

## 4. HVAC AND REFRIGERATION SYSTEM

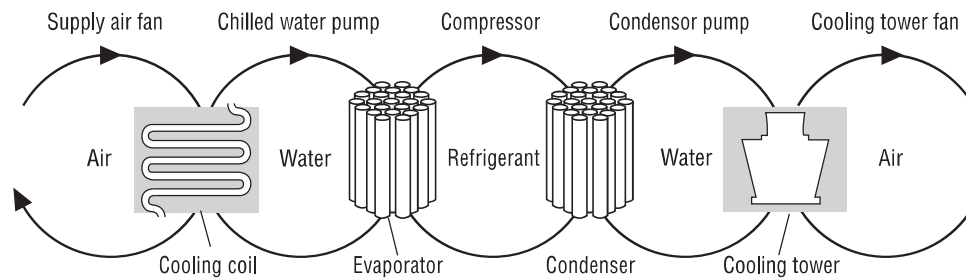
**Introduction, Psychrometrics and air conditioning processes, Types of refrigeration systems, Refrigerants and properties, Compressor types, Selection of refrigeration system, Performance assessment of room air conditioners (window and split), Factors affecting performance of refrigeration and air conditioning system, Energy savings opportunities. Cold storage, Heat pumps and their applications, Ventilation system, Ice bank system, Humidification system, Standards and labeling of air conditioners.**

### 4.1 Introduction

The Heating, Ventilation and Air Conditioning (HVAC) and refrigeration system transfers the heat energy from or to the products, or building environment. Energy in form of electricity or heat is used to power mechanical equipment designed to transfer heat from a colder, low-energy level to a warmer, high-energy level.

*Refrigeration deals with the transfer of heat from a low temperature level at the heat source to a high temperature level at the heat sink by using a low boiling refrigerant.*

There are several heat transfer loops in refrigeration system as described below:



**Figure 4.1 Heat Transfer Loops in Refrigeration System**

In the Figure 4.1, thermal energy moves from left to right as it is extracted from the space and expelled into the outdoors through five loops of heat transfer:

- **Indoor air loop.** In the leftmost loop, indoor air is driven by the supply air fan through a cooling coil, where it transfers its heat to chilled water. The cool air then cools the building space.
- **Chilled water loop.** Driven by the chilled water pump, water returns from the cooling coil to the chiller's evaporator to be re-cooled.
- **Refrigerant loop.** Using a phase-change refrigerant, the chiller's compressor pumps heat from the chilled water to the condenser water.
- **Condenser water loop.** Water absorbs heat from the chiller's condenser, and the condenser water pump sends it to the cooling tower.
- **Cooling tower loop.** The cooling tower's fan drives air across an open flow of the hot condenser water, transferring the heat to the outdoors.

## Chilled Water Storage

Depending on the nature of the load, it is economical to provide a chilled water storage facility with very good cold insulation. Also, the storage facility can be fully filled to meet the process requirements so that chillers need not be operated continuously. This system is usually economical if small variations in temperature are acceptable. This system has the added advantage of allowing the chillers to be operated at periods of low electricity demand to reduce peak demand charges - Low tariffs offered by some electric utilities for operation at night time can also be taken advantage of by using a storage facility. An added benefit is that lower ambient temperature at night lowers condenser temperature and thereby increases the COP.

If temperature variations cannot be tolerated, it may not be economical to provide a storage facility since the secondary coolant would have to be stored at a temperature much lower than required to provide for heat gain. The additional cost of cooling to a lower temperature may offset the benefits. The solutions are case specific. For example, in some cases it may be possible to employ large heat exchangers, at a lower cost burden than low temperature chiller operation, to take advantage of the storage facility even when temperature variations are not acceptable. Ice bank systems which store ice rather than water are often economical.

## System Design Features

In overall plant design, adoption of good practices improves the energy efficiency significantly. Some areas for consideration are:

- Design of cooling towers with FRP impellers and film fills, PVC drift eliminators, etc.
- Use of softened water for condensers in place of raw water.
- Use of economic insulation thickness on cold lines, heat exchangers, considering cost of heat gains and adopting practices like infrared thermography for monitoring - applicable especially in large chemical / fertilizer / process industry.
- Adoption of roof coatings / cooling systems, false ceilings / as applicable, to minimize refrigeration load.
- Adoption of energy efficient heat recovery devices like air to air heat exchangers to pre-cool the fresh air by indirect heat exchange; control of relative humidity through indirect heat exchange rather than use of duct heaters after chilling.
- Adopting of variable air volume systems; adopting of sun film application for heat reflection; optimizing lighting loads in the air conditioned areas; optimizing number of air changes in the air conditioned areas are few other examples.

## 4.9 Performance Assessment of window, split and package air conditioning units

### Air Conditioners

**Energy Efficiency Ratio (EER):** EER is calculated by dividing a chiller's cooling capacity (in watts) by its power input (in watts) at full-load conditions. This definition of EER has been adopted in BEE star labeling programme.

The energy efficiency ratio (EER) = Refrigeration effect in Watts/ Power input in Watts

Based on the condition of the air, the air properties such as specific volume and enthalpy at both inlet and outlet conditions can be obtained from psychrometric charts. From these parameters the capacity delivered by the air conditioner can be evaluated, which when compared with power drawn would reveal its performance in terms of kW/TR and EER.

#### Performance Assessment of Package Air Conditioner – Example

Package air conditioner capacity	-	10 TR
Average Air Velocity	-	2.27 m/s (across suction side filter)
Cross Sectional Area	-	0.58 m <sup>2</sup>
Air Flow Rate	-	1.32 m <sup>3</sup> /sec - 4751 m <sup>3</sup> /hr
<b>Inlet Air Condition</b>		
DBT	-	20 °C
WBT	-	14 °C
Sp. Vol	-	0.8405 m <sup>3</sup> /kg
Enthalpy	-	9.37 kcal/kg
<b>Outlet Air Condition</b>		
DBT	-	12.7 °C
WBT	-	11.3 °C
Enthalpy	-	7.45 kcal/kg
Cooling Effect Delivered	-	3.6 TR = 12.7 kW
<b>Power Drawn</b>		
Compressor	-	4.71 kW
	-	4.3 kW (shaft power@ 90% motor efficiency)
Pump	-	2.14 kW
C.T Fan	-	0.384 kW
<b>Specific Energy Consumption</b>		
Compressor	-	1.31 kW/TR
Overall	-	2 kW/TR
EER	-	12700/4300
	-	2.95 W/W

Note: The Package A/C unit has two compressors of 5 TR capacity each, of which only one was in operation due to low cooling load.

## 4.10 Cold Storage Systems

A Refrigerated storage which includes cold storage and frozen food storage is the best known method of preservation of food to retain its value and flavor.

The refrigeration system in a cold storage is usually a vapour compression system comprising the compressor, condenser, receiver, air cooling units and associate piping and controls.

In smaller cold rooms and walk-ins the practice is to use air cooled condensing units with sealed, semi-sealed or open type compressors. In the light of the CFC phase out the trend now is to use HCFC-22, HFC-134a or other substitute refrigerants. In the medium and large sized units the practice is to use a central plant with ammonia as the refrigerant.

In some present day medium and large sized units with pre-fabricated (insulated) panel construction the trend is to use modular HCFC-22/HFC units which are compact, light weight and easy to maintain.

### Energy Saving Opportunities in Cold Storage Systems:

Energy cost constitutes a major part of the running cost of a cold store. Apart from the problems of the availability of electrical energy, the ever increasing rate of electrical energy seriously affects the economic viability of cold store units.

Following are some of the measures adopted to achieve energy efficient operation.

- Cold Store Building Design: Proper orientation, compact arrangement of chambers, shading of exposed walls, adequate insulation etc. are some of the important factors.
- Refrigeration System: The system must be designed for optimum operating conditions like evaporating and condensing temperatures, as these conditions have a direct bearing on energy consumption.
- Compressor capacity control system helps in energy savings during partial load operation.
- Control System: The proper control systems for refrigerant level, room temperature, compressor capacity etc., are required to further optimize energy consumption.
- Air Curtain or Strip Curtain: The use of air curtains and strip curtains is a common feature in present day cold stores as they help reduce air infiltration due to frequent and some times long door openings. Fan operated air curtains are expensive and work on electrical power whereas strip curtains are cheaper and need no energy for operation.
- Heat Recovery System: In processing plant cold stores, a heat reclaim system can be installed to recover a part of the heat rejected by the refrigeration system. This can be gainfully utilised in generating hot water free of cost.

## 4.11 Heat Pumps and Their Applications

### Heat Pump Technology

A heat pump is same as an air conditioner except that the heat rejected in an air conditioner becomes the useful heat output. Heat flows naturally from a higher to a lower temperature. Heat pumps, however, are able to force the heat flow in the other direction, using a relatively small amount of high quality

The number of stars displayed on the energy label. The available stars are between a minimum of one and a maximum of five shown in one star interval. The star rating is calculated from the Star Rating Band.

The Table 4.8 & 4.9 below is valid for split and unitary type air conditioners between 01 January 2014 and 31<sup>st</sup> December 2015.

**Table 4.8 Star Rating Band valid for Split type air conditioners  
(from 01 January 2014 to 31 December 2015)**

Star Rating	Energy Efficiency Ratio (Watt/Watt)	
	Minimum	Maximum
<b>1 Star *</b>	2.70	2.89
<b>2 Star **</b>	2.90	3.09
<b>3 Star ***</b>	3.10	3.29
<b>4 Star ****</b>	3.30	3.49
<b>5 Star *****</b>	3.50	

**Table 4.9 Star Rating Band valid for Unitary type air conditioners  
(from 01 January 2014 to 31 December 2015)**

Star Rating	Energy Efficiency Ratio (Watt/Watt)	
	Minimum	Maximum
<b>1 Star *</b>	2.50	2.69
<b>2 Star **</b>	2.70	2.89
<b>3 Star ***</b>	2.90	3.09
<b>4 Star ****</b>	3.10	3.29
<b>5 Star *****</b>	3.30	

#### 4.16 Energy Saving Opportunities

##### a) Cold Insulation

Insulate all cold lines / vessels using economic insulation thickness to minimize heat gains; and choose appropriate (correct) insulation.

##### b) Building Envelope

Optimise air conditioning volumes by measures such as use of false ceiling and segregation of critical areas for air conditioning by air curtains.

##### c) Building Heat Loads Minimisation

Minimise the air conditioning loads by measures such as roof cooling, roof painting, efficient lighting, pre-cooling of fresh air by air- to-air heat exchangers, variable volume air system, optimal thermo-static setting of temperature of air conditioned spaces, sun film applications, etc.

**d) Process Heat Loads Minimisation**

Minimize process heat loads in terms of TR capacity as well as refrigeration level, i.e., temperature required, by way of:

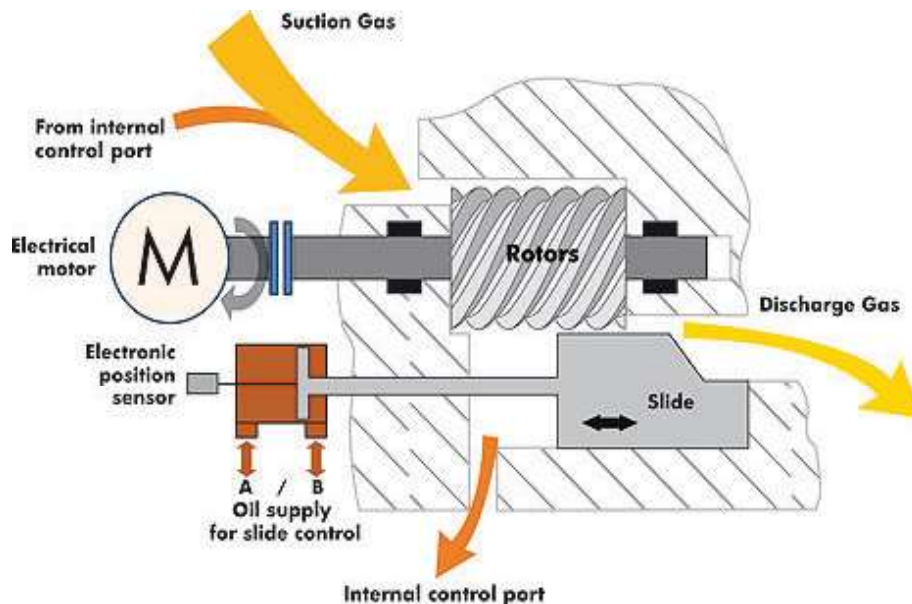
- i) Flow optimization
- ii) Heat transfer area increase to accept higher temperature coolant
- iii) Avoiding wastages like heat gains, loss of chilled water, idle flows.
- iv) Frequent cleaning / de-scaling of all heat exchangers

**f) At the Refrigeration A/C Plant Area**

- i) Ensure regular maintenance of all A/C plant components as per manufacturer guidelines.
- ii) Ensure adequate quantity of chilled water and cooling water flows, avoid bypass flows by closing valves of idle equipment.
- iii) Minimize part load operations by matching loads and plant capacity on line; adopt variable speed drives for varying process load.
- iv) Make efforts to continuously optimize condenser and evaporator parameters for minimizing specific energy consumption and maximizing capacity.
- v) Adopt VAR system where economics permit as a non-CFC solution.

**4.17 Case Study: Screw Compressor Application****Background**

Rotary Screw Compressors are widely used for refrigeration applications to compress ammonia & other refrigerating gases. A typical sectional view of the compressor is shown below in Figure 4.15.



**Figure 4.15 Section of Screw Compressor showing the meshing screws & slide valve**