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.

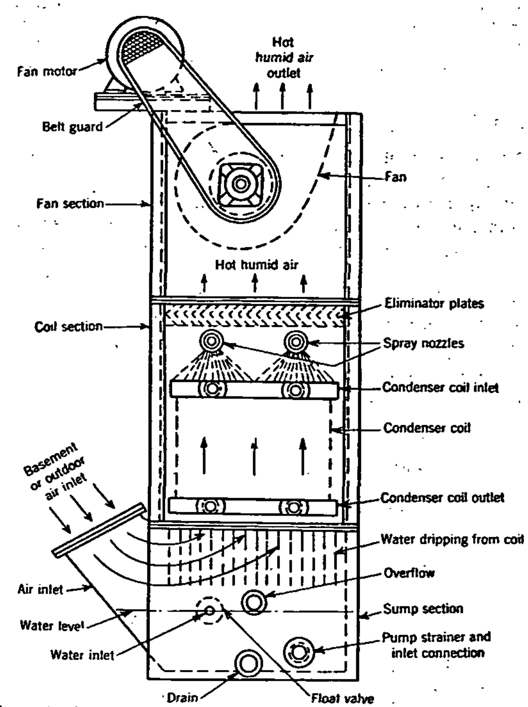

FIG. 17. SCHEMATIC VIEW OF AN EVAPORATIVE CONDENSER

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 surface, cooling it to approximately the wet-bulb temperature of the surrounding atmosphere.

The end view of a typical evaporative condenser is shown in Fig. 17. The fan draws the air over the condenser surface which is kept wet by a water spray. The discharge refrigerant gas from the compressor enters the top of the condenser coil, and the liquid refrigerant is drained from the bottom of the coil into a liquid receiver, and then circulates through the remaining portion of the system in the usual way.

The water is circulated through the spray nozzles, and the level is maintained in the sump by means of a float valve. The eliminator plates are placed in the path of the water-air mixture so as to remove the entrained water. The air leaving the unit is almost completely saturated, so that care must be taken in locating discharge ducts to prevent condensation.

Evaporative condensers are available in sizes up to 300 tons or more. These