

Fig. 1 .... Ammonia Shell-and-Tube Brine Cooler

cifically applicable to low temperature cooling where the static liquid head temperature penalty of a flooded cooler is too large a percentage of the available temperature difference. The required refrigerant charge is low and is much less affected by load variations than in the case of flooded coolers. A mechanical refrigerant pump is required to circulate the refrigerant.

Dry Expansion Type

In a dry-expansion cooler the refrigerant is expanded into the inside of tubes and vaporized completely before recirculation. The fluid being cooled is circulated on the outside of the tube surface and within an enclosing shell. A baffle arrangement is usually provided within the shell to direct the fluid flow across the tubes in order to produce the desired fluid velocity. (See Fig. 3.)

The refrigerant feed device is usually a thermostatic expansion valve controlled by the amount of superheat in the refrigerant vapor leaving the evaporator. A superheater may be employed beyond the liquid valve control point to further superheat the suction vapor by heat exchange with the warm refrigerant liquid from the condenser.

The dry expansion cooler is specifically suitable where water or brine is to be cooled to a temperature approaching its freezing point. Any malfunction of the system, resulting in freezing, unless repetitive, normally does not damage the cooler. Proper design of the refrigerant circuit and the method

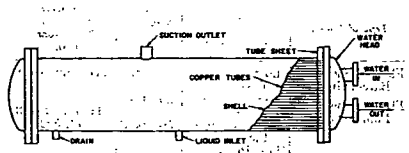

Fig. 2 .... Flooded Halocarbon Water Cooler

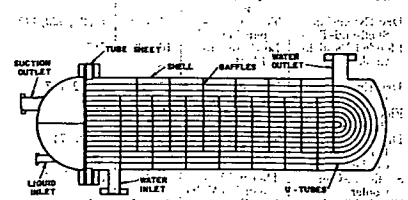

Fig. 3 .... Dry Expansion Halocarbon Water Cooler

of feeding the liquid will establish refrigerant velocities sufficiently high to assure oil return to the compressor with a reasonable refrigerant pressure drop through the circuit. For capacities below 150 tons of refrigeration the dry-expansion cooler usually will be more compact and less subject to freezing than other types. For ship installations, the rolling and pitching of the ship has little effect on its operation.

The dry expansion cooler may be modified so that the liquid refrigerant is not completely evaporated during its first passage through the inside tube surfaces. The remaining liquid is recirculated by mechanical or jet pumps, or by thermo-siphon action.

Baudelot Coolers

Baudelot coolers (Fig. 4) are used in industrial applications where it is desired to cool water to 35 F or lower. In this type of cooler the fluid is circulated over the outside of a number of horizontal tubes one above the other. The fluid is distributed

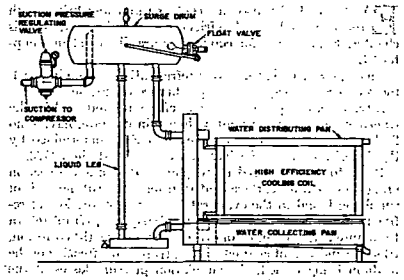

Fig. 4 .... Baudelot Cooler

uniformly along the length of the top tube and flows by gravity to the tubes below. The cooled water drops from the lower tube into a collecting pan from which it is pumped to the source of heat and then back to the top of the cooler. The cooler may be enclosed by insulated walls to avoid unnecessary loss of refrigerating effect.

Refrigerant 717 (ammonia) is commonly used with the Baudelot cooler arranged for flooded operation, using the conventional gravity feed system with surge drum. A low-pressure float valve maintains a suitable refrigerant liquid level in the surge drum.

Baudelot coolers using other common refrigerants are usually of the dry expansion type, using thermostatic expansion valves.

Double-Pipe Coolers

In double-tube coolers each tube consists of a tube within a tube. The refrigerant may be circulated in either the inner tube or in the annular space between the tubes. Because of fouling or corrosive conditions inherent with water and brines, these liquids are usually circulated through the inner tubes to facilitate control of such conditions. Double-tube coolers may be operated flooded or as dry expansion coolers. Methods of operation are similar to that of the Baudelot coolers.

Shell-and-Coil Type

A very simple type of *shell-and-coil cooler* (Fig. 5) has been used in small capacities for cooling water for drinking purposes, bakeries, and photographic laboratories. It consists of a steel or alloy tank containing a helical coil through which the refrigerant is circulated. The water is contained in the tank surrounding the coil. This type of cooler has the advantage of having cold water storage capacity, useful where peak loads occur at intervals.

Flooded Tank-and-Agitator Type

The tank or boiler-type coil system (Fig. 6) for cooling brine or water has been in almost universal use for large systems

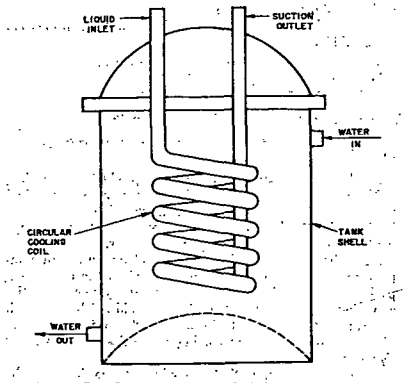

Fig. 5 .... Shell-and-Coil Cooler

for many years, where sanitation is secondary. A large steel tank contains the fluid to be cooled. At one side or the center of the tank is placed a closely nested set of pipe coils, baffled off from the tank, and fitted with an agitator to circulate the brine or water in the tank over the coils at a relatively high velocity (100 to 150 fpm).

The agitator circulates large quantities of brine or water to maintain uniform temperatures throughout the tank (the total temperature difference is frequently less than 1 F deg). Coils are usually arranged with short lengths of travel from liquid headers to suction headers to minimize refrigerant pressure drop. In an alternate arrangement to that shown in Fig. 6 the coils are bent in V-form between the headers.

This same type of system is used for freezing ice in can-type tanks. The tank is enlarged to accommodate the ice cans with brine flowing past the cans at approximately 25 fpm.

Coolers for Centrifugal Systems

Evaporators designed for use with centrifugal compressors are generally used for cooling water or brine, and are usually of the flooded shell-and-tube type.

Centrifugal compressors may be designed for various conditions but customarily are used in high-volume flow, low-pressure rise applications. In the normal range of water-chilling for comfort air conditioning, Refrigerants 11 and 113 are most often used. The higher volume of vapor handled per ton of refrigeration capacity for refrigerants of this type, necessitates special design features in the coolers.

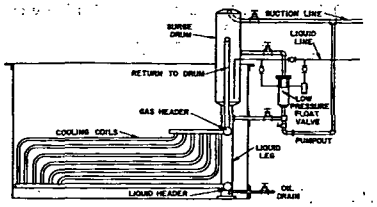

Fig. 6 .... Tank or Boiler Type System for Cooling Water or Brine

Coolers for centrifugal compressors ordinarily have finned nonferrous tubing for water cooling service, but ferrous or prime surface tubes may be used for special applications or process cooling. More space is provided for vapor, with less of the shell being utilized for heat transfer surface, than in coolers used with high-pressure refrigerants. The relatively high volumes of vapor tend to create velocities that would induce liquid carryover. It is customary to provide liquid eliminators in these coolers, either of the blade type or a woven mesh de-mister. For large shell volumes, the eliminators may be omitted.

The suction connections or refrigerant outlets from coolers used with centrifugal compressors are usually on the side of the shell above the eliminator section and frequently take the form of a transition section from a flared rectangular or elliptical opening to a round connection.

The centrifugal refrigeration cooler is usually supplied with refrigerant by means of a high-side float valve. For multi-stage units, where interstage liquid cooling is used, the float chambers and expansion chambers are sometimes made an integral part of the cooler.

In centrifugal refrigeration coolers, the height of liquid refrigerant also has considerable influence on temperature effects, due to static head. The designs must allow for this effect.

DESIGN CRITERIA

Mechanical Requirements

Pressure vessels must be constructed and tested under the rules and regulations of national, state, and local codes. Usually, vessels designed for operation at 15 psig or less or with a gross internal volume of less than 5 cu ft are exempted.

The more common applicable codes and standards with a brief explanation of the purpose and extent of each are:

1. *ARI Standard 480-61, Refrigerant Cooled Liquid Coolers*, which covers industry standards for standard equipment, standard safety provisions, marking and recommended procedures for testing and rating refrigerant liquid coolers. Reference is made in this standard to the testing procedure described in item 2.

2. ASHRAE *Standard 24-61, Methods of Testing for Rating Liquid Coolers.*

3. *ASA B9.1-1964, Safety Code for Mechanical Refrigeration.* This code is based on the current ASHRAE Standard 15-63. It involves specific design criteria, use of materials, and testing. Many phases refer in toto to the ASME Boiler Code. Field test