Chapter – 15  Refrigerant Liquid Feed Circuits

The way of supplying refrigerant liquid to the evaporator depends on the type of evaporator is used. The most common use evaporators for industrial refrigeration application are DX, Flooded, Liquid Recirculation and Thermosyphone.

**Direct Expansion (DX):**

Direct Expansion is also called Dry Expansion. The special character of a DX circuit is that the refrigerant is always through the tubes instead of shell; the liquid refrigerant is controlled by a thermostatic expansion valve which is to throttle just enough liquid to match the refrigeration load; the liquid is evaporated completely before leaving the heat exchanger and the thermostatic expansion valve also controls to provide just enough liquid refrigerant flow to provide 10°F to 15°F superheat at the outlet of the heat exchanger as shown in Figure 15-1.

Figure 15-2 and Figure 15-3 are typical DX shell-and-tube heat exchanger for either process fluid or brine or water cooling. The refrigerant is through the tubes and the fluid is through the shell is guided by vertical baffles. One of the advantage of the DX cooler has no submerge penalty for low temperature application because the refrigerant is through the tubes.

The advantages of using a DX heat exchanger are low cost, operation charge is minimized and oil return problem is simplified. However, the size of DX valve is limited; therefore, the DX evaporator is mostly used for smaller capacity system. Also, the DX system is usually used for higher evaporative temperature application.

The cooler may be with single refrigerant circuit or multi-circuit with each circuit fed by a DX valve or by a pilot operated valve as shown in Figure 15-4. A pilot operated valve is usually used for a larger capacity.

Sometimes, a pipe-in-pipe heat exchanger is used in the suction line to ensure the suction gas is superheated as shown in Figure 15-4.

**Flooded:**

Refrigerant liquid feed to a flooded type evaporator is through a throttling valve with liquid level controller to control the liquid level inside the shell; the refrigerant liquid level inside the shell is automatically maintained just enough to flood all the tubes no matter how the heat load fluctuates.
Figure 15-5 shows a sketch of refrigerant feed diagram for a half bundle shell-and-tube heat exchanger. The evaporator is with a single liquid inlet and multiple outlet connections arrangement. The sketch only shows an idea of liquid valve with a liquid level controller; no specific type of liquid feed valve and what type of liquid level controller is shown.
Figure 15-3  DX Shell-and-tube Heat Exchanger

Figure 15-4  Direct Expansion Cooler with Pilot Operated DX Control Valve
Figure 15-6 shows a half bundle shell-and-tube evaporator with a pilot operated low pressure float valve. The liquid level is controlled by the pilot float valve.

Figure 15-5 Refrigerant Feed for Half Bundle Shell-and-Tube Heat Exchanger

Figure 15-6 Pilot Control Liquid Valve for Half Bundle Shell-and-Tube Heat Exchanger
In Figure 15-7, the refrigerant level is controlled by a modulating liquid level controller which is to regulate the pneumatic power to open or close the liquid throttling valve for the half bundle design evaporator. Figure 15-8 shows the same application except that the heat exchanger is a full bundle design. The liquid and gas separation is taken place in the upper shell.

Figure 15-9 shows the refrigerant feed for coil type flooded heat exchanger. The refrigerant from high pressure receiver or from intercooler is throttling through a low pressure float valve to the surge drum. The low pressure float valve also serves as the liquid level controller to maintain the liquid level inside the surge drum. If the design ET is 20°F, the liquid in the surge drum is 20°F. The coil is flooded with 20°F refrigerant liquid. Evaporated gas in the coil flows back to the surge drum; the flash gas combines with the evaporated gas return to compressor suction.

Figure 15-10 is a typical refrigerant feed arrangement for a product cooler with flooded coil. The refrigerant valve is a low cost solenoid expansion valve which is controlled by a simple liquid level float switch. Unit cooler or product cooler air coil type heat exchangers are mostly used for food process industries.

**Liquid Recirculation:**

Liquid recirculation system is to pump the refrigerant liquid to the evaporator. This system is mostly used for food process industries to increase the heat transfer efficiency for the evaporators. This system is also used for those industrial applications to ensure no flash gas is in the liquid line for a high vertical column or for remote evaporators.

Figure 15-11 shows the sketch for the liquid recirculation set-up. The liquid from high pressure receiver or from intermediate intercooler, is throttling into a horizontal design pump receiver through a liquid valve which is controlled by a liquid level controller to maintain the liquid level in the pump receiver. The temperature in the pump receiver is controlled at the evaporative temperature as design. For example, the ET is -15°F as shown in the diagram of Figure 15-11. The liquid from the pump receiver is overfed to the evaporator by the liquid pump and the amount to be fed to the evaporator(s) is about 2 to 4 time more than what is needed for the heat load depending on what type of refrigerant is used. The overfed rate is about 4:1 for ammonia and 3:1 for R-22. If the recirculation rate is 3:1; that means only 1/3 of liquid refrigerant is evaporated for the heat load; 2/3 of liquid and 1/3 of the vapor are returned to the pump receiver; the liquid and gas are separated in the pump receiver. The temperature is still at the saturated temperature of -15°F. The evaporated gas in the evaporator combining with the flash gas from the liquid throttling to pump receiver are returned to the compressor suction. The gas leaving the pump receiver is still at the saturated temperature of -15°F as shown.

For all the liquid recirculation systems, the refrigerant flow leaving the evaporator back to the pump receiver is a two-phase flow of liquid and vapor. The flow pressure drop of a two-phase flow is much greater than a single phase flow of either 100% liquid or 100% gas.
Figure 15-7  Modulating Refrigerant Feed Valve for Half Bundle Shell-and-Tube Heat Exchanger

Figure 15-8  Modulating Refrigerant Feed Valve for Full Bundle Shell-and-Tube Heat Exchanger
Figure 15-9  Flooded Evaporator
Coil Type Heat Exchanger

Figure 15-10  Flooded Evaporator
Product Cooler
Only single refrigerant pump is shown in the sketch. However, to ensure continuous operation of the system, most liquid recirculation systems are equipped with dual liquid pumps; one is the stand-by for service and repair.

Figure 15-12 is a diagram of liquid recirculation circuit for a vertical pump receiver. The liquid level control is by a low pressure float type liquid level control valve. The refrigerant from high stage is throttling through this float valve. Then; combining with the return liquid/gas from evaporator, flows back to the vertical pump receiver. The liquid and gas are separated in the pump receiver; the saturated vapor is returned to compressor suction. Three liquid level switches are shown for the safety operation of the pump receiver; one is for high liquid level cutout; one is for high liquid level alarm and one is the float switch for low liquid level alarm.

The charts of Figure 15-13 and Figure 15-14 are the rates of evaporation for R-22 and R-717 respectively; it can be used for the rough approximate estimates to obtain the rate of evaporation for either R-22 or R-717.

For example: A 65 TR R-22 system, ET is 25°F; from Figure 15-13, the rate of evaporation is 0.205 GPM/TR; the amount of R-22 liquid evaporated is 65 x 0.205 = 13.325 GPM; the normal liquid recirculation rate recommended for R-22 is 3:1; therefore, the total liquid recirculation is 13.324 x 3 = 39.975 GPM or a 40 GPM pump is to be selected for this liquid recirculation system.

Same rules apply for the system if the refrigerant is ammonia instead of R-22, except that the liquid recirculation rate recommended for R-717 is 4:1.

Use P-H diagram to calculation the refrigerant flow if accurate rate of recirculation is desired.

**Thermosyphone:**

The typical liquid feed circuit for the Thermosypone evaporator is shown in Figure 15-15. The liquid is throttling through the liquid valve to the inlet of the surge drum which is on top of the heat exchanger; the pneumatic operator of the valve is controlled by the liquid level controller to control the liquid level in the surge drum. Usually, a pneumatic air supply approximately 20 psig is required for this modulating proportional liquid level control valve operation.

The refrigerant is circulated through the tubes by gravity thermal siphoning. Refrigerant liquid enters to the heat exchanger from the bottom side of the front channel box of the heat exchanger; the liquid and evaporated vapor mix returns to the surge accumulator from the top of the rear channel box of the heat exchanger. The liquid and gas are separated in the surge accumulator. The evaporated gas and the throttling flash gas are returned to compressor suction.
Figure 15-12  Liquid Recirculation System with Vertical Pump Receiver
Figure 15-13 Rate of Evaporation for R-22
Figure 15-14  Rate of Evaporation for R-717
Figure 15-15  Refrigerant Feed
Thermosyphon Evaporator