# TECH TIP # 53

HARDI
HEATING, AIRCONDITIONING & REFRIGERATION DISTRIBUTORS INTERNATIONAL

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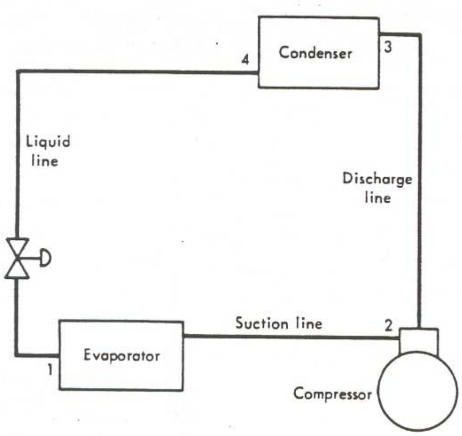
## THE WHY BEHIND PIPING PRACTICES

Practically every manufacturer provides installation instructions with their equipment, but often under the pressure to get the job done, instructions are followed blindly without fully understanding why certain steps are required. This is especially true in the area of refrigerant piping. In this article let's see if we can provide some of the important explanations that lie behind many of today's piping practices.

The most common refrigerant cycle is of course referred to as the vapor ─ compression cycle. A low temperature, low (relative) pressure liquid absorbs heat in an evaporator and boils into a gas; the gas is then pumped to a higher pressure and temperature where it can be conveniently condensed back into a liquid in a condenser and then throttled down to the previous low pressure, low temperature liquid and the cycle can start again. Refrigeration components are shown schematically in Figure 1 and the process, assuming no friction, is illustrated by the broken lines on a pressure--enthalpy (heat energy) chart of refrigerant properties in Figure 2.

If the system was free of friction, the refrigerant would flow from Point 1' through the evaporator and suction line to point 2' at constant pressure; then be compressed and discharged to the condenser from Points 2' to 3' and finally passed through the condenser at constant pressure to the start of the liquid line leading to the expansion device and evaporator (Point 4').

In actuality, all components and piping offer frictional resistance to the flow of refrigerant; consequently, the refrigeration process **with friction** follows the solid lines in Figure 2. Thus as the refrigerant flows through the evaporator and suction line there is a drop in pressure and the refrigerant gas enters the compressor at Point 2, not Point 2', and must be discharged at a higher pressure (3 not 3') to account for the pressure drop through the condenser. Finally, the liquid leaving the condenser is actually subcooled to Point 4, rather than Point 4', partially to account for losses in the liquid line (more on this later).

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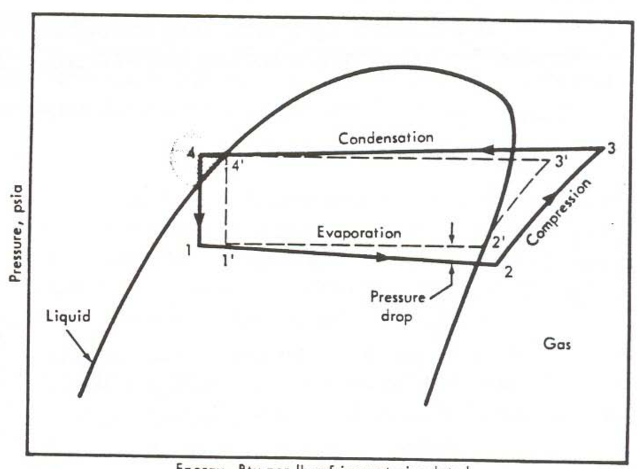


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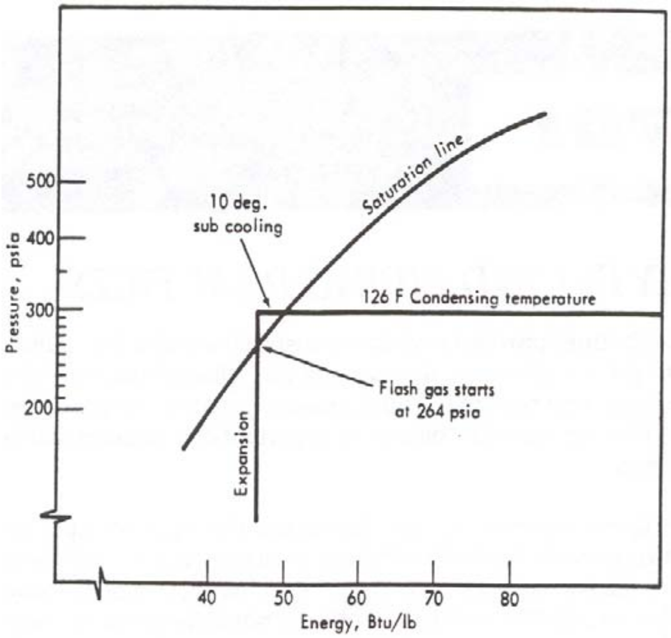



**Figure 3 - Subcooling of liquid in condenser is useful since it prevents premature flashing (liquid into gas) of refrigerant before reaching the expansion device. With 10 degrees of subcooling at 300 psia condensing pressure, the pressure of liquid R-22 may drop to 264 psia before reaching the saturation line and the start of a phase change. Thus the pressure drop between the condenser and expansion device could theoretically be as high as 36 psia (300-264) without the danger of flashing. (See also Figure 4 below.)**

The net effect of component and piping friction is that cooling capacity is reduced and the horsepower per ton of cooling is increased (work of compression from Point 2 to Point 3 is greater than from 2' to 3'. Obviously, then, undersized or unduly long refrigerant lines are undesirable and are reflected in operating cost and cooling performance.

The first reaction to this problem might be to merely "oversize" all lines. Unfortunately, another, very important, problem is involved -- oil. The compressor needs lubrication and some of the lubricating oil provided gets past the cylinders and is carried into the discharge line. If this oil is not carried all the way back to the compressor, compressor burnout could occur. As a result of this phenomenon there are minimum refrigerant velocities that must be maintained throughout the system in order to sweep or carry oil back to the compressor. This means, of course, that there are both maximum and minimum line sizes.

***Suction/Liquid Lines are Contractor's Responsibility***

In packaged equipment only the liquid line between the condenser and cooling coil and the suction line between the cooling coil and compressor are of direct concern to the contractor.

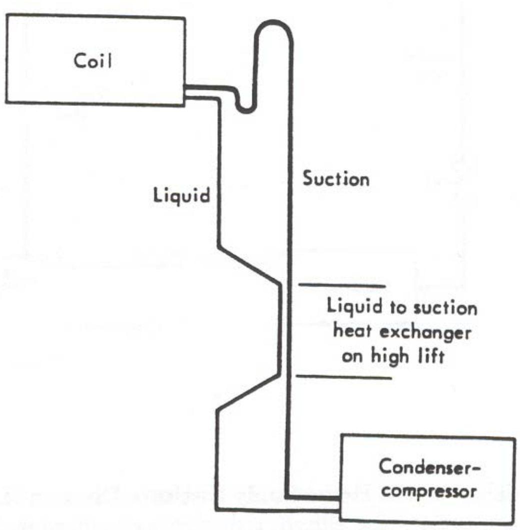



**Figure 4 - On high liquid lift (coil above compressor), liquid to suction heat exchanger is necessary to increase liquid subcooling and prevent flashing. Liquid lift causes about 1 psi drop in pressure for every 2 ft. of rise.**

The discharge line between the compressor and the condenser is the manufacturer's responsibility.

The liquid line presents the least number of problems, partially because compressor lubricating oil mixes well with **liquid** refrigerants and is carried along quite readily; therefore refrigerant velocity is less important when sizing liquid lines.

The single most important consideration when sizing liquid lines is to avoid a pressure loss sufficient to cause the formation of flash gas before reaching the expansion device. Flash gas can restrict flow, reduce cooling capacity and damage certain types of expansion devices.

### *Expansion Process Up Close*

Figure 3 details the condenser to expansion valve process as originally depicted in Figure 2 (shaded area).

If we assume that R-22 is the refrigerant and the condensing temperature is 126º F, then the high side pressure is approximately 300 psia. If there is 10 degrees of subcooling, that is, the liquid leaving the condenser is at 116º F, then from that point and moving straight down the chart, the process line would reach the saturation curve at a pressure of 264 psia. Upon reaching the saturation line, of course, some refrigerant would flash into a gas. This means that in this case the absolute maximum pressure loss in the liquid line would be 300 minus 264, or 36 psi. To appreciate the importance of subcooling, consider that with only 4 degrees of subcooling rather than 10, the maximum loss in the liquid line could only be 15 psi.

### *Loss Equals Friction Plus Liquid Lift*

There are two elements contributing to the total pressure loss in the liquid line -- friction and liquid lift, or elevation, when the cooling coil is ***above*** the condenser-compressor unit.

Present practice is to limit the pressure drop due to friction to the equivalent of one or maybe two degrees change in saturated temperature. Reference to any standard table of refrigerant properties would show that a one degree change in saturated liquid temperature is equivalent to nearly 2 psi pressure drop for R-12 refrigerant, just over 3 psi for R-22 and over 4.64 for R-410A for condensing temperatures near 100 or 110º F. Using R-22 as an example and with 3 psi earmarked to overcome friction, only 33 of the original 36 psi is left to overcome liquid lift or elevation. In round numbers, if 1 psi is lost with every 2 foot of liquid rise, vertical separation between evaporator and compressor-condenser would theoretically be limited to 66 feet, for the conditions originally assumed -- that 10 degrees of subcooling existed. Practically speaking, to provide a safety factor the rise would probably be limited to perhaps only 50 feet.

Should field conditions demand a greater vertical rise, a liquid line to suction line heat exchanger (Figure 4) is normally recommended to increase subcooling and avoid premature flash gas.
The cold suction line absorbs heat from the liquid line, thereby increasing the degree of subcooling and at the same time adding several degrees of superheating to the compressor inlet, a desirable feature in itself, to avoid any possibility of liquid carryover into the compressor cylinders.

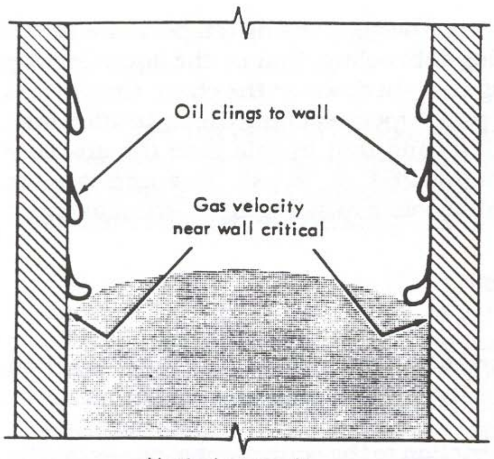
It's important to note that liquid lift is a problem only when the cooling coil is above the compressor. When the compressor-condenser is above the evaporator, liquid drop, not lift, is involved. Consequently, elevation causes a pressure gain, not loss.

### *Make No Mistake on Suction Lines*

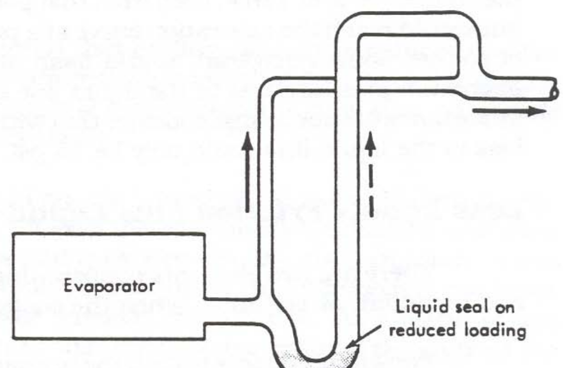
Because compressor inlet conditions -- refrigerant pressure, temperature and specific volume -- dramatically affect capacity and horsepower requirements, an **undersized** suction line can be costly.

Even a 2 to 3 psi loss through the suction line causes a drop in cooling capacity of over 4 percent. Conversely, because lubricating oil and refrigerant **vapor** are not miscible -- the evaporator acts as sort of a “still” to separate oil and refrigerant -- gas velocities must be kept high to entrain and literally carry oil back to the compressor. Thus **oversizing** suction lines can be equally costly.

The pressure drop considered acceptable for suction lines is typically equivalent to a 2º F drop in saturated temperature. For a system with R-12 refrigerant, this means limiting suction line pressure to about 1.8 psi, with R-22, to 2.9 psi and with R-410A to 9.64 psi --- assuming a 40 degree suction temperature in these cases. (Permissible pressure drop values decrease as suction temperature decreases.)




**5** Oil clings to inside surfaces of vertical suction lines. Momentum of refrigerant gas at wall is made deliberately high to carry oil up and back to the compressor.




**6** DOUBLE suction riser is used to assure oil carryover when refrigerant capacity — hence gas flow — is modulated. At low capacity, oil collects in trap and seals off large line and only small pipe is used. With resumption of full flow, seal is broken and both lines carry gas and oil back to compressor.

***Must Fight Gravity***

The most difficult problem in sizing suction lines involves any vertical sections in the suction run. Carrying oil vertically is difficult. It often requires double the refrigerant velocity utilized in horizontal runs, say 1400 fpm instead of 700 fpm. Figure 5 depicts the problem.

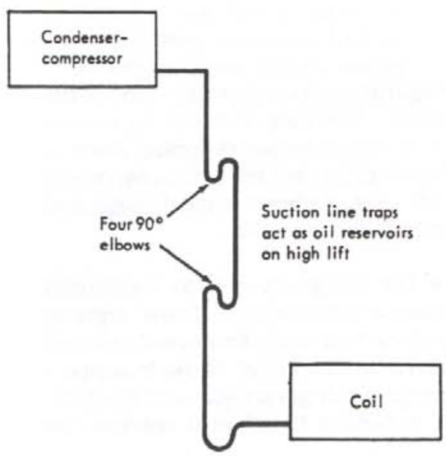
In a suction riser, oil clings to the tube walls and must be pushed along by the momentum of the refrigerant gas near the wall of the tubing. As the suction temperature decreases, the density of the refrigerant decreases and a greater velocity is required to carry the oil up the riser. To maintain high velocities in a suction riser, a vertical run must be made smaller, hence impose a greater pressure drop than horizontal runs. Not always, but sometimes. Also, where some form of modulation is incorporated, it may be necessary to utilize what is termed a double suction riser (Figure 6) to assure continuous oil return at minimum operation and at the same time avoid excessive pressure drop at full capacity.

Normally, one line is sized to provide sufficient gas velocity at minimum flow to carry oil up and into the horizontal run and a second riser is sized to provide an acceptable pressure drop at full flow. The combined cross-sectional area should not, however, exceed the size of a single pipe that might be sized to carry oil upward at full flow without regard to pressure drop.

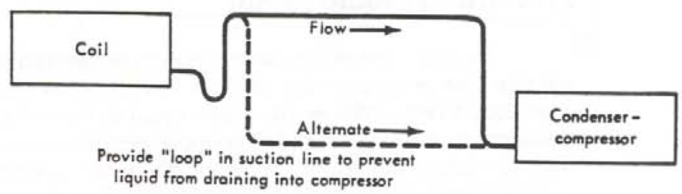
The double riser operates as follows: On minimum flow, there is initially insufficient gas velocity to carry oil upward, and oil begins to collect in a trap at the bottom of the risers, eventually sealing the larger line, whereupon the velocity of the smaller line increases and carries oil upward and back to the compressor. On the resumption of full flow the seal is broken and both lines are utilized. It's important that the trap be made of close coupled elbows in order to provide a minimum oil holding reservoir.

***Pipe Routing Important, Too***

Besides accurate pipe sizing to control refrigerant flow and guarantee oil return, certain physical piping configurations are used to aid oil return and protect the compressor from possible damage due to liquid refrigerant "draining" into the compressor during the off periods. Not all designers and engineers agree as to the merit of many of the loops, traps, etc., that have evolved, generally through experience rather that through research. For example, some designers feel that it's important to pitch horizontal suction lines toward the compressor to encourage oil return, others feel that it's unnecessary when lines are properly sized.



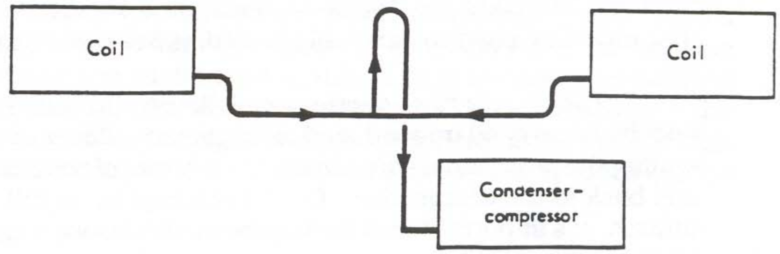

**7** SUCTION line traps, placed at discrete intervals, are used when compressor is placed high above the cooling coil to act as oil reservoirs and assure a rapid supply of oil on start-up.



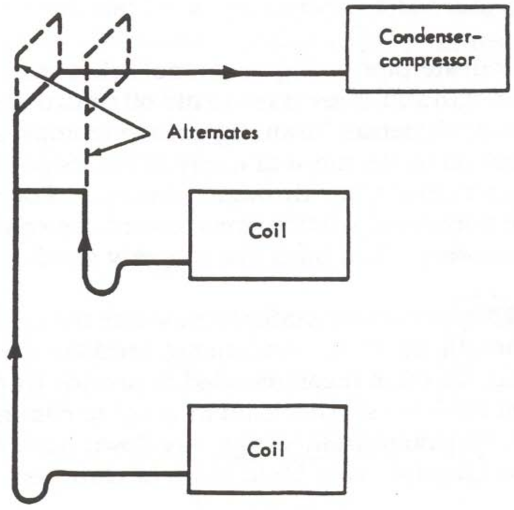

**8** WITH coil above compressor, a loop is often provided in suction line so that liquid refrigerant does not drain into compressor during off cycle. (See Fig. 9.)

On very high suction lift installations, where the compressor-condenser is **above** the cooling coil, as the case might be when condensing sections are placed on the roof of the multi-story apartment building, it's often recommended to provide traps in the suction line at specific heights (Figure 7) to act as oil reservoirs. This is an attempt to eliminate any delay of oil return on start-up. Without the traps, oil would drain all the way down back to the evaporator. One manufacturer's rule is to place one trap for every 20 to 25 ft. of elevation.

9 ONE method of providing protective suction loop (to avoid liquid drain into compressor) when two coils are placed above a common compressor-condensing section. . . (See also Fig. 8.)




10 PIPING configurations suggested to avoid liquid drain from one coil into another when coils are stacked. . .




***Preventing Liquid Drain***

Perhaps one of the most common suggested piping configurations is to provide a loop in the suction line whenever the cooling coil is above the compressor. The loop is made by merely providing a rise in the suction line equal to the height of the cooling coil before dropping down to the compressor. The intended purpose here is to prevent any liquid refrigerant left in the evaporator from draining into the compressor when the compressor is off. Figure 8 shows typical suggested arrangements for the single coil hookup -- Figure 9 shows connections for two coils.

The value of such a loop has been challenged by a few designers and in residential precharged applications practice seems to be to ignore the loop configuration. Those arguing against the value of the loop suggest that it collects liquid until start-up and then merely causes a large slug of liquid to enter the compressor as the refrigerant gas pushes it along. Those in support say that the liquid that collects does not completely block passage of refrigerant gas and on start-up the gas leaving the evaporator breaks up the liquid and vaporizes it before it reaches the compressor.

In addition to looping to protect compressors from liquid drain, variations of the loop are also used to protect one cooling coil from draining into another where multiple cooling coil hookups are stacked one above the other, say in a two story house where a coil on each level is served by a common compressor-condenser. Figure 10 shows possible piping arrangements that prevent the second level coil from draining into the lower coil during off periods.

One final frequent recommendation is to provide a trap in front of an evaporator whenever a thermostatic expansion valve is used as a metering device. Supposedly the trap prevents liquid from accumulating under the sensing bulb attached to the suction line and thereby eliminates any possibility of erratic valve operation. Such a trap is "required" whenever the suction line leads up or straight out from the evaporator. (See Figure 11).

***What You Should Know***

There are numerous handbooks and manufacturers' manuals available that contain specific tables on actual sizing of refrigerant lines. The intention of this article has been to provide the essential objectives behind piping procedures. Those objectives are:

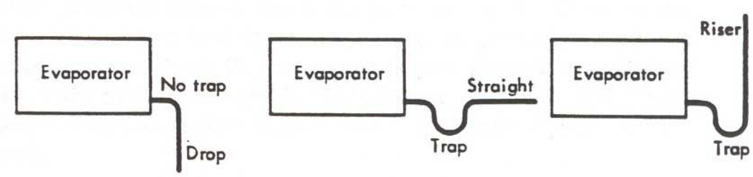
(1) To adequately supply liquid refrigerant to the evaporator.

(2) To minimize pressure drop in order to minimize horsepower requirements and optimize cooling capacity.

(3) To protect the compressor by a) returning oil discharged into the system, and b) preventing liquid refrigerant from reaching the compressor.

In addition to the sizing and configuration guidelines discussed, suction lines should always be insulated, with liquid lines whenever ambient temperatures exceed liquid line temperatures and valuable subcooling might be lost and flash gas formed in the liquid line.

**11** EXPANSION valve manufacturers often request a liquid trap in suction line right at the coil to prevent liquid refrigerant from accumulating under valve's sensing bulb. . .

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