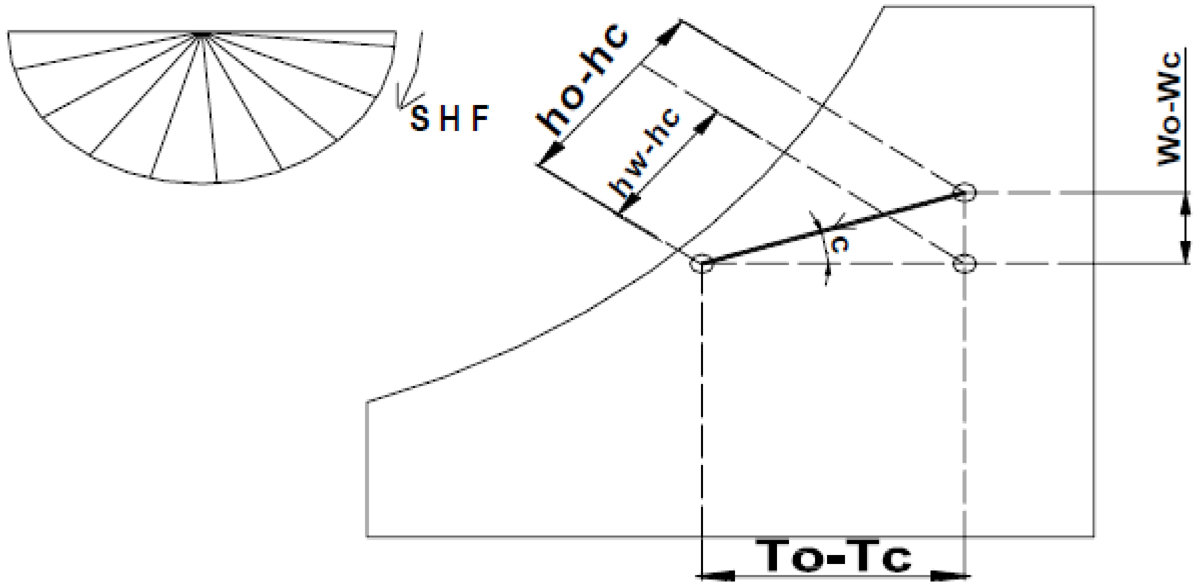
where

$$Q_l = m_a(h_O - h_W) = m_a.h_{fg}(w_O - w_C)$$

$$Q_s = m_a(h_W - h_C) = m_a.c_{pm}(T_O - T_C)$$

By separating the total heat transfer rate from the cooling coil into sensible and latent heat transfer rates, a useful parameter called Sensible Heat Factor (SHF) is defined. SHF is defined as the ratio of sensible to total heat transfer rate, i.e., SHF = Qs /Qt = Qs /(Qs + Ql)

From the above equation, one can deduce that a SHF of 1.0 corresponds to no latent heat transfer and a SHF of 0 corresponds to no sensible heat transfer. A SHF of 0.75 to 0.80 is quite common in air conditioning systems in a normal dry-climate. A lower value of SHF, say 0.6, implies a high latent heat load such as that occurs in a humid climate.



It can be seen that the slope of the process line O-C is given by:

tan c = Δ w / Δ T

From the definition of SHF,
$$\frac{1-\text{SHF}}{\text{SHF}}=\frac{Q_l}{Q_s}=\frac{m_a h_{fg}\Delta w}{m_a c_{pm}\Delta T}=\frac{2501\Delta w}{1.0216\Delta T}=2451\frac{\Delta w}{\Delta T}$$

Hence:
$$\tan c=\frac{1}{2451}\left(\frac{1-\text{SHF}}{\text{SHF}}\right)$$

Thus we can see that the slope of the cooling and de-humidification line is purely a function of the sensible heat factor, SHF. Hence, we can draw the cooling and dehumidification line on psychrometric chart if the initial state and the SHF are known. In some standard psychrometric charts, a protractor with different values of SHF is provided. The process line is drawn through the initial state point and in parallel to the given SHF line from the protractor as shown in the figure above.

The temperature Ts is the effective surface temperature of the cooling coil, and is known as apparatus dew-point (ADP) temperature. In an ideal situation, when all the air comes in perfect contact with the cooling coil surface, then the exit temperature of air will be same as ADP of the coil. However, in actual case the exit temperature of air will always be greater than the apparatus dew-point temperature due to boundary layer development as air flows over the cooling coil surface and also due to temperature variation along the fins etc. Hence, we can define a by-pass factor (BPF) as:

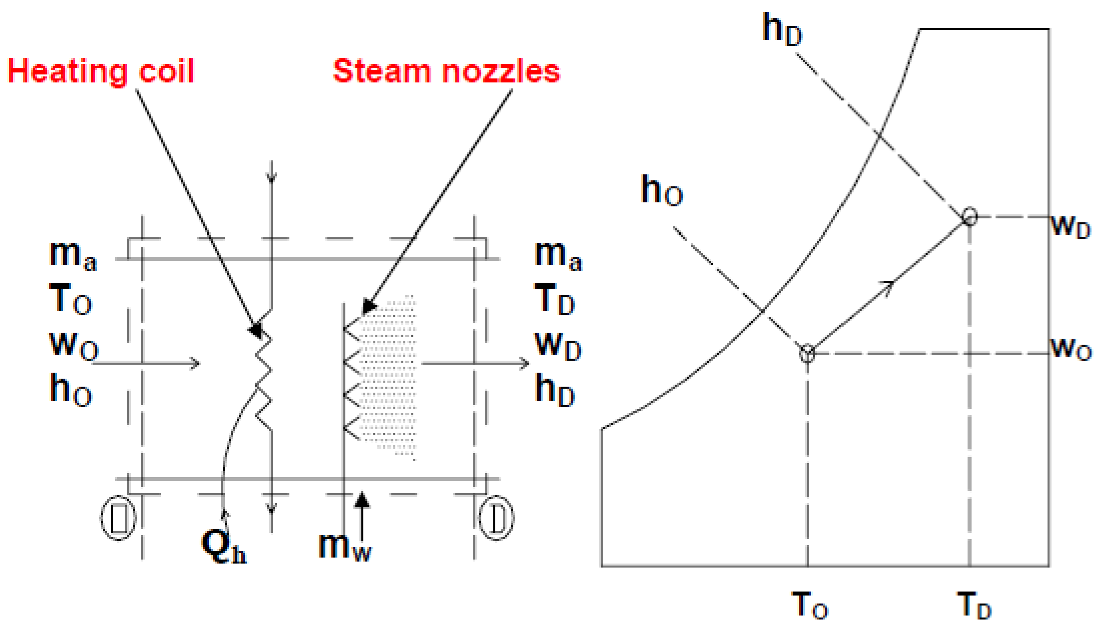
$$BPF = \frac{T_C - T_S}{T_O - T_S}$$

It can be easily seen that, higher the by-pass factor larger will be the difference between air outlet temperature and the cooling coil temperature. When BPF is 1.0, all the air by-passes the coil and there will not be any cooling or de-humidification. In practice, the by-pass factor can be increased by increasing the number of rows in a cooling coil or by decreasing the air velocity or by reducing the fin pitch. Alternatively, a contact factor(CF) can be defined which is given by:

CF = 1−BPF

d) Heating and Humidification:

During winter it is essential to heat and humidify the room air for comfort. This is normally done by first sensibly heating the air and then adding water vapour to the air stream through steam nozzles as shown in the figure.



Mass balance of water vapor for the control volume yields the rate at which steam has to be added, i.e., mw:

mw = ma (wD − wO)

where ma is the mass flow rate of dry air.

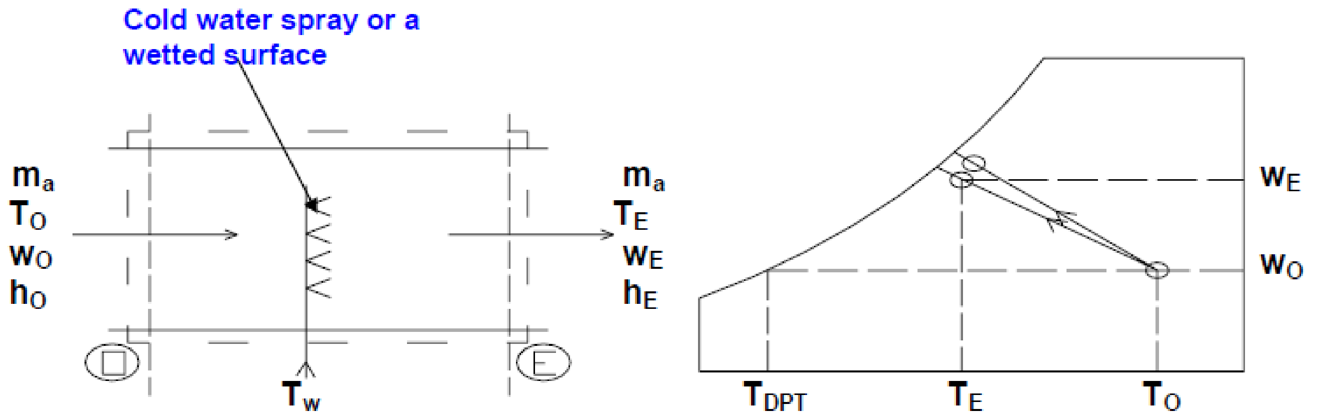
From energy balance: Qh = ma (hD − hO) −mw.hw

where Qh is the heat supplied through the heating coil and hw is the enthalpy of steam.

Since this process also involves simultaneous heat and mass transfer, we can define a sensible heat factor for the process in a way similar to that of a cooling and dehumidification process.

e) Cooling & humidification:

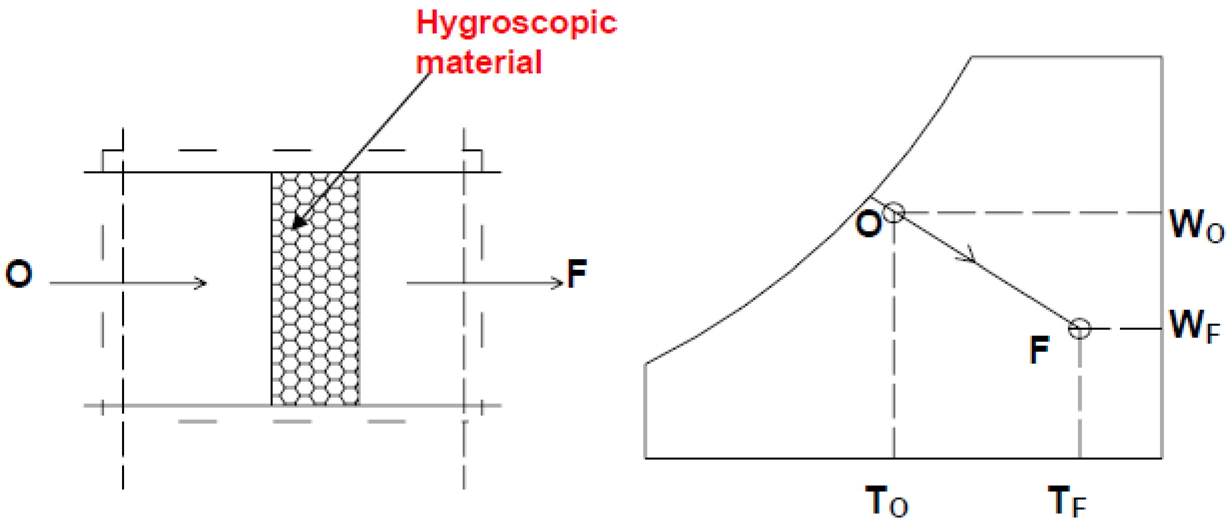
As the name implies, during this process, the air temperature drops and its humidity increases. As shown in the figure, this can be achieved by spraying cool water in the air stream. The temperature of water should be lower than the dry-bulb temperature of air but higher than its dew-point temperature to avoid condensation (Tdpt < Tw < To).



It can be seen that during this process there is sensible heat transfer from air to water and latent heat transfer from water to air. Hence, the total heat transfer depends upon the water temperature. If the temperature of the water sprayed is equal to the wet bulb temperature of air, then the net transfer rate will be zero as the sensible heat transfer from air to water will be equal to latent heat transfer from water to air. If the water temperature is greater than WBT, then there will be a net heat transfer from water to air. If the water temperature is less than WBT, then the net heat transfer will be from air to water. Under a special case when the spray water is entirely recirculated and is neither heated nor cooled, the system is perfectly insulated and the make-up water is supplied at WBT, then at steady-state, the air undergoes an adiabatic saturation process, during which its WBT remains constant. This is the process of adiabatic saturation. The process of cooling and humidification is encountered in a wide variety of devices such as evaporative coolers, cooling towers etc.

f) Heating and de-humidification:

This process can be achieved by using a hygroscopic material, which absorbs or adsorbs the water vapor from the moisture. If this process is thermally isolated, then the enthalpy of air remains constant, as a result the temperature of air increases as its moisture content decreases. This hygroscopic material can be a solid or a liquid. In general, the absorption of water by the hygroscopic material is an exothermic reaction, as a result heat is released during this process, which is transferred to air and the enthalpy of air increases.

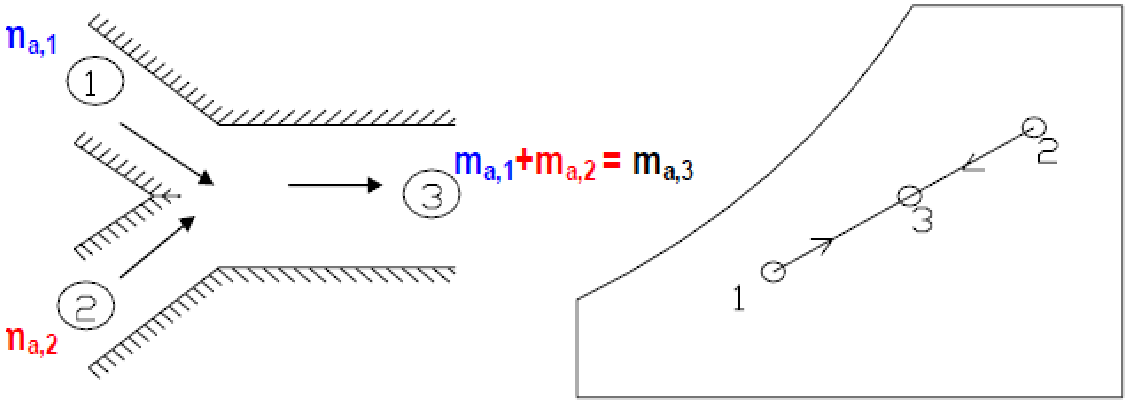


g) Mixing of air streams:

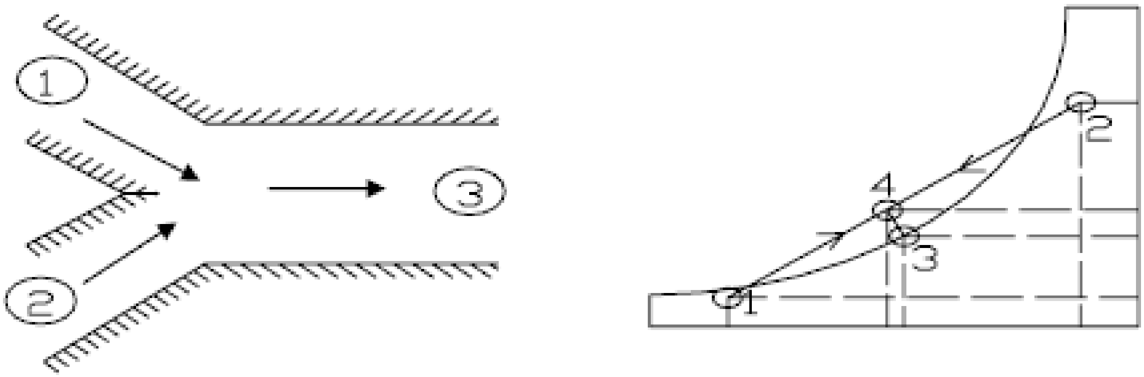
Mixing of air streams at different states is commonly encountered in many processes, including in air conditioning. Depending upon the state of the individual streams, the mixing process can take place with or without condensation of moisture.

i) Without condensation: Figure shows an adiabatic mixing of two moist air streams during which no condensation of moisture takes place. As shown in the figure, when two air streams at state points 1 and 2 mix, the resulting mixture condition 3 can be obtained from mass and energy balance.

It can be observed that the final enthalpy and humidity ratio of mixture are weighted averages of inlet enthalpies and humidity ratios. A generally valid approximation is that the final temperature of the mixture is the Version 1 ME, IIT Kharagpur 9 10 weighted average of the inlet temperatures. With this approximation, the point on the psychrometric chart representing the mixture lies on a straight line connecting the two inlet states. Hence, the ratio of distances on the line, i.e., (1-3)/(2-3) is equal to the ratio of flow rates ma,2/ma,1. The resulting error (due to the assumption that the humid specific heats being constant) is usually less than 1 percent.



ii) Mixing with condensation: As shown in Fig, when very cold and dry air mixes with warm air at high relative humidity, the resulting mixture condition may lie in the two-phase region, as a result there will be condensation of water vapor and some amount of water will leave the system as liquid water. Due to this, the humidity ratio of the resulting mixture (point 3) will be less than that at point 4. Corresponding to this will be an increase in temperature of air due to the release of latent heat of condensation. This process rarely occurs in an air conditioning system, but this is the phenomenon which results in the formation of fog or frost (if the mixture temperature is below 0o C). This happens in winter when the cold air near the earth mixes with the humid and warm air, which develops towards the evening or after rains.

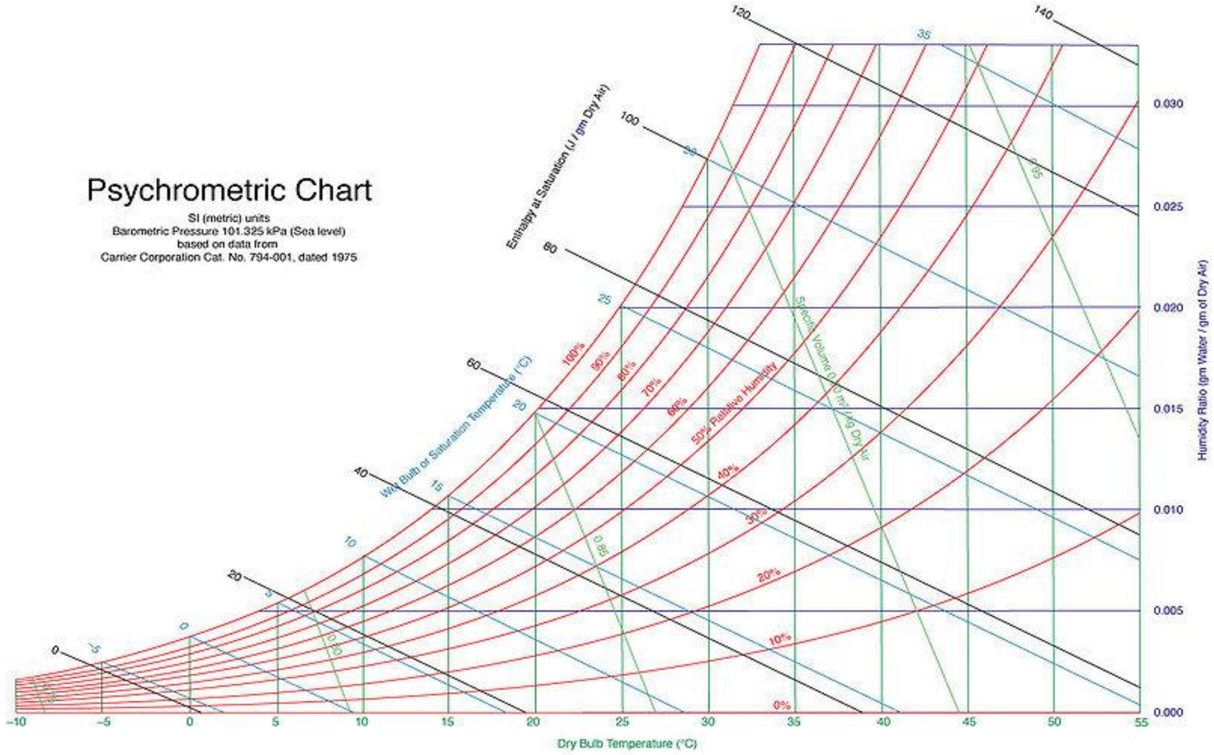


Psychrometric charts:

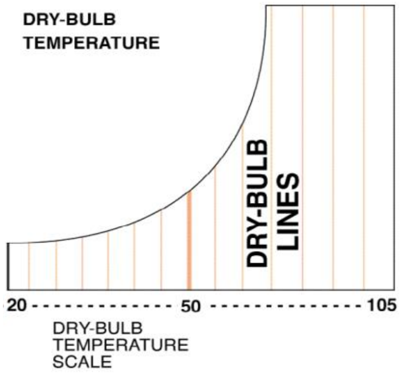
Psychrometric charts are complex graphs that can be used to assess the physical and thermodynamic properties of gas-vapour mixtures at a constant pressure. They are often used to assess the properties of moist air. This can be useful in the design of heating, ventilation and air-conditioning systems for buildings, and psychrometric charts often include a zone in the middle that represents the range of conditions that people find comfortable under different circumstances (such as summer and winter).

Typically, the properties represented on psychrometric charts are:

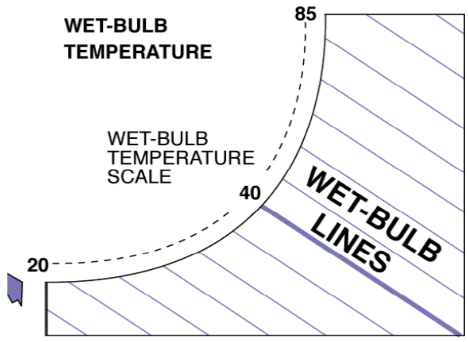
Dry-bulb temperature: A measure of air temperature recorded by a thermometer exposed to the air but shielded from radiation and moisture.
Wet-bulb temperature: The temperature recorder by a thermometer that has its bulb wrapped in cloth and moistened with distilled water. The rate of evaporation from the wet bulb, and so the temperature it records varies depending on the humidity of the air it is exposed to.
Relative humidity: The ratio of the actual vapour pressure relative to the vapour pressure of saturated air at the same temperature, expressed as a percentage.
Specific volume: The volume of a unit weight of dry air.
Dew point temperature: The highest temperature at which water vapour will condense.
Humidity ratio: The dry-basis moisture content of air expressed as the weight of water vapour per unit weight of dry air.
Enthalpy: The energy content of air.



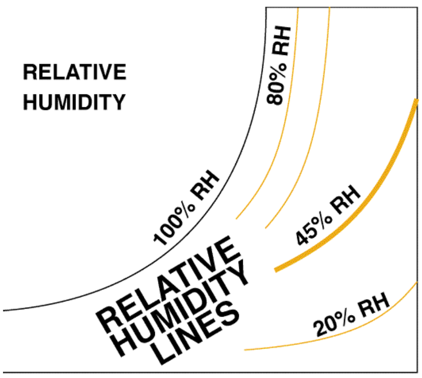
Psychrometric Chart
SI (metric) units
Barometric Pressure 101.325 kPa (Sea level)
based on data from
Carrier Corporation Cat. No. 794-001, dated 1975
Enthalpy at Saturation (J / gm Dry Air)
Wet Bulb or Saturation Temperature (°C)
50% Relative Humidity
Humidity Ratio (gm Water / gm of Dry Air)
Dry Bulb Temperature (°C)



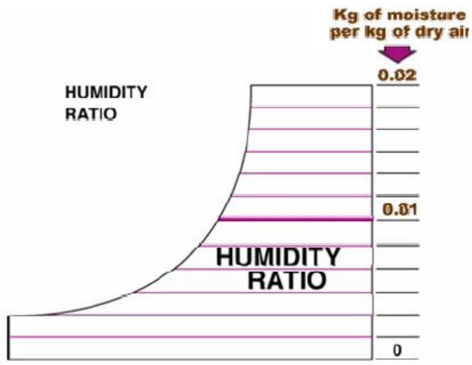
DRY-BULB TEMPERATURE
DRY-BULB LINES
20
50
105
DRY-BULB TEMPERATURE SCALE



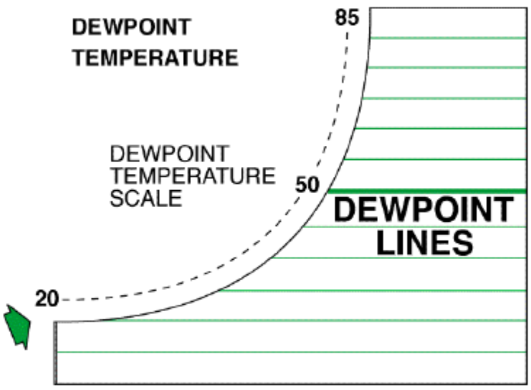
WET-BULB TEMPERATURE
85
WET-BULB TEMPERATURE SCALE
40
20
WET-BULB LINES

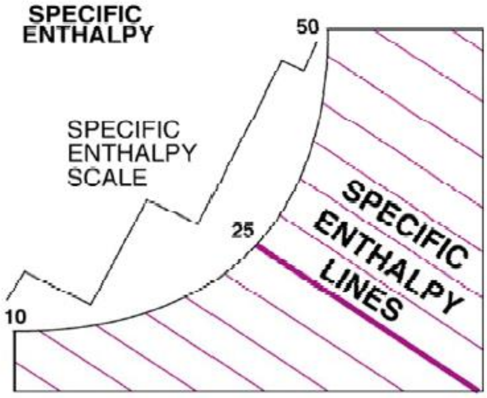


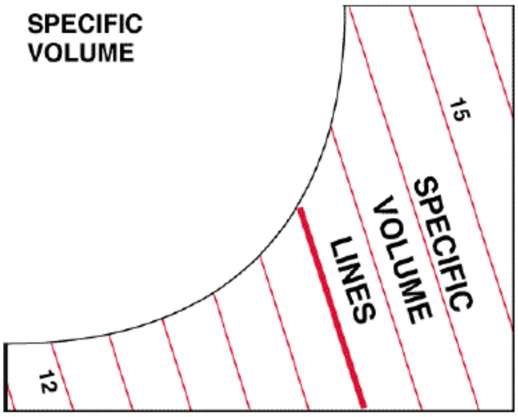
RELATIVE HUMIDITY
80% RH
100% RH
45% RH
RELATIVE HUMIDITY LINES
20% RH



Kg of moisture per kg of dry air
0.02
HUMIDITY RATIO
0.01
HUMIDITY RATIO
0

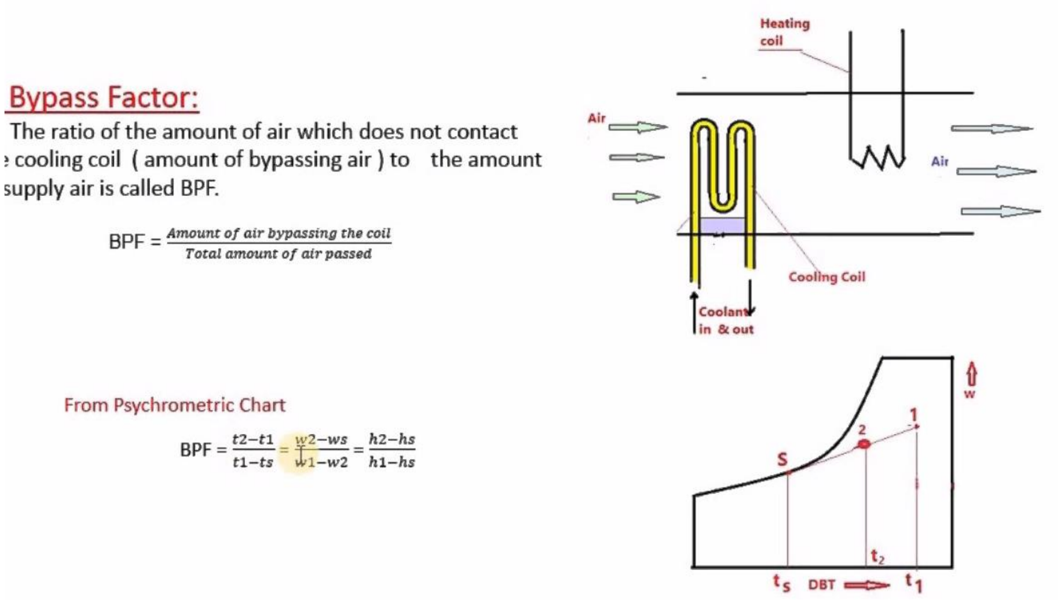






By-Pass factor:

The inability of a coil to cool or heat the air to its temperature is indicated by a factor called by-pass factor (BPF) or Coil Bypass Factor. This inability is due to the coil inefficiency and some amount of air just bypassing the coil without getting affected by it.



Comfort Air Conditioning

Following are the Factors affecting Comfort Air conditioning:

Temperature
Humidity
Air movement
Air Purity.

1. Temperature : Convection Heat transfer depends upon the temperature difference.So an adequate difference between body temperature and ambient temperature would ensure the convection heat transfer.Temperature difference would cause chilling effect as in winter. In such cases insulation in th form of pullover would avoid chill.Greater activity bye rubbing your hand would generate some engery for the heat dissipation and makes you feel better. So preferred temperature are in between 20- 25 Degree.

2. Humidity : At higher ambient temperature convection heat transfer is either not adequate or is in reverse direction. The evaporation of perspiration by body heat is the only means of heat dissipation.Ambiebt air contains some water vapour in it and water evaporation depei upon vapour pressure difference.so we can say that higher humidity would reduce evaporation of sweat from out body.Even at low temperature water vapour is given out through body pores due to vapour pressure difference.So in dry climate excessive loss of moisture leads to drying of skin and blister on the skin. So humidity maintain in between 30 to 70 % .

3. Air Movement : Convection heat transfer depends upon air movement and evaporation rate also can be maintained by constantly carrying away the vapour from evaporation surface.So it would be helpful for giving comfort and heat dissipation takes place properly.If the air movement is high it would cause the noise discomfort. Similarly we maintained higher air movement of fan in summer and slow air movement in winter for better comfort.The limited air velocity ranging in between 8–15 m/min.

4. Air Purity :. Since air conditioner supplies conditioning air for comfort. Atmospheric air has many impurities in it.The range of impurities like dust,pollen, other carbon particles is in microns i e. Nearly 180 micron and for virua and bacteria size rang is 0.05 micron. At some point odorous gases makes you feel discomfort. so air conditioner needs to be remove unwanted impurities as per requirement.At normal place air filtration would be down to 10 micron and in ICU , Operations Theatre the filtration woulf down to 0.05 micron.

MULTIPLE CHIOCE QUESTIONS

QUESTION	OPTION 1	OPTION 2	OPTION 3	OPTION 4	ANSWER
A mixture of dry air and water vapour, when the air has diffused the maximum amount of water vapour into it, is called	dry air	moist air	saturated air	specific humidity	saturated air
The temperature of air recorded by a thermometer, when it is not effected by the moisture present in it, is called	wet bulb temperature	dry bulb temperature	dew point temperature	none of these	dry bulb temperature
For unsaturated air, the dew point temperature is…………wet bulb temperature.	equal to	less than	more than		less than
The difference between dry bulb temperature and wet bulb temperature, called	dry bulb depression	wet bulb depression	dew point depression	degree of saturation	wet bulb depression
The wet bulb depression is zero, when relative humiditiy is equal to	zero	0.5	0.75	1	1
The relative humidity of air is defined as the ratio of	mass of water vapour in a given volume to the total mass of the mixture of air and water vapour	mass of water vapour in a given volume to the mass of water, if air is saturated at the same temperature	mass of water vapour in a given volume to the mass of air	mass of air to the mass of vapour in the mixture of air and water vapour	mass of water vapour in a given volume to the mass of water, if air is saturated at the same temperature
The vertical and uniformly spaced lines on a psychometric chart indicates	dry bulb temperature	wet bulb temperature	dew point temperature	specific humidity	dry bulb temperature
The curved lines on a psychometric chart indicates	dry bulb temperature	wet bulb temperature	specific humidity	relative humidity	relative humidity

During sensible cooling of air, the specific humidity	increases	decreases	remains constant		remains constant
During sensible cooling of air, the dry bulb temperature	increases	decreases	remains constant		decreases
During sensible cooling of air, the wet bulb temperature	increases	decreases	remains constant	none of these	decreases
The minimum temperature to which moist air can be cooled under ideal conditions in a spray washer is	dew point temperature of inlet air	wet bulb temperature of inlet air	water inlet temperature	water outlet temperature	wet bulb temperature of inlet air
The by-pass factor of a cooling coil decreases with	decrease in fin spacing and increase in number of rows	increase in fin spacing and increase in number of rows	increase in fin spacing and decrease in number of rows	decrease in fin spacing and decrease in number of rows	decrease in fin spacing and increase in number of rows
The process generally used in water air conditioning to warm and humidity the air, is called	humudification	dehumidification	heating and humidification	cooling and dehumidification	heating and humidification
In order to cool and dehumidify a stream of moist air, it must be passed over the coil at a temperature	which lies between the dry bulb and wet bulb temperature of the incoming stream	which lies between the wet bulb and dew point temperature of the incoming stream	which is lower than the dew point temperature of the incoming stream	of adiabatic saturation of incoming stream	which is lower than the dew point temperature of the incoming stream
Humidification is the process of ________________________moisture	increasing	decreasing	maintaining	Removing	increasing
Dehumidification is the process of _____________________ moisture	increasing	decreasing	maintaining	Removing	decreasing
During a cooling process the specific humidity remains constant is known as	Sensible cooling	Sensible heating	Dew point temperature	Wet bulb temperature	Sensible cooling
During a heating process the specific humidity remains constant is known as	Sensible cooling	Sensible heating	Dew point temperature	Wet bulb temperature	Sensible heating

The curved lines on a psychrometric chart indicates	Dry bulb temperature	Wet bulb temperature	Specific humidity	Relative humidity	Relative humidity
During sensible cooling of air, the specific humidity	Increases	Decreaes	Remains constant	Less than zero	Remains constant
During sensible heating of air, the specific humidity	Increases	Decreaes	Remains constant	Less than zero	Remains constant
During sensible cooling of air, the dry bulb temperature is	Increases	Decreaes	Remains constant	Less than zero	Decreaes
The process generally used in winter air conditioning to warm and humidify the air is called	Humidification	Dehumidification	Cooling & dehumidification	Heating and humidification	Heating and humidification
The horizontal line in the psychrometric chart indicates	Specific humidity	Absolute humidity	wet bulb depression	dew point depression	Specific humidity
The inefficiency of the cooling oil is expressed by	By pass factor	By pass rider	RPF	PRF	By pass factor

UNIT – IV

COOLING LOAD CALCULATIONS

Heating and cooling load calculations are carried out to estimate the required capacity of heating and cooling systems, which can maintain the required conditions in the conditioned space. To estimate the required cooling or heating capacities, one has to have information regarding the design indoor and outdoor conditions, specifications of the building, specifications of the conditioned space (such as the occupancy, activity level, various appliances and equipment used etc.) and any special requirements of the particular application. For comfort applications, the required indoor conditions are fixed by the criterion of thermal comfort, while for industrial or commercial applications the required indoor conditions are fixed by the particular processes being performed or the products being stored. As discussed in an earlier chapter, the design outdoor conditions are chosen based on design dry bulb and coincident wet bulb temperatures for peak summer or winter months for cooling and heating load calculations, respectively.

Heating versus cooling load calculations:

As the name implies, heating load calculations are carried out to estimate the heat loss from the building in winter so as to arrive at required heating capacities. Normally during winter months the peak heating load occurs before sunrise and the outdoor conditions do not vary significantly throughout the winter season. In addition, internal heat sources such as occupants or appliances are beneficial as they compensate some of the heat losses. As a result, normally, the heat load calculations are carried out assuming steady state conditions (no solar radiation and steady outdoor conditions) and neglecting internal heat sources. This is a simple but conservative approach that leads to slight overestimation of the heating capacity. For more accurate estimation of heating loads, one has to take into the thermal capacity of the walls and internal heat sources, which makes the problem more complicated.

For estimating cooling loads, one has to consider the unsteady state processes, as the peak cooling load occurs during the day time and the outside conditions also vary significantly throughout the day due to solar radiation. In addition, all internal sources add on to the cooling loads and neglecting them would lead to underestimation of the required cooling capacity and the possibility of not being able to maintain the required indoor conditions. Thus cooling load calculations are inherently more complicated as it involves solving unsteady equations with unsteady boundary conditions and internal heat sources.

For any building there exists a balance point at which the solar radiation (Qsolar) and internal heat generation rate (Qint) exactly balance the heat losses from the building. Thus from sensible heat balance equation, at balanced condition:

$$(Q_{solar} + Q_{int})_{sensible} = UA(T_{in} - T_{out})$$

where UA is the product of overall heat transfer coefficient and heat transfer area of the building, Tin is the required indoor temperature and Tout is the outdoor temperature.

From the above equation, the outside temperature at balanced condition (Tout,bal) is given by:

$$T_{out,bal} = T_{in} - \frac{(Q_{solar} + Q_{int})_{sensible}}{UA}$$

by the above equation, i.e., when Tout > Tout,bal, then there is a need for cooling the building. On the other hand, when the outdoor temperature is less than the balanced outdoor temperature, i.e., when Tout < Tout,bal, then there is a need for heating the building. When the outdoor temperature exactly equals the balanced outdoor temperature, i.e., when Tout = Tout,bal, then there is no need for either cooling or heating the building.

For residential buildings (with fewer internal heat sources), the balanced outdoor temperature may vary from 10 to 18oC. As discussed before, this means that if the balanced outdoor temperature is 18oC, then a cooling system is required when the outdoor temperature exceeds 18oC. This implies that buildings need cooling not only during summer but also during spring and fall as well. If the building is well insulated (small UA) and/or internal loads are high, then from the energy balance equation (35.2), the balanced outdoor temperature will reduce leading to extended cooling season and shortened heating season. Thus a smaller balanced outdoor temperature implies higher cooling requirements and smaller heating requirements, and vice versa. For commercial buildings with large internal loads and relatively smaller heat transfer areas, the balanced outdoor temperature can be as low as 2oC, implying a lengthy cooling season and a small heating season. If there are no internal heat sources and if the solar radiation is negligible, then from the heat balance equation, Tout,bal = Tin, this implies that if the outside temperature exceeds the required inside temperature (say, 25oC for comfort) then there is a need for cooling otherwise there is a need for heating. Thus depending upon the specific conditions of the building, the need for either cooling system or a heating system depends. This also implies a need for optimizing the building insulation depending upon outdoor conditions and building heat generation so that one can use during certain periods free cooling provided by the environment without using any external cooling system.

Methods of estimating cooling and heating loads:

Generally, heating and cooling load calculations involve a systematic, stepwise procedure, using which one can arrive at the required system capacity by taking into account all the building energy flows. In practice, a variety of methods ranging from simple rules-of-thumb to complex Transfer Function Methods are used in practice to arrive at the building loads. For example, typical rules-of-thumb methods for cooling loads specify the required cooling capacity based on the floor area or occupancy. Table 35.1 shows typical data on required cooling capacities based on the floor area or application. Such rules-of-thumb are useful in preliminary estimation of the equipment size and cost. The main conceptual drawback of rules-of-thumb methods is the presumption that the building design will not make any difference. Thus the rules for a badly designed building are typically the same as for a good design.

Sl.no	Application	Required cooling capacity (TR) for 1000 ft^2 of floor area
1.	Office buildings: External zones Internal zones	 25% glass: 3.5 TR 50% glass: 4.5 TR 75% glass: 5.0 TR 2.8 TR
2.	Computer rooms	6.0 – 12.0 TR
3.	Hotels Bedrooms Restaurants	 Single room: 0.6 TR per room Double room: 1.0 TR per room 5.0 - 9.0 TR
4.	Department stores Basement & ground floors Upper floors	 4.5 – 5.0 TR 3.5 – 4.5 TR
5.	Shops	5.0 TR
6.	Banks	4.5 – 5.5 TR
7.	Theatres & Auditoriums	0.07 TR per seat

More accurate load estimation methods involve a combination of analytical methods and empirical results obtained from actual data, for example the use of Cooling Load Temperature Difference (**CLTD**) for estimating fabric heat gain and the use of Solar Heat Gain Factor (**SHGF**) for estimating heat transfer through fenestration. These methods are very widely used by air conditioning engineers as they yield reasonably accurate results and estimations can be carried out manually in a relatively short time. Over the years, more accurate methods that require the use of computers have been developed for estimating cooling loads, e.g. the **Transfer Function Method** (TFM). Since these methods are expensive and time consuming they are generally used for estimating cooling loads of large commercial or institutional buildings. ASHRAE suggests different methods for estimating cooling and heating loads based on applications, such as for residences, for commercial buildings etc.

Cooling load calculations:

As mentioned before, load calculations involve a systematic and stepwise procedure that takes into account all the relevant building energy flows. The cooling load experienced by a building varies in magnitude from zero (no cooling required) to a maximum value. The design cooling load is a load near the maximum magnitude, but is not normally the maximum. Design cooling load takes into account all the loads experienced by a building under a specific set of assumed conditions.

The assumptions behind design cooling load are as follows:

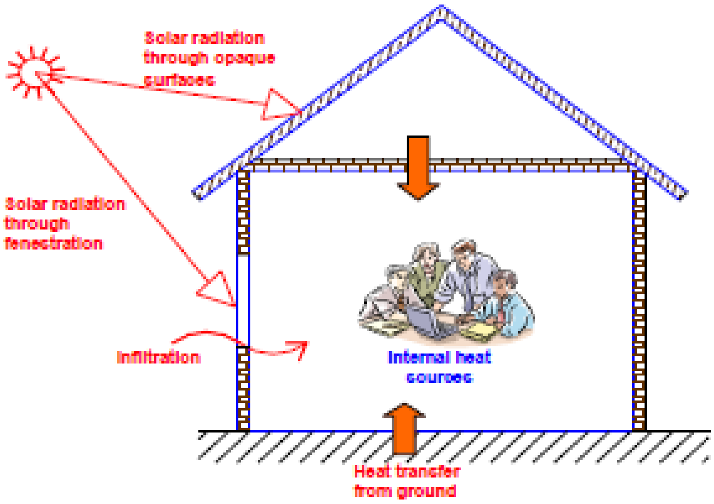
1. Design outside conditions are selected from a long-term statistical database. The conditions will not necessarily represent any actual year, but are representative of the location of the building. Design data for outside conditions for various locations of the world have been collected and are available in tabular form in various handbooks.
2. The load on the building due to solar radiation is estimated for clear sky conditions.
3. The building occupancy is assumed to be at full design capacity.
4. All building equipment and appliances are considered to be operating at a reasonably representative capacity.

The total building cooling load consists of heat transferred through the building envelope (walls, roof, floor, windows, doors etc.) and heat generated by occupants, equipment, and lights. The load due to heat transfer through the envelope is called as external load, while all other loads are called as internal loads. The percentage of external versus internal load varies with building type, site climate, and building design. The total cooling load on any building consists of both sensible as well as latent load components. The sensible load affects dry bulb temperature, while the latent load affects the moisture content of the conditioned space.

Buildings may be classified as externally loaded and internally loaded. In externally loaded buildings the cooling load on the building is mainly due to heat transfer between the surroundings and the internal conditioned space. Since the surrounding conditions are highly variable in any given day, the cooling load of an externally loaded building varies widely. In internally loaded buildings the cooling load is mainly due to internal heat generating sources such as occupants or appliances or processes. In general the heat generation due to internal heat sources may remain fairly constant, and since the heat transfer from the variable surroundings is much less compared to the internal heat sources, the cooling load of an internally loaded building remains fairly constant. Obviously from energy efficiency and economics points of view, the system design strategy for an externally loaded building should be different from an internally loaded building. Hence, prior knowledge of whether the building is externally loaded or internally loaded is essential for effective system design.

As mentioned before, the total cooling load on a building consists of external as well as internal loads. The external loads consist of heat transfer by conduction through the building walls, roof, floor, doors etc, heat transfer by radiation through fenestration such as windows and skylights. All these are sensible heat transfers. In addition to these the external load also consists of heat transfer due to infiltration, which consists of both sensible as well as latent components. The heat transfer due to ventilation is not a load on the building but a load on the system. The various internal loads consist of sensible and latent heat transfer due to occupants, products, processes and appliances, sensible heat transfer due to lighting and other equipment. Figure 35.1 shows various components that constitute the cooling load on a building.

Estimation of cooling load involves estimation of each of the above components from the given data. In the present chapter, the cooling load calculations are carried out based on the CLTD/CLF method suggested by ASHRAE. For more advanced methods such as TFM, the reader should refer to ASHRAE and other handbooks.



Estimation of external loads:

a) Heat transfer through opaque surfaces: This is a sensible heat transfer process. The heat transfer rate through opaque surfaces such as walls, roof, floor, doors etc. is given by:

$$Q_{opaque} = U.A.CLTD$$

where U is the overall heat transfer coefficient and A is the heat transfer area of the surface on the side of the conditioned space. CLTD is the cooling load temperature difference.

For sunlit surfaces, CLTD has to be obtained from the CLTD tables as discussed in the previous chapter. Adjustment to the values obtained from the table is needed if actual conditions are different from those based on which the CLTD tables are prepared.

For surfaces which are not sunlit or which have negligible thermal mass (such as doors), the CLTD value is simply equal to the temperature difference across the wall or roof. For example, for external doors the CLTD value is simply equal to the difference between the design outdoor and indoor dry bulb temperatures, Tout-Tin.

For interior air conditioned rooms surrounded by non-air conditioned spaces, the CLTD of the interior walls is equal to the temperature difference between the surrounding non-air conditioned space and the conditioned space. Obviously, if an air conditioned room is surrounded by other air conditioned rooms, with all of them at the same temperature, the CLTD values of the walls of the interior room will be zero.

Estimation of CLTD values of floor and roof with false ceiling could be tricky. For floors standing on ground, one has to use the temperature of the ground for estimating CLTD. However, the ground temperature depends on the location and varies with time. ASHRAE suggests suitable temperature difference values for estimating heat transfer through ground. If the floor stands on a basement or on the roof of another room, then the CLTD values for the floor are the temperature difference across the floor (i.e., difference between the temperature of the basement or room below and the conditioned space). This discussion also holds good for roofs which have non-air conditioned rooms above them. For sunlit roofs with false ceiling, the U value may be obtained by assuming the false ceiling to be an air space. However, the CLTD values obtained from the tables may not exactly fit the specific roof. Then one has to use his judgement and select suitable CLTD values.

b) Heat transfer through fenestration: Heat transfer through transparent surface such as a window, includes heat transfer by conduction due to temperature difference across the window and heat transfer due to solar radiation through the window. The heat transfer through the window by convection is calculated using Eq.(35.3), with CLTD being equal to the temperature difference across the window and A equal to the total area of the window. The heat transfer due to solar radiation through the window is given by:

$$Q_{trans} = A_{unshaded}.SHGF_{max}.SC.CLF$$

where Aunshaded is the area exposed to solar radiation, SHGFmax and SC are the maximum Solar Heat Gain Factor and Shading Coefficient, respectively, and CLF is the Cooling Load Factor. As discussed in a previous chapter, the unshaded area has to be obtained from the dimensions of the external shade and solar geometry. SHGFmax and SC are obtained from ASHRAE tables based on the orientation of the window, location, month of the year and the type of glass and internal shading device.

The Cooling Load Factor (CLF) accounts for the fact that all the radiant energy that enters the conditioned space at a particular time does not become a part of the cooling load1 instantly. As solar radiation enters the conditioned space, only a negligible portion of it is absorbed by the air particles in the conditioned space instantaneously leading to a minute change in its temperature. Most of the radiation is first absorbed by the internal surfaces, which include ceiling, floor, internal walls, furniture etc. Due to the large but finite thermal capacity of the roof, floor, walls etc., their temperature increases slowly due to absorption of solar radiation. As the surface temperature increases, heat transfer takes place between these surfaces and the air in the conditioned space. Depending upon the thermal capacity of the wall and the outside temperature, some of the absorbed energy due to solar radiation may be conducted to the outer surface and may be lost to the outdoors. Only that fraction of the solar radiation that is transferred to the air in the conditioned space becomes a load on the building, the heat transferred to the outside is not a part of the cooling load. Thus it can be seen that the radiation heat transfer introduces a time lag and also a decrement factor depending upon the dynamic characteristics of the surfaces. Due to the time lag, the effect of radiation will be felt even when the source of radiation, in this case the sun is removed. The CLF values for various surfaces have been calculated as functions of solar time and orientation and are available in the form of tables in ASHRAE Handbooks.

c) Heat transfer due to infiltration: Heat transfer due to infiltration consists of both sensible as well as latent components. The sensible heat transfer rate due to infiltration is given by:

$$Q_{s,inf} = \dot{m}_o\, c_{p,m}(T_o - T_i) = \dot{V}_o\, \rho_o c_{p,m}(T_o - T_i)$$

where is the infiltration rate (in mo.V3/s), ρo and cp,m are the density and specific heat of the moist, infiltrated air, respectively. To and Ti are the outdoor and indoor dry bulb temperatures.

The latent heat transfer rate due to infiltration is given by:

$$Q_{l,inf} = \dot{m}_o\, h_{fg}(W_o - W_i) = \dot{V}_o\, \rho_o h_{fg}(W_o - W_i)$$

where hfg is the latent heat of vaporization of water, Wo and Wi are the outdoor and indoor humidity ratio, respectively.

As discussed in an earlier chapter, the infiltration rate depends upon several factors such as the tightness of the building that includes the walls, windows, doors etc and the prevailing wind speed and direction. As mentioned before, the infiltration rate is obtained by using either the air change method or the crack method.

The infiltration rate by air change method is given by:

$$\dot{V}_o = (ACH).V/3600 \quad m^3/s$$

where ACH is the number of air changes per hour and V is the gross volume of the conditioned space in m3. Normally the ACH value varies from 0.5 ACH for tight and well-sealed buildings to about 2.0 for loose and poorly sealed buildings. For modern buildings the ACH value may be as low as 0.2 ACH. Thus depending upon the age and condition of the building an appropriate ACH value has to be chose, using which the infiltration rate can be calculated.

The infiltration rate by the crack method is given by:

$$\dot{V}_o = A.C.\Delta P^n \quad m^3/s$$

where A is the effective leakage area of the cracks, C is a flow coefficient which depends on the type of the crack and the nature of the flow in the crack, ΔP is the difference between outside and inside pressure (Po-Pi) and n is an exponent whose value depends on the nature of the flow in the crack. The value of n varies between 0.4 to 1.0, i.e., $0.4 \le n \le 1.0$. The pressure difference ΔP arises due to pressure difference due to the wind (ΔPwind), pressure difference due to the stack effect (ΔPstack) and pressure difference due to building pressurization (ΔPbld), i.e.,

$$\Delta P = \Delta P_{wind} + \Delta P_{stack} + \Delta P_{bld}$$

Semi-empirical expressions have been obtained for evaluating pressure difference due to wind and stack effects as functions of prevailing wind velocity and direction, inside and outside temperatures, building dimensions and geometry etc.

Representative values of infiltration rate for different types of windows, doors walls etc. have been measured and are available in tabular form in air conditioning design handbooks.

d) Miscellaneous external loads: In addition to the above loads, if the cooling coil has a positive by-pass factor (BPF > 0), then some amount of ventilation air directly enters the conditioned space, in which case it becomes a part of the building cooling load. The sensible and latent heat transfer rates due to the by-passed ventilation air can be calculated using by replacing with , where is the ventilation rate and BPF is the by-pass factor of the cooling coil. o.VBPF.Vvent.vent.V

In addition to this, sensible and latent heat transfer to the building also occurs due to heat transfer and air leakage in the supply ducts. A safety factor is usually provided to account for this depending upon the specific details of the supply air ducts.

If the supply duct consists of supply air fan with motor, then power input to the fan becomes a part of the external sensible load on the building. If the duct consists of the electric motor, which drives the fan, then the efficiency of the fan motor also must be taken into account while calculating the cooling load. Most of the times, the power input to the fan is not known a priori as the amount of supply air required is not known at this stage. To take this factor into account, initially it is assumed that the supply fan adds about 5% of the room sensible cooling load and cooling loads are then estimated. Then this value is corrected in the end when the actual fan selection is done.

Estimation of internal loads:

The internal loads consist of load due to occupants, due to lighting, due to equipment and appliances and due to products stored or processes being performed in the conditioned space.

a) Load due to occupants: The internal cooling load due to occupants consists of both sensible and latent heat components. The rate at which the sensible and latent heat transfer take place depends mainly on the population and activity level of the occupants. Since a portion of the heat transferred by the occupants is in the form of radiation, a Cooling Load Factor (CLF) should be used similar to that used for radiation heat transfer through fenestration. Thus the sensible heat transfer to the conditioned space due to the occupants is given by the equation:

$$Q_{s,\,occupants} = (\text{No. of people})(\text{Sensible heat gain / person})\,CLF$$

The value of Cooling Load Factor (CLF) for occupants depends on the hours after the entry of the occupants into the conditioned space, the total hours spent in the conditioned space and type of the building. Values of CLF have been obtained for different types of buildings and have been tabulated in ASHRAE handbooks.

Since the latent heat gain from the occupants is instantaneous the CLF for latent heat gain is 1.0, thus the latent heat gain due to occupants is given by:

$$Q_{l,occupants} = (\text{No. of people})(\text{Latent heat gain / person})$$

b) Load due to lighting: Lighting adds sensible heat to the conditioned space. Since the heat transferred from the lighting system consists of both radiation and convection, a Cooling Load Factor is used to account for the time lag. Thus the cooling load due to lighting system is given by:

$$Q_{s,lighting} = (\text{Installed wattage})(\text{Usage Factor})(\text{Ballast factor})\,CLF$$

The usage factor accounts for any lamps that are installed but are not switched on at the time at which load calculations are performed. The ballast factor takes into account the load imposed by ballasts used in fluorescent lights. A typical ballast factor value of 1.25 is taken for fluorescent lights, while it is equal to 1.0 for incandescent lamps. The values of CLF as a function of the number of hours after the lights are turned on, type of lighting fixtures and the hours of operation of the lights are available in the form of tables in ASHRAE handbooks.

c) Internal loads due to equipment and appliances: The equipment and appliances used in the conditioned space may add both sensible as well as latent loads to the conditioned space. Again, the sensible load may be in the form of radiation and/or convection. Thus the internal sensible load due to equipment and appliances is given by:

$$Q_{s,appliances} = (\text{Installed wattage})(\text{Usage Factor})\,CLF$$

The installed wattage and usage factor depend on the type of the appliance or equipment. The CLF values are available in the form of tables in ASHARE handbooks.

The latent load due to appliances is given by:

$$Q_{l,appliance} = (\text{Installed wattage})(\text{Latent heat fraction})$$

For other equipment such as computers, printers etc, the load is in the form of sensible heat transfer and is estimated based on the rated power consumption. The CLF value for these equipment may be taken as 1.0 as the radiative heat transfer from these equipment is generally negligible due to smaller operating temperatures. When the equipment are run by electric motors which are also kept inside the conditioned space, then the efficiency of the electric motor must be taken into account. Though the estimation of cooling load due to appliance and equipment appears to be simple as given by the equations, a large amount of uncertainty is introduced on account of the usage factor and the difference between rated (nameplate) power consumption at full loads and actual power consumption at part loads. Estimation using nameplate power input may lead to overestimation of the loads, if the equipment operates at part load conditions most of the time.

If the conditioned space is used for storing products (e.g. cold storage) or for carrying out certain processes, then the sensible and latent heat released by these specific products and or the processes must be added to the internal cooling loads. The sensible and latent heat release rate of a wide variety of live and dead products commonly stored in cold storages are available in air conditioning and refrigeration handbooks. Using these tables, one can estimate the required cooling capacity of cold storages.

Thus using the above equations one can estimate the sensible (Qs,r), latent (Ql,r) and total cooling load (Qt,r) on the buildings. Since the load due to sunlit surfaces varies as a function of solar time, it is preferable to calculate the cooling loads at different solar times and choose the maximum load for estimating the system capacity. From the sensible and total cooling loads one can calculate the Room Sensible Heat Factor (RSHF) for the building. As discussed in an earlier chapter, from the RSHF value and the required indoor conditions one can draw the RSHF line on the psychrometric chart and fix the condition of the supply air.

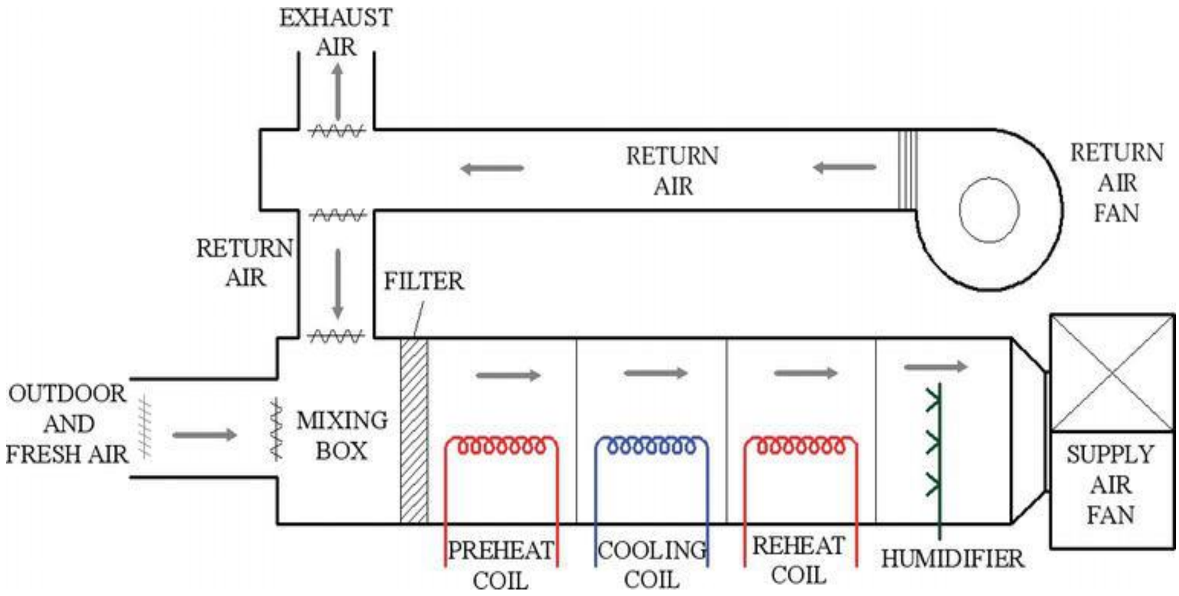
Heating load calculations:

As mentioned before, conventionally steady state conditions are assumed for estimating the building heating loads and the internal heat sources are neglected. Then the procedure for heating load calculations becomes fairly simple. One has to estimate only the sensible and latent heat losses from the building walls, roof, ground, windows, doors, due to infiltration and ventilation. Equations similar to those used for cooling load calculations are used with the difference that the CLTD values are simply replaced by the design temperature difference between the conditioned space and outdoors. Since a steady state is assumed, the required heating capacity of the system is equal to the total heat loss from the building. As already mentioned, by this method, the calculated heating system capacity will always be more than the actual required cooling capacity. However, the difference may not be very high as long as the internal heat generation is not very large (i.e., when the building is not internally loaded). However, when the internal heat generation rate is large and/or when the building has large thermal capacity with a possibility of storing solar energy during day time, then using more rigorous unsteady approach by taking the internal heat sources into account yields significantly small heating small capacities and hence low initial costs. Hence, once again depending on the specific case one has to select a suitable and economically justifiable method for estimating heating loads.

Central Air Conditioning Systems

A central HVAC system may serve one or more thermal zones, and its major equipment is located outside of the served zone(s) in a suitable central location whether inside, on top, or adjacent to the building. Central systems must condition zones with their equivalent thermal load. Central HVAC systems will have as several control points such as thermostats for each zone. The medium used in the control system to provide the thermal energy sub-classifies the central HVAC system.

The thermal energy transfer medium can be air or water or both, which represent as all-air systems, air-water systems, all-water systems. Also, central systems include water-source heat pumps and heating and cooling panels. All of these subsystems are discussed below. Central HVAC system has combined devices in an air handling unit which contains supply and return air fans, humidifier, reheat coil, cooling coil, preheat coil, mixing box, filter, and outdoor air.



MULTIPLE CHIOCE QUESTIONS

QUESTION	OPTION 1	OPTION 2	OPTION 3	OPTION 4	ANSWER
In summer air conditioning, the air is	cooled & humified	cooled & dehumified	heated & humified	heated & dehumified	cooled & dehumified
In winter air conditioning, the air is	cooled & humified	cooled & dehumified	heated & humified	heated & dehumified	heated & humified
For summer air conditioning, the relative humidity should not be less than	40%	60%	75%	90%	60%
For winter air conditioning, the relative humidity should not be more than	40%	60%	75%	90%	40%
The sensible heat factor for auditorium or cinema hall is generally kepts as	0.6	0.7	0.8	0.9	0.7
The conditioned air supplied to the room must have the capacity to take up	room sensible heat load only	room latent heat load only	both room sensible heat & latent heat loads		both room sensible heat & latent heat loads
The alignment circle is marked on the psychromatic chart at	20°C DBT & 50% RH	26C DBT & 50% RH	20°C DBT & 60% RH	26C DBT & 60% RH	26C DBT & 50% RH
The supply air state of cooling coil with a by-pass factor lies at	intersection of RSHF line with saturation curve	intersection of GSHF line with saturation curve	point dividing RSHF line in proportins of BPF and (1-BPF)	intersection of RSHF line & GSHF line	intersection of RSHF line & GSHF line
When the outside air is introduced for ventilation purposes, there is a	sensible heat gain	latent heat gain	latent heat gain as well as sensible heat gain	none of these	latent heat gain as well as sensible heat gain
The recommended outside air required per person for theatres is	0.23m3/min	0.36m3/min	0.45m3/min	1.5m3/min	0.23m3/min
The human body in a cooled space constitutes cooling load of	sensible heat only	latent heat only	latent heat & sensible heat	none of these	latent heat & sensible heat
The sensible heat produced by a person working in a bank is about	53W	58W	88W	136W	58W

The latent heat gain from an electrical egg boiler is about	234W	352W	440W	730W	234W
during sensible cooling of air, the wet bulb temperature	Increases	Decreasses	Zero	None of these	Decreasses
The minimum temperature at which the moist air can be condensed is known as	Wet bulb temperature	Dry bulb temperature	Dew point temperature	Wet bulb depression	Dew point temperature
The by pass factor of a cooling coil decreases with	Decreases in fin spacing and increase in number of rows	Increase in fin spacing and increase in number of rows	Increase in fin spacing and decrease in number of rows	Decrease in fin spacing and decrease in number of rows	Decreases in fin spacing and increase in number of rows
The process generally used in winter air conditioning to warm and humidify the air is called	Humidification	Dehumidification	Heating and humidification	Cooling and dehumidification	Heating and humidification
In order to cool and dehumidify a stream of moist air, it must be passed over the coil at a temperature	which lies between the dry bulb and wet bulb temperature of the incoming stream	which lies between the wet bulb and dew point temperature of incoming stream	Which is lower than the dew point temperature of the incoming stream	of adiabatic saturation of incoming stream	Which is lower than the dew point temperature of the incoming stream
Refrigeration is used to control	Humidity	Air velocity	Temperature	None of these	Temperature
Air conditioning is used to control	Humidity	Air velocity	Temperature	a,b,c	a,b,c

UNIT – V

AIR CONDITIONING

Air Conditioning Filter

Air conditioning filter in the house or offices is used to remove solid contaminants such as smoke, pollen, dust, grease and pollen to ensure better air quality for the occupants. A study showed that indoor pollution is common these days due to the chemicals that are used in household furnishings and various goods.

These filters are usually placed on the return air of the air conditioning system. The air that contained the contaminants are trapped here. Clean air is then discharged into the space together with the cool air.

Types of Air Conditioning Filter

Plastic mesh filters are commonly installed at the return air of most indoor unit of room or window air conditioner. They trapped bigger particles of dust and should be cleaned every two weeks and more frequent if the space being conditioned is polluted.

If you look at the manual, they are easy to take out from the unit. Wash thoroughly with water and household dish washing detergent to remove dirt that stuck to it. Leave to dry and put back.

These simple steps of cleaning help to ensure the efficiency of the unit and hence save electricity as well besides providing a cleaner air space for you.

Electrostatic air filters are commonly placed in the return air of the air conditioner unit where the air is subjected to high voltage up to 12kV between two plates. The ionized particles are then drawn to the grounded plates. The electronic circuit used to generate the voltage is usually embedded on the control printed circuit board or a separate module.

Carbon and Adhesive filters are other types used. Carbon type is made of activated carbon that is effective in removing odour causing gases and bacteria. Adhesive type is made of cotton and fiber glass material coated with adhesive oil or liquid which trapped the particles.

Humidifier

Humidifier is equipment used to increase the relative humidity of a room to ensure that the dry space has enough moisture for the comfort of the occupants. This happens often during winter when the heater is turned on causing the relative humidity of the air in the house to decrease.

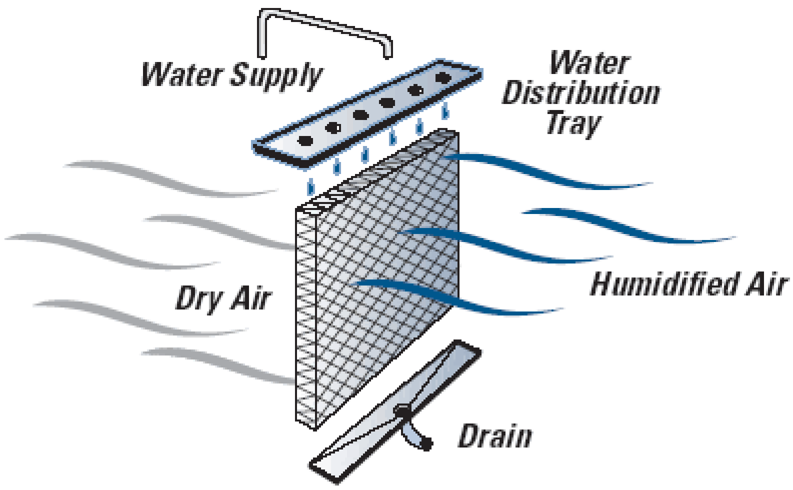
The relative humidity(RH) shows the percentage of moisture in the air and different room temperature can hold different amount of moisture.

Air that is low in RH will tend to absorb water vapor from the surrounding including the people inside the room. This can cause discomfort to the nose, mouth, eyes and throat. It can also cause damage to the furnishing in our homes such as causing the wood to shrink and cracks.

Too much moisture can also cause problem such as mold growing on moist surfaces. On top of that unpleasant smell and the feeling of dampness inside the house also cause discomfort to the occupants.

This situation is bad for our health hence when this happens, you will need to have a dehumidifier to remove the excessive moisture from the air.

A study shows that the typical RH that is comfortable to the human body is between 30% to 50% RH.



Types of Humidifier

The typical equipment used is the **evaporative type** and consists of a reservoir of water, wick, fan and basic humidistat control. Some higher end unit has heater to reheat the humidified air before being discharged to the room.

Indicators to indicate the ON/OFF status of the unit and the need to top up the water are sometimes included. Find out other types of device that you can purchase from the market.

Spray Type consists of a chamber that contains spray noozles, tank to hold water and a water pump that circulates the water. The incoming air that enters the chamber is forced to be in contact with the water that is sprayed from the nozzles causing heat transfer between the water and the air.

Humidification occurs when the temperature of the water is higher that the dew point of the air.

Ultrasonic Type has a piezo transducer that that is vibrated at ultrasonic frequency. This causes the water droplets to breakdown in smaller size and into fine mist which is then discharged to the room by the use of the blower. The diameter of the mist is typically 1 um.

Steam Type is sometimes called vaporizer and it basically boil the water and discharge the steam into the room. It usually consists of a metal reservoir to contain the water, a heater element and a float. The float is used to regulate the water that comes in from the household water supply.
Once power is supplied to the device, the heater will heat up speedily and cause steam to be produced which moisturizes the warm air passing over it. The moist air is then discharged to the room and humidity of the room will increase.

Bypass Type typically consists of an evaporator pad, motor, drain valve, float, water tank, rotating disc and overflow line. The evaporator pad is connected to the rotating disc which enables the pad to dip into the water to absorb the moisture.

Warmer air that comes in passes over the rotating pad causing the moisture to evaporate and hence humidify the air. The moist air is then directed back to the space which need to be humidified.

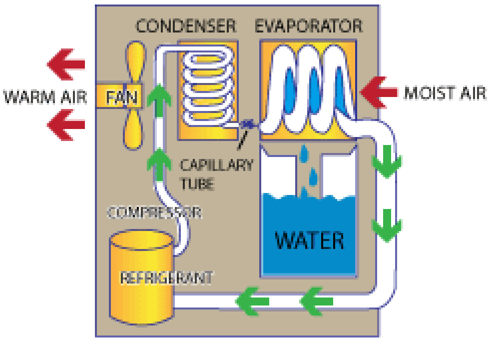
Dehumidifier

Dehumidifier is an equipment used to decrease the relative humidity of a room to ensure that the moist space water molecules are reduced for the comfort of the occupants. The relative humidity(RH) shows the percentage of moisture in the air and different room temperature can hold different amount of moisture.

Air that is high in RH will cause sweating and little evaporation and hence discomfort to the occupants. It also caused the growth of mould and mildew which cause health risks to the people in the house.

Besides that, the humid environment is ideal for cockroaches, dust mites and moths to thrive. The dampness also creates an unpleasant smell in the room.

A study shows that the typical RH that is comfortable to the human body is between 30% to 50% RH. Hence, using proper dehumidification equipment is crucial to ensure a healthy and comfortable environment in the homes or offices.



Types of Dehumidifier

There are basically three types of equipment that you can use.

Refrigeration Type

Spray Type

Absorption Type

Refrigeration Type is the most common type of humidification system that is used in a typical household. It removes moisture from the air by passing the air over a cooling coil.

This causes the air molecules to lose heat and condense. The water that condensate is then collected on a tray or discharge to the drain outside the house through a drainage hose.

Air conditioner in your house is an example of this type of dehumidification process. It acts as a cooling equipment as well as reducing the humidity of the room. For effective removal of moisture, the dewpoint of the air entering the cooling coil should be higher than the dewpoint of the air leaving it.

Dedicated refrigeration equipment usually consists of a compressor, condenser, evaporator and capillary tube. The fan motor draws the air towards the cooling coil and condenses into a pan or directly into the drain.

The control that is used is called a humidistat. It ON or OFF the compressor and fan based on the condition of the air.

It usually has features to indicate that the pan need to be emptied, the status of the unit, timer control, auto shut-off when pan is full, frost sensor to off the unit when frosting occurred, air filter to ensure only clean air is discharged to the room and variable fan speeds.

The other consideration before buying is to check the noise level of the unit.

Spray Type consists of a chamber that contains spray nozzles, tank to hold water and a water pump that circulates the water. The incoming air that enters the chamber is forced to be in contact with the water that is sprayed from the nozzles causing heat transfer between the water and the air.

Dehumidification occurs when the temperature of the water is lower than the dew point of the air. This type of dehumidification process is able to absorb odor and cleaner air compared to the refrigeration type.

Absorption Type is used in industrial application and uses sorbent material to absorb the moisture from the air. The material consists of microscopic pores that absorbed the moisture from the air. The liquid-absorbent type uses bromides or chloride brines in a chamber.

The air is then directed to contact the brine solution with a vapor pressure below that of the entering air. As a result, the air that is discharged will be drier than the entering air.

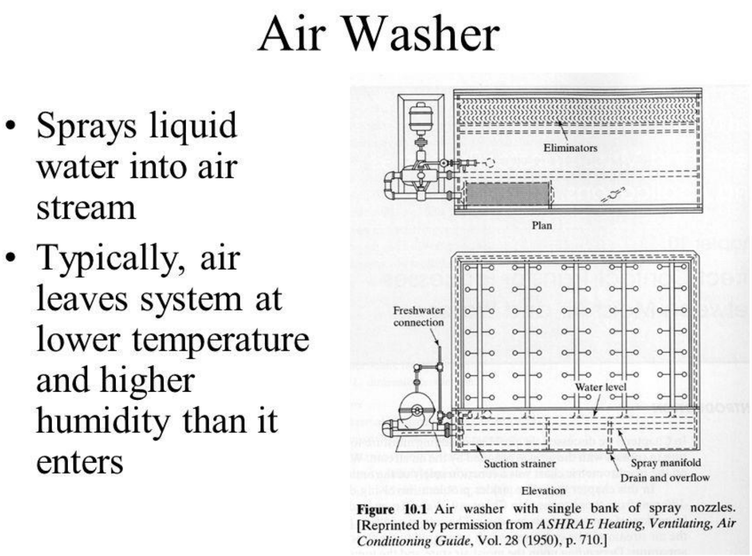
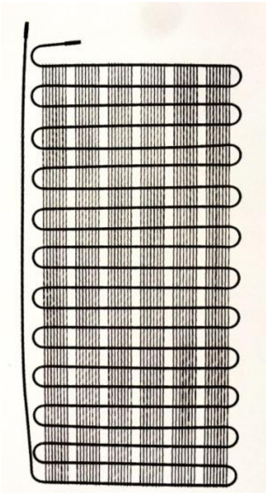


Figure 10.1 Air washer with single bank of spray nozzles. [Reprinted by permission from *ASHRAE Heating, Ventilating, Air Conditioning Guide*, Vol. 28 (1950), p. 710.]

Condenser

Function of Condenser



In a cooling cycle of a refrigeration system, heat is absorbed by the vapor refrigerant in the evaporator followed by the compression of the refrigerant by the compressor. The high pressure and high temperature state of the vapor refrigerant is then converted to liquid at the cond. It is designed to condense effectively the compressed refrigerant vapor.

There are basically three types of condensing unit depending on how the heat is removed by the condensing medium which is usually water, air or a combination of both.

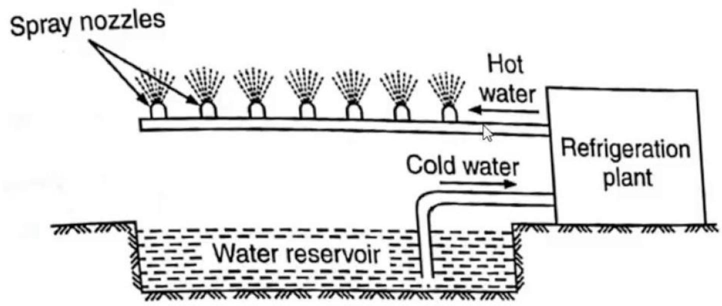
- **Air-Cooled** types are usually used in the residential and small offices applications. They are used in small capacity systems below 20 tons. The advantages of using this design include not having to do water piping, not necessary to have water disposal system, saving in water costs and not much scaling problems caused by the mineral content of the water. It is also easier to install and has lower initial cost. There isn't much maintenance problems.The disadvantages are that it requires higher power per ton of refrigeration, has shorter compressor life and on days when most cooling is required, the least is available
- The circulation of air-cooled type can be by natural convection or by forced convection (usually using blower or fan). Due to its limited capacity, natural convection is used in smaller applications such as freezers and refrigerators. In forced convection, air is circulated by using a fan or blower that pulls the atmospheric air through the finned coils. Internally, the refrigerant circulates through the coil and air flows across the outside of the tubes.
- **Water-Cooled** There are 3 types commonly being used. They are shell and tube, shell and coil, and double tube. The most commonly used is the shell and tube type and are usually available from two tons up to couple of hundred tons. This design has lower power requirements per ton of refrigeration and the compressors can last longer compared to the air-cooled type. A water cooling tower is frequently used for higher capacity application.
- **Evaporative type** which is a combination of water and air-cooled.

Cooling Towers and Spray Ponds

The purpose cooling tower is to cool the water used in the water cooled condenser of the refrigeration plant so that the same water can be reused to absorb the heat at the condenser. The basic principle of cooling of water is the evaporative cooling achieved by using atmospheric air. The condenser water is sprinkled through nozzles and air on passing over the water droplets creates evaporative cooling of water. The heat lost from the water is carried by the air which increases the enthalpy of air leaving the cooling tower. The temperature drop achieved depends on the following factors.

- Surface area of water exposed to air stream.
- Dry bulb and wet bulb temperature of the air.
- Velocity of air.
- Water inlet temperature
- Direction of air flow in relation to water
- Contact time period of air with water.

Theoretically, it is possible to cool the water up to wet bulb temperature (wbt) of the air entering the cooling tower. Generally, the temperature of water coming out from the cooling tower is 3 ºC to 5ºC above the wbt of the entering air. It is very important to operate the cooling tower at optimum efficiency to get water at lowest possible temperature for the condenser.



Types of Cooling Tower

There are two main categories of cooling towers.

1. Natural draft cooling tower

2. Mechanical draft cooling tower

Natural draft cooling tower

The natural draft atmospheric cooling tower consists of a sump and arrangement for the spray of water from the height of about 5 m to 8 m

It is necessary to provide side louvers to minimize carry over water loss. The warm water from the condenser is nuzzled and the cooled water is collected in the sump constructed at the bottom. The performance of this cooling tower varies due to variation of air velocity and it requires more space for the installation of the cooling tower.

Mechanical draft cooling tower

In case of mechanical draft, fan or blower is used to supply the air through the cooling tower. In recent design of the cooling tower, warm water is passed over the supporting medium in form of thin sheet and air is blown through the cooling tower. Induced draft cooling is preferred over the forced draft cooling tower as air distribution is more uniform in induced draft cooling tower.

Maintenance Aspects of Cooling Tower

· Use the soft water as make up water to compensate the quantity of water evaporated.

· Cleaning of nozzles, filling material, sump etc. is necessary at regular interval.

· Replacement of cooling tower water at regular interval as salt concentration of water increases due to evaporation of water.

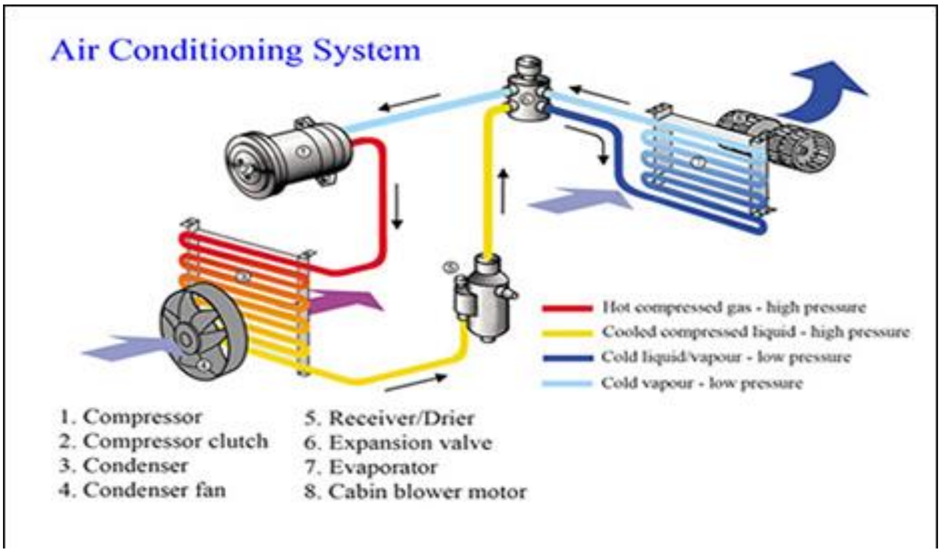
· Follow general maintenance requirement of pumps, fans etc.

· Adopt corrosion control measures depending on the material of construction of the cooling tower.

Duct System

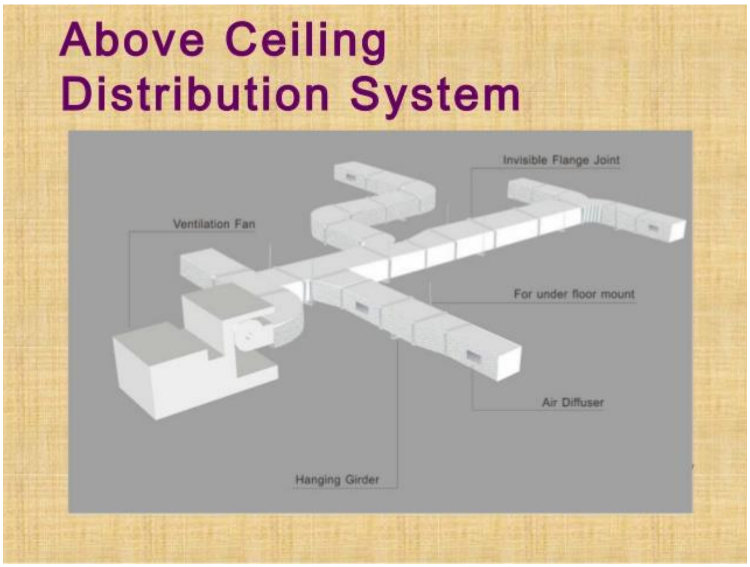
The duct, or air distribution, system used in cooling and heating your home is a collection of tubes that distributes the heated or cooled air to the different rooms. This branching network of round or rectangular tubes—usually constructed of sheet metal, fiberglass board, or a flexible plastic-and-wire composite—is found within your home. The duct system is designed to supply rooms with air that is "conditioned"—that is, heated or cooled by the heating, ventilation, and air conditioning (HVAC) equipment—and to circulate or return the same volume of air back to the HVAC equipment. Typical air-duct systems lose 25 to 40% of the heating or cooling energy put out by the cooling and heating system. Leaks, one way in which conditioned air is lost in the duct system, make the HVAC system work harder, thus increasing your utility bill. In addition, duct leakage can lessen comfort and endanger your health and safety. Your duct system has two main air-transfer systems—supply and return. The supply side delivers the conditioned air to the home through individual room registers—what you feel blowing out of the registers.

The return side withdraws inside air and delivers it to the air handler of your central system. All of the air drawn into the return duct(s) is conditioned and should be delivered back through the supply registers.



Air Distribution

Air-distribution systems include air handlers, ductwork, and associated components for heating, ventilating, and air-conditioning buildings. They provide fresh air to maintain adequate indoor-air quality while providing conditioned air to offset heating or cooling loads. Their many components need to operate in unison to properly maintain desired conditions. They use relatively large amounts of energy so applying smart operational strategies and good maintenance practice can significantly reduce energy consumption.



Key Components of Air Distribution Systems

The key components of air distribution systems are:

- Fans
- Coils
- Filters
- Dampers
- Ducts

Fans

Fans move air by pushing it with impellers (blades) powered by a motor. Pushing the air increases pressure which is measured in inches of water.

As the air is pressurized, it is heated by friction as it passes through the fan. More heat is added if the fan motor is located in the air stream. The air temperature can rise from 1 to 5 or more degrees, depending on the system operating pressure.

The most common fan designs used in HVAC systems are centrifugal and axial.

Coils

Coils are heat exchangers that transfer energy between the supply-air stream and the energy-transport medium: water, steam, or refrigerant.

Most coils are made of copper tubing arranged in rows, specifically designed for the amount of energy transfer required. They may be bare tubes when differential temperatures are high, or have extended fins where differential temperatures are lower.

Generally, to transfer more energy per cubic foot of air, more rows and fins are required. Adding rows makes the coil "deeper" and increases the static pressure loss across the coil.

Filters

Air filters are used to prevent airborne particulates from entering and recirculating within a building, and to protect fans, coils, other downstream equipment and the occupants. Most contaminants in the air stream are generated internally from occupants by items such as clothing, paper dust, and copier toner. External contaminants also contribute particulates to the indoor environment. For instance, engine exhaust contains a fine soot-like substance. Filters have various levels of filtration and are classified by ASHRAE Standard 52.2 by MERV (Minimum Efficiency Reporting Value).

Most air handlers are sized to move air at 300-600 fpm through the filter section. Higher velocities cause particulates to blow through the filters, reducing their effectiveness. Airflow through all filter banks should therefore be as uniform as possible to avoid creating areas of high velocity characteristic of turbulent airflow.

Dampers

Dampers direct and control airflow through the air distribution system. They can also be installed in certain fire-rated walls or floors for life-safety to prevent the migration of fire and smoke. These motorized units are typically controlled by the fire-alarm system but recent advances in the reliability of direct-digital-control (DDC) systems have allowed the HVAC DDC system to also control life-safety systems.

Ducts

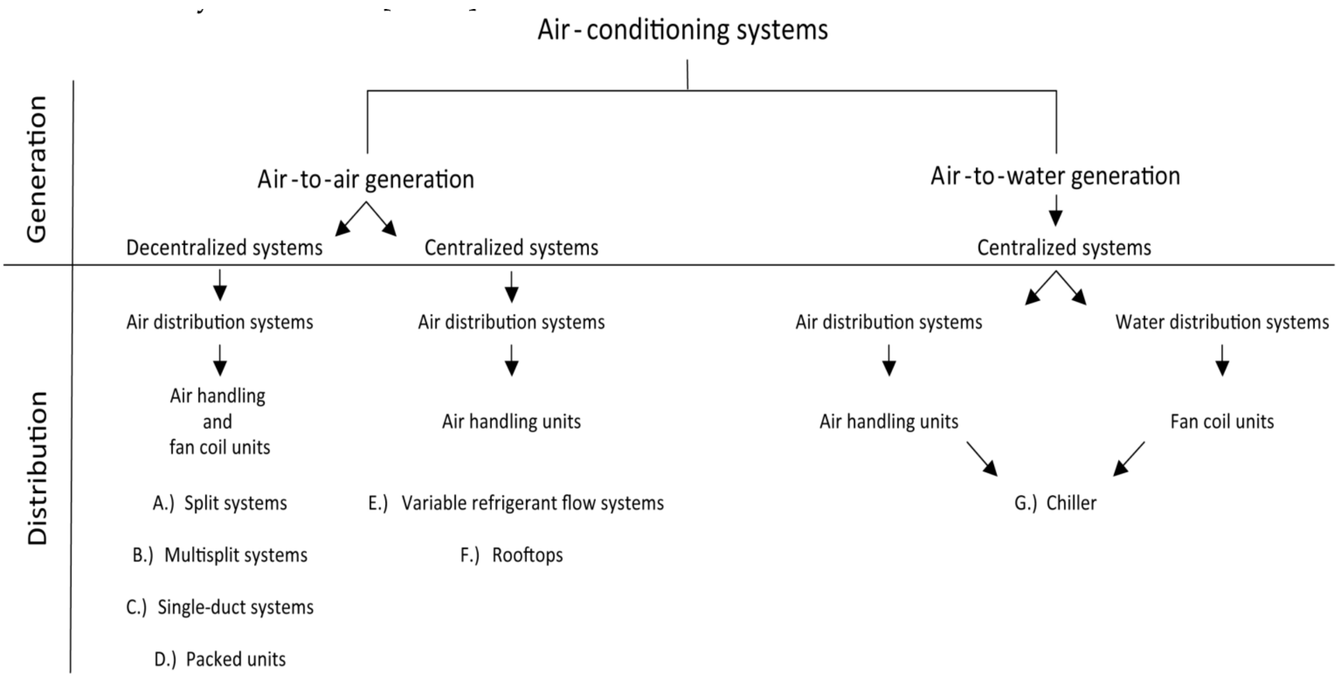
There are two general types of duct systems: single-duct and dual-duct. Each type can be used in both constant- and variable-flow applications.

Ducts are usually made of galvanized steel and are commonly wrapped or lined with fiberglass thermal insulation, both to reduce heat loss or gain through the duct walls and to prevent water vapor from condensing on the exterior of the duct when the duct is carrying cooled air. Insulation, particularly duct liner, also reduces duct-borne noise. Both types of insulation reduce "breakout" noise through the duct walls.

While galvanized steel is the most common material, ducts can be manufactured from duct board, a rigid form of fiberglass. The fiberglass provides built-in thermal insulation and the interior surface absorbs sound, helping to quiet the operation of the HVAC system. This type of ducting is typically used in low-pressure systems, 2" wg or less, due to the structural limitations of the material.

Flexible ducts, also called "flex," have a variety of material configurations, but are typically flexible plastic over a metal wire coil to make round, flexible duct. Most often, a layer of fiberglass insulation covers the duct, and a thin plastic layer protects the insulation. Flexible duct is convenient for attaching supply-air outlets to the rigid ductwork. However, the pressure loss through flex is higher than for most other types of ducts. As such, duct runs should be short, less than about 15 feet, and as straight as possible. Kinks in flex must be avoided. The most common use of flex is to connect ducted supply air to terminal units.

Regardless of the material, sealing ducts properly is critical to prevent unavoidable leakage.



Thermal Insulation

Thermal insulation in air conditioning system is primarily used to reduce heat gain or heat loss from piping. Other factors include preventing the icing of water vapor and condensation on cold surface.

Water vapor from the air or surrounding area must be kept from entering the cold side of the pipe to prevent condensation of moisture from the air on the outside of the cold piping.

Condensation can cause damage to surrounding areas such as carpet or other furnishing. Hence, the insulation must also acts as a vapor barrier.

It also helps to reduce the noise level, absorb the vibration generated by the system, prevent the spread of fire and adding structural strength to the walls or ceilings.

Well chosen material can also protects the piping being insulated from harsh environmental conditions such as UV light, salt, water, dusts, chemicals and oil. Other characteristics may include the ability to inhibit the growth or viruses, bacteria and fungi.

Insulation Characteristics

- ✓ Low thermal conductivity.
- ✓ Reasonable strength

- ✓ Non-combustible.
- ✓ Resistance to Fungi such as one that is based on ASTM G21 standard.
- ✓ Excellent resistance to ozone
- ✓ Excellent resistance to UV.
- ✓ Does not deteriorate or rot over time.

Pipe insulation materials can be manufactured from rubber, wool, glass fibers or cork. The polyurethane or P.U. is a synthetic material that is commonly used these days due to its low thermal conductivity and other good properties.

Air conditioning system – Applications

Car air conditioning is a system within your car that allows you to cool the interior air of the vehicle in hot weather, providing for a cooler environment for the occupants.

Air conditioning now comes as standard in almost all newly produced cars and is a feature that most car owners have come to expect.

The concept of air conditioning in a car was first properly developed by the Packard Motor Company in the United States. In 1939, they launched air conditioning as an add-on extra for purchasers of their cars.

Air conditioning was initially slow to grow in popularity but by 1970, almost half of all new cars produced had air conditioning.

Although over 75-years-old, the air conditioning in your car now still works to the same basic principles as developed in the 1930s. Your car's air conditioning system is made up of three main parts – the compressor, the condenser and the evaporator.

They all work together moving a substance called refrigerant through a high pressure/low pressure closed-loop system. Refrigerant changes from gas to liquid, and back to gas, and is a vital part of the air conditioning system and process.

The compressor is driven by a belt attached to the car engine. This is where the low-pressure refrigerant gas is compressed into a high-pressure, high-temperature gas before being pumped to the condenser.

The condenser works like your car's radiator by dissipating out heat but also cooling the high-pressure refrigerant gas so it forms into a high-pressure liquid.

This high-pressure liquid then has any water removed from it by a small until called the receiver-dryer before being pumped to the thermal expansion valve.

Here, the high-pressure liquid is allowed to expand and become a low-pressure liquid, as it enters the low-pressure side of the loop system before moving to the evaporator which is located within the vehicle interior.

At this point, the low-pressure refrigerant liquid again turns into a gas and moves out of the evaporator taking the heat from the interior of the vehicle.

During this process, a fan blows over the exterior of the compressor, blowing cool air into the interior of the vehicle.

The low-pressure refrigerant gas now enters the compressor once more and the process begins again.

Public Buildings

Air conditioning is used in most commercial properties, ranging from small shops and cafés to large office buildings and public spaces.

To meet these diverse applications, air conditioning systems have different heating and cooling capacities and come with various setups and layouts.

There are almost infinite configurations within each category, but the main types of commercial air conditioning are:

Single Split System
Multi-Split System
VRF or VRV System

They all use the same basic technology and identical wall- or ceiling-mounted indoor units. However, they have very different applications, so it’s important to find out which is best for you

Split System Air Conditioning

Single splits are the most affordable type of air conditioning system and suitable for use in small commercial buildings. They provide heating and cooling to individual rooms, making them ideal solutions for small offices, shops, cafés and server rooms.

They can also be used in combination to serve larger spaces and multiple rooms. The only downside is that you need enough external space to have one outdoor unit for every indoor unit.

However, there are advantages to doing it this way. Firstly, it’s often cheaper than installing a central system, and, as each system is self-contained, if one unit breaks down, the others remain fully functional.

Even though they’re the cheapest type of air conditioning, single splits are effective and energy-efficient systems. Their versatility makes them great for all kinds of applications and they’re extremely popular with small businesses.

Multi-Split System Air Conditioning

Multi-splits work in exactly the same way as single splits but, depending on the model, you can connect up to nine indoor units to one outdoor unit. They’re most frequently used in places like restaurants, offices, doctor’s surgeries and shops.

It’s always preferable to have fewer outdoor units, particularly if you lack space or want to preserve your building’s external appearance. That gives multi-splits a distinctive advantage over several single splits.

Another selling point is that you aren’t limited to using just one type of indoor unit. If you wanted to, you could have any combination of wall- and ceiling-mounted air conditioning units, along with an air curtain over the entrance.

However, multi-split systems are slightly more complex and require more pipework than several single splits. That can make the installation more expensive and take longer, particularly if you’re only looking to install a few indoor units.

Ultimately, the best solution depends on the layout of your building and the heating and cooling capacity you require.

VRF or VRV Air Conditioning

VRF stands for variable refrigerant flow, while VRV stands for variable refrigerant volume. It might seem confusing but they mean exactly the same thing.

VRF/VRV air conditioning is the best solution for medium to large applications, including hotels, retail spaces, larger offices and mixed-use buildings.

The systems are extremely efficient, reliable and easy to control, capable of meeting larger buildings' complete heating and cooling requirements. They also come with reduced installation times, minimising disruption.

There are two types of VRF/VRV system, heat pump and heat recovery. Heat pump VRF/VRV systems can provide either heating or cooling to a building at any given time, making them ideal for open plan areas.

Heat recovery VRF/VRV systems are capable of providing simultaneous heating and cooling to different areas at the same time, making them perfect for buildings with lots of individual rooms. The most efficient commercial air conditioning systems, they recover waste heat from around the building, using it to heat other rooms and hot water. Heat recovery systems are also more flexible, as you have the option to heat one room while cooling another.

MULTIPLE CHIOCE QUESTIONS

QUESTION	OPTION 1	OPTION 2	OPTION 3	OPTION 4	ANSWER
It is the temperature of air recorded by a thermometer when the moisture present in it begins to condense	Dew point temperature	Dew point depression	Dry bulb temperature	Wet bulb temperature	Dew point temperature
In a mixture of dry air and water vapour, when the air has diffused the maximum amount of water vapour into it, is called	Dry air	Moist air	Saturated air	Hot air	Saturated air
The vertical and uniformly spaced lines on a psychrometric chart indicates	Dry bulb temperature	Wet bulb temperature	Dew point temperature	Specific humidity	Dry bulb temperature
S1) For unsaturated air, the dew point temperature is less than the wetbulb temperature. S2) For unsaturated air, the dew point temperature is greater than the wetbulb temperature	S1 is correct	S2 is correct	Both S1 and S2 are correct	Both S1 and S2 are wrong	S1 is correct
The cause for sweating is	More moisture present in the air	Less moisture present in the air	More pressure of air	Less pressure of air	More moisture present in the air
The term (CPa+WCps) is called	Humid specific heat	Humidity	Absolute humidity	Absolute density	Humid specific heat
Humidity is the indication of ________________________ present in the air	Moisture	Density	Temperature	Pressure	Moisture
The relative humidity of air is defined as the ratio of	Mass of water vapour in a given volume to the total mass of the mixture of air and water vapour	Mass of water vapour in a given volume to the mass of water vapour, if air is saturated at the same temperature	Mass of water vapour in a given volume to the mass of air	Mass of air to the mass of water vapour to the mass of air.	Mass of water vapour in a given volume to the mass of water vapour, if air is saturated at the same temperature
During a refrigeration cycle, heat is rejected by the refrigerator in a	Compressor	Condensor	Evaporator	Expansion valve	Condensor

The highest temperature of refrigeration cycle occurs after	Compression	Condensation	Expansion	Evaporation	Compression
Latent heat is used to	Change the phase of the system	Change the temperature of the system	Change the pressure of the system	Change the shape of the system	Change the phase of the system
In winter air conditioning, the air is	Cooled and dehumidified	Cooled and humidified	Heated and humidified	Heated and dehumidified	Heated and humidified
For summer air conditioning, the relative humidity should not be less than	0.4	0.6	0.75	0.9	0.6
For winter air conditioning, the relative humidity should not be more than	0.4	0.6	0.75	0.9	0.4
The human comfort temperature is	25°C	28°C	30°C	32°C	25°C
A fasting, weak or sick man will have ____________________ metabolic heat production	Less	More	Constant	None of these	Less
The degree of warmth or cold felt by a human body depends mainly on,	Dry bulb temperature	Relative humidity	Air velocity	All of these	Air velocity
When the specific humidity remains constant during a heat process then it is known as	Sensible heating	Sensible cooling	Humidification	Dehumidification	Dehumidification
The human comfort air velocity is	4 to 6 m/min	4 to 8 m/min	4 to 10 m/min	4 to 12 m/min	4 to 6 m/min
Failure of blood circulation due to over heating is known as	Heat exhaustion	Heat release	Heat stroke	Heat cramp	Heat exhaustion
Salt loss due to over heating is known as	Heat exhaustion	Heat release	Heat stroke	Heat cramp	Heat cramp
The permanent brain damage due to overheating is known as	Heat exhaustion	Heat release	Heat stroke	Heat cramp	Heat stroke
.Psychrometry is the study of	air	water	water vapour	air and water vapour	air and water vapour
When the temperature of air recorded by a thermometer, when it is not affected by the moisture present in air is known as	Dry air	Moist air	Dry bulb temperature	Wet bulb temperature	Dry bulb temperature

It is the temperature of air recorded by a thermometer, when its bulb is surrounded by a wet cloth exposed to the air is known as	Dry air	Moist air	Dry bulb temperature	Wet bulb temperature	Wet bulb temperature
The difference between dry bulb temperature and wet bulb temperature at any point is known as	Wet bulb depression	Dew point depression	Dry bulb temperature	Wet bulb temperature	Wet bulb depression