EVAPORATIVE CONDENSERS

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1. GENERAL

1.01 This section describes the operation and the procedures followed for maintaining evaporative condensers used in refrigeration systems.

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

2. DESCRIPTION

2.01 The evaporative condenser is a device for condensing hot refrigerant gas. It is a compact combination of a forced draft water cooling tower and an air condensing coil. The evaporative condenser receives the hot gas refrigerant from the compressor of the refrigerating system and dissipates this heat to the atmosphere through the medium of high latent heat of vaporization of water. It is preferably located on the roof, but can be placed inside of a building to permit winter operation.

2.02 The evaporative condenser is more compact than a water cooling tower of the same capacity; however, like the water cooling tower, it is a water saving device. The evaporative condenser conserves about 95 percent of the cooling water as compared to a once-through-to-waste type of condensing arrangement. The evaporative condenser is used in single units in capacities up to 100 tons and in multiple units in excess of 100 tons. It is used to advantage where:

(a) Water is required in large quantities and economy in water consumption is necessary due to cost.

(b) Water supplies are limited and usage is restricted by city ordinance.

(c) Water is exceedingly hard or otherwise unsuitable.

(d) Water waste or sewerage facilities are limited.

(e) Year round operation is required.

(f) Space is limited.

The evaporative condenser has several disadvantages. Where the evaporative condenser is remotely located from the compressor unit, the interconnecting piping increases the refrigerant charge to the system substantially and, due to pipe friction losses, increases the compressor discharge pressure. With additional piping, the refrigerant leak potential is increased proportionally when compared with a close-coupled unit or cooling tower. Scale removal from the outside of the tube bundle is rather difficult since the tubes are closely nested and provide poor access for cleaning purposes. Units with finned tubes should be avoided.

2.03 Figure 1 is a schematic diagram of a typical small direct expansion refrigeration system with an evaporative condenser as the condensing component.

2.04 Generally speaking, the evaporative condenser is made entirely of metal. The fan housing, fan, eliminators, side and end panels, water distributor, spray heads, and catch basin are the major components of the evaporative condenser and are supported by means of a heavy angle-iron framework. These components have either a galvanized or painted finish.

2.05 Figure 2 is a schematic diagram of a typical evaporative condenser. The hot gas refrigerant from the compressor passes through the condenser coils where it gives up its latent heat of condensation to the water being sprayed over the coils. The fans draw air in at the bottom in a counterflow to the water and expel it at the top. As the heat from the hot refrigerant gas passes into the water, the temperature of the cooling water is raised and some of the water evaporates into water vapor (about 2 percent) which passes out through the fans with the air to the atmosphere. When the hot gas is condensed to liquid refrigerant, it is piped to a storage tank or receiver that may be located in the evaporative condenser basin or near the condensing unit.

2.06 The sprayed cooling water that has not evaporated falls back into the basin of the condenser to be used again. A float valve in the basin maintains a set water level and serves to admit additional water to replace that which has evaporated or is lost due to intentional waste.

2.07 The evaporative condenser is equipped with one or more fans to provide a counterflow of air through the spray water, condenser coils, and eliminator plates. This movement of air aids in breaking up the water into a fine spray and increases the evaporation rate. Eliminator plates between the spray heads and the fans serve to prevent spray water from being drawn into the fans and discharged to the atmosphere.

3. CAPACITY RATING

3.01 Evaporative condensers are customarily rated in terms of the tonnage rating of the compressor to which they may be connected.

3.02 In addition to the heat picked up by the refrigerant in the evaporator, heat is added during the compression process, ie, the heat equivalent of the horsepower of the compressor motor.

3.03 As a result, the condenser water must not only carry away the heat absorbed by the refrigerant in the evaporator, but also the heat added during the compression process. The heat absorbed by the refrigerant in the evaporator amounts to 12,000 BTUs per hour per ton of refrigerating capacity. The amount of heat absorbed for every horsepower required by the compressor is approximately 3000 BTUs per hour. The heat of compression, therefore, increases the heat load to be rejected by the evaporative condenser about 25 percent for a total of 15,000 BTUs per hour per ton of refrigeration capacity. A 10-ton compressor (120,000 BTUs per hour of cooling) would require an evaporative condenser capable of rejecting 150,000 BTUs per hour even though it would still be classified as a 10-ton evaporative condenser.

4. OPERATION

4.01 The evaporative condenser in which the high pressure refrigerant is flowing and condensing is part of the high side of the compression system. The best indicator of the performance of the evaporative condenser is the compressor head pressure. More efficient functioning of the evaporative condenser will result in lower temperature and pressure of the refrigerant.

4.02 The discharge pressure obtained by the use of an evaporative condenser will depend primarily upon the amount of air passed by the fan and the amount of water evaporated from the surface of the condenser coil. The amount of water evaporated will be directly proportional to the moisture content of the incoming air which is reflected in the wet bulb temperature of that air. Therefore, the wet bulb temperature becomes the governing factor in the heat transfer process. It is important also to keep the condenser coil surfaces completely wet and free from scale and foreign matter.

4.03 The spray water that returns to the evaporative condenser basin assumes a temperature between the condensing temperature of the vapor and the entering wet bulb temperature of the air. For any specific condensing and entering wet bulb temperatures, the exact temperature that the spray water will assume depends upon the amount of air supplied as well as upon the surface area of the coil.

4.04 If the evaporative condenser is properly designed and the coil surfaces are clean, the temperature of the refrigerant corresponding to the compressor head pressure may be reduced to within 20°F of the wet bulb temperature of the incoming air. This cooling effect ensures maximum efficiency.

4.05 For example, if the wet bulb temperature of the entering air is 60°F, the condensing temperature of R-12 could be as low as 80°F, corresponding to 85 psig compressor discharge pressure. If the design of the evaporative condenser were such that the capacity was undersized or the coil dirty or encrusted, or the pump or fan inefficient, the condensing temperature might run up to 95°F, (corresponding to 108 psig compressor discharge pressure) with the same 60°F wet bulb entering air.

4.06 Since compressor discharge pressures are dependent on wet bulb temperatures, geographical areas that have high dry bulb temperatures and low humidities afford more favorable operating conditions.

4.07 The following table gives approximate compressor discharge pressures for air entering the evaporative condenser at various wet bulb temperatures and the corresponding condensing temperatures under efficient operating conditions.

WET BULB TEMPERATURE OF AIR ENTERING EVAPORATIVE CONDENSER	CONDENSING TEMPERATURE OF REFRIGERANT		CORRESPONDING COMPRESSOR DISCHARGE PRESSURES (PSIG)			
			R-12		R-22	
	FROM	TO	FROM	TO	FROM	TO
60°	80°	95°	85	108 psig	145	183 psig
65°	85°	100°	90	117 psig	157	198 psig
70°	90°	105°	100	126 psig	170	213 psig
75°	95°	110°	108	136 psig	183	229 psig
80°	100°	115°	117	145 psig	198	245 psig

5. AIR REQUIREMENTS

5.01 The heat from the refrigerant gas is carried away primarily by the water vapor in the air. The performance of the evaporative condenser is fully dependent upon a sufficient amount of air passing through the coils to carry away the water vapor containing the heat. The amount of air required depends on a number of factors involving design but, in general, from 200 to 300 cubic feet of air per minute per ton of refrigeration must be passed through the evaporative condenser to maintain efficient operation and reasonably low compressor head pressures.

6. WATER LOSSES

6.01 ***Evaporation Losses:*** Since the latent heat of vaporization of water is 1000 BTUs per pound, each pound of water evaporated in the evaporative condenser will absorb approximately 1000 BTUs from the hot gas in the condenser coil. As pointed out in paragraph 3.03, the refrigerant absorbs heat in the cooling coil and more heat is added at the compression stage for a total heat content of 15,000 BTUs per ton of refrigerating capacity.

6.02 To absorb 15,000 BTUs of heat per hour requires the vaporization of 15 pounds of water per hour (15,000 ÷ 1000), or 1.8 gallons of water per ton (15 ÷ 8.35) of refrigerating capacity. A 10-ton unit would, therefore, have an evaporation loss of approximately 18 gallons of water per hour.

6.03 ***Water Bleed-Off Losses:*** All water contains small amounts of dissolved solids that will deposit as scale on the heat transfer surfaces if allowed to concentrate in the circulating water of the evaporative condenser. As a result of the evaporation of the circulating water as it passes through the evaporative condenser, the dissolved solids concentrate in the basin water. As these concentrations build up, increasing amounts of chemicals would have to be added to hold the dissolved solids in suspension. The cost of this procedure would be prohibitive, and a point would be reached where the dissolved solid content would be so great that chemical treatment would be ineffective.

6.04 Since the makeup water is relatively low in dissolved solids, the proper procedure is to bleed off the highly concentrated basin water and automatically replace it by means of a float valve on the makeup water line. This would dilute the dissolved solids in the basin water.

6.05 Enough water can be run off to waste to maintain a safe concentration of dissolved solids without chemical treatment. The cost of water under this procedure could be excessive. Usually a limited amount of water is run to waste, and proper chemical treatment is applied to the remainder. It has been found that the average economical balance between the bleed off and chemical treatment occurs when the amount of dissolved solids in the circulating water is maintained at between three and five times the concentrations of the dissolved solids in the makeup water. To maintain not more than this concentration of the dissolved solids in an evaporative condenser, the bleed off should be approximately one-half to one gallon per hour per ton of refrigeration capacity. A 10-ton unit would, therefore, have 5 to 10 gallons of water per hour bled to waste in order to hold concentrations within the 3 to 5 range. This is known as cycles of concentrations.

6.06 In highly industrial areas where the contaminants in the air cause excessive acidity in the circulating water, a bleed off is an essential part of corrosion control. This bleed off will tend to reduce the acidity of the basin water. It will also reduce the dissolved solid content resulting from the use of neutralizing chemicals for pH control. Cycles of concentration between five and eight times the makeup water solids can be maintained under perdominantly corrosion-producing conditions. To maintain 5 to 8 cycles of concentration, 1/2- to 1/3-gallons of basin water per hour per ton of refrigeration should be bled to waste. A 10-ton unit, therefore, would have a bleed off loss of 5 to 3-1/3 gallons per hour to maintain cycles of concentrations between 5 and 8.

6.07 The following table can be used to determine the approximate bleed off required for the following cycles of concentration.

CYCLES OF CONCENTRATION	BASIN WATER BLEED-OFF TO WASTE PER HOUR PER TON OF REFRIGERATION (GPH)
2	1.80
3	0.90
4	0.60
5	0.45
6	0.33
7	0.30
8	0.25
9	0.22
10	0.20

7. TROUBLES

7.01 Evaporative condenser troubles that may cause high compressor head presssure are:

(a) Inadequate air flow

(b) Inadequate water circulation

(c) Improper water treatment

(d) Scale blocking or coating coil surface.

Inadequate Air Flow

7.02 Inadequate air flow in the evaporative condenser is usually caused by:

(a) Slipping or broken fan belts

(b) Blown fuses or tripped overload relay on fan motor

(c) Clogged air intake screens or eliminator baffles

(d) Reverse rotation of fan motor or other motor trouble.

Slipping or broken belts are probably the most frequent cause of inadequate air flow. Refer to Section 770-220-308, "Installation and Maintenance of V-Belts," for replacement of belts if this is the cause.

Inadequate Water Circulation

7.03 If there is an indication of lack of sufficient water pressure at the spray nozzles, the circulating water pump screen should be checked to see if it is clogged. Clean, if necessary. If the clogging is caused by air-borne silt or algae, drain evaporative condenser basin and refill, treating water with an algicide.

7.04 Inadequate water circulation over the coils may be caused by clogged spray nozzles. Removal of the spray heads and flushing of the lines is generally adequate to clear the nozzles. Where scale is encountered, clean with a commerical grade of inhibited muriatic acid. The necessary safety precautions should be observed where acid is used. The building mechanic shall wear suitable eye protection and rubber gloves and have available a source of water for flushing the skin should he/she be splashed by acid.

7.05 Inadequate water circulation may be caused by faulty operation of the circulating pump and associated components. The following should be checked:

(a) Pump packing or shaft seal for binding or excessive leakage

(b) Blown fuse or tripped overload relay

(c) Sticking check valve

(d) Makeup water float valve closed

(e) Closed hand valves or open bypass valve

(f) Reverse operation of pump motor

(g) Worn impeller and bearings.

Improper Water Treatment

7.06 Improper water treatment under scale forming water conditions would cause high compressor head pressures due to the insulating effect of the scale (1/10-inch scale reduces capacity 50 percent). Slime and algae under these same conditions would also contribute to the poor heat exchange on the coil surfaces. Under corrosive water conditions, products of corrosion such as rust or metal scale will clog pump intake screens and spray nozzles and thereby restrict the flow of water and cause high compressor head pressures. If difficulties with water treatment are being experienced, the services of a competent water treating company should be obtained.

Silt and Sludge Removal

7.07 The contact of air and water in the evaporative condenser results in a secondary action other than cooling the circulating water and coils, namely, air washing. This air washing action not only contaminates the water with undersirable gases and microorganisms but also removes airborne dust that settles in the water basin in the form of silt or sludge. In small quantities, this material does not adversely affect the operation of the circulating system to a major degree. However, in settling out in the catch basin, it does eliminate the oxygen content of the water in the silt covered area. This differen in oxygen content of the free flowing water and the area covered by silt sets up a local cell action and promotes galvanic action and electrochemical corrosion. Metal loss in this case is limited to local pitting but can be extremely severe and result in early repair or replacement of the basin.

7.08 Removal of silt or sludge can readily be accomplished by draining the catch basin and should be performed per the preventative maintenance schedule. Under circumstances where plant shutdown is not possible for basin cleaning, or where the condition may be extremely severe and require frequent cleaning with resultant loss of chemical treatment, a small portable pump, wet pickup vacuum cleaner, or syphon hose with a suitable cleaning attachment on the suction hose should be used. This will remove the foreign material without plant shutdown and with minimum water losses.

Scale Removal From Evaporative Condenser Coil

7.09 The tubes of the evaporative condenser coil are closely nested together which prevents descaling by mechanical means such as wire brushing. Scale, being an alkaline substance, can best be dissolved and removed by acid treatment. If this work is performed by the building mechanic, all necessary safety precautions shall be observed. Suitable eye protection and rubber gloves shall be worn and a source of water for flushing the skin made available should he/she be splashed by acid.

7.10 An accepted procedure for acid cleaning the evaporative condenser coil is first to drain and flush out the system with clean water making sure that the water spray pattern is completely wetting the coil. Clogged nozzles would necessitate removal and acid cleaning before going any farther. Inhibited muriatic acid, such as Oakite Compound 32 or Pennsalt 90, is added to the catch basin water and circulated until all scale is removed. The system is then drained and refilled; a neutralizine agent such as trisodium phosphate is added and circulated about 5 minutes. The system is again drained, flushed, and refilled with water.

7.11 After scale is removed, consideration should be given to an adequate water treatment program coupled with a water bleed arrangement in order to hold the dissolved solids to a level which avoids scale formation on the condenser coil.

Low Compressor Head Pressure

7.12 Generally under light load conditions, the capacity of the evaporative condenser will be much greater than the cooling load and cause an unduly low compressor head pressure. As a result of this lower head pressure, less refrigerant is passed through the expansion valve which limits the scavenging of the compressor oil that has migrated throughout the system. The balance of oil leaving and returning to the compressor has been affected by lack of returned oil to the point that the low oil level in the crankcase will cause the unit to shutdown on low oil pressure.

7.13 To rectify this condition of condenser capacity and cooling load unbalance and resulting plant shutdown due to low oil pressure, one of two methods may be used, namely;

(a) Cycle the operation of the evaporative condenser fan rather than run it continuously. Where this method is used, cycling of the water pump may also be necessary during winter operation.

(b) Restrict the air flow through the evaporative condenser by means of a damper. Winter operation of the evaporative condenser without circulation of water will provide satsifactory condensing below 50 degrees outside dry bulb temperature.

7.14 The control device used to adjust evaporative condenser capacity by the above methods may be actuated by either the compressor head pressure or the temperature of the evaporative condenser water, the former being preferred.

Circulating Water Bleed-Off Arrangement and Control

7.15 Water bleed-off to waste is an essential part of any water treatment program and must be controlled to effect economies. There are two methods of bleed-off regulation that have been used successfully. One involves the bleed line located on the discharge side of the circulating pump; the second involves a collecting funnel or basin located on the overflow pipe.

7.16 The bleed off located on the discharge side of the circulating pump has one disadvantage. That is, under heavy silt conditions, the valve or orifice becomes easily clogged and reduces water bleed off to waste.

7.17 The second method eliminates the possibility of clogging. The collecting funnel is located under the condenser coils and connected directly to the overflow pipe. Spray water that falls into the funnel is run to waste and constitutes the bleed off. Wind velocity has an affect on this method; however, variations are not too wide. Control is gained by a lid that may slide over the funnel. The funnel rim is rectangular in shape.

8. TROUBLE CHART FOR EVAPORATIVE CONDENSERS

SYMPTON	TROUBLE	POSSIBLE CAUSE	REMEDY
High head pressure (Liquid refrigerant in receiver very warm)	(1) Insufficient air circulating through evaporative condenser.	(a) Low voltage to fan motor	(a) Increase wire size; consult power company
		(b) Blown fuses or tripped overload relay	(b) Replace fuses or reset relay and find cause
		(c) Belts slipping or broken	(c) Adjust motor base or replace all belts with matched set
		(d) Loose motor or fan pulley	(d) Tighten; if of a recurring nature, use castellated nuts with safety wire; on pulley, use double set screws
		(e) Motor and fan running backwards	(e) Reverse motor leads; if not a new installation, check for recent power changeover
		(f) Obstruction in air ducts or grills	(f) Clean air discharge ducts and intake grills
		(g) Excessive static pressure against fan	(g) Increase size of discharge duct; discharge duct damper closed
		(h) Dirty eliminators or scaled tube bundle causing restricted air passage	(h) Clean eliminators; chemically clean tube bundle
	(2) Insufficient water	(a) Low voltage to pump motor	(a) Increase wire size; consult power company
		(b) Blown fuses or overload relay tripped	(b) Replace fuse or reset relay and find cause
		(c) Pump coupling loose or broken	(c) Repair or replace coupling, check alignment

SYMPTON	TROUBLE	POSSIBLE CAUSE	REMEDY
		(d) Motor and pump running backwards	(d) Reverse motor leads; if not a new installation, check for recent power changeover
		(e) Pump suction line screen clogged (algae)	(e) Clean screen; if algae, use algicide
		(f) Spray nozzles clogged (scale or algae)	(f) Clean spray nozzles; treat water accordingly
		(g) Scale on tube bundle obstructs water flow	(g) Chemically remove scale; treat water accordingly
		(h) Water level in pan low	(h) Float valve stuck closed; makeup water shut off, water pressure low
		(i) Obstruction in water lines	(i) Check for full flow; rod out or chemically clean
		(j) Bypass valve open	(j) Close bypass valve and label as such
		(k) Eroded impeller	(k) Replace
		(l) Pump packing too tight	(l) Adust packing gland to drip water slowly
	(3) Scale on tubes	(a) Total dissolved solids in circulating water excessively high	(a) Inrease bleed to give three concentrations of total dissolved solids
		(b) Insufficient water treatment	(b) Increase water treatment chemicals or reevaluate; chemical feeder clogged
		(c) Insufficient water circulation	(c) Inspect water distribution system for obstruction or malfunction

SYMPTON	TROUBLE	POSSIBLE CAUSE	REMEDY
		(d) Evaporative condenser undersized	(d) Add desuperheat coil at evaporative condenser fan discharge or air cooled condenser before evaporative condenser
Low condensing pressure	(1) Winter operation	(a) Condenser too large or inlet air too cold	(a) Install inlet or discharge damper on fan or cycle fan
	(2) Low refrigerant charge	(a) Refrigerant leak or insufficient initial refrigerant charge	(a) Explore entire system with halide torch before adding refrigerant to system
Compressor shutdown on low oil pressure	(1) Suction pressure too low	(a) Light load conditions resulting in low head pressure and suction pressure	(a)&(b) Install inlet or discharge damper on evaporative condenser fan, or cycle fan operation using a control actuated by head pressure or basin water temperature
		(b) Condenser too large or inlet air too cold	
Noisy operation	(1) Complaint from nearby residence and building personnel	(a) Water in fan housing	(a) Add or replace eliminators; drill drain hole in fan housing
		(b) Fan out of balance	(b) Balance fan; if unbalanced due to corrosion, replace
		(c) Bearings worn or "dry"	(c) Replace bearings or lubricate
		(d) Fans or pulleys loose on shafts	(d) Tighten fan or pulley using double setscrew
		(e) Too much endplay of fan shaft	(e) Adjust endplay collar
		(f) Bent shaft	(f) Replace shaft
		(g) Loose side panels	(g) Install additional fasteners and braces to panels

SYMPTON	TROUBLE	POSSIBLE CAUSE	REMEDY
		(h) Vibration noise amplified by duct work	(h) Install canvas connection from gan housing to duct work
		(i) Loose pump, motor, hangers, tube, pipes, other parts	(i) Tighten loose parts
		(j) Belts too loose	(j) Tighten belts
		(k) Evaporate condenser not level	(k) Level evaporative condenser
Oil spot under refrigeration piping	(1) Refrigerant leak	(a) Faulty connection; vibration causing metal fatigue	(a) Clean and braze connection or install vibration loop or vibration dampener in line
Water spotting of nearby buildings, automobiles, residence	(1) Carry-over of water treatment or dissolved solids	(a) Lack of adequate eliminators	(a) Replace, improve, or install eliminator; change type of water treatment; relocate fan discharge outlet
Corrosion of metal parts	(1) Low pH of circulating water	(a) Inadequate bleed	(a) Increase bleed
		(b) Insufficient water treatment	(b) Increase water treatment; check make up water float level in relation to overflow pipe level
		(c) Adjacent to smoke or industrial waste discharge stack	(c) Eliminate source of contaminating gases or relocate air intake

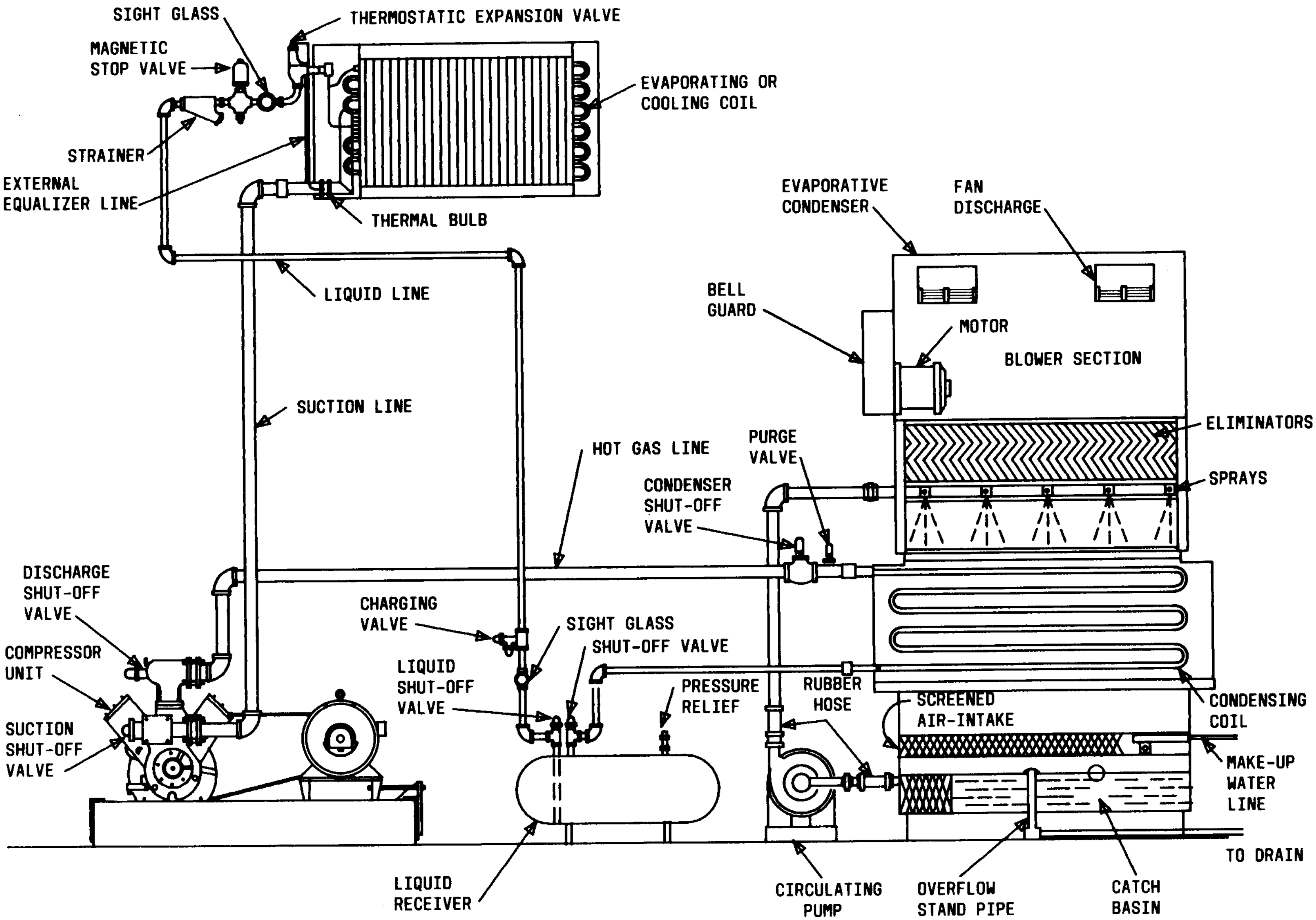

Fig. 1—Schematic Diagram of a Typical Direct Expansion Refrigeration System With an Evaporative Condenser

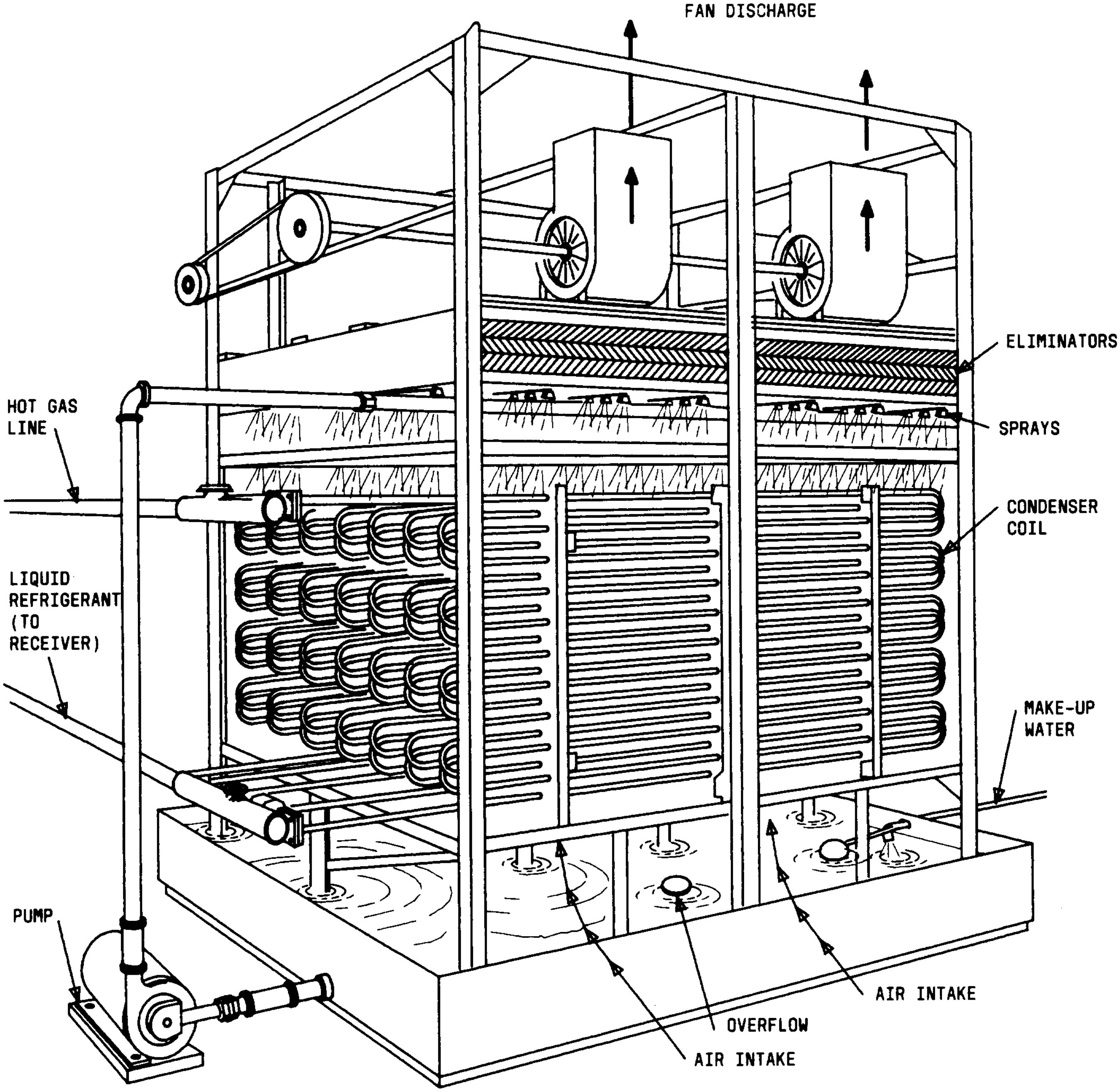

Fig. 2—Evaporative Condenser (With Side Panels Removed)