The selection of a proper water-cooling range depends upon: (1) type of service—refrigeration, internal-combustion engine, or steam condenser, (2) wet-bulb air temperature at which the equipment must operate, and (3) type of condenser or heat exchanger employed.

Because the design of an entire plant is usually affected by the quantity and temperature of the cooling water supply, plants should be designed for cooling water conditions which can be most efficiently attained. The first consideration is usually the limiting temperature of the plant. For example, if an ammonia compressor refrigerating plant is to be designed for 185 psig head pressure as a normal maximum, the limiting temperature of the ammonia in the condenser is 96 F. Should the ammonia temperature go above this figure the head pressure will exceed 185 psig and the power consumption increases. To obtain this head pressure, the temperature of the circulating water leaving the condenser must always be less

TABLE 6. CONDENSER DESIGN DATA

GAS	DESIRED PRESSURE IN CONDENSER	GAS TEMPERATURE IN CONDENSER, FAHRENHEIT	LEAVING HOT-WATER TEMPERATURE, FAHRENHEIT	
			Best Condenser Design	Average Condenser Design
Steam	28 in. vacuum	101.2	97	93
Steam	27 in. vacuum	115.1	110	105
Steam	26 in. vacuum	125.4	120	114
Ammonia	185 psi*	96.0	92	88
Carbon dioxide	1030 psig*	86.0	83	80
Methyl chloride	102 psig*	100.0	96	92
Freon, F-12	117 psig*	100.0	96	93
Freon, F-12	126 psig*	105.0	100	97
Freon, F-12	136 psig*	110.0	104	101

* Head pressure.

than 96 F by an amount depending upon the size and design of the condenser, the quantity of water being circulated, and the refrigerating tonnage being produced. A condenser having a large surface per ton of refrigeration may be designed to operate satisfactorily with the leaving hot-water temperature within 3 or 4 deg of the ammonia temperature corresponding to the head pressure, while a small condenser may require a 10 deg difference.

Table 6 lists several gases with data for the temperatures and pressures for which commercial condensers are designed. Careful evaluation of costs of water and electrical power should be made before deciding to use city water for jacket water and condensers. Economy of operation generally indicates the use of either a water-cooling tower or an evaporative condenser for most refrigeration installations of five tons or more capacity. Refer to Chapter 36, for information on Evaporative Condensers. Internal-combustion engines have limiting hot water temperatures of 140 to 180 F for closed systems, and 110 to 130 F for open systems, depending upon the quality of the cooling water. The cooling of such fluids as milk or wort has variable requirements, and is usually accomplished in counterflow heat-exchangers in which the leaving circulating water is at a much higher temperature than is the leaving fluid.

OPERATION AND MAINTENANCE

Water Treatment. The amount of make-up water required by a cooling tower depends upon evaporation loss, drift loss, and blow-down. Evaporation losses average 0.80 per cent of the water circulated for each 10 F deg range. Drift loss is the water carried out of the tower by the air currents in the form of droplets or mist. In properly designed induced draft towers this loss normally approximates one-tenth of one per cent, and most cooling tower manufacturers will guarantee a drift loss not to exceed two-tenths of one per cent. The amount of blow-down water wasted depends upon the hardness of the circulating water, type of water softening used and the amount of drift loss. Blow-down is normally controlled to maintain the concentration of soluble and scale-forming solids below the point where the formation of scale would occur or would be caused by corrosion.

Algae formations will plug nozzles and prevent proper distribution of the water over the tower filling. This growth may also collect on equipment served by the cooling tower, and thereby reduce the heat transfer rate. Algae should be held at a minimum or eliminated by use of bromine, chlorine, chlorinated lime, copper sulfate, or various blends of chlorophenates (see Chapter 42).

Although some scale-forming materials are found in practically all water, those which cause trouble in water-cooling systems are normally calcium and magnesium carbonates. Scale formation in equipment served also reduces heat transfer rates. Scale can be reduced materially or prevented by softening the make-up water with lime and soda ash, zeolite, or sulfuric acid, or by use of small amounts of sodium hexametaphosphate. Water softening or treatment requires close regulation and control by a competent chemist. Too high a concentration of soluble solids in cooling tower water may raise the temperature of the water leaving the tower, and may cause sludge deposits or corrosion in the system. Concentration of solids is normally controlled by either blowing down or by a continuous overflow to the sewer. Refer also to Chapter 42.

Delignification. The presence of sodium carbonate in the circulating water results in delignification of any wood with which water comes in contact. This chemical dissolves lignin which binds the wood fibers together and leaves the wood surface in a white fibrous condition. Prolonged exposure reduces the structural strength of the wood. Delignification first appears on parts of the tower that are alternately wet and dry, since evaporation at such points rapidly increases the concentration of dissolved solids. The presence of sodium carbonate in harmful amounts is generally indicated by a high pH of 9 to 11. The effect of the sodium carbonate may be neutralized by the use of sulfuric acid. It is desirable to have the pH value of the water at 7 to 7.5 (7.2 pH value is neutral for redwood).

Two-speed Motors. For readily adapting tower performance to temporary or seasonal decreases in heat load, and especially for winter operation, the use of two-speed motors (for fan drives) is recommended. The chief advantage is that when operated at half-speed, fans require only about 15 per cent of the power used at full speed. Particularly in multi-fan towers, the ready flexibility provided by two-speed motors results in considerable savings, even though load reductions may sometimes call for only one or a few fans to be operated at half speed.

Cold-weather Operation. Extremely cold water normally does not in-