STORAGE CONSTRUCTION
FRUITS & VEGETABLES

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After produce is harvested, growers must follow proper management techniques and procedures to offer a fresh and good-looking product to the wholesaler, retailer and consumer, and to get the maximum return on their investment. Proper management and handling practices require a reduction in produce temperature to maintain quality and market value.

Produce cooling after harvest starts on the farm. Unless the produce is shipped from the farm immediately after harvest, its temperature must be reduced (See MF-1002, “Precooling Produce”).

The minimum facility a grower must have to precool produce and to take advantage of the benefits of cold handling is refrigerated storage (See MF-1030, “Storage Options”).

Independent of the type of cold storage facility added to the farmstead, there are several common factors to take into consideration—site selection, size of the storage facility, structure and thermal insulation, and refrigeration load.

Site Selection

The type of cold storage depends on the desired function. The primary function of the facility determines the location. For example, for retail sales, location of the cold storage must be near a major road, and the area must have available parking space. If the facility is mainly to store produce prior to shipping, the facility should be close to the grading and packing room with convenient access to fields or orchards. Also, there must be space available for movement and storage of empty containers, equipment, and supplies. Ideally, an area should be planned to include future expansion of the preprocessing or primary processing of fruits and / or vegetables—washing, sorting, waxing, drying and packing.

A cold storage facility must be in a well-drained area. It requires drains to remove water from condensation, and cleaning and sanitation operations. Providing good drainage is essential.

The availability of utilities is another factor to consider. What 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 such as washers, sorters, and baggers. 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 cleaning produce and for washing and sanitizing the storage facilities. 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 facility. Gas might be required for heating and drying operations.

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

Size

To define the size of the refrigerated storage, evaluate the following factors:

1. volume of product to store.
2. produce containers (pallet bins, boxes, bulk).
3. volume required per container (ft^3/bu).
4. aisle space needed (mechanical or manual operation).
5. lateral and head space.
6. available site space.

The amount of produce to store and the type of containers used for storage define volume requirements. In defining the size of the storage facility, 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 (ft^3);

v is the volume occupied by one produce container in cubic feet per bushel, per crate, per box, per bin, etc. (See Table 1 for some commodities and their standard containers and see MF-979, "Containers and Packaging");

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 and walkways. An additional 40 percent of the volume occupied by one produce 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

Table 1. Standard size and net weight of common containers used for produce

Commodity	Container	Capacity cu.ft.	Net Weight (lb)
Apples	Tray pack carton	1.67	40-45
	Bushel carton (face and fill)	1.24	40-44
	Carton, cell pack	—	36-38
	Carton, tray pack	1.61	41-43
	Northwest wood box	1.26	41-43
Asparagus	Pyramid crate	1.00	30-36
Beans, snap	Bushel hamper	1.24	28-32
	Carton	1.24	20-22
Berries	24 qt. wirebound crate	0.93	27-36
	12 pt. tray	0.23	7-9
Cabbage	Crate/carton	2.40	50
	Wooden crate	2.00	50
Cantaloupe	½ carton	2.03	35-40
	Jumbo carton	2.30	70-80
	⅔ carton	2.15	53-55
Corn, sweet	Wirebound crate	1.68	42-50
Cucumber	Bushel carton	1.24	50-55
	1⅑ bushel	1.38	50-55

Table 1. Standard size and net weight of common containers used for produce. *(Continued)*

Commodity	Container	Capacity cu.ft.	Net Weight (lb)
Grapes	Wood lug or carton	0.72	26-28
	12 qt. basket, eastern grapes	0.47	18
Greens	Bushel crate, carton	1.24	20-25
	1 ⅑ bushel	1.38	30-35
Peaches	¾ bu. basket (bulge)	0.93	36-39
	½ bu. basket (flat)	0.62	24-26
	Wirebound crate	1.05	38-42
	Wood lug	0.72	22-24
Peppers, green	Bushel carton	1.24	25-30
	1 ⅑ bushel crate	1.38	25-30
Potatoes	Carton	1.28	50
Squash, winter	1 ⅑ bushel	1.38	40-50
summer	⅝ bushel	0.69	21
	½ bushel	0.69	21
	1 ⅑ bushel	1.38	42-45
Sweet potatoes	Bushel carton	1.24	50
Tomatoes	Carton	0.88	25
	Lug	0.50	20

mechanical operation, the aisles should be at least 1½ times the width of the forklift.

For air circulation, allow 6–8 inches of space between containers and walls, at least 18 inches between containers and the ceiling. Also, allow enough space to spread the produce for rapid cooling.

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.

Structure and Thermal Insulation

Structural alternatives for a new cold storage facility are wood pole and post construction, steel buildings, concrete block, and walk-in prefabricated cooler. Every alternative has advantages and disadvantages and the choice depends on capital available to invest. For small applications, the walk-in cooler presents great advantages, but it also carries the highest price tag per cubic foot of storage. Second-hand or used walk-in coolers are common alternatives (See MF-1030, "Storage Options").

In all the alternatives, a slab floor is required. For most common farm applications, four inches of wire-mesh-reinforced concrete over two inches of water-proof plastic foam insulation board provides a good floor. For unusually heavy loads, the slab floor should be 5–6 inches thick. Where ramps are required, they should have slope no greater than 1 to 5.

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 movement, and its cost. Among insulation materials, loose fill cellulose is the cheapest, followed by batts and blankets, and various foam sheet materials. The most expensive are 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 / in for cellulose versus 6.5 / in for sprayed-in-place); however, the cellulose price is 20–30 times less per square foot per inch of thickness than sprayed materials. Nonetheless, sprayed-on 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.

A storage facility 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 facility is under the same roof as the packing area, the packing area does not need as much insulation.

The minimum insulation requirements for a small cold storage room for fruits and vegetables, 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 2 shows insulation values for several construction materials.

The number of doors in a cold storage room should be minimal, without compromising 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 weather-stripped 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—mechanized or manual. If a fork lift is used, the door width must be at least 1 ½ times the fork lift width.

Refrigeration Load

The most common unit used to quantify refrigeration load is the refrigeration ton. One ton of refrigeration is defined as the energy removed from one ton (2,000 pounds) of water so it freezes in 24 hours. It is equivalent to 288,000 Btu in one day or 12,000 Btu per hour.

To maintain the optimum temperature inside a cold storage facility, the system must have a properly desiged refrigeration load. Determining the refrigeration load requires quantifying field heat and heat of respiration of the produce, conductive heat gain, convective heat gain, equipment load, and service and defrost factors of the facility.

Field Heat. Field heat is the amount of cooling necessary to reduce the produce from harvest temperature to the safe storage temperature within a given time period (See Extension bulletin MF-978, “Storage Conditions”). The hotter the produce coming into the cold storage facility, the more energy needed to reduce the temperature, and the more time required to operate the 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 facility, the less conductive heat gain.

Convective Heat Gain. The convective heat gain is heat that enters the facility during the mixing of outside air with the cool inside environment. This load is directly related to the amount 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.

Table 2. 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.

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

Service and Defrost Factors. The service factor accounts for brief periods of unusually 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** facility, 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 facility (See "Design of Cold Storage" by Rolando A. Flores).

The position of the evaporator coil fans should provide air flow to the end of the longest side of the facility. If using additional fans to precool produce, they should be properly located, and the refrigeration equipment should accommodate that purpose. When forced air is used to precool produce, the cooling time could be reduced by 80 percent compared with that for regular cooling in the refrigerated facility.

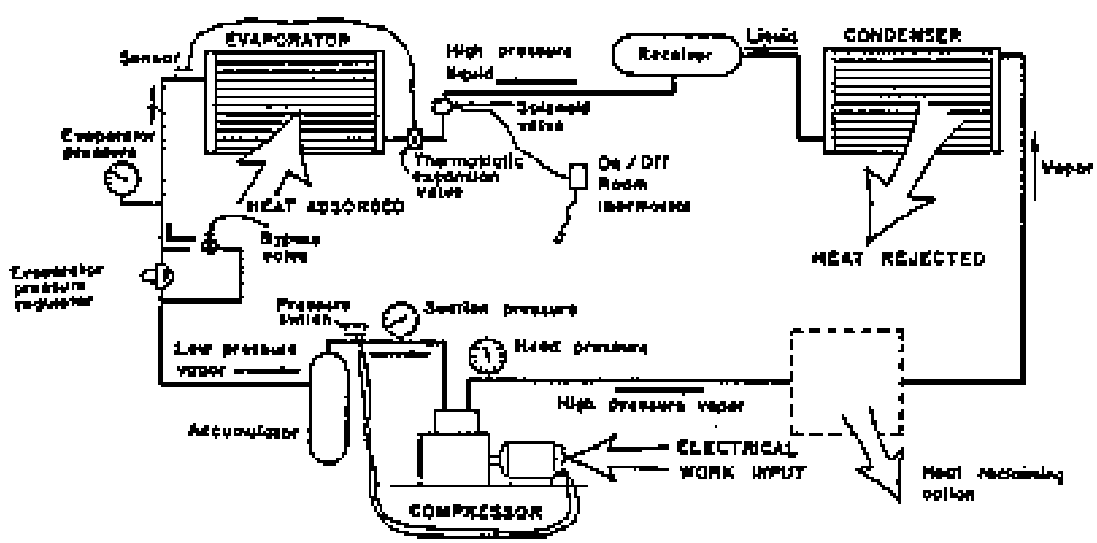
The most common refrigeration systems for cold storage facilities are the direct expansion system and the flooded system. Most small storage units work with the direct expansion system; the flooded system is used only in large facilities. Figures 1 and 2 show schematic diagrams of the direct expansion and the flooded system respectively.

The following cases illustrate the impact of harvest temperature and insulation on refrigeration load and building costs.

Case 1: Effect of Harvest Temperature on Refrigerated Storage

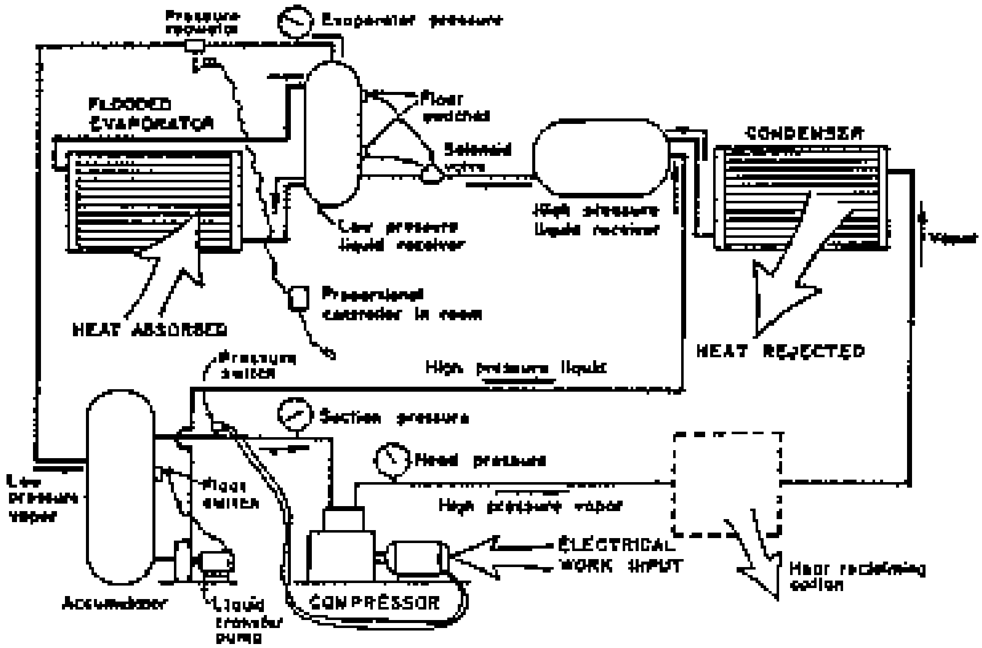
Table 3 shows the results of load calculation for tomatoes and grapes. Each commodity is harvested at two different temperatures for the same volumes, 300 tons of tomatoes and 380 tons of grapes. The tomatoes are stored at 55°F and the grapes are stored at 32°F. The 10°F difference in the harvest temperature of the tomatoes indicates an extra load requirement of 3.0 tons of refrigeration for those harvested at 80°F. The 22°F difference in the harvest temperature for the grapes demands 6.5 more tons of refrigeration to cool down and maintain the grapes.

Figure 1. Schematic representation of a direct expansion refrigeration system.



Source: Bartsch and Blanpied

Figure 2. Schematic representation of a flooded refrigeration system.



Source: Bartsch and Blanpied

Case 2: Effect of Insulation on Refrigerated Storage

Table 4 indicates the total construction costs for a cold storage facility designed to store 840 bushels of apples harvested at 88°F, at a rate of 32 bushels per day, stored at 32°F. The facility dimensions are 18' long, 12' wide, and 10' high.

There are three alternatives for insulating the facility. 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 self-built units.

Alternative C corresponds to a new prefabricated walk-in cooler with an insulation of 30-30-30 R-values for the walls, ceiling, and floor.

The construction costs are slightly less under alternative B; however, the total cost of the facility is greater due to a larger cooling unit of 3.2 tons. The cooling unit for alternative B is larger because the cooling load is greater due to lack of insulation in

Table 3. Cooling load for alternative harvesting temperatures.

	Tomatoes		Grapes	
Harvest Temperature (°F)	80	70	78	56
Storage Temperature (°F)	55	55	32	32
Storage Capacity (ton)	300	300	380	380
Harvest Rate Per Day (ton)	30	30	38	38
Refrigeration Load (ton)	16.5	13.5	18.0	11.5

Table 4. Insulation alternatives for a cold storage unit.

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

[b]Approximated values

the floor. Therefore, even if the construction cost is less for alternative B ($0.05/ft^3 less than A), the total cost of the refrigerated facility is greater than that for alternatives A and C. The operational costs for alternative B, not included in Table 4, will also increase due to larger electricity demand by the refrigeration unit.

Summary

In sizing, locating, and determining the refrigeration load for a cold storage facility, specific design steps and precautions need to be followed to have an efficient and profitable operation. **Remember, produce quality cannot be improved; it can only be maintained.**

References

Barstch J.A. and G.D. Blanpied. 1990. *Refrigerated and Controlled Atmosphere Storage for Horticultural Crops.* (NRAES - 22) Northeast Regional Agricultural Engineering Service, 152 Riley-Robb Hall, Cooperative Extension, Ithaca, NY 14853.

Flores, Rolando A. 1991. *Design of Cold Storage for Produce.* ASAE paper MC91-122, presented at the 1991 Mid-Central Meeting sponsored by The American Society of Agricultural Engineers, St. Joseph, MI 49085-9659.

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