size motor provided to prevent overloading of the fan motor as the air flow is throttled.

Another commonly used method of head pressure control is to modulate the active condensing surface. This is accomplished by filling a portion of the condenser with refrigerant, and thus rendering it inactive. Several methods now in use are based on this principle. The *modulated bypass* method which was introduced first (U.S. Patent No. 2,564,310) is illustrated in Fig. 20. An outlet pressure-actuated modulating valve W is installed in a bypass between the condenser inlet and outlet. At low receiver pressures, the valve opens and permits discharge vapor to flow through the bypass to the receiver, restricting drainage of liquid refrigerant from the condenser so as to flood the condenser. The quantity of bypassed discharge vapor is adjusted by the valve which responds to receiver pressure.

Modulated bypass control may also be accomplished by use of a three-way valve in the liquid return line. This valve controls the amount of hot gas bypass from the hot gas line to the return line leaving the condenser in response to condenser pressure (Fig. 21).

In the *heat exchanger* method shown in Fig. 22, the liquid return line from the condenser to the receiver is heated by discharge vapor at lower than normal head pressures; vaporization of liquid in the return line causes the condenser to flood. When the head pressure is normal, the liquid side of the heat exchanger is bypassed through a pressure regulating valve responsive to inlet pressure. This pressure regulating valve modulates flow at intermediate conditions to proportion the liquid flow between the bypass and the heat exchanger.

The *liquid throttling* method is similar to the heat exchanger method except that it omits the heat exchanger and substitutes an open bypass, from the condenser discharge to the receiver inlet, which contains a check valve (Fig. 23). The pressure regulating valve in the liquid return line from the condenser to the receiver opens on a rise in condenser pressure and throttles on a drop in condenser pressure, forcing the check valve to open so that discharge gas is bypassed to the receiver, thereby causing flooding of the condenser.

The control methods described maintain sufficient head pressure for proper expansion valve operation. On off-cycles with low outdoor ambients, the refrigerant will migrate from the evaporator and receiver and condense in the cold condenser. The system pressure will drop and may correspond to the outdoor temperature. On startup, insufficient feeding of liquid refrigerant to the evaporator due to low head pressure will result in cycling of the compressor until the suction pressure reaches an operating level above the setting of the low pressurestat. At extremely low outdoor temperature, the pressure in the system may be below the cut-in point of the low pressurestat and the compressor will not start. This difficulty is solved by either of two methods: (1) bypassing the low pressure switch on startup, or (2) use of the condenser isolation method of control.

1. On system startup, a time delay relay may be used to bypass the low pressure switch for a period of approximately three minutes to permit the head pressure to build up, and permit compressor operation.

2. The *condenser isolation method* adds to the modulated bypass of Fig. 20 an inlet pressure regulating valve R in the the discharge line (Fig. 24). Valve R is closed during the off-cycle to isolate the cold condenser from the evaporator and thereby prevent migration of refrigerant vapor from the evaporator to the condenser. A check valve C at the receiver inlet prevents liquid migration from the receiver to the condenser so that receiver pressure is substantially unaffected during the off-cycle. When the primary control starts the compressor, bypass valve W opens and permits head pressure to act directly on the receiver, while valve R prevents any flow to the condenser until the receiver pressure is raised to the control point. Valves R, W, and C are combined into one assembly.

When head pressure control of the flooding type, or air-side control where the liquid temperature from the condenser may be lower than the evaporator temperature, is used, a non-condensable, charged thermostatic expansion valve must be used. This prevents erratic operation of the expansion valve due to condensation of the thermal bulb charge on the head of the expansion valve.

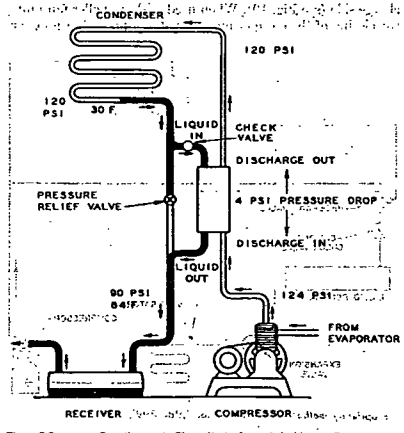
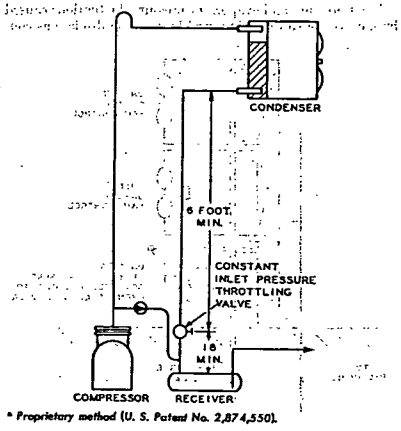


Fig. 22 .... Condenser Flooding by the Heat Exchanger Method



* Proprietary method (U. S. Patent No. 2,874,550).

Fig. 23 .... Modulated Condenser Flooding by the Liquid Throttling Method

INSTALLATION AND MAINTENANCE

The installation and maintenance of remote unit condensers require little labor because of their relatively simple design. The absence of water and sewer connections and the simple electrical hookup make it possible to complete an installation without subcontractors. Remote condensers are located at any desired distance from the compressor, either indoors or outdoors. They may be located far above or below the level of the compressor. Various considerations relating to installation and maintenance follow.

Indoor unit condensers. Where unit condensers are located indoors, the warm discharge air must be conducted to the outdoors. An outdoor-air intake opening near the condenser is provided, and may be equipped with shutters. Indoor condensers can be utilized for space heating during the winter and for ventilation during the summer. (See Fig. 25.)

Outdoor installation. In outdoor installations of vertical face condensers, prevailing winds should blow towards the air intake, or discharge shields should be used to deflect opposing winds.

Piping. Piping practice with unit condensers is identical with that established by experience with other types of remote condensers. Discharge piping should be sized for a total pressure drop equivalent to 2 F deg saturated temperature drop. For satisfactory oil return, the gas velocity in vertical risers should be in accordance with the recommendations in Chapter 77 of the 1964 Guide And Data Book. To minimize transmission of compressor vibration to the piping, run the suction and discharge lines at least 6 pipe diameters in each of three directions before reaching the first point of support. In this manner, the piping can absorb the vibration without being overstressed. Oil separators are used in the hot gas line from the compressor in systems having extensive pipe lines, especially with unloading type compressors or with numerous evaporators. The oil separator must be installed in conjunction with a check valve at its outlet; otherwise, it fills with liquid refrigerant during shut down, resulting in drainage of the refrigerant to the compressor crankcase with nuisance trip-outs on the oil safety switch on start up. Proper piping design often eliminates the need for oil separators.

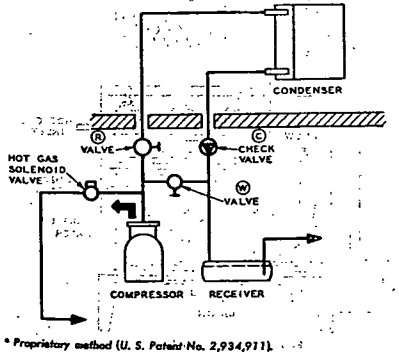
Discharge piping should be well supported without transmitting vibration to the building. A muffler in the discharge line may be used to prevent noise due to refrigerant pulsation, particularly with high speed compressors.

Thermal expansions. Long discharge mains may undergo considerable thermal expansion and contraction due to temperature changes. Discharge piping must therefore be designed so that it can move without damage to itself or the condenser. Branch lines from the discharge main to individual condensers should be laid off with offsets in accordance with standard piping practice.

Receiver. Unit condensers may be equipped with built-in receivers, or the receiver may be separate and installed at a distance from the condenser. Certain system designs, particularly those with capillary tubes, function without any receiver. If the receiver is located in a comparatively warm ambient temperature, the liquid drain line from the condenser to the receiver should be sized for a liquid velocity of 100 fpm for gravity drainage and venting to the condenser. The receiver should be equipped with a purge valve and sight glass.

Maintenance. Relubrication of fan motor and fan bearings should be scheduled from once every six months to once every year, depending on location. Adjustment of belt tension may be necessary after installation and at yearly intervals. Industrial refrigeration experience indicates that the maintenance cost of air-cooled condensing equipment is only 25 percent of that of water-cooled equipment, while the capacity loss due to fouling with increased age is less with air-cooled condensing equipment than with wet condensing equipment.

Unit condensers are usually in locations that are relatively free of dust or dirt. In dirty locations, the condenser coil may require periodic removal of lint or leaves, either with a long bristle brush, steam, or compressed air. A cleaning solution will be required to remove grease. Indoor condensers in dusty locations such as textile mills or supermarkets should be equipped with washable filters.



* Proprietary method (U. S. Patent No. 2,934,911).

Fig. 24 .... Condenser Control by the Isolation Method

PART III: EVAPORATIVE CONDENSERS

The term *evaporative condenser* is applied to equipment including a coil with its inner surface condensing refrigerant and its outer surface wetted with water and exposed to a moving air stream for the purpose of rejecting heat to it, principally by evaporation. Fig. 26 shows typical arrangements of components.

Coils

Coils are generally fabricated from copper tube, steel tube, or iron pipe, in multiple passes and circuits. When ferrous materials are used, they are protected externally, generally by hot-dip galvanizing.

Extended external-finned surface is sometimes added, although it is not so essential as with air-cooled condensers, due to the higher heat transfer rates obtained on the air side of the evaporative condenser.

The coil design should be such as to provide sustained performance under fouling water conditions and should be accessible for cleaning.

Coil Wetting Means

Coil wetting is usually accomplished by a recirculating system consisting of a sump, a pump, and a distributor.

The sump catches the drainage off the coil. The correct operating level is maintained by a float valve positioned to admit make-up water above the maximum water level attainable in the sump (a water supply sanitation requirement). Overflow and cleanout drains are supplied.

Nozzles or pans are commonly used as distributors to provide thorough wetting of the coil. Nozzles provide greater atomization and require higher pump heads, but permit

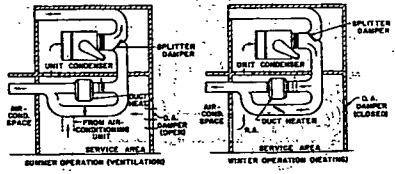


Fig. 25 .... Air-Cooled Unit Condenser for Winter Heating and Summer Ventilation