The product to be handled in a refrigerated facility defines the building’s function. Will the incoming product be fresh or frozen? If the product is fresh, how much and what kind of further processing will there be done in the facility? This consideration will define the need for ice production and handling, special cutting, portioning, or other processing and/or cooking machinery.

Will the further-processed product then be frozen? What the freezing requirements will be is a function of several factors. The quantities to be frozen, how they are prepared and how they are packaged all enter into the choice of process freezing method. Handling of the product, freezing time, and both capital and operating costs are also primary considerations.

There are two process freezing techniques - contact freezing and air blast freezing. Contact freezers typically have lower operating costs, particularly from the standpoint of the amount of refrigeration required to accomplish the freezing and the cost of the associated energy required to do the freezing.

Contact freezers are most commonly referred to as plate freezers, as the freezing media are flat plates to which the food products are brought into direct contact. The plates are hollow between the two flat surfaces which the product contacts. Cold refrigerant flows through the hollows, chilling the plate surfaces and thus freezing the product. There are two configurations of plate freezers - horizontal and vertical, referring to the planes in which the plates lie in the freezer. Figure 1 is a photo of a vertical plate freezer, which is very common in seafood processing. Vertical plate freezers are used for both packaged and unpackaged product.
Horizontal plate freezers are most commonly used for packaged product. It is important to note there are limitations on the kind of packaging that either vertical or horizontal plate freezers can handle, relative to the shape of the package. Moreover, the plate spacing must be mechanically set for a given size package so that only one package size can be accommodated at a time. If it is desired to process a different size package, the plate spacing must be reset. This is an obvious limitation to the versatility of the plate freezer.

Air blast freezers are also produced in two varieties: batch and continuous. Batch-type air blast freezers are of quite simple construction and are thus much lower cost than continuous freezers. Figure 2 is a sketch that schematically describes a batch-type blast freezer. Typically they are used for packaged and palletized product, although they are also used for loose product in totes, barrels and bins. A blast freezer of this type is often comprised of a small room that can be closed off from the rest of the facility, but with a large door for ease of access with fork trucks, a rack system for holding the product in a preset geometric array during freezing and a powerful air-cooling unit.
Product handling in these kinds of blast freezers includes some extra steps in that when the product is initially palletized, spacers must be placed between each layer of cartons to allow for air circulation. After freezing, the spacers must be removed and the product re-stacked. There are machines that do this, but they are costly and the steps must still be taken, whether they are done manually or mechanically.

Figure 3 is an artist’s rendering of one style of continuous freezer - the spiral freezer, the spiral referring to the configuration of the conveyor system that carries the product through the freezer. Typically, unpackaged product is frozen in this kind of freezer. It too comprises a room that is closed off from the rest of the facility, the only openings in which are the conveyor openings for the inflow and outflow of the product, and access doors for personnel. The cooling coils are typically very large and the fans are mounted remotely from the cooling coils so they can be located strategically to optimize airflow for the most efficient cooling.
Continuous freezers like this are very costly and are typically applied to high-volume production. They are, however, extremely flexible, that is, capable of handling many different kinds, sizes and shapes of product - in some circumstances several different ones at the same time. Also, because the product is unpackaged or minimally wrapped, freezing times are very short, which contributes to its high-volume capability.

The primary reason why contact freezers are less costly to operate is that they do not use fans for air movement. The cooling is accomplished by direct contact of product with a surface that is in direct contact with the refrigerant. The fans in either of the types of air-blast freezers require a significant amount of energy to operate. Of course, the fans are also located in the cooled space so that the heat generated by their motors adds to the cooling load in the space which the refrigerating system must take care of in addition to the product load.

When the facility is for storage-only the design considerations and the refrigerating system are simpler than for a processing facility. There are still many issues that must be addressed in order for the completed facility to be able to provide the greatest utility and the most effective and efficient refrigeration.
The first consideration is the operating temperature of the facility. Figure 4 is a graphical representation of the average storage life of approximately a dozen different species of Pacific Northwest seafood versus storage temperature. While there is considerable variation in actual numbers from species to species, on average lowering the storage temperature from 0°F to −20°F doubles the storage life of the product, from approximately seven months to approximately 14 months. That, of course, refers to how long it can be held without sacrificing quality.

Figure 4: Average storage life of approximately a dozen common Pacific Northwest seafood species with relation to storage temperature.
The selection of a low operating temperature, while extremely beneficial from a product durability and quality standpoint, is not without cost. Figure 5 is a graphical representation of the relative cost of power, for the operation of a refrigerating system, versus storage temperature. Assuming an arbitrary cost of power, per unit of refrigeration, of unity at $0^\circ$ F, the cost of the power for the same amount of refrigeration would be 1.35 at $-20^\circ$ F, or 35% greater.

Moreover, the actual amount of cooling that would be required for the same size freezer holding the same amount of product would also be greater. For any given ambient (outside) temperature, the lower the temperature in the freezer the greater will be the amount of heat that enters the room.
through the walls and ceiling insulation and through the door when it is opened. That increased amount of heat entering the freezer increases the amount of refrigeration required to cool it.

The receiving temperature of the product also has an impact on the refrigeration requirement. Even with the product arriving at the facility already frozen, it imposes a load on the refrigerating plant if its temperature is higher than the storage temperature maintained within the facility. The refrigerating plant must be able to cool the product down to the storage temperature. The lower that storage temperature is than the temperature at which the product is received, the greater the cooling load.

Other cooling load elements are likewise affected, as will be scrutinized later. In the aggregate, it is not impossible that the refrigerating requirement could be 20%, or more, greater at a −20°F storage temperature than at a 0°F storage temperature. That would bring the actual cost of the energy to operate the system to more than 60% more at the lower storage temperature than at the higher storage temperature.

Finally, with the amount of refrigeration required at the lower storage temperature being greater than that at the higher temperature, more, or larger, refrigerating equipment is required to do the cooling. Moreover, the capacity of the primary refrigerating machinery diminishes as the operating temperature is lowered, further affecting the size, and therefore the cost, of the refrigerating plant. The capital cost could increase as much as 50% between 0°F storage temperature and −20°F storage temperature.

Once the decision of storage temperature has been made, the actual storage room size and arrangement must be determined. Numerous factors enter into those decisions. The primary factors are product related. What exactly is the product to be stored? How many different varieties of products will there be and in particular how will they be packaged? What will be the density of a typical SKU? How many cartons will be loaded on a pallet? What will be the stacked height of a pallet and what will a full pallet weigh?
The primary factor determining the size and layout of the storage is the amount of product to be held and for what duration. The final design will be based on those two factors, additionally influenced by material handling considerations. Storage volume turnover is the annual product receipts divided by the normal total amount of product in storage.

The answers to these questions lead to the selection of a rack system design, which must be made in conjunction with the decision(s) on specific material handling equipment. In particular, the selection of type(s) and size(s) of fork truck affects a number of other decisions about the facility design. It affects, or is interconnected with, such wide ranging parameters as type of rack system, rack layout, building layout, sizes and locations of freezer doors and sizes of aisles.

The selection of a truck type is based on lift capacity, lift height, mast height, overall length of the truck and its maneuverability, which in turn affect the design particulars of the rack system and certain aspects of the building.

Figure 6: General-purpose material mover

Figure 6 is a photo of a general-purpose material mover. It is relatively compact (front-to-back), maneuverable, because of its three-point wheel arrangement and rear-wheel steering, and swift in
straight-line motion. It is ideal for loading and unloading trucks with palletized product as well as moving pallets quickly from one location to another within the facility. Figure 7 is a photo of a reach truck, in this case a double-reach able to move product in and out of double-deep racks. Figure 8 is a photo of a high-lift reach truck operating in a freezer.

Figure 7: Double-reach truck used with double-deep racks.
Figure 8: High-lift truck.

Figure 9 is an illustration that allows one to see how important the selected fork truck(s) is to the design of the building. The overall collapsed height (OACH) of the truck, that is, the height of the top of the mast with the forks just clear of the ground, is the limiting parameter for the clear-height requirement of doors. For front-wheel steering trucks in particular, such as reach trucks, the overall length of the truck determines the minimum aisle width for maneuverability.
The rack layout is engineered to provide the maximum usable storage volume in the freezer while minimizing the amount of handling required of a product during the time it is in storage. Design criteria considered includes rack height, that is, the number of tiers and the rack arrangement, single-deep, double deep or some other arrangement. The two most common types of racks are select and drive-in.

Figure 10 shows a single-deep select rack and Figure 11 shows a double-deep select rack. Figure 12 shows a rack arrangement called double-deep, back-to-back. For longer-term storage products, this particular rack arrangement is generally the most cost effective and efficient from a space utilization standpoint. Figure 13 shows a double-deep, back-to-back select-rack system just being erected.
Figure 10: Example of a single-deep select rack.

Figure 11: Example of a double-deep select rack.
Figures 14 and 15 show double-deep drive-in racks. The name implies how they are used. Simpler, less complicated fork trucks can be used with these racks — reach trucks are not required - but there are logistical issues to be considered. If there is product stored on a lower tier at the aisle and an upper tier is unused, such as in Figure 16, it is not possible to drive into the rack to set product on the upper tier without moving the product on the lower tier out of the way. On the other hand,
because there is no interference or timing problems to contend with, drive-in racks are what are used for blast freezers.

Figure 14: Example of double-deep, drive-in rack system.

Figure 15: Another example of double-deep, drive-in racks.
Figure 16: Why it is important to carefully select rack systems.

Figure 17 is a hypothetical layout of a 10,000 square foot freezer that would provide approximately 1,050 pallet stations, with a 4-tier high rack, or space for approximately 1,000,000 pounds of product, at 1,000 lb/pallet and 95% utilization. Obviously, the taller the building and the higher the rack the more storage that can be made available in a given footprint, which enhances the economy of the design. However, other considerations also affect the economics of the design. For example, above a certain height of the rack system, “in-rack” fire sprinklers are specified by code, which drives costs up.
Figure 17: Hypothetical layout of one million pound cold storage.

The building considerations include the layout of the building, that is, the floor plan, and construction details such as foundation and floors, envelope construction, insulation and utilities.

The building layout is determined by ease of use; that is, where are things located relative to accessibility and material handling resources. These considerations encompass such things as the receiving and shipping of product, building maintenance and worker amenities. The things that need to be considered are the size, shape and location of the freezer within the building and particularly the quantity and location of freezer doors, how shipping and receiving areas are to be arranged, truck access to the property and to the building and parking and whether there is to be rail access. Also, where are the mechanical, electrical, and battery charging areas, and offices, to be located? Is there to be a maintenance shop or parts stores and other things such as pallet storage and repair, fork truck parking, and packaging, stacking, palletizing and wrapping machinery locations, if used?
Foundation and floor design will primarily be determined by whether or not permafrost is a consideration. If it is, special construction methods developed specifically for contending with permafrost are likely to be required. For non-permafrost sites, heated ground techniques must be employed, with the heat commonly coming from the refrigerating system.

The choice of envelope construction is based on sturdiness, to hold up to a harsh environment, and something that will require the minimum amount of maintenance. Some of the choices are built-up masonry, tilt-up pre-cast panels and insulated panels. It also includes the choice of insulating material. The factors that go into the decision of the choice of insulation are durability, cost, fire rating and thermal performance.

<table>
<thead>
<tr>
<th>Type of Insulation</th>
<th>4&quot; Thickness R-value</th>
<th>Relative Cost (1)</th>
<th>Flammability (2) (3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expanded Polystyrene (EPS)</td>
<td>15.4</td>
<td>0.38</td>
<td>Material melts and forms a flammable liquid</td>
</tr>
<tr>
<td>Extruded Polystyrene (XEPS)</td>
<td>20.0</td>
<td>0.74</td>
<td>Material melts and forms a flammable liquid</td>
</tr>
<tr>
<td>Polyurethane</td>
<td>23.5</td>
<td>0.71</td>
<td>1.2 – 3.0</td>
</tr>
<tr>
<td>Polyisocyanurate</td>
<td>23.5</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Molded Glass</td>
<td>12.1</td>
<td>3.2</td>
<td>Non-flammable</td>
</tr>
</tbody>
</table>

Notes:
1) Ratio of the approximate cost of the insulation-only to the cost of polyisocyanurate, at the same R-value
2) Dimensionless comparison of flame-spread velocity
3) Architectural issues that include insurance considerations

Table: Insulation options.
The table of insulation-comparisons outlines key relative performance and cost factors. The cost comparison column is for the necessary thickness of the insulation to provide the same R-value as polyisocyanurate. The costs are as a ratio to the cost of polyisocyanurate. Polyisocyanurate is taken as the comparison basis as it is often the preferred material because of its superior fire rating, compared to the other flammable insulation materials. The lowest cost insulation is expanded polystyrene (EPS) or beadboard. The highest cost is molded glass which has the benefit of being non-flammable.

Even when polyisocyanurate is chosen for the majority of the insulation in a building, the predominant choice of insulation for floors is extruded polystyrene (XEPS) because of its superior resistance to moisture permeation and absorption. It is also frequently used in built-up roofs.

Design considerations for electrical utilities include selecting operating voltages and determining the reliability of the supply. Might standby generation be required? This is particularly likely to be needed if there is to be process freezing going on in the facility. Loss of power in a storage-only facility is not disastrous. Shutdowns due to loss of power for as long as three days have been experienced, in warm weather, in the Southern US with no loss of product. A winter shutdown in Chicago due a snow emergency left a plant without power for seven days with no product loss.

Other utilities that need consideration in the design development are water for fire sprinklers, domestic use, and processing and heating fuel. Also, will there be any special water treatment for effluent required?

There are a number of choices for the refrigerating plant, including the type of system and equipment and choice of refrigerant. The types of system available are the central plant and the distributed system, comprised of multiple sets of unitary equipment. Figure 18 is a schematic diagram that describes the central plant system. In a central system, a machine room, compressors, (typically several to include standby and redundancy), operate in close proximity to pressure vessels and other system specialties, all interconnected by field-erected piping. A condenser is mounted outdoors near the compressors. The cooling units are located in the refrigerated spaces throughout the plant with the interconnecting piping running between them and the central machine room.
Figure 18: Schematic of a central plant refrigeration system.

Figure 19 is a photo of a large machine room of an ammonia system showing five large screw compressors, the system pressure vessels, and refrigerant pumps in the far right-hand corner. Figure 20 is a photo of the outside of a machine room showing three evaporative condensers, the condenser piping, and some of the piping that runs between the machine room and the rest of the plant, in this case over the roof. There are two different styles of forced-draft condenser and an induced-draft condenser shown. Figure 21 is a photo of one of the screw compressors in the machine room.
Figure 19: Photo of a large ammonia refrigeration system machine room.

Figure 20: Photo of three evaporative condensers.
Figure 21: Photo of one screw compressor in machine room.

Figure 22 is a photo of a machine room with 10 semi-hermetic compressors, several pressure vessels, and controls. The condenser for this system is just outside the machine room. Figure 23 is a photo of a typical air-cooled condenser, which is the type of condenser often used with semi-hermetic compressors. However, the actual decisions concerning the choice of condenser is based on plant operating conditions, power consumption, and maintenance issues.

Figure 22: Machine room with semi-hermetic compressors and related equipment.
Figure 23: Photo of typical air-cooled condenser.

Figure 24 is a photo of a typical air-cooling unit, which would be universally applicable. A unit of this type would be used as part of a central plant system or a distributed system and with any refrigerant. The only effect on the air-cooling unit that the choice of refrigerant would have would be the materials of construction. The basic design of the unit, however, would be the same.

Figure 24: Photo of air-cooling unit.

Figure 25 is a schematic diagram that describes a unitary refrigerating system used in distributed refrigeration plants. A compressor and a condenser are combined in a single factory-packaged unit, along with certain specialties and controls, in a cabinet. This unit is called a “condensing unit”. It is completely self-contained. It is engineered to match capacities with one or two specific air-cooling units. The installation consists of mounting the condensing unit, typically on the roof, immediately above where the air-cooling unit will be hung from the ceiling in the refrigerated space.
Figure 25: Schematic of unitary refrigeration system.

Figure 26 is a photo of two condensing units in place on a roof. Figure 27 is a photo of a refrigerated room with two air-cooling units located in an aisle. These units would be connected to the condensing units on the roof above them by two short runs of pipe.
There are a number of advantages to central plant refrigerating systems over distributed systems. First, any refrigerant can be utilized — ammonia or HFCs, although semi-hermetic compressors are commonly limited to use with HFCs. Second, the defrosting method can be hot gas defrost, which has been shown to have a lower operating cost than electric defrost, the common alternative in some systems. Built-in redundancy is easily added and either air-cooled or water-cooled condensers can be used. Finally, certain heating requirements can be supplied by the refrigerating system, such as the heat for the ground warming system.
There are also some disadvantages to central plant refrigerating systems. First, a machinery room is required. That affects the design and cost of the entire building. The controls are more complex and there is more piping required. A larger refrigerant inventory is required to charge the system than for unitary equipment and smaller systems, less than 200-250 hp, often have a higher first cost.

Ammonia systems have a number of advantages over HFC systems, including robust system designs, heavy-duty, and reliable equipment. Ammonia equipment can be used with HFC refrigerants as well, a highly efficient operation. Ammonia systems have some disadvantages as well. Ammonia is listed as hazardous chemical as pertains to certain OSHA regulations (CFR 1910.119) and therefore must be covered by special management procedures. These include complex and costly administrative controls for systems containing more than 10,000 pounds of refrigerant. The equipment in ammonia systems requires regular maintenance by skilled technicians and the skilled-labor pool available for this type of work is limited.

Distributed systems have advantages as well. The installed cost is low for small to medium size systems, there is minimal piping required, and there is a very small refrigerant inventory, which is important when utilizing HFC refrigerants, which are very costly. There is a very low maintenance requirement.

The main disadvantage to unitary equipment is that its operating efficiency is poor - they have a very high energy cost and there is little or no capital cost advantage for systems larger than 300 hp.

Economic aspects of refrigerated warehouses comprise two categories of costs, capital costs and operating costs. Capital costs are made up of construction cost and outfitting. The primary operating costs are payroll and energy. On average the energy consumption in a typical storage freezer warehouse breaks down as

- Battery Charging 15 - 20%
- Refrigeration 70 - 75%
- Lighting and Miscellaneous 10%
The factors that affect the cost of operation of a refrigerating plant are the refrigerating system efficiency, based primarily on the system type and the refrigerant. Other factors that affect plant operation are weather, product receipt temperature, and product inventory turnover.

LOAD SUMMARIES 1-4

**LOAD SUMMARY 1 - TYPICAL**

10,000 sq. ft. -20° F Storage Freezer @ Anchorage, AK

<table>
<thead>
<tr>
<th>Load Element</th>
<th>Load (Tons)</th>
<th>Percent of Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmission (1)</td>
<td>8.0</td>
<td>25</td>
</tr>
<tr>
<td>Product (2)</td>
<td>3.0</td>
<td>9</td>
</tr>
<tr>
<td>Internal generation</td>
<td>8.1</td>
<td>26</td>
</tr>
<tr>
<td>Infiltration (3)</td>
<td>7.8</td>
<td>25</td>
</tr>
<tr>
<td>Defrost (4)</td>
<td>1.8</td>
<td>6</td>
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<tr>
<td>Safety factor</td>
<td>2.9</td>
<td>9</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>31.8</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

Notes:
1) Based on R-25 walls and floor and R-42 roof
2) Based on 100,000 lb/day into freezer @ 0° F
3) Based on 8' x 8' high-speed unprotected door open to unrefrigerated dock
4) Electric defrost cooling units as part of a distributed refrigerating system
## LOAD SUMMARY 2 - TYPICAL

10,000 sq. ft. -20° F Storage Freezer @ Anchorage, AK

<table>
<thead>
<tr>
<th>Load Element</th>
<th>Load (Tons)</th>
<th>Percent of Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmission (1)</td>
<td>8.0</td>
<td>30</td>
</tr>
<tr>
<td>Product (2)</td>
<td>3.0</td>
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</tr>
<tr>
<td>Internal generation</td>
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<td>30</td>
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<tr>
<td>Infiltration (3)</td>
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<tr>
<td>Defrost (4)</td>
<td>1.0</td>
<td>4</td>
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<tr>
<td>Safety factor</td>
<td>2.4</td>
<td>9</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>26.7</strong></td>
<td><strong>100</strong></td>
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</tbody>
</table>

Notes:

1) Based on R-25 walls and floor and R-42 roof
2) Based on 100,000 lb/day into freezer @ 0° F
3) Based on 8' x 8' high-speed door, with strips, open to unrefrigerated dock
4) Electric defrost cooling units as part of a distributed refrigerating system
### LOAD SUMMARY 3 - TYPICAL

10,000 sq. ft. –20°F Storage Freezer @ Anchorage, AK

<table>
<thead>
<tr>
<th>Load Element</th>
<th>Load (Tons)</th>
<th>Percent of Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmission (1)</td>
<td>8.0</td>
<td>26</td>
</tr>
<tr>
<td>Product (2)</td>
<td>3.0</td>
<td>10</td>
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<tr>
<td>Internal generation</td>
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<tr>
<td>Infiltration (3)</td>
<td>7.8</td>
<td>25</td>
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<tr>
<td>Defrost (4)</td>
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</tr>
<tr>
<td>Safety factor</td>
<td>2.8</td>
<td>9</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>30.9</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

Notes:

1) Based on R-25 walls and floor and R-42 roof
2) Based on 100,000 lb/day into freezer @ 0°F
3) Based on 8' x 8' high-speed unprotected door open to unrefrigerated dock
4) Hot gas defrost cooling units as part of a central-plant refrigerating system
The load summaries 1 - 4, provide illustrations of several of the issues affecting building design, refrigerating plant size and, therefore, capital cost and operating cost. The estimated loads are peak loads, based on summer outside conditions. The transmission load is the heat that enters the freezer through the walls, roof and floor. As can be seen, for the model selected, the transmission loss is a maximum of 30% of the total load.

In the case of Load Summary 4, doubling the insulation thickness would reduce the total transmission load by approximately 16% (including a proportionate reduction in the safety factor), but would increase the cost of the insulation by approximately 75%. The reduction in load may or may not affect the size of the refrigerating machinery because of the stepped nature of the capacities
of available equipment. Also, the percentages apply only to summer conditions. In cooler times of the year the differences in load are commensurately smaller as, accordingly, are the operating cost savings. However, the savings may not warrant the increased cost of the insulation. There is an optimum economic thickness of insulation, based primarily on the cost of energy.

Product load, in these cases, is based solely on all product being received already frozen. The load is based on the assumption that, although frozen, the product will be warmer than the storage room and will have to be cooled to room temperature. In the case of plants that will also be doing process freezing, the product load will likely be the largest single component of the total.

Internal generation loads are unavoidable heat loads that are only minimally controllable. They are such things as the heat given off by lights, fork trucks, people and the air-cooling unit fan motors.

Infiltration is a very large source of heat that must be removed by the refrigeration. It is the heat that enters the freezer in the warm air each time the door is opened. There are a number of things that can be done to minimize that load. One of the most significant things that can be done is to refrigerate the dock or other area immediately adjacent to the freezer, where the doors are. That, however, complicates, and adds to the cost of the refrigerating plant and the economic benefit needs to be analyzed on an individual basis.

Another thing that is almost universally applied is plastic strip curtains on the freezer door openings. As can be seen by comparing Load Summaries 1 and 2, the difference is great. Strips, however, are a high-maintenance item and commonly must be repaired or replaced often.

Finally, the defrosting of the air-cooling units adds heat to the space, more for electric defrost units than for hot gas defrost units. Which type of unit would be utilized would depend on the type of refrigerating system is selected. Unitary equipment is most often electric defrost.

The size of refrigerating plant required is directly and almost linearly proportional to the size of the freezer. Figure 28 is a set of curves of total refrigerating plant connected horsepower versus freezer
size. Of particular interest here is the comparison between the peak power requirement of a central plant ammonia system and R-404A unitary equipment with hermetic compressors.

Figure 28: Refrigeration plant connected power versus freezer size.
In certain areas of Alaska, of course, the cost of power is very high. Figure 29 is a curve unit annual cost of power versus power rate, including the effects of hours of light activity and seasonal weather variations. At the higher tariffs, it can be economically advantageous to choose a system design for its operating cost benefits, even at a higher cost of construction. For example, for a 20,000 square foot freezer, with a cost of power of $0.24/kWh, the estimated difference in annual operating cost is almost $90,000.00, even including time utilization and seasonal weather effects.

Editor's Note: Contact author concerning all technical questions. Contact information below paper title.