Direct Expansion Systems

The direct expansion systems are nearly a model of the fundamental textbook vapor compression refrigeration system. It is simple and of low first cost but very energy inefficient in large industrial applications. The basic components are as follows:

Evaporator: As with all types of systems the evaporator is a heat exchanger. The liquid inside the coils of the evaporator is kept at a temperature generally 10 to 15F lower than the desired room temperature. Therefore, since heat flows from high temperature to low, the heat in the refrigerated space is absorbed into the liquid inside the coil. This liquid is essentially saturated, meaning that it is at its boiling point. As you know when water reaches 212F any further heat addition does not raise its temperature but rather causes a phase change – liquid to steam. This phase change absorbs far more heat than does a simple temperature change. The *latent heat of vaporization* is far greater than the *specific* heat (the heat required to raise the temperature of one pound of a substance on degree). That is why vapor phase refrigeration is so much more effective than other means. So, when the liquid refrigerant inside the coil absorbs heat it changes phase from liquid to vapor.

Compressor: Now it is necessary to get rid of the heat that was absorbed in the evaporator so that the same refrigerant can absorb heat the next time it passes through the evaporator. Again, heat will not flow without a temperature difference. In order to dump the heat from the refrigerant into a warm environment such as outdoors the refrigerant must have its temperature raised. As you know from your recollection of the gas laws it is possible to raise the temperature of a gas without adding heat to it. If you squeeze a volume of gas into a smaller volume you force all the molecules closer together, they undergo more collisions with each other, and as a result the temperature goes up, but no heat has been added. The compressor in a refrigeration system serves this function; it raises the pressure, hence temperature, of the refrigerant vapor to something higher than the outdoor temperature so that the heat picked up in the evaporator can be given up to the environment via the condenser.

Condenser: The condenser performs the opposite function of evaporator. The refrigerant vapor, now warmer than the surrounding environment, gives up heat. Since it is a *saturated vapor* it will undergo a phase change as it gives up heat; it will condense from a high temperature, high-pressure vapor into a high temperature, high-pressure liquid. Since this liquid is warmer than the refrigerated space it cannot perform any refrigeration – cannot absorb heat from a cold space. Therefore it has to be converted back into a low temperature liquid. This is the function of the expansion valve.

Thermal Expansion Valve: When a liquid is throttled from a high pressure to a low pressure across a valve no heat is added or subtracted (*constant enthalpy process*). If this liquid is saturated, again, at its boiling point, a drop of pressure will cause it to *flash* (boil rapidly). In order for a liquid to boil off to a gas it must absorb heat. In the case of the expansion process the source of the heat is the liquid itself; it gives up heat to a portion of itself in order to boil off a portion. Since the heat comes from the liquid its temperature must drop. So, as the high pressure, high temperature liquid from the condenser passes through the thermal expansion valve it flashes back to a low pressure, low temperature mixture of liquid and vapor. This brings us back to the evaporator, and we start the process all over again.

However, compressors can only compress vapors; if you try to compress a liquid enormous forces are required, and the compressor will break. Therefore, it is necessary that absolutely all the liquid that enters the evaporator be boiled off. In a direct expansion system the last 25 to 30% of the evaporator coil is used to ensure this *dry* refrigerant. The vapor is actually superheated to at temperature about 12°F higher than the boiling (evaporating) point. The thermal expansion valve accomplishes this by using a remote sensor that senses the amount of superheat in the vapor exiting the evaporator and tells the valve just how much liquid to meter in to maintain that superheat. This works pretty much the same as the thermostat in your radiator.

Discussion: The lack of energy efficiency in the direct expansion system results for a couple of reasons. The best heat transfer in an evaporator coil is obtained when the inside coil surface is thoroughly wetted. Since the TX (thermal expansion) valve meters in a controlled supply of both liquid and vapor the coil surfaces do not get very effectively wetted.

Since the *high side* (the refrigeration system between the compressor and the TX valve) pressure is what moves the refrigerant through the system there is very little adjustability allowed in that pressure – too low and the TX valve will not distribute refrigerant properly. The greatest efficiency is gained when the compressor discharge (or head) pressure (hence temperature) is kept as low as possible and the evaporating pressure (hence temperature) is kept as high as possible. So the direct expansion system and related types of systems have the great energy disadvantage of not being able to take advantage of cool days – these systems cannot allow the head pressure to *float down with ambient*. The controls in a DX system have to fool the compressor into thinking that it is a 95°F Summer day even if it is -15°F outside.

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