Piping

Table of Contents

Lesson One Piping Materials and Fittings..........3

Lesson Two Discharge Line..........21

Lesson Three Liquid Line..........37

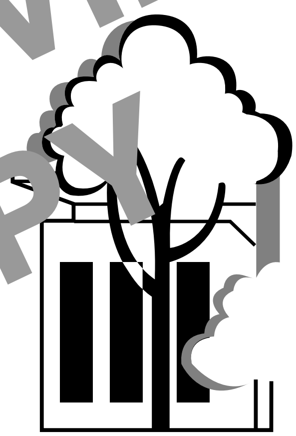
Lesson Four Suction Line..........53

Lesson Five Piping-Systems Maintenance..........67

PIPING

Lesson One

Piping Materials and Fittings



TPC Training Systems

43601

Lesson

1 Piping Materials and Fittings

TOPICS

The Refrigeration Piping System
Compatibility of Materials
Sizing Refrigeration Piping
Oil Migration in Refrigeration Piping
Pipe vs. Tubing
Pipe Materials
Standard Pipe Sizes
Pipe Schedules and Codes
Valves and Pipe Fittings
Cutting Pipe Accurately
Methods of Joining Pipe
Uses for Tubing in Refrigeration
Tubing Material and Sizes
Advantages of Tubing
Cutting Tubing
Flaring Tubing
Bending Tubing
Fittings for Tubing
Soldering Tubing Fittings
Brazing Tubing Fittings
Safety in Soldering and Brazing

OBJECTIVES

After studying this Lesson, you should be able to…

- Name the three main lines of piping in a refrigeration system.
- Explain why air conditioning and refrigeration piping must be sized correctly.
- Contrast pipe and tubing and explain why tubing is often preferred over piping.
- Explain how pipe is classified according to schedule.
- Name three methods of joining steel pipe.
- Explain how tubing is cut, flared, bent, and joined.
- Describe the step-by-step procedure for making a brazed joint.

KEY TECHNICAL TERMS

Piping 1.13 closed system that conveys fluids
Pipe 1.13 formed from rolled sheet metal and welded
Tubing 1.13 formed from a solid piece of metal using a drawing process
Faces 1.30 mating flange surfaces
Brazing 1.58 hard soldering

A modern refrigeration system requires a complex network of piping for not only the refrigerant lines, but for water lines as well. Both pipe and tubing are used in refrigeration systems. The size, material, and construction of pipe and tubing must be exactly right if the system is to function as it was designed. Valves and fittings that connect the components of the system must meet the same exacting specifications as the pipe and tubing.

This Unit describes the functions of the compressor discharge, liquid, and suction lines and explains how to select and size each line for maximum efficiency. It also tells how to attach the lines to the compressor and other components. This Lesson explains how to cut and join pipe and tubing for trouble-free service. Good piping, when properly installed, not only extends the service life of costly equipment, it also decreases downtime and the need for repairs.

The Refrigeration Piping System

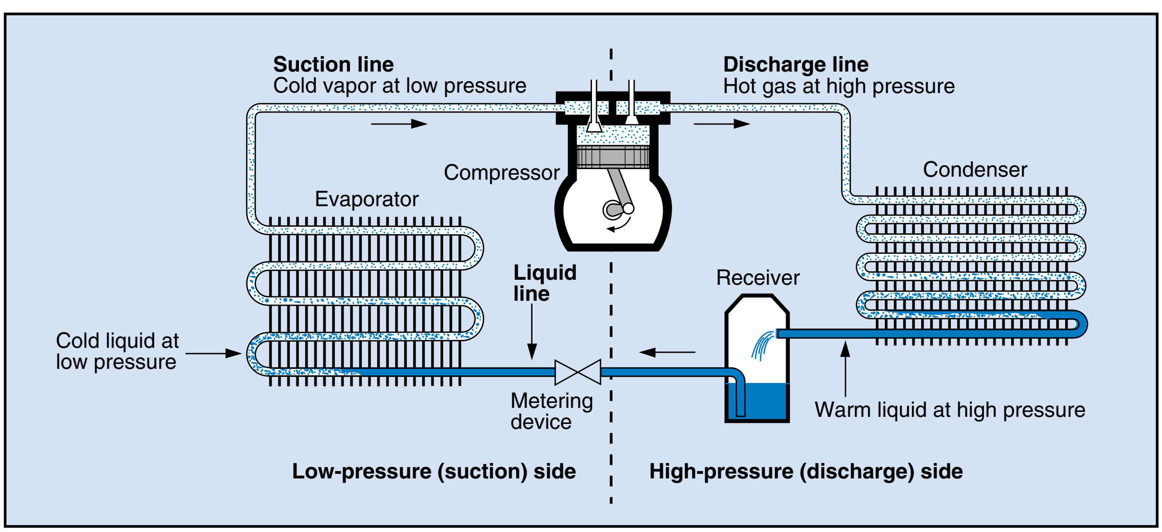
1.01 The main components of a refrigeration system are the compressor, the condenser, the metering device, and the evaporator. Each component is designed and built to rigid specifications and is warranted to perform the task for which it is designed. But a system requires piping to connect the components so they can work together. Figure 1-1 illustrates the piping in a refrigeration system.

1.02 A refrigeration piping system needs carefully designed and assembled piping for the following reasons:

- Drops in pressure decrease cooling capacity and increase power requirements, so a refrigeration system must be built to minimize pressure drop
- The fluid in the system changes its phase (vapor to liquid to vapor) as it circulates.
- The system must aid lubrication by preventing the buildup of liquid refrigerant in the compressor crankcase.
- Oil must return to the crankcase at the same rate at which it leaves.

1.03 When installing or repairing refrigeration piping, always use new pipe. Never use a piece of scrap pipe left over from another job. The correct piping, when properly installed, makes the system components last longer. It reduces downtime by reducing the need for repairs and it prevents the damage to valves and fittings that can be caused by poorly installed piping.

Fig. 1-1. Basic piping for refrigeration system



1.04 The three main lines of piping in a refrigeration system, as shown in Fig. 1-1, are:

- *discharge line*—connects the compressor out let to the condenser inlet
- *liquid line*—connects the condenser outlet to the metering device inlet
- *suction line*—connects the evaporator outlet to the compressor inlet.

Other piping lines and components in the system include the condenser water-supply line (in some systems), drain lines, and the valves that control refrigerant flow and pressure. Before installing or repairing any piping, you should have an assembly drawing showing the material, size, and specifications of all the piping and components.

Compatibility of Materials

1.05 When piping a refrigeration system, make sure the materials, components, and refrigerant are compatible. In other words, the refrigerant must not attack and destroy the piping or fittings. Such action can go on very slowly and often is not obvious-until it causes a breakdown. For example, never use copper or brass pipe in an ammonia system, because the ammonia will destroy the copper. Also, make certain the refrigerant will not attack gaskets and cause leaks.

1.06 Halogenated refrigerants (those containing chlorine, fluorine, etc.) are very stable compounds. In normal service, they do not attack steel, copper, aluminum, or other metals. In the presence of moisture and high temperatures, however, they break down. When breakdown occurs, they release a gas (chlorine or fluorine) which, at a high enough temperature from the compressor, combines with moisture to form a corrosive acid that attacks the metals.

Sizing Refrigeration Piping

1.07 It is vital to the operation of any refrigeration system to use the right size piping for the refrigerant discharge, liquid, and suction lines. It might not be your job to size the piping, but you should understand that sizing is very important, especially when replacing system components. In sizing piping, it is necessary to consider piping cost, pressure drop, and oil return. The right piping for a job will be:

- as small as possible to keep the cost down
- large enough to prevent excessive suction-pressure drop
- small enough to promote oil return with the help of oil traps, where needed.

Other Lessons in this Unit will provide more detail on the importance of specifying refrigerant lines accurately.

Oil Migration in Refrigeration Piping

1.08 To operate properly, a reciprocating compressor must have a good supply of oil for the crankshaft bearings and the cylinders-just as an automobile engine. The compressor crankcase must always be filled to the proper level with oil. Good lubrication is equally important in other kinds of compressors. Refrigerant leaving the compressor carries some of the oil into the discharge line, to the condenser, and on through the system. The oil *migrates* (moves) through the system.

1.09 To make certain the compressor does not run short of oil, the piping must carry the oil along with the refrigerant through the evaporator and back to the compressor. Pitching the discharge line downward away from the compressor at least $^{1}/_{2}$ in. for every 10 ft of length helps drain oil from the pipe walls. This pitch also prevents oil from flowing back to the compressor during the off-cycle.

1.10 Many refrigerants mix readily with refrigerant oil when they are in liquid form. As gases, however, they can be poor carriers of oil. The oil becomes a mist in the hot discharge line, and the refrigerant and oil mist do not mix. The oil usually collects on the cool pipe walls and drains toward low points in the system. If the refrigerant has enough velocity, however, it will *entrain* (pick up) the oil and carry it through the system.

1.11 Under conditions of minimum load, the velocity of refrigerant gas in horizontal lines must be 500 to 700 fpm (feet per minute). This velocity is sufficient to enable the oil to rise in a short vertical line.

If the rise is more than about 10 ft, however, the velocity must be in the range of 750 to 1500 fpm. To start the oil rising in a vertical line, it is often necessary to install an oil trap. Oil traps are described later in this Unit.

Pipe vs. Tubing

1.12 Both pipe and tubing play a part in conveying fluids in most refrigeration systems. Although many people confuse the two, you should understand that pipe and tubing are not the same. Also, the methods of specifying and connecting pipe are entirely different from the methods of specifying and connecting tubing. Pipe and tubing are also cut using different tools.

1.13 The term *piping* is often used to refer to any closed system that conveys fluids. A *pipe* is usually formed from rolled sheet metal with its edges butt-welded. *Tubing*—also called *seamless tubing*—is made from a solid piece of metal using a drawing process. Tubing is generally lighter and stronger than welded pipe. You can bend it readily without splitting, because it has no seam. The inside surfaces of both pipe and tubing must be smooth and free from defects that could interfere with fluid flow and cause excessive friction loss and pressure drop.

1.14 An air conditioning or refrigeration system actually uses more tubing than pipe. When technicians speak of "piping a system" (installing system piping), they are installing tubing in most cases. Seamless tubing in sizes as small as 1/8 in. and as large as 6 in. in diameter is used for the discharge, suction, and liquid lines.

Pipe Materials

1.15 The most common pipe materials for refrigeration systems are steel, iron, and copper. All materials are selected according to applicable codes and size standards, as well as specifications covering corrosion, scale, mechanical fatigue, thermal fatigue, and other effects.

1.16 Welded steel pipe is usually used for low-pressure service. The seam is either butt welded or resistance welded. Iron pipe is generally either wrought iron or alloyed iron. Wrought iron, which is especially resistant to corrosion, is a high-purity iron containing about 3% of a glass-like iron-silicate slag. Iron alloy and stainless steel pipe are very useful for high-pressure service.

Standard Pipe Sizes

1.17 Pipe sizes for refrigeration are standardized and are usually expressed in inches of *nominal* (approximate) inside diameter (ID). The principal characteristics of pipe are:

- inside diameter
- wall thickness
- length
- weight per unit of length.

1.18 Most refrigeration manuals and handbooks contain pipe sizing tables. These tables show the capacity, in tons of refrigeration, of pipe sizes based on total pressure drop or equivalent length of run. The *equivalent length of run* is a means of allowing for an average pressure drop in valves, elbows, and other fittings. The tables are generally set up for the standard conditions of 40°F (4°C) suction temperature and 105°F (40°C) condensing temperature. Pressure drop is covered in more detail in Lesson Two.

Pipe Schedules and Codes

1.19 Steel pipe is classified according to *schedule* and according to *weight*. In the refrigeration industry, the most commonly used schedule numbers are *Schedule 40* and *Schedule 80*. Weights are designated as *standard weight* and *extra strong*. Although schedule number and weight are related, they are not the same for all pipe sizes. The dimensions of standard-weight steel pipe correspond to Schedule 40 sizes for pipe diameters from 1/8 through 10 in. For 12 in. and larger pipe, the wall thickness of standard-weight pipe remains constant, while the wall thickness of Schedule 40 pipe increases with size. The dimensions of extra-strong steel pipe are the same as Schedule 80 for pipe ranging from 1/8 through 8 in. in diameter. At larger sizes, extra-strong pipe has a constant 0.5 in. wall, while Schedule 80 pipe wall thickness increases. For 8 in. pipe diameter and larger, a Schedule 30

Table 1-1. Steel pipe data

Nominal size, in.	Pipe OD, in.	Schedule number or weight	Wall thickness, in.	Inside diameter, in.	Surface area: Outside, ft²/ft	Surface area: Inside, ft²/ft	Cross section: Metal area, in²	Cross section: Flow area, in²	Weight: Pipe, lb/ft	Weight: Water, lb/ft
1/4	0.540	40 ST	0.088	0.364	0.141	0.095	0.125	0.104	0.424	0.045
		80 XS	0.119	0.302	0.141	0.079	0.157	0.072	0.535	0.031
3/8	0.675	40 ST	0.091	0.493	0.177	0.129	0.167	0.191	0.567	0.083
		80 XS	0.126	0.423	0.177	0.111	0.217	0.141	0.738	0.061
1/2	0.840	40 ST	0.109	0.622	0.220	0.163	0.250	0.304	0.850	0.131
		80 XS	0.147	0.546	0.220	0.143	0.320	0.234	1.087	0.101
3/4	1.050	40 ST	0.113	0.824	0.275	0.216	0.333	0.533	1.13	0.231
		80 XS	0.154	0.742	0.275	0.194	0.433	0.432	1.47	0.187
1	1.315	40 ST	0.133	1.049	0.344	0.275	0.494	0.864	1.68	0.374
		80 XS	0.179	0.957	0.344	0.251	0.639	0.719	2.17	0.311
1 1/4	1.660	40 ST	0.140	1.380	0.435	0.361	0.669	1.50	2.27	0.647
		80 XS	0.191	1.278	0.435	0.335	0.881	1.28	2.99	0.555
1 1/2	1.900	40 ST	0.145	1.610	0.497	0.421	0.799	2.04	2.72	0.881
		80 XS	0.200	1.500	0.497	0.393	1.068	1.77	3.63	0.765
2	2.375	40 ST	0.154	2.067	0.622	0.541	1.07	3.36	3.65	1.45
		80 XS	0.218	1.939	0.622	0.508	1.48	2.95	5.02	1.28
2 1/2	2.875	40 ST	0.203	2.469	0.753	0.646	1.70	4.79	5.79	2.07
		80 XS	0.276	2.323	0.753	0.608	[illegible]	4.24	7.66	1.83
3	3.500	40 ST	0.216	3.068	0.916	0.803	[illegible]	7.39	7.57	3.20
		80 XS	0.300	2.900	0.916	[illegible]	[illegible]	[illegible]	10.25	2.86
4	4.500	40 ST	0.237	4.026	1.178	[illegible]	3.17	12.73	10.78	5.51
		80 XS	0.337	3.826	1.178	[illegible]	[illegible]	11.50	14.97	4.98
6	6.625	40 ST	0.280	6.065	[illegible]	[illegible]	5.58	28.89	18.96	12.50
		80 XS	0.432	[illegible]	[illegible]	[illegible]	8.40	26.07	28.55	11.28
8	8.625	30	0.277	[illegible]	[illegible]	2.113	7.26	51.16	24.68	22.14
		40 ST	[illegible]	[illegible]	2.258	2.089	8.40	50.03	28.53	21.65
		80 XS	[illegible]	[illegible]	2.258	1.996	12.76	45.66	43.35	19.76
10	10.75	30	[illegible]	[illegible]	2.814	[illegible]	10.07	80.69	34.21	34.92
		40 S[illegible]	[illegible]	[illegible]	2.814	[illegible]	11.91	78.85	40.45	34.12
		XS	0.500	9.750	[illegible]	[illegible]	16.10	74.66	54.69	32.31
		80	0.593	9.564	[illegible]	[illegible]	18.92	71.84	64.28	31.09
12	12.75	30	0.330	[illegible]	[illegible]	[illegible]	12.88	114.8	43.74	49.68
		ST	0.375	[illegible]	[illegible]	3.141	14.58	113.1	49.52	48.94
		40	[illegible]	[illegible]	[illegible]	3.125	15.74	111.9	53.48	48.44
		XS	[illegible]	[illegible]	3.338	3.076	19.24	108.4	65.37	46.92
		80	[illegible]	[illegible]	3.338	2.978	26.03	101.6	88.44	43.98

pipe is available for low-pressure applications. Table 1-1 gives the general dimensions and weights of steel pipe. Wrought-iron pipe has thicknesses slightly greater than those for steel pipe of the same size.

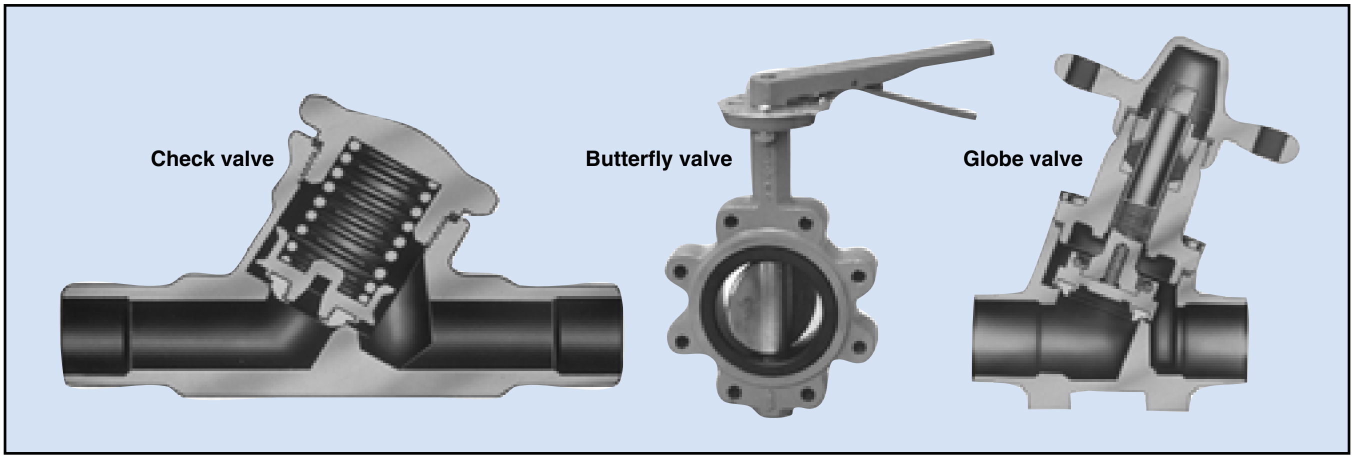
1.20 Several engineering societies and standards groups have devised codes, standards, and specifications that meet most pipe application requirements. Some codes provide formulas for calculating the proper pipe size and wall thickness for a given application. The American Society for Testing and Materials (ASTM) code provides information on pipe material, manufacturing method, specification number, grade of pipe, and the maximum stress to which the pipe can safely be subjected.

1.21 Most codes contain tables that specify the correct pipe to use for conveying many kinds of fluids under various conditions of temperature and pressure. Because piping often carries dangerous fluids under high pressure, a code helps to provide a margin of safety for the protection of both the equipment and the personnel around it.

Valves and Pipe Fittings

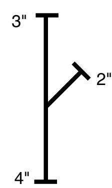
1.22 A refrigeration system typically contains several valves to control the pressure of the refrigerant. A spring-loaded *relief valve* opens to relieve the pressure at a predetermined setting. A *pressure regulator* keeps the system pressure constant. It also reduces a fluctuating pressure to a uniform, usable service pressure.

Fig. 1-2. Valves used in refrigeration piping

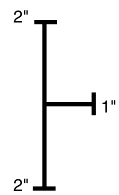


1.23 At times, the refrigerant flow must be throttled or completely stopped. *Globe* or *butterfly valves* are recommended for throttling (decreasing) flow. *Gate* and *ball valves* are used for starting and stopping flow. Sometimes protection against backflow is required. A *check valve* is the best protection against backflow. Examples of several valves are shown in Fig. 1-2.

1.24 Pipe *fittings* join one length of pipe to another. Fittings come in a variety of types-elbows, couplings, unions, tees, and reducers, for example. These fittings can be flanged, threaded, or welded. They are generally steel, cast iron, copper, or brass. Pipe fittings are identified by their nominal pipe size and are sized according to American National Standards Institute (ANSI) standards.



1.25 When designating the size of a fitting for joining pipes of unequal size, the size of the largest opening is given first, followed by the opening at the other end of the run. The branch size is given last. For instance, a 4 × 3 × 2 in. Y-branch has a 4 in. inlet, a 3 in. outlet, and a 2 in. branch outlet. A 2 × 2 × 1 in. tee has a 2 in. inlet and outlet with a 1 in. branch outlet.



The Programmed Exercises on the next page will tell you how well you understand the material you have just read. Before starting the exercises, remove the Reveal Key from the back of your book. Read the instructions printed on the Reveal Key. Follow these instructions as you work through the Programmed Exercises.

1-1. A refrigeration system requires ________ to connect the components.	1-1. PIPING Ref: 1.01, Fig. 1-1
1-2. What are the three main lines of piping in a refrigeration system?	1-2. DISCHARGE LINE, LIQUID LINE, SUCTION LINE Ref: 1.04, Fig. 1-1
1-3. Can copper pipe be used in an ammonia refrigeration system?	1-3. NO Ref: 1.05
1-4. Three important considerations in sizing piping are cost, pressure drop, and ________.	1-4. OIL RETURN Ref: 1.07
1-5. A vertical line often needs a(n) _______ to help the oil rise.	1-5. TRAP Ref: 1.11
1-6. Steel pipe is classified according to ________ and ________.	1-6. SCHEDULE; WEIGHT Ref: 1.19
1-7. The best protection against backflow is a(n) ________ valve.	1-7. CHECK Ref: 1.23
1-8. If a Y-branch is designated as $3 \times 2 \times 1$, what is the size of the branch?	1-8. 1 in. Ref: 1.25

Cutting Pipe Accurately

1.26 Connecting pipe and installing valves and fittings is much easier when the ends of the pipe are cut square—that is, at right angles to the centerline of the pipe. This square cutting helps prevent misalignment when screwing or welding a length of pipe to a valve or fitting.

1.27 Pipe is cut with a *pipe cutter*. An example is shown in Fig. 1-3. The T-handle screwed through the cutter frame operates an adjustable jaw. To get the best results, always *track* the pipe first by lightly engaging the cutting wheels and turning the cutter completely around the pipe. If the cutter tracks straight around the pipe, you will get a straight cut. Apply cutting force by turning the T-handle. Make one complete revolution of the cutter before applying more force. Continue this process until the pipe is cut through completely. Use a *pipe reamer* to deburr the inside edge of the cut pipe.

Methods of Joining Pipe

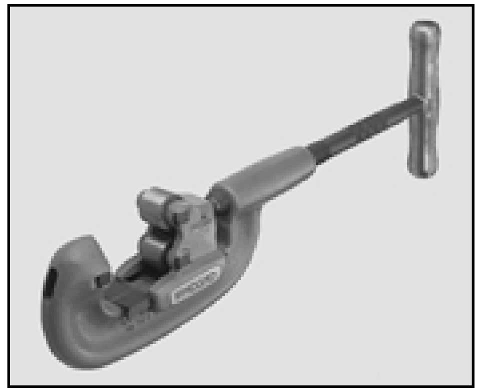
1.28 Metal pipe can be joined in a number of ways. The best method to use depends on the:

- nature of the metals being joined (ferrous or nonferrous—*ferrous* metals contain iron)
- type of fluid in the pipe
- phase of fluid in the pipe (liquid or vapor)
- line pressure and temperature
- need for access to various sections of the line.

1.29 Metal pipe is most often joined using flanged, threaded, or welded joints. Each type serves a special purpose, and each is formed in a different manner, as shown in Fig. 1-4. Soldered and brazed joints are used primarily for connecting tubing. The processes for making joints in tubing are described later in this Lesson.

1.30 **Flanged pipe joints.** *Flanges* are rims or rings welded or cast on the ends of pipe sections and fittings. The flanges are bolted together to form a joint. The *faces* (mating surfaces) of the flanges must

Fig. 1-3. Common pipe cutter



be smooth and flat so the joint will be tight and free of leaks. To ensure a tight seal, a gasket is placed between the flanges. The gasket, usually made of rubber or another elastic material, spreads under compression when the flange bolts are tightened, forming a seal. Make sure the gasket material is compatible with the refrigerant in the system.

1.31 When making a flanged joint, clean each part first. Then use a solvent-soaked cloth to remove the factory-applied rust-preventing grease from the flanges. Clean the gasket. When the pipe is in place, support it so the flange carries no weight. Line up the flanges and check the joint with a spirit level both horizontally along the pipe and vertically across the flange faces.

1.32 Iron and bronze flanges usually have *plain* (not raised) faces. Steel flanges have *raised* faces. Do not bolt a plain face to a raised one. If you must bolt a steel flange with a raised face to an iron or bronze

Fig. 1-4. Joints used in refrigeration piping

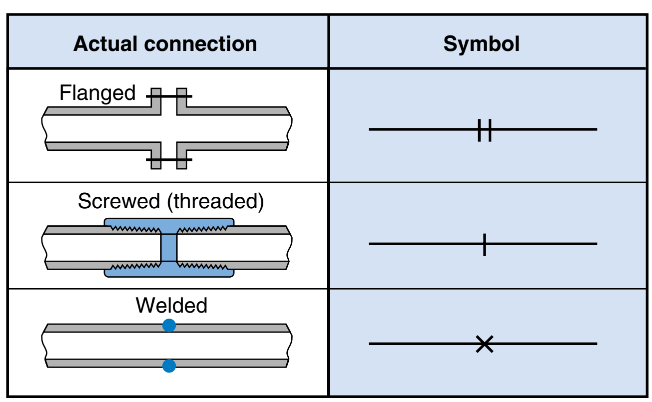


Fig. 1-5. Flanged joints require matching faces

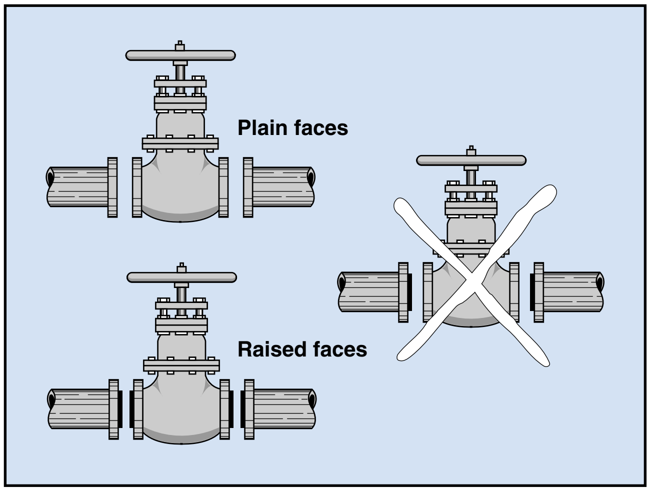
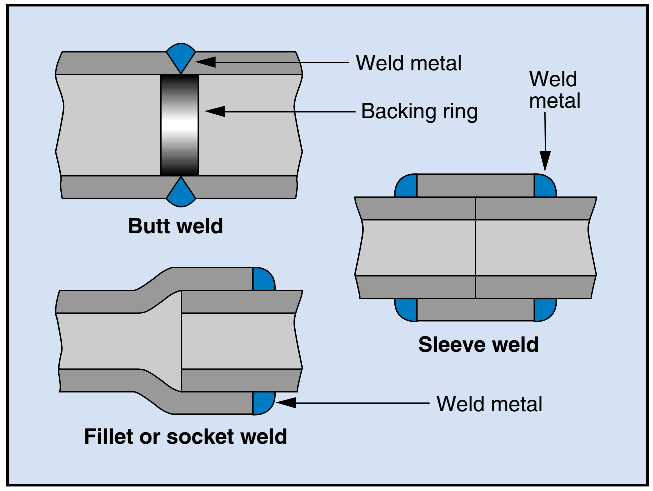


Fig. 1-6. Welded joints for refrigeration piping



flange with a plain face, remove the raised steel face by machining. Because flanged joints are often heavier than the pipes they connect, make sure to give the pipe enough support near the joint. Both plain and raised faces are shown in Fig. 1-5.

1.33 **Threaded pipe joints.** Threaded joints are commonly used to connect pipe ranging from $^1/_8$ to about 6 in. in diameter. Threaded fittings are understood to have *female* (internal) threads unless otherwise specified. If external threads are desired, the order for the fitting must specify *male* threads. Threaded joints are usually used in low-pressure lines.

1.34 The correct class, form, and fit of threads for various pipe diameters are specified in an established code called the American Pipe Thread Standard. Threads must be smooth, clean, and precision cut to provide a good fit. Since most couplings have threads on the inside, the pipe is generally threaded on the outside. To get the proper fit when connecting a threaded fitting and pipe, you should be able to engage 3 to 4 threads by hand and 5 to 7 threads with a wrench to tighten the connection.

1.35 Pipe ends can be threaded by *dies* or *chasers*, with either a hand-held or a power-operated diestock. A pipe die can be solid or it can consist of a number of adjustable dies or chasers mounted in a die head. When cutting threads, a thread-cutting oil lubricates the dies or chasers, provides cooling action, and helps to remove chips. After cutting the threads, clean them with a wire brush to remove dirt, chips, and cutting oil. Because pipe threads might not be perfect, use pipe compound or "dope" (on the male threads only) to ensure a good fit and to help lubricate the threads when you join them. Start the joint by hand and then tighten it with a wrench. Do not overtighten the joint as you can damage it by making it too tight.

1.36 **Welded pipe joints.** A major advantage of welding is that the joined pipes become one continuous pipe. A properly welded joint is as strong as the pipe itself. Welded joints are especially useful in high-pressure and high-temperature piping. They are often used in ammonia refrigeration systems. Shielded metal-arc welding (SMAW) is the process most widely used to weld steel pipe. Gas metal-arc welding (GMAW) is used for stainless steel and aluminum pipe. Oxyacetylene welding is often used for thin-walled pipe or tubing. This process greatly reduces the formation of *icicles*, which are solidified weld metal projections inside the pipe. Icicles can break off and enter the fluid, causing damage to valves and other components and increasing pressure drop.

1.37 When installing new lines of pipe, you will usually follow blueprints and procedures, established by code. The code ordinarily specifies the kind of welded joint to use. When repairing a pipe, you might not have such detailed instructions, but you must still follow any code that applies to the job.

1.38 The three welded joints commonly used to connect refrigeration piping are shown in Fig. 1-6:

- In the *butt weld*, pipe sections are placed end-to-end. A backing ring is used inside the joint to provide a surface on which to build up the weld.
- In the *fillet* or *socket weld*, one pipe fits inside the other. The weld is made on the outside of the lap.
- In the *sleeve weld*, the pipe sections are placed end-to-end inside a sleeve. The welds are made at both ends of the sleeve.

After welding any type of pipe joint, always clean out the line to remove icicles and weld spatter.

1.39 The first step in making a good welded joint is to have a good fit. The pipe ends should be accurately cut and beveled and the pipe held in alignment with the correct space between the ends. The second step is proper welding procedure. You will be welding most joints when the piping is in its final position. Most welding will be vertical with the pipe horizontal. You might sometimes weld horizontally with the pipe vertical. Occasionally, the pipe will be at an angle to the horizontal.

Uses for Tubing in Refrigeration

1.40 As stated earlier, tubing is used widely in refrigeration applications. Tubing is used for the main lines of the system—discharge, liquid, and suction. It is also used for the auxiliaries found in most systems—supply and drain lines, water pipes, equalizer lines, bypasses, etc. Because most tubing is designed for brazed, soldered, or flared connections (not threaded ones), its walls can be made much thinner than the walls of the same size pipe.

1.41 The main considerations in selecting tubing are material, inside diameter, and wall thickness. Table 1-2 shows standard sizes of copper tubing. The inside diameter (ID) determines the rate of flow that can be passed without excessive pressure drop. The wall thickness determines the bursting pressure for any given diameter.

Tubing Material and Sizes

1.42 In refrigeration work, tubing is usually copper or steel. Most tubing resists corrosive fluids and

Table 1-2. Dimensions, weights, and allowable pressures for copper tubing

Nominal diameter, in.	Diameter, in.		Wall thickness, in.	Weight per ft, lb	Surface area sq ft per linear ft		*Allowable internal pressure, psi			
	OD	ID			OD	ID	100°F	200°F	300°F	400°F
1/8	0.125	0.065	0.030	0.0347	0.0327	0.0170	3130	2870	2480	1570
3/16	0.188	0.128	0.030	0.0577	0.0492	0.0335	1990	1820	1570	990
1/4	0.250	0.190	0.030	0.0804	0.0655	0.0497	1450	1330	1150	720
5/16	0.312	0.248	0.032	0.109	0.0817	0.0649	1230	1120	970	610
3/8	0.375	0.315	0.030	0.126	0.0982	0.0821	900	820	710	450
3/8	0.375	0.311	0.032	0.134	0.0982	0.0814	1010	920	800	500
1/2	0.500	0.436	0.032	0.182	0.131	0.114	740	680	590	370
1/2	0.500	0.430	0.035	0.198	0.131	0.113	800	730	630	400
5/8	0.625	0.555	0.035	0.251	0.164	0.145	640	590	510	320
5/8	0.625	0.540	0.040	0.285	0.164	0.143	740	670	580	370
3/4	0.750	0.666	0.042	0.362	0.196	0.174	650	590	510	330
7/8	0.875	0.785	0.045	0.455	0.229	0.206	590	540	460	300
1 1/8	1.125	1.025	0.050	0.655	0.294	0.268	510	460	400	260
1 3/8	1.375	1.265	0.055	0.884	0.360	0.331	460	420	360	230
1 5/8	1.625	1.505	0.060	1.14	0.425	0.394	430	390	330	220
2 1/8	2.125	1.985	0.070	1.75	0.556	0.520	370	340	290	190
2 5/8	2.625	2.465	0.080	2.48	0.687	0.645	350	320	270	180
3 1/8	3.125	2.945	0.090	3.33	0.818	0.771	330	300	260	170
3 5/8	3.625	3.425	0.100	4.29	0.949	0.897	320	290	250	160
4 1/8	4.125	3.905	0.110	5.38	1.08	1.02	300	270	240	150

*NOTE: Allowable pressure is for tubing itself—*not* for joints and fittings.

Fig. 1-7. Cutter for steel and copper tubing

carries high pressure well. When you have an otherwise even choice between using pipe or tubing, you must balance the higher cost of tubing against its low maintenance costs, easy installation, and longer service life.

1.43 Tubing is made in sizes up to about 12 in. ID. Some copper tubing is only 1/32 in. ID. The sizes commonly used in refrigeration work range from 3/8 to about 6 in. Like pipe, refrigerant tubing is listed in the tables of various manuals and handbooks that show the capacity, in tons of refrigeration, for sizes based on total pressure drop or equivalent length of run. Table 1-2 lists the allowable internal pressures for various sizes of copper tubing. Notice that unlike pipe, nominal tubing size is given as OD, not ID.

Advantages of Tubing

1.44 Tubing has several advantages over pipe. These advantages make it ideal for use in refrigeration systems:

- Tubing is lighter in weight and easier to handle than pipe.
- Annealed (soft) tubing can be bent easily to fit an installation, saving time and money.
- The bendability of tubing reduces the number of fittings needed. Fewer fittings means less chance of leakage.
- Its greater flexibility allows tubing to absorb much more shock and vibration than pipe.
- It is easier and faster to remove and replace tubing and its components.
- The inside wall of tubing is much smoother than the inside wall of pipe, thus reducing pressure drop.

Cutting Tubing

1.45 To install or repair refrigeration tubing, first cut off a piece of tubing from a stock supply. To ensure a good joint, use a *tubing cutter*. The cutter looks similar to a pipe cutter, but the cutting wheel has a knob handle instead of a T-handle, as shown in Fig. 1-7. The knob handle prevents you from applying too much force and collapsing the tubing. The operation of the two devices is the same.

1.46 Like pipe, tubing must be tracked before cutting to ensure a square cut. Engage the cutter lightly on the tubing and turn it one revolution in one direction. Then, in the opposite direction, increase the depth of cut for each revolution, making a cutoff in three or four revolutions. Make sure to smooth the end of the tubing with a *deburring tool* to remove the small metal burrs from both the inside and outside edges. A tubing cutter, when properly used, leaves very few burrs.

Flaring Tubing

1.47 To make a good, leak-proof flare joint, the end of the tubing must be flared properly. Flaring makes the end of the tubing bell-shaped. The angle of the flare for air-conditioning and refrigeration work is 45° with the centerline of the tubing. It must match the angle of the fitting exactly. When tubing is correctly flared, the flare seats firmly in the fitting when the nut is tightened. Flares that are too short result in thin walls that can break or leak. Flares that are too long will stick or jam during assembly. Examples of correct and incorrect flaring are shown in Fig. 1-8.

1.48 Figure 1-9 shows a *flaring tool*. The end of the tubing is placed in the hole of matching size in the split female die, and the die is closed to hold the tubing securely. Then the tubing is flared either by hammering a male die into the end of the tubing or by screwing a die into the tubing with a viselike handle.

Fig. 1-8. Correct and incorrect tube flaring

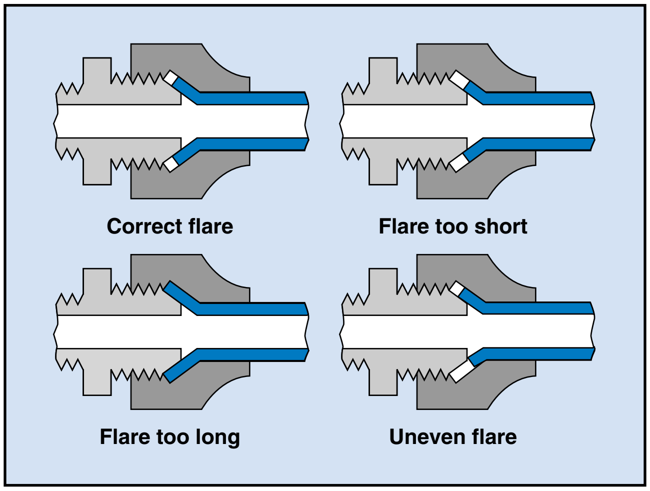
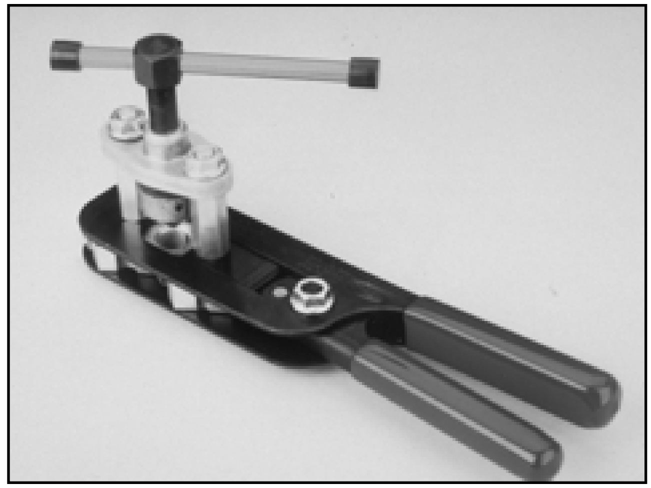


Fig. 1-9. Tube flaring tool



Bending Tubing

1.49 Refrigeration lines should normally be as short and as free of bends as possible. Tubing should not be assembled in a completely straight line, however. A bend helps eliminate strain by absorbing vibration. It also allows for thermal contraction and expansion. Bends are better than elbows or sharp turns, because they are more gradual and do not offer as much resistance to fluid flow. Thus, they do not consume as much power. Whenever you can, bend tubing to reduce the number of fittings required.

1.50 Most tubing is bent with a *hand bender.* A *hydraulic bender* is used for large tubing. It is important to obtain the desired bend without flattening, kinking, or wrinkling the tubing. Unless the tubing has the same diameter throughout a bent section, the bend will cause turbulence and pressure drop. If you are going to use the bent tubing in a corrosive atmosphere, anneal it before installing it to prevent stress corrosion. *Annealing* is the process of heating and then slowly cooling a metal to make it softer and less brittle. Annealing also relieves internal stresses present in the metal.

Fittings for Tubing

1.51 *Fittings* for metal tubing come in the same wide variety of shapes and sizes as those for pipe. Fittings for refrigeration service are selected on the basis of their safe working pressures. All fitting manufacturers publish lists of the services and pressures for which their products are suited. The most commonly used types of fittings are flared, compression, and sweat (soldered or brazed) fittings.

1.52 When assembling tubing and fittings, follow these basic rules:

- Place the nuts and sleeves on the tubing before making the flare on the tubing.
- Support long lengths of tubing with clamps or hangers.
- Install and remove all tubing assemblies with hand tools only. Do not bend or twist the tubing.
- Support valves, filters, and similar components independently. Do not support their weight with the tubing.

Soldering Tubing Fittings

1.53 Refrigeration tubing is usually *soldered* with 95-5 solder, a mixture of 95% tin and 5% antimony. The mixture begins to melt at 450°F (232°C) and becomes totally liquid at 465°F (241°C). It can be easily worked with an acetylene or propane torch. The 95-5 mixture is harder than the common 50-50 (50% tin, 50% lead) solder, which is not recommended for use in refrigeration tubing. It is not strong enough to handle the pressure developed and the vibration present in many systems.

1.54 Tubing to be soldered must be clean and free of oxides, paint, and scale. Remove oxides by scouring the surfaces with a wire brush, steel wool, or sandpaper—right down to the bright metal. Fittings must be thoroughly clean inside before you solder them to tubing. Use a noncorrosive flux to dissolve oxides that form when the tubing and/or fitting are heated.

1.55 To produce a gas-tight joint, the tubing must fit snugly in the fitting so the space (or tolerance) between them is the same at all points. The tubing should not fit loosely in the fitting, but should be free enough that you can slip the fitting on and off by hand.

1.56 When heating the joint, remember to:

- Heat the joint evenly, allowing solder to fill the entire joint.
- Heat the joint rapidly so oxide formation is minimized.
- Avoid overheating so you do not char the flux or damage the joint.
- Apply the hottest point of the flame to the center of the fitting where the end of the tubing is.

1.57 When the parts are hot, touch the solder to the place where the tubing enters the fitting. The solder will melt and be drawn into the joint. Do not heat the solder and drop it on the joint. It will not stick. After the solder is in place around the tubing and is still molten, clean up the joint by wiping it smooth with a soft brush or a piece of cloth.

Brazing Tubing Fittings

1.58 *Brazing* (also called *hard soldering*) requires a brazing alloy with a silver base rather than a tin base. Brazing alloys, which usually contain bronze, have a melting range of 1120 to 1510°F (605 to 820°C)—much higher than common solder. A propane or acetylene torch is required to produce this temperature.

1.59 Brazing produces joints that are corrosion resistant, strong, leak proof, and vibration proof. You can use this process to join dissimilar metals (steel to iron or brass to steel, for example). The free-flowing silver alloy makes a joint that is actually stronger than the parent metal. It freely penetrates the entire area of close-fitting joints with a minimum of oxidation.

1.60 Like common soft soldering, brazing requires clean surfaces, uniform tolerance, proper fluxing with a flux made especially for brazing applications, and controlled heating. For refrigeration work, apply flux around the tubing end before inserting it into the fitting. If possible, revolve the tubing or fitting to spread the flux. Brush the flux over the entire end of the fitting.

1.61 Support the joint to hold its alignment and keep strain off of it during heating and cooling. Then proceed as follows:

1. With a neutral (50% oxygen) flame, heat the tubing all around about 1/2 to 1 in. from the fitting.
2. When the flux on the tubing melts, heat the fitting.
3. When the flux on the fitting melts, apply the brazing alloy to the area where the tubing enters the fitting.

Like soft solder, the brazing alloy will melt and will be drawn into the joint. Continue to heat the joint and apply alloy until you can see that the clearance is filled with material. Avoid applying too much alloy as it will enter into the system.

Safety in Soldering and Brazing

1.62 When soldering or brazing, observe the common safety rules that apply to welding. Use goggles with dark lenses to protect your eyes. Wear gauntlet gloves, sleeve covers, and a protective apron. Make sure you have enough fresh air, especially if the operation produces smoke, fumes, or odors. Some brazing alloys contain cadmium, which produces toxic cadmium oxide vapors when heated.

1-9. A flanged pipe joint requires a(n) ________ to ensure a tight seal.	1-9. GASKET Ref: 1.30
1-10. Solidified weld metal projecting inside a pipe is called a(n) ________.	1-10. ICICLE Ref: 1.36
1-11. When one pipe fits inside another, the weld is a(n) ________ weld.	1-11. FILLET or SOCKET Ref: 1.38(2), Fig. 1-6
1-12. Which tubing dimension determines its bursting pressure for a given diameter?	1-12. WALL THICKNESS Ref: 1.41
1-13. Because of its flexibility, tubing can absorb more shock and ________ than pipe.	1-13. VIBRATION Ref: 1.44(4)
1-14. Tubing must be bent without kinking to avoid turbulence and ________.	1-14. PRESSURE DROP Ref: 1.50
1-15. The process of heating, then slowly cooling a metal in order to make it less brittle is called ________.	1-15. ANNEALING Ref: 1.50
1-16. When joining tubing by soldering, should you heat the joint or heat the solder?	1-16. HEAT THE JOINT Ref: 1.57

Answer the following questions by marking an "X" in the box next to the best answer.

1-1. Which line carries refrigerant from the evaporator to the compressor?

☐ a. Discharge line
☐ b. Hot gas line
☐ c. Liquid line
☐ d. Suction line

1-2. To carry the oil with the refrigerant, refrigerant gas velocity in a horizontal discharge line must be at least ________ fpm.

☐ a. 250
☐ b. 500
☐ c. 750
☐ d. 1000

1-3. Which valve is used for starting and stopping refrigerant flow?

☐ a. Ball
☐ b. Check
☐ c. Globe
☐ d. Relief

1-4. The main types of joint for connecting metal pipe are

☐ a. brazed, soldered, and screwed
☐ b. brazed, soldered, and welded
☐ c. brazed, screwed, and welded
☐ d. flanged, screwed, and welded

1-5. A pipe flange with a plain face should be joined to a flange with a ________ face.

☐ a. plain
☐ b. raised
☐ c. recessed
☐ d. threaded

1-6. To provide cooling and help remove chips when cutting threads, you should use

☐ a. cutting oil
☐ b. pipe compound
☐ c. solder
☐ d. solvent

1-7. You must use a backing ring inside the pipe joint when making a ________ weld.

☐ a. butt
☐ b. fillet
☐ c. sleeve
☐ d. socket

1-8. When compared to pipe, tubing is

☐ a. easier to bend
☐ b. heavier
☐ c. more difficult to replace
☐ d. rougher inside

1-9. To allow for thermal contraction and expansion, tubing should be

☐ a. bent
☐ b. crimped
☐ c. flared
☐ d. honed

1-10. Silver-based solder is used for

☐ a. brazing
☐ b. flaring
☐ c. fusion welding
☐ d. soft soldering

SUMMARY

For a refrigeration system to function efficiently, the system piping must be carefully designed and installed with a minimum pressure drop. The three main piping lines in a refrigeration system are the discharge line, the liquid line, and the suction line. When piping a refrigeration system, make certain that the piping, components, and refrigerant are all compatible. When sizing the piping, consider piping cost, pressure drop, and oil return.

Both pipe and tubing are used in refrigeration systems. Although they serve similar purposes, they are not the same—they are manufactured, specified, cut, shaped, and connected differently. Most refrigeration system piping is made from steel, iron, and copper. Various schedules, tables, and codes are available to assist in selecting pipe. A variety of valves and fittings is common in refrigeration systems. Pipe is cut with a pipe cutter and reamed to deburr the inside edges of the cut pipe. Pipe ends can be joined by flanges, threads, or welding.

The tubing used in refrigeration work is usually copper or steel. Tubing has several advantages over pipe—it is lighter in weight than pipe and is easier to handle and bend. It requires fewer fittings, is easier and faster to remove and replace, and has a smoother inside wall. Tubing is cut and deburred much like pipe, but is easily flared and bent. Tubing can be joined with flared fittings, compression fittings, and by soldering or brazing.

Answers to Self-Check Quiz

1-1. d. Suction line. Ref: 1.04

1-2. b. 500. Ref: 1.11

1-3. a. Ball. Ref: 1.23

1-4. d. Flanged, screwed, and welded. Ref: 1.29

1-5. a. Plain. Ref: 1.32

1-6. a. Cutting oil. Ref: 1.35

1-7. a. Butt. Ref: 1.38

1-8. a. Easier to bend. Ref: 1.44

1-9. a. Bent. Ref: 1.49

1-10. a. Brazing. Ref: 1.58

Contributions from the following sources are appreciated:

Table 1-1. Reprinted with permission of the American Society of Heating, Refrigerating, and Air Conditioning Engineers
Figure 1-2. Watts Regulator Water Products Div., Amcast, Superior Valve Co.
Figure 1-3. Ridgid Tool Company
Figure 1-7. Wheeler Mfg., Div. of Rex International USA Inc.
Figure 1-9. Reed Mfg. Co.