COOLING TOWERS

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1. GENERAL

1.01 This section describes the operation and maintenance of mechanical draft cooling towers used for air conditioning systems.

1.02 Since this reissue is a general revision, arrows ordinarily used to indicate changes have been omitted. The references to both water treatment and preventive maintenance were eliminated due to coverage of these subjects in separate sections.

2. DESCRIPTION

2.01 A cooling tower cools the water which has been used in the condenser of the refrigeration equipment for extracting heat from the refrigerant. It cools the water sufficiently for reuse and thereby minimizes the amount of water consumed for this purpose. Its place in an air conditioning system is illustrated in Fig. 1.

2.02 Cooling is accomplished by exposing the condenser heated water to outside air so that the water loses heat partly by transfer of sensible heat to the cooler air, but mainly by evaporation of a portion of the water.

2.03 The tower consists of an enclosure of wood, metal, or asbestos cement board. Water is admitted to the top of the enclosure and is sprayed or dripped down over a series of slatted decks to be accumulated in a water basin at the bottom of the tower. Means are provided for forcing air through the sprays of falling water. The cooled water is accumulated in the basin of the tower and returned to the condenser for recirculation.

2.04 Cooling towers are divided into two general types: natural draft and mechanical draft. The natural draft tower relies on prevailing winds or on chimney effect for air flow through the tower. The mechanical draft tower is equipped with one or more fans to supply the required quantity of air. Disadvantages inherent in the natural draft tower, eg, large size, sprayed nuisance, dependence on natural conditions, etc, generally preclude the use of this type for telephone buildings. This practice is accordingly concerned only with the mechanical draft cooling tower.

2.05 The mechanical draft towers are divided into two general types: forced draft, illustrated in Fig. 1, and induced draft, illustrated in Fig. 2 and 3. In the forced draft tower, the fan is located in the air inlet to the tower. In the induced draft, the fan is located in the air outlet from the tower.

2.06 The path of air flow through the tower serves to further classify the mechanical draft tower. In the crossflow tower, air flows horizontally across the path of the falling water. In the counterflow tower, illustrated by Fig. 2, air flows vertically upward, counter to the path of falling water. The doubleflow tower, illustrated by Fig. 3, has air flowing in horizontally from both ends of the tower, then upward through the fan discharge.

2.07 Various means are used to break up the water into fine particles in order to expose greater water surface to the cooling action of the tower. Spray headers, illustrated in Fig. 1 and 2, break the water into fine drops. In another arrangement, illustrated in Fig. 3, the warm water is fed to a distribution basin located at the top of the tower. The floor of this basin is equipped with a number of uniformly spaced ceramic or neoprene distribution nozzles. Another method, not illustrated, simply utilizes overflow troughs to distribute the water.

2.08 The water is distributed over a series of staggered slatted decks, called the fill, which retards the rate at which it returns to the catch basin and serves further to break up the water into fine drops. The fill may be of metal, wood, or asbestos cement boards.

2.09 Air flowing through the tower will entrain small water particles. Water lost due to this effect is called drift loss. Baffles (drift eliminators) in the air stream leaving the tower impede the air flow so the small water particles impinge on the eliminator plates and drop back into the tower, thus minimizing drift loss.

2.10 The water basin of the cooling tower is equipped with a float valve to prevent the water from falling below a certain level and an overflow pipe to prevent the water from rising above a certain level. There is also a drainpipe for emptying the basin, and a screened sump for the pump inlet to screen out debris. Each of the items is illustrated in Fig. 1, 2, and 3.

3. OPERATION

3.01 As noted, the water in a tower is cooled mainly by evaporation of a portion of the water as it passes through the tower. The latent heat required to evaporate a pound of water is approximately 1000 BTUs. This heat is taken from the water which does evaporate and results in a loss of sensible heat. As the water surrenders sensible heat, its temperature will drop one degree per pound for each BTU surrendered. Applying the above figures, the heat absorbed by the evaporation of the pound of water will cool 100 pounds of cooling tower water 10 degrees.

3.02 The cooling tower theoretically can continue to cool the tower water until the water temperature reaches the wet bulb temperature of the air passing through the tower. When this limiting temperature is reached, evaporation ceases. However, a cooling tower designed to cool water to the wet bulb temperature would be of infinite size; so in actual practice, towers are designed to approach the wet bulb temperature. The closer the final water temperature approaches the wet bulb temperature, the larger the tower must be for a given capacity. The actual temperature difference between the final temperature of the water cooled by the tower and the wet bulb temperature is called the ***approach*** of the tower. For air conditioning applications, towers are sized to provide an approach of 5 to 10 degrees, usually 7.5 degrees.

3.03 The warm water is fed to the tower and cooled to a certain approach to the wet bulb temperature. The temperature difference between the inlet water and the outlet water is called the ***cooling range*** of a tower. Cooling towers used for air conditioning applications are sized to provide a cooling range of 5 to 15 degrees, usually 10 degrees.

3.04 As an illustration, a tower which received water at 95 degrees and cooled it to 85 degrees at an ambient (surrounding) wet bulb air temperature of 78 degrees would have a 10-degree range (95 to 85 degrees) and a 7-degree approach (85 to 78 degrees). Manufacturers will supply range and approach figures for their towers under various wet bulb temperatures and cooling loads.

3.05 The water cooling tower is generally used with the larger capacity refrigerating systems. Its alternate water saving device, the evaporative condenser, is usually made in sizes up to 100 tons. Good design requires that the evaporative condenser be installed near the refrigeration equipment. A cooling tower, on the other hand, may be remotely located from the refrigeration equipment. Thus, the tower is well suited for installations in which package units are mounted on various floors of a multistory building, or where the refrigeration equipment is in the basement and the tower is on the roof. It is also used with centrifugal compressors, in which the refrigerant circuit must be kept short.

3.06 During conditions of light load on the refrigerating system or when outdoor wet bulb temperatures are low, the cooling tower water temperature will drop. When such conditions occur, the capacity of the cooling tower exceeds requirements and is out of balance with the load on the refrigeration system. Abnormally low water temperature in the condenser causes abnormally low compressor discharge pressure. As the discharge pressure drops, the compressor tends to lose its oil to the refrigerant piping system, creating difficulties in compressor lubrication with the possibility of plant shutdown.

3.07 To minimize potential trouble of this kind, the fans in the cooling tower may be controlled either by a pressure controller on the compressor discharge line or by a temperature controller in the condenser waterline from the cooling tower. Such controls will maintain satisfactory compressor discharge pressure.

3.08 Another method of controlling the temperature of the cooled water from the tower is by means of a modulated bypass valve which bypasses water from the warm water line to the cooled water line without circulating through the cooling tower. The modulated valve is operated by a modulating-type temperature controller in the cooled water line from the tower.

3.09 Normally, operation of the refrigeration equipment and the tower is unnecessary in the winter season, and the tower is drained to prevent damage by freeze-ups. However, sometimes on warm winter days the outside air intake ducts are too small to dissipate the heat developed in telephone equipment rooms, and the temperatures in the switch rooms may rise above recommended temperature guidelines. If careful study shows increasing the capacity of the outside air ducts to be impractical, it will be necessary to operate the refrigeration equipment and the tower during the winter season. Whenever the outdoor temperature drops below the freezing point, ice will form on the intake louvers and the fill of the tower. Shutting down the tower fan will, in most cases, melt the ice. One method of preventing ice formation on the tower when operating during freezing weather is necessary to provide a bypass arrangement around the spray heads or distribution deck. The warm water coming from the condenser is valved off from the spray heads or distribution deck and piped directly into the collection basin in such a way as to create a swirling motion of the water in the basin. The fill and air intake louvers remain dry and thus cannot form ice. The warm condenser water swirling into the basin prevents the basin from freezing over.

4. CAPACITY RATINGS

4.01 Cooling tower capacity ratings are listed by the manufacturer in table form or in a series of rating curves. The tables or curves specify the amount of refrigeration in tons of capacity that the tower will handle under various conditions of wet bulb temperature, inlet water temperature, and gallons per minute of water circulated through the tower. The range and approach of the tower under varying conditions will also be found in the tables or curves.

4.02 Cooling towers are sized to remove 15,000 BTUs per hour per ton of refrigerating capacity. Since a refrigerating system absorbs only 12,000 BTUs per hour per ton, the extra 3000-BTU capacity of the tower is provided to remove the heat added in compressing the refrigerant and the heat added by the tower circulating pump.

4.03 It is possible to make a rough test on the performance of the tower to determine if it is functioning properly. The following information is required:

(a) ***Cooling range of the tower***—This is found by subtracting the temperature of the outlet water from the temperature of the inlet water of the tower.

(b) ***Weight of the water circulated through the tower per hour***—This may be measured by several means. If a pitot tube measuring device is available, the flow of water through the inlet pipe may be measured. If pump capacity curves are available, the amount of water pumped may be determined by noting the total pumping head on the pump pressure gauges and reading rate of flow corresponding to the pump curve.

(c) ***Wet bulb temperature of outside air.***

(d) ***Approach***—This is found by subtracting the wet bulb temperature from the outlet water.

4.04 The information gathered will give the operating capacity of the cooling tower when substituted in the following formula:

$$\text{Cooling cap in tons of refrig} = \frac{\text{Wt of water circulated per hr X range}}{15{,}000 \text{ BTU/hr/ton}}$$

The results obtained may be checked against the manufacturer's rating tables to see if the tower is performing satisfactorily.

4.05 As an example of the above test, assume a tower serving a 300-ton refrigerating system operating at full capacity. The measured rate of water flow is 900 gallons per minute (gpm). The inlet water temperature is 95 degrees, the outlet water temperature is 85 degrees, and the wet bulb air temperature is 75 degrees. Substituting in the formula, the solution is:

$$\text{Cooling cap in tons of refrig} = \frac{900 \text{ gpm X } 8.33 \text{ lbs/gal} \times 60 \text{ min/hr} \times 10° \text{ range}}{15{,}000 \text{ BTU/hr/ton}}$$

$$\text{Cooling cap} = \frac{4{,}498{,}200}{15{,}000}$$

$$\text{Cooling cap} = 299.9 \text{ tons}$$

The manufacturer's table for this tower rates it at 300 tons with a 10-degree range and 10-degree approach at a wet bulb temperature of 75 degrees. This corresponds with the test results so the tower is operating properly.

4.06 If the measured cooling range is greater than specified for the tower, it is an indication that the rate of water flow is less than design rate. Generally, cooling ranges and water flow rates follow the following table:

FLOW RATE	COOLING RANGE
2 gpm/ton	15 degrees
3 gpm/ton	10 degrees
4 gpm/ton	7.5 degrees

If the measured approach of the tower is greater than specified, it is an indication that the tower is not performing properly. A higher than normal approach may be caused by any of the troubles listed in the trouble chart under the symptom of high head pressure.

5. AIR REQUIREMENTS

5.01 Mechanical draft cooling towers require from 300 to 400 cfm of air per ton of capacity for efficient functioning. Obstructions near the tower, which restrict the free entry of air or which cause recirculation or short cycling of discharge air into the air inlet of the tower, will adversely affect tower efficiency.

6. WATER LOSSES

6.01 Cooling towers circulate from 2 to 4 gallons of water per minute per ton of refrigerating capacity. Approximately 1 percent of the water circulated is evaporated for every 10 degrees of tower cooling range.

6.02 Since a cooling tower is sized to remove 15,000 BTUs/hour per ton of refrigerating capacity and since one pound of water absorbs 1000 BTUs in evaporating, the evaporation loss of a tower is 15 pounds or 1.8 gallons per hour per ton of capacity.

6.03 Drift loss through entraining of small particles by air flowing through the tower is minimized by drift eliminators in the discharge air stream and is negligible in a well designed tower. Drift from a redwood tower may stain surroundings due to the water leaching tannin from the redwood.

6.04 Blow down or bleed loss is an intentional loss to a drain and is adjusted to limit the concentration of solids caused by evaporation of the water. It is further described under water treatment (Section 770-230-301). Bleeding may be accomplished by means of a small valved line from the warm water inlet pipe of the tower to a drain. It may be necessary to provide a solenoid valve in series with the bleed adjusting valve if the bleed line continues to flow when the pump is off and the tower is inoperative. The electrical connections of the solenoid should be tied into the pump starting control to operate only when the circulating pump operates. Another method of bleed-off utilizes a collecting funnel. The funnel is installed in the overflow pipe of the tower in the path of the water falling through the tower. The rate of bleed is adjusted by means of a sliding lid on the rectangular top rim of the funnel. This type is especially suited for smaller rates of bleed where silt or debris might clog a small bleed line. The bleed rate may also be controlled by raising the basin level so that water overflows.

7. TROUBLES

7.01 Since the function of the cooling tower is to cool water used by the condenser in a refrigeration system, any trouble in a tower generally results in warmer water being supplied to the condenser. With warmer water in the condenser, the discharge pressure of the compressor will rise. Thus the discharge pressure gauge of the compressor indicates the relative efficiency of the cooling tower.

7.02 ***Trouble Chart for Cooling Tower:***

SYMPTOM	TROUBLE	POSSIBLE CAUSE	REMEDY
High head pressure; liquid refrigerant in bottom of condenser or receiver very warm; compressor may cut out on high head pressure	(1) Insufficient air through tower; (less than 300 to 400 cfm/ton of capacity)	(a) Blown fuses, tripped overload relays, or tripped vibration switch	(a) Find cause of failure; repair and replace fuses or reset overload relay or vibration switch
		(b) Motor and fan running backwards	(b) Reverse motor leads; if not a new installation, check for recent power changes; if a single phase capacitor, start motor; check for stuck centrifugal starting switch in the motor
		(c) Low voltage to fan motor (over 10% difference in actual and rated voltage is bad for motor)	(c) Increase wire size; consult power company; change taps on owned transformers
		(d) Fan drive shaft or fan drive coupling broken	(d) Replace drive shaft or coupling
		(e) Gear box frozen or binding	(e) Repair gear box

SYMPTOM	TROUBLE	POSSIBLE CAUSE	REMEDY
		(f) Loose motor pulley or fan pulley	(f) Align pulleys and tighten setscrews
		(g) Fan belts slipping or broken	(g) Adjust belt tension or replace belts with matched set
		(h) Pitch setting on fan blades changed due to loose setscrews	(h) Reset pitch on blades to proper angle and tighten setscrews; check motor current afterwards to stay within motor current rating
		(i) Obstructions in fill, louvers, or eliminators	(i) Clean fill, louvers, and eliminators
	(2) Insufficient water circulation	(a) Clogged strainers in circulation piping	(a) Clean strainers
		(b) Clogged pump intake screen	(b) Clean screen
		(c) Clogged spray nozzles	(c) Clean nozzles
		(d) Scale in lines or condensers	(d) Chemically remove scale; treat water to prevent recurrence
		(e) Pump coupling loose or broken	(e) Repair or replace coupling; check alignment
		(f) Eroded pump impeller	(f) Replace impeller

SYMPTOM	TROUBLE	POSSIBLE CAUSE	REMEDY
		(g) Pump packing too tight or binding on shaft	(g) Loosen or replace packing; check for damage to shaft
		(h) Low voltage to pump motor	(h) Increase wire size; consult power company
		(i) Blown fuses or tripped overload relay	(i) Find cause and replace fuses or reset relay
		(j) Pump motor running backwards	(j) Change power leads; if not a new installation, check recent power change-over
		(k) Float valve stuck closed	(k) Repair float valve
	(3) Insufficient water breakup	(a) Spray nozzles; distribution nozzles or distribution troughs clogged with algae or debris	(a) Clean; treat water for algae if necessary.
		(b) Collapsed, broken, missing, or warped fill	(b) Replace or repair fill
	(4) Tower discharge air recirculating into tower intake	(a) Intake and discharge of tower too close	(a) Install baffle or duct work to separate intake and discharge areas
		(b) Discharge air leaves at too low velocity	(b) Increase fan speed or fan blade pitch; do not overload fan motor in making change

SYMPTOM	TROUBLE	POSSIBLE CAUSE	REMEDY
Noisy Operation	(1) Complaint of building occupants or neighbors	(a) Gear box or fan drive shaft worn or out of alignment	(a) Repair or relaign
		(b) Pump, fan, or drive motor bearings worn	(b) Replace bearings
		(c) Fan unbalanced	(c) Balance fan
		(d) Pump or fan coupling worn or broken	(d) Repair coupling
		(e) Fan belts loose	(e) Adjust belt tension
		(f) Three-phase motor operating on single phase due to faulty wiring or blown fuse	(f) Repair wiring or replace fuse

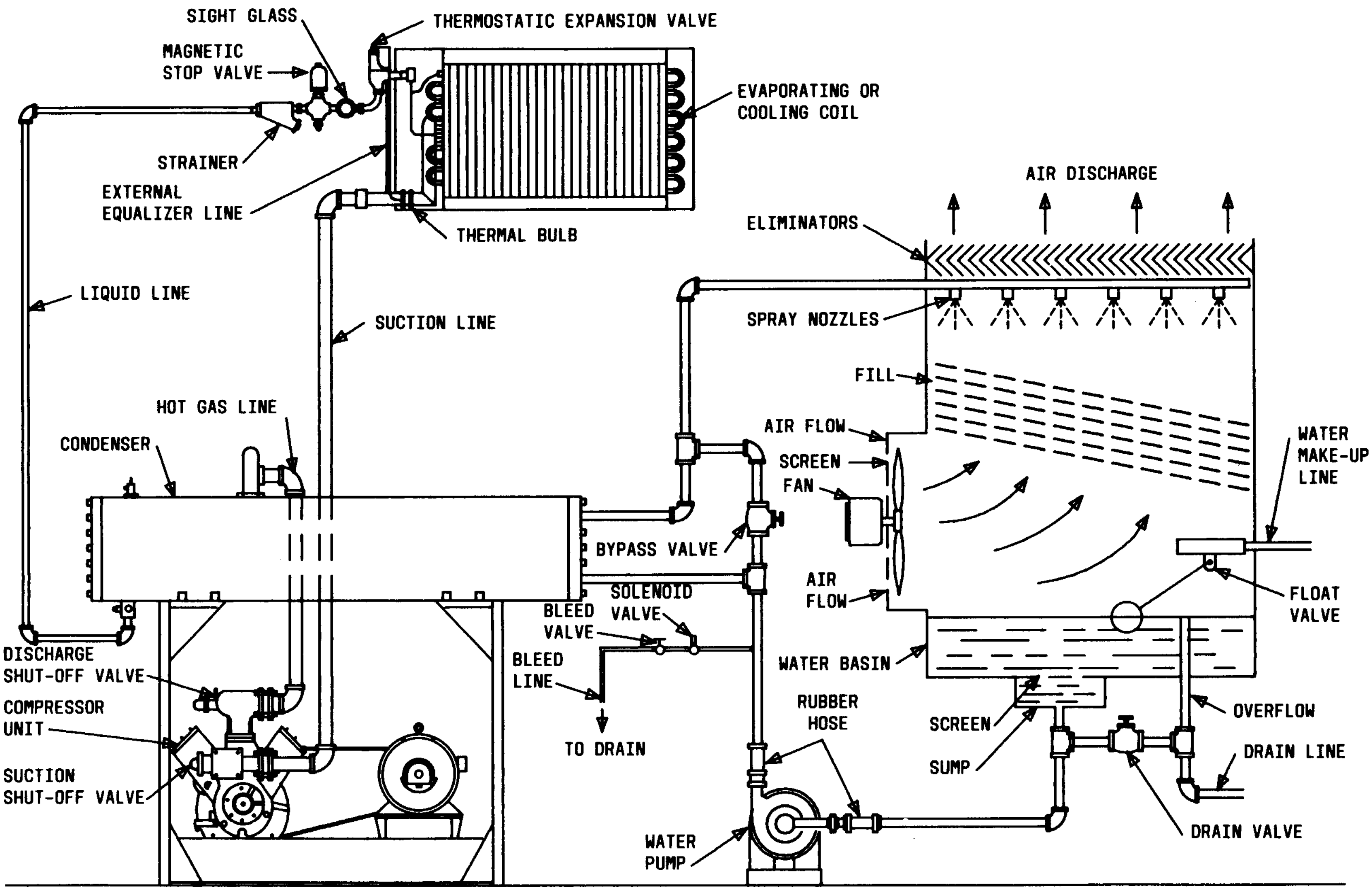

Fig. 1—Forced Draft Cooling Tower Serving Refrigeration System

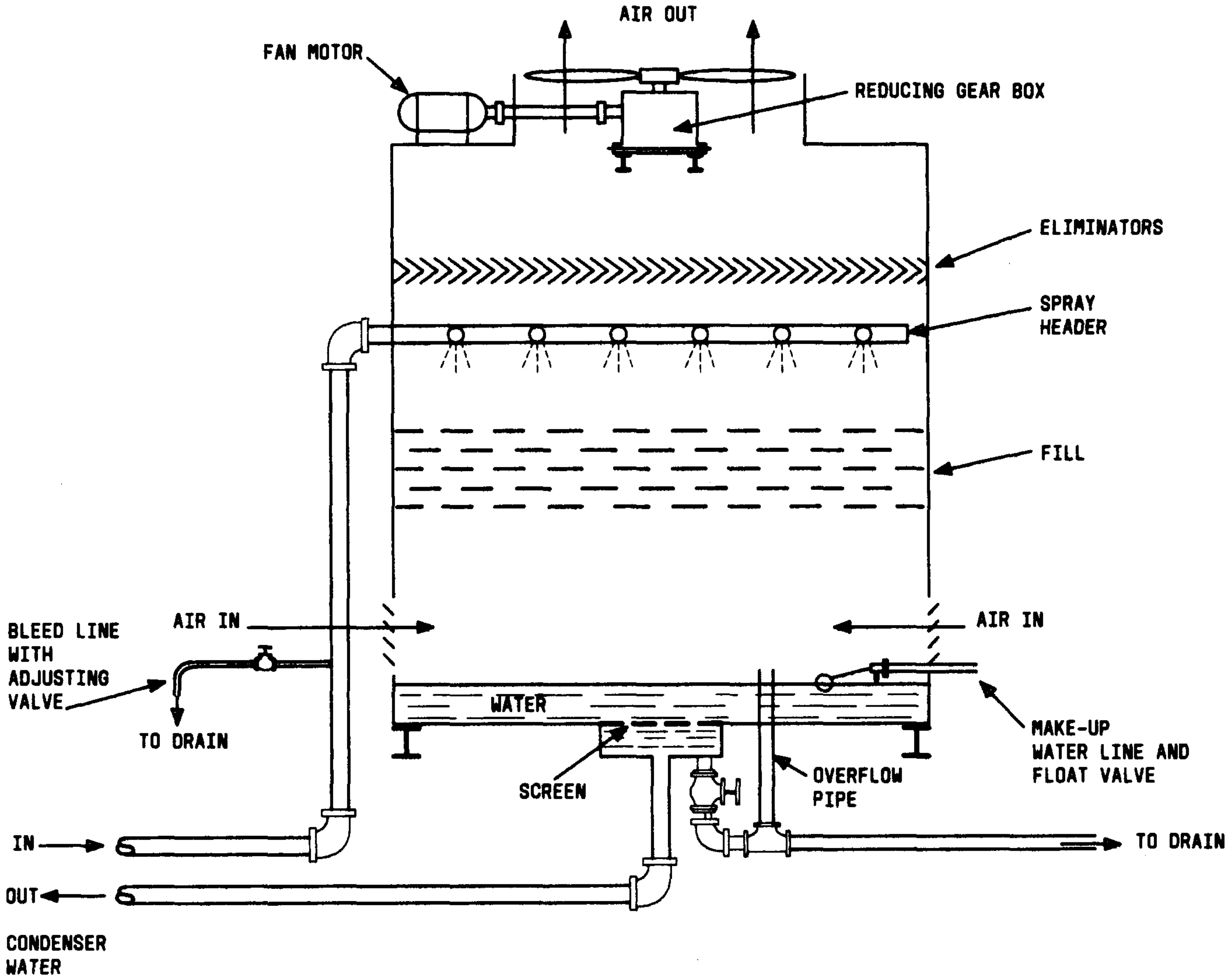

Fig. 2—Induced Draft Counterflow Cooling Tower

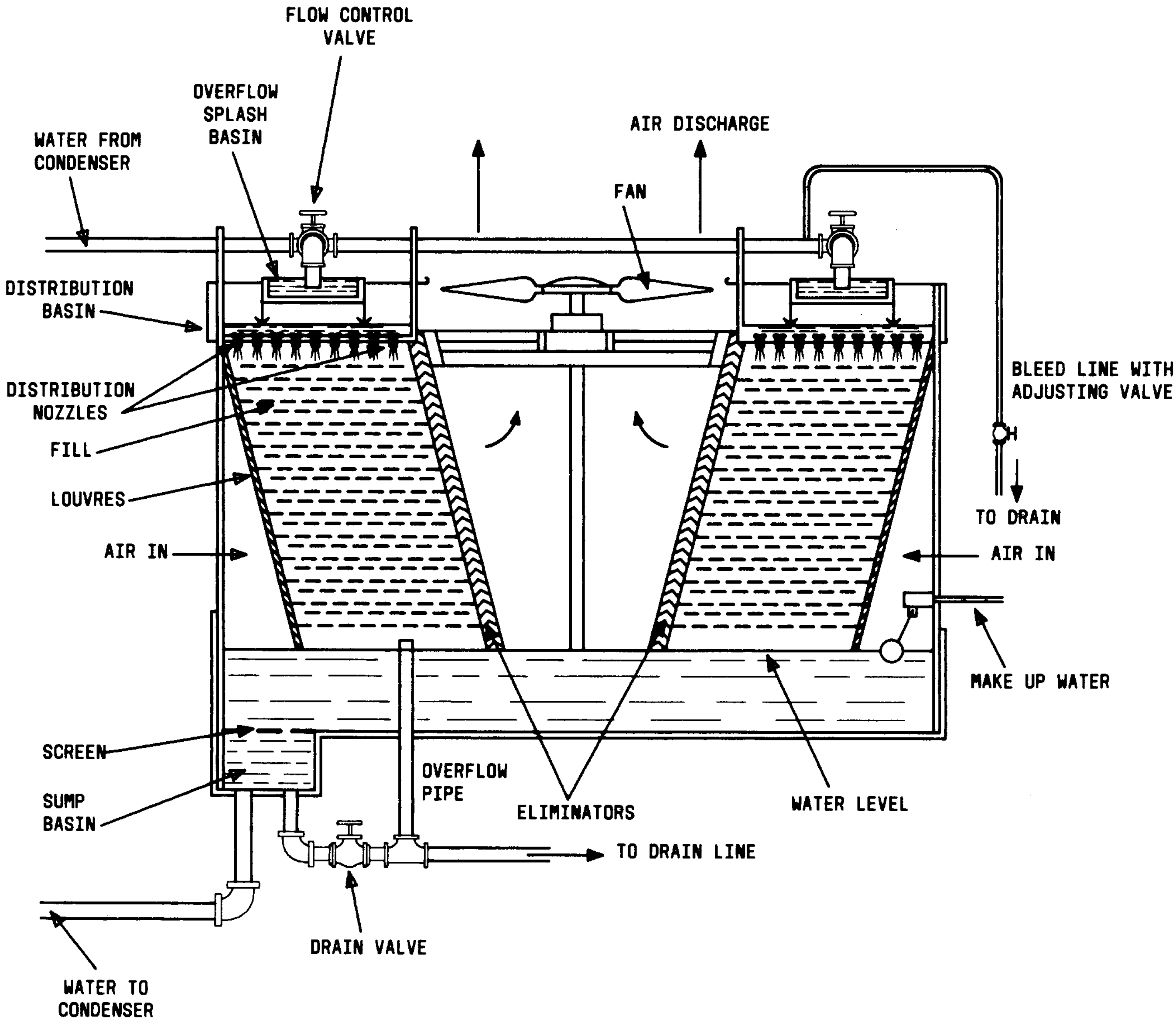

Fig. 3—Induced Draft Doubleflow Cooling Tower