Farm Structures
FACTSHEET

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REFRIGERATION PRINCIPLES

REFRIGERATION CYCLE

Continuous refrigeration in small applications is usually accomplished by the vapour compression system more commonly known as the simple compression cycle. There are two pressures existing in the compression system, the evaporating or low pressure and the condensing or high pressure. The refrigerant acts as a transportation medium to move heat from the evaporator to the condenser when it is given off to the ambient air. The change of state from liquid to vapour and back to liquid allows the refrigerant to absorb and discharge large quantities of heat very efficiently.

The basic cycle operates as follows:

High pressure liquid refrigerant is fed from the receiver through the liquid line and through the filter-drier to the metering device separating the high pressure side of the system from the low pressure evaporator. A thermostatic expansion valve controls the feed of liquid refrigerant to the evaporator and, by means of an orifice, reduces the pressure of the refrigerant to the evaporating or low side pressure.

The reduction of pressure on the liquid refrigerant causes it to boil or vapourize until the refrigerant is at the saturation temperature corresponding to its pressure. As the low temperature refrigerant passes through the evaporator coil, heat flows through the walls of the evaporator tubing and fins to the refrigerant causing the boiling action to continue until the refrigerant is completely vapourized.

The expansion valve regulating the flow through the evaporator is necessary to maintain a pre-set temperature difference between the evaporating refrigerant and the vapour leaving the evaporator. As the temperature of the gas leaving the evaporator varies, the expansion valve power element bulb senses its temperature and acts to modulate the feed through the expansion valve as required.

The refrigerant vapour leaving the evaporator travels through the suction line and accumulator and then on to the compressor inlet. The compressor takes the low pressure vapour and compresses it, increasing both the pressure and the temperature. The hot, high-pressure gas is forced out the compressor discharge valve and into the condenser.

As the high pressure gas passes through the condenser, it is usually cooled by a fan and fin-type condenser surface. As the temperature of the refrigerant vapour reaches the saturation temperature corresponding to the high pressure in the condenser, the vapour condenses into a liquid and flows back to the receiver to repeat the cycle.

DEFROST SYSTEMS

Evaporators operating in rooms colder than 36^0 F will have to be defrosted. Defrosting is usually done automatically at a pre-set time and for a certain time frame. Regardless of the defrost system used, it should always be operated to remove all the ice from the evaporator coils. Maximum air distribution and rapid cooling are obtained only when the coil is free of ice. Partially melted ice may refreeze and collapse evaporator tubes or deform fins, tubes and electric defrost heating elements. The defrost system should never be left on longer than needed because heat will be added to the cold storage room.

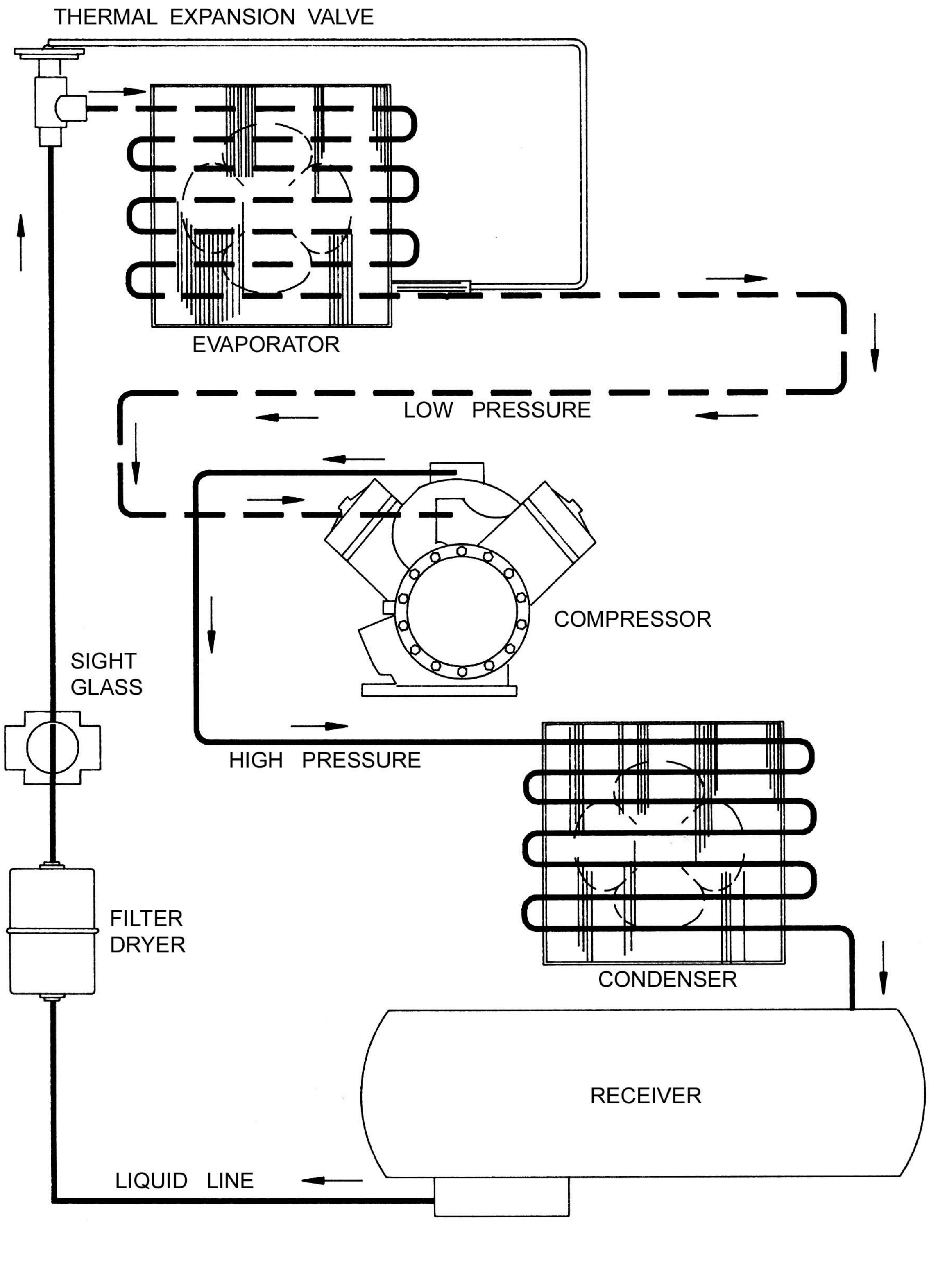
Although there are several defrosting methods, the hot gas, reverse cycle and electric heater systems are the most commonly ones used for smaller cooling systems.

In a “hot gas” system, hot refrigerant vapour is pumped directly through the evaporator tubing. The system has a refrigerant line running directly from the compressor discharge line up to the evaporator. The line is opened and closed by a solenoid shut-off valve. At the pre-determined time, the time clock stops the evaporator fan motors. Hot compressed vapour rushes along the suction line. To keep the defrost water from freezing in the drain pan and tube, part of the hot gas defrost line, or an electric heater is installed under the drain pan and the drain pipe.

The “reverse cycle” system defrosts evaporators by reversing the flow of the refrigerant. This causes the evaporator to become the condenser and the condenser an evaporator. When the evaporator functions as a condenser, it melts the accumulated frost. The cycle reversing is handled by installing a four-way valve. To operate on defrost, the four-way valve is turned automatically and hot gas from the compressor travels up the suction line. It heats the evaporator when gas condenses in it and bypasses refrigerant control by means of a check valve. It passes through the receiver and, as it leaves the receiver, a check valve bypasses it through another refrigerant control into the condenser. The refrigerant evaporates in the condenser and is returned to the compressor in a vapour state. The liquid receiver is designed to permit the reverse flow of vapour to travel over the reverse liquid in the receiver. It does not return the vapour to the condenser.

The “electric heater” system uses heating coils, which are installed in or around the evaporator or within the refrigerant passages to furnish heat. One type uses resistance wire heating elements mounted underneath the evaporator, under the drain pan and along the drain pipe. A timer stops the refrigerating unit, closes the liquid line and pumps the refrigerant out of the evaporator. Then, the blowers and electric heaters are turned on. The heaters quickly melt the frost from the evaporator and the water drains away. When the evaporators are warm enough to ensure that all the frost is gone, a thermostat on the evaporator returns the system to normal operation. This system is probably the cheapest and most fail-proof system to install; however, it is a little more expensive, in terms of energy input, to operate. For short term, small structures, this is probably the best system to use.

SCHEMATIC OF REFRIGERATION SYSTEM



HEAT LOAD

The total heat load that a refrigeration facility must be able to handle over a given period is dependent on two main factors, namely heat leakage and heat usage or service load. The heat leakage load is the amount of heat that leaks through walls, windows (if any), ceilings and floors per unit of time (usually 24 hours). The heat usage or service load is the sum of the heat loads of: cooling the contents to cabinet temperature; cooling of air changes; removing field and respiration heat from fresh produce; removing heat released from electrical lights and motors; and removing heat given off by people entering and/or working in the storage room per unit of time (usually 24 hours).

a) Structural Heat Leakage

Heat loss through structural members, such as walls, ceilings, floors and windows, are calculated as follows:

$$\text{Heat Loss} = \frac{\text{ft}^2 \text{ of surface} \times {}^0\text{F temp. diff.} \times 24 \text{ hrs}}{\text{R factor of structural member (hr ft}^2\, {}^0\text{F/BTU)}}$$

b) Air Exchange

The smaller the storage structure, the more frequent the air exchanges for the same frequency use. Air exchange losses are calculated as follows:

$$\text{Heat loss} = \text{volume of room} \times \frac{\text{no. of exchanges}}{\text{day}} \times 2.09\,\frac{\text{BTU}}{\text{ft}^3}$$

Use the following exchanges as a guide for the size of structure used.

Volume (ft^3)	Exchanges per 24 hrs
500	26
1,000	17
1,500	14
2,000	12
3,000	9
5,000	7

c) Product Load

Product load is usually calculated for a 24-hour period. Not only must the product itself be cooled but, the containers as well. Product cooling load is calculated as follows:

Product load =
lbs of product + container x specific heat x temp. difference

Note: Values of specific heat for various products can be obtained from Engineering Note No. 306.300-1, *"Refrigeration Requirements for Fruits and Vegetables."*

d) Respiration Load

Even though respiration is significantly slowed during cold storage, the products will produce some heat. To calculate daily heat production, the following formula is used:

Respiration heat load =
lbs of produce x respiration rate (BTU/lbs/day)

Note: Values of respiration rates for various products can be obtained from Engineering Note No. 306.300-1, ***"Refrigeration Requirements for Fruits and Vegetables."***

e) Human Load

Humans entering or working in the storage structure give off heat which adds to the total heat load. Calculations are made as follows:

$$\text{Human heat load} = \frac{\text{No. of man-hours in storage}}{24 \text{ hrs}} \times \frac{950 \text{ BTU}}{\text{man-hr}}$$

f) Miscellaneous Load

Fan motors and lights give off heat. Calculations can be made using the following:

$$\text{Motor loads} = \text{No. of motors} \times \text{h.p.} \times 4{,}250\,\frac{\text{BTU}}{\text{hp/hr}} \times 24 \text{ hrs. of operation}$$

Use the following as a guide for various h.p. ranges.

h.p.	BTU/h.p./hr
1/8 – 1/2	4,250
1/2 – 3	3,700
3 – 20	2,950

$$\text{Lamp loads} = \text{No. of lamps} \times \text{lamp wattage} \times \frac{\text{hrs. of operation}}{24 \text{ hrs.}} \times 3.42\,\frac{\text{BTU}}{\text{Watt}}$$

The total heat load is an addition of all of the above individual loads based on a 24-hour period. Because time allowances must be made for the evaporators to be defrosted, a normal operating time of 16 hours out of 24 hours is standard practice. Part of the remaining 8 hours can also act as a safety factor. The capacity of the refrigeration system is, therefore, based on 16 hours of operation. A one ton refrigeration machine is capable of 12,000 BTU/hr.

Table 1 **Heat Load (BTU/Hr) For Various Typical Small Storages**

Product Load (lbs/day)	8x8x8	10x10x8	12x12x8	16x16x8
500	5,500	6,800		
1,000	7,400	8,600	9,100	
1,500	9,200	10,300	10,800	13,000
2,000	11,000	12,300	12,800	15,000
3,000		16,000	16,500	18,700
4,000			20,200	22,400
5,000				26,100

Note: The above table is a sample of typical calculations which would include good insulation, container heat requirements and human, product and motor loads. Actual calculations will have to be made for a specific structure, product load and use.

Table 2 **Small Refrigeration Machines and Approximate Outputs**

(Based on 16 hours of operation in 24)

Horsepower (h.p.)	Size of Unit (BTU/hr)
0.5	4,000
0.75	6,000
1.0	10,000
1.5	12,000
2.0	18,000
3.0	30,000
4.0	40,000

EVAPORATOR DESIGN

To maintain the relatively high humidity required for the storage of most small fruits and vegetables, emphasis must be given to the design or capacity of the evaporators. To maintain a relative humidity of 85% – 95% at 32^0 F, the temperature difference between the storage room temperature and the evaporator refrigerant exhaust temperature should not be greater than 6^0 F. The following table shows the effect of temperature difference and relative humidity that can be naturally achieved. To achieve high relative humilities in cold storage, larger than usual evaporator coils will be required.

Table 3	Evaporation Temperature Difference and Relative Humidity		
Temperature Difference (TD) in F degrees	**Minimum Relative Humidity (%) at various storeroom temperatures**		
	32% F	**35% F**	**38% F**
2	95.8	96.1	96.1
4	91.2	92.3	92.4
6	87.1	88.7	88.8
8	83.0	84.7	85.3
10	79.4	80.9	82.0

TD is the temperature difference between the average storeroom temperature and the evaporator refrigerant exhaust temperature. (From New York State College of Agriculture and Life Sciences, Department of Agricultural Engineering.)

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