direct steam turbine drive because of their high operating speed. Water cooling equipment of one design is operated between 3500 and 4000 rpm for units developing 1000 to 2000 tons capacity, and from 7000 to 8000 rpm for units developing 100 to 200 tons capacity. However, a great many applications, particularly in the smaller sizes, are electric motor-driven and equipped with standard gear-type speed increasers. Centrifugal systems are particularly well adapted to large capacities (up to 3000 tons) although it is also possible to secure units as low as 50 tons in rating. Because centrifugal units operate best with refrigerants possessing a high specific volume, and because of the simplification of lubrication difficulties, they are frequently used for extremely low temperature applications. They are

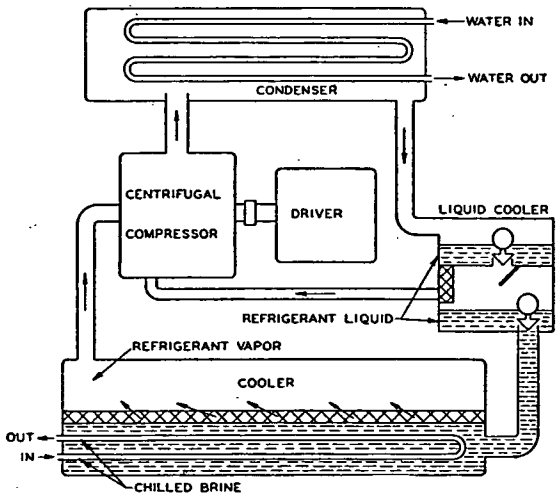

FIG. 12. ENCLOSED TYPE CENTRIFUGAL CONDENSING UNIT

adaptable to a wide range of temperatures from −130 F to 50 F. One important advantage is their flexibility under varying loads, since units may be designed to operate with reasonable efficiency at capacities as low as 20 percent of normal load.

Control of Centrifugal Compressors

Capacity Control usually is accomplished by a controller measuring the chilled water or evaporator pressure and either (1) varying the flow of vapor from the chiller to the compressor or (2) varying the compressor speed.

1. *Vapor flow control* for compressors driven by constant speed motors is accomplished by the use of suction dampers or inlet vanes which are positioned by automatic operators to maintain constant water temperature leaving the chiller or constant suction pressure in the evaporator.

2. *Speed Control* for compressors driven by constant speed motors may be accomplished through the use of an eddy current clutch or a hydraulic coupling under control of an automatic operator. Variable-speed motors for speed control are more common on the larger machines. Steam turbines for driving compressors can operate at various speeds under control of an automatic valve in the governor oil circuit.

Safety Controls provide protection for the compressor by stopping the motor or reducing the capacity through the capacity control system. Those which usually stop the motor are similar to those described for reciprocating compressors and respond to (1) low oil pressure, (2) low refrigerant temperature, (3) low chilled water temperature, (4) high condensing temperature, (5) high motor temperature, (6) high motor current, and (7) low line voltage. Frequently controls are used to measure some of these conditions and reduce capacity before the limit is reached in order to prevent system shutdown.

In addition to the above safety controls most centrifugal machines have thermostatically controlled heating and cooling of the oil, and some have water cooled motors with the water sometimes thermostatically controlled. Usually there is a system of interlocks which prevents the compressor from starting unless the condenser water pump and the chilled water pump are running.

Condensers

Condensers used for liquefying the refrigerant are of three general designs: (1) *air cooled*, (2) *water cooled*, and (3) *evaporative* (combination air and water).

1. *Air cooled condensers* are seldom used for capacities above 3 tons of refrigeration, unless an adequate water supply is extremely difficult to obtain, as, for instance, in railway air conditioning. Even on fractional tonnage installations, air is used as the condensing medium only where water is expensive, or where simplicity of installation warrants the higher condensing pressure and consequent power costs higher than would be obtained using water as the condensing medium.

The conventional air cooled condenser consists of an extended surface coil across which air is blown by a fan. The hot discharge gas enters the coil at the top and, as it is condensed, flows to a receiver located below the condenser. Air cooled condensers should always be located in a well ventilated space so that the heated air may escape and be replaced by cooled air.

The principal disadvantages of air cooled condensers are the power required to move the air, and the reduction of capacity on hot days. This loss of capacity, due to high condensing pressures on hot days, requires that equipment of increased capacity be selected to meet the peak load. Thus at normal loads the equipment is oversized. The principal advantages are low installation costs and simplicity, and for these reasons they are frequently used in small self-contained units.

2. *Water cooled condensers* are commonly used with compressors of one horsepower or larger in size, and they are found almost exclusively on large installations. They usually prove to be the most economical choice if an adequate water supply and means for its disposal are available. Although water cooled condensers may be of many designs, the shell and coil and the shell and tube are most commonly found in present day practice.

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 determine a balance so that the quantity of water insures economical compressor operation.

Because there is a decided tendency to conserve the water in city mains, and because most large cities are restricting the use of water for air conditioning and refrigeration equipment, it is often necessary to install cooling towers or evaporative condensers. 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 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 percent of the entire cooling period, it can be disregarded as a factor in establishing yearly operating costs. For further information on cooling towers, reference may be made to Chapter 34.

3. *Evaporative condensers* were developed to alleviate the over-burdened water supply and drainage facilities of communities where many small air conditioning systems using water cooled condensers were applied. The evaporative condenser combines the functions of the two by using a minimum amount of water on the sur-