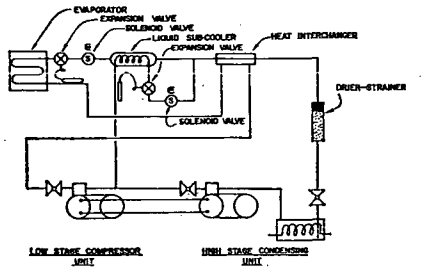

Fig. 2 .... Typical Compound Schematic Piping

the high stage of compound systems. Some modifications may be required on the low stage compound compressor such as crankcase heating or cooling, sealing of ports between crankcase and suction line, etc. Capacity ratings for compressors operating at other than published conditions of pressure and temperature must be carefully calculated and checked to be certain that unduly severe operation will not occur. Operation at low suction pressures greatly affects compressor efficiency. Hermetic compressors are adaptable to cascade systems where the crankcases need not be connected together for oil level equalization and where it is desirable to minimize the possibility of loss of expensive refrigerant through a shaft seal. Suction cooled hermetic units require careful application to assure that motor overheating does not occur.

The high-pressure refrigerants used in the low stage side of a cascade system have pressures which would be excessive with liquid in the system at room temperatures. It is impracticable to keep the low-stage condenser refrigerated at all times. The common solution to this problem is to provide an expansion tank or space where the refrigerant vapor may be superheated and held at a safe pressure level at room temperature. Some small systems which contain a small critical charge use the hermetic compressor casing for the expansion space.[8]

Evaporators

Most test chambers have direct expansion evaporators. It is desirable to design for low temperature differences in the evaporator commensurate with proper distribution and pressure drop for oil return. This is done because so much horsepower per ton is required at low temperature operation and system capacity falls off rapidly as refrigerant evaporating temperatures drop. For this reason, extended surface coils are used for cooling air with fin spacings of 4 to 8 fins per in. Wider fin spacing is used where frosting conditions are expected. To reduce heat loads, fan horsepower is kept low by using large face areas and fewer rows of tubes might be used for commercial freezer applications.

The walls of low temperature altitude chambers should be refrigerated to serve as a radiant heat sink. Where operation at simulated altitudes between site level and 50,000 to 80,000 feet is to be anticipated, a satisfactory approach is to cover as much of the wall area as possible with finned coils and to increase air flow at the reduced air pressures. At high simulated altitudes, direct cooling of black-body panels or the

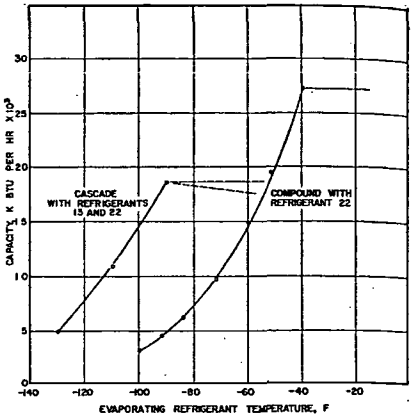

Fig. 3 .... Capacity of 10 Hp Two-Stage Systems

liner walls of the chamber is desirable to produce realistic conditions.

Quite often, a combination of cold-wall and air blast extended surface evaporators is used. The cold-wall evaporators operate at a lower surface temperature and consequently tend to pick up most of the frost, thereby making long-term operation at subzero temperatures possible. The cold walls also absorb wall transmission heat gain and reduce air temperature gradients within the work space. The air blast evaporator takes care of heat leakage through doors, windows, penetrations, and the internal heat released from fans and test specimens.

Several approaches are possible for the chilling of liquids. Common mild steel should not be employed for shells below about −20 F because of its low temperature embrittlement. Several forms of evaporators are commonly used such as direct or dry expansion shell-and-tube or shell-and-coil chillers, extended surface evaporators submerged in a liquid, or storage tanks with evaporators located around the wall. Because of the increase in viscosity of liquids at reduced temperatures, careful heat transfer evaluation must be made for the film factor between the liquid and cooling surface. Flooded evaporators are not very practical for most low temperature chillers. When using low pressure refrigerants such as Refrigerant 22 evaporator pressures are low. The liquid gravity head radically changes the evaporating temperature from top to bottom of the chiller. When using high pressure refrigerants, expansion tanks become unreasonably large and costs become excessive.

The design of evaporators for low temperatures can be a complex problem.[9] Additional information is given in Chapter 33, Evaporators for Liquid Cooling, and Chapter 34, Air Cooling and Dehumidifying Coils, in the 1961 Guide And Data Book.

The effects of refrigerant pressure drop are severe at low evaporator pressures; refrigerant circuits should be shorter or the tubing larger than for designs in higher temperature

ranges. Due to wide load fluctuation, it is sometimes better to use separately fed multiple evaporators.

Refrigerant Flow Control

All methods of refrigerant flow control used on single-stage systems have probably been used successfully on multistage systems. Thermostatic expansion valves are very useful for small and medium sized systems. They tend to be sluggish on compound systems operating at low suction pressures due to the high superheat change necessary to produce sufficient pressure in the valve mechanism to overcome the internal friction. For this reason, special valves with extra-sensitive superheat response are recommended. Cascade systems have operating pressures similar to those found in commercial refrigeration practice. Many test chamber manufacturers adapt standard valves in some special way to their own requirements for this service.

Automatic expansion valves may be used in cases where only one refrigerant evaporating temperature, pressure, and system capacity are required. Likewise, restrictor or capillary tubes may be used on small systems where operating pressures remain quite stable and load fluctuations are not encountered. Oil plugging may be a problem with such designs if operation is in the temperature range where refrigerant oils freeze.

System Accessories

Oil separators are so important that they can scarcely be considered an accessory. The pour point of the best low temperature oil is about −70 F, therefore the amount of oil flowing to the low side must be kept at an absolute minimum.

Liquid solenoid valves are frequently used to assure tight shut-off during the off-cycle. Sometimes a pump-down cycle is used with the temperature controller shutting off the liquid solenoid valve and a pressure cut-out turning off the compressor. This system can produce an overrun of the controller set point.

Suction line solenoid valves are frequently used when close temperature control is desired because cooling of the evaporator ceases at almost the instant of valve closure. Means must be provided to prevent damage to the compressor by the rapid reduction of suction pressure. An artificial loading device may be used or a surge tank connected into the suction line between the valve and compressor. A relief valve or capillary tube should be used to insure that no liquid refrigerant is trapped between the valves in the evaporator. Low-temperature systems must be as clean and dry as possible and therefore, a good strainer-drier should be installed in the liquid line. Vacuum drying and nitrogen purging techniques must be carefully executed.

Liquid-to-suction heat interchangers should be carefully considered. Although liquid subcooling is important, it should not cause compressor overheating due to high suction superheat, particularly for Refrigerant 22 systems. Pressure drop should be kept low in a suction line interchanger. Otherwise, the drop can nullify the gain in system capacity due to the interchanger.

Refrigerant 13 low-stage circuits may incorporate a liquid-to-suction interchanger if a bypass for the relatively cold liquid is provided around the warm exchanger during the initial part of the pull-down, or if the system operates most of the time with suction vapor temperatures below that of the saturated liquid.

The operation of the compressors without vapor passing through them (during the off cycle) may result in overheating on some models. Oil cooling by a refrigerant or water heat exchanger will help keep crankcase temperatures to a safe point (below 150 F).

Piping

All piping on non-ammonia systems should be copper with as few flared or flanged fittings as possible. It should be silver brazed with a small flow of an inert gas such as dry nitrogen bled through it to prevent internal oxidation. Cleanliness is then assured.

Line sizes should be checked carefully for pressure drop and velocity. Every precaution must be taken to reduce suction line pressure drop on compound systems to the lowest practical value. The reason is apparent when it is noted that at −110 F, the pressure difference corresponding to 1 F deg for Refrigerant 22 is 0.065 psi. Other precautions and techniques for good refrigerant piping should be followed.

For proper oil return, suction lines should be run either horizontally or pitched down toward the compressor. If equipment heights do not permit this, they may be carried to a P trap and a reduced diameter riser used near the compressor. It is advisable to have the suction gases as warm as practical in a riser to decrease viscosity of the oil.

Capacity Modulation and Load Limiting

Fig. 3 indicates the magnitude of change in capacity as a function of evaporating refrigerant temperature with both cascade and compound systems. Although the capacity of a cascade system does not vary beyond the limits of a compound type, many of the same modulation methods will be applicable and perhaps necessary. The following are several possible approaches:

1. Compressor cylinder bypass set-ups similar to standard unloaders.
2. Discharge vapor bypassed to suction of compressor with liquid refrigerant injection to minimize suction vapor superheat.
3. Bypass of discharge vapors directly into the evaporator inlet or to a midpoint in an evaporator to artificially load the system.
4. Multiple evaporators separately fed by individual expansion devices.
5. Multiple expansion valves feeding a single evaporator with valves of varying characteristics and capacity as required. This design requires careful consideration of possible oil return problems.
6. Suction pressure limiting means including pressure limit expansion valves or liquid solenoid valves actuated by reverse acting low-pressure control devices. This method is commonly used to prevent motor overloads in low back pressure rated compressors.

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