COLD STORAGE

FOR SPECIALTY CUT FLOWERS AND PLANT MATERIAL

Cooling is one of the most important steps in bringing fresh specialty cut flower materials from the grower to the marketplace. Low temperatures provide many advantages to extend vaselife by;

- reducing respiration and internal breakdown by enzymes
- reducing water loss and wilting
- slowing the growth of disease organisms
- reducing the production of ethylene
- providing "time" for proper handling, packaging and marketing.

Once harvested, flower quality cannot be improved, only maintained—deterioration cannot be reversed, only slowed. The cold storage facility should be dedicated to fresh flower holding and not be used for mixed storage of produce and flowers. Problems will arise with the ethylene production by fruit and vegetables that are fruits.

This publication will cover cold storage options, construction factors, equipment, and operation practices for fresh flower and plant material postharvest management. The information is valuable whether the market is for fresh flowers or for holding fresh material until it can be preserved.

Storage Options

As growers expand their production and markets from picking flowers the morning they deliver them to market, to harvesting several times a week for large wholesale markets, they will need to acquire cold storage facilities to ensure a high-quality product for their consumers. The grower has the following options for cold storage facilities:

- Built-in-place cold storage
- Adapted cold storage
- Prefabricated cold storage

Built-in-place cold storage can be constructed out of wood pole and post, steel and/or concrete block. The construction cost will depend on labor cost and on the type of materials used for the frame, walls, floor, ceiling and insulation. The design should consider where handling equipment is located and where handling procedures will be done so product flows smoothly in and out of cold storage. Space for future expansion is another consideration.

Figure 1, on page 6 and 7, shows a suggested plan for the construction of built-in-place cold storage. The Kansas State University Extension Biological and Agricultural Engineering Department has plans available for the construction of built-in-place cold storage. The plans include:

- USDA Plan 6228—Fruit and Vegetable Storage Room
- USDA Plan 6380—Farm Market Walk-in Refrigerator
- USDA Plan 6386—Two-Temperature Walk-in Refrigerator
- USDA Plan 6145—Refrigerated Storage Building

Although these are labeled for food crops they can be used as a reference to develop the most suitable option for the growers' needs.

Adapted cold storage is using an insulated container to transport refrigerated products. Examples include ice cream trucks, refrigerated railway cars and refrigerated semi-tractor trailers (figure 2).

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Figure 2. Refrigerated semi-tractor trailer

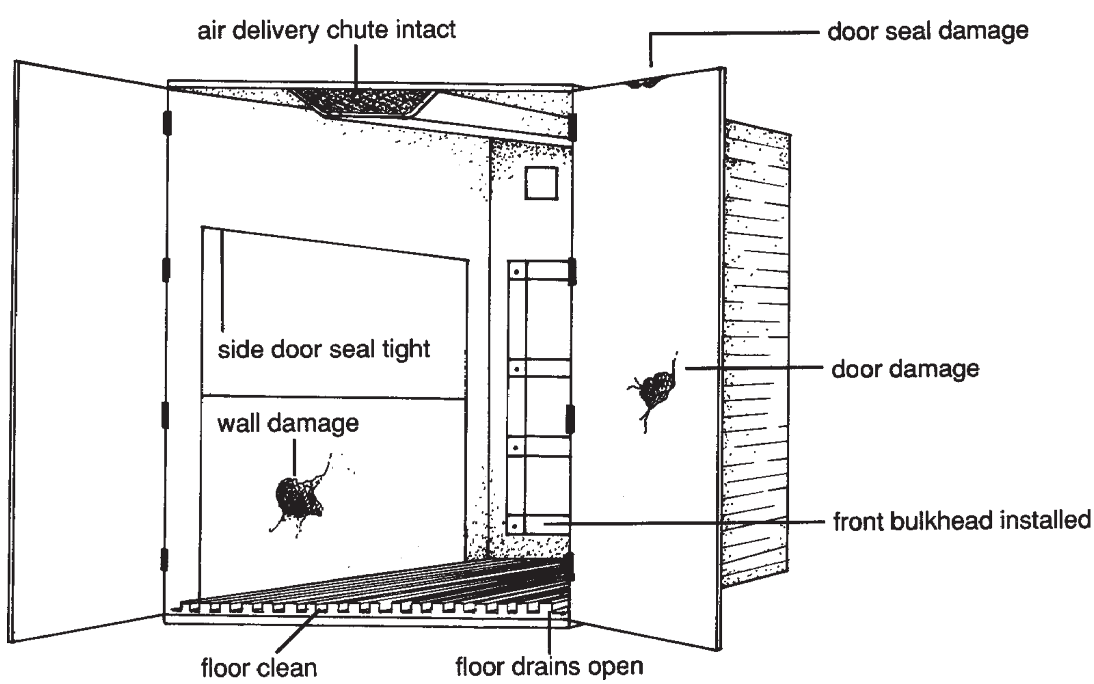


Figure 3. Inspection factors

When purchasing one of these units, special attention must be paid to the general condition of the container's insulation, door seals, wall covers, drains, air delivery chutes and refrigeration equipment (figure 3). The type of electricity needed to power the compressor motor, the refrigerant used, and what products are being transported are also important factors to consider. Some products leave residuals that are toxic to flowers. Sometimes, transportation of railway cars to the operation site may presents problem to the purchaser, as well as additional cost.

Prefabricated cold storage (figure 4) is probably the most commonly known. But unless it is a used one, it carries the highest price tag per cubic foot of the three options. When purchasing a used, prefabricated cold storage, the same attention must be paid to the components as with the adapted cold storage. This option can easily be transported, installed, relocated and maintained.

The best option will depend on the specific use of the facility and the cost to acquire and operate each.

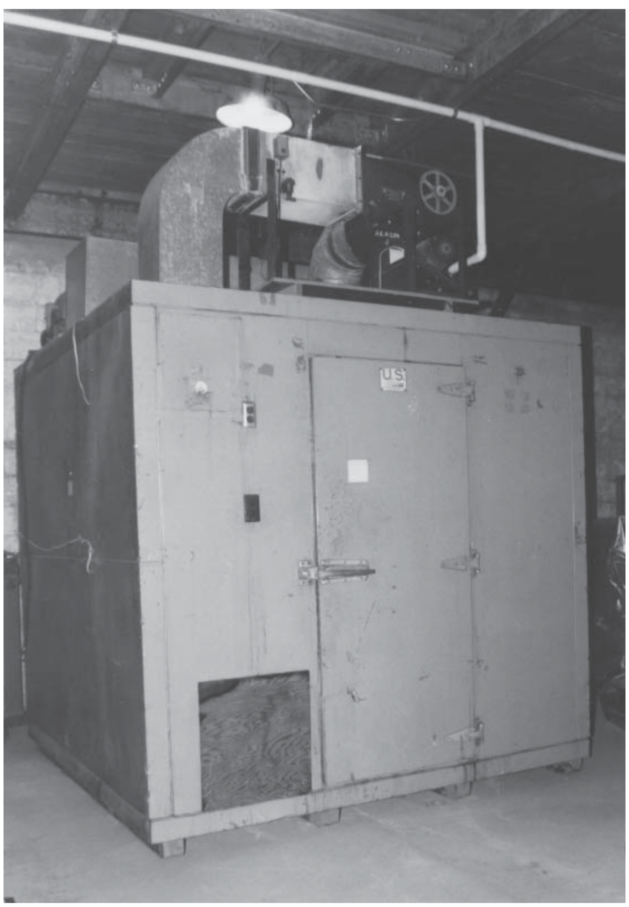


Figure 4. Prefabricated cooler

Storage Construction

Independent of the type of cold storage selected, there are several construction factors to be considered when cold storage is needed. These factors are site selection, size of the storage, structure and thermal insulation.

Site Selection. Marketing strategy will determine the type of cold storage and its location. For example, for retail sales, the cold storage and sale outlet must be close to a major road, and the area must have some parking space available. If the cold storage is mainly to store flowers before shipping to market, the facility should be close to the grading and packing room and have convenient access to fields. Also, there must be some space available for the movement and storage of empty containers, equipment, and supplies. Ideally, an area should be planned for any future expansion.

The cold storage needs to be placed in a well-drained area. It needs drains to remove water from condensation, cleaning and sanitation operations. The availability of utilities is another factor to consider. What natural and propane gas, electric and water utilities will the facility need? Is three-phase electricity available? The type of electricity available will determine the type of electric motors used to operate the compressor, fans and other equipment. When more than 10 tons of refrigeration are needed, three-phase electricity is necessary. Proximity to utilities could be a deciding factor; connection can be expensive. Availability of water is critical. Water is necessary for preservative solutions and for cleaning and sanitizing the cold storage and handling area. The water demand must be satisfied and the quality must be adequate. Also, wastewater disposal must be considered. Sewage service for restrooms is required if workers are operating in and/or around the cold storage. Natural and propane gas might be required for heating and drying operations.

Applicable laws, regulations, construction codes and zoning restrictions might affect where the cold storage is located. Construction codes, worker and health regulations should be examined when the storage is designed.

Size. To define the size of the cold storage, evaluate the following factors:

- Volume of product to store
- Product containers (boxes, hampers, buckets)
- Volume required per container
- Aisle space needed (mechanical or manual operation)
- Lateral and head space
- Available site space

As for dimensions, production schedules will dictate how much product will be moving in and out of the storage at any given time determining the amount of floor space needed. Since most flowers are stored wet in buckets and never stacked on shelves, the height of the storage need only be seven to eight feet. The amount of product to store and the type of containers for storage define the volume requirements. In defining size of the storage, peak storage and future needs must be considered. The following formula helps to define cold storage size:

$$V = v(C+S)$$

V is the total volume needs in cubic feet.

v is the volume occupied by one product container in cubic feet.

C is the maximum number of containers to be cooled at any one time.

S is the maximum number of containers to be stored at any one time.

The volume (V) obtained from the above formula does not include space for air circulation, aisles or walkways. An additional 40 percent of the volume occupied by one product container is used in stacking, spacing, and air circulation. As a rule of thumb, 25 percent of the floor area is devoted to aisles and walkways. If the storage involves mechanical operation, the aisles should be at least one and one-half times the width of the forklift.

The space available at the site for cold storage might be the major constraint in determining its size. In this case, special attention should be paid to operating needs of the facility during peak storage demand.

Structural and Thermal Insulation. Structure options were discussed earlier. In all the alternatives, slab floor is required. For most common applications, four inches of wire-mesh-reinforced concrete over two inches of waterproof plastic foam insulation board provides a good floor. For unusually heavy loads such as forklifts, semi-tractors and trailers, the slab floor should be five to six inches thick. Where ramps are required, they should have slope no greater than one to five.

The thermal insulation for the storage proposed must be cost effective and adequate for the proposed storage. Selection of insulation material is based on the R-value, resistance of the material to heat transfer movement, and its cost. Among insulation materials, loose fill cellulose is the cheapest, followed by batts and blankets, and the various foam sheet materials. The most expensive are the sprayed or foam-in-place materials. Loose fill cellulose has half the R-value per square foot per inch of thickness of sprayed-in-place materials (3.5 per inch for cellulose versus 6.5 per inch. for sprayed-in-place). However, the cellulose price is 20 to 30 times less per square foot per in of thickness than sprayed materials. Nonetheless, sprayed-in-place and foam-in-place materials provide good seals and reduce labor and material costs because they are relatively easy to apply, do not require interior panel, and reduce the wall or ceiling thickness.

Insulation is good as long as it is dry. To prevent condensation, install a vapor barrier on the “warm side” of insulation in the walls, ceiling and floor.

Cold storage must have the means to circulate air above the unit. This will prevent hot air in the summer from overloading refrigeration equipment. If the cold storage is under the same roof as the handling area, the packing area does not need as much insulation. The minimum insulation requirements for a small cold storage located in a warehouse or sheltered area are R-10 for the floor, R-20 for walls, and R-30 for the ceiling. The larger the R-value, the less heat absorbed, and the lower the refrigeration requirements. Table 1 shows insulation values for several construction materials.

The number of doors in a cold storage should be minimal and not compromise the operations. Every time a door is opened, cold air leaves the storage and warm air comes in. The doors should provide a good seal and must have the same insulation as walls. They should be weatherstripped to reduce warm air infiltration, have adequate gaskets to provide a good seal, have good quality hinges, and latches and should open from both inside and outside. In medium-sized and large facilities, plastic strip curtains are recommended to prevent heat gain during loading and unloading operations.

The size of the doors corresponds to the type of operations. They can be either mechanized or manual. If a forklift is used, the door width must be least one and one-half times the forklift width.

Refrigeration Load. Once the type and size of cold storage has been determined, the refrigeration needs or load must be calculated according to the product and storage needs. The refrigeration load is critical to maintain the desired product storage temperature. Some factors determining the refrigeration load are:

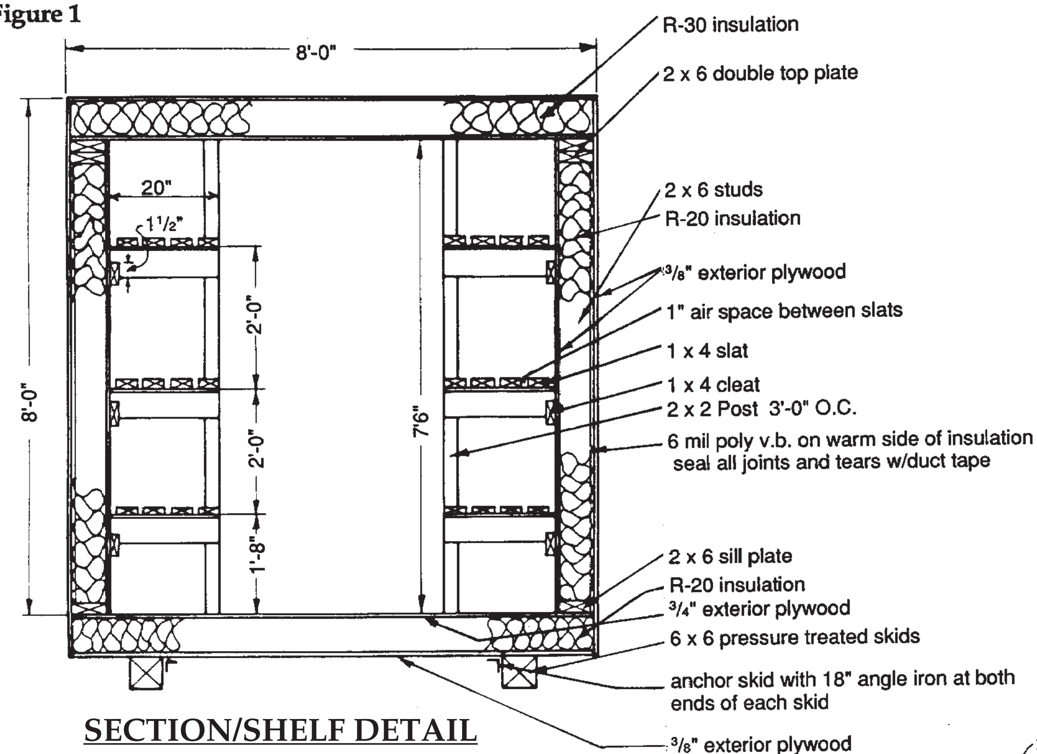
- size of the cold storage
- type of product stored
- amount of product stored
- temperature of product coming into the cold storage
- optimum storage temperature for the product
- type and amount of insulation used in the cold storage
- location of the cold storage
- characteristics of the refrigeration equipment
- management practices used in the operation of the cold storage

Table 1. Insulation values for selected building materials.

	R-value	
Material	**Per inch (approximate)**	**For thickness listed**
Batt and blanket insulation	3.00 - 3.80*	
Glass or mineral wool, fiberglass		
Fill-type insulation		
Cellulose	3.13 - 3.70	
Glass or mineral wool	2.50 - 3.00	
Vermiculite	2.20	
Shavings or sawdust	2.22	
Hay or straw, 20"		30 +
Rigid insulation		
Exp. polystyrene,		
Extruded, plain	5.00	
Molded beads	5.00	
Expanded rubber	4.55	
Expanded polyurethane, aged	6.25	
Glass fiber	4.00	
Wood or cane fiberboard	2.50	
Polyisocyanurate	7.04	
Foam-in-place insulation		
Polyurethane	6.00	
Building materials		
Concrete, solid	0.08	
Concrete block, 3 hole, 8"		1.11
Brick, common	0.20	
Softwoods, fir and pine	1.25	
Hardwoods, maple and oak	0.91	
Plywood, ⅜"	1.25	0.47
Plywood, ½"	1.25	0.62
Particleboard, medium density	1.06	
Hardboard, tempered, ¼"	1.00	0.25
Insulating sheathing, 25⁄32"		2.06
Gypsum or plasterboard, ½"		0.45
Wood siding, lapped, ½" x 8"		0.81
Asphalt shingles		0.44
Wood shingles		0.94

* The insulation value of fiberglass varies with batt thickness. Check package label.
Source: Structures and Environment Handbook, MWPS-1, 11th Edition, 1983.

Figure 1



SECTION/SHELF DETAIL

Notes:

1. Refrigeration: Many vegetables are best stored at 32°F, some at 45°F and others, like tomatoes, closer to 55°F. Usually a compromise is made-accepting somewhat shorter shelf life for a less costly warmer temperature. With box temperatures below 40°-45°F – depending on equipment choices-defrosting is needed for coils. To avoid freezing of coils, operate above this range. Continuous operation of the cooling coil blower will reduce the chances of frost build-up and improve air circulation.

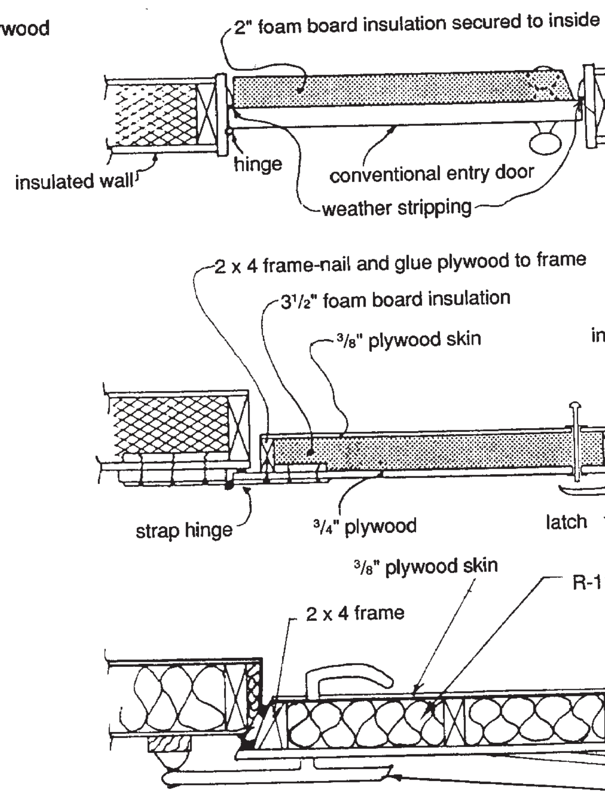
   Assuming a temperature difference of 50°F between inside and outside air and using 4000 btu/hr for the heat load due to conduction through surfaces and air exchange, a 3.4 hp unit (about 9000 btu/hr) should cool 1/4 ton in 5 hours. A 1 hp unit should cool 1/2 ton in five hours. More vegetables could be cooled with less than a 50°F temperature difference or if vegetables were brought in at a temperature less than that of the hot part of the day.

2. Fresh air: Good sanitation and management reduce the need for fresh air. Ordinarily the door will be opened often enough to supply fresh air. If not, a small 60 cfm fan could be installed near the ceiling in one end to blow air into the box, with another similarly sized opening at the other end to release the air. A flap should be installed to close both openings when the fan is off. Openings should be covered with screen. Knowledge of produce needs is important; for example, tomatoes emit ethylene to which some other products are sensitive. Fresh air dilutes the ethylene. (See Extension publication “Storage Operations”, MF-1033)

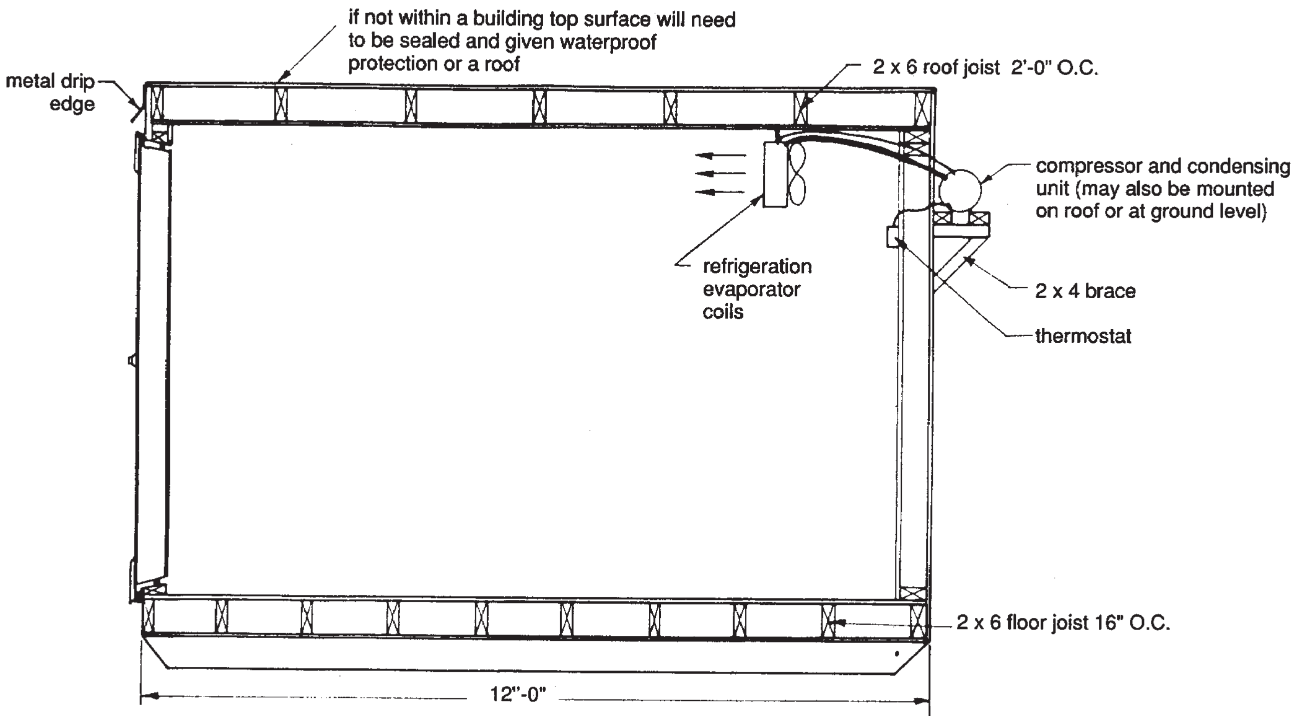
3. Shelving: Perforated or expanded metal treated to prevent rust would ensure better air circulation. Metal post and shelf supports would be a further improvement. Note 20" shelf depth may be too narrow for some operators. Preservative treated shelf supports and shelving would lengthen life, but be sure that the preservative is approved for this use.

4. Insulation: To minimize surface heat exchange, use R-20 insulation with 2 x 6 studs, 24" o.c., but many operators prefer the extra four inches of interior width that 2 x 4 studs provide. Note: A plastic strip curtain inside of door reduces heat gain when opening door.

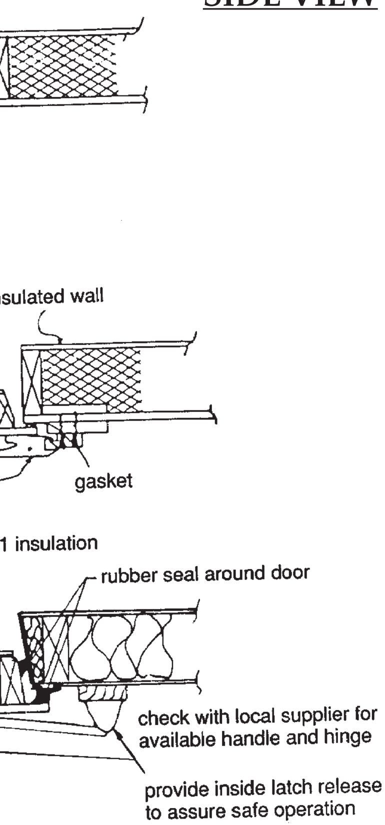
5. Lamps should be installed as needed but used sparingly to reduce heat gain.

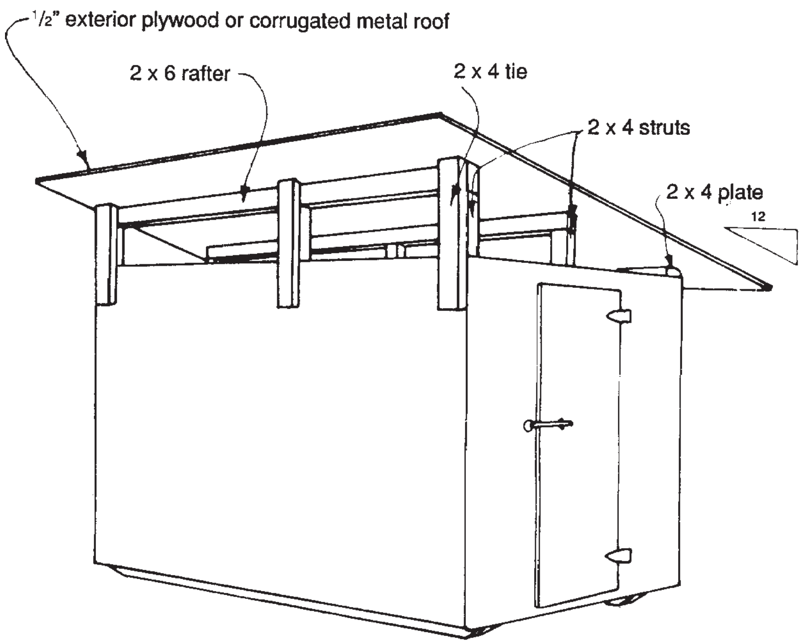


ALTERNATIVE DOOR DETAILS



SIDE VIEW





PERSPECTIVE WITH OPTIONAL SHED ROOF

Farm Market Walk-In Refrigerator

Plan 6380, USDA

SECTION/SHELF DETAIL

The most common unit used to quantify the refrigeration load is the refrigeration ton. One ton of refrigeration is defined as the amount of energy removed from one ton (2000 pounds) of water so it freezes in a period of 24 hours. It is the equivalent to 288,000 BTU in one day or 12,000 BTU per hour.

To maintain the optimum temperature inside the cold storage, the system must be properly designed and the refrigeration load determined. The following sources of heat need to be quantified and added to determine the refrigeration load: field heat, heat of respiration of the plant material, conductive heat gain, convective heat gain, equipment load, and service and defrost factors of the cold storage.

Field Heat. Field heat is the amount of cooling necessary to reduce the product temperature from harvest temperature down to the safe storage temperature within a given time period. The hotter the product coming into the cold storage, the more energy needed to reduce the product temperature and the more time required to operate the refrigeration equipment.

Heat of Respiration. The heat of respiration is the energy released by the produce as it respires during storage. The warmer the produce, the more heat of respiration generated.

Conductive Heat Gain. The conductive heat gain is heat gained by conduction through the building floor, walls and ceiling. It is directly related to the insulation installed in the facility. The better insulated the cold storage, the less conductive heat gain.

Convective Heat Gain. The convective heat gain is heat that enters the facility during the mixing of other air with the cool inside environment. This load is directly related to the number of doors in the facility. The more doors in the facility, the higher the possibility of air currents. The amount of heat gained increases with the amount of times and periods that doors are open.

Equipment Load. Equipment operating in the storage, such as fans and lights, generate additional heat load. Lighting does not need to be excessive, just bright enough to identify product and labels clearly and allow safe movement.

Service and Defrost Factors. The service factor accounts for brief periods of unusual hot weather, loading rates that temporarily exceed those anticipated, or other unusual conditions of short duration. The defrost factor considers the time lost during coil defrost.

The engineering procedure followed to determine the refrigeration load estimates the cooling needs under critical weather and capacity conditions. For every cold storage, it is important to determine the cooling load properly. Manual calculations or computer programs are available to determine the refrigeration load for a properly designed cold storage.

The position of the evaporator coil fans should provide air flow to the end of the longest side of the cold storage. If using additional fans to precool product, they should be properly located, and the refrigeration equipment should accommodate this. When forced air is used to precool product, the cooling time could be reduced by 80 percent compared to room cooling in cold storage.

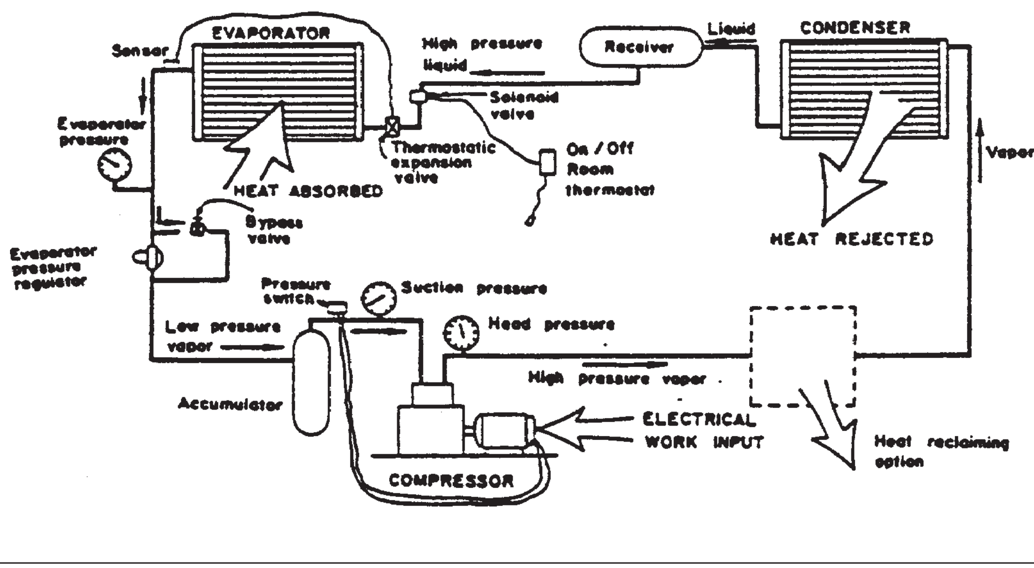


Figure 5. Schematic representation of a direct expansion refrigeration system.

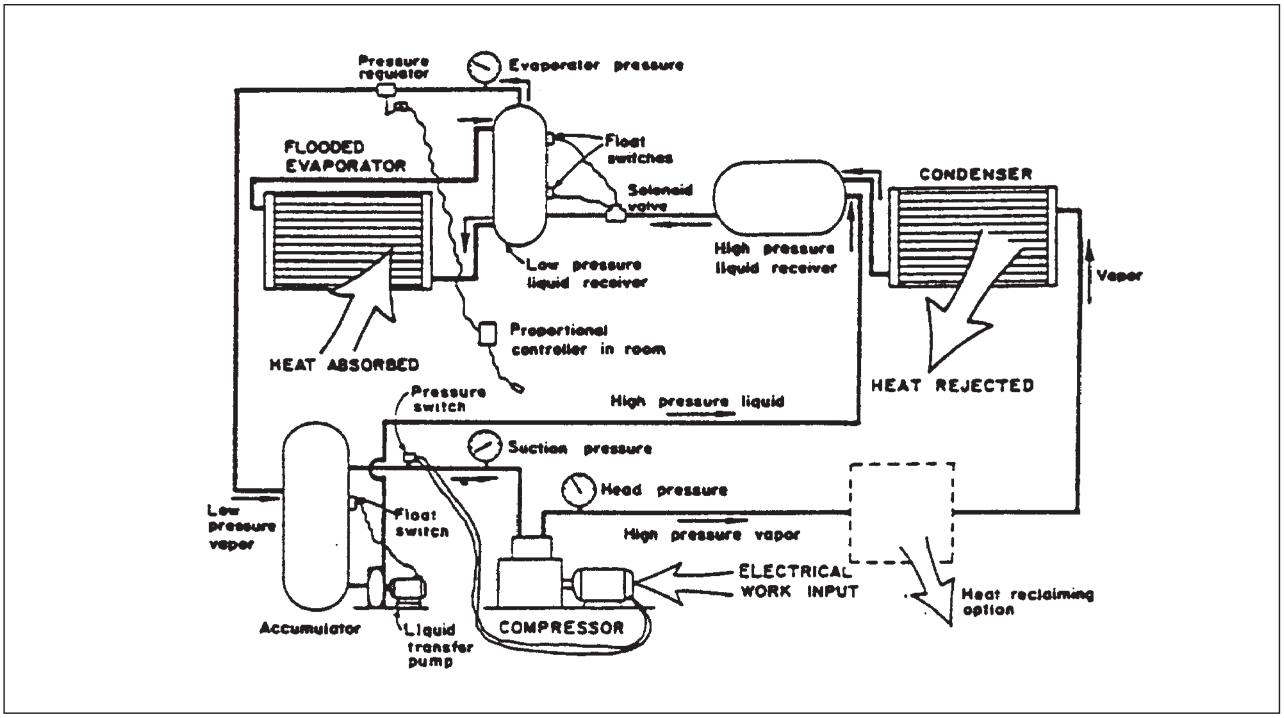


Figure 6. Schematic representation of a flooded refrigeration system.

Table 2. Comparisons of refrigeration load requirements and construction costs needed with different R-value insulation amounts for three cold storages.

	Cold Storage A	Cold Storage B	Cold Storage C
		R-VALUES	
Floor	10	0.4	30
Walls	20	20	30
Ceiling	30	30	30
Refrigeration (tons)	2.0	3.2	1.9
Refrigeration Unit Costs	$3,000	$4,500	$3,000
Construction Costs	$5,400	$5,292	$6,102
Unitary Costs($/cu.ft.)	2.50	2.45	2.73
Total Cost	$8,400	$9,792	$9,012
Total Unitary Cost($/cu.ft.)	3.89	4.53	4.17

The most common refrigeration systems for cold storage are the direct expansion system (figure 5) and the flooded system (figure 6). Most small storage units work with the direct expansion system; the flooded system is used only in large facilities.

The following case illustrates the impact of insulation on refrigeration load and building cost. Table 2 indicates that total construction costs for a cold storage designed to store 1050 cubic feet of product harvested at 88°F, at a rate of 40 cubic feet per day, stored at 32°F. The cold storage dimensions are 18 feet long, 12 feet wide and 10 feet high. There are three alternatives for insulation for the cold storage. Alternative A uses 10-20-30 R-values for the floor, walls, and ceiling, respectively. Alternative B uses 0.4-20-30 R-values, which are equivalent to no insulation in the floor and only a concrete slab 4 inches thick. Alternatives A and B correspond to grower built units. Alternative C corresponds to a new prefabricated walk-in cooler with an insulation of 30-30-30 R-values for the walls, ceilings, and floor.

The construction costs are slightly less under alternative B; however, the total cost of the facility is greater due to a larger refrigeration unit of 3.2 tons. The refrigeration for alternative B is larger because the refrigeration load is greater due to lack of insulation in the floor. Therefore, even if the construction cost is less for alternative B ($0.05/cubic feet less than A), the total cost of the cold storage is greater than that for alternatives A and C. The operational costs for alternative B, not included in Table 2, will also increase due to larger electricity demand by the refrigeration unit.

Refrigerants

New regulations governing the use, disposal, and manufacturing of refrigerants require close attention for users of cold storage. Refrigerants are chosen for their heat exchange properties and cost. Among the best are chlorofluorocarbons (CFC) and hydrochlorofluorocarbons (HCFC), but both types damage the ozone layer and CFCs contribute to global warming.

The United States Clean Air Act mandated that no more CFCs will be manufactured after December 1995 and will only be available after that time as a recovered and remanufactured product. HCFCs will begin reduction in manufacturing in 1996 and be completely phased out by 2030.

Manufacturers are developing new mixtures of refrigerants that are safer for the environment, but they are not always readily interchangeable with the old one. Different solvents and oils in them can cause undue wear and deterioration on fittings and gaskets. Different refrigerants operate at different pressures so fittings and gaskets may not work. Check with the manufacturer before you change refrigerants. It is best to have trained professionals to service your refrigeration equipment, who can properly capture and dispose of old refrigerants. Also, check the refrigerant type needed in used refrigeration equipment, so you can save yourself problems later.

Maintenance

Equipment maintenance, monitoring, and management are integral parts of all the activities. More specifically, the aspects that need special attention when managing a cold storage system are condensation and humidity control, temperature control, sanitation, maintenance, container design and positioning, and storage compatibility of commodities.

Condensation and Humidity Control. The relative humidity in refrigerated storage must be within the optimum range for the commodity. For fresh flowers, the optimum relative humidity is 85 to 95 percent and for dried/preserved plant materials it's 50 to 65 percent. When relative humidity for fresh plant material is less than 90 percent, a humidifier should be used. The relative humidity of the storage can be monitored with a recording hygrometer or at intervals with a sling psychrometer.

The air-to-coil temperature differential of the refrigeration unit be no greater than 5°F. The temperature differential equals the difference between the temperature of the refrigerant entering the evaporator coil and the temperature of the air in the cold storage. Air-to-coil temperature differentials greater than 5°F condense water vapor in the air, reducing relative humidity in the facility and producing ice accumulations on the evaporator coils. When the humidity is lowered, air absorbs water from the stored flowers causing them to wilt. If the air-to-coil differential cannot be adjusted, the installation of a humidifier in the refrigerated storage is necessary. The addition of moisture to the facility by dumping water on the floor is a common practice to add moisture to the air. However, wetting the floor is not a good sanitation procedure because it also wets hidden and hard-to-reach places where disease organisms can grow.

The removal of ice accumulations on the coils is necessary to keep the refrigeration unit operating properly. Ice accumulations make the equipment operate for longer periods of time to maintain the temperature in the cold storage, consuming more electricity and reducing the lifetime of the refrigeration unit. Some ways to eliminate ice accumulations on the coils are electrical defrost, warm water sprays, reverse refrigerant flow, and equipment shutdown for six to eight hours. The selection of one of these depends on the equipment and storage size.

Temperature Control. A thermostat is an integral part of the cold storage. The thermostat controls the operation of the refrigeration unit so a preset temperature can be maintained in the storage. The thermostat's thermometer should not be used to monitor the storage temperature. A separate recording thermometer should be installed for this purpose. This type of thermometer will be helpful in determining whether the cold storage is maintaining ideal conditions. A thermometer that fixes the maximum and minimum temperatures could be an alternative for the recording thermometer.

These thermometers, however, show the air temperature in the cold storage and not the flower temperature. The most important temperature to control is the flowers' temperature. Therefore, it is necessary to check the temperature of the flowers in the buckets and boxes. A comparison of the flower temperature, the amount of time the flowers have been in storage, and the thermostat setting can indicate to the operator that the thermostat needs resetting or the equipment needs adjusting.

The refrigerated facility should be equipped with more than one thermometer so they can be compared and recalibrated if necessary. To prevent undercooling or chill injury and the resulting economic losses, readings of a sling psychrometer and settings of the thermostat and humidistat must be compared.

Sanitation. Every commodity requires special sanitation procedures. To prevent contamination, the cleanliness and sanitation of the cold storage and containers must be assured. The removal of condensation water, dirt, residuals, and trash from the cold storage will help maintain flower quality and extend the life of the facility.

If mold is present on the walls, floor or containers, they must be disinfected with a solution of 0.50 percent sodium hypochlorite, prepared by mixing 1 gallon chlorine bleach with 9 gallons of water. This solution must be applied where needed and the surface vigorously brushed. After cleaning with the bleach solution, it is best to leave the cold storage open to the air to dry. Cleaning walls, and floors with this solution is a good pre- and post-season practice for every cold storage. If there are problems with decay, cleaning should be done more often, and handling practices should be changed to ensure a cleaner workplace. Harvest and holding containers should be cleaned after each use.

Maintenance. Cold storage calls for regular inspection of refrigeration coils, fans, motors, compressor, ducts, doors, locks and hinges, lights, and any other piece of equipment. When inspecting the refrigeration coils, all dust and dirt must be removed. Adjustments should be made so there are no parts touching the fans or other moving elements. Belts should have protective covers at all times. If a cover is broken, it must be fixed, but not removed. Any unusual noise must be inspected and repaired. The oil level in the compressor must be checked, changed, and maintained. Air infiltration through door seals must be prevented and seals adjusted, repaired or replaced. The cold storage should be as airtight as possible.

Refrigerant pressure must be checked periodically. A scheduled maintenance program is not difficult to set up and would help the facility operator prevent losses due to equipment failures.

Storage Product Handling

Storage Loading. Due to the high perishability of flowers, long-term storage is considered for only a few species. Nonetheless, many factors determine how the cold storage should be loaded:

- how long will it be stored
- the maturity at harvest
- how it is packed
- whether it was precooled
- the size and shape of the cold storage
- mechanical or manual loading

The standard practice is “first in, first out,” whether it is stored a few hours or a few days. To keep track of the storage time, containers, buckets or boxes should be clearly labeled with the date it entered the storage. It is recommended to maintain inventory cards for the flowers that go into cold storage in a safe place. These cards should have the following information: type of flowers, quantity, harvest date, packing date, storage entry date, and any special handling procedures used.

Container Design and Positioning. The container design and its positioning in the cold storage must allow for air circulation within containers and around the

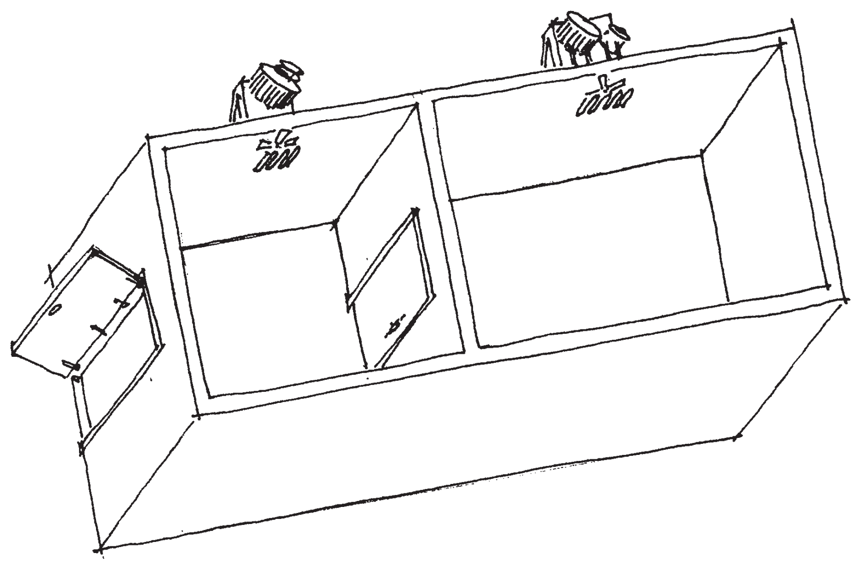


Figure 7. Precooling and Storage Room Combination.

flowers. Containers should not obstruct air circulation. For good air circulation, there should be from six to eight inches between the containers and the walls, and at least 18 inches between the containers and the ceiling. Also, allow enough space to spread the product for rapid cooling if forced air precooling is not used. Flowers in buckets should never touch the walls. Guidelines painted on the floor and walls are helpful in getting containers spaced correctly. The cold air must move freely not only around the containers but also within the containers during precooling.

Precooling. Room cooling and forced air cooling are the only viable methods to precool flowers. Forced air cooling is preferable because it lowers the temperature of the flowers much quicker than room cooling. In forced air cooling, cold air is blown/forced through the plant material via fans directed at the flowers. Figure 7 shows a precooling room and storage room combination. The precooling room is used to lower the tissue temperature of the newly harvested flowers to the desired storage level. The flowers are then transferred to the storage room for long-term storage. This combination storage arrangement lowers cooling costs by removing heat from harvested materials in a smaller space thus placing a reduced load on the large refrigeration unit of the main storage room. Frosting over of the evaporator coils is also greatly reduced so less energy is used in defrosting cycles.

Storage Compatibility. Flowers are not compatible with any kind of fruit or vegetable in cold storage. Fruits and vegetables produce ethylene, which is harmful to flowers. Ethylene pollution can present serious postharvest handling problems for growers. It can come from many sources, the flowers themselves, pollinated ones and ones past their prime; internal combustion engines; CO_2 generators; inefficiently running heaters; diseased and decayed plant material; bruised and damaged plant material; plant disease organisms; and fruit and fruit vegetables. There is a three-prong approach to managing ethylene levels below the phytotoxic level. First, is preventing ethylene pollution by not using internal combustion engines in the facility, servicing equipment so they do not produce ethylene, not storing flowers with fruits and fruit vegetables, having good sanitation practices to clean up diseased and decaying plant material and to dispose of "old" flowers, and handling flowers carefully as not to injure them. Second, is to inhibit the production of ethylene. Low temperatures inhibit the production of ethylene and its effect. Prestorage treatment of sensitive species with silver thiosulfate prevents the endogenous production of ethylene. Third, is the removal of ethylene. This aspect deals more with the construction and equipping of a cold storage than the other two. Ethylene can be removed by ventilation and scrubbers. Ventilation requires close attention to the number of air exchanges in the cold storage. You will want enough to keep ethylene levels low but not so many you over work the refrigeration unit. Scrubbers are filters impregnated with $KMnO_4$. As ethylene is absorbed by the scrubbers, the $KMnO_4$ is reduced to $KMnO_2$. The filters change color from purple to brown. The best scrubbers are those where the storage air is actively pulled through the filter. These though need to be installed with the air handling system and do not retrofit well. The other type passively absorbs ethylene. They are usually batts impregnated with $KMnO_4$ that are hung in the storage or small sachets that are placed in shipping containers.

References

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