Refrigerant Line Sets Can Cause Compressor Failures

Understanding refrigerant piping for air conditioners and heat pumps is easy. It is also necessary in order to perform service correctly and perhaps to spot the service errors of others.

Among other things, an incorrectly sized line set can lead to premature compressor failures.

This article is intended to give you a very general overview of piping design considerations and to help you to determine when you might need to take extra measures during an installation, but should not be used for making piping design decisions.

The best approach to piping design is to use the manufacturer's piping design guidelines for the system you are planning to install.

The three primary issues that drive line sizing are velocity, pressure drop, and refrigerant charge. When determining the size of suction lines, the line must be kept large enough to minimize pressure drop, which minimizes capacity loss, but small enough to keep velocities high enough to maintain oil return to the compressor.

Liquid lines must be large enough to minimize pressure drop, but small enough that the extra refrigerant they hold will not damage the compressor.

Suction Line Action

Let's start out with a more detailed description of what's happening in the suction line of an air conditioner.

Air conditioning compressors continually pump small amounts of oil into the refrigerant stream. This entrained oil must be returned to the compressor or eventually it will cause refrigerant system blockages; or, in serious circumstances, damage the compressor due to lack of oil.

To keep the oil entrained in the refrigerant so that it does not drop out somewhere in the refrigerant system, refrigerant velocities must remain at about 1,200 feet per minute (FPM) or more. To accomplish this, we make sure that the piping is small enough in diameter to keep velocities high enough.

On the other hand if, in our attempt to keep velocities up, we make the suction line too small, the resistance to refrigerant flow (which is expressed as pressure drop) will reduce the capacity and efficiency of the equipment. The reason for this is that the lower the suction pressure is when the gases return to the compressor, the less dense they are. The less dense the suction gases are when they enter the compressor cylinder, the less refrigerant volume it can pump per stroke.

Less refrigerant means less capacity.

Sizing the Suction Line

To determine how to size a suction line, we can use charts that have been developed to determine capacity loss at different equivalent lengths. Figure 1 shows the approximate percentage of cooling capacity loss for different-size systems at different equivalent line lengths.

You can see, for example, that a 3-ton system with an equivalent line length of 50 feet will have a 7 percent capacity loss if 3/4-inch copper is used, but only a 2 percent loss with 7/8-inch copper. Generally it is good practice to keep capacity loss at 3 percent or below.

Estimated Percentage of Nominal Cooling Capacity Losses*

UNIT NOMINAL SIZE (BTUH)	LONG-LINE VAPOR LINE DIAMETER (IN.)†	EQUIVALENT LINE LENGTH (FT)					
		50	75	100	125	150	175
18,000	5/8	5	7	9	12	12	14
	3/4	1	3	4	5	5	7
24,000	5/8	6	9	13	16	19	22
	3/4	0	1	1	2	3	4
30,000	5/8	6	8	10	13	15	17
	3/4	2	3	4	5	6	7
36,000	3/4	7	10	14	17	21	NR
	7/8	2	4	6	8	10	11
42,000	3/4	7	10	13	17	20	23
	7/8	3	4	6	7	8	10
	1-1/8	0	0	1	1	2	2
48,000	3/4	10	14	18	22	NR	NR
	7/8	4	6	7	9	11	13
	1-1/8	0	0	1	1	2	2
60,000	7/8	7	9	11	14	16	19
	1-1/8	1	2	2	3	3	4

Figure 1. Approximate percentages of cooling capacity loss for different-size systems at different equivalent line lengths.

Charts like this are also helpful for use in avoiding installing an oversized suction line, because suction lines that are too large are usually not listed.

By the way, “equivalent line length” is not the same as linear line length. Equivalent line length takes into account the resistance of elbows and fittings. The resistance of an elbow, for example, is expressed as the number of feet of straight pipe that would have an equivalent resistance.

For example, a short-radius 7/8-inch elbow has an equivalent length of 2 feet. So, the linear length of the suction line plus the equivalent length of the fittings in that line is the equivalent length of the suction line.

Sizing the Liquid Line

Liquid lines have similar design limitations as suction lines. A liquid line that is too small will have too much pressure drop. This can cause the liquid to begin to boil before it reaches the metering device.

This effectively causes a restriction. Less refrigerant can reach the metering device, and therefore the evaporator, in a given length of time. This causes low capacity and high superheat, which overheats the compressor.

Liquid lines that are too large cause one of two problems: overcharge or undercharge. Liquid lines rob refrigerant from the system. Any refrigerant that is in the liquid line is doing nothing for the cooling or heating process. It is simply being transported to one of the coils, so it can get back to work absorbing or dissipating heat energy. When you increase the size of a liquid line, it just robs more refrigerant from the places where it can do some good: the coils.

If the refrigerant that the liquid line robs from the coils is not replaced during installation or during a repair — which is very common — the system will operate undercharged, impairing capacity as well as compressor reliability. If the refrigerant that is being robbed by the liquid line is replaced, the system is effectively overcharged.

Excess refrigerant in the system puts the compressor at risk due to refrigerant migration and flood back to the compressor.

So, the goal is to make the liquid line large enough to minimize restriction, yet not so large that the compressor is at risk. In some cases, the size of the liquid line required to make the machine operate properly will require more refrigerant than the system can tolerate, in which case special modifications must be made to the equipment to handle these situations.

Line Charge Allowance (R-22) oz./ft

Line O.D. (in.)	Liquid	Suction
1/4	0.22	
3/8	0.58	
1/2	1.14	
5/8	1.86	0.04
3/4		0.06
7/8		0.08
1 1/8		0.15
1 3/8		0.22

Figure 2. Line charge allowances for R-22 (ounces/foot).

Too Easy To Overcharge

To give you an idea how easy it is to overcharge a system due to excessive liquid line diameter or length, let's look at an example.

Say you are installing a 3-ton system that holds a factory charge of 7 pounds of R-22 with a 100-foot-long liquid line. The factory charge will handle up to 15 feet of 3/8-inch line. This means you must add refrigerant for 85 feet of 3/8-inch line.

According to the chart (Figure 2), you would have to add 3 pounds and 1 ounce to this system to get it to work properly. This means you have to overcharge the system by about 44 percent.

If you consider the charge that the extra suction line will need, the problem is even worse. Some systems may come from the factory designed to tolerate this overcharge, but others may not.

There are many other things to take into consideration when determining line sizing for a particular installation, such as:

- Vertical location of outdoor unit relative to the indoor unit;
- The refrigerant handling limitations of the particular model of machine being installed;
- What kind of metering device is being used; and/or
- Whether it is a heat pump or an air conditioner.

Some machines have maximum line length guidelines in the literature or on the labels. If your line set will exceed these limitations, then you know some action is necessary. Many distributors can help you design the line sets or provide you with factory piping design literature.

If piping limitations are not available for the system, such as when you are moving an older machine, you can use a general rule of thumb. If the line set will not be more than 75 feet long, you are using the factory-recommended line size, and it's not pushing liquid uphill more than 25 feet, very likely no special considerations are necessary. Remember, this is just a rule of thumb.

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