Ammonia, probably the best known refrigerant, has the disadvantage of being toxic, and under certain circumstances, explosive, corrosive, and irritating, even in small quantities in the atmosphere.

Dichloromethane operates at pressures below that of the atmosphere, and it is to some extent toxic.

Dichlorodifluoromethane under normal circumstances is non-toxic, non-irritating, and non-explosive, but under high temperatures breaks down into several obnoxious, poisnous components.

Methyl-chloride, under certain conditions, is explosive and slightly toxic.

The steam ejector water vapor system has none of the disadvantages of toxicity, explosiveness and corrosiveness encountered in the other refrigerants, but the system operates at less than atmospheric pressure. This, however, is not an important factor as there are no moving parts in the compressor and the possibility of inleakage of air is remote as all of the equipment can be welded air and watertight. The supply of water is inexhaustible, and as a refrigerant, the makeup cost is negligible. The same boiler equipment for heating in winter and for cooling in summer can be used.

## Motors

The motors used for driving compressors can be roughly classified in three groups; synchronous, multi-speed, or variable speed. Further information on motors may be found in Chapter 17.

## Coolers

The types of coolers used in connection with air conditioning work fall into three general groups. The *first* is the direct cooling of water; the *second*, direct cooling of air; and the *third*, cooling of brine for circulation in a closed system, which can cool either water or air. In the order named, the cooling of water sprayed in the dehumidifier is the type most generally in use and can be accomplished in several ways. One method is to install direct expansion coils in the spray chamber so that the water sprayed in the air comes in direct contact with the cooling coils. Another common and rather efficient method of cooling spray water, is to use a baudelot type of heat absorber where the water flows over direct expansion coils at a rate sufficiently high to give efficient heat transfer from water to refrigerant, and used in connection with a storage tank or collecting pan insures good operation of the refrigeration equipment if proper attention is given to the load on the system.

Another type of spray water cooler is the shell and tube heat exchangers; the refrigerant being expanded into a shell enclosing the tubes through which the water flows. The velocity of the water in the tubes affects the rate of heat transfer, and as the refrigerant is in the shell, completely surrounding the tubes at all times, good contact and a high rate of heat transfer is insured. The disadvantage of such a system is that with the falling off of load on the compressor, the suction temperature or the temperature in the evaporator drops and there is a possibility of freezing the water in the tubes, which, of course, would split the tubes and allow the refrigerant to escape into the water passage. This danger can be eliminated by complete automatic safety devices.

Another system of cooling spray water is to submerge coils in the spray collecting tank, or in a separate tank used for storage. The heat transmission through the walls of the coils, however, is low and a great deal more surface is required than any other type of cooler. However, with large storage tanks, this type of cooling can be utilized to advantage.





In the second group of coolers mentioned, that of direct cooling of air, there is only one type to be considered; the coil type with the refrigerant in the coil and the air passing over it. Cooling depends upon convection and conduction for removing the heat from the air. The type of coil used for cooling can be either smooth or finned; the finned coil being more economical in space requirement than the smooth coils.

The third group of coolers, which are sometimes called indirect coolers, where brine is cooled by the refrigerant and the resulting cold brine used to cool either air or water, introduces several other considerations. It is not the most economical from a power consumption standpoint, as it is necessary to cool the brine to a temperature sufficiently low so that there is an appreciable difference between the average brine temperature and the substance being cooled. This requires that the temperature of the refrigerant must be still lower, and consequently the amount of power required to produce a given amount of refrigerant increases due to the higher compression ratio, but there are other considerations which make such a system desirable. In the first place, where a toxic refrigerant is undesirable or cannot be used, due to fire or other risks, especially in densely populated areas, the brine can be cooled in an isolated room or building, and the brine then circulated through the air conditioning equipment in perfect safety; the brine being used to cool the water or air, without any possibility of direct contact between the air and refrigerant.

When an indirect system of cooling is used, it will be found that the heat transfer rate of the water cooler is considerably higher as a general rule than a direct exapansion cooler for the same requirements. With direct expansion interchangers, it is almost inpossible to keep the entire system flooded with liquid, whereas with brine interchangers, the cooling medium completely fills the space of the interchanger and perfect contact is insured.

There is one other type of water cooling which might be mentioned, and that is the use of ice. Its application is limited because of the cost of ice, although the efficiency of cooling is higher than any other water cooling system. The word "water cooling" is used advisedly in that the direct cooling of air by ice is, while not impossible, rather impractical. It might be said that ice coolers are economical for systems requiring a maximum rate of 20 tons ice melting effect per 24 hours where the load fluctuates considerably, and it is possible to introduce ice only as it is required to cool water. The most general method of cooling water with ice is to spray the water over the surface of the ice, insuring as much contact as possible and approximating the same performance as the baudelot type of cooler. Because of the large fluctuations in load in the air conditioning system, the higher cost of refrigerating effect when ice is used, is offset by the fact that there are no motor and condenser inefficiencies under partial load, and the cost of the mechanical refrigeration equipment for the small system being so much higher per unit of effect, the fixed charges are small enough to overbalance the extra cost of the ice.

## Condensers

Condensers are usually either double pipe or shell and tube type. Shell and tube condensers are almost identical with coolers. Double pipe condensers are arranged so that water passes through the inner of two con-