COLD STORAGE BASICS

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Cold Storage Basics

Part I

Introduction to Cold Storages

Preservation of food by proper storage assumes greater importance in a country like India, where there is a substantial production of a variety of perishable foods like fruits and vegetables, milk products, fish, poultry and meat products. Amongst the various methods of preserving food products, refrigeration is the most important one. Cold storage conditions for food products differ from product to product, but certain basic facts are true for all fruits, vegetables and other fruit products. In the case of fruits and vegetables particularly, the problems faced in storage and handling are:

1. Dessication or loss of moisture
2. Physical break-down of tissue
3. Chemical changes such as oxidation of certain matter in the product, hydrolysis of fats and esters, and changes in the food proteins.
4. Respiration changes in which the living cells take in oxygen and give up carbon dioxide (this action takes place along with the enzyme actions).
5. Bacterial, yeast and mold growth in or on the product. Such growth is very rapid at room temperatures, decreasing as the temperature is lowered and almost ceasing as the temperature drops to about (–)10 to (–)12 °C.

Cold stores can be classified, utility-wise, as follows:

1. Long term stores for fresh produce.
2. Long term stores for frozen products.
3. Short term or retail stores for fresh and frozen products.
4. Controlled atmosphere (CA) stores for fresh produce where oxygen and carbon dioxide levels are controlled in the chambers.

Temperaturewise, cold stores can be classified as :

1. Medium temperature cold stores - generally designed for storing a variety of products at 0 to 8°C. Commodities include various types of fresh fruits and vegetables, dry fruits, spices, pulses, milk products etc. The cold stores may be designed for a single commodity such as potatoes, chillies, apples etc. or multipurpose type for storage of various commodities. The chambers in multi-commodity stores have to be designed for maintaining different temperatures and some times different relative humidities to suit various products. The bulk commodity stores have chambers of large sizes whereas the multi-purpose units have many chambers

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of smaller sizes to suit the customer needs. These medium temperature cold stores are, generally, constructed as single floor structures for small capacities and multi-floor structures for larger capacities.

2. Frozen food stores - designed for commodities which have to be processed and frozen for preservation over long periods of time. These include green peas, corn, okra, mixed vegetables, mango pulp and tomato puree. Other items are ice cream, butter, fish and meat products. Frozen food stores are designed for temperature of (–)18 to (–)22°C for most foods, but for items like ice cream, lower temperatures in the range of (–) 25 to (–) 30°C are specified. Frozen food stores are, normally, a part of food processing and freezing complex. However, they are also set up as a part of multi-purpose cold stores or as independent units to offer facilities for storage of

Product	Storage Temp ° C	Product Life Weeks
Potato	2 to 4	32 - 36
Cauliflower	0 to 1.5	8 - 10
Cabbage	0 to 1.5	10 - 12
Tomatoes	7	4 - 5
Ginger	2 to 4	14
Lime	8	6
Orange	7 to 8	8
Sweet Lime (Mosambi)	6 to 8	8
Apples	0 to 15	16 - 20
Eggs	1 to 5	20 - 24
Mango	8 to 10	4 - 6
Frozen foods	-18 to -20	24 or more

Table - 1. Cold Storage Data for some fruits & vegetables.
R.H for most products is in the range of 85% to 95%

About the Author

Arvind Surange is a post graduate from University of Roorkee with an experience of over 42 years in the field of HVAC&R. He has undergone specialized training in Germany and Denmark and is a leading consultant practicing for over 34 years, specializing in process air conditioning, cold stores and freezing plants. He is a member of ASHRAE and ISHRAE and is president emeritus of ISHRAE Pune chapter. He can be contacted at *asurange@vsnl.com*

products, already frozen, at the food freezing plants.

The storage data such as temperature, relative humidity etc. for certain common variety of products stored in India is given in *Table 1*. Information on other products may be found in ISHRAE Refrigeration Hand book, ASHRAE Refrigeration Handbook etc.

Older Types of Cold Stores

The old designs of cold stores had conventional construction with brick walls, sheet roofing with trusses or R.C.C. slab as roof. R.C.C. or steel internal structures, with wooden batten gratings were used for the floor.

Thermal insulation was provided with cork or even rice husk in some cases. After 1960, better insulation materials like expanded polystyrene or fiberglass were used. Later, polyurethane foam got introduced as insulation material.

The refrigeration systems used in most cases were ammonia systems, although, for very small units CFC and HFCs were used. Ammonia systems usually consisted of slow speed compressors (360 to 500 RPM), atmospheric type condensers and floor mounted air cooling units (usually called diffusers) with ducting for air distribution. A typical chamber with a floor mounted unit is shown in *Figure 1*.

In some areas like U.P., West Bengal, M.P etc some of the multistoried cold stores had bunker coil type evaporators located on the topmost floor of the cold store and ordinary ceiling fans were used for air circulation. See *Figure 2*. Loss of valuable cold storage space , lower RH, lower rate of cooling of products and non uniform temperatures in the chambers are some of the problems associated with bunker coil design.

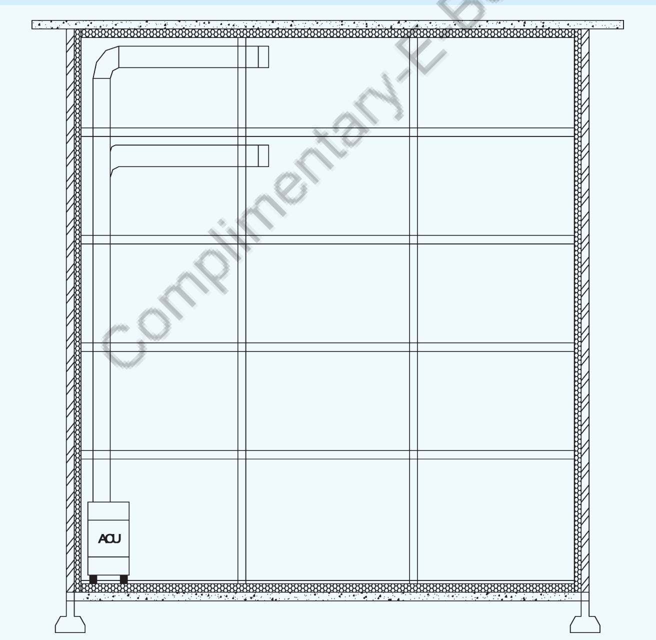

Figure 1: Typical cold store with R.C.C. slab roof & floor mounted air cooling unit with ducting

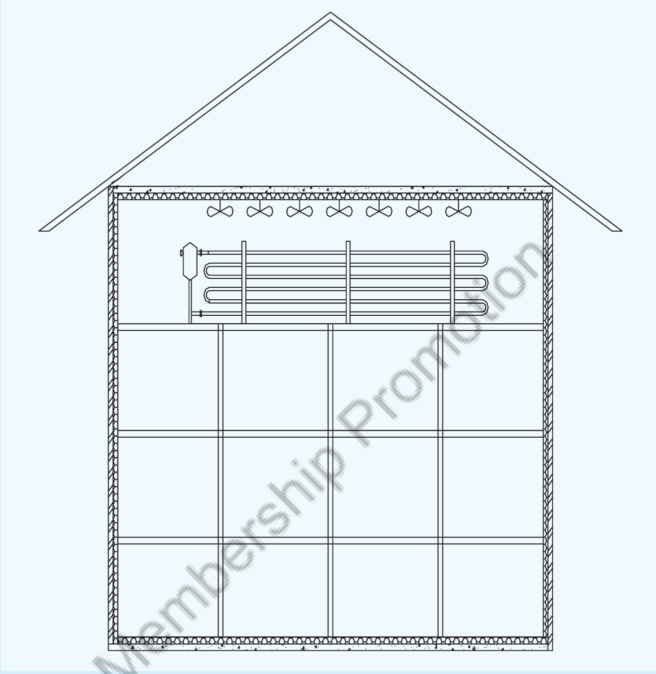

Figure 2: Typical old design of cold store with steel roofing and large bunker type cooling coil (section).

A typical cold chamber with bunker coil unit is shown in *Figure 2*.

The details of types of cold store construction will be dealt with in the next part.

Cold Storage Basics

Part 2

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Types of Cold Storages

Cold stores may be identified by their size into the following categories:

a) Small Cold Stores

They are typically walk-in cold stores, working in different temperature ranges. They are generally used in hotels, super markets, food malls etc. for storage of different items and are closest to the consumer, almost like window shops (for food items).

A photograph of a walk-in cold store is shown in *Figure 1*. and a typical layout of the same is shown in *Figure 2*.

Figure 1 : A display window in a walk-in cold store

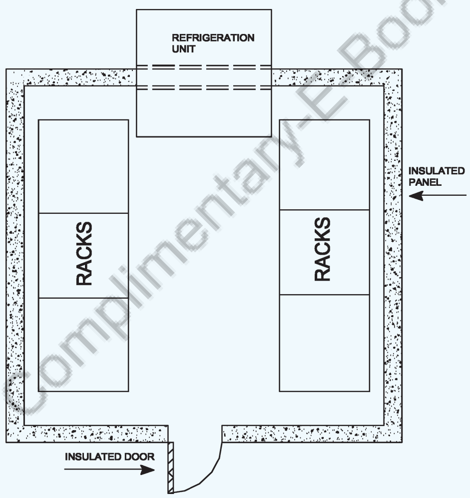

Figure 2 : Typical walk-in cold layout

b) Medium Sized Cold Stores

Medium capacity cold stores range from 50 to 500 MT capacity with 1 or 2 chambers. They may be located at the farms (i.e producing area), market places (i.e consuming area), process / precooling plants, airports etc and may be used for storage of fresh foods as well as for frozen foods.

c) Large Sized Cold Stores

These are bulk or multipurpose type and the capacities, generally, range from 1000 MT to 25000 MT. The bulk stores are, usually, located in the producing areas and also near market places and generally, have fewer chambers of large capacities.

The multipurpose stores are mostly located near consuming centres. They have a number of chambers usually ranging from 4 to 50.

Bulk cold stores generally store large quantities of fewer items whereas multipurpose cold stores are used for storing a variety of items requiring different storage conditions.

Information on normal utilization of bulk and multipurpose units is shown in *Table 1*.

Bulk Cold Stores at Producing & Consuming Centres	Multipurpose Cold Stores at Consuming Centres
Potatoes	Fruits & Vegetables
Apples	Dry Fruits
Oranges	Spices
Tamarind	Pulses
Raisin etc.	Jaggery
	Milk Products etc.

Table 1 : Typical products stored in bulk & multipurpose stores
Apart from these, items like pharmaceuticals, chemicals, films etc. are also stored in cold stores.

A typical layout of a bulk cold store is shown in *Figure 3* and a typical layout of a multipurpose cold store is shown in *Figure 4*.

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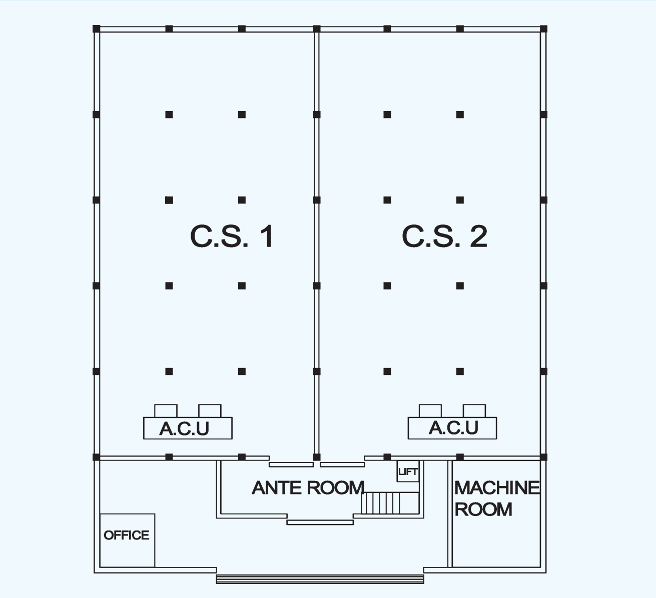

Figure 3 : Typical plan of a bulk cold store.

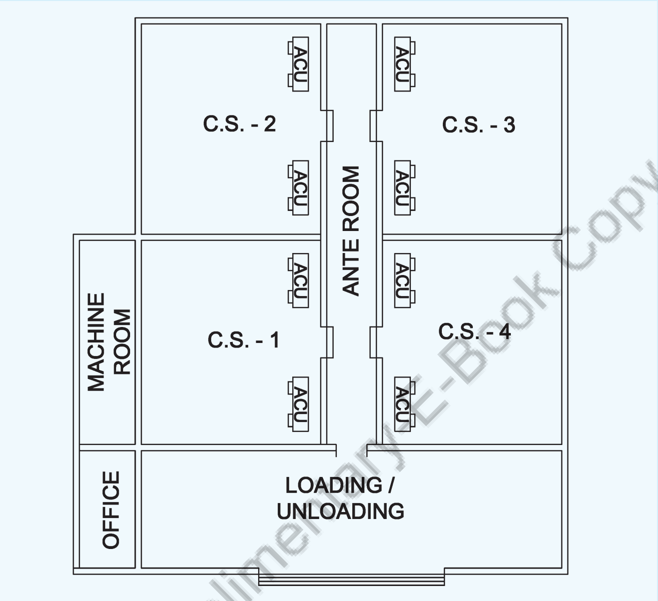

Figure 4 : Typical plan of a multi floor - multipurpose cold store

Construction Practices

The construction practices in India vary depending on the size of the unit, the location and the pattern of utilization.

Small cold stores usually have factory fabricated sandwich panel construction.

In case of medium and large cold stores, the facilities involve a) loading / unloading areas b) ante rooms c) cold storage chambers d) stair cases & lifts e) machine room f) office & toilets etc. Conventional buildings have multi-floor chambers where loading and unloading is done manually. The floor height ranges from 2 to 2.5m and the number of floors from 3 to 6.

The walls are usually brick masonry with RCC framework and the roofs are mostly truss type with cement, asbestos or metal sheet cover. In some cases, the roofs are of RCC slabs. The internal structures, in most cases, are of steel or RCC with flooring made of wooden battens or steel sections to allow storage as well as movement of air within the chamber.

A recent trend is to have cold chambers in single floor construction with heights varying from 5 to 12m or higher with mechanized loading / unloading facilities. Some units have racks for stacking the goods.

Such units are commonly constructed for precooling plants and frozen food stores. They do not have any columns and beams within the chambers and generally, have factory fabricated sandwich panel construction.

Thus the construction practices can be summarized as under:

Small Cold Stores

Generally have insulated panel construction.

Medium / Large Cold Stores

Conventional construction with :

Walls : brick / concrete blocks

Roofs : RCC slab / sheet roof on trusses

Internal Structure : steel structure / RCC columns & beams

Internal Flooring :

(i) Wooden batten - jungle wood like Bija, Babool, Neem etc.

(ii) Structural steel members such as square tubes / flats

(iii) RCC grilles made out of precast battens

Recent Practices

Walls and ceiling	:	Insulated panel construction
Roof	:	Sheet metal roofing on trusses
Internal structures	:	a) Steel structure with steel grille floors for conventional loading
		b) Racks for mechanized loading

Thermal Insulation

Thermal insulation is an extremely important component in a cold store system. It has two vital functions to perform :

1. To minimize the flow of heat from the surrounding to the inside space

2. To minimize the flow of moisture from surrounding areas to cold chambers

It is, therefore, important to select proper material, thickness, vapour barrier, cladding and the method of application to ensure that the basic objectives of providing the thermal insulation are fulfilled in the best

Sl.No.	Characteristics	Rigid Polyurethane Foam (PUF)	Expanded Polystyrene (EPS)	Resin bonded Glass Wool	Resin bonded Mineral Wool	Phenolic Foam
1.	Physical Form	Closed cellular rigid plastic foam	Air filled closed cellular rigid thermoplastic foam	Open celled resilient resin bonded glass wool	Open celled resilient resin bonded fibre drawn from rock or slag	Open celled rigid phenolic foam
2.	Density (kg/m^2)	32 – 40	13 to 25	12 to 48	40 to 144	24 to 32
3.	Thermal Conductivity (k cal/m.hr. ° C	0.019	0.028 for 18 kg/m^2 density	0.032 (for 32 kg/m^2 density)	0.035 (for 48 kg/m^2 density)	0.0266
4.	Compressive Strength at 10% deformation (kg/m^2)	1.72	0.7 to 1.0	Negligible	Negligible	0.75 to 1.16
5.	Fire performance	Self extinguishing with mean extent of burn value Part exposed to flame chars, inhibiting its spread and inner layers are protected	Normal variety not self extinguishing. Fire spreads the surface	During fire, the glass fibre melts and fuses the inner layers to flame. Also resin gets burnt.	Mineral fibre is incombustible. But resin catches fire.	Self extinguishing and non-flammable.
6.	Water Vapour (per cm)	1	0.95	Very High	Very High	4
7.	Water Absorption	Negligible	Negligible	Very High	Very High	Very High
8.	Working Temp. range °C	-200 to +130°C	-200 to +80°C	0 to +232°C	0 to +232°C	-196 to +130°C
9.	Effect of chemicals, alkalies, solvent based adhesives, lubricants	Unaffected by dilute acids and alkalies. Soluble in petrol, turpentine, bitumen etc.	Unaffected by dilute acids and alkalies. But resin gets affected by these.	Glass fibres are unaffected by dilute acids and resin by alkalies. Causes corrosion on alkalies due to presence of chloride and sulphur	Mineral fibres are affected by alkalies	Unaffected by dilute acids
10.	Effect of microbes & vermin, mould, pests, insects, birds etc.	Not attacked by vermin, birds etc.	Gets eaten by rats, ants and pests. Also sustains mould growth	Not attacked by microbes	Not attacked by microbes & pests.	Not attacked by microbes & pests

Table 2 : Properties of thermal insulating materials

possible manner. Whereas the refrigeration system may work for a certain number of hours, depending on the load requirement, the insulation has a continuous 24 × 7 duty to perform for the entire period of storage.

Insulation Materials

In some old units cheap natural material like rice husk was used as the thermal insulation. Although the insulation material itself is very cheap, it necessitated very large insulation thicknesses and also caused maintenance and hygiene problems. This method is now almost extinct.

In cold stores, having conventional construction, built after the '70s, the practice has been to use insulation materials like Expanded Polystyrene (EPS), Fiberglass, Mineral Wool, Polyurethane (PUF) or similar materials. The characteristics of different insulation material are shown in *Table 2*.

Ancillary Materials for Insulation

A vapour barrier is provided in all cases to arrest migration of moisture to the cold store. Barrier material (such as steel, aluminium, bitumen, reinforced plastic sheets, metal foils, mastic type hot or cold application paints) is provided on the warmer side of the insulation.

Methods of Application

There are different methods of application of insulation in cold stores. The older methods employed, involved wire and washer method or wooden pegs and batten frame work for fixing the insulation on walls and ceilings. The final finish used to be with cement sand plaster. This involved painting of the surfaces with consequent requirement of maintenance due to possible damage, as also problems due to growth of fungus etc.

The latest trend is to use sheet metal cladding in place of the cement and sand plaster. The cladding materials are generally, aluminium sheets or precoated and profiled galvanized steel sheets.

The modern method of application of insulation on walls, ceilings and floors is given below:

Walls & Ceilings

a) Apply a coat of bituminous primer followed by two coats of hot bitumen (industrial grade).

b) Fix vapour barrier such as polythene sheet or aluminium foil.

c) Fix teakwood pegs of suitable size with depth equal to the insulation thickness, using nylon sleeves and wood screws. The spacing of the pegs should be decided to suit the type of cladding.

d) Fix first layer of insulation using bitumen, over the vapour barrier.

e) Fix second layer of insulation in a staggered manner, over the first layer, using wood screws/ plastic screws to secure the insulation in place.

f) Fix runners of metallic channel over the pegs in lateral and longitudinal directions forming a rectangular grid.

g) Fix sheet metal cladding e.g: aluminium sheet or profiled, pre-coated G.S sheets over the runners using sheet metal screws.

h) Seal the joints with suitable beading.

Floors

a) Follow step a) above

b) Fix polythene sheet on the surface with proper overlaps and extended over the walls by 200 / 225 mm.

c) Fix first layer of insulation using hot bitumen.

d) Fix second layer of insulation in a staggered manner over the first layer.

e) Lay tarfelt or polymeric bituminous water proofing membrane over the insulation with proper overlappings.

f) Finally cover the insulation with P.C.C layer of suitable thickness (or other floor finish, if required).

Figure 5 below shows sectional view of typical details of insulation for walls, ceilings and floor.

Prefab Insulated Panel Structure

The development of factory fabricated insulated panels has brought in a revolution in cold storage construction the world over. Although, these panels have been in use for cold storage construction for over three decades in the developed countries, in India, pre-fab panels have been in use for the last 15 years. Also called sandwich panels, they are, mainly available in two types.

1. Expanded Polystyrene (or popularly known as EPS) panels with EPS bonded to the sheet metal skins by using a special adhesive.

2. PUF panels using Polyurethane as insulation material foamed between the two metal skins. These panels are structurally strong and have a better insulation value as compared to EPS panels for a given thickness.

Insulated panels have been used for making cold stores, right from the small walk-ins to very large cold stores. In fact the application of panels has gone beyond the cold stores sector and the panels have been used for the construction of processing plants, prefabricated houses, warehouses, clean rooms, etc. Such panels have also been used for fabricating doors for the cold stores which are light and simple in construction as compared to the old conventional insulated doors.

The highlights of the panel construction are shown in *Table 3* and also given below :

1. Greater flexibility and faster construction.
2. Better thermal efficiency due to a better isolation between outside and inside.
3. The panels serve as walls and ceilings and therefore, the brick walls are eliminated, thereby, increasing the cold store volume on a given floor area.
4. Modular construction is feasible and offers advantage of addition / expansion as per requirement.
5. Increased hygienic quality of the structures. Panels can have metal skin finish as per the requirement and are easier to clean and maintain.

Refrigeration Load Calculation

The load calculation is generally, made for a 24 hour period and covers the following:

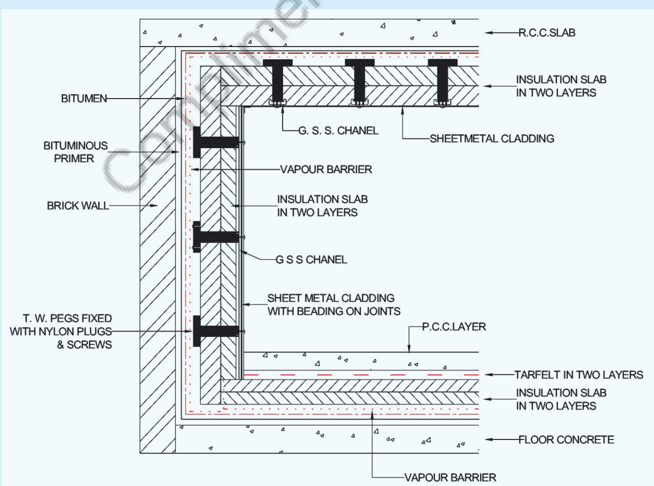

Figure 5 : Insulation details for wall, ceiling & floor (section)

Characteristics	EPS	PUF
Insulation Material	Expanded Polystyrene	Poly Urethane Foam
Density in kg/m^3	16 - 18	38-40
Temp Range in °C	–118 to +82	– 80 to +95
Skin material	Precoated, profiled G.S.sheet / S.S sheets	
Type of joints Tongue	Tongue & Groove	Cam Lock with & Groove
Commonly used panel thicknesses		
Application temp		
0 to 10 °C	80 / 100 mm	60 / 80 mm
(-) 20 °C	200 mm	120 mm
(-) 30 / (-) 40 °C	225 / 250 mm	150 mm

Table 3 : Typical characteristics of sandwich panels

1. Transmission load
2. Load due to workmen
3. Air change load
4. Electrical lighting and motor load
5. Product load

The method of calculating the various loads is as follows:

Transmission load (Qt)

The transmission heat gain through walls, roofs and floors can be determined by the following formula.

Qt kcal/day = area m^2 × U factor (kcal/hr.–m^2–°C) × temp diff (°C) × 24 hrs.

The temperature difference shall be the difference between the outside and inside design temperature plus the effect of solar gain on walls and roof. The solar effects may be considered as follows:

Walls	East	South	West	Roof
Medium colour	3	2	3	8
Light colour	2	1	2	5

Load due to workmen (Qw)

The people working in the cold stores dissipate heat at a rate depending on the temperature of the room but, usually, for a short period during the day. The typical amounts of heat generated by a person can be taken as follows:

Room Temp. °C	kcal/hr. per person
5	210
0	235
– 20	340

Thus the heat generated can be calculated as Qw (kcal/day) = number of workmen × number of hours per day × heat generated/person

Air change (Qa)

Fresh air enters the cold store due to door openings and adds to the refrigeration load. The average air changes per day can be considered as follows:

The air changes can be increased by 100% in case of heavy usage caused by frequent door openings. If strip curtains are provided on cold room doors the air changes can be reduced by around 50%

The air change load can be calculated by the following formula.

Qa (kcal/day) = air quantity kg/day × (H1-H2)

Where H1 = enthalpy of air at ambient condition in kcal/kg

Room Volume	Average air changes / 24 hrs. at 0°C room temp	Average air changes / 24 hrs at -20°C room temp
10	32.0	24.0
100	9.0	7.0
500	2.7	2.3
1000	2.5	2.0
2000	1.7	1.3

And H2 = enthalpy of air at inside temp in kcal/kg

Electrical lighting and motor load (Qa + Qm)

The light levels vary between 2.5 watts/m^2 to 10 watts/m^2 in cold stores. The fan motors generate heat as per the energy inputs to the motors. Thus the cooling load can be calculated as follows:

Load for lighting (Ql)

Qt kcal/day = total watts × number of hours/day × 0.86

The following table can be used for the heat generated by various sizes of motors.

Motor kW	Heat generated
0.25 to 0.37 kW	1233 kcal/hr-kW
larger upto 15 kW	984 kcal/hr-kW

Additional load maybe considered for fork lift trucks etc. if operated inside the cold store.

Load for motors :

Qm kcal/day = total kW × heat generated per kW × number of hours/day

Product load (Qp)

The product load in case of a normal cold store can be calculated as follows:

Qp kcal/day = product kg/day × specific heat ×(Tp-Tf)

Where Tp is the initial product temperature and Tf is the final product temperature.

In case of a frozen food store, if the product is pre-frozen but if the incoming product temperature is somewhat higher than the storage temperature, the additional load can be calculated as per the above formula. However, if the product is not frozen, the additional load for freezing and sub-cooling have to be considered.

Apart from the product cooling / freezing load the heat generated due to respiration has to be considered. However these values are very small and can be ignored for all practical purposes. For instance some of the typical values are given hereunder:

For apples stored at 0°C the respiration heat is approx. 0.2 kcal/kg/24 hrs

For potatoes stored at 4°C the respiration heat is approx. 0.3 kcal/kg/24 hrs.

Note : Generally the product cooling is assumed to be achieved within 24 hours. However, if faster cooling is required the product load can be calculated separately on an hourly basis and added to the total of other loads reduced to hourly basis.

Safety factor

A safety factor of 10 to 15% can be added on the refrigeration load to obtain the total refrigeration load. Generally the running time for the plant is considered as 16 to 20 hours/day and the hourly load can be calculated on the basis of the hours of plant operation.

Typical example of refrigeration load calculation

Store dimensions : 10m x 6m x 3m ht.

Insulation thickness :
Walls : 80mm EPS
Ceiling : 100mm EPS
Floor : 50mm EPS
Outside design conditions : 40°C DBT, 25°C WBT
Inside design conditions : 4°C +/–1°C, 75% RH
Product : Daily 3000 kg/day entering at 30°C
Consider 2 men working for 4 hrs.

1. Transmission Load (Qt)

a) Walls – $96\ m^2 \times \frac{0.027}{0.08} \times (38\ deg.^*) \times 24$

= 29548.8 kcal/day

b) Ceiling – $60\ m^2 \times \frac{0.027}{0.1} \times (41\ deg.^*) \times 24$

= 15940.80 kcal/day

c) Floor – $60 m^2 \times \frac{0.027}{0.05} \times (33 deg.^*) \times 24$

= 25660.8 kcal/day

Total transmission load Qt = **71150.4 kcal/day**

*(*An average solar gain effect of 2°C for walls and 5°C for exposed roof has been considered and added to the normal TD. The floor TD is reduced by 3°C.)*

2. Workmen Load (Qw)

Qw = 2 × 4 hrs × 210 = **1680.0 kcal/day**

3. Air Change Load (Qa)

Qa = 180 m^3 × 7.5 (airchanges/day) × 1.10 (density) × (18.34 – 3.24) (enthalpy diff.) = **22423.5 kcal/day**

4. Electrical load (Ql + Qm)

a) Lighting : Ql = 60 m^2 × 5 W/m^2 × 8 hrs × 0.86 = 2064.0

b) Motor : Qm = 1.5 kW × 24 hrs × 984 = 35424.0

Total Electrical Load Ql + Qm = **37488.0 kcal/day**

5. Product Load (Qp)

Qp = 300 kg/day × 0.85 × (30°C – 4°C) = **66,300.0 kcal/day**

Thus total load Q = Qt+Qw+Qa+Ql+Qm+Qp = **199041.9 kcal/day**

Considering a safety factor of 10% the total estimated load= **218946.09 kcal/day**

Based on 18 hrs. of operation per day the refrigeration capacity will be = **12164 kcal/day**
= 14.14 kW

In the next part we shall study the type of refrigeration systems and the selection of equipment for the cold stores. ❖

Cold Storage Basics

Part 3

Refrigeration Systems

The refrigeration system must be selected to meet the following requirements :

1. Proper cooling of products loaded in chambers to the desired temperature, maintenance of the temperature and the desired relative humidity levels. The daily product loading is an important factor in cooling load estimates.

2. Proper air distribution in the cold chambers for uniform cooling and maintenance of desired conditions.

3. System design to achieve the best possible energy efficiency since energy bills constitute the biggest component of running expenditure of the cold stores.

4. The system should have compressor capacity control to regulate the capacity in response to the loads. The system should also have, especially for larger units, provision for full or partial standby compressor capacity, as failure of the system may cause huge product spoilage.

5. System shall have automatic / semi-automatic controls and instruments for recording storage conditions and a facility for setting the desired temperature level in the chambers, depending on the product requirement.

6. For high humidity storage requirement, provision of external humidification or use of sprayed coil air handlers should be made.

7. The system shall be simple to maintain with easy availability of spares, refrigerant gas and service.

Types of Refrigeration Systems

Types of refrigeration systems for cold stores can be classified as :

1. Vapour Compression Systems

There are generally two types of vapour compression systems commonly based on the refrigerants used:

- HCFC / HFC-based systems
- Ammonia-based systems

The details of HCFC/HFC and Ammonia systems are given in the subsequent paragraphs.

2. Absorption Systems

The absorption refrigeration systems, especially those based on Ammonia - water combination, also offer an alternative to the vapour compression systems. The absorption systems have a basic advantage that they work on direct thermal heat available from any type of fuel oil or other agricultural waste. Although, the initial cost of the absorption system may be higher at present, the saving in the operational cost would be considerable and the higher initial cost could be recovered through savings in energy bills in 3-5 years. However, a proper study has to be made in each case before selecting an absorption system.

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HCFC/HFC-based Refrigeration Systems

The selection of such systems depends on the size of the cold stores. For small and modular cold rooms it is customary to use package type, wall/ceiling mounted units which incorporate an air cooled condensing unit (some what like a window air conditioner). In the light of the CFC phase out the trend now is to use R-22, HFC-134A/ R 404A or other substitute refrigerants. Condensing units

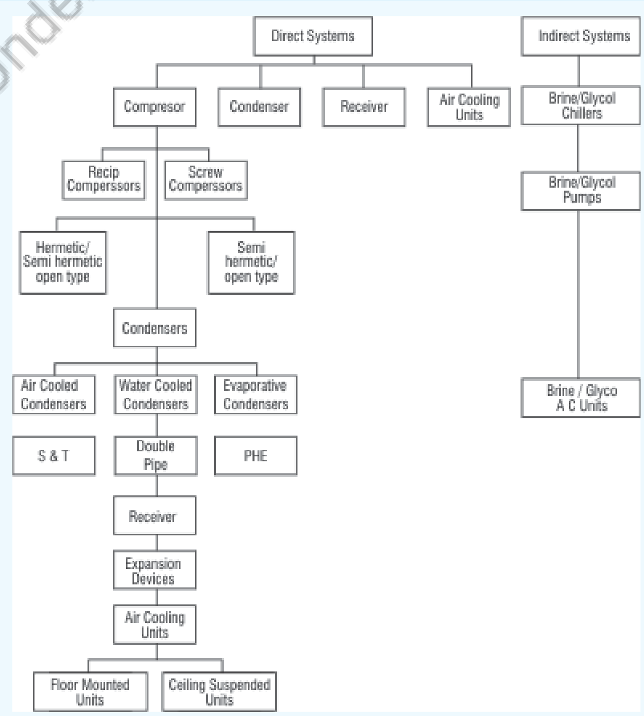

Figure 1: HCFC/HFC - based systems showing main components

About the Author

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Uniblock refrigeration system

Split refrigeration system

are mostly air cooled type although water cooled units with shell and tube condensers find application in some of the large sized units.

The units are also used as split units with the condensing unit mounted separately and the air cooling unit with wall / ceiling mounting installed in the cold room. For larger sized cold rooms, a number of such units are installed to meet the total refrigeration requirement.

In case of multi-chamber cold stores, it is possible to use condensing units with a number of compressors operating in parallel and individual air cooling units located in each room. The compressors have built in capacity control (and/or compressor "on/off" control) to regulate the compressor capacity in response to the room loads.

On some large sized multi-room projects such as controlled atmosphere stores, central plants designed for glycol chilling can also be used. The systems cost more, consume more energy for operation but have the advantage of better individual control of room conditions.

System Components

The main components of these systems are shown in *Figure 1* and are described below:

Compressors

Compressors used are reciprocating or screw, in hermetic / semi hermetic or open designs. Reciprocating compressors are mostly multi-cylinder, single stage type and can work upto (–) 25°C room temperature with R 22 / R 404A refrigerant. For low storage temperature applications, screw compressors are generally used which can work upto (–) 35° C room temperature with R 22 / R 404A.

Condensers

Condensers, generally used are (i) air cooled (ii) water cooled (iii) evaporative type.

Generally, small capacity units incorporate air cooled condensers. These can be used for low temperatures upto (–) 25°C for normal Indian ambient temperatures. It is advisable to use air pre-cooling system for condenser air, for temperatures beyond 35°C, wherever feasible, to lower the condensing temperature and thereby energy consumption.

Water cooled condensers are used for larger units and can be S&T type or PHE type. They need additional equipment such as a cooling tower, water pumps and piping and the water quality has to be reasonably soft.

In case of water cooled condensers, the compressors can work at lower evaporating temperatures as compared to the compressors working with air cooled condensers. The power consumption of the compressors working with water cooled condensers is also lower due to lower condensing temperatures as compared to air cooled systems.

Evaporative condensers can be used with good results on these systems. They offer the advantage of lower condensing temperatures and lower make up water requirement.

Air Cooling Units

ACUs based on HCFC/HFC refrigerants are generally ceiling suspended type although , in some of the older cold stores, floor mounted units with ducting for air distribution have been used.

The evaporator coils are made of copper and have aluminium fins and are dry expansion type (DX). In case of indirect refrigeration systems the evaporator coils are designed for brine / glycol circulation. The fans are generally axial or propeller type depending on the duty required. The fans are mounted either in a blow through or pull through arrangement.

The defrosting systems are of different types such as (i) water (ii) hot gas and (iii) electric. The hot gas and

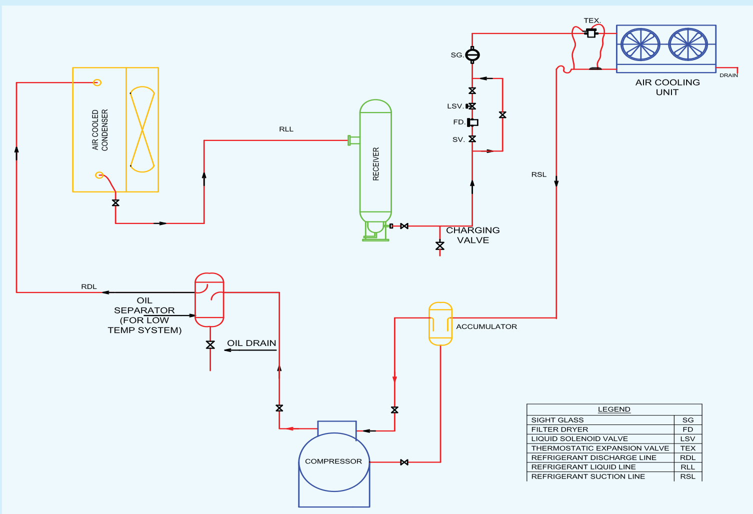

Figure 2: Typical flow diagram (HCFC/HFC system)

electric defrosting are faster and are chosen in most modern system designs.

The selection of air cooling units is a very important aspect in cold store system designing. Apart from the refrigeration duty, the units have to be selected for maintenance of proper RH and with proper defrosting system. The airflow rates and the air throws are also important for the particular room size. The manufacturer's catalogues contain information about the capacities of the units based on various evaporating temperatures, the temperature differences between the evaporator and the entering air, airflows, air throws etc. Sample selections will be shown in subsequent parts of this series.

A typical flow diagram (for HCFC/HFC system) is shown in *Figure 2*.

Ammonia-based Refrigeration Systems

Ammonia refrigeration technology has been used for over 100 years in the cold storage industry the world over. Ammonia is a natural refrigerant, is low cost and easily available. It has been used as a refrigerant in over 90% of the medium and large sized cold stores in India. Needless to say that Ammonia has proved itself as an economical and reliable refrigerant, especially, in the industrial refrigeration field including cold stores.

In the medium and large units, say 500 MT and higher capacities, the practice in India is to use central plants with Ammonia refrigerant. These systems mostly employ flooded coil evaporators, where a certain level of the refrigerant is maintained in the evaporator coil. In case of large cold store units the trend is to use a refrigerant pumping system for the circulation of low temperature/ low pressure refrigerant with the help of refrigerant pumps. Pump systems offer the advantage of a centralized control and efficient performance of the evaporator coils due to forced circulation of the liquid.

In a few cases, indirect systems working on brine/ glycol circulation are used if the process so demands.

The major components of Ammonia systems are shown in *Figure 3* and comprise :

Compressors

Reciprocating compressors of slow speed type have been used on a large number of cold store units in the past. Medium speed reciprocating compressors with speeds ranging from 750 to 1450 rpm, with a better energy efficiency and built-in capacity control have been installed in most of the recent units.

For large cold stores and frozen food stores screw compressors are preferred for many units. Screw compressors have very few moving parts and offer the advantage of stepless capacity control, generally in the range of 10 to 100%.

Condensers

The various types of condensers used in Ammonia refrigeration systems are :

a) water cooled b) air & water cooled condensers and c) air cooled condensers

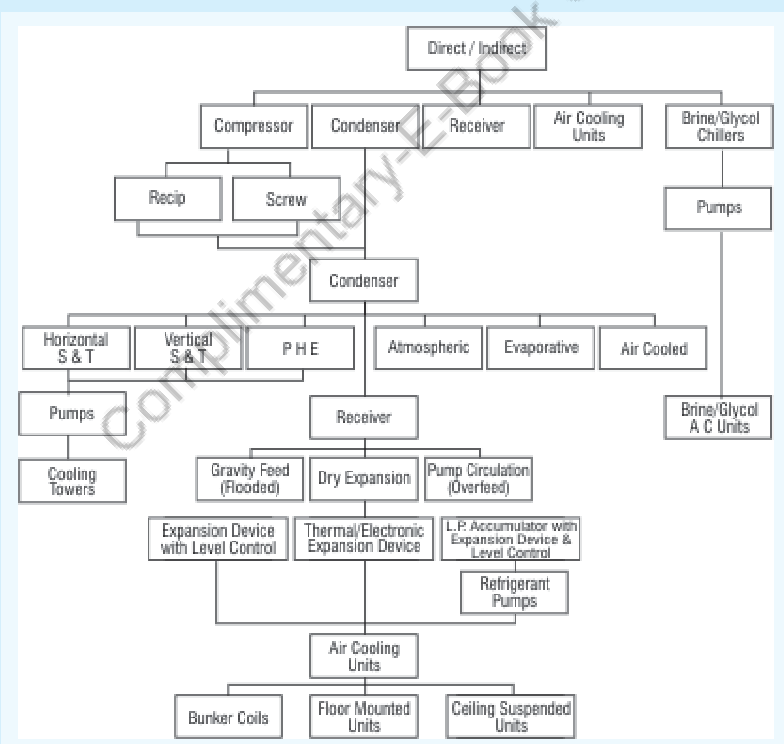

Figure 3: The major components of Ammonia systems.

*a) **Water cooled condensers***

The design of these condensers is based on circulation of water as the cooling medium. The water is, generally, recirculated and the condenser heat is rejected to the atmosphere through a cooling tower. Following types of water cooled condensers are used in cold storage plants

- **Shell & Tube Type**

These are of two different types - horizontal and vertical.

Horizontal shell & tube condensers are generally in multi-pass design and are available in sizes ranging from 200 to 1500 mm shell dia and lengths varying from 3 to 6 m. The tubes are, generally, 25 to 32 mm OD seamless steel or ERW and the number of passes range from 4 to 12.

The water side pressure drop in these condensers is, generally , higher than those for halocarbon condensers due to longer lengths and larger number of passes. The water velocities range between 1 to 2 m/sec.

The advantages are • compactness • adequate subcooling possible • mechanical tube cleaning possible.

The disadvantages are • large pressure drops on water side • difficulty in repairing in case of tube leakage.

Vertical shell & tube condensers are installed vertically over a water sump and the height is in the range of 3 to 5 m. The tubes are, generally, 50 or 65 mm size.

The heat transfer coefficient is higher due to the air currents formed in the tubes through which water flows. However, adequate subcooling is not achieved in this design as compared to the horizontal type.

The main advantages are • considerable space saving • better heat transfer performance • convenience in tube cleaning.

The disadvantages are • inadequate subcooling • higher scaling effect.

• Double Pipe Type

This type comprises of two tubes, one within another. The refrigerant vapour is condensed in the inner tube or in the annular space. The units are available, generally, upto 180kW capacity and parallel multi-row installation is possible for larger capacities. Water velocities range from 0.2 to 2 m/sec.

The advantages are • subcooling achieved upto 2°C of entering water temperature • modular installation possible.

The disadvantage is that mechanical cleaning of tubes is not possible (unless the water tubes are straight and openable at both ends and such designs are now available).

These designs can also be used for desuperheating of gas in waste heat recovery applications, for free heating of water.

• PHE Type

Like PHE chillers, commonly, used in dairy applications PHE evaporators and condensers are now widely available for ammonia refrigeration systems.

The material of plates is, usually, S.S. with semi-welded or nickel brazed construction. These condensers are extremely compact, hold a small refrigerant charge but have a high water and refrigerant side pressure drop. The heat transfer factors are much better as compared to other types.

The main advantages are • extreme compactness • very low refrigerant charge.

The disadvantages are • high pressure drops on water and refrigerant side • mechanical cleaning of semi-welded types requires dismantling. Mechanical cleaning is not possible for nickel brazed types • higher cost compared to other types.

b) *Air and Water Cooled Condensers*

The design of these condensers is based on circulation of both air and water over the condensing surface and thus, combines the functions of a condenser and a cooling tower. Whereas the circulation of water is carried out by the pumps, the air flow is either natural or by mechanical means.

• Atmospheric Type

These are the most common types of condensers used on the majority of cold stores and ice plants in India. These are simple in design and combine the functions of the condenser and the cooling tower with natural air circulation. Atmospheric condensers are fabricated in different designs such as 'U' bend type; serpentine coil type & header type. These are some of the simplest forms of condensers. These condensers are usually made of 50mm heavy gauge steel pipes.

These condensers are installed over water tanks and the whole system takes up considerable space. The installation can be done either on the ground or on terraces.

All the above mentioned types are based on parallel flow operation. Some manufacturers in Europe have developed a design with counterflow arrangements and with intermediate tapping of condensed liquid at various points to improve condenser capacity. The heat transfer coefficient in such cases is reported to be much higher.

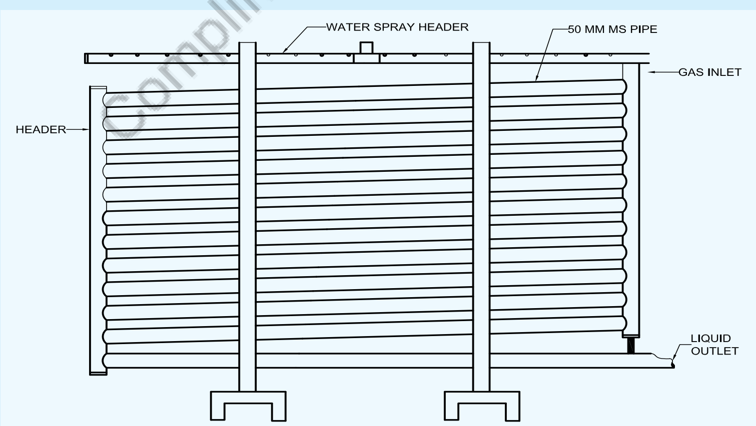

Figure 4: Atmospheric condenser - header type

• Evaporative Type

This type combines the function of the condenser and cooling tower in a compact form and has better performance than the other types. These condensers are made in two types - (i) Forced draft with the fans on the air inlet side and (ii) Induced draft with the fans on the discharge side.

The coils are fabricated from 20 mm to 32 mm OD steel pipes and are hot dip galvanized. In the latest design, coils are also made of 20/25 mm S.S. pipes. The fans are axial flow or centrifugal type. The heat transfer performance depends on air velocity, water flow and the RH of the outside air.

The advantages of these units are • compactness • much lower water circulation rate and fresh water requirement and • possibilities of operation without water circulation with low ambient temperatures.

The disadvantages are: • no possibility of mechanical cleaning of tubes • additional requirement of electrical power for fan operation.

c) ***Air Cooled Condensers***

Although, not very common, air cooled condensers have been developed for Ammonia application and offer a good alternative for installations where ambient temperatures are not very high.

Precooling of condenser air by evaporative cooling could improve the performance of air cooled condensers. Provision of a desuperheating section for heat recovery application would also be beneficial in case of such condensers.

The advantages are • simplicity in operation • no water required for operation.

The disadvantages are: • higher condensing temperature • lower plant COP and • higher energy consumption.

Air Cooling Units

There are a number of designs of air cooling units available in the market today. They are (i) conventional floor mounted units with prime surface coils and finned coils (ii) ceiling mounted units with finned coils and (iii) dual discharge finned coil units.

Bunker Coils

Many of the old cold stores in India have bunker type of evaporator coils. These are plain pipe coils with large surface areas and are located on the top floor of multifloor chambers. A battery of ceiling fans is installed under the ceiling of the chamber, over the coils.

These coils have poor heat transfer characteristics and the air circulation is not very effective, especially in the lower part of the chambers. Non-uniformity of temperatures, higher frosting levels, resulting in lower RH and weight loss in produce stored are some of the problems with this system. Also the loss of useful storage volume due to large space occupied by the coils is a direct revenue loss to the owners, throughout the life cycle of the storage.

Floor Mounted Units

In most other types of older designs, the practice was to install floor mounted air cooling units (usually called diffusers). These usually had plain pipe evaporators with centrifugal fans. The air distribution was accomplished with sheet metal ducting from the units to the topmost floor and additional branches to the intermediate floor.

As an improvement over the floor mounted air cooling units, finned coils and axial flow fans were used, in later years. These were more compact and more energy efficient due to the use of axial fans.

Ceiling Suspended Units

A recent practice is to install ceiling suspended air cooling units which have finned pipe evaporator coils and axial flow fans / propeller fans in a compact arrangement. The coils are made of M.S. pipes with M.S. fins which are hot dip galvanized after assembly. Some manufacturers offer M.S. pipe coils with aluminium fins but the latest designs have S.S. pipe coils with aluminium fins. These are light weight due to smaller thickness of S.S. pipes. Generally, for small rooms propeller fans offer adequate air circulation but for larger rooms with larger air flow requirements, axial fans are provided. The fan impellers are of M.S., cast aluminium or S.S. with aerofoil design.

Generally, ceiling suspended units with some air distribution ducting, if required, offer a good cooling performance and occupy much less space which is so expensive in a cold store. The energy consumption of the ceiling suspended unit is also lower than that of the floor mounted units. The fans used on these units are, generally, of axial designs and have aluminium or S.S. impellers.

The air cooling units have to be selected for the required refrigeration duty, for proper air circulation and the desired relative humidity in the cold rooms. This topic will be dealt with in later issues.

Types of Ammonia Systems

Two types of systems are used depending on the application:

(i) Single Stage Systems and (ii) Two Stage Systems

Generally, ammonia systems with single stage reciprocating compressors are used for cold room temperatures upto (–) 15°C and screw compressors upto (–) 20°C.

For lower room temperatures such as

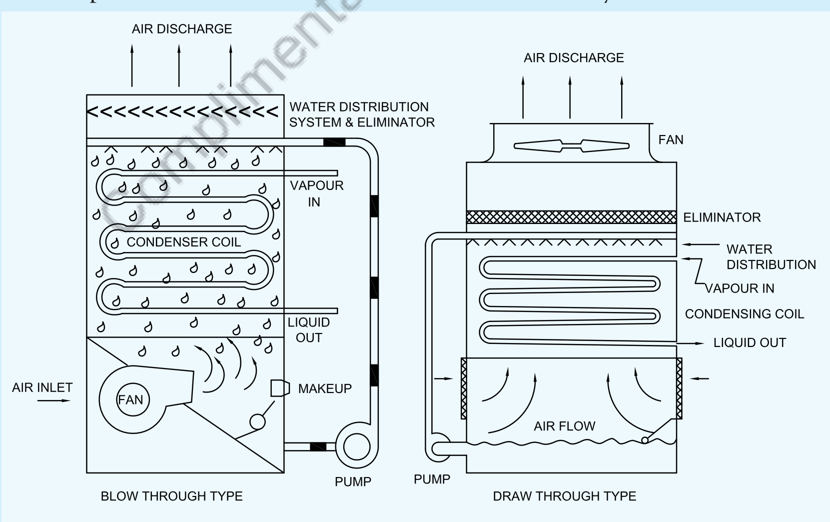

Figure 5: Evaporative condenser.

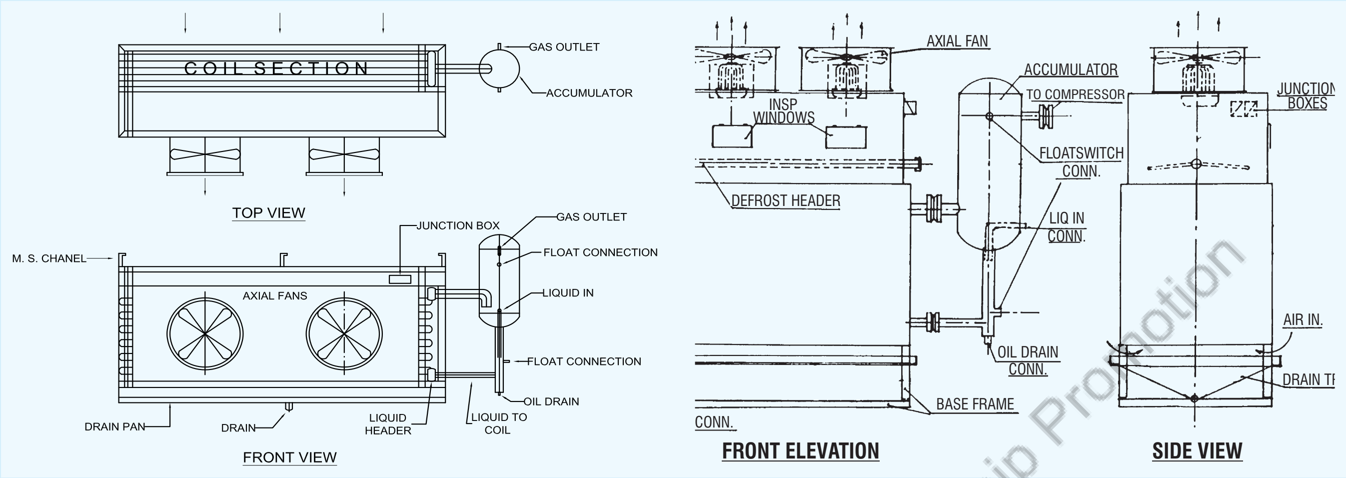

Figure 6 & 7: Air cooling unit with accumulator

frozen food stores, hardening rooms, various types of freezers, two stage systems are installed. They incorporate low stage compressors and high stage compressors or compound compressors which have both the low stage and the high stages built in the same body. A gas-cum-liquid intercooler is incorporated in the system to achieve desuperheating of low stage discharge gas and sub-cooling of refrigerant liquid from the receiver before it is fed to the evaporators.

Note: There are a few old designs of slow speed reciprocating compressors which can work upto say (–) 20° C cold room temperatures but the compression ratios are high and the power consumption is also high for a given refrigeration duty.

Typical flow diagrams for single stage (*Figure* 8) and two stage systems (*Figure* 9) are shown below.

Indirect Systems (Brine / Glycol)

In indirect systems, a secondary medium such as brine is cooled by the refrigeration machine and the chilled medium is then circulated through the coolers installed at various locations. Typical examples are chemical industries, breweries etc.

The selection of condensers and air cooling units will be dealt with in the next issue. ❖

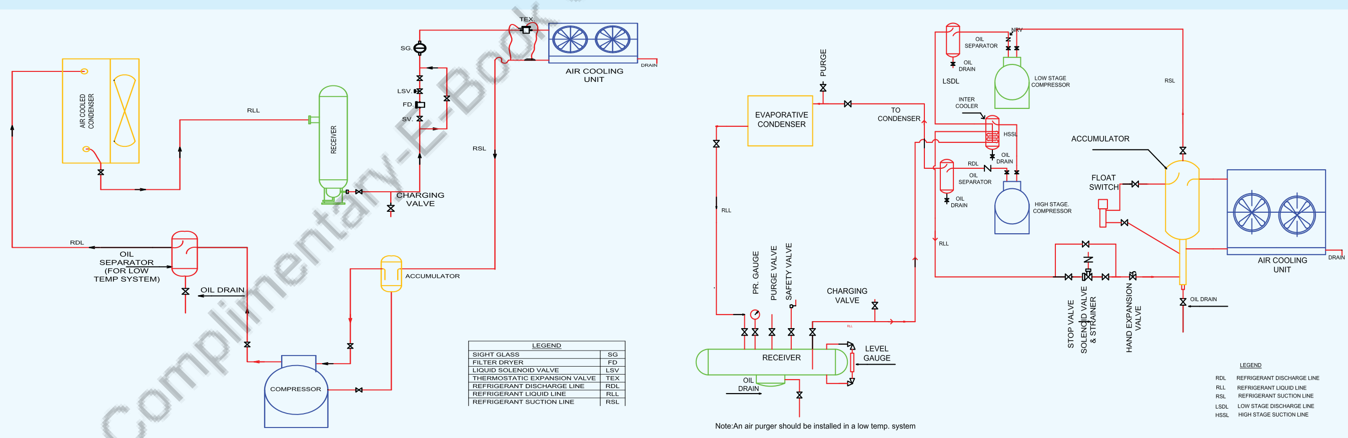

Figure 8 & 9: Typical refrigerant flow diagram.

An error has crept into Table 2, Sl. No. 9, "Cold Storage Basics", Page 125 of April-June 2006 issue. The correct version of this item is given below :

Sl. No.	Characteristics	Rigid Polyurethane Foam (PUF)	Expanded Polystyrene (EPS)	Resin bonded Glass Wool	Resin bonded Mineral Wool	Phenolic Foam
9.	Effect of chemicals, alkalies, solvent based adhesives, lubricants	Unaffected by dilute acids, alkalies, solvent based adhesives, lubricants, bitumen etc.	Unaffected by dilute acids and alkalies.	Glass fibres are unaffected by dilute acids and alkalies. But resin gets affected by these.	Mineral fibres are affected by dilute acids and resin by alkalies. Presence of chloride and sulphur causes corrosion on other materials	Unaffected by dilute acids

Cold Storage Basics

Part 4

Selection of Equipment for Cold Stores

After having computed the refrigeration capacity required, the next step is to design the basic system and select equipment to meet the performance requirements. The system selection is based on the type of refrigerant to be used. i.e HFC / HCFC or Ammonia. The types of systems used in cold stores have already been described in Part 3 of the series.

Following is the main equipment to be selected for cold stores:

HFC/HCFC based systems.

1. Condensing Units - air cooled or water cooled.
2. Air Cooling Units
3. Refrigerant Piping
4. Water Piping, if applicable
5. Controls and accessories

Ammonia based systems

1. Compressors
   a. Reciprocating / Screw / Single stage / Low and High Stage / Compound
   b. Electric Motors
   c. Accessories such as oil separator
2. Condensers
   a. Shell and Tube
   b. Atmospheric
   c. Evaporative
   d. PHE
3. Receivers
4. Inter-stage coolers in case of two stage systems
5. L.P. accumulators and refrigerant pumps in case of pump recirculation systems
6. Air Cooling Units
   a. Floor mounted type
   b. Ceiling suspended type

The units shall be provided with horizontal or vertical accumulators in case of gravity feed systems

7. Refrigerant piping
8. Water piping
9. Controls and accessories

Factors Influencing Selection of Equipment

1. The system should provide the required refrigeration capacity during the loading as well as the holding season.

2. The system shall be sound and reliable and should have adequate standby compressor capacity, especially, in case of ammonia systems. In case of HCFC/HFC systems for larger cold stores, the number of condensing and air cooling units should be such that there is no total failure of the system, at any time, in case of a breakdown of one of the units.

3. The system should have the best possible energy efficiency.

4. The system should be easy to operate and maintain and the necessary spares & after sales service should be available, promptly, at reasonable cost.

This series of articles by Arvind Surange covers the fundamentals of cold storage design. The articles will serve as a source of reference for newcomers joining the industry as well as for experienced engineers wishing to brush up on fundamentals.

Equipment for HFC / HCFC Based Systems

1. Condensing Units

The condensing units incorporate refrigeration compressor & motor, air cooled condenser with fans or water cooled condenser, liquid receiver, inter-connecting piping, control panel and the base frame. The condensing units can be selected for working on R22 / R134a / R404a and R507.

The compressors can be hermetically sealed recip, semi-hermetic or open type. Screw compressors are also available in certain ranges. The condensing units can be selected on the basis of following parameters:

• Refrigeration capacity at the selected evaporating and condensing temperature. Generally, the evaporating temperature is selected considering the room temperature required and the desirable relative humidity. For most common applications, the evaporating temperature selected is 5 to 7°C lower than the room temperature. However, in some cases where lower RH is required, the TD between evaporating and room can be as high as 8 to 10°C.

The condensing temperature would depend on the type of the condenser i.e air cooled, water cooled or evaporative type and the ambient conditions. Generally, in case of air cooled condensers, the condensing temperatures selected are higher by 10 to 12°C over the summer DB temperature. In case of water cooled condensers like S & T, the condensing temperatures

About the Author

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could be 10 to 12°C higher than the maximum WB temperature. In case of evaporative condensers, the condensing temperatures can be as low as 8 to 10°C over the ambient WB temperature.

It must be noted that the selection of the evaporating temperature is guided by the application requirement, whereas the condensing temperature selected should be as low as possible to achieve the best possible energy efficiency.

• Number of condensing units - generally the practice is to use individual condensing units for smaller cold rooms with one or two air cooling units. For larger rooms two units of 50 % capacity can be selected. More number of units can be selected for very large rooms.

• Multiple compressor racks - for large sized cold stores, condensing units with multiple compressors in parallel operation can also be selected.

Table 1 shows a sample of typical condensing unit selection data for a particular model of a compressor. The manufacturers' selection charts will show similar data for different models of condensing units. The charts will also give the details of the compressors, the condensers, the fan & the airflow capacities etc. and the over all dimensions and weights of the units.

In case of water cooled condensers, the tables would indicate the evaporating temperature and the temperature of cooling water entering the condenser. The capacity ratings can be interpolated for intermediate design temperature requirements.

Condensing Units Model	Amb. Temp In °C	Cooling Cap in kW / Power in kW	Evaporating Temperature in °C								
			10	5	0	-5	-10	-15	-20	-25	-30
XYZ	27	Cap	2.7	2.3	1.9	1.5	1.2	0.95	0.70	0.49	0.32
		Power	0.7	0.65	0.6	0.53	0.47	0.42	0.37	0.32	0.27
	32	Cap	2.6	2.2	1.8	1.4	1.1	0.86	0.63	0.44	0.27
		Power	0.76	0.69	0.62	0.56	0.50	0.44	0.38	0.33	0.27
	43	Cap	2.2	1.9	1.5	1.2	0.96	0.72	0.51	0.33	0.18
		Power	0.85	0.77	0.70	0.63	0.55	0.48	0.41	0.33	0.25

Table 1 - Condensing Unit for HFC/HCFC System

2. Air Cooling Units

The selection of air cooling units is based on the following factors:

1. Refrigeration capacity at the selected evaporating temperature
2. T.D. between evaporating and the air entering temperature
3. Relative humidity to be maintained
4. Number of cooling units to be installed as per the designer's choice
5. Desired air flow capacity with static pressure
6. Air throw required
7. Type of defrosting
8. Materials for coils and fins
9. Type of mounting - floor / wall / ceiling / above the rail

As per present practice, the units are ceiling suspended type for most cold stores and the floor mounted types are employed for applications like pre cooling and blast freezers. "Above The Rail" (ATR) type units are generally selected for chilling rooms, packing rooms etc.

The evaporator coils have copper tubes with aluminium fins. The fin spacing is selected considering the room temperature and the type of defrosting. The fin spacing is generally closer in the range of 4 to 6 mm for room temperatures of 0 to 5°C and 8 to 10 mm for lower temperatures.

The temperature difference between the evaporating and the air entering is generally 4 to 5°C for RH above 80% whereas the TDs can be 8 to 10°C for lower RH application. The air flow shall be higher for higher RH application and lower in case of lower RH requirement. Where the direct air throw from the ACU to the opposite wall of the cold store is feasible, it is advisable to select the unit for the required air throw. However in case of some cold stores with low floor heights, as in case of conventional multi-floor cold stores in India, it is necessary to provide duct mouth pieces to direct the air flow from the fans towards the upper part of the floor to achieve uniform distribution. For rooms upto, say 10 metre air throw requirement, the units are available with propeller type fans. For longer throw and units with duct connection, axial fans which can give adequate external static pressure have to be selected.

There are different types of defrosting systems available for the AC Units

e.g: (a) Air defrosting (b) Water defrosting (c) Hot gas defrosting. (d) Electric defrosting

Generally air defrosting is acceptable for room temperatures above 3°C. For lower temperatures, electric defrosting is preferred in the current day practice.

A sample of a typical selection chart for selection of AC Unit is shown in *Table 2*.

The charts for the selection of units are available from a number of manufacturers with a variety of models of

Model	Fin spacing	Rating kW		Surface Area	Air flow	Air throw	Connection		Weight	Fan details		
	mm	RT +2°C TD= 6K	RT -20°C TD= 6K	m^2	m^3/hr	m	Inlet mm	Outlet mm	kg	Qty Nos.	Impeller Dia mm	Watt per fan
ABC	4.25	3.7	2.5	42	1840	8	15	22	50	2	300	100
DEF	8.5	3.00	2.10	24	1900	9	15	22	45	2	300	100

Table 2 - Air cooling Unit for HFC/HCFC System.

different capacities, different fin spacings, physical dimensions of the units and weights etc.

3. Refrigerant Piping

The type of refrigerant piping used is shown below:

For sizing of the pipes, reference can be made to

Piping	Fittings
Hard copper tubing type 'L"	Wrought copper, wrought brass or tinned cast brass
Seamless steel pipe for sizes above 50 NB	Welded or threaded malleable iron

ISHRAE Refrigeration Handbook / *ASHRAE Handbook* or other design literature.

4. Water Piping

For water cooled systems, water piping is required to interconnect the condensers, the pumps and the cooling tower. This piping is generally G.I class 'B' upto 50 NB and M.S 'C' class piping for larger sizes. The fittings upto 50 NB size are threaded G.I. type and for larger sizes weldable M.S. fittings are used.

Valves upto 40 NB are gate / globe / ball valves and for larger sizes butterfly valves are usually selected.

5. Controls and Accessories

The controls in the cold storage systems include refrigerant feed controls such as thermostatic expansion valves, solenoid valves, thermostats, humidistats apart from the pressure and other controls provided on the condensing units. The present trend is to use digital temperature indicator cum controller in place of ordinary thermostats. Control systems are designed as per the system requirement to achieve temperature regulation, RH regulation in some cases, defrost system operation, data logging etc.

Important accessories include suction / liquid heat exchanger, accumulator in the suction line etc.

Cold stores also need emergency alarm systems in each of the cold chambers as a safety measure, in case any person is locked accidentally inside the chamber.

Equipment for Ammonia Based Systems

Ammonia systems are widely used on most medium and large cold stores.

These systems have to be designed as tailor made systems for specific applications. They offer a lot of flexibility in terms of parallel operation of compressors with common standby compressor, two stage systems with low and high stage compressors or compound compressors. Ammonia systems can be designed as integrated systems for medium temperature and low temperature loads as in case of multi-temperature applications with the choice for liquid feed as gravity feed or pump recirculation.

Various components and the factors influencing their selection are as follows:

1. Compressors

The compressors can be reciprocating or screw type. Recip compressors have to be selected with accessories like oil separators, crank case heaters, electrical motors, drive sets, pressure gauge and pressure cut-out panels etc. They are, generally, belt driven although direct drive arrangements are possible in certain cases. Screw compressors are available in a package form incorporating compressor, motor, oil separator, oil cooler, control panel etc.

The desirable features are

a. Reliable and sturdy design

b. Manual / automatic capacity control

c. Water cooling for heads / jackets (some manufacturers also offer air cooled compressors for some ranges of operation)

d. Low energy consumption levels at full load and part load

e. Low noise generation and vibration free operation

f. Prompt availability of spares and services

The compressors have to be selected on the basis of the following factors:

- Refrigeration capacity at the design evaporating and condensing temperatures. In case of two stage systems with low stage and high stage compressors, the low stage compressor can be selected for design evaporating & inter stage temperature, in place of condensing temperature. The high stage compressor is selected for inter stage temperature as evaporating temperature and the design condensing temperature. The high stage compressor load would be the sum of the low stage load and the energy input for the low stage compressor motor.
- Steps of capacity controls in case of recip compressors and steps & range of stepless capacity control in case of screw compressors.

Table 3 shows sample typical parameters for the selection of a compressor for an ammonia system.

2. Condensers

Ammonia systems are water cooled type and can

Evap. Temp. °C	Cap / Power	Condensing Temp. °C					
		+20	+25	+30	+35	+40	+45
0	kcal/h	222000	215000	207000	199000	190000	180000
	kW	31	36	40	45	50	54
(-) 5	kcal/h	182000	175000	168000	160000	153000	145000
	kW	31	35	39	43	47	51
(-)15	kcal/h	116000	111000	105000	99000		
	kW	29	32	35	37		
(-) 20	kcal/h	90000	85000	80000			
	kW	27	29	31			

Table 3 : Recip Compressors for Ammonia System

incorporate a number of types of condensers as per designer's choice. Although ammonia air cooled condensers have been developed by some manufacturers, they are not in common use. The types of condensers and their selection factors are as follows:

Shell & Tube Condensers

They are not very commonly used on cold store application as a separate cooling water system with a cooling tower, pump and piping are required along with the condenser. The construction is 'all steel' with tubes welded to the end plates of the condenser. The condensers can be selected as per manufacturer's selection tables and procedures based on the heat rejection capacity, condensing temperature, the water inlet and outlet temperatures, fouling factor etc.

These condensers are available as horizontal or vertical types. In the vertical type, the tubes are open at both the ends and the condensers are mounted over a water sump. However a cooling tower is required for the cooling of condenser water. Problems are faced on these condensers when leakages occur at the tube ends. Also regular cleaning of tubes is required.

Atmospheric Condensers

These are the most commonly used condensers on conventional cold stores in India. They work on the principle of evaporative cooling with natural draft of air and perform the functions of the condenser as well as the cooling tower. Due to the direct contact of air and water over the condenser surface, the condensing pressures are fairly low for the given ambient conditions. The rows of condensers are mounted on a water sump and the whole system takes a lot of space on the ground or on the terrace. Frequent cleaning of tubes and leakages at the tube header joints are common problems associated with this type. The condensers are constructed usually with 50 mm dia heavy gauge black steel pipe, spray galvanized or coated with anti-corrosive paint.

The standard design consists of rows of tubes which are 12 to 16 pipes high. In the older design 'U' bends were used to make one row of condenser. However in designs introduced in the '70s, the pipes are connected to vertical headers on both sides as shown in *Figure 4* of Part 3 basics. This design offers a lower pressure drop as compared to the 'U' bend design.

The heat rejection capacity of each row of condenser, 12 pipes high, is estimated between 20 to 27 kW (17200 to 23220 kcal/h) depending on the ambient wet bulb temperatures varying from 28°C to 24°C. This means that the heat rejection capacity would be lower with high ambient RH in a place like Mumbai.

Evaporative Condensers

These are the most efficient type and are widely used globally on cold stores and other refrigeration applications. They are the mechanical draft condensers with both the forced and the induced draft types available from various manufacturers. They offer the advantage of compactness, better thermal performance and lower water circulation requirement. The coils are made from steel pipes which are hot dip galvanized. Some manufacturers have also developed condenser coils with S.S tubes which require less maintenance.

These condensers require soft water for operation and also constant bleeding of water to reduce scaling and corrosion effects.

The evaporative condensers can be selected from the manufacturer's selection data based on the heat rejection capacity, desired condensing temperature, ambient air wet bulb temperature etc. *Table 4* shows a sample of typical details for selection of evaporative condenser.

The technical data would also indicate the number and type of fans, the fan motor size, pump details, overall dimensions, weights etc.

Note: The above data is based on condensing temperature of 38°C.

PHE (Plate Heat Exchanger) Condensers

These are rarely used on cold store applications. They have a high heat transfer coefficient and are very compact in size. However the cooling water system with cooling tower etc. is required as in the case of S & T condensers. The manufacturers offer the size of the condenser based on the heat rejection capacity, condensing temperature and water inlet & outlet temperatures.

Model	Air Flow m^3/s	L/s Water Flow	Heat Rejection in kW		
			Air WB 25° C	Air WB 27° C	Air WB 29° C
EC -1	6.0	10.0	245	220	200

Table 4 - Evaporative Condenser for Ammonia System

3. Receivers

Receivers maintain a minimum stock of refrigerant during the normal operation and are normally designed to store the refrigerant liquid in the entire system or a part of the system which may have to be pumped down during a breakdown or shut down. Receivers are designed as pressure vessels as per ASME or other standards. *Table 5* gives the commonly used sizes, although larger sizes are also used as per the system requirement.

The receivers are provided with inlet and outlet connections, level gauge with isolating valves, purge and safety valve connections, oil drain and stands etc.

Normally the factory rules require testing of pressure vessels as per state regulations and hence it is advisable to use two receivers in the system so that isolation is possible for pressure testing purpose.

Model	Diameter mm	Length mm	Approx. contents Litres	Approx. weight kgs.
1	350	1800	140	170
2	350	2400	190	225
3	500	2700	450	400
4	500	4800	800	750
5	600	4800	1100	900

Table 5 : Horizontal Ammonia Receivers

4. Inter-stage Coolers

These are most commonly used for two stage systems for low temperature cold stores. They perform the function of de-super heating of the discharge gas from low stage compressor before it enters the high stage compressor and also the sub cooling of the liquid coming from the receiver before it is fed to the evaporators. This is an essential component and helps in improving the capacity and energy efficiency of the system.

5. L.P. Accumulators & Refrigerant Pumps

These components are used for refrigerant recirculation systems, generally, for large sized cold stores with a large number of chambers. In this case, the refrigerant, after expansion, is fed to a central low pressure accumulator and the liquid is pumped to the various evaporators at a rate which may be 3 to 6 times the rate of evaporation of the liquid.

Description of this system will be dealt with separately in later issues.

6. Air Cooling Units

The air cooling units working on ammonia refrigerant are selected on the basis of the factors which have been mentioned earlier for the HFC/HCFC systems.

The evaporator coils are made of steel pipes with steel fins which are hot dip galvanized. Some manufacturers also offer coils with SS tubes and aluminium fins which have the advantage of less maintenance and longer life. The fin spacing is selected to suit the application. For temperatures between 0 to 5°C, 6 to 8mm spacing is selected and for sub-zero temperatures spacing of 8 to 10mm or even 12mm is selected.

Typical sample data for the selection of AC Units is given in *Table* 6.

The selection data is available from a number of manufacturers for different designs of air cooling units using different types of materials for coils and fins, fan types and arrangement, air flow & air throw, types of liquid feed, types of defrosting, physical dimensions of the units, weights etc.

Note :- The capacities are based on (–)10°C

Model	Cap in kW	Air Volume m^3/hr	Fin spacing mm	Fan detail			Weight kg	Coil Vol. Lits
				No.	Dia mm	kW		
ABC	5.3	6500	6	1	500	0.37	100	4.6
DEF	6	6500	8	1	500	0.37	160	6.2

Table 6 : Air Cooling Units for Ammonia System

evaporating temp and 5.5°C temperature difference between evaporating and room air. The capacities are for gravity feed (flooded) systems.

Correction factors for other evaporating temperatures are shown in *Table* 6A.

7. Refrigerant Piping

Refrigerant piping and fittings used in ammonia systems are as under:

The valves used are straight globe valves, angle valves, ball valves etc. For sizing of the pipes, reference can be made to *ISHRAE Refrigeration Handbook/ ASHRAE Handbook* or other design literature.

8. Water Piping

Water piping is required for (a) condenser water circulation (b) compressor head / jacket cooling (c) defrosting in case of water defrost systems (d)condensate drain piping.

Evap. Temp. °C	0	-5	-10	-15	-20	-25	-30	-35	-40
Flooded Coil	1.05	1.03	1.0	0.98	0.96	0.93	0.91	0.89	0.87
Pumped circulation	1.10	1.08	1.05	1.03	1.01	0.99	0.96	0.94	0.92

Table 6A : Correction Factors for Different Evaporating Temperatures

This piping is generally G.I class 'B' upto 50 NB and M.S 'C' class piping for larger sizes. The fittings upto 50 NB size are threaded G.I. type and for larger sizes weldable M.S. fittings are used.

Piping	Fittings
Black steel welded pipe of malleable iron as per IS 1239 / ASTM A53 / ASTM A106	Welded or threaded

For drain piping PVC pipes are also used in some cases.

Valves upto 40 NB are gate / globe / ball type and for larger sizes butterfly type are usually selected.

9. Controls and Accessories

The controls for ammonia systems include refrigerant feed controls such as hand expansion valves, float switches for liquid level controls, solenoid valves, thermostats, humdistats etc. apart from the pressure and capacity controls provided on the compressors.

The present trend is to use digital temperature indicator cum controller in place of ordinary thermostats. Control systems are designed as per the system requirement to achieve temperature regulation, RH regulation in some cases, defrost system operation, data logging etc.

Cold stores also need emergency alarm systems in each of the cold chambers as a safety measure, in case any person is locked accidentally inside the chamber.

Some of the additional accessories include air purgers, especially in case of low temperature systems where the evaporating pressure is likely to be negative (vacuum). These purgers could be manual or automatic depending on the size of the plant and the designer's choice.

In the next issue we will look at ammonia pump systems, safety norms and standards. ❖

Cold Storage Basics

Part 5

In the previous chapter we had studied the selection of equipment for both HFC/HCFC–based systems and Ammonia-based systems.

There are many cold storage projects which are large in capacity and have a large number of chambers .Many units have to construct additional structures / buildings while going in for expansion of capacities.The options available in such cases are :

a) To design separate refrigeration systems, based on HFC/HCFC refrigerants for various chambers / zones / buildings with individual operation & control facilities. This involves a number of installations and maintenance points.

b) To design central Ammonia system with flooded evaporators and flow controls for each cold room. However due to longer pipe lengths, these systems become inefficient in operation.

c) To design an indirect system using glycol for circulation with a centralized refrigeration system.

d) To design the system using pump recirculation both for above zero and sub zero temperatures. In this case, the refrigerant, after expansion, is fed to a central low pressure accumulator and the liquid is pumped to the various evaporators at a rate which may be 3 to 6 times the rate of evaporation of the liquid. The details of the pump recirculation system are described below:

Refrigerant Pump Circulation Systems (also known as Liquid Overfeed Systems)

The refrigerant pump circulation systems, commonly known as “Overfeed Systems” combine the advantages of the direct systems and the indirect systems used in refrigeration. These systems basically, incorporate specially designed refrigerant pumps for the circulation and distribution of expanded low pressure / low temperature refrigerant through the evaporators. These systems have become popular in the industrial refrigeration field since, apart from the lower first costs, they have the advantage of better thermal performance and lower energy costs as compared to the indirect systems. The pump systems have become popular, especially, for the large sized plants with low cost refrigerants like Ammonia as also for equipment like Blast Freezers, IQF Units etc. Application of the pump systems with HFC / HCFC refrigerants has been limited due to the high cost of refrigerant as the systems require large quantities of refrigerant charge.

This series of articles by Arvind Surange covers the fundamentals of cold storage design. The articles will serve as a source of reference for newcomers joining the industry as well as for experienced engineers wishing to brush up on fundamentals.

Basic System

The basic components of the pump recirculation system are illustrated in *Figure 1*.

Apart from the compressors/condensers and receivers, the main component is a central accumulator where the liquid from the receiver is fed through the expansion device, maintaining the liquid level is a certain range. This eliminates the need of the individual accumulators and the associated expansion devices for each evaporator. The expanded liquid is circulated to the various evaporators by use of refrigerant pumps. Thus the expanded liquid at lower pressure can be fed to a number of evaporators at different locations or on different floors. The quantity of the liquid circulated is, generally, 3 to 6 times the quantity of liquid evaporated. The system offers following advantages:

1. Being a direct system, the evaporating pressure is higher than that in the indirect system and therefore the energy consumption is lower by around 15%.

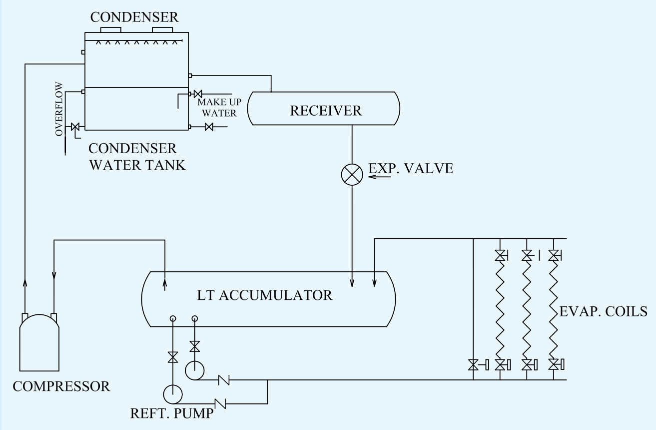

Figure 1: Typical Basic Flow Diagram for Refrigerant Pump System

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Secondly, the pumping power of refrigerant pumps is much lower as compared to the power required for brine/ glycol pumps.

2. A centralized control of the refrigerant flow is possible in the main plant room or a nearby location.

3. The piping sizes for the refrigerant lines are also smaller as compared to the piping for chilled liquid in indirect systems.

4. The forced circulation of the liquid improves the thermal performance of the evaporators.

5. Simpler arrangement is possible for hot gas defrosting.

6. The condition of the gas leaving the accumulator is nearly saturated which is a favourable condition for compressor operation. The oil circulation to the evaporators is also reduced.

The points not favourable to the pump circulation system are :

1. Some what larger pipe sizes are required for supply and return lines.

2. Additional insulation cost as insulation is required both for supply and return lines.

Accumulator

This is an important component of the pump circulation system with the following functions:

1. To serve as liquid separator.

2. To maintain stock of the liquid with level control for ensuring proper liquid supply to the pumps.

3. Store the liquid drained from the evaporators, especially, when the evaporators are at higher levels.

The accumulators can be horizontal or vertical but, generally, horizontal designs have been preferred due to their better liquid separation capacity. Vertical accumulators are likely to cause a whirlpool near the liquid outlet points. The general arrangement of a typical horizontal accumulator is shown in *Figure 2*.

The connections on the accumulators have to be carefully located. It is desirable to have separate feed lines for each refrigerant pump. The main problem that can occur is the cavitation at the inlet of the pumps due to fluctuation in pressures or levels in the accumulator. Although, the pumps can withstand some cavitation effects, they stop pumping liquid during such periods. It is desirable to keep a height difference of about 1.5 m between the pump and the lowest liquid level in the accumulator.

Refrigerant Pumps

There are various types of pumps such as open type, semi-hermetic type and hermetic pumps. These pumps are mostly side channel type or centrifugal type. The main important features of these pumps is their ability to handle liquid gas mixture unlike the conventional water or other liquid pumps. The pumps with a steep flow / head characteristics and reliability in operation are best suited for refrigerant circulation system.

Experience shows that the side channel pumps are more suitable for handling cavitation i.e. gas / liquid mixtures. Centrifugal pumps for refrigerants which were introduced later in the 70's have been found to have better efficiency and suitability for handling small impurities also.

Arrangement of Pumps

Some of the possible pump arrangements are described below :

1. In a single pump arrangement a number of evaporators can be fed and each can be controlled with a solenoid valve operated by a thermostat. When the majority of units get switched off the pressure on the pumps increase and therefore a provision is made for a bypass line with a pressure regulating valve to avoid very high static pressures on the pump.

2. In a multi-pump arrangement the pumps operate in parallel and the operation can be controlled through pressure switches and bypass flow control across the pumps.

3. In the individual circuit pump arrangement, each evaporator or a section of the system can be provided with a dedicated pump with individual operational control. Thus, for a multi–floor application a separate pump can be provided for each floor. It is for the designer of the system to select a proper pumping arrangement considering the flexibility of operation, load fluctuation and other factors involved.

4. In the two stage refrigeration systems with a multi temperature requirement separate

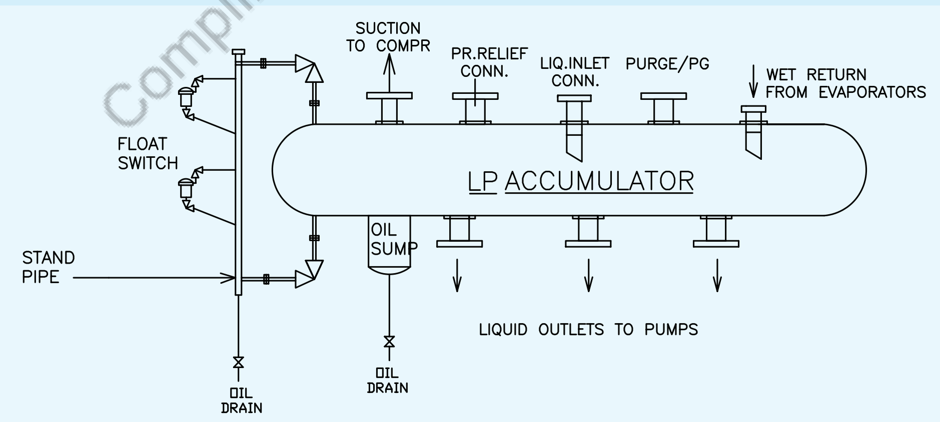

Figure 2: Horizontal LP (Low Pressure) Accumulator – General Arrangement

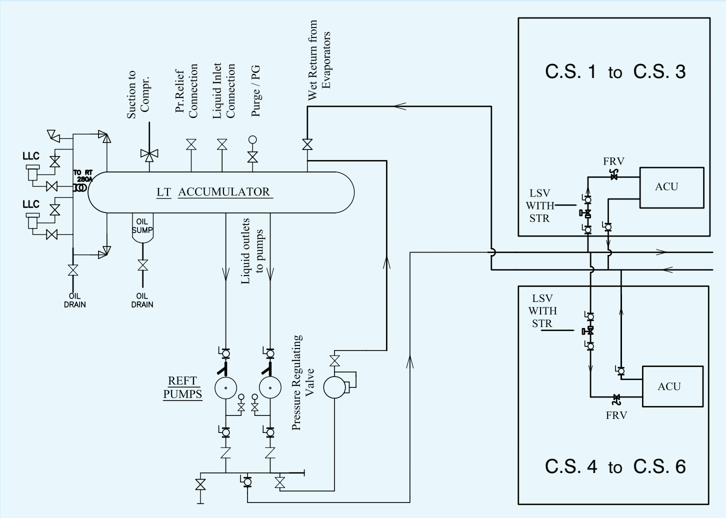

Figure 3: Typical Refrigerant Flow Diagram for Multichamber Cold Store with pump circulation

pumps have to be provided for the low stage and the high stage application with separate accumulators.

A typical refrigerant flow diagram showing the L.P. accumulator, refrigerant pumps and the refrigerant distribution in a multi–chamber cold store is shown in *Figure 3.*

The accumulator is provided with a refrigerant liquid level control and a high level control and an oil sump or a separate oil pot. A bypass pressure control is provided across the refrigerant pumps. The cooling units in the cold chambers are provided with a control setup incorporating liquid solenoid valves, which are controlled by room temperature controllers. Hot gas defrosting system can be provided by feeding hot gas to the individual coils and returning the condensate to the wet return line leading to the L.P. accumulator.

Conclusion

Pump systems combine the advantages of the direct flooded systems and indirect systems. Due to their various advantages including the most important one of energy saving, they have become popular in the larger cold storage sector and the food processing sectors. The systems need careful designing and provision of proper control system for efficient and trouble free operation.

In the next issue we will deal with the safety aspects and standards applicable to cold store technology. ❖

Cold Storage Basics

Part 6
Concluding Part

This series of articles by Arvind Surange covers the fundamentals of cold storage design. The articles will serve as a source of reference for newcomers joining the industry as well as for experienced engineers wishing to brush up on fundamentals.

Safety Aspects

Cold storage projects involve a number of engineering technologies for their construction and operation. These involve a) Civil and structural works b) Thermal insulation or insulated panels and insulated doors c) Refrigeration systems d) Control systems e) Water supply and sanitary systems f) Electrical installations including D.G. sets and lighting systems g) Fire fighting h) Goods lifts and other material handling equipments i) Security and other miscellaneous items etc.

Safety systems for the cold stores would, therefore, involve safety considerations and provisions for each of the systems during design, construction, installation, testing, commissioning, operation and maintenance.

The important safety aspects for the various systems are given hereunder:

1) Civil & Structural Work

The conventional medium and large sized cold stores in India have multistoried chambers with a number of inter floors with 2 to 2.5 m floor heights. They generally have an ante-chamber located on one side of the cold chambers or between the two rows of the cold chambers. Smaller cold stores and those built with sandwich panels, generally, are of single floor construction only.

Following points need to be considered in regard to safety of C. S. structures :

a) Cold store floors should be designed for the given product loading with proper safety factors.

b) Roofs should be designed providing a leak proof cover with proper slope for the drainage of water. In case the equipment is located on RCC slab type roofs, the structure should be designed to take care of static and dynamic load of the equipments. In case of evaporative, atmospheric condensers, cooling tower and water storage tanks, extra weight of equipment with water must be considered.

c) The air cooling units are mostly ceiling suspended or some times floor mounted. The roof slabs / roof structure should be designed considering this load at the selected location.

d) The foundation for compressors and motors should have proper structural design. The machine room flooring should be designed for equipment loads such as condensing units, L.P. & H.P. receivers, pumps, electrical panels, etc.

e) In case of floors in cold chambers, the insulation should be selected with higher density to meet the higher compression load and the concrete layer should also be laid with proper specification and thickness to meet the loading requirements.

f) For cold stores built with insulated panels, the structure must be designed to withstand the expected wind pressure loads.

g) In case of multifloor cold stores, the ante rooms have stair cases and goods lifts. It is desirable to locate the stairs and lifts near the external walls as also to have an additional stair as a fire escape stair. Provision for openable windows for emergency exit, light and emergency ventilation are recommended for ante rooms.

h) In excessively humid places and during monsoon, the problem of a lot of moisture accumulation is experienced in ante rooms. The moisture accumulation can be damaging to the structure and the insulation. The problem can be minimized by providing strip curtains at proper locations and in case of units with heavy goods movement, by providing air cooling units in ante rooms to arrest moisture ingress from outside.

i) In case of medium and large cold store units, the machine room should be located preferably in an independent block close to the cold store building. The machine room should have two / three sides open to outside and a large sized access door and an additional escape door. The equipment layout should be designed to allow adequate space for movement and maintenance

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of equipment.

The flooring in a machine room should be anti-skid type. Trenches for cables / pipes should be avoided in machine rooms.

j) The cold store structures have also to be designed to withstand earthquakes, as per the latest applicable local codes. Designers are advised to refer to the National Building Code and the locally applicable regulations while constructing cold store buildings.

k) The cold store buildings should conform to Grade 2 Fire Resistance grading as specified in IS-1641- 1960. The building height should not exceed 25 m and in case of multi-storeyed construction, alternate means of escape should be provided.

2) Thermal Insulation

The following factors need attention:

a. The thermal insulation material used in cold stores should be non-combustible, self extinguishing type. It should have cladding of metal sheet or FRP sheet (cement plaster was used in cold stores of older design). The floor insulation should also be covered with a layer of concrete with / without light reinforcement.

b. Insulated doors provided in cold stores should be openable from inside.

c. In case of insulated panel structure, one very important consideration is the balancing of air pressure in the cold chambers. The internal pressure tends to decrease during cooling down process and tends to increase during defrosting operation. The vacuum or over pressure so created can cause serious damage to the panel structure. It is, therefore, necessary to provide pressure relief valves in adequate numbers on the panel structure.

d. In case of stores designed for subzero temperatures, it is important to make provision for sub-floor heating / ventilation to ensure that the floor temperature below the insulation is above freezing point. This is to prevent any possible frost formation under the floor in situations where ground water levels are high and the sub-floor temperature goes below freezing point of water, as a result of temperature gradient which may occur between the room and the floor below. Occurrence of frost in sub-floor region could seriously damage the floor and even the structure of the cold store building.

The methods usually followed are :

1) Heating of floor below the insulation
   a. By using electrical heating mats
   b. By circulating warm glycol through network of piping
2) Providing ventilated pipes in the floor below insulation

It is recommended that consultant / design engineers make this requirement clear to the architects of the building during the design stage only.

3) Refrigeration Systems

Safety aspects in the refrigeration systems have to be considered at all stages i.e designing, planning, manufacturing, fabricating , installing, testing, commissioning, operation and maintenance.

It is essential to follow relevant safety codes published by BIS / ASHRAE and other organizations. Some of the commonly used controls and provisions include :

a. High pressure, low pressure and oil pressure cutouts on compressors.
b. Interlocks between condenser fans / water pumps and compressors.
c. Pressure relief safety valves on H.P receivers, condensers, L.P. receivers and other pressure vessels.
d. Metal protection for liquid level gauges on receivers.

All the high pressure vessels should conform to ASME or other relevant codes. All refrigerant pressure vessels should be hydrostatically pressure tested as per standard norms. The factory inspectors insist on testing of high pressure equipments periodically under the Factories Act and it is therefore advisable to have two H.P. receivers in the system so that testing is possible by isolating any one of the receivers in the system.

All the refrigerating equipment, piping, fittings, valves, accessories and controls should be suitable for the refrigerant used. Copper and copper alloys should not be used for systems using ammonia. The equipment and piping installation should be done following best engineering practices and following safety norms as recommended in IS-660 / ASHRAE 15 Safety Code for Mechanical Refrigeration.

After installation the system should be pressure tested in accordance with the test pressures specified in the Safety Codes mentioned above.

Pressure relief valves should be provided on all pressure vessels of 0.15 m^3 or higher volume. The discharge from the pressure relief valves should be so piped that the discharge would not affect the surroundings of the building. In case of ammonia, the refrigerant should be discharged in a vessel containing water only.

In case of plants containing more than 25 kg refrigerant, proper display boards with instructions for operation, precautions in case of break downs, leakages and emergency shut down etc. should be provided.

4) Electrical Installation

The entire electrical installation should be done as per

Indian Electricity Regulation and other relevant local codes.

The lighting in cold stores should be done using cables in PVC conduits or armoured cables. The light fittings in medium temperature cold stores can be CFL type with vapour proof acrylic cover. In subzero temperature stores, sodium vapour lamps are preferred. Emergency lighting should be provided in machine rooms, ante rooms and atleast one point on each floor of the cold room.

Emergency alarm system must be provided for the cold store located at a common place with push button points located near the cold room doors.

For large cold store buildings, lightning arrestors must be provided at two different points with proper earthing.

5) Fire Protection

Adequate fire protection measures must be provided in all the cold store installations. These include :

a. Provision of fire and smoke sensors located in different areas with fire alarm systems.

b. Provision of dry chemicals and CO_2 fire extinguishers and sand buckets.

c. Provision of water sprinklers in cold store areas (where feasible) and over high pressure refrigerant receivers.

d. Provision of water based fire fighting system as per local codes for all medium and large sized cold stores.

A drawing showing various fire protection provisions desirable in a cold store is shown in *Figure 1*.

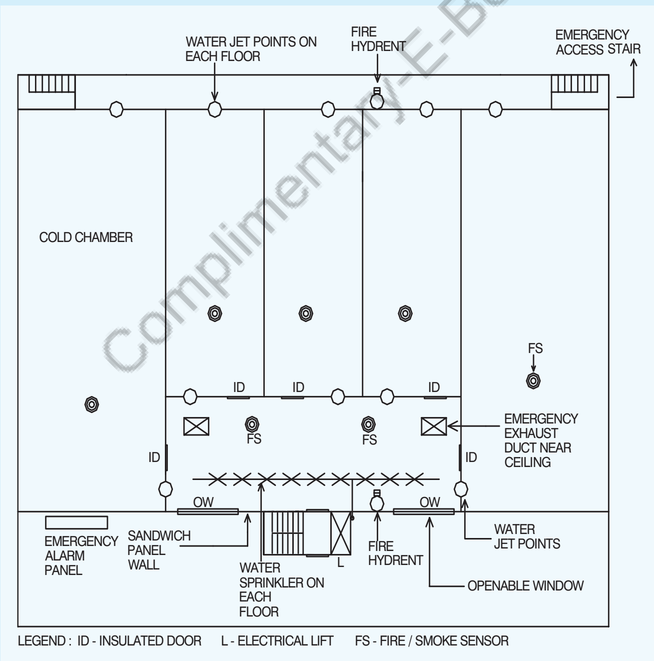

Figure 1 : Typical cold store with suggested fire protection provisions

General Aspects Related to Safety

Cold stores are expensive units in terms of first cost and the value of goods stored is, in most case, many times the cost of cold store unit. Safety aspects are, therefore, of vital importance at all stages of construction, operation and maintenance. Occurrence of fire, if not controlled in time, can lead to loss of stored products, equipment, insulation and building structure, electrical installation etc. and can also lead to loss of manpower, if the people get trapped inside. Similarly, leakages of refrigerant, if not controlled in time, can lead to loss of stored products and can harm the operating staff.

It is therefore necessary to impart proper training to the manager and operators to follow Safety Rules and to handle any accidents / fires effectively to avoid loss of product, property and personnel.

The practice of handling and stacking of goods in cold stores also needs to be safe. The passages must be wide and clear enough for movement of handling equipment / men and material.

Adequate clearance between the light fittings and stacked goods should always be maintained.

It is absolutely essential to insure the cold store building, insulation, plant and machinery, electricals, workmen and stored goods against all kinds of accidents, fires or any other damages.

Codes & Standards

Some of the codes and standards applicable for cold storage construction are given below:

a) Safety in Mechanical Refrigeration

	Safety Code for Mechanical Refrigeration	IS 660 - 1963 (Revised) / ASHRAE 15 - 2001
	Equipment Design and Installation of Ammonia Mechanical refrigeration Systems	ANSI / IIAR 2 - 1992
	Ammonia Compressor Units	ANSI/ARI 510 - 1993

b) Piping Systems / Equipments

	Refrigeration Piping	ASME/ANSI B 31.5 - 1992
	Copper Tubes for Refrigeration & Airconditioning	IS 10773
	Mild Steel Tubes and fittings	IS 1239
	Seamless Carbon Steel Pipes	ASTM A106
	Seamless & Welded Black / Hot dip zinc coated pipes	ASTM A53
	Seamless & Welded Steel pipe for low temperature services	ASTM A333

c) Pressure Vessels

	Refrigerant Liquid Receivers	ANSI / ARI 495- 1999
	Water-cooled Condensers	ARI 450 - 2007
	Air-cooled Condensers	ARI 460 - 2005
	Evaporative Condensers	ARI 490 - 2003
	Unit coolers for Refrigeration	ARI 420 - 2000

d) Thermal Insulation

	Code of practice for Thermal Insulation for Cold Storages	IS 661 - 2000
	Specification for Expanded Polystyrene for Thermal Insulation purposes	IS 4671 - 1984
	Specification for Preformed Rigid Polyurethane(PUR) & Polyisocynurate(PIR) Foams for Thermal Insulation	IS 12436 - 1988
	Specification for Rigid Phenolic Foam for Thermal Insulation	IS 13204 - 1991
	Code of practice for the application of Polyurethane Insulation by In-situ pouring method	IS 13205 - 1991
	Code of practice for Industrial application and finishing of thermal insulation materials for (-) 80 deg C to 750 deg C	IS 14164 - 1994

e) Buildings

	National Building Code - Constructional Practices & Safety	NBC - 2005 (Part 7)
	National Building Code - Building Services - Electrical & Allied Installations	NBC - 2005 (Part 8, Section 2)
	National Building Code - Building Services - Air conditioning, Heating and Mechanical Ventilation	NBC - 2005 (Part 8, Section 3)
	Energy Conservation Building Code	ECBC - 2006 by BEE

f) Electrical Installations

	PVC Insulated cables for working voltages upto and including 1100 V (Third Revision)	IS 694 - 1977
	PVC insulated (heavy duty) electric cables: Part 1 For working voltages upto and including 1100 V (Third Revision)	IS 1554 - 1981
	Code of Practice for Electrical Wiring Installations (Third Revision)	IS 732 - 1989
	Code of practice for earthing (First Revision)	IS 3043 - 1987
	Three-phase induction motors (Fifth Revision)	IS 325 - 1996

g) Fire Fighting

	Code of Practice for Fire Safety of Industrial Buildings: General Storage and warehousing including Cold Storages	IS 3594 - 1967
	National Building Code - Fire and Life Safety	NBC - 2005 (Part 4)

Why Not A "Green Cold Store" ?

Cold stores are meant to preserve precious foods, drugs, blood, films etc. by maintaining the quality and extending the period of availability. The whole operation has to be handled properly by personnel with adequate training, keeping safety aspects of the construction, plant and machinery, stored goods and the workmen, customers and visitors.

Energy charges are the major running expenses for cold stores and hence it is imperative that an "energy saving culture" is adopted at every level in the functioning of cold store units. It is a good practice to load fresh goods coming in at ambient temperature, during early morning hours to take benefit of free natural cooling at nights.

Today, the concept of 'Green Projects' is gaining the attention of promoters, designers, engineers and managers all over the world. One should certainly aim at creating the concepts of 'Green Cold Stores' - based on sound and safe technology and high energy efficiency of the plants.

Some important guidelines to achieve sound, safe and energy efficient functioning for cold store units are highlighted below:

a) Building design having minimum external surface area to volume ratio.

b) Building orientation to achieve minimum solar heat gains. Creating shades by planting trees on west side can be helpful. Doors should be positioned on shady and down wind side of the store to reduce refrigeration load due to air infiltration.

c) Use of flexible plastic strip curtains to reduce air exchange through doors.

d) Liberally designed thermal insulation system with proper vapour barrier for achieving minimum possible heat transmission and vapour transmission to cold chambers, piping, accumulators etc.

e) Refrigeration system based on ecofriendly refrigerant with zero or minimum Ozone Depleting Potential (ODP) and Global Warming Potential (GWP).

f) Provision of rain water harvesting system and use of recycled water for condensers / cooling towers, wherever possible.

g) Refrigeration system designed to achieve best possible energy efficiency. Compressors should have capacity control either stepless or with a number of steps. Compressors may be selected to ensure part load working with optimum efficiency.

h) Use of precooled air for air cooled condensers for HFC / HCFC systems and evaporative condensers for ammonia systems to reduce energy consumption. AC Unit fans should be selected on the basis of low motor power requirement. Application of Variable Frequency Drives (VFD) is recommended for fan and pump motors

i) Use of waste heat reclaim system for generating hot water if it can be utilized gainfully.

j) Energy efficient lighting in cold chambers i.e lower wattage lamps for the required duty. Electrical system should have power factor correction facility to achieve the best possible power factor. Emergency lights and alarms are a must.

k) Use of renewable energy systems eg. solar PV lighting

l) Adequate control systems for temperature indication, regulation of capacity and refrigerant flow etc.

m) Design to facilitate safe and efficient loading / unloading and stacking practices keeping in view the safety of the plant, goods stored and workmen.

Conclusion

Apart from sound and energy efficient systems required in cold store design, construction, operation and maintenance, safety aspects play an extremely important role at all stages.

There are safety codes available on building designs and other engineering aspects of cold store construction, which must be taken care of by following sound and safe design and construction practices. Training of personnel for following safety practices and handling of emergency situations is essential.

Efforts should be made to think "Green" in the whole concept of cold store construction and operation.

References:

1. ISHRAE Handbook - Refrigeration 2006
2. ASHRAE Handbook - Refrigeration 2002 & 2006
3. Various BIS / ASHRAE and other standards. ❖

ISHRAE

INDIAN SOCIETY OF HEATING REFRIGERATING & AIR CONDITIONING ENGINEERS

ISHRAE PUBLICATIONS

S. No.	Publication Name
1	HVAC Handbook (Edition 2014)
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3	Refrigeration Handbook (Edition 2015)
4	Weather Data Handbook 2014
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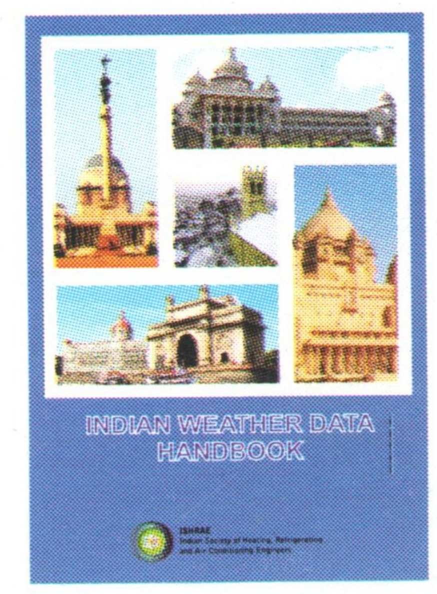

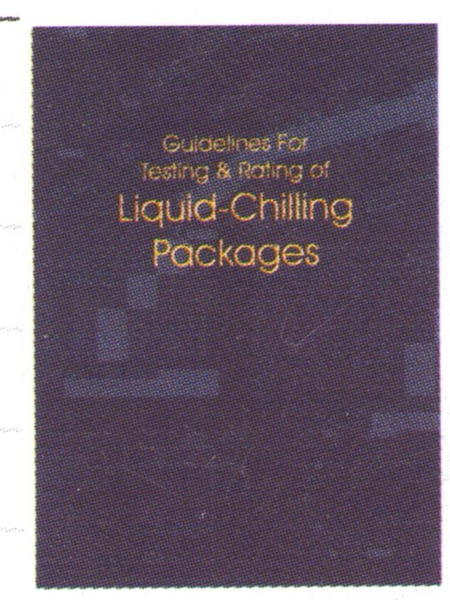

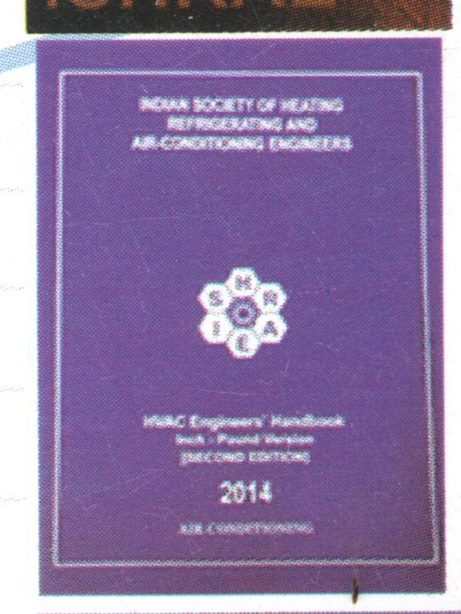

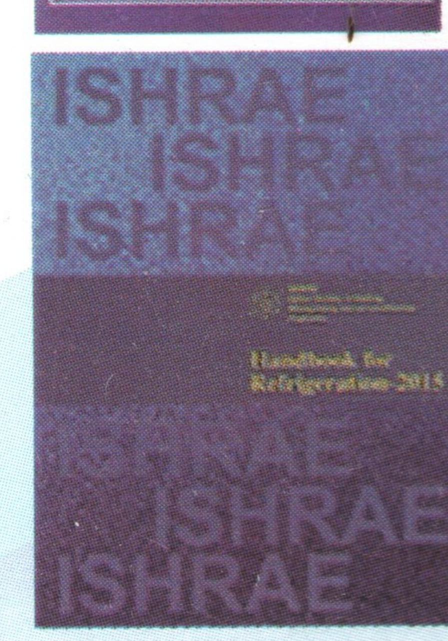

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