THE COOL FACTS

A Guide to Refrigerated Facility Design, Operation and Maintenance

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VERSICO ROOFING SYSTEMS

BUILDING VALUE

REFRIGERATED FACILITY DESIGN, OPERATION AND MAINTENANCE

This guide to refrigerated facilities design, operation and maintenance is compiled of information published by the EPA (Environmental Protection Agency), USDA (United States Department of Agriculture) and OSHA (Occupational, Safety and Health Administration). Information pertaining to building envelope design, minimum insulation recommendations and recommended seals has been gathered from ASHRAE publication Chapter 13, " Refrigerated Facility Design".

Information contained herein is intended for use by Versico employees, and sales representatives/distributors to increase their familiarity with the design requirements, operation and maintenance of cold storage/freezer facilities.

Information concerning Versico's minimum requirement to warrant a roofing system on a refrigerated facility can be found in the Versico applicable specification published separately.

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REFRIGERATED FACILITY **DESIGN**

Refrigerated facilities are any buildings or sections of a building that achieve controlled storage conditions using refrigeration. Two basic storage facilities are:

1. Coolers that protect commodities at temperatures usually above 32°F.
2. Low-temperature rooms (freezers) operating under 32°F to prevent spoilage or to maintain or extend product life.

The conditions within a closed refrigerated chamber must be maintained to preserve the stored product. Specific items for consideration include:

- Uniform temperatures
- Effective relative humidity
- Effect of air movement on employees
- Controlled ventilation, if necessary
- Expected duration of storage

In the United States, the U.S. Public Health Service Food and Drug Administration developed the Food Code (FDA 1997), which consists of model requirements for safeguarding public health and ensuring that food is unadulterated. The code is a guide for establishing standards for all phases of handling refrigerated foods. It treats receiving, handling, storing, and transporting refrigerated foods and calls for sanitary as well as temperature requirements. These standards must be recognized in the design and operation of refrigerated storage facilities.

Regulations of the Occupational Safety and Health Administration (OSHA), Environmental Protection Agency (EPA), the U.S. Department of Agriculture (USDA), and other standards must also be incorporated in warehouse facility and procedures.

The five categories for the classification of refrigerated storage for preservation of food quality are:

- Controlled atmosphere for long-term storage of fruits and vegetables
- Coolers at temperatures of 32°F and above
- High-temperature freezers at 27 to 28°F
- Low-temperature storage rooms for general frozen products, usually maintained at -10 to -20°F
- Low-temperature storages at -10 to -20°F, with a surplus of refrigeration for freezing products received at above 0°F

It should be noted that due to ongoing research, the trend is toward lower temperatures for frozen foods.

Configuration and Size Determination

Building configuration and size of a cold storage facility are determined by the following factors:

- **What relative percentages of merchandise are for cooler and for freezer storage?** Products requiring specially controlled conditions, such as fresh fruits and vegetables, may justify or demand several individual rooms. Seafood, butter, and nuts also require special treatment. Where overall occupancy may be reduced because of seasonal conditions, consideration should be given to providing multiple-use spaces.
- **What percentage is anticipated for long-term storage?** Products that are stored long term can usually be stacked more densely.
- **Will the product be primarily in small or large lots?** The drive-through rack system or a combination of pallet racks and a mezzanine have proved effective in achieving efficient operation and effective use of space. Mobile or moving rack systems are also plausible.
- **How will the product be palletized?** Dense products such as meat, tinned fruit, drums of concentrate, and cases of canned goods can be stacked very efficiently. Palletized containers and special pallet baskets or boxes effectively hold meat, fish, and other loose products. The slip sheet system, which requires no pallets, eliminates the waste space of the pallet and can be used effectively for some products. Pallet stacking racks make it feasible to use the full height of the storage and palletize any closed or boxed merchandise.

Stacking Arrangement

Typically, the height of the refrigerated spaces is at least 28 to 35 feet or more clear space between the floor and structural steel to allow forklift operation.

Generally, 6 to 10 feet minimum clear height is required from top of product to bottom of support structure to ensure there is no interference with drain pan and draft lines of air units. Greater clear heights are usually required if automated or mechanized equipment is used.

The floor area in a facility where diverse merchandise is to be stored can be calculated on the basis of 8 to 10 pounds per gross cubic foot to allow about 40% for aisles and space above the pallet stacks. In special-purpose or production facilities, products can be stacked with less aisle and open space, with an allowance factor of about 20%.

Essential Items:

- Refrigerated shipping docks with seal-cushion closures on the doors
- Blast freezer or separate sharp freezer room for isolation of products being frozen
- Cooler or convertible space

Shipping and Receiving Docks

Regulations on temperature control during all steps of product handling have led to designing the trucking dock as a refrigerated anteroom to the cold storage area. Dock refrigeration is an absolute necessity in humid and warm climates. Maintaining the dock at 35 to 45° F offers the following advantages:

- Refrigeration load in the low-temperature storage area, where energy demand per unit capacity of refrigeration is higher, is reduced.
- Less ice or frost forms in the low-temperature storage because less humid air and warm air infiltrates into the area.
- Refrigerated products held on the dock maintain a more favorable temperature, thus maintaining product quality.
- Packaging remains in good condition because it stays drier. Facility personnel are more comfortable because temperature differences are smaller.
- Less maintenance on forklifts and other equipment is required because condensation is reduced.
- Need for anterooms or vestibules to the freezer space is reduced or eliminated.
- Floor areas stay drier, particularly in front of freezer door areas. This assists in housekeeping and improved safety.

Utility Space (Safety)

Electrically operated material-handling equipment is used to eliminate inherent safety hazards of combustion-type equipment. Battery-charging areas should be designed with high roofs and must be ventilated due to the potential for combustible fumes resulting from the charging activity.Specialized Storage Facilities

Material handling methods and storage requirements often dictate design of specialized storage facilities. Automated material handling within the storage, particularly for high stack piling, may be an integral part of the structure or require special structural treatments. Controlled atmosphere rooms and minimal air circulation rooms require special building designs and mechanical equipment to achieve design requirements. Drive-in and/or drive-through rack systems can improve product inventory control and can be used in combination with stacker cranes, narrow-aisle high stacker cranes, and automatic conveyors. Mobile racking systems may be considered where space is at a premium.

In general, specialized storage facilities may be classified as follows:

- Public refrigerated facility with several chambers designed to handle all commodities. Storage temperatures may range from 35 to 60°F (with humidity control) and to -20°F (without humidity control).
- Mechanized refrigerated facility with stacker cranes, racks, in-feed and out-feed conveyors, and conveyor vestibules. Such as facility may have an interior ceiling 60 to 100 feet high. Evaporators should be mounted in the highest internal area to help remove moisture from outside air infiltration. A penthouse to house the evaporators can be accessed through doorways into the penthouse on the roof for maintenance, providing a means of controlling condensate drip, and allowing added rack storage space in the freezer area.

Controlled Atmosphere Storage Rooms

Controlled atmosphere storage rooms may be required for storing some commodities, particularly fresh fruits and vegetables that respire, consuming oxygen (O_2) and producing carbon dioxide (CO_2) in the process. The storage life of such products may be greatly lengthened by a properly controlled environment, which includes control of temperature, humidity, and concentration of non-condensable gases (O_2, CO_2, and nitrogen). Hermetically sealing the room to provide such an atmosphere is a challenging undertaking, often requiring special gaslight seals. Although information is available for some commodities, the desired atmosphere usually must be determined experimentally for the commodity as produced in the specific geographic location that the storage room is to serve.

Commercial application of controlled atmosphere storage as historically been limited to fresh fruits and vegetables that respire. The storage spaces may be classified as having either:

1. Product-generated atmospheres, in which the room is sufficiently well sealed that the natural oxygen consumption of the fruit balances the infiltration of O_2 into the space; or
2. Externally generated atmospheres, in which nitrogen generators or O_2 consumers assist the normal respiration of the fruit. The second type of system can cope with a poorly sealed room, but the cost of operation may be high; even with the external gas generator system, a hermetically sealed room is desired.

In most cases, a CO_2 scrubber is required; the exception is the case where the total desired O_2 and CO_2 content is 21%; which is the normal balance between O_2 and CO_2 during respiration.

Among the systems of room sealing to prevent outside air infiltration are:

1. Galvanized steel lining the walls and ceiling of the room and interfaced into a floor sealing system;
2. Plywood with an impervious sealing system applied to the inside face;
3. Carefully applied sprayed urethane finished with mastic, which also serves as a fire retardant.

A room is considered sufficiently sealed if, under uniform temperature and barometric conditions:

- 1 hour after the room is pressurized to 1 inch of water gauge, 0.1 to 0.2 remains.
- A room with external gas generation is considered satisfactorily sealed if it loses pressure at double the above rate.
- A room with product-generated atmosphere should have one air change of the empty room in a 30-day period.

Extreme care in all details of construction is required to obtain a seal that passes the tests outlined above.

Controlled atmosphere rooms in multi-floor buildings, where the structure deflects appreciably under load, are extremely difficult to seal.

Gasket seals are normally applied at the cold side of the insulation, so they may be easily maintained and points of leakage can be detected. However, this placement causes some moisture entrapment, and the insulation materials must be carefully selected so the moisture causes minimal damage. In some installations, cold air with a dew point lower than the inside surface temperature is circulated through the space between the gas seal and the insulation to provide drying of this area.

Refrigerated Rooms

Refrigerated rooms may be appropriate for long-term storage at temperatures other than the temperature of the main facility, for bin storage, for controlled atmosphere storage, or for products that deteriorate with active air movement. Mechanically cooled walls, floors, and ceilings may be economical options for controlling the temperature. Embedded pipes or air spaces through which refrigerated air is re-circulated can provide the cooling; with this method, heat leakage is absorbed into the walls and prevented from entering the refrigerated space.

The following must be considered in the initial design of the room:

- Initial cool-down of the product, which can impose short-term peak loads
- Service loads when storing and removing product
- Odor contamination from products that deteriorate over long periods
- Product heat of respiration

Supplementary refrigeration or air-conditioning units in the refrigerated room that operate only as required can usually alleviate such problems.

Construction Methods

Cold storage, more than most construction, requires correct design, quality materials, good workmanship, and close supervision. Close cooperation between the general, roofing, insulation, and other contractors increases the likelihood of a successful installation.

Enclosure construction methods can be classified as:

1. Insulated structural panel
2. Mechanically applied insulation
3. Adhesive or spray-applied foam systems. These construction techniques seal the insulation within an airtight, moisture tight envelope that must not be violated by major structural components.

Three methods are used to achieve an uninterrupted vapor retarder/insulation envelope:

1. The first and simplest is total encapsulation of the structural system by an exterior vapor retarder/insulation system under the floor, on the outside of the walls, and over the roof deck. This method offers the least number of penetrations through the vapor retarder, as well as the lowest cost.
2. The second method is an entirely interior system in which the vapor retarder envelope is placed within the room and insulation is added to the walls, floors, and suspended ceiling. As with an exterior system, the moisture barrier is best applied to the outside of the enclosures. This technique is used where walls and ceilings must be washed, where an existing structure is converted to refrigerated space, or for smaller rooms that are located within large coolers or unrefrigerated facilities or are part of a food-processing facility. Special purpose rooms will require separate analysis to determine proper moisture barrier location.
3. The third method is interior-exterior construction, which involves an exterior curtain wall of masonry or similar material tied to an interior structural system. Adequate space allows the vapor retarder/insulation system to turn up over

a roof deck and be incorporated into a roofing system, which serves as the vapor retarder. This construction method is a viable alternative, although it allows more interruptions in the vapor retarder than the exterior system.

The total exterior vapor retarder system is the best because it has the fewest penetrations and the lowest cost. Areas of widely varying temperatures should be divided into separate envelopes to retard heat and moisture flow between them.

Space Adjacent to Envelope

Condensation at the envelope is usually caused by high humidity and inadequate ventilation. Poor ventilation occurs most often within a dead air space such as a ceiling plenum, hollow masonry unit, through-metal structure, or beam cavity. All closed air spaces should be eliminated, except those large enough to be ventilated adequately. Ceiling plenums, for instance, are best ventilated by mechanical vents that move air above the envelope.

All steel beams, columns, and large pipes that project through the insulation should be vapor-sealed and insulated. Conduit, small pipes, and rods should be insulated at four times the regular wall insulation thickness. In both cases, the thickness of insulation on the projection should be half that on the regular wall or ceiling.

Other considerations include the following:

- Vapor retardants should be placed on the warm side of insulation systems
- Prefabricated, self-locking wall panels also serve as vapor barriers
- Roof vapor membranes are often used; these large rubber sheets are laid over roof insulation, overlapped, sealed, and attached to the roof with non-penetrating fasteners or covered with small stone ballast, which is light-colored to help reflect solar heat

Air/Vapor Treatment at Junctions

Air and vapor leakage at wall/roof junctions is perhaps the predominant construction problem in cold storage facilities.

When a cold room of interior-exterior design is lowered to operating temperatures, the structural elements (roof deck and insulation) contract and can pull the roof away from the wall. Negative pressure in the space of the wall/roof junction can cause warm, moist air to leak into the room and form frost and ice. Therefore, proper design and construction of the air/vapor seal is critical.

An air/vapor flashing system is best for preventing leakage. This is a transition from the roof system vapor retarder to the exterior wall system vapor retarder. A good corner-flashing sheet must be flexible, tough, airtight, and vapor tight. Proper use of flexible insulation at overlaps, mastic adhesive, and a good mastic sealer ensure leak-free performance.

To remain airtight and vapor tight during the life of the facility, a properly constructed vapor retarder should:

- Be flexible enough to withstand building movements that may occur at operating temperatures.
- Allow for thermal contraction of the insulation as the room is pulled down to operating temperature.
- Be constructed with a minimum of penetrations that might cause leaks. (Wall ties and structural steel that extend through the corner flashing sheet may eventually leak no matter how well sealed during construction; keep these to a minimum, and make them accessible for maintenance.)
- Have corner flashing sheet properly lapped and sealed with adhesive and mechanically fastened to the wall vapor retarder.
- Have corner flashing sealed to roof without openings.
- Have floor to exterior vapor retarders that are totally sealed.

Poor design and shoddy installation cause moist air leakage into the facility, resulting in frost and ice formation, energy loss, poor appearance, loss of useful storage space, and, eventually, expensive repairs.

Floor Construction

Refrigerated facilities held above freezing need no special under-floor treatment. A below-the-floor vapor retarder is needed in facilities held below freezing, however. In these facilities, the subsoil eventually freezes; any moisture in this soil also freezes and causes floor frost heaving. In warmer climates, under floor tubes vented to ambient air may be sufficient to prevent heaving. Artificial heating, either by air circulated through under floor ducts or by glycol circulated through plastic pipe, is the preferred method to prevent frost heaving. Electric heating cables installed under the floor can also be used to prevent frost formation. The choice of heating method depends on energy cost, reliability, and maintenance requirements. Air duct systems should be screened to keep rodents out and sloped for drainage to remove condensation.

Wearing slab heating under the dock area in front of the freezer doors will help eliminate moisture at the door and floor joints.

Surface Preparation

Where room temperatures are to be below freezing, masonry walls should be leveled and sealed with cement back plaster. Smooth poured concrete surfaces may not require back plastering.

The surface must be warm and dry for a sprayed foam system. Any cracks or construction joints must be prepared to prevent projection through the sprayed insulation envelope. All loose grout and dust must be removed to ensure a good bond between the sprayed foam insulation and the surface. Very smooth surfaces may require special bonding agents.

No special surface preparation is needed for insulated panels used as a building lining, assuming the surfaces are sound and reasonably smooth. Grade beams and floors should be true and level where panels serve as the primary walls.

Finishes

Insulated structural panels with metal exteriors and metal or reinforced plastic interior faces are prevalent for both coolers and freezers. They keep moisture from the insulation, leaving only the joints between panels as potential areas of moisture penetration. They are also available with surface finishes that meet government requirements.

For sanitary wash downs, a scrubbable finish is sometimes required. Such finishes generally have low permeance; when one is applied on the inside surface of the insulation, a lower-permeance treatment is required on the outside of the insulation.

All insulated walls and ceilings should have an interior finish. The finish should be impervious to moisture vapor and should not serve as a vapor retarder, except for panel construction. The permeance of the in-place interior finish should be significantly greater than the permeance of the in-place vapor retarder.

Suspended Ceilings

The space above the ceiling must be ventilated at a minimum of six air changes per hour to minimize the possibility of condensation. Roof-mounted exhaust fans and uniformly spaced vents around the perimeter of the plenum may be used. The mechanical ventilators should be thermostat and humidistat controlled to turn off when the outside air temperature is below 50°F or the outside humidity is 60% rh. At these conditions, condensation rarely occurs, and the ventilation only reduces the insulating effect of the dead air space.

Floor Drains

Floor drains should be avoided if possible, particularly in freezers. If they are necessary, they should have short, squat dimensions and be placed high enough to allow the drain and piping to be installed above the insulation envelope.

Electrical Wiring

Heat tracing is suggested inside the freezer only from the air-handling unit drain outlet panel to the insulated wall panel. Heat tracing within the wall could be a possible fire hazard and cannot be serviced. Drain tracing can continue external to the freezer on a separate electrical circuit.

Tracking

Cold room meat tracking, wherever possible, should be erected and supported within the insulated structure, entirely independent of the building itself. This eliminates flexure of the roof structure or overhead members, and simplifies maintenance.

Cold Storage Doors

Doors should be strong yet light enough for easy opening and closing. Hardware should be of good quality, so that it can be set to compress the gasket uniformly against the casing. All doors to rooms operating below freezing should be equipped with heaters.

In-fitting doors are not recommended for rooms operating below freezing unless they are provided with heaters, and they should not be used at temperatures below 0°F with or without heaters.

Refrigerated Docks

Refrigerated docks maintained at temperatures of 35 to 45°F require about 5 tons of refrigeration per 1000 square feet of floor area; however, actual load calculation should be done per AHSRAE methodology.

Schneider System

The Schneider system, and modifications thereof, is a cold storage construction and insulation method primarily used in the western United States, with most of the installations in the Pacific Northwest. It is an interior-exterior vapor system. The structure uses concrete tilt-up walls and either glue-laminated wood beams or bowstring trusses for the roof. Fiberglass batts coupled with highly efficient vapor retarders and a support framework are used to insulate the walls and the roof. The floor slab construction, insulation, and under floor heat are conventional for refrigerated facilities.

The key to success for the Schneider system is an excellent vapor retarder system that is professionally designed and applied, with special emphasis on the wall/roof junction. Fiberglass has a high permeability rating and loses its insulating value when wet. It is therefore absolutely essential that the vapor retarder system perform at high efficiency. Typical wall vapor retarder materials include aluminum B foil and heavy-gauge polyethylene, generously overlapped and adhered to the wall with a full coating of mastic. The roofing materials act as a vapor retarder for the roof. The vapor retarder at the wall/roof junction is usually a special aluminum foil assembly installed to perform efficiently in all weather conditions.

The fiberglass insulation applied to the wall is usually 10 to 12 inches thick for freezers and 6 to 8 inches thick for coolers. It is retained by offset wood or fabricated fiberglass-aluminum sheathed studs on 24-inch centers. Horizontal girts are used at intervals for bracing. The inside finish is provided by 1 inch thick perforated higher-density fiberglass panels that can breathe to allow any moisture that passes through the vapor retarder to be deposited as frost on the evaporator coils.

The fiberglass insulation applied to the roof structure is usually 12 to 14 inches thick for freezers and 8 to 10 inches for coolers and is applied between 2 by 12 inch or 2 by 14 inch joists that span the glue-laminated wood beams, purlins, or trusses. The exterior finish is the same as described for walls. Battens attached to the underside of the joists hold the finish panels and insulation in place.

Choice of Refrigerant

The choice of refrigerant is a very important decision in the design of present-day refrigerated facilities. Typically ammonia has been used, particularly in the food and beverage industries, but R-22 has been and continues to be used as well. Some low-temperature facilities now also use R-507, which is one of the replacements of choice for R-502 and R-22.

Factors to consider when choosing refrigerants include:

- Cost
- Safety code issues (i.e., code requirements regarding the use of refrigerant in certain types of occupied spaces)
- System refrigerant charge requirements
- State and local codes, which may require full- or part-time operators with a specific level of expertise
- Effects on global warming and ozone depletion (ammonia has no effect on either)

Load Determination

The refrigeration loads for refrigerated facilities of the same capacity vary widely. Many factors, including building design, indoor and outdoor temperatures, and especially the type and flow of goods expected and the daily freezing capacity, contribute to the load.

Load factors to be considered include:

- Heat transmission through insulated enclosures
- Heat and vapor infiltration load from warm air passing into refrigerated space and improper air balance
- Heat from pumps or fans circulating refrigerant or air, power equipment, personnel working in refrigerated space, product-moving equipment, and lights
- Heat removed from goods in lowering their temperatures from receiving to storage temperatures
- Heat removed in freezing goods received unfrozen
- Heat produced by goods in storage

Heat leakage or transmission load can be calculated using the known overall heat transfer coefficient of various portions of the insulating envelope, the area of each portion, and the temperature difference between the lowest cold room design temperature and the highest average air temperature for three to five consecutive days at the building location. For freezer storage floors on ground, the average yearly ground temperature should be used.

Heat infiltration load varies greatly with the size of the room, number of openings to warm areas, protection on openings, traffic through openings, and cold and warm air temperatures and humidities. Calculation should be based on experience, remembering that most of the load usually occurs during daytime operations.

Vapor Retarder System

The primary concern in the design of a low-temperature facility is the vapor retarder system, which should be as close to 100% effective as is practical. The success or failure of an insulation envelope is due entirely to the effectiveness of the vapor retarder system in preventing water vapor transmission into and through the insulation.

The driving force behind water vapor transmission is the difference in vapor pressure across the vapor retarder. Once water vapor passes a vapor retarder, a series of detrimental events begin. The water migrating into the insulation diminishes the thermal resistance of the insulation and eventually destroys the envelope. Ice formation inside the envelope system usually grows and physically forces the building elements apart to the point of failure.

Another practical function of the vapor retarder is to stop air infiltration. The driving force behind infiltration can be atmospheric pressure or ventilation.

After condensing or freezing, some of the water vapor in the insulation re-vaporizes or sublimes and is eventually drawn to the refrigeration coil and disposed of via the condensate drain, but the amount removed is usually not sufficient to dry out the insulation unless the vapor retarder break is located and corrected.

The vapor retarder must be located on the warm side of the insulation. Each building element inside the prime retarder must be more permeable than the last to permit moisture to move through it, or it becomes a site of condensation or ice. This precept is abandoned for the sake of sanitation at the inside faces of coolers. However, the inside faces of freezers are usually permitted to breathe by leaving the joints uncaulked in the case of panel construction or by using less permeable surfaces for other forms of construction. Factory-assembled insulation panels endure this double vapor retarder problem better than other types of construction.

In walls with insufficient insulation, the temperature at the inside wall surface may during certain periods reach the dew point of the migrating water vapor, causing condensation and freezing. This can also happen to a wall that originally had adequate insulation but, through condensation or ice formation in the insulation, lost part of its insulating value. In either case, the ice deposited on the wall will gradually push the insulation and protective covering away from the wall until the insulation structure collapses.

It is extremely important to properly install vapor retarders and seal joints in the vapor retarder material to ensure continuity from one surface to another (i.e., wall to roof, wall to floor, or wall to ceiling). The failure of vapor retarder systems for refrigerated facilities is almost always due to poor installation. The contractor must be competent and experienced in the installation of vapor retarder systems to be able to execute a vapor tight system.

Condensation on the inside of the cooler is unacceptable because:

1. The wet surface provides the culture base for bacteria growth.
2. Any dripping onto the product gives cause for condemnation of the product in part or in whole.

Stagnant or dead air spots behind beams or inside metal roof decks can allow localized condensation. This moisture can be from within the cooler or freezer (i.e., not necessarily from a vapor retarder leak).

There is no 100% effective vapor retarder system. A system is successful when the rate of moisture infiltration equals the rate of moisture removal by refrigeration, with no detectable condensation.

Types of Insulation/Insulated Panels

Rigid Insulation – Insulation materials, such as polystyrene, Polyisocyanurate and polyurethane have proven satisfactory when installed with the proper vapor retarder and finished with materials that provide protection from fire and form a sanitary surface. Selection of the proper insulation material should be based primarily on the economics of the installed insulation, including the finish, sanitation, and fire protection.

Panel Insulation – The use of prefabricated insulated panels for insulated wall and roof construction is widely accepted. These panels can be assembled around the building structural frame or against masonry or precast walls. Panels can be insulated at the factory with either polystyrene or urethane. Other insulation materials do not lend themselves to panelized construction.

The basic advantage, besides economics, of using insulated panel construction is that repair and maintenance are simplified because the outer skin also serves as the vapor retarder and is accessible. This is of greater benefit if the structure is to be enlarged in the future. Proper vapor retarder tie-ins then become practical.

Foam-in-Place Insulation – This application method has gained acceptance as a result of developments in polyurethane insulation and equipment for installation. Portable blending machines with a spray or frothing nozzles feed insulation into the wall, floor, or ceiling cavities to fill without joints the space provided for monolithic insulation construction. This material has no usable vapor resistance; its application in floor construction should be limited.

Precast Concrete Insulation Panels – This specialized form of construction has been successful when proper vapor retarder and other specialized elements are incorporated. As always, vapor retarder continuity is the key to a successful installation.

Insulation Thickness

The R-value of insulation required varies with the temperature held in the refrigerated space and the conditions surrounding the room. The table below shows recommended R-values for different types of facilities. The range in R-values is due to variations in energy cost, insulation materials, and climatic conditions. Insulation with R-values lower than those shown should not be used.

Recommended Insulation R-Values

Type of Facility	Temperature Range, °F	Thermal Resistance R, °F · ft² · h/Btu		
		Floors	Walls/ Suspended Ceilings	Roofs
Coolers[1]	40 to 50	Perimeter insulation only	25	30 to 35
Chill Coolers[1]	25 to 35	20	24 to 32	35 to 40
Holding Freezer	-10 to -20	27 to 32	35 to 40	45 to 50
Blast Freezers[2]	-40 to -50	30 to 40	45 to 50	50 to 60

Note: Because of the wide range in the cost of energy and the cost of insulation materials based on thermal performance, a recommended R-value is given as a guide in each of the respective areas of construction.

[1]If a cooler has the possibility of being converted to a freezer in the future, the owner should consider insulating the facility with the higher R-values from the freezer section.

[2]R-values shown are for a blast freezer built within an unconditioned space. If the blast freezer is built within a cooler or freezer, consult a designer and/or insulation supplier.

Applying Insulation

Roofs

Suspended insulated ceilings, whether built-up or prefabricated, should be adequately ventilated to maintain near-ambient conditions in the plenum space; this minimizes both condensation and deterioration of vapor retarder materials. Permanent sealing is needed around insulating hanger rods, columns, conduit, and other penetrations.

The structural designer usually includes roofing expansion joints when installing insulation on top of metal decking or concrete structural slabs for a building larger than 100 feet by 100 feet. Because the refrigerated space is not normally subject to temperature variations, structural framing is usually designed without expansion or contraction joints if it is entirely enclosed within the insulation envelope.

Board insulation laid on metal decking should be installed in two or more layers with the seams staggered.

Walls

Wall construction must be designed so that as few structural members as possible penetrate the insulation envelope. Insulated panels applied to the outside of the structural frame prevent conduction through the framing. Where masonry or concrete wall construction is used, structural framing must be independent of the exterior wall. The exterior wall cannot be used as a bearing wall unless a suspended insulated ceiling is used.

Where interior insulated partitions are required, a double column arrangement at the partition prevents structural members from penetrating the wall insulation. For satisfactory operation and long life of the insulation structure, envelope construction should be used wherever possible.

Governing codes for fire prevention and sanitation must be followed in selecting a finish or panel. For conventional insulation materials other than prefabricated panels, a vapor retarder system should be selected.

Abrasion-resistant membranes, such as 10-mil thick black polyethylene film with a minimum of joints, are suitable vapor retarders. In refrigerated facilities, contraction of the interior finish is of more concern than expansion because temperatures are usually held far below installation ambient temperatures.

Floors

Freezer buildings have been constructed without floor insulation, and some operate without difficulty. However, the possibility of failure is so great that this practice is seldom recommended.

Under floor ice formation, which causes heaving of floors and columns, can be prevented by heating the soil or fill under the insulation. Heating can be by air ducts, electric heating elements, or pipes through which a liquid is re-circulated.

The air duct system works well for smaller storages. For a larger storage, it should be supplemented with fans and a source of heat if the pipe is more than 100 feet long. The end openings should be screened to keep out rodents, insects, and any material that might close off the air passages. The ducts must be sloped for drainage to remove condensed moisture. Perforated pipes should not be used.

The pipe grid system is usually best because it can be designed and installed to warm where needed and can later be regulated to suit varying conditions. A heat exchanger in the refrigeration system, steam, or gas engine exhaust can provide a source of heat for this system. The temperature of the re-circulated fluid is controlled at 50 to 70°F, depending on design requirements. Almost universally, the pipes are made of plastic.

The pipe grid system is usually placed in the base concrete slab directly under the insulation. If the pipe is metal, a vapor retarder should be placed below the pipe to prevent corrosion. The fluid should be an antifreeze solution such as propylene glycol with the proper inhibitor.

The amount of warming for any system can be calculated and is about the same for medium-sized and large refrigerated spaces regardless of ambient conditions. The calculated heat input requirement is the floor insulation leakage based on the temperature difference between to 40°F under floor earth and room temperature (e.g., 50°F temperature difference for a -10°F storage room). The flow of heat from the earth, about 1.3 Btu/h per square foot of floor, serves as a safety factor.

Freezer Doorways

An important factor in warehouse productivity is maintaining safe working conditions at doorways in high-usage freezers. At doorways, infiltration air mixes with air inside the freezer, forming airborne ice crystals. These crystals can accumulate on walls, ceilings, and nearby appurtenances.

Other Considerations

Temperature Pulldown

Because of the low temperatures in freezer facilities, contraction of structural members in these spaces will be substantially greater than in any surrounding ambient or cooler facilities. Therefore, contraction joints must be properly designed to prevent structural damage during facility pulldown.

The first stage of temperature reduction should be from ambient down to 35°F at whatever rate of reduction the refrigeration system can achieve.

The room should then be held at that temperature until it is dry. Finishes are especially subject to damage when temperatures are lowered too rapidly. Portland cement plaster should be fully cured before the room is refrigerated.

If there is a possibility that the room is airtight (most likely for small rooms, 20 feet by 20 feet maximum), swinging doors should be partially open during pulldown to relieve the internal vacuum caused by the cooling of the air, or vents should be provided. Permanent air relief vents are needed for continual operation of defrosts in small rooms with only swinging doors. Both conditions of possible air heating during defrost and cooling should be considered in design of air vents and reliefs.

The concrete slab will contract during pulldown, causing slab/wall joints, contraction joints, and other construction joints to open. At the end of the holding period (i.e., at 35°F), any necessary caulking should be done.

An average time for achieving dryness is 72 hours. However, there are indicators that may be used, such as watching the rate of frost formation on the coils or measuring the rate of moisture removal by capturing the condensation during defrost.

After the refrigerated room is dry, the temperature can then be reduced again at whatever rate the refrigeration equipment can achieve until the operating temperature is reached. Rates of 10°F per day have been used in the past, but if care has been taken to remove all the construction moisture in the previous steps, faster rates are possible without damage.

Fire Protection

Local regulations may require ceiling isolation smoke curtains and smoke vents near the roof in large refrigerated chambers. These features allow smoke to escape and help firefighters locate the fire.

Inspection and Maintenance

Buildings can change in dimension due to settling, temperature change, and other factors; therefore, cold storage facilities should be inspected regularly to spot problems early, so that preventive maintenance can be performed in time to avert serious damage.

Inspection and maintenance procedures fall into two areas: basic system (floor, wall, and roof/ceiling systems) and apertures (doors, frames, and other access to cold storage rooms).

Basic System Inspection and Maintenance

- Stack pallets at a sufficient distance (18 inches) from walls or ceiling to permit air circulation.
- Examine walls and ceiling at random every month for frost buildup. If buildup persists, locate the break in the vapor retarder.
- For insulated ceilings below a plenum, inspect the plenum areas for possible roof leaks or condensation.
- If condensation or leaks are detected, make repairs immediately.

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