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Designing & Installing Large Cold Stores with Prefab Insulated Panels

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Editor

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The increasing demand for fresh vegetables, fruits, frozen food and ice cream in our large cities for hotels, restaurants, fast food outlets and retail establishments has brought about a growth in the demand for medium and large size modern refrigerated storage facilities.

Customers insist on short completion periods which consultants and contractors can meet only by recourse to the use of factory pre-fabricated insulated panels, factory assembled condensing units and unit coolers working mostly with HCFC-22 refrigerant, as such equipment can be supplied and erected within short periods compared to the old conventional brick-and-mortar cold stores using ammonia systems.

Sea food processing, freezing and storage facilities, meat freezing plants and the very large refrigerated warehouses on the outskirts of large cities however continue to install ammonia refrigeration systems.

This article will dwell on several aspects of design and installation of such prefab stores, some of which are not appreciated and understood by the new engineers entering this expanding field. It will be assumed that working out heat loads and determination of cooling capacity does not present any problem to the design engineer.

Selecting the Condensing Unit

The capacity of the condensing unit is normally based on a 16 to 18 hour operating time and is obtained by dividing the total heat load for 24 hours, including a safety margin, by 16 or 18. This means that the condensing unit is oversized in order to handle the 24 hour load in a 16 to 18 hour period. Some designers may select the unit based on an 18 to 20 hour operating time which leads to a more economic selection.

Condensing units, if purchased from a reputable manufacturer, can be factory equipped with a receiver and shut-off valve, safety switches, liquid sight glass and filter-drier. A suction accumulator can also be provided. So also a weather-proof housing. All these options can save considerable time required to complete the erection work.

Photo 1 : A large cold store with pre-fab insulated panels under installation for Snowman Frozen Food, Kochi. Room dimensions 50 × 20 × 9.5m high. *Photo courtesy of Beardsell Ltd.*

Hermetic or Semi-hermetic?

Condensing units for refrigerating plants normally employ semi-hermetic compressors which are serviceable in the field, come equipped with oil and vapor equalizing connections for parallel operation with other compressors, have oversized motors and in general are more robust in design.

Air-cooled or Water-cooled?

Air-cooled units are preferred over water-cooled, since air is plentiful, available at all times and is free. While water is becoming scarcer by the year and water shortages do occur during poor monsoons in India, water must also be metered and paid for, water quality must be right to avoid condenser scaling and of course cooling towers with pumps require maintenance. The only time when water-cooled units are a 'must' is when they are installed in a basement or a hot kitchen where inadequate cooling air is available for an air-cooled condenser.

Shell-and-tube water-cooled condensers are preferred over shelland- coil, co-axial or plate type since they are easier to clean, at frequent intervals, given the poor quality of most of our water supply.

Multiple Units and Standby

When the product load is heavy or the size of the cold store is large, it is recommended that the total capacity of the refrigeration system be divided among multiple units to provide the customer with some comfort level in the event of mechanical failure or refrigerant leak. Also as the refrigeration load is calculated for the worst outside temperature conditions and maximum product load, multiple units provide for some capacity control. In low load situations, some units can be turned off and the room maintained adequately with a fraction of the horsepower necessary for the peak operation. Multiple units started in sequence can also help cut down the demand charges levied by the electric supply company and thus reduce electric bills. Generally, any load that requires more than a 10 hp unit should be split into two or three smaller units, with a standby unit added if considered necessary.

The capacity of the condensing unit should be selected at a suction temperature, after correction for suction line pressure drop. Maximum recommended pressure drop in suction lines is given in **Table 1**.

Table 1: Recommended suction line pressure drop

Suction temperature range	Pressure drop allowed, psig
50 to 30°F	4 Lbs
30 to 10°F	3 Lbs
10 to –10°F	1.6 Lbs
–10 to –30°F	1.2 Lbs
–30 to –50°F	0.8 Lbs

Parallel Operation of Compressors

The need for greater system flexibility, lower operating cost, and energy conservation has brought about the growing application of parallel compressor systems. This type of system uses multiple compressors with one common discharge line and common suction line for a common operating evaporator temperature.

Since the compressors are piped in parallel, the workload is divided and when one compressor is down for maintenance, there is minimal to no variation in product temperatures, that means less product spoilage and more peace of mind.

Parallel systems have some potential problems, one of them being the maintenance of the correct oil level in the compressor crankcase at all operating conditions. Crankcase oil level must be controlled and there are companies that can supply a reliable oil level control system, eliminating the need for complex piping and valving. It does not require that the compressors be level, or be the same make or model

This system consists of three basic components : oil seperator, oil reservoir and oil level regulators. Each compressor has an oil level regulator attached to control the oil level in the individual compressor. The regulators are supplied oil by the common oil reservoir, which in turn is supplied oil by the oil seperator. See **Figure 1**.

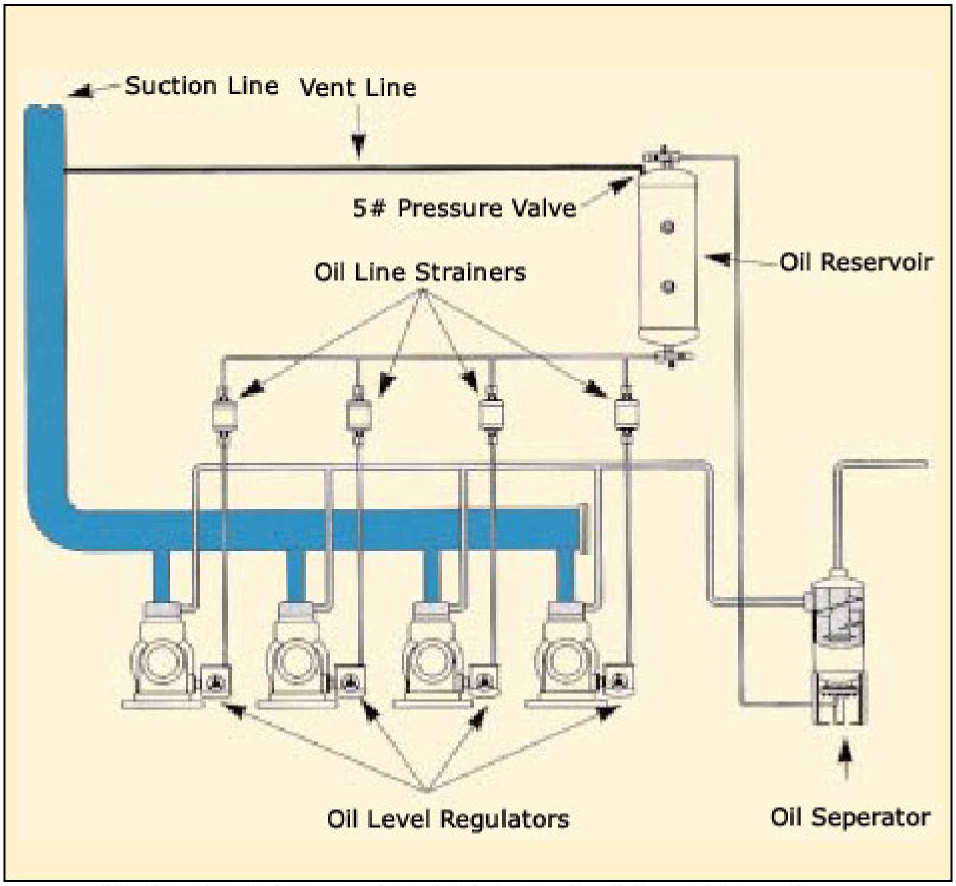

Figure 1 : Oil control for parallel compressor system.
Courtesy of Henry Valve Co., USA

Selecting a Unit Cooler

The unit cooler or evaporator must be selected to balance the capacity of the condensing unit at a desirable temperature difference (TD) between the refrigerant in the unit cooler and the air in the refrigerated storage room. Note the definition of TD, which is commonly used by refrigeration engineers, as compared to the definition used by food technologists and some others as the 'temperature difference between the air entering the unit cooler (room temperature) and leaving the cooler'.

Selecting the proper size unit cooler is important not only to maintain the desired temperature but also the correct level of relative humidity, if the stored products are to be maintained in a suitable condition. For example, if flowers are kept in a room with low humidity the petals will turn brown and wilt. Vegetables also require high humidity. Meat will become slimy if the humidity is too high and the outside of the meat will become hard if the humidity is too low. Apples, which at times must be stored for months, will not remain crisp if the relative humidity is too low. Also, packaging can be adversely affected if humidity is too high - labels on bottles can loosen and cardboard containers can weaken due to the moisture absorbed.

Matching condensing unit and evaporator to achieve both the desired space temperature and relative humidity requires one to first determine the proper TD between the refrigerated space and the compressor suction temperature. The nature of the stored product determines the desirable relative humidity for the storage room. The desirable relative humidity, in turn, dictates the approximate design TD. **Table 2** gives the recommended temperature differences for various products and **Figure 2** gives the TD required for various relative humidity levels in a 1.7°C (35°F) room.

Table 2: Recommended Temperature Difference (TD) for Four Classes of Foods (Forced Air Unit Coolers)
Courtesy of Heatcraft Inc., USA

Class	TD	Approx. RH	Description of Product Classes
1	7° – 9°F	90%	Results in a minimum amount of moisture evaporation during storage. Includes vegetables, produce, flowers, unpackaged ice and chill rooms
2	10° – 12°F	80 – 85%	Includes general storage and conventional store coolers, packaged meats and vegetables, fruits and similar products. Products require slightly lower relative humidity levels than those in Class I
3	12° – 16°F	65 – 80%	Includes beer, wine, pharmaceuticals, potatoes and onions, tough skin fruits such as melons and short term packaged products. These products require only moderate relative humidities.
4	17° – 22°F	50 – 65%	Includes prep and cutting rooms, beer warehouses, candy or film storage and loading docks. These applications need only low, relative humidities or are unaffected by humidity.

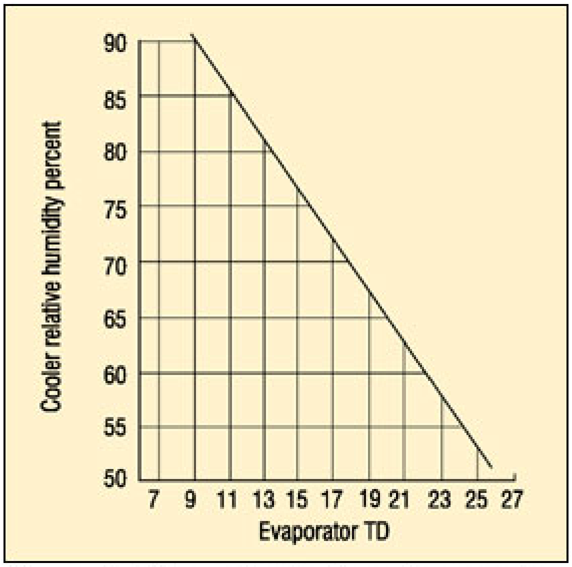

Figure 2 : Approximate forced convection evaporator TD for 35 F rooms
Courtesy of Heatcraft Inc., USA

For the general purpose cold store, involving meats, vegetables and dairy products, it is common procedure to balance the unit cooler to the condensing unit at a 5.5 to 6.6°C (10 to 12°F) TD.

If this is done then from experience one can expect to maintain in a 1.7°C (35°F) room a 80 to 85% relative humidity which is a good range for general storage.

In a freezer room where the product is stored below 0°C (32°F) all moisture is in the form of ice or frost; the product is frozen solid and therefore a 5.5°C (10°F) TD is satisfactory for all products.

There are many other products for which a 5.5°C (10°F) TD is not the answer: paper, film, cigarettes, cheese etc. Storage of any of these products in rooms cooled by systems based on 5.5°C (10°F) TD can produce disastrous results.

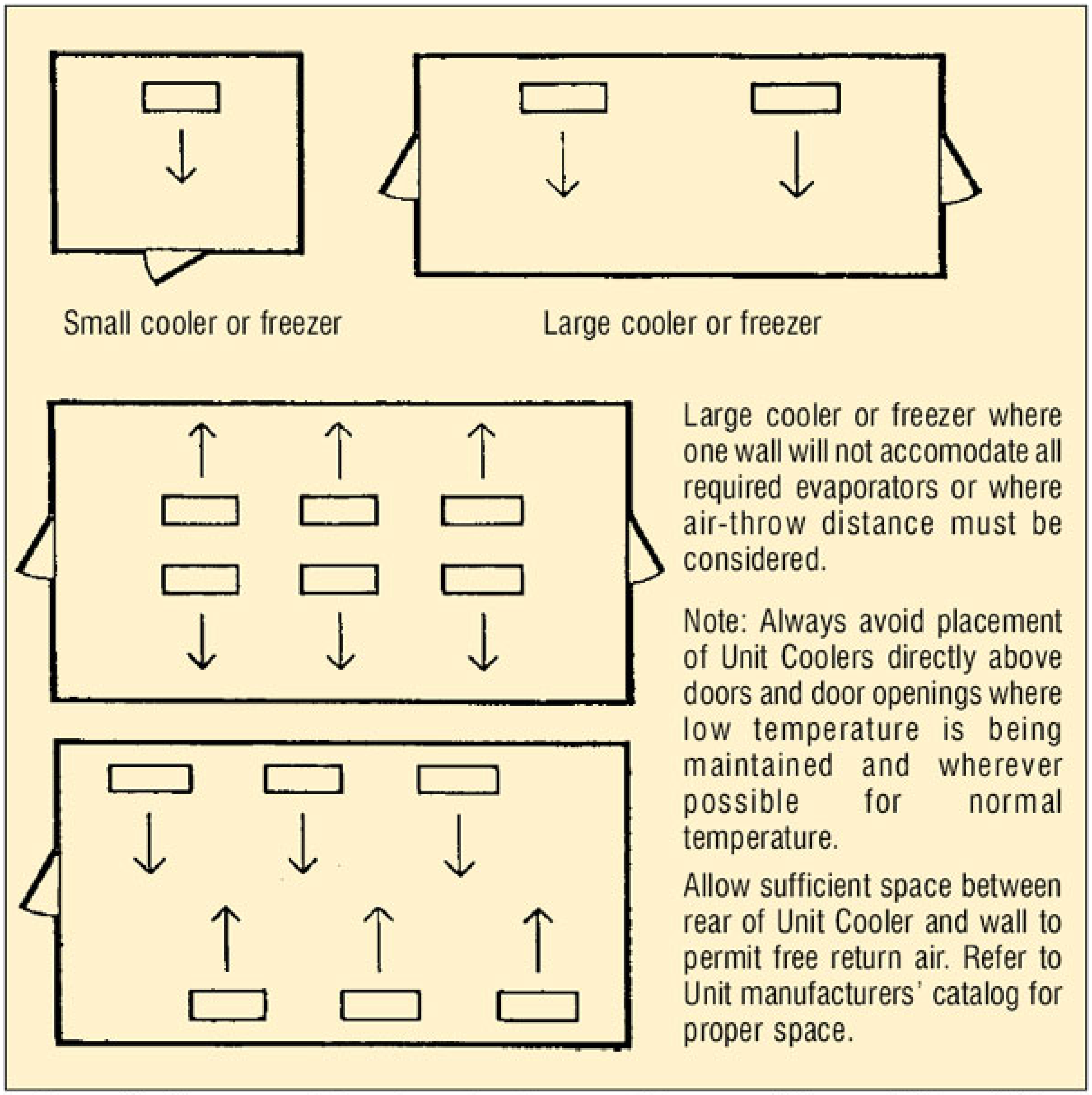

Figure 3 : Recommended unit cooler placement *Courtesy of Heatcraft Inc., USA*

Proper Placement of Unit Coolers

Two important considerations in the selection and location of the unit cooler are uniform air distribution and air velocities which are compatible with the particular application.

The direction of the air throw should be such that there is movement of air where there is a heat gain; this applies to the room walls and ceiling as well as the product. The unit cooler or coolers should be arranged to direct its discharge air at any doors or openings, if possible. Avoid placing the unit cooler in a position close to the door where it may induce additional infiltration into the room. This can cause fan icing. Also avoid placing a unit in the air stream of another unit because defrosting difficulties can result. See **Figure 3**.

Pre-fabricated Insulated Panels

The use of factory pre-fabricated insulated panels has helped to speed up the completion period and simplified the site work involved in the older, masonry shell-with-fieldapplied-insulation type of construction.

Two types of pre-fabricated insulated panels are available from Indian manufacturers:

• Polyurethane foam injected panels (PUF)

• Continuous laminated panels with expanded polystyrene

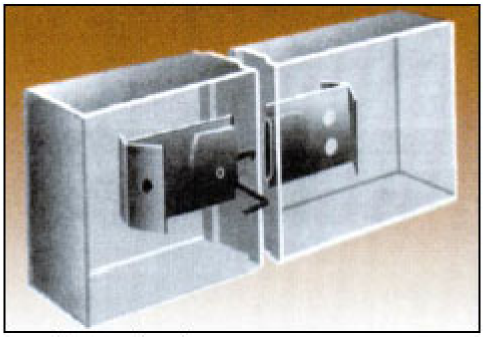

Figure 4 : A camlock for holding together PUF insulated panels *Courtesy of Blue Star Ltd.*

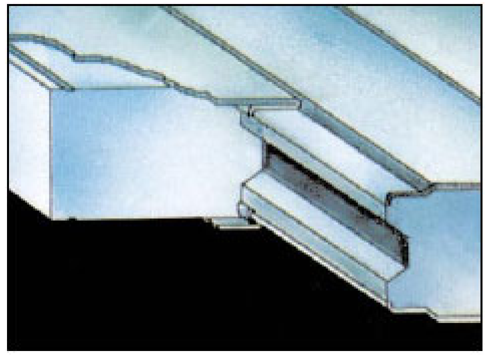

Figure 5 : A slip joint for connecting panels. *Courtesy of Beardsell Ltd.*

The PUF panels are formed by injecting polyol, isocyanide and a foaming agent between two metal sheets in a mould which is then held tight in a heated press for curing. The vertical edges of the panel are moulded in a tongue-and-groove fashion with a locking system, referred to as 'camlock', foamed in place along the panel edges, see **Figure 4**. Maximum length of the panel depends on the length of the mould and press available with the manufacturer and is restricted to 6 metres with Indian companies at this time.

The continuous laminated panel consists of three layers of material bonded together with heat polymerising adhesive, so that they behave as one entity. The outer skins of the panel are normally pre-painted galvanized steel which bears most of the load of the panel. The thicker central core of polystyrene insulation material stabilizes the outer skins and prevents distortion under stress. Any length of panel can be supplied, as long as transport and handling at the site is not a limiting factor. Insulation thickness ranges from 80 to 300 mm of Polystyrene. Panels are joined together by a tight fitting sheet metal 'slip joint' with the insulation edges in tongue and groove fashion. See **Figure 5**.

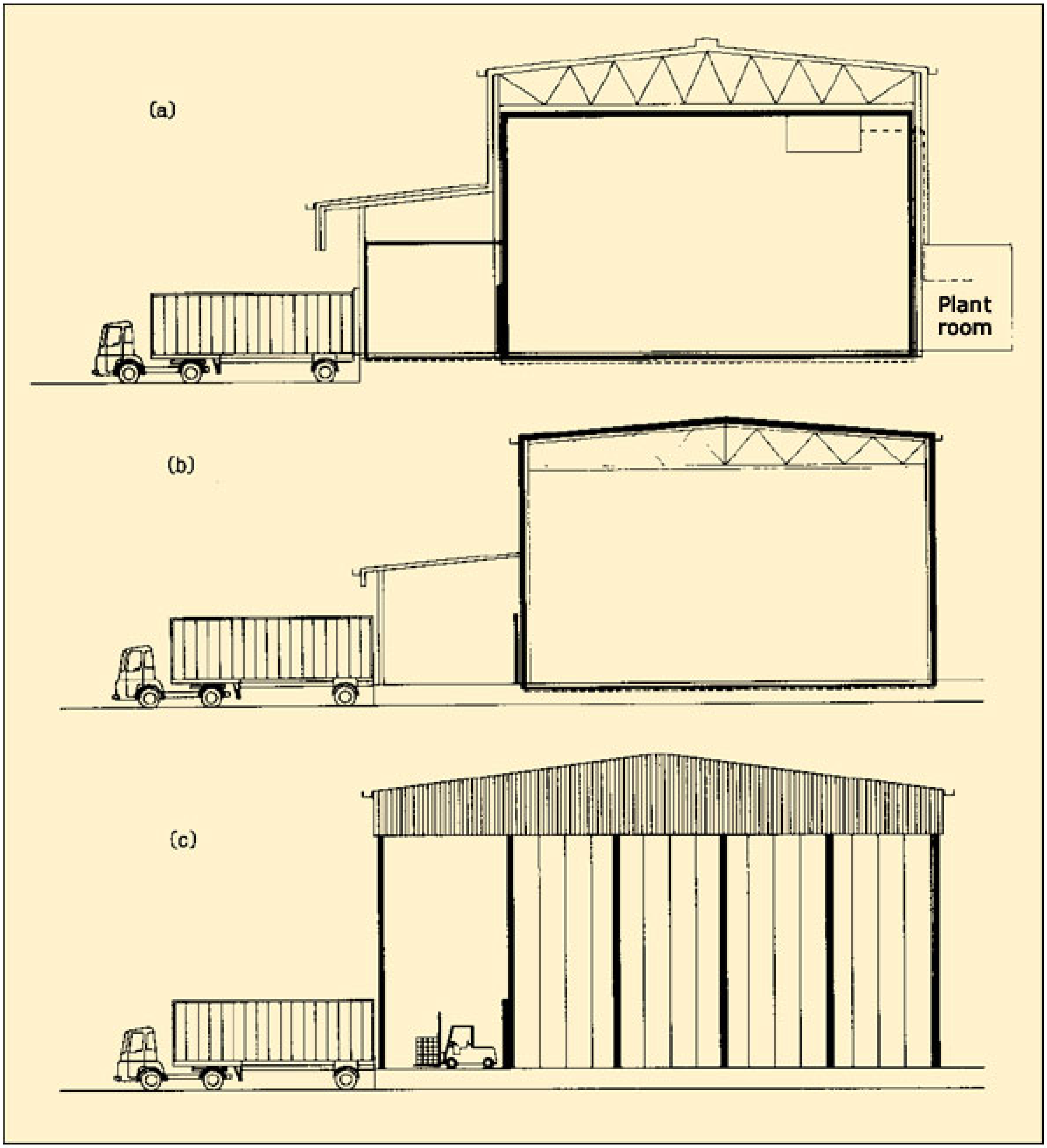

Figure 6 : Types of insulation: (a) internal insulation systems with external wall and roof cladding; (b) external insulation system; and (c) internal insulation system with roof and partial external wall cladding

Application of Pre-Insulated Panels

The application of pre-fabricated panels to cold store structures is a mater of customer preference, depending on the consultant's advice and site conditions. Structures may be internally or externally insulated. Internally insulated systems require wall and roof cladding. See **Figure 6**.

Internal Insulated Systems with External Wall and Roof Cladding (6a)

The steel structure is designed to support not only the external cladding of the building but also the insulated ceiling panels from the underside of the trusses. The vertical steel work also incorporates the lightweight horizontal steel channels to give additional support to the insulated wall panels.

External Insulation System (6b)

Insulated wall panels are fixed to the steel structure, with the external face of the panels designed to be fully weather proofed. The roof is also insulated by laying insulated panels over the steel frame, sealing all joints and then covering the whole area with a weather proof membrane. In many cases the external membrane is then covered with white stone pebbles that reflect the heat from the sun.

This system of construction can also be used where static racking replaces the steel structure.

Internal Insulation System with External Roof and Partial External Wall Cladding (6c)

This system commonly known as a 'Dutch barn' construction is designed to save costs. The insulated ceiling panels are secured from the trusses but the wall panels are exposed to the weather, with the external cladding forming a valance around the periphery of the store protecting the exterior of the ceiling and the wall-to-ceiling joints from the weather. The external joints of the wall panels are designed to give maximum weather protection and the external wall cladding should have a paint coating for protection from ultraviolet rays. See **Photo 2.**

Photo 2 : The 'Dutch Barn' construction design of cold store for Snowman Frozen Foods, Kochi.
Photo courtesy of Beardsell Ltd.

Care of Ceiling Pre-Fabricated Panels

Ceiling panels when installed correctly offer a limited walk-on facility suitable for intermittent personnel use. However certain precautions must be taken to prevent abuse and damage of the panels and these are:

- The panels are not to be used as a working platform.
- Plant and equipment i.e. pipes, refrigeration equipment, ductwork etc should not be supported from the panels but from the overhead steel structure.
- Apertures can be cut in the panels but these must be suitably framed and supported.
- Newly installed ceiling panels should be immediately covered by 6 mm thick (minimum) plywood or similar material until the installation is complete.
- Ceiling areas subject to future maintenance access should be protected as detailed above. • Personnel should not gather in groups greater than 2 on any single panel, particularly adjacent to apertures.
- Do not jump or bounce on the ceiling.
- Signs displaying all the above points should be permanently erected at all points of ceiling area access.

If excessive loading is anticipated, suitable walkways or catwalks supported from the structural frame should be provided above the panels.

Vapour Barriers

An effective vapour barrier on the outer surface of cold storage insulation is the most important single feature of a successful cold store and one of the most difficult to achieve and maintain. The process of water vapour penetration into insulation is simple but frequently not appreciated since it cannot be observed. When a cold store is in service, the difference between the inside and outside temperature gives rise to a water vapour partial pressure differential across the thickness of the insulation.

On the low temperature side, this pressure is low and more or less constant since the inside temperature and humidity is stable. On the warm side of the insulation it varies significantly with changes of weather and season, reaching its maximum when the ambient temperature is at its maximum and the relative humidity is 100 per cent. Water vapour in the atmosphere surrounding the enclosure thus constantly seeks to penetrate into the relatively cold panel insulation where the partial pressure is lower.

Water vapour finds its way through any discontinuity in the vapour barrier and permeates into the insulation until it reaches the temperature frontier corresponding to the dew point, where it condenses. This lowers the vapour pressure locally, encouraging further invasion of water vapour. Condensed moisture continues to penetrate the insulation until it reaches the zero degree countour, where it freezes.

While the metal outer skin on pre-fabricated wall and ceiling panels of a cold store is an effective vapour barrier, the joints between panels, between wall and ceiling panels, between wall and floor panels, if any, or the floor itself and all the openings made in the panels for passage of pipes, conduits, and suspension rods, if not properly sealed permanently, will cause water and ice to form (if the room temperature is below freezing). This reduces the insulation properties, increases operating cost, delaminates the panels and may even cause collapse of some panels.

Wherever possible, cold rooms should be designed to enable the maintenance staff to inspect the vapour seal and caulking periodically. There should be sufficient clear room around the wall and the ceiling panels for this purpose. This clearance also helps to provide some air circulation around the panels preventing sweating during high ambient humidity levels.

Another potential area of concern and misunderstanding is the vapour barrier below the concrete flooring and the insulation wherever floor pre-fabricated panels are not installed. The vapour barrier commonly used for cold rooms these days is polyethylene sheet, which should be of adequate thickness to prevent tearing and puncturing during installation. The minimum thickness specified should be 0.3 mm or 12 mil with 1 mil equaling 0.001 inch (0.025 mm)

The polyethylene is laid continuously over the full sub-floor area before applying the floor insulation. All joints must be lapped and bonded together and must continue under the wall panels. All projections and loose stones in the sub-floor must be removed to prevent puncturing the vapour barrier.

Placing a 'slip sheet' of polyethylene of 1.5 mm thickness (6 mil) between the finished concrete floor and insulation is advisable. This 'slip sheet' (not a vapour barrier), which during construction is placed on the insulation before pouring the concrete serves two purposes. It permits differential expansion between the insulation and concrete, and it keeps the moisture of the concrete from contacting the insulation until the concrete dries. See **Figure 7**.

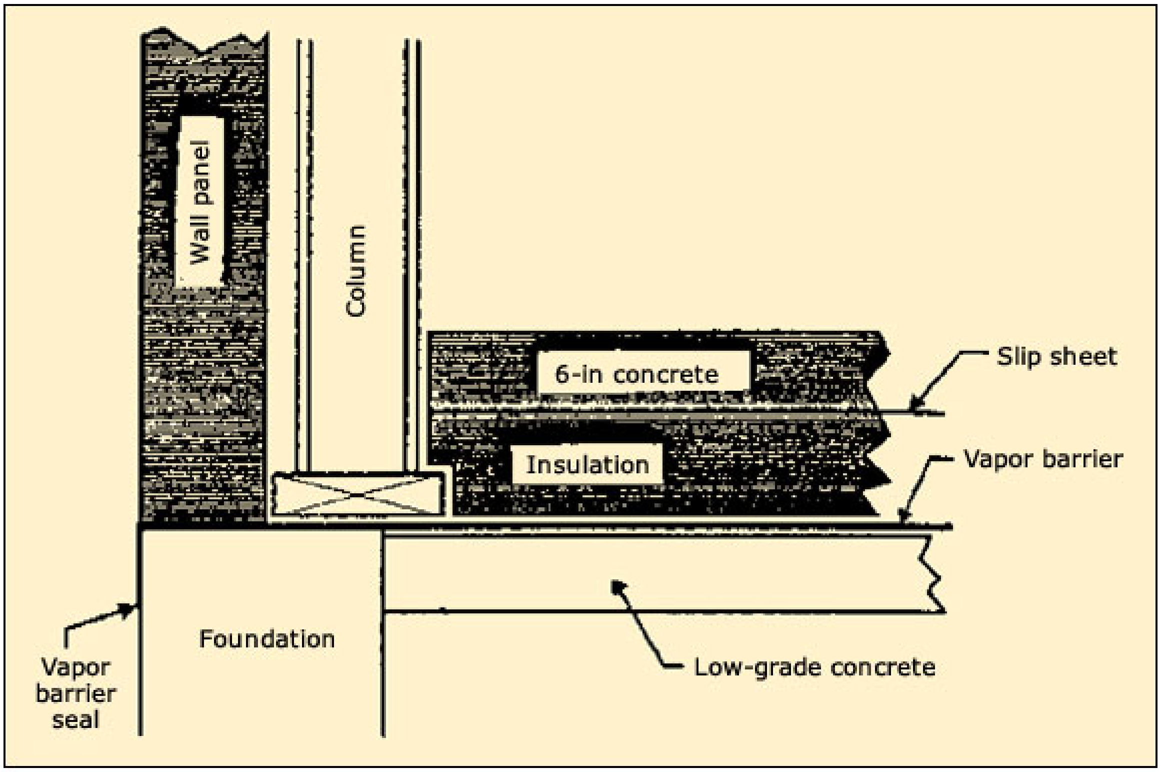

Figure 7 : Position of vapor barrier and slip sheet

This second layer or 'slip sheet' as it is referred to, is not to be considered as a vapor barrier and hence it is advisable not to seal all joints as carefully as one would in the first layer of polyethylene which acts as the real vapor barrier. Should water go past the vapor barrier due to any opening in the barrier it is better for it to travel right through the insulation and slip sheet and be deposited onto the unit cooler instead of staying inside the insulation and ruining its insulation value.

Since the insulation must withstand the compressive stress of the concrete as well as the weight of pallets and fork-lift trucks, if used, its inherent compressive strength must be factored into its selection.

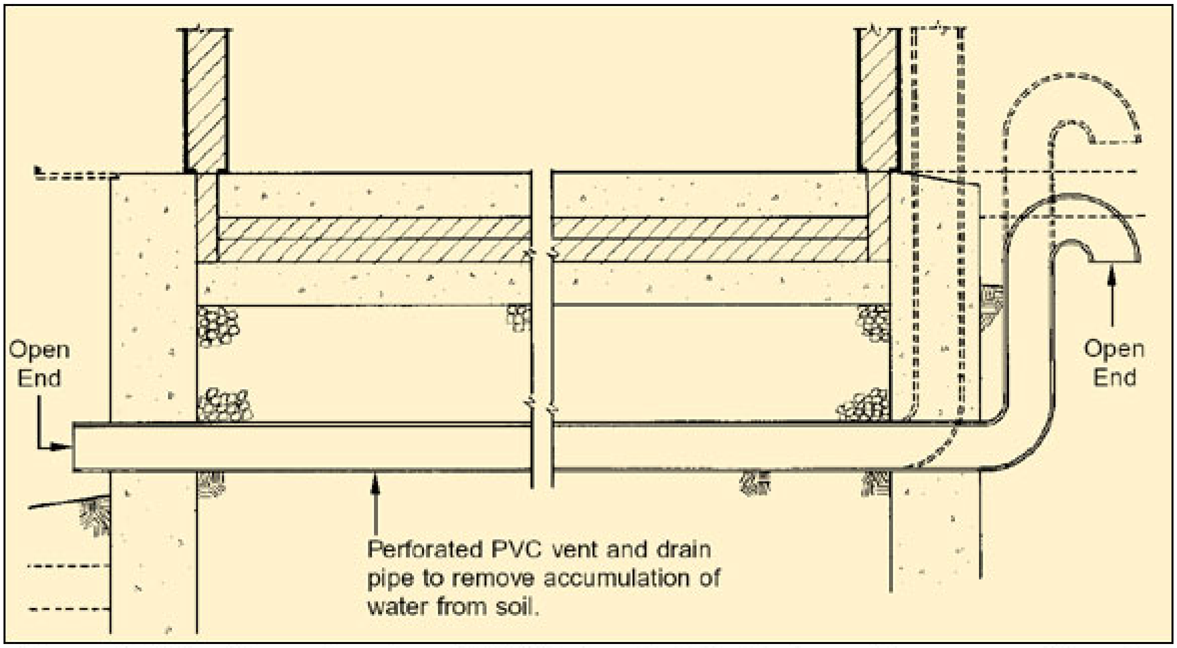

Figure 8 : Gravity vent system of PVC pipes installed below a freezer room floor to prevent freezing of sub-soil water. *Courtesy of Bally Inc., USA*

Under Floor Heating

Any cold store operating at subfreezing temperature with a concrete finished floor over insulation is subject to the possibility of ice formation under the floor, which if not protected by some form of heating, can cause the concrete floor to crack and be pushed up. Because the soil beneath the floor contains moisture, it can freeze and expand causing the damage, unless some form of heating is incorporated to maintain the soil temperature high enough to prevent freezing, Low-voltage electric heaters or heated-glycol circulating piping can be installed below the insulation but these options are expensive and subject to failure. The gravity vent system is simpler and fool proof and consists of a series of PVC pipes 100 to 150 mm diameter at 1200 mm centres placed on a slope of approximately 1 in 50 to induce air drafts and placed in the soil right below the base slab. It must be ensured that the pipe ends are not blocked by dirt. See **Figure 8**.

Pressure Relief Valves

Pressure changes either inside or outside a low temperature cold room will cause large forces to act on wall and roof panels.

Pressure decrease occurs as the room is brought down to working temperature. Panels can be deflected inwards and doors may be difficult to open. Pressure increase occurs, as evaporator fans switch on after defrost or as produce is loaded. Panels can be deflected outwards and doors forced open.

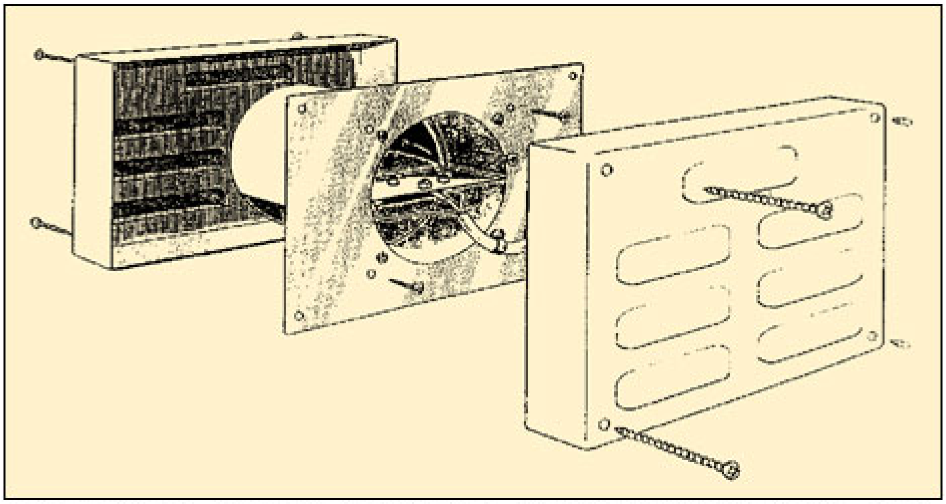

Figure 9 : A pressure relief valve. *Courtesy of Isowall Co., UK*

The pressure relief valve, see **Figure 9** equalizes internal and external pressures to reduce the possibility of these problems occurring. The number and size of the relief valves can be calculated using the following formula:

$$A = 0.063\,Q / \sqrt{P(T + 273)}$$

Where A is the required venting area in m², Q is the rate of heat production or extraction in the cold store in kW, T is the cold store temperature in °C and P is the allowable pressure difference from store to outside, in N/m² or Pa.

It is recommended that at least the following Q values should be considered when determining the maximum possible value of Q to be used in the formula:

- Maximum possible rate of extraction.
- Maximum possible rate of heat input during defrosting.
- Maximum rate of heat input during any possible transient conditions, such as might arise after a defrost, if cold air were blown through a hot finned cooler.

Loading Docks

Used for in-loading of products to be stored as well as out-loading the refrigerated products from and to delivery trucks. They should be as spacious as possible because of the high activity levels. They should also be well lit and temperature controlled to about 5°C. The loading dock acts as a buffer between the temperature controlled areas and the ambient.

Dock Levellers

Since a variety of trucks will be bringing in and taking out the products, it is necessary to provide a 'dock leveller' that can cope with differing floor heights of trucks. As a guide, the dock leveler should be long enough to keep the slope down to the lowest vehicle no more than 10%. See **Photo 3**.


Photo 3 : A typical Dock Leveler. *Courtesy of Pioneer, USA*

Photo 4 : A typical Dock Seal. *Courtesy of Pioneer, USA*

Photo 5 : A typical Dock Shelter. *Courtesy of Pioneer, USA*

Dock levellers can be electrohydraulically operated or manual. They can have a fixed lip, a folding lip or a hydraulically operated lip. The more vehicle movements there are, the better is the case for hydraulic assistance to raise and lower the leveller.

Dock Seals, Dock Shelters and Overhead Doors

To provide a good seal between the truck door opening and the loading dock, a 'dock seal' with a stationary foam - filled header provides a tight seal at the sides and top o f the truck. If the dimensions of the vehicle are known a n d unlikely to vary, these stationary seals provide a reasonably tight seal preventing hot humid air from the outside infiltrating into the dock area. See **Photo 4**.

With varying sizes, inflatable dock seals using a built-in small blower can make universal sealing of all sizes of vehicles a possibility. Since such inflatable seals can be expensive, a 'dock shelter' with rubber flaps on the sides and top of the shelter can provide a snug fit between varying vehicle sizes and the dock. See **Photo 5**.

Finally, in order to seal off the loading dock from the several truck access openings, a segmented manual or power operated overhead door is installed at each dock seal or dock shelter, for security reasons, openable only from the inside of the dock area. See **Figure 10**.

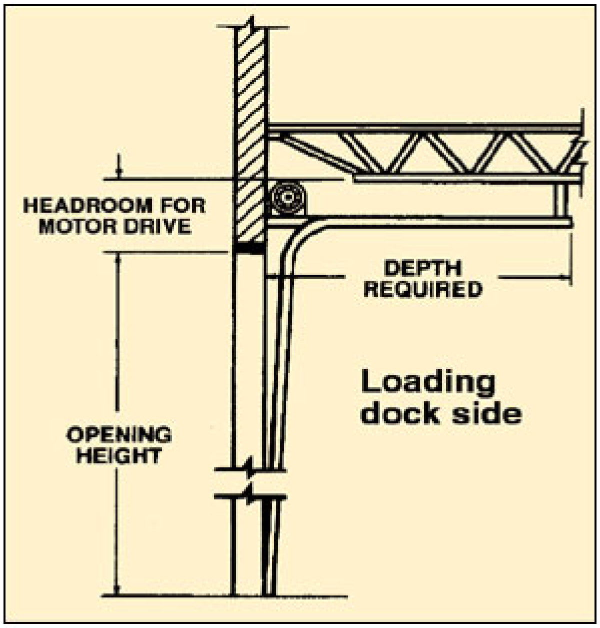

Figure 10 : A section across a typical Overhead Dock Door.
Courtesy of Wayne Dalton, USA

Insulated Doors

Access to a cold store must be through an insulated door designed with insulation equivalent in value to that of the wall insulation and constructed using a rigid frame or a heavy duty metal channel incorporating a thermal break between the internal and external temperatures. Door frames should be of material not only capable of supporting the door, but also constructed to ensure the integrity of the wall panels to which the frames are fitted.

Photo 6 : A typical protection barrier in the shape of a goalpost with a Bi-Parting Horizontal Sliding Power Operated door. *Courtesy of Jamison Door Co., USA*

Where doors are installed in a sub-freezing room, heater elements must be provided on doors or door frames to prevent sticking due to ice build-up.

All door hardware should be corrosion-resistant and large enough to ensure the easy operation of doors.

Since doors are subject to frequent handling and abuse they must be extremely well designed, rugged and manufactured by specialist insulated door manufacturers, particularly since the variety of door designs is vast and outside the range of all insulated panel manufacturers.

All doors installed in a cold store must be protected from damage by fork lift trucks moving in and out of doors at high speeds. The commonest form of protection is in the shape of a goalpost, securely bolted to the floor. All such protection barriers should be boldly painted in black and yellow stripes for easy identification. See **Photo 6**.

Curbs

Medium to large size cold storages used for bulk storage or warehousing with a concrete floor should have a concrete or steel curb, 20cm high by 15 cm deep placed along the inside perimeter of the room.

The curb protects the insulated panels from damage by a fork lift or stored products and also maintains refrigeration efficiency by keeping the products away from the walls, thus allowing circulation fo cool air all around the product. See **Figure 11**.

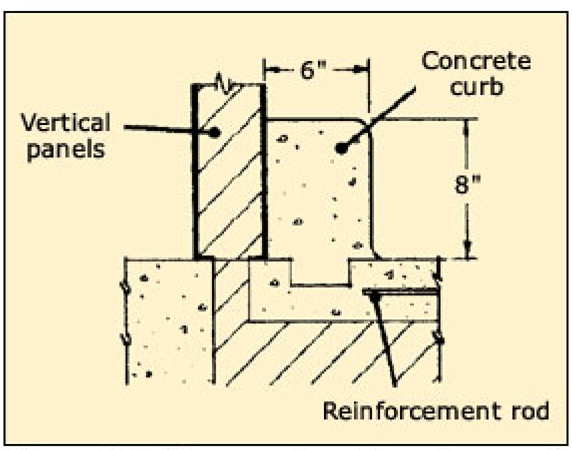

Figure 11 : A concrete curb protects wall panels from damage and provides space for air circulation around stored products

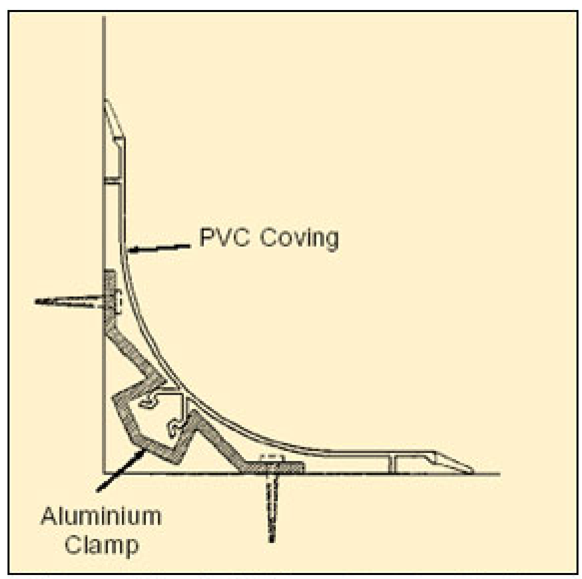

Figure 12 : A PVC coving installed in a sharp corner between two walls or wall/ ceiling. *Courtesy of Isowall Co., UK*

Coving

The food industry frowns when they see sharp corners, wherever walls meet or along the corners formed by ceiling and wall panels or floor and wall panels. Corners tend to collect dirt and small pieces of stored products and are difficult to keep clean and become a breeding area for bacteria when food products deteriorate.

Rounded corners or 'covings' made of PVC, aluminium or stainless steel can be obtained from specialist manufacturers of such accessories and installed as shown in **Figure 12**.

Floor Channels

PVC channels are also available for bolting on a finished concrete floor along the perimeter of the room and used to provide a support to the wall panels installed on the floor. Different widths of such channels are available to suit varying panel thickness.

Conclusion

Designing and installing a medium to large size refrigerated storage warehouse using prefabricated insulated panels, calls for experience and knowledge, not only, of refrigeration equipment but also of panel installation, steel supporting framework, cold storage doors and their proper mounting, loading docks, dock seals, dock shelters and a host of small, but important details that help in putting together a structure to satisfy the users for a long period of time. Before carrying out this activity users should employ knowledgeable and experienced consultants and contractors to save themselves endless problems and costs.

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