compression ratio is high, and their design follows closely that of any other centrifugal equipment, such as general service pumps and fans.

Steam jet compressors which have recently entered the field are simple and compact and, having no moving parts, they produce practically no vibration but are not economical for water temperatures much below 40 F or where the cost of generating steam is higher than the cost of operation with other prime movers.

Reciprocating compressors are generally used for methyl chloride and dichlorodifluoromethane because of their relatively low pressure and compression ratios. These compressors find widest use for fractional tonnage duty.

Refrigerants

The source of condensing water to some extent governs the type of refrigerant used. If condensing water is available at temperatures of not more than 70 to 75 F any of the refrigerants mentioned can be used economically, but if the available condensing water temperature is above 80 F, carbon dioxide becomes uneconomical as its critical temperature is approximately 88 F. A condensing water temperature over 80 F makes the power required for compression high. All refrigerants, except carbon dioxide, have critical temperatures and pressures sufficiently high so that their efficiency is not materially affected by the condensing water temperatures, except insofar as this temperature affects the compression ratio. Steam jet cooling systems can use water up to 85 F, or even slightly warmer.

The applicability of the various refrigerants is interesting. Carbon dioxide is limited by the condensing water temperature; the power consumption is slightly higher than that of other refrigerants; and the pressures are three to four times that of ammonia.

The condenser pressures of methyl chloride and dichlorodifluromethane are approximately one-half that of ammonia.

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. An indirect closed system vented method or double indirect open spray vented method of refrigeration is used for cooling water or brine in air conditioning systems employing ammonia as the refrigerant.

Sulphur dioxide is corrosive and irritating even in small quantities in the atmosphere and it is toxic under certain circumstances.

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

Dichlorodifluromethane and trichloromonofluoromethane under normal circumstances are odorless, non-irritating, non-toxic, non-flammable, non-explosive, non-corrosive and will do no damage to any materials with which they may come in contact.

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 water tight. The supply of water is inexhaustible, and as a refrigerant, the make-up cost is negligible. The same boiler equipment can be used for heating in winter and for cooling in summer.

Electric Motors

The motors used for driving compressors can be roughly classified in three groups: synchronous, multispeed, or variable speed. Further information on motors and their controls may be found in Chapter 42.

CONDENSERS

Condensers are usually either the double pipe type or the 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 concentric pipes, and refrigeration passes through the annular space in the outer pipe. Where possible, there should be counter flow of the refrigerant and the condensing water to maintain maximum temperature differences.

The amount and temperature of the condensing water determine the condensing temperature and pressure, and indirectly the power required for compression. It is, therefore, necessary to strike a balance so that the quantity of water insures economical compressor operation.

As part of the condenser, or attached to it, there must be storage space for liquid refrigerant. The installation of all equipment should be made accessible for inspection, repair, and cleaning. Both the coolers and condensers should have space for pulling tubes.

Because there is a decided tendency to conserve the water in city mains and most large cities are restricting the use of water, in order to use air conditioning systems and refrigeration equipment it is often necessary to install cooling towers. The cooling towers, unfortunately, produce the warmest condensing water at the time when the load on the system is greatest, so that the refrigeration equipment must be designed to meet not only the maximum load at normal conditions, but also the maximum load at abnormal condensing water temperatures. If properly designed, this makes little difference in the efficiency of operation throughout the year except at those times when the condensing water temperature is highest. As this occurs only for 5 per cent of the entire cooling period it can be disregarded as a factor in establishing yearly operating costs.

The cooling tower has a certain advantage over the use of water from the city mains in that the temperature of the condensing water varies directly with the outdoor temperature and, as pointed out, the refrigeration load also varies with this temperature. Certain economies are possible when a cooling tower is used which cannot be achieved by the use of condensing water from city mains, even where the city water temperature is extremely low. Normally, the lowest city water temperature met during the summer months is from 65 to 70 F. This temperature range takes