Lesson Two – Metal Piping

Preface

The modern plant facility has a number of piping systems made up of different sizes and materials. In this lesson you will learn about pipes made from cast iron, steel, copper, and other metals. You will also learn about the behavior of fluids in a piping system, and the major methods of connecting sections of pipe.

Knowledge of the basic characteristics of the metals used for piping will provide clues to the uses of the pipelines you will work with. Such knowledge will be extremely helpful to you, by making your job much easier and more interesting.

Pipes

2.01 Pipe sizes are standardized and are usually expressed in terms of inches (") or fractions of inches. As a rule, the size of the pipe is given in terms of the outside diameter (O.D.) or inside diameter (I.D.). Figure 2-1 shows the terminology that applies to a section of pipe.

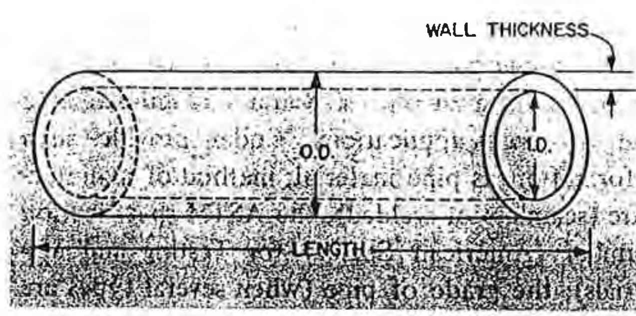
The principal dimensions are as follows:

1. Outside diameter (O.D.)
2. Inside diameter (I.D.)
3. Wall thickness
4. Length

Another consideration is weight per foot, which varies according to the pipe's wall thickness and material.

2.02 As a rule, pipe sizes are designated by diameter. Commercial sizes 12 inches and less are usually known by their nominal or approximate inside diameters. Above 12 inches, a pipe is ordinarily designated by its outside diameter. The actual O.D. of smaller diameter pipes is greater than the nominal I.D. For example, a 4" diameter pipe is actually 4½ inches in diameter, while a 10" or 12" pipe is ¾ of an inch greater than the size used. Piping 14 inches in diameter and above, however, is very close to size, within a few thousandths of an inch. In all cases, whether the O.D. be small or large, the dimensions are closely held to accommodate various fittings.

Fig. 2-1. Pipe size terminology.



Pipe Schedules

2.03 At one time, piping was designated as STANDARD, EXTRA-STRONG, and DOUBLE EXTRA-STRONG. That system allowed no variation for wall thickness, however, and, as pipe requirements became more numerous, greater variation was needed. As a result, piping today is classified according to SCHEDULE, the most common schedule numbers being 40, 80, 120, and 160. In diameters from 1/8" to 10", the dimensions of Standard weight steel pipe correspond to Schedule 40 sizes. From 12 through 24 inches, wall thickness is 0.375" (3/8 inch) for the Standard or Schedule 40 pipe.

2.04 The dimensions of Extra-Strong steel pipe are the same as Schedule 80 sizes for piping ranging from 1/8 through 8 inches diameter. From 10 through 24 inches, Extra-Strong steel pipe has a wall thickness of 0.500" (½ inch) in accordance with Schedule 80 specifications. The Double Extra-Strong pipe has no exact equivalent schedule number.

2.05 Schedule numbers range from 10 to 160, the difference being the wall thickness. As an example, a Schedule 40 3" diameter pipe, whose actual O.D. is 3.500", has a wall thickness of 0.216". The same pipe in a Schedule 80 (Extra-Strong) would have a wall thickness of 0.300". When the wall thickness of any given size of pipe is increased, the inside diameter (I.D.) will decrease. You will often hear piping referred to either in terms of its diameter or schedule number.

Other Pipe Codes

2.06 Because of the increasing variety of requirements for piping, a number of engineering societies and standards groups have devised codes, standards, and specifications that meet most applications. The codes that determine pipe sizes are a good example.

2.07 Some codes provide formulas for determining the minimum pipe size and wall thickness to use in given applications. Codes provide such information as pipe material; method of manufacture (seamless or welded); the ASTM specification number (American Society for Testing and Materials); the grade of pipe (when several types are available); and the stress that the pipe can be subjected to at various pressures and temperatures. Other tables provide recommendations for the correct pipe to use for many different fluids.

2.08 By consulting such codes, a designer can determine exactly what piping specification should be used for any application. Since pipelines often carry dangerous materials and fluids under high pressures, following a code helps ensure the safety of personnel, equipment, and the piping system itself.

2.09 Selecting a pipe according to code recommendations is something like the procedure followed by an automobile mechanic who checks the service manual to see what type of oil filter should be used for a particular year and model of car.

2.10 A well-designed network of piping includes the right types of pipe, fittings, and valves. Other considerations include proper selection and spacing of supports; adequate safety precautions; insulation; and ease of maintenance.

Types of Systems

2.11 Piping systems fall into either of two main categories: PROCESS LINES and UTILITY or SERVICE LINES.

Process Lines

2.12 Process lines carry the fluids used in a manufacturing *process*. For example, one of the first operations in a paper mill is the reduction of incoming logs to chips of wood. The chips are then "cooked" in a unit called a digester, which contains a chemical solution of sodium sulfide and caustic soda pumped through pipes. Because it is a processing operation, these pipes are called process lines.

Utility or Service Lines

2.13 Utility or service line pipes carry steam, gas, water, compressed air, and air-conditioning fluids. All are part of the general support system of a plant's operation. Service lines help heat and cool the plant, provide water wherever it is needed, and carry the air which drives air tools and equipment.

Table 2-1. Color Identification Code (American National Standards Institute A 13.1-1981)

Classification	Color field	Color of letters for legends
Fire quenching materials	Red	White
Materials inherently hazardous	Yellow	Black
Materials of inherently low hazard		
Liquid	Green	White
Gas	Blue	White
Size of color field and lettering		
Outside diameter of pipe or covering in inches	**Length of color field in inches**	**Height of letters in inches**
3/4 to 1¼	8	½
1½ to 2	8	3/4
2½ to 6	12	1¼
8 to 10	24	2½
Over 10	32	3½

2.14 Steam lines, for instance, are used for general heating, and they furnish the energy to drive steam turbines. Steam is also used to heat many chemical solutions in process applications. This can be done by circulating the steam through coils of pipe submerged in the chemical solution. The steam itself does not come in contact with the solution, even though its heat does help the process. Such a line is classified as a utility or service line.

2.15 ANSI (American National Standards Institute) has established a code for identification of pipelines. This code involves the use of legend, nameplates or tags, and color (Table 2-1). The code states that "identification of the contents of a piping system shall be by lettered legend giving the name of the contents in full or abbreviated." The code goes on to say that the legend should include "sufficient additional details such as temperature, pressure, etc., as are necessary to identify the hazard." This identification may be accomplished by stenciling, the use of tape, or markers. Color should be used to identify the characteristic hazards of content, but its use shall be in combination with legend.

2.16 Color provides a general indication of the type of material carried in a pipe. The piping carrying fire quenching material are painted red. This classification includes sprinkler systems and other piped fire fighting or fire protection equipment. Pipes carrying materials inherently hazardous are colored yellow. This classification includes materials that are flammable or explosive, chemically active or toxic, at high temperatures or pressure, or radioactive. Materials of inherently low hazard, indicated by either green or blue, are not hazardous by nature.

2.17 Familiarize yourself with the pipe coding used in your plant. All plants may not follow the Code recommendations, which can be confusing if you are not familiar with the system used.

Metal Piping

2.18 Man has worked with metals for several thousand years, making tools, swords, armor and pipes. Until recent times, however, metallurgy (the science and study of metals) was more an art than a science. The information needed to assure maximum strength of metals and minimizing their failures was unknown. Metalworkers and blacksmiths knew that certain processes worked, but were not able to say why.

2.19 Fortunately, as new requirements and applications for chemicals developed, so did man's understanding of the composition, behavior, and structure of metals. The result has been the development of new metals and the improvement of those already in use. Piping systems and components can now be designed to efficiently handle more materials. With increased knowledge of metallurgy, it is also possible to devise new pipe materials to meet the requirements of newly developed chemicals. Another benefit is greater pipe reliability and easier maintenance.

2-1. Pipe sizes are expressed in ________ or fractions of ________.

2-2. The size of the pipe refers to the ________ or ________.

2-3. Pipe size above 12 inches is designated by its ________ diameter.

2-4. In diameters from 1/8 through 10 inches, Standard weight pipe dimensions correspond to Schedule ____ sizes.

2-5. The difference in Schedule numbers represents the difference in the ________ ________ of pipes.

2-6. When pipe wall thickness increases, the I.D. will ________.

2-7. Name the two main classes of piping systems.

____

____

2-8. A red color code on a pipeline indicates that the line is carrying ________ materials.

Characteristics of Metals

2.20 Different metals have different characteristics, which make them usable in a variety of applications. Here are definitions of a few terms that you should know: An ALLOY is a metal made up of two or more metals which dissolve into each other when melted together. An alloy can also be formed by mixing a metal and a non-metal. Brass is an example of the first type because it is an alloy or blending of the two metals, copper and zinc. An example of the second type is steel, which is a mixture of iron (a metal) and carbon (which is not a metal).

2.21 Metals are referred to as being FERROUS or NONFERROUS. A ferrous metal is one that contains iron, while a nonferrous metal such as brass, does not. You will be working with both ferrous and nonferrous metals.

2.22 Piping is commonly made of wrought iron, cast iron, or steel. The difference among them is largely the amount of carbon which each contains. Wrought iron, for example, has only a small percentage of carbon. Cast iron is an alloy of iron, carbon, and silicon cast in a mold. It is hard and brittle. Steel, one of the basic production materials of modern industry, has less carbon than cast iron. Each of the three is made by a different process.

2.23 A DUCTILE metal is one which can be fashioned into a new form without breaking. For instance, it can be drawn or pulled out into wire. Copper is an example of a ductile metal. A MALLEABLE metal can be extended or formed readily, usually by heating and then hammering or rolling it.

2.24 ANNEALING is the common process of heating a metal and permitting it to cool gradually to make it softer and less brittle. Annealing also relieves internal stresses or strains present in the metal.

2.25 In addition to the more common ferrous and nonferrous metals, there are special pipe materials for special applications. Aluminum pipe is lightweight and corrosion resistant, although its strength decreases as temperature increases; lead pipe has considerable resistance to corrosive materials; and tantalum pipe is highly resistant to acids such as hydrochloric acid. Titanium pipe and zirconium pipe also handle corrosive materials. Piping made from special materials is less common, of course, and is more expensive. On the other hand, such materials are needed to carry highly corrosive fluids.

2.26 Stainless steel, a ferrous metal, is an alloy of steel and chromium. Other materials may be included to make up the variety of stainless steels used where rust and other corrosion are particular problems. When piping is made of stainless steel it is identified by an "S" after the schedule number.

Pipe Manufacturing Methods

2.27 Metal piping is made by many different processes. The four major ones produce wrought seamless pipe, forged seamless pipe, welded pipe, and cast pipe. Within each process, there are other processes that are convenient variations.

2.28 Wrought seamless carbon steel and alloy pipe are made in diameters up to 26 inches. The basic process and its variations begin with a round *billet* or block of steel. The steel is heated, and a hole is driven through it. Successive operations form it to the desired diameter and length.

2.29 Forged pipe is made in larger diameters and heavier wall thicknesses for applications where other seamless types are not readily available. In this process, a steel billet is heated and then is lengthened by forging hammers until it is stretched out to a diameter about one inch greater than that of the finished pipe. The O.D. and I.D. are then machined to size.

2.30 Welded pipe ordinarily begins as a flat strip of steel which, after successive rolling operations, forms a tube. The seam is then welded. Cast pipe is made by pouring molten metal into a mold where it is allowed to cool. Practically all metal piping is made by a variation of one of those four processes.

2.31 Once manufactured, piping may be subject to a number of tests. Depending on its intended use, the pipe is tested for its resistance to chemical corrosion and for its mechanical strength. It may also be tested for its resistance to speed and pressure of the fluids it will carry. In such cases, an adequate safety factor is allowed for. Such tests are made according to specified codes to meet required standards.

Behavior of Fluids in Piping

2.32 An understanding of how fluids behave in piping will be useful to you. You learned that fluids are divided into liquids and gases. A liquid, like water or oil, cannot be compressed. You cannot squeeze a quart of water into a pint container. Although a gas *is* compressible, it will expand to fill any container that it is placed in. If you were to release a quart container of steam into an empty gallon container, the gas would expand to fill it. When liquid doesn't completely fill a pipe, it has a top surface, like that of a creek or river. But in the same pipe, gas expands to fill all of the available space. It is common to speak of gases and vapors, vapors being materials in a gaseous state which can easily condense back into a liquid. Both steam and ammonia are vapors. Oxygen is not.

2.33 Liquids and gases have a property known as VISCOSITY, which is a measure of the thickness of a liquid or the density of a gas or vapor. A thin liquid is said to have a low viscosity, while a thick liquid, like molasses, has a high viscosity rating. The viscosity of a liquid goes down as the temperature increases; that is, it becomes thinner. On the other hand, the viscosity of a gas goes up or gets heavier as the temperature increases. Whenever a liquid or gas gets thicker or denser, it flows more slowly in a piping system.

2.34 The effect on piping is: As viscosity rises, or the fluid density increases, so does friction in the pipes. This in turn requires more effort by the pump. In a compressed air line, friction causes the pipes to heat up, which results in expansion and strain on the piping.

Piping Applications

2.35 Piping applications are given in general terms. Information about specific piping for various materials is available from pipe manufacturers. Welded or seamless steel pipe is used for plumbing, heating, water, gas, and air lines. For high-temperature applications, and when pipe must be bent or shaped to allow interpipe connections, seamless carbon-steel pipe is used. Special steel welded pipe is used for gas, liquid, and vapors. Welded wrought-iron pipe is common for the condensate return lines of steam systems. Heavy-wall alloy steel pipe is also used for high-temperature applications. Because ductile iron pipe can readily be formed into special shapes, it is also used in such cases.

2.36 Cast iron pipe is used for water and gas distribution systems and sewage lines, because it has a relatively long life owing to its heavy wall and good resistance to both internal and external corrosion. Cast iron is being used increasingly in systems carrying both natural gas and dry manufactured gas. It is also used in oil refineries and in some process industries because cast iron is more corrosion-resistant than most steels.

2.37 When liquids to be carried are strong processing solutions, which would react with ferrous piping or injure it, nonferrous types are commonly used. Good examples are red brass and copper pipes, which are frequently used in chemical plants. Although such piping may be more expensive than ferrous piping, it is actually more economical to use in the long run. It has a longer life in corrosive situations, which means less downtime for maintenance.

Steam Piping

2.38 An example of piping systems that carry gases and vapors is a steam line. In addition to its value in heating systems, steam is extremely important to industry because it drives the steam turbines to generate electricity.

2.39 Steam is commonly classified according to three ranges of pressure. The steam used in heating systems is in the pressure range from 0 to 15 psi. SATURATED STEAM has a pressure of from 50 to 150 psi, and it is used in a number of industrial processes. SUPERHEATED STEAM, rated at 200 psi and up, is used in heavy industrial applications, such as driving large turbines.

2.40 Many kinds of steam pipe are required to meet these various needs. This is an example where advances in metallurgy have produced piping to meet those needs. Steam pipe includes welded and seamless steel pipe; welded wrought iron pipe or condensate lines; heavy-wall alloy steel pipe; and ductile iron pipe.

Water Piping

2.41 Among the types of water carried by piping systems are: service water; city water; treated or processed water; and distilled water. Service water, used for cooling and flushing purposes, is untreated water that may have been strained, but is otherwise just as it comes from a river, lake, or deep well. City water is, like that in your own home, drinkable. Treated water has been processed to remove minerals that might cause corrosion or sludge in piping. Distilled water is specially purified.

2.42 Water pipes are subject to the formation of scale from minerals and rusting. Water pipes also may be affected by TUBERCULATION, which is the formation of compounds on the inner lining of the pipe. Such compounds are the result of bacterial action in the water, and they cannot be dissolved by water.

Maintenance Considerations

2.43 Maintenance of metal piping is the result of its characteristics in part, but also includes the kind of maintenance common to all piping systems. The major considerations are: (1) the effect of temperature changes; (2) outside material in the lines – dirt, scale, sand, rust, metal chips; (3) shifting of pipe supports; (4) corrosion; and (5) "water hammer."

2.44 Because metal piping is rigid, and laid out in specified lengths, it is especially subject to the effects of temperature changes. You have learned that metals expand or contract according to temperature variations. Over a long run (length of pipe), the effects can cause considerable strain on the lines. If the piping is bent out of shape because of those strains, damage and failure may result.

2.45 When fluids move through pipes at high speed, solid impurities in the fluid have an abrasive effect on the inner surface or wall of the pipe, and score it. Impurities can also build up inside the pipe and slow down the fluid flow.

2.46 Rust is a good example of such an impurity. Rust is iron oxide. An oxide is a compound

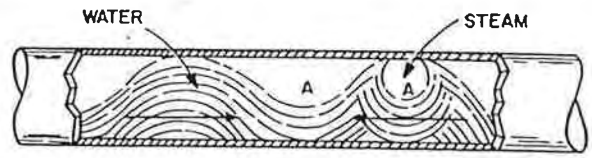


Fig. 2-2. Water hammer.

formed by the reaction of oxygen with another element or material. You might say that iron has an appetite for oxygen, but needs water or some other liquid to start the reaction going. That's why a ferrous pipe carrying water and air will rust. The rust weakens the pipe, and its particles also get into the fluid, where they are carried through the system.

2.47 Pipe supports may loosen in time, and, therefore, they require periodic inspection. Vibration, as well as expansion and contraction in the metal piping, can cause the supports to loosen. Fluids traveling at high speeds and pressures, are one cause of vibration. Water hammer is another.

2.48 All metal pipes are subject to corrosion. Many materials react chemically with metal piping to produce scale, rust, and other oxides. Caustic solutions, acids, and similar materials are typical causes of pipe corrosion.

2.49 WATER HAMMER can damage or destroy piping, valves, fittings, and equipment. Usually noisy, water hammer happens when a moving column of water in a pipe is suddenly stopped or slowed. Waves form as the water (or other liquid) hits the blocking point. The shock thus caused passes back through the system. (That's what causes the noise.) At times, the shock can be severe enough to rupture the pipe.

2.50 Figure 2-2 illustrates water hammer conditions in a steam condensate line. The two waves (called "slugs") coming together under the pockets of steam ("A") may meet with a considerable impact. The steam will compress enough to absorb some of the shock, but the wave action will continue back and forth through the system, gradually diminishing.

2.51 Except to repair damage that results, there isn't much you can do about water hammer. You should report it, however, if you hear water hammer in a pipeline.

Use these programed exercises to he

2-9.	If a metal is a ferrous metal, it contains ______.
2-10.	Annealing makes a metal ______ and less ______.
2-11.	A Schedule 40S pipe is made of ______ ______.
2-12.	When fluids are defined, they are divided into two classes, ______ and ______.
2-13.	The viscosity of a liquid goes down as the temperature ______.
2-14.	As viscosity rises, so does ______ in the pipes.
2-15.	Rust is another name for ______ oxide.
2-16.	Piping, valves, and fittings can be ______ or ______ by water hammer.

Joining Pipe

2.52 Metal pipes can be connected or joined in a number of ways. The method used depends on: (1) the nature of the metal sections being joined (ferrous, nonferrous); (2) type of fluid to be carried by the system (liquid and what kind, gas); (3) pressure and temperature in the line; and (4) the need to provide access to sections of the line.

2.53 A JOINT is the connection between elements in a piping system. The five major types of joints used for joining metal pipe are:

1. Bell-and-spigot
2. Welded
3. Soldered or brazed
4. Screwed
5. Flanged (covered in a later lesson)

Each type is used for a special purpose and each has a different appearance, as shown in Fig. 2-3. The illustration also shows the symbols used to represent them in diagrams of a piping system.

2.54 Bell-and-spigot joints are used for connecting lengths of cast iron water pipe. The enlarged section at one end of the pipe is the bell, the plain end is the spigot. This kind of pipe and joint is used in waste water systems, which are not under pressure. The plain end is fitted into the bell, and the joint is sealed. One of the common ways to make a watertight seal is by filling or caulking the joint with a material called oakum. Molten lead is then poured over the oakum and solidifies, making the seal.

2.55 Welding is the process of heating materials to such a high temperature that the sections to be joined melt and blend together. A basic advantage of welding is that the pieces joined become one continuous piece. A properly welded joint is as strong as the piping itself. Welded joints are chosen for applications involving high pressures and temperatures.

2.56 A number of welding processes can be used to provide the needed heat. All methods rapidly heat the area to be welded in such a way that the heat is confined to the area close to the joint. Heating a larger section would probably cause deformation of the metal.

2.57 The three basic welded joints are: (1) the BUTT WELD, in which the sections to be welded are placed end to end; (2) the SOCKET or FILLET WELD, in which one pipe fits inside the other, the weld being made on the outside of the lap; and (3) the SLEEVE WELD joint, in which the pipe

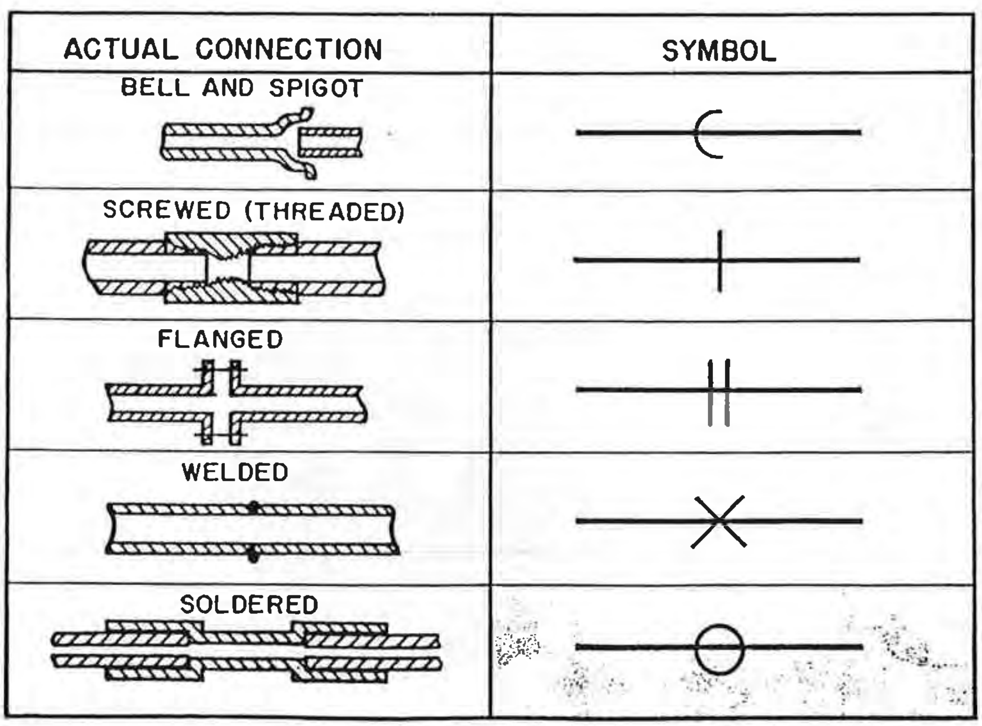


Fig. 2-3. Common pipe joints and symbols.

sections are placed end to end inside a sleeve, the weld being made at the ends of the sleeve. All three are illustrated in Fig. 2-4.

2.58 Figure 2-5 shows the shape of a correctly made butt weld. Note that the edges to be joined are beveled, which leaves a "V"-shaped space between them. The V-shaped space is filled when the weld is made. Figure 2-5 also shows what's called an ICICLE, a piece of weld metal which projects into the area inside the pipe. Icicles are undesirable, because they can break off and get into the flow of fluid.

2.59 If the weld is not carefully made, fragments of weld metal may also get into the pipe. Such fragments are sometimes called SPLATTER. Both icicles and splatter must be avoided. In a high-speed, high-pressure line, the fragments act like small bullets, causing damage to valves and fittings, as well as to the pipe itself.

2.60 In a typical pipe-welding operation, a backing ring is used inside the joint to provide a surface

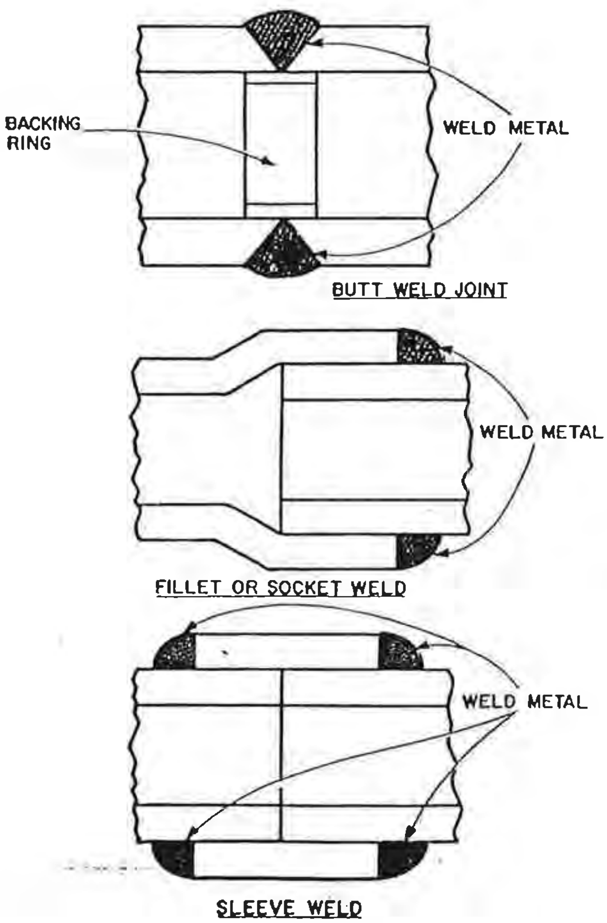


Fig. 2-4. The basic welded pipe joints.

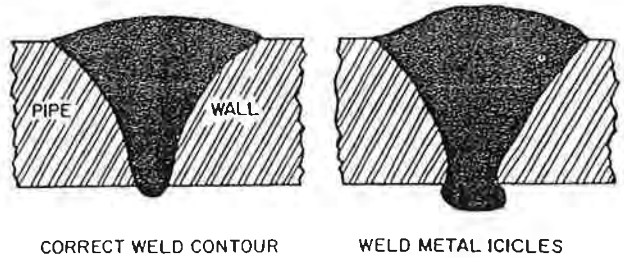


Fig. 2-5. A correct and an undesirable weld.

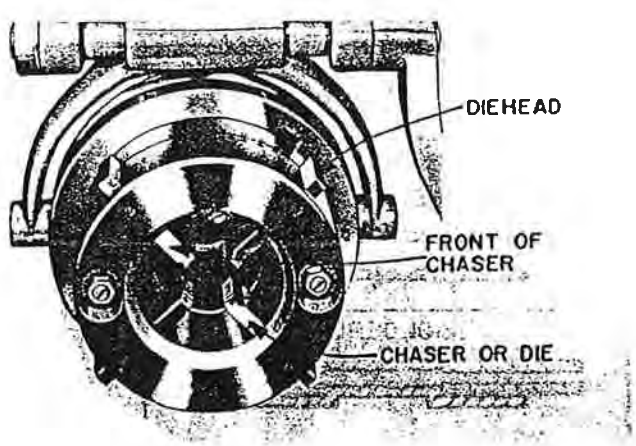
on which to build up the metal. The ring also prevents the formation of an icicle, and keeps splatter from getting into the line. After a pipe joint has been welded, it is good practice to clean out the line.

2.61 Soldered or brazed joints are used primarily for joining nonferrous metals. A major difference between welding and brazing is that brazing is done at far lower temperatures. Brazing, in turn, uses higher temperatures than soldering. Brazing is sometimes referred to as *hard* soldering, because it is done at higher temperatures than *soft* soldering, the process used in wiring electrical connections.

2.62 In brazing, the joint is heated, and kept clean by applying a flux that prevents oxides from forming. The clean, hot joint is then filled with brazing rod to form the connection.

2.63 Screwed or threaded joints are commonly used to join sections of smaller diameter pipe, which carries fluids at low pressures and normal temperatures. Diameters of pipe joined by threading range from 1/8" up to 4" and 8". Both ferrous

Fig. 2-6. Front view of diehead, showing position of chasers.



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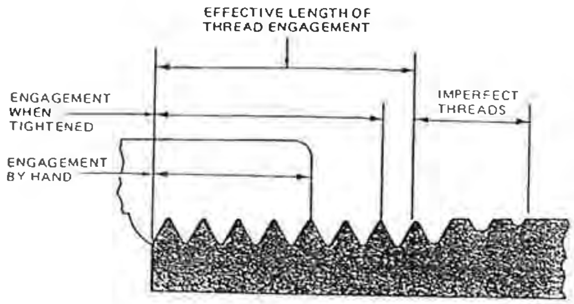

Fig. 2-7. Pipe thread fits.

Crane Company

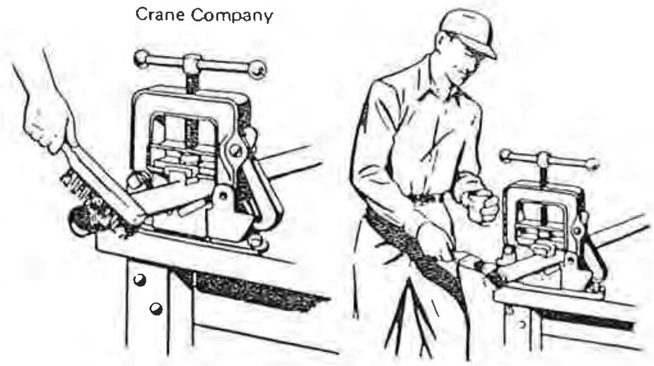

Fig. 2-8. Cleaning and doping newly cut pipe threads.

and nonferrous pipes are joined in this way. Most couplings have threads on the inside surface. The pipe is threaded on the O.D. The correct class, form, and type of thread for various pipe diameters and uses are specified in established codes. You probably will work most often with threads covered by the American Pipe Thread Standards code.

2.64 Pipe ends are threaded with dies or chasers, either by hand with diestocks or by die heads, which can be either hand- or power-operated. A pipe die can be solid, or it can include a number of dies or chasers, which are mounted in a die head, as shown in Fig. 2-6. Become familiar with the equipment used in your plant.

2.65 It is essential that threads be smooth, clean, and properly cut if they are to provide the correct fit. Thread cutting should be regarded as a precision operation.

2.66 Figure 2-7 shows a profile of pipe threads. Note that the end section is labeled "imperfect thread." They are imperfect because the first three or more threads on the chaser are cut away to permit the pipe to enter the die. In cutting threads, a thread-cutting oil provides cooling action, lubricates the dies or chasers, and assists in chip removal. After the threads have been cut, clean them with a wire brush to remove dirt and metal chips. (See Fig. 2-8.)

2.67 Because pipe threads may not be perfect, a pipe compound (or "dope") is then applied to the threads (male threads only) to ensure a good fit and help lubricate the threads while the joint is being tightened. Compounds used depend on the kind of piping involved.

2.68 The joining is usually begun by hand to determine if the thread engagement is right. The joint is then tightened with a wrench. Avoid excessive tightening which can damage both the threads and the coupling. Again, it is good practice to clean the piping out to be sure that no chips remain, and that no compound is inside the pipe to cause possible contamination.

2-17. A joint is the ________ between the elements of a piping system.

2-18. What kind of joint is ordinarily used to connect sections of cast iron water pipe?

____

2-19. A common method of making a bell-and-spigot joint watertight is to first caulk the joint with a material called ________.

2-20. For high temperature and high pressure applications, what kind of joint is used?

____

2-21. Name the three basic types of welded joints.

____

____

____

2-22. Nonferrous metals are usually connected by ________ or ________.

2-23. Brazing is sometimes called ________ *(hard/soft)* soldering.

2-24. To ensure a good fit and help lubricate the threads while the joint is being tightened, ________ ________ is used on the male threads.