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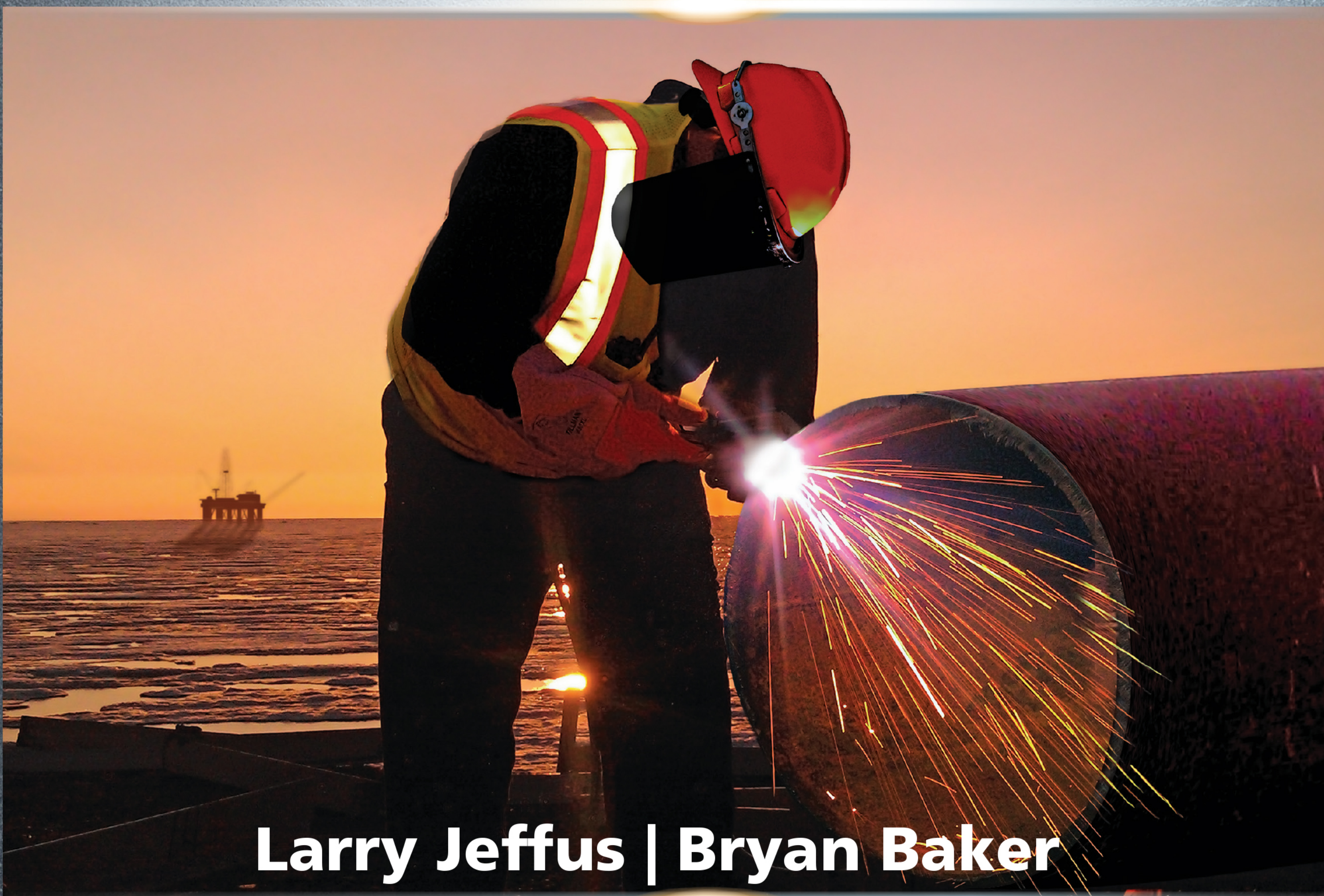
PIPE WELDING



Larry Jeffus | Bryan Baker

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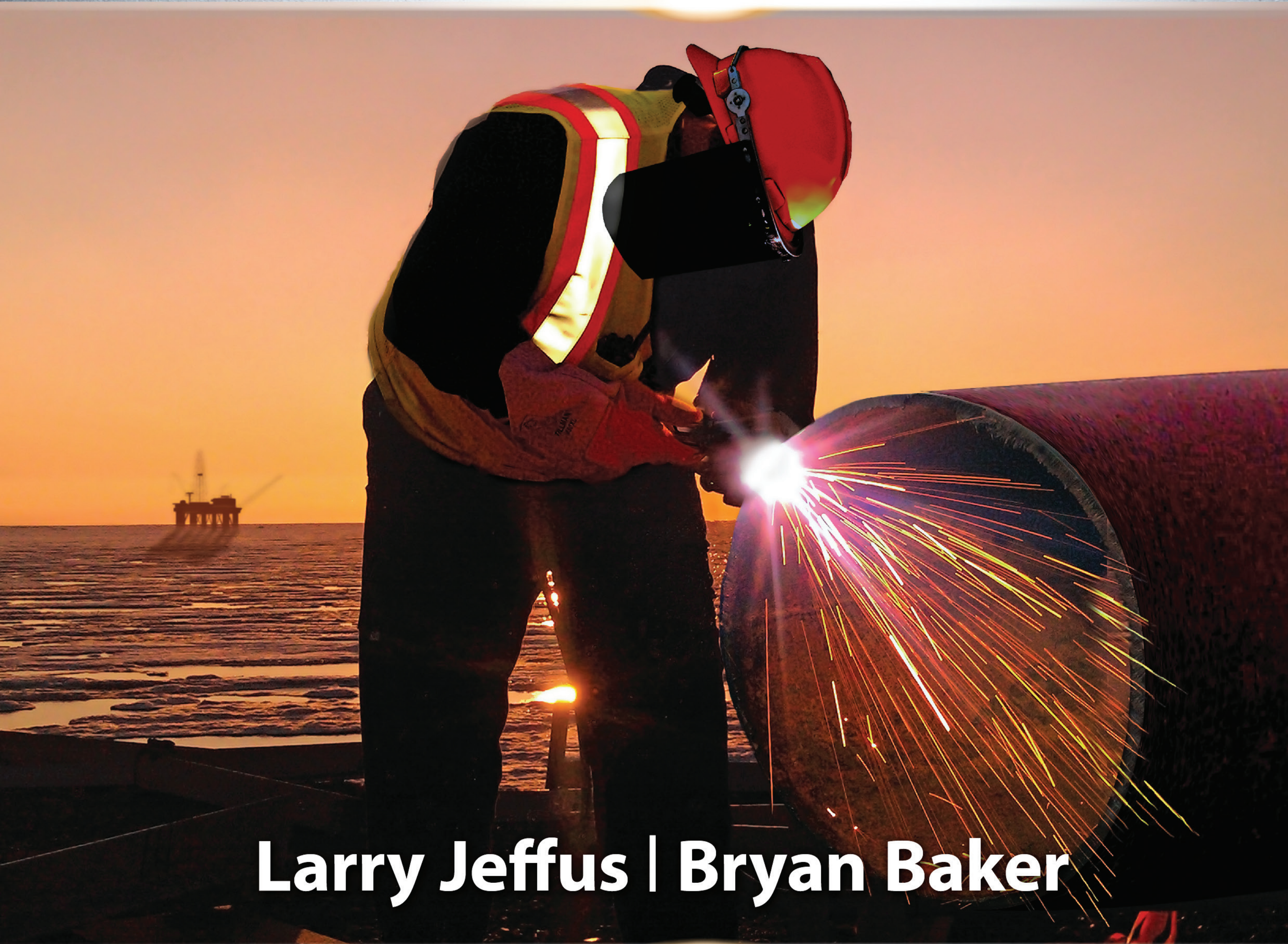
First Edition



Larry Jeffus | Bryan Baker

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***Pipe Welding*, First Edition**
Larry Jeffus, Bryan Baker

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Notice to the Reader

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Dedication

"This book is dedicated to some very special people—my family."
—Larry Jeffus

"I dedicate this book to my wife, daughter, parents, brothers, and in-laws."
—Bryan Baker

Contents

Preface

Introduction

With the introduction of more and more oil and gas exploration sites around the nation and the world, the need for skilled pipe welders is at an all-time high. This demand for more pipe welders is expected to continue growing for decades. In addition to growth in the energy sector, there has been an expansion of pipe-welding jobs in almost every sector of industry.

Students who are preparing for a career in pipe welding will need to:

- be alert and work safely.
- know the theory and application of the various welding and cutting processes.
- read and interpret welding drawings and sketches.
- work well with tools and equipment.
- be able to resolve basic mathematical problems.
- have excellent eye–hand coordination.
- be able to follow written and verbal instructions.
- work with or without close supervision.
- work well individually and in groups.

Some pipe welding jobs may require welders to:

- work outdoors, in all types of weather.
- travel outside their home area.
- stay at a remote worksite for days or weeks at a time.
- work on elevated platforms or down in trenches and excavations.
- work in confined spaces.

Pipe Welding is a comprehensive classroom/shop textbook designed to turn a skilled plate welder into an employable pipe welder. This textbook focuses on pipe welding as a career. It covers the unique safety issues that pipe welders may encounter, in addition to pipe layout, assembly, and welding using shielded metal arc welding (SMAW), gas metal arc welded (GMAW), flux cored arc welded (FCAW), and gas tungsten arc welded (GTAW) processes. It provides a single source for students to build their basic welding skills so that they can become pipe welders. It is written for students who want to take their skill and career potential to the next level to make them more competitive in the job market and take advantage of the surge in demand for pipe welders. This textbook has

- Chapter objectives
- Key terms
- Review questions
- Practices
- Over 500 figures

It covers

- pipe-welding safety
- practices for pipe layout, assembly, and welding
- tools unique to pipe layout, assembly, and welding
- print reading

Pipe welding offers a number of unique safety concerns, such as welders being expected to work in excavations or on scaffolding. These and other issues are addressed to help make pipe welding safer.

Throughout the textbook, students are provided with opportunities to develop their skills in pipe layout, assembly, and welding through step-by-step instructions progressing from the very basics of pipe welding to advanced skills and American Welding Society (AWS) Schools Excelling through National Skills Education (SENSE) certification testing.

There are a number of specialized tools available to pipe welders that aid in layout, assembly, and welding; most of these are illustrated in this textbook. These items can increase a welder's productivity and increase his or her value to the company. Piping systems have many unique attributes as well, which are presented in mechanical drawings that welders must understand in order to fabricate piping systems properly.

Supplements

Instructor Companion Website The Instructor Companion Website, found on cengagebrain.com, includes the following components to help minimize instructor preparation time and help engage students:

- **Microsoft PowerPoint®** lecture slides, which present the highlights of each chapter.
- An **Image Gallery**, which offers a database of images from the text. These can easily be imported into the PowerPoint presentations.
- An **Answer Key** file, which provides the answers to all end-of-chapter review questions.

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- Bryan Baker would specifically like to acknowledge those who have helped him grow in his knowledge and skill as a welder and teacher: Don Mugg, Larry Jeffus, Dewayne Roy, D. A. Smith, Jay Jones, James King, Kyle Emmons, and Pat N. McLeod, PhD.
- Josh Jeffus for the cover photo of him working on the North Slope of Alaska.

About the Author

Larry Jeffus

Larry Jeffus is a welder with over 55 years of welding experience, and he has his own well-equipped welding shop.

In his welding career, he has passed many welding certification tests in a wide variety of processes, positions, and on many different material types and thicknesses. Larry has provided welding and professional consulting services locally, nationally, and internationally to major corporations, small businesses, government agencies, schools, colleges, and individuals. He is a Life Member of the American Welding Society (AWS).

Larry Jeffus has over 40 years of experience as a dedicated classroom teacher and is the author of several Delmar Cengage Learning welding publications. Prior to retiring from teaching, Professor Jeffus taught at Eastfield College, part of the Dallas County Community College District. Since retiring from full-time teaching, he remains very active in the welding community, especially in the field of education. He serves on several welding program technical advisory committees and has visited high schools, colleges, and technical campuses in more than 40 states and four foreign countries. Professor Jeffus was selected as Outstanding Post-Secondary Technical Educator in the State of Texas by the Texas Technical Society. He has served for 12 years as a board member on the Texas Workforce Investment Council in the Texas governor's office, where he works to develop a skilled workforce and bring economic development to the state. He served as a member of the Apprenticeship Project Leadership Team, where he helped establish apprenticeship training programs for Texas, and he has made numerous trips to Washington, D.C., lobbying for vocational and technical education. Larry Jeffus holds a BS degree and has completed postgraduate studies.

Bryan Baker

Bryan Baker became interested in welding while taking metal shop classes in high school. This sparked a desire in him to learn as much about welding as possible. Upon completing high school, he enrolled in Eastfield College and completed an Associate of Applied Science degree in welding technology. He has worked in various industries, including aerospace, manufacturing, communications, food, and construction. He has worked in both large and small private businesses and has had his own welding business. While working in industry, he started teaching as an adjunct instructor at Eastfield College and Mountain View College. His experiences in teaching encouraged him to continue his education and complete both bachelor's and master's degrees from the University of North Texas.

Bryan has been involved in developing welding programs at Northeast Texas Community College and is currently the department chair of welding/industrial trades at Tyler Junior College. In addition, he has served on the board of the East Texas Section of AWS for many years.

Chapter 1

Introduction to Pipe Welding

OBJECTIVES

After completing this chapter, the student should be able to:

- Describe the history of piping systems.
- List the four different major categories of piping systems.
- Explain the various specifications that may be used to specify pipe and tubing.
- Discuss the difference between the three basic groupings for pipe welds.
- Explain the system of pipe schedules.
- List the three general areas that pipe welding jobs may be divided into.
- Discuss the importance of teamwork for pipe welders.

KEY TERMS

Collection piping systems
Construction pipe-welding jobs
Distribution piping systems
High-pressure piping systems
High-strength service pipes
Light-duty service pipes
Low-pressure piping systems
Manufacturing pipe-welding jobs
Medium-pressure piping systems
Medium structural service pipes
Pipeline-welding jobs
Process piping systems
Seamed pipe
Seamless pipe
Transportation piping systems

INTRODUCTION

The earliest piping systems were built by the Greeks approximately 5,000 years ago to provide water to the residences on the island of Crete, **Figure 1-1**. Later, as the Roman Empire began to develop, the Romans expanded the Greek clay piping system of freshwater to include a separate system for drainpipes throughout the city. These early Roman clay piping systems were gradually replaced with lead pipe. The artisans of the day developed a new process to weld sections of lead pipe together. Over time, much of the ancient city of Rome was plumbed for water through lead pipes. Fortunately for the Romans, their water had a high mineral content that quickly coated the inside of the lead pipes, preventing lead poisoning. Small-diameter lead pipes were used throughout Europe and in many of the older cities in the Americas, including New York

(*Continued*)

City, Boston, and Montreal. Water mains were initially constructed by hollowing out logs. Later, large water mains were made much like very long wooden barrels. Workers used narrow wood strips held together with metal bands tightly wrapped around the outside, **Figure 1-2**. Over time, the lead pipes were removed; however, a few of the early wooden water mains that were constructed are still in service.

These days, there are millions of miles (kilometers) of pipe used in a wide range of applications throughout the world. The ancient world was limited to only a few materials such as clay, lead, and wood; but today, pipe can be made from many popular materials, such as cast iron, steel, stainless steel, copper, brass, plastic, glass, fiberglass, and concrete. In this textbook, the major concentration will be on fitting and welding steel pipe because the skills learned with steel pipe can be transferred to stainless steel, aluminum, and other metal piping materials.

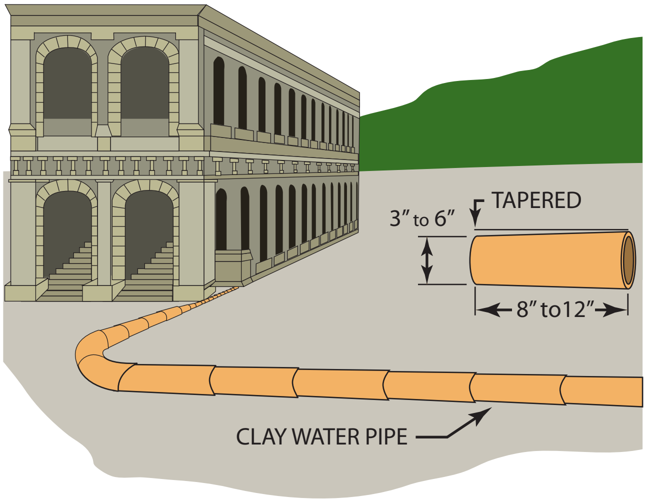

FIGURE 1-1 Clay water pipe systems for fresh water were first used approximately 5,000 years ago.

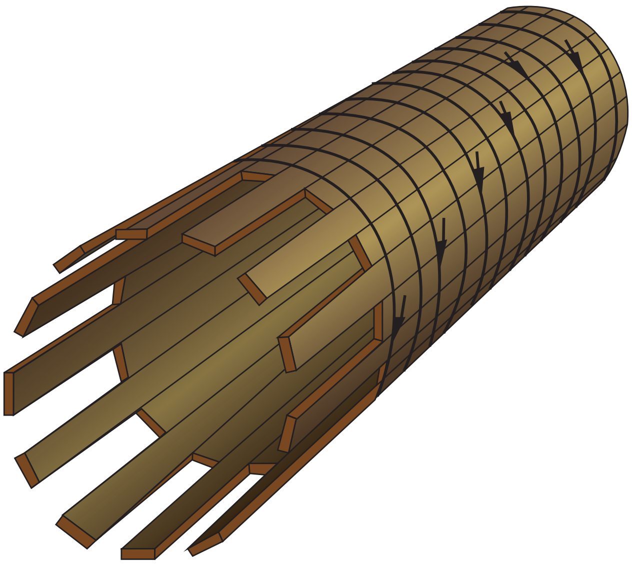

FIGURE 1-2 Some wooden water pipes constructed like long barrels in the 1700s are still in use in some early American cities.

PIPING SYSTEMS

Piping systems can be divided into four major categories: collection, transportation, distribution, and processing.

Collection piping systems have smaller pipes joining larger pipes as the material in the smaller pipes combine, thus requiring a larger pipe to handle the flow. Some examples of collecting piping systems are sewer pipes from various appliances in a home, stormwater drainage pipes in a neighborhood or city, and oilfield piping, where pipes collect product from various wells for storage or processing facilities, **Figure 1-3**.

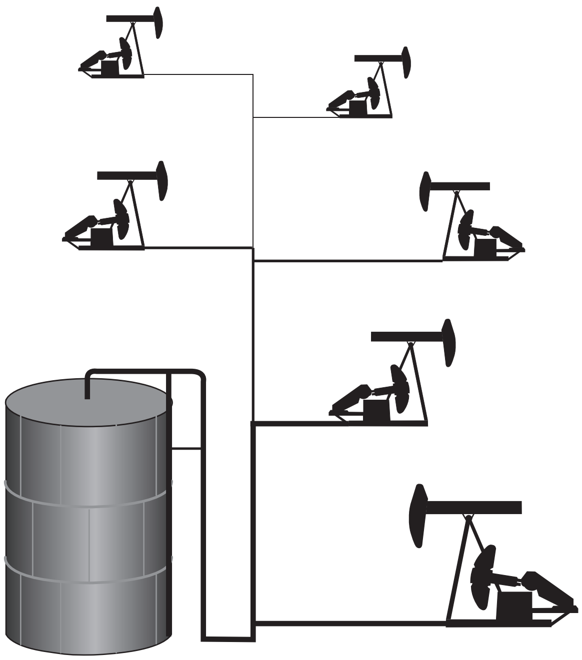

FIGURE 1-3 Collection piping systems.

Transportation piping systems are pipes that move various products throughout the community, state, or nation. Transportation pipelines are typically larger in diameter than collection pipelines and extend for hundreds of miles. They are usually buried beneath the Earth's surface and can be seen only where they surface at pumping or pressure regulator stations, **Figure 1-4**. Some examples of transportation pipelines are water pipes that are used to move raw water from reservoirs to water treatment plants; fuel lines that move gasoline, diesel fuel, and jet fuel from coastal refineries to distribution facilities inland; and the Alaskan pipeline, which moves crude oil 800 miles from Prudhoe Bay to the harbor at Valdez, **Figure 1-5**.

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FIGURE 1-4 Natural gas pig insertion and recovery station.

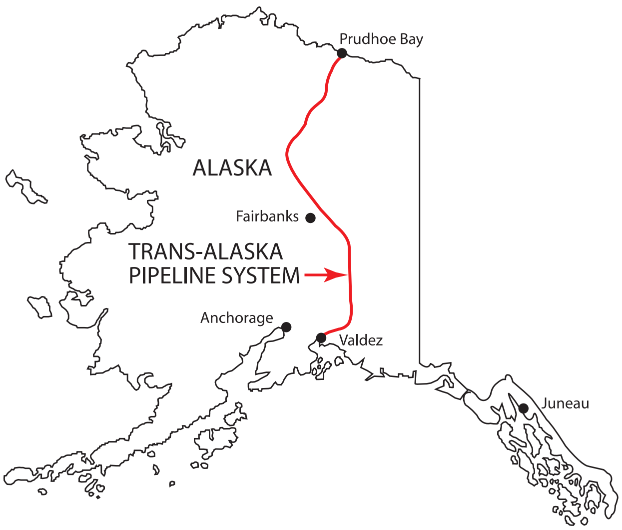

FIGURE 1-5 The trans-Alaskan pipeline went into service in 1977.

Distribution piping systems have smaller individual pipes connected to larger mains. They are used to deliver products such as natural gas and water for homes and factories, compressed air for pneumatic tools, shielding gases for welding, and chilled water for air conditioning, **Figure 1-6**. For many years, a brewery in Germany moved beer directly from its plant to a nearby stadium through a distribution piping system.

Process piping systems can be very diverse in size and materials. The diameter of some pipes may be as small as a fraction of an inch (in.) or a few millimeters (mm) all the way through several feet (ft) or meters (m) in diameter. The smaller pipes may be used to supply a chemical agent or other such material from a storage tank to a processing vat. The larger pipes are used to move products through a manufacturing facility or refinery. Examples of processing piping systems can be found in oil refineries, paint manufacturers, cosmetic manufacturers, and many food processing plants, **Figure 1-7**.

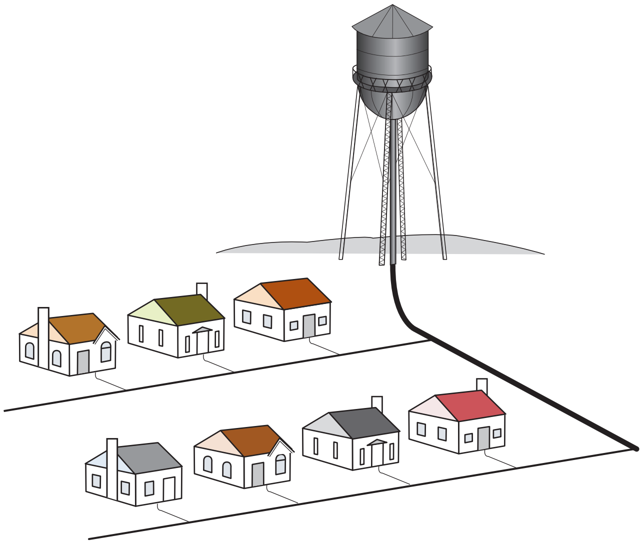

FIGURE 1-6 Distribution piping system.

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FIGURE 1-7 Process piping system.

PIPE APPLICATIONS

Tubing is most often used to build items such as bicycle, motorcycle, race-car, and aircraft frames, handrails, and playground equipment; however, pipe is used for many of these applications, too. Both are used for structural applications, ornamental, or decorative art. Examples of structural applications are a walkway between a hospital and parking garage in Columbia, South Carolina, (**Figure 1-8**), and the framework for pyramid buildings at Moody Gardens in Galveston, TX, **Figure 1-9**. Examples of ornamental applications of pipe include the farm post shown in **Figure 1-10**. Examples of decorative art include the windmill shown in **Figure 1-11**.

FIGURE 1-8 A pedestrian crosswalk over a major city street makes downtown safer.

FIGURE 1-9 Modern pyramids built on frameworks of pipes and tubes.

FIGURE 1-10 Rain gauge/hummingbird feeder pipe garden post.

FIGURE 1-11 A windmill built out of ½-in. (13-mm) electrical mechanical tubing.

HOW PIPE IS MADE

Pipe can be manufactured as seamed or seamless. **Seamed pipe** has a longitudinal weld along its full length. It is formed from flat plates that are first heated then passed through rollers that bend it into the pipe shape. Resistance seam welding machines use rollers to pass the welding current through the pipe to fuse the edges of the plate together, forming the longitudinal weld, **Figure 1-12**. A cutter removes the small amount of weld flash from the outside of the weld. The small weld flash on the inside of the pipe may or may not be removed. The pipe is then cut into sections.

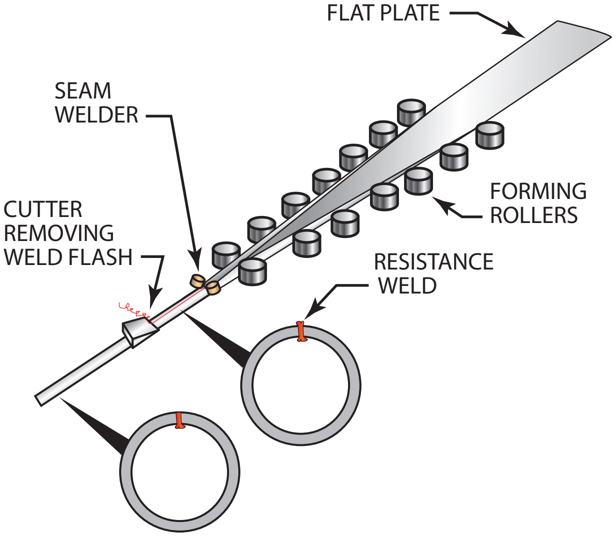


FIGURE 1-12 Seamed pipe manufacturing technique.

Seamless pipe is formed so there is no need to make a longitudinal weld. It is made by forcing heated metal through a forming die that has an internal mandrel to form the center opening in the pipe, **Figure 1-13**. Both seamless and seamed pipe sections are thoroughly inspected following manufacturing to ensure that they are sound. Both types of pipes are incredibly strong, and they can provide years of reliable service.

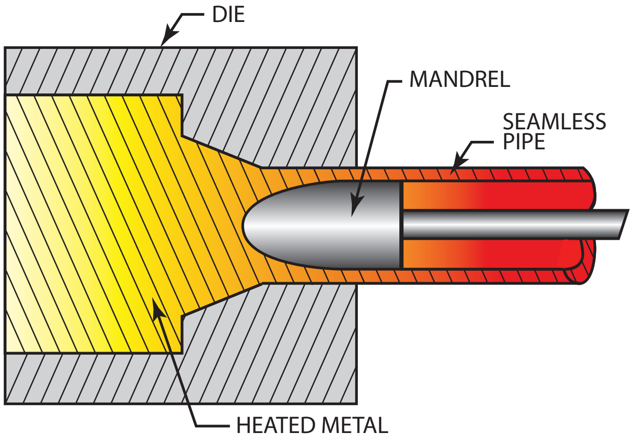


FIGURE 1-13 Seamless pipe manufacturing technique.

Spiral pipe is formed of long coils of hot rolled steel that are wound into a long spiral much like the cardboard tube in the center of a roll of paper towels, **Figure 1-14**. As the metal coil is unwound, its edges are trimmed and beveled so that as it is formed into a round cylinder, the two edges form a double V-groove. The V-groove is first welded on the inside and then on the outside using a process known as *submerged arc welding (SAW)*. Once the pipe is welded, it is cleaned of all flux, and the welds are thoroughly inspected before it is heat treated and coated, **Figure 1-15**.

NOTE

Because pipe and round tubing are very similar in their appearance and applications, the term *pipe* will be used throughout this text, as opposed to *pipe and tubing*. The term *tubing* will be used only when tubing is specifically being addressed. All of the fit-up welding inspections that apply to pipe can also be applied to most tubing welds unless otherwise stated.

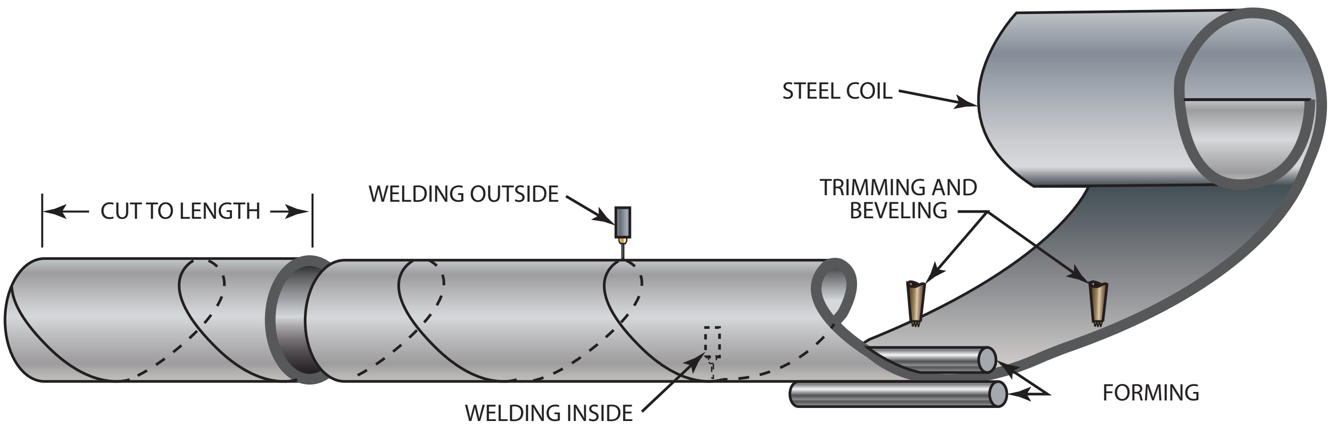
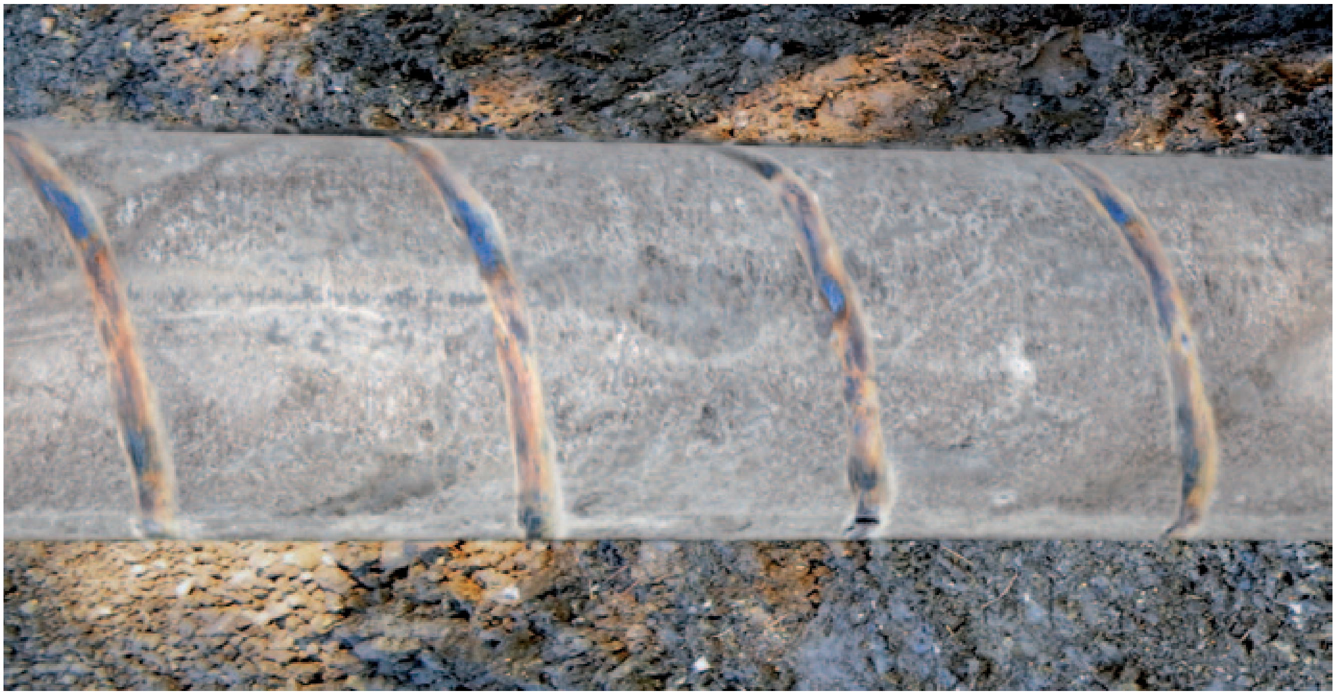


FIGURE 1-14 Spiral pipe manufacturing technique.

(A)



(B)

FIGURE 1-15 (A) 8-ft (2.4-m) spiral water pipe; (B) 6-in (150-mm) spiral pipe.

PIPE VERSUS ROUND TUBING

Pipe and round tubing are not the same, although they can appear the same and may be used for similar applications. Pipe is primarily used to move both liquids like water, gasoline, oil, and other petroleum products; and gases like air, steam, and engine exhaust, **Figure 1-16**. In addition, tens of thousands of other products are safely and efficiently moved through millions of miles of pipe every day.

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FIGURE 1-16 Formula 1 racecar exhaust manifold constructed from stainless steel tubing.

Round tubing is used for both structural applications and to move fluids. Tubing is the structural component of many common products such as classroom and office furniture, highway guardrails, playground equipment, and roller coasters.

Pipe and round tubing are different in the way they are specified. All or part of the following pipe and round tubing specifications may be included on a bill of materials or material specification sheet. For example, the weight of pipe or round tubing, usually expressed as pounds per foot (lb/ft) or kilograms per meter (kg/m) of pipe, may be written in the specifications, but it is not often included since it can be found on most pipe charts.

Pipe Standards

One of the major differences between pipe and tubing is how the material is specified. When the American Standards Association, now the American National Standards Institute (ANSI), first standardized the dimensions for steel and iron pipe and tubing, there were few applications for pipe, so only a few different pressure ranges were available. The various pressure ranges determined the thickness of the wall of the pipe, **Figure 1-17**. The original standards only included standard, extra strong, and double extra strong. Today, standard (STD) pipe is often schedule 40, extra strong (XS) pipe is often schedule 80, and double extra strong (XXS) pipe does not have a schedule number. **Table 1-1** shows the various pipe schedules and wall thicknesses for a variety of pipe diameters that are available today. Changes in the marketplace have resulted in a significant increase in the various pressure ranges and wall thicknesses of pipe. Some of the things that have affected the wall thicknesses of pipe are changes in material and application. Since stainless steel pipe, which was first introduced in the 1920s, is much stronger and less likely to have corrosion reduce the thickness of the pipe over time, this allows a much thinner wall section for the same schedule. In addition, thinner-walled sections of pipe were introduced for applications other than critical, such as drainage, ornamental, or decorative work. One drawback to the thinner sections is that they cannot be threaded because of the thinner walls.

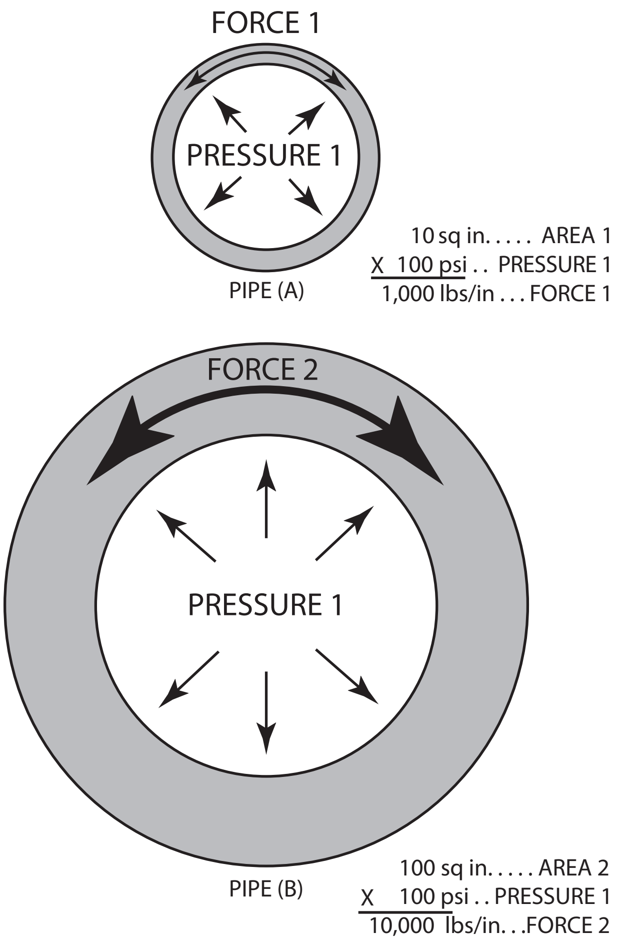


FIGURE 1-17 Diameter and wall thickness versus pressure.

Pipe Specifications

Typical pipe specifications include:

- **Length**—This is the overall length of a section or piece of pipe. Common lengths for steel pipe are 10, 20, and 21 ft (3, 6, and 6.5 m).
- **Diameter**—The inside diameter (ID) dimension is given for pipe that is smaller than 12 in. (300 mm) in diameter, and the outside diameter (OD) dimension is given for pipe that is 12 in. (300 mm) or larger. The actual diameter of pipe may vary slightly because of many factors; therefore, the term *nominal pipe size (NPS)* is used for standard pipe, and *Diamétre Nominal (DN)* is used for metric pipe.

NPS*	DN**	OD***	Schedule (SCH) and Wall Thickness decimal inches (mm)							
			SCH 5	SCH 10	SCH 30	SCH 40 STD	SCH 80 XS	SCH 120	SCH 160	XXS
1/8	6	0.405 (10.29)	0.035 (0.889)	0.049 (1.245)	0.057 (1.448)	0.068 (1.727)	0.095 (2.413)	—	—	—
1/4	8	0.540 (13.72)	0.049 (1.245)	0.065 (1.651)	0.073 (1.854)	0.088 (2.235)	0.119 (3.023)	—	—	—
3/8	10	0.675 (17.15)	0.049 (1.245)	0.065 (1.651)	0.073 (1.854)	0.091 (2.311)	0.126 (3.200)	—	—	—
1/2	15	0.840 (21.34)	0.065 (1.651)	0.083 (2.108)	0.095 (2.413)	0.109 (2.769)	0.147 (3.734)	—	0.188 (4.775)	0.294 (7.468)
3/4	20	1.050 (26.67)	0.065 (1.651)	0.083 (2.108)	0.095 (2.413)	0.113 (2.870)	0.154 (3.912)	—	0.219 (5.563)	0.308 (7.823)
1	25	1.315 (33.40)	0.065 (1.651)	0.109 (2.769)	0.114 (2.896)	0.133 (3.378)	0.179 (4.547)	—	0.250 (6.350)	0.358 (9.093)
1 1/4	32	1.660 (42.16)	0.065 (1.651)	0.109 (2.769)	0.117 (2.972)	0.140 (3.556)	0.191 (4.851)	—	0.250 (6.350)	0.382 (9.703)
1 1/2	40	1.900 (48.26)	0.065 (1.651)	0.109 (2.769)	0.125 (3.175)	0.145 (3.683)	0.200 (5.080)	—	0.281 (7.137)	0.400 (10.160)
2	50	2.375 (60.33)	0.065 (1.651)	0.109 (2.769)	0.125 (3.175)	0.154 (3.912)	0.218 (5.537)	0.250 (6.350)	0.343 (8.712)	0.436 (11.074)
2 1/2	65	2.875 (73.02)	0.083 (2.108)	0.120 (3.048)	0.188 (4.775)	0.203 (5.156)	0.276 (7.010)	0.300 (7.620)	0.375 (9.525)	0.552 (14.021)
3	80	3.500 (88.90)	0.083 (2.108)	0.120 (3.048)	0.188 (4.775)	0.216 (5.486)	0.300 (7.620)	0.350 (8.890)	0.438 (11.125)	0.600 (15.240)
3 1/2	90	4.000 (101.60)	0.083 (2.108)	0.120 (3.048)	0.188 (4.775)	0.226 (5.740)	0.318 (8.077)	—	—	0.636 (16.154)

*NPS - Nominal pipe size (given in inches)
**DN - Diamètre nominal/nominal diameter (given in millimeters)
***OD - Outside diameter

TABLE 1-1 Pipe Schedule and Wall Thickness

- **Wall thickness**—Pipe wall thickness was originally standardized back in 1939. The early system used a system of schedules that were related to a pressure range. The basis of that original system grouped pipe into three pressure ranges—STD, XS, and XXS. The current standard for pipe wall thickness is the National Pipe Standard, Table 1-1. Note on the chart that the current system still has some relationship to the earlier STD, XS, and XXS terminology, but it is important to note that now there is not a pressure range relationship (i.e., a Schedule 40 STD steel pipe has a higher pressure range than a Schedule 40 PVC pipe would have).
- **Material**—The American Society of Mechanical Engineers (ASME) has a number of specifications that cover a wide range of materials and methods of manufacturing pipe. The ASME specifications range from AS-135, for electric resistant welded steel pipe, to AS-378, for seamless austenitic high-temperature pipe.
- **Fittings**—The ends of pipe can be joined by different methods such as butt welded, socket welded, or threaded.

Pipe Dimensioning

The ASME standard for pipe scheduling lists the OD of the pipe, and the wall thickness can vary based on the schedule; therefore, the ID of a 6-in. (152-mm) Schedule 40 pipe is slightly larger than the ID of a 6-inch (152-mm) Schedule 80 pipe. This system is used on pipe from 1/8 in up to 12 in. (3–305 mm). Above 12 in (305 mm), the OD of the pipe is given, and the wall thickness changes the ID of the pipe, **Figure 1-18**.

Round Tubing Specifications Generally, tubing has a more rigid set of specifications as compared to most pipe. Tubing specifications may include:

- **Material**—Tubing is available in a number of different types of metal, as well as other materials such as plastic, rubber, silicon, fiberglass, composite, and glass. ASTM International (formally the American Society of Testing and Materials) has established standard specifications that cover most types of metal tubing.
- **Diameter**—The diameter for tubing is always expressed as the OD, **Figure 1-19**.

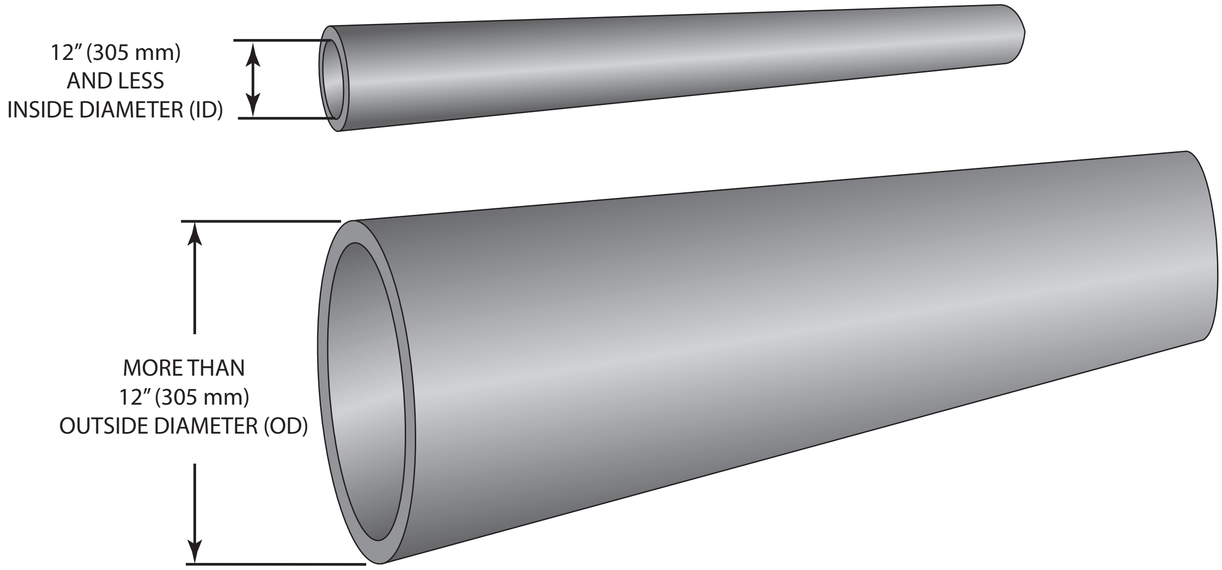


FIGURE 1-18 ID versus OD for pipe diameters.

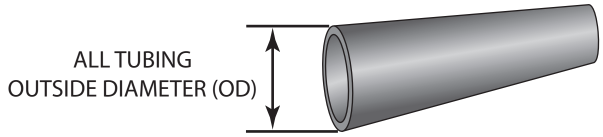


FIGURE 1-19 Tubing diameter measurement.

- **Wall thickness**—The wall thickness of rigid round tubing may be given as a gauge thickness or as a specific dimension.
- **Shape**—The shape of tubing must be specified because it is available in shapes other than round, such as rectangular, square, oval, and a wide range of specialty shapes.
- **Length**—Rigid round tubing can be purchased in lengths ranging from 5–24 ft (1.5–7 m), and flexible round tubing can be purchased in coils ranging from a few feet to several hundred feet. Common lengths for flexible tubing are coils of 25 and 50 ft (7.5 and 15 m).
- **Pressure range**—Because some types of tubing are designed to carry pressurized fluids, a pressure range for these tubes would be included in their specifications.
- **Temperature range**—The operating temperature range or the minimum and/or maximum service temperature are important because both high and low temperatures will affect the performance of tubes.
- **Bending radius**—The minimum-bending radius of a tube can be a major determination in the selection since tubing is often bent to a particular shape before welding.
- **Strength**—Tubing that is designed to be used in structural applications will include the tensile strength, bending strength, compression strength, and other characteristics as needed for particular applications.
- **Finish**—Tubing is available in a variety of surface finishes, including cleaned, galvanized, polished, and coated.
- **Temper**—Annealed tubing is soft and more easily bent or shaped than half-hardened or fully hardened tubing. Half-hardened and fully hardened tubing is often referred to as *rigid tubing*.
- **Application**—The intended application of tubing will affect the available or approved types in some cases. Aerospace and aircraft tubing must have certification paperwork that must be kept with the tubing through the fabrication process all the way to the final customer. Some of the applications that can be specified for tubing include general-purpose, automotive, chemical, cryogenic, food and beverage processing, medical, and oil and fuel, among others.

Tubing Dimensions

Round tubing is specified by the OD and wall thickness, so a 6-in. (152-mm) diameter tube with a quarter-inch wall thickness could possibly fit inside of a 6-in. (152-mm) Schedule 40 pipe. It is possible, then, to have a 14-in.

(355-mm)-diameter pipe and 14-in. (355-mm)-diameter tube that would have the same wall thickness if the tubing wall thickness was specified to be the same as the pipe.

PRESSURE AND STRENGTH RANGES

In this textbook, pipe welded joints are grouped into three general categories based on their strength requirements for both piping systems and structural applications. These groupings are loosely based on the level of critical service that the pipe is performing. Basically, the groups relate to the degree or extent of injury, property damage, or both that might happen if a catastrophic failure of the welded joint were to occur. The three general categories are:

- Low-pressure or light-duty service
- Medium-pressure or medium structural service
- High-pressure or heavy structural service

Low-pressure piping systems may be used for collector systems such as wastewater systems, agricultural irrigation systems, and building sprinkler systems. **Light-duty service pipes** may be used for bicycle stands, agricultural fences and gates, and art sculptures. If a catastrophic failure occurred in a low-pressure piping system or light structural service application, there might be some property damage, but little chance of injuries.

Medium-pressure piping systems may be used for water supplies, compressed air, and residential gas distribution. **Medium structural service pipes** may be used for signposts, railroad crossing signals, **Figure 1-20**, and truck brush guards. If a catastrophic failure occurred in a medium-pressure system or medium structural service application, there would be some property damage, and there could be some minor injuries.

High-pressure piping systems may be used for cross-country transmission of oil, gasoline, or natural gas, oil refinery, and high-pressure steam pipes in power plants. **High-strength service pipes** may be used for aircraft engine mounts, building frameworks, and tank support legs. A catastrophic failure in high-pressure systems and high-strength structures will result in significant property damage and can result in serious injury or possible death.

So the welding requirements for each of the systems varies from a low-pressure system with a visual inspection, medium pressure with a little greater scrutiny, and a high-pressure system that would be thoroughly tested, **Figure 1-21**.

FIGURE 1-20 Railroad crossing signals are an example of medium structural service pipes.

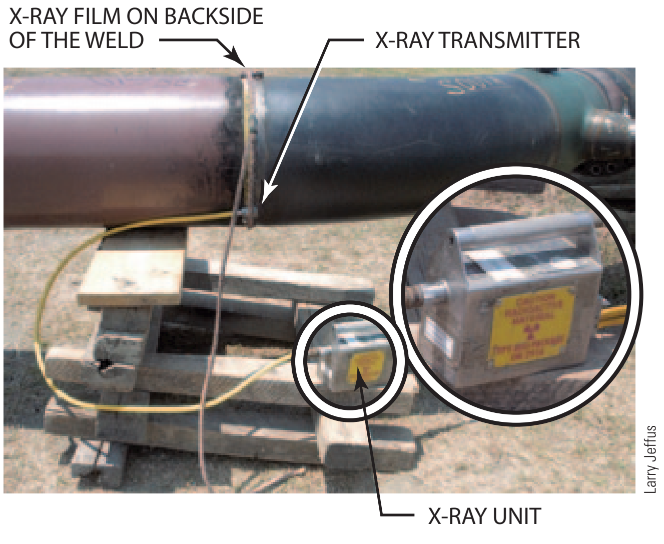


FIGURE 1-21 X-ray testing of pipe welds.

PIPE SYSTEMS CODES AND STANDARDS

The American Petroleum Institute (API) 1104 code is one of the most widely used piping welding standards in the industry. It is used for both structural and piping applications. The American Welding Society D1.1 structural welding code has specifications for structural pipe applications. These applications can vary from a system that is primarily ornamental, such as a piece of art or yard decoration, to something that is more critical, such as a handrail or guardrail, to an application that would be critical if it failed, such as the crosswalk or structural building components.

PIPE WELDING PROCESSES

All of the major welding processes can be used to weld pipe. The most important factor to consider when selecting a welding process is the applicable codes and standards. But within these codes and standards, there are opportunities to make choices between different welding processes. Some of the other factors that should be considered when selecting the welding process include the pipe diameter and schedule, the pipe material, whether the welding will be done in a shop or in the field, and the number of welds that will be required.

Steel pipe that is an inch or less in diameter can be oxyacetylene welded (OAW), gas tungsten arc welded (GTAW), gas metal arc welded (GMAW), or flux core arc welded (FCAW). But with these small-diameter pipes, shielded metal arc welding (SMAW) can be a difficult process. Larger-diameter pipe and thick-walled pipe cannot be oxyacetylene welded OAW efficiently, but almost any other welding process can be used.

Stainless steel pipe can be welded with GTAW, GMAW, and FCAW. Aluminum pipe is usually welded with GTAW.

This textbook will cover SMAW, GTAW, GMAW, and FCAW, which are the most commonly used welding processes for pipe welding.

TYPES OF PIPE WELDING JOBS

Pipe welding jobs can be divided into three general areas—manufacturing, construction, and pipeline. Each of these general job groupings has its own skills, opportunities, and requirements.

Manufacturing Pipe Welding Jobs Examples of these pipe welding jobs include welding many common products, ranging from motorcycle frames to booms for cranes and many other items, **Table 1-2**. When the size and shape of parts being manufactured allow the use of weld positioners, the welds can be made in the rotated flat position (1G). Because the pipe welder does not have to transition between welding positions, 1G pipe welding is considered to be easier than the other welding positions. Many manufacturing companies have climate-controlled work areas, so welding in the summer is not too hot and welding in the winter is not too cold.

For many welders, manufacturing jobs offer the convenience of not having to travel to different job sites. These jobs also offer the stability of working with the same people. Because production requirements may be high, the welders may be required to weld for longer periods of time than welders working in other types of jobs.

Construction Pipe Welding Jobs Examples of these welding jobs include constructing oil refineries, chemical plants, boiler room piping, and many other structures, **Table 1-3**. The size and complexity of construction projects can vary greatly. Some nuclear plant construction projects may last for years, while a pumping station job may take only a few weeks. Construction at a power plant

Pipe Welded Items	
Welding booth tables and coupon stands	Handrails
Racecar frames	Utility trailers
Rails for stage lighting	Sculptures
Boilers	Automotive engine hoist
Food processing equipment	Earth-moving machine
A/C chillers	Dental office equipment
Cooling towers	Exercise equipment
Pickup truck bumpers and racks	Aircraft frames
Gas manifolds for medical and welding gases	Commercial kitchen carts and table frames
Furniture	Farm equipment
Highway signpost	Trailer axles
Railroad crossing guards	Cattle squeeze shoot
Commercial swimming pool equipment	Oil drilling equipment
Gas pumps	Equipment and machines for industries
Hospital equipment	Plastic injection machines
Picnic table frame	Micro beer brewing equipment
Outdoor furniture frames	Oil drilling equipment
Wastewater treatment equipment	Pumping stations

TABLE 1-2 Pipe Items That Are Manufactured with Pipe

Construction Projects	
Coal power plants	Pumping stations
Natural gas power plants	Breweries
Bridges	Distilleries
Nuclear power plants	Bottling plants
Amusement rides	Refrigeration plants
Cooling towers	Fire sprinkler systems
Ships	Water supply systems
Water treatment plants	Wineries

TABLE 1-3 Construction Projects Made with Pipe

or refinery will require a great deal of skill to make quality welds on various types and sizes of pipe, as well as requiring welders to weld in all positions while, in some cases, working around obstructions. In addition to welding skills, welders often must be comfortable working high above the ground.

Almost all construction jobs require traveling, and some may stipulate that welders relocate to a different city or state. There may be little protection from the rain, heat, cold, wind, snow, or other weather conditions. From the first day on the job, construction welders are working themselves out of a job—when the building is finished, they have to look for another job.

Pipeline Welding Jobs Examples of these jobs include all types of cross-country pipelines, **Table 1-4**. Pipelines can range in length from a mile or less to hundreds of miles. They may also range in diameter from an inch or two to several feet in diameter. In most cases, the pipe is welded above grade, but welders may be required to work in open trenches. Much like construction welders, pipeline welders may be required to travel or relocate and work in all types of weather.

Types of Pipelines	
Freshwater pipelines	Gasoline pipelines
Sewer pipelines	Irrigation water pipelines
Natural gas pipelines	Dredge pipelines
Crude oil pipelines	

TABLE 1-4 Pipelines

TEAMWORK

There is a lot of work that needs to be done to make a weld on large-diameter pipe. Often there is more work than a single welder can do in a timely manner to meet the scheduled deadline, so most pipeline welding jobs and many pipe construction welding projects are done by a crew, **Figure 1-22**. The crews are made up of welders and helpers, all of whom take directions from the site supervisor. On large jobs where several welding crews are working, the supervisor may be the project engineer. On smaller crews, the pipe welder is the person in charge of the welding crew.

Larry Jeffus

FIGURE 1-22 It takes teamwork to move large pipe sections into place.

Each member of the crew has specific job responsibilities. The welder acts as the leader and directs the other crew members. The welder helper assists with the preparation and fit-up of the pipe joint. They are also responsible for wire brushing and grinding the weld between weld passes and weld crater cleanup (if needed) before a new electrode is started. The welder helper may also be responsible for making small adjustments in the welding amperage settings as requested by the welder, **Figure 1-23**.

Larry Jeffus

FIGURE 1-23 Welder helpers make a valuable contribution to fashioning quality pipe welds.

A crew member may serve as the fire watch. The fire watch's primary responsibilities are to make sure that the site is safe so no accidental fires get started, alert the welder and sound the alarm if a fire does occur, and be prepared to use the available fire extinguisher to put out the fire. When all of the combustible materials cannot be removed from the welding area, this person may wet them down or cover them up, **Figure 1-24**.


Larry Jeffus

FIGURE 1-24 Plywood used to protect dry grass from the sparks given off from the cutting torch.

Other crew members may operate equipment to lift and place pipe joints and pipe sections in place, as well as performing other tasks as required.

Leadership

A team leader must have knowledge of the Equal Employment Opportunity Laws regarding job discrimination and make sure that these laws are followed. A good team leader should have a positive attitude, think and plan ahead, treat everyone with respect, show confidence in crew members' abilities, and most important, communicate clearly to each member what is expected of him or her. It is important to recognize the various strengths and weaknesses of each crew member so that that person can be used in the most effective manner to get the job done. When necessary, leaders should coach crew members in how they want them to do their jobs. Often, demonstrating the proper way to do something can be helpful.

A crew that works well together will be much more productive than one that is dysfunctional. As crew leader, you need to be able to help resolve conflicts between team members. Identify the key issues that might be causing the conflict, and get the crew to agree on how the problem can be resolved. A work crew's performance is usually evaluated on the productiveness of the team, so hard work and cooperation are rewarded.

METRIC UNITS

Both standard and metric (SI) units are given in this text. The SI units are in parentheses ( ) following the standard unit. When nonspecific values are used—for example, "set the gauge at 2 psig," where 2 is an approximate value—the SI units have been rounded to the nearest whole number. Round-off occurs in these cases to agree with the standard value and because whole numbers are easier to work with. SI units are not rounded off only when the standard unit is an exact measurement.

Often students have difficulty understanding metric units because exact conversions are used even when the standard measurement was an approximation. Rounding off the metric units makes understanding the metric system much easier, **Table 1-5**. By using this approximation method, you can make most standard-to-metric conversions in your head, without needing to use a calculator.

1/4 in.	=	6 mm
1/2 in.	=	13 mm
3/4 in.	=	18 mm
1 in.	=	25 mm
2 in.	=	50 mm
1/2 gal	=	2 L
1 gal	=	4 L
1 lb	=	1/2 K
2 lb	=	1 K
1 psig	=	7 kPa
1°F	=	2°C

TABLE 1-5 Approximate Standard to Metric Conversions

Once you have learned to use approximations for metric, you will find it easier to make exact conversions whenever necessary. Conversions must be exact in the shop when a part is dimensioned with one system's units and the other system must be used to fabricate the part. For that reason, you must be able to make those conversions. **Tables 1-6** and **1-7** are set up to be used with or without the aid of a calculator. Many calculators today have built-in standard/metric conversions. It is a good idea to know how to make these conversions with and without these aids, of course. Practice making such conversions whenever the opportunity arises.

TEMPERATURE

Units

°F (each 1° change)	=	0.555°C (change)
°C (each 1°change)	=	1.8°F (change)
32°F (ice freezing)	=	0°Celsius
212°F (boiling water)	=	100°Celsius
–460°F (absolute zero)	=	0°Rankine
–273°C (absolute zero)	=	0°Kelvin

Conversions

°F to °C ______ °F – 32 = ______ × .555 = ______ °C
°C to °F ______ °C × 1.8 = ______ + 32 = ______ °F

LINEAR MEASUREMENT

Units

1 inch	=	25.4 millimeters
1 inch	=	2.54 centimeters
1 millimeter	=	0.0394 inch
1 centimeter	=	0.3937 inch
12 inches	=	1 foot
3 feet	=	1 yard
5280 feet	=	1 mile
10 millimeters	=	1 centimeter
10 centimeters	=	1 decimeter
10 decimeters	=	1 meter
1000 meters	=	1 kilometer

Conversions

in. to mm	______ in.	×	25.4	=	______ mm
in. to cm	______ in.	×	2.54	=	______ cm
ft to mm	______ ft	×	304.8	=	______ mm
ft to m	______ ft	×	0.3048	=	______ m
mm to in.	______ mm	×	0.0394	=	______ in.
cm to in.	______ cm	×	0.3937	=	______ in.
mm to ft	______ mm	×	0.00328	=	______ ft
m to ft	______ m	×	3.28	=	______ ft

AREA MEASUREMENT

Units

1 sq in.	=	0.0069 sq ft
1 sq ft	=	144 sq in.
1 sq ft	=	0.111 sq yd
1 sq yd	=	9 sq ft
1 sq in.	=	645.16 sq mm
1 sq mm	=	0.00155 sq in.
1 sq cm	=	100 sq mm
1 sq m	=	1000 sq cm

Conversions

sq in. to sq mm ______ sq in. × 645.16 = ______ sq mm
sq mm to sq in. ______ sq mm × 0.00155 = ______ sq in.

VOLUME MEASUREMENT

Units

1 cu in.	=	0.000578 cu ft
1 cu ft	=	1728 cu in.
1 cu ft	=	0.03704 cu yd
1 cu ft	=	28.32 L
1 cu ft	=	7.48 gal (U.S.)
1 gal (U.S.)	=	3.737 L
1 cu yd	=	27 cu ft
1 gal	=	0.1336 cu ft
1 cu in.	=	16.39 cu cm
1 L	=	1000 cu cm
1 L	=	61.02 cu in.
1 L	=	0.03531 cu ft
1 L	=	0.2642 gal (U.S.)
1 cu yd	=	0.769 cu m
1 cu m	=	1.3 cu yd

Conversions

cu in. to L	______ cu in.	×	0.01638	=	______ L
L to cu in.	______ L	×	61.02	=	______ cu in.
cu ft to L	______ cu ft	×	28.32	=	______ L
L to cu ft	______ L	×	0.03531	=	______ cu ft
L to gal	______ L	×	0.2642	=	______ gal
gal to L	______ gal	×	3.737	=	______ L

WEIGHT (MASS) MEASUREMENT

Units

1 oz	=	0.0625 lb
1 lb	=	16 oz
1 oz	=	28.35 g
1 g	=	0.03527 oz
1 lb	=	0.0005 ton
1 ton	=	2000 lb
1 oz	=	0.283 kg
1 lb	=	0.4535 kg
1 kg	=	35.27 oz
1 kg	=	2.205 lb
1 kg	=	1,000 g

Conversions

lb to kg	______ lb	×	0.4535	=	______ kg
kg to lb	______ kg	×	2.205	=	______ lb
oz to g	______ oz	×	0.03527	=	______ g
g to oz	______ g	×	28.35	=	______ oz

PRESSURE AND FORCE MEASUREMENTS

Units

1 psig	=	6.8948 kPa
1 kPa	=	0.145 psig
1 psig	=	0.000703 kg/sq mm
1 kg/sq mm	=	6894 psig
1 lb (force)	=	4.448 N
1 N (force)	=	0.2248 lb

Conversions

psig to kPa	______ psig	×	6.8948	=	______ kPa
kPa to psig	______ kPa	×	0.145	=	______ psig
lb to N	______ lb	×	4.448	=	______ N
N to lb	______ N	×	0.2248	=	______ psig

VELOCITY MEASUREMENTS

Units

1 in./sec	=	0.0833 ft/sec
1 ft/sec	=	12 in./sec
1 ft/min	=	720 in./sec
1 in./sec	=	0.4233 mm/sec
1 mm/sec	=	2.362 in./sec
1 cfm	=	0.4719 L/min
1 L/min	=	2.119 cfm

Conversions

ft/min to in./sec ____ ft/min × 720 = ____ in./sec
in./min to mm/sec ____ in./min × .4233 = ____ mm/sec
mm/sec. to in./min ____ mm/sec × 2.362 = ____ in./min
cfm to L/min ____ cfm × 0.4719 = ____ L/min
L/min to cfm ____ L/min × 2.119 = ____ cfm

TABLE 1-6 Formulas for Calculating the Exact Conversion of Standard to Metric

U.S. Customer (Standard) Units

°F	=	degrees Fahrenheit				
°R	=	degrees Rankine				
	=	degrees absolute F				
lb	=	pound				
psi	=	pounds per square inch				
	=	lb per sq in.				
psia	=	pounds per square inch absolute				
	=	psi + atmospheric pressure				
in.	=	inches	=	in.	=	″
ft	=	foot or feet	=	ft	=	′
sq in.	=	square inch	=	$in.^2$		
sq ft	=	square foot	=	ft^2		
cu in.	=	cubic inch	=	$in.^3$		
cu ft	=	cubic foot	=	ft^3		
ft-lb	=	foot-pound				
ton	=	ton of refrigeration effect				
qt	=	quart				

Metric Units (SI)

°C	=	degrees Celsius
°K	=	Kelvin
mm	=	millimeter
cm	=	centimeter
cm^2	=	centimeter squared
cm^3	=	centimeter cubed
dm	=	decimeter
dm^2	=	decimeter squared
dm^3	=	decimeter cubed
m	=	meter
m^2	=	meter squared
m^3	=	meter cubed
L	=	liter
g	=	gram
kg	=	kilogram
J	=	joule
kJ	=	kilojoule
N	=	newton
Pa	=	pascal
kPa	=	kilopascal
W	=	watt
kW	=	kilowatt
MW	=	megawatt

Miscellaneous Abbreviations

P	=	pressure	sec	=	seconds
h	=	hours	r	=	radius of circle
D	=	diameter	π	=	3.1416 (a constant used in determining the area of a circle)
A	=	area			
V	=	volume			
∞	=	infinity			

TABLE 1-7 Abbreviations for Standard Units

Summary

Pipe welding offers welders a wide range of opportunities for jobs in a wide range of industries. It also can be one of the most rewarding welding fields, both personally and financially. The high-quality welds required for most pipe welding let welders truly demonstrate their welding abilities. Completing a high-quality pipe weld job can be very personally rewarding. Because of the high level of skill required for many pipe-welding jobs, these welders receive some of the highest rates of pay.

The diversity of the jobs will allow pipe welders to work in a single area for years, or allow them the freedom to travel and experience different parts of the country.

Review Questions

1. What material was used to make water pipes during the early Greek and Roman Empire?
2. List two examples of collection piping systems.
3. Which category of piping system would the Alaskan pipeline be classified in?
4. Which category of piping system would be used to supply compressed air for pneumatic tools in a factory?
5. List four examples of process piping systems.
6. What process is used to weld the longitudinal seam on seamed pipe?
7. What is used to form the center opening in seamless pipe?
8. What is pipe's primary purpose?
9. List two items that round tubing can be used to construct.
10. What was the basis for the original three pipe schedules?
11. List two common lengths that pipe may be purchased in.
12. What do the abbreviations NPS and DN stand for?
13. What does the abbreviation XXS stand for?
14. Above what amount does pipe diameter dimensioning change from OD to ID?
15. What organization has established standard specifications that cover most types of tubing?
16. Why is it important to specify shape when ordering tubing?
17. List two examples of a low-pressure piping system.

(*Continued*)

18. List two examples of a light-duty structural application.
19. List two examples of a medium-pressure piping system.
20. List two examples of a medium-service structural application.
21. List two examples of a high-pressure piping system.
22. List two examples of a high-strength service structural application.
23. What are the most commonly used pipe-welding processes?
24. Which type of welding job offers the convenience of not having to travel to different job sites?
25. Building piping in a boiler room is most like which type of welding job?
26. List four qualities that a good team leader should have.

Chapter 2

Welding Safety

OBJECTIVES

After completing this chapter, the student should be able to:

- Describe the types of personal protective equipment (PPE) required to keep themselves safe.
- Demonstrate the proper way of storing, handling, and disposing of hazardous and nonhazardous materials.
- Explain the hazards and precautions that must be addressed to prevent falls.
- Explain the hazards and precautions associated with working in or around excavations.
- Describe how to prevent accidental fires when working outside a shop or building.
- Demonstrate how to rig and lift a load safely.

KEY TERMS

American National Standards Institute (ANSI)

Benching

Cave-ins

Excavation

Extension ladder

Fire watch

Ground-fault circuit interrupter (GFCI)

National Institution for Occupational Safety and Health (NIOSH)

Occupational Safety and Health Administration (OSHA)

Personal protective equipment (PPE)

Planned maintenance (PM)

Powered air-purifying respirators (PAPRs)

Safety Data Sheet (SDS)

Self-contained breathing apparatus (SCBA)

Shoring

Sloping

Stepladders

Straight ladders

Supplied-air respirators (SARs)

Trench

Underwriters Laboratories (UL)

INTRODUCTION

Good welding safety practices are extremely important to every work site. By the time most welders have developed the skills required to start learning pipe welding, they have already developed the necessary safety habits. The safety material in this chapter is primarily designed as a review of the major safety issues facing all welders. It is designed to reinforce what should be a firmly based set of safe working habits by now.

Because pipe welding can offer some unique safety challenges, such as working at heights above the ground and working in excavations below the ground, those topics will be covered in depth here.

All welders should periodically review welding and job safety practices. This chapter can serve as a basis for such a review. Additional safety material can be reviewed in textbooks such as *Welding Principles and Applications* and *Safety for Welders*, as well as in the safety guides that manufacturers supply with their equipment.

If an accident does occur on a welding site, it can have consequences far beyond just the person who gets injured. Serious accidents can result in local, state, or national investigations. For example, if the federal office of **Occupational Safety and Health Administration (OSHA)** becomes involved, the job site may be closed for hours, days, weeks, months, or even permanently. While the job site is closed for an investigation, you may be out of work, without pay. If it is determined that your intentional actions contributed to the accident, you may lose your job, be fined, or worse.

BURNS

Pipe welders are continuously exposed to hot welding sparks, hot metal, the arc's light rays, and other burn hazards. They must take proper precautions to prevent these burn hazards from resulting in painful injuries. The key to preventing burns starts with proper clothing. **Figure 2-1** shows the typical clothing and **personal protection equipment (PPE)** that a pipe welder should wear for burn protection. Additional PPE, such as leather aprons, spats, and leggings, may be needed; and in extreme cases, a full fire-resistant suit might be required.

FIGURE 2-1 Personal protection equipment.

NOTE

Pipe welding crew members may not be fully aware of potential burn hazards, so a safety briefing about these should be given to them before work starts. In addition, the crew members should be advised of any actions the welder will be taking that might expose them to possibility of being burned, such as oxy-fuel cutting.

INJURIES

Everyone hopes that there will never be job-related injuries; however, accidents may occur. Trained medical personnel must treat serious injuries immediately. Minor injuries such as small scrapes, cuts, or burns may be treated with the job site first aid kit. Report all injuries to the job site supervisor, site safety official, or company representative as soon as possible. This information can be used to improve job site safety.

EYE, FACE, AND EAR PROTECTION

Eye and Face Protection

Because the possibility exists that you could be struck in the eye at any time by flying welding or grinding sparks or dirt or debris, you must wear eye protection at all times when working. Most of the time, welders wear safety glasses with side shields even under their welding hoods, **Figure 2-2**. But in extremely windy conditions, goggles may be needed. The glasses and face shield can be clear, or they may be slightly shaded. The shading will help protect your eyes from accidental arc flash burns. Welding helmets that have self-darkening lenses, flip-front lenses, or a full face shield can be used to protect your face when grinding.

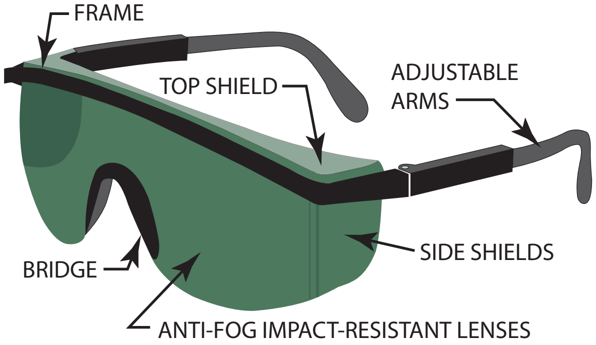


FIGURE 2-2 Safety glasses.

AUTHOR'S NOTE

Recently, I was suddenly struck by shot blast debris at a pipe welding site even though I was more than 75 feet away from the sandblaster. Fortunately, I was wearing my safety glasses.

Ear Protection

Grinding, engine generator welders, excavation equipment, air compressors, and other pieces of equipment can produce dangerous levels of noise, **Table 2-1**. To protect your hearing from possible damage caused by prolonged exposure to high levels of sound, some type of ear protection should be worn, **Table 2-2**. Earplugs fit into the ear canal. They can be disposable or reusable and work well when you need to protect yourself from high sound levels but still want to hear someone speaking to you. Earmuffs fit over the entire ear. They also provide protection to the ears from flying sparks. Some electronic earmuffs have sound canceling features that eliminate undesirable sound but still allow speech to be easily understood.

Typical Sound Pressure Levels	Sound Pressure Level (dB)
Chipping hammer	120
Large air compressor	110
Angle grinder	100
Engine generators	90
Small air compressor	80
Average factory noise	70
Conversation speech	60

TABLE 2-1 Typical Types of Welding Equipment and the Sound Levels They Can Produce

Average Daily Sound Level	Time of Noise
90	8 hours
95	4 hours
100	2 hours
105	1 hour
110	30 minutes
115	15 minutes

TABLE 2-2 Sound Levels and Time Limits of Exposure Without Proper Ear Protection

CAUTION

Damage to your hearing caused by high sound levels may not be detected until later in life, and the resulting loss in hearing is nonrecoverable. Your hearing will not improve with time, and each exposure to high levels of sound will further damage your hearing. So always wear hearing protection when you are working in an area with high sound levels.

RESPIRATORY PROTECTION

Although almost all transmission pipeline welding, and much of construction welding, is done out of doors with good ventilation, all pipe welders need to be aware of potential respiratory hazards and take the necessary precautions to protect themselves and the other crew members. When new pipes are being used, there are no additional hazards beyond other welding types. However, anytime and anywhere repair work is being performed, there can be additional hazards from product residuals left in the pipe or in the area.

CAUTION

Always refer to the Safety Data Sheet (SDS) for the product or products that the pipeline carries before any welding or cutting begins on piping. If a product is flammable, explosive, or in any way dangerous, the area must be completely cleaned before welding begins.

Residual product in the area can be a significant respiratory problem if you are making a repair on a leaky pipe. Do not assume that any residual product is safe. You must make sure that the product itself is absolutely safe. Many materials will decompose and form hazardous vapor or fume byproducts when exposed to the heat of the arc or ultraviolet and infrared arc light. The safest thing is to remove all the material from the welding area.

Always check with the company or job site safety officer before beginning any welding.

Welders are responsible for following the welding shop's established written respiratory protection program. Guidelines for the respiratory protection program are available from the OSHA office in Washington, DC.

Training must be a part of the welding shop's respiratory protection program. This training should include instruction for any or all of the following procedures:

- Proper use of respirators, including techniques for putting them on and removing them
- Schedules for cleaning, disinfecting, storing, inspecting, repairing, discarding, and performing other aspects of maintaining respiratory protection equipment
- Selection of the proper respirators for use in the workplace and any respiratory equipment limitations
- Procedures to test for tight-fitting respirators
- Proper use of respirators in both routine and reasonably foreseeable emergency situations
- Regular evaluation of the effectiveness of the program

All respiratory protection equipment used in a welding shop should be certified by the National Institution for Occupational Safety and Health (NIOSH). Some of the types of respiratory protection equipment that may be used are the following:

- Air-purifying respirators have an air-purifying filter, cartridge, or canister that removes specific air contaminants by passing ambient air through the air-purifying element.
- Atmosphere-supplying respirators supply breathing air from a source independent of the ambient atmosphere; this includes both **supplied-air respirators (SARs),** or airline respirators, which are atmosphere-supplying respirators that have air piped in through a flexible hose from a large central air supply; and **self-contained breathing apparatus (SCBA)** units, for which the breathing air source is designed to be carried by the user.
- Demand respirators are atmosphere-supplying respirators that admit breathing air to the facepiece only when negative pressure is created inside it by inhalation.
- Positive pressure respirators are respirators in which the pressure inside the respiratory inlet covering exceeds the ambient air pressure outside the respirator.
- **Powered air-purifying respirators (PAPRs)** are air-purifying respirators that use a blower to force the ambient air through air-purifying elements to the inlet covering.

VENTILATION

Even though much of pipe welding is done outside, additional ventilation may be required for some jobs. Examples of when additional ventilation can be needed are when you are welding in an excavated area or inside a structure. For the most part, portable fans can be used to provide enough air movement to ventilate the welding area adequately. Care must be taken when using portable fans so that the arc shielding is not blown away, because that can cause weld defects to occur.

MATERIAL SPECIFICATION DATA

All material manufacturers must provide to users detailed information regarding possible hazards resulting from use of their products. These **Safety Data Sheets (SDS)** must be provided to anyone using the products or anyone working in the area where the products are being used. Companies will post these sheets on a bulletin board or put them in a convenient place near the work area. Some states have right-to-know laws that require specific training of all employees who handle or work in areas with hazardous materials.

WASTE MATERIAL RECYCLING AND DISPOSAL

Proper recycling and disposal of waste materials at welding job sites are very important. This is especially true when work is being done on cross-country pipelines. Because these pipelines are being constructed in open areas, many of which are environmentally sensitive, every effort should be made to protect the environment. Many times, there are special regulations in place to protect the environment. It is your responsibility to familiarize yourself and your crew with these regulations so that the regulations can be followed.

All welding generates waste materials. Much of the waste is scrap metal. All scrap metals, including electrode stubs, can be recycled. Recycling is good for the environment, and recycling metal can be a source of revenue for the welding shop.

Recycling of other materials may not be as easy as that of metal. Many local communities have recycling programs, which may differ significantly as to which materials they will accept and how the materials need to be separated for recycling. So check with your local community before starting work in a new area.

Some of the waste generated during welding may be considered hazardous materials, such as burned flux, cleaning solvents, paints, oils, and other chemicals. Check with the material manufacturer or an environmental consultant to determine if any waste material is considered hazardous.

CAUTION

Throwing hazardous waste material into the trash, pouring it on the ground, or dumping it down the drain is illegal. Before you dispose of any welding shop waste that is considered hazardous, you must first consult local, state, and federal regulations. *Protecting our environment from pollution is everyone's responsibility.*

FALLS

Falls are the major cause of workplace injuries and death. Any time that work is being performed on overhead platforms, elevated workstations, scaffolds, or around holes in the floors and walls, appropriate fall protection must be installed and used. In addition to protecting workers from falls, it is important that materials and equipment be secured so it cannot fall onto workers below. OSHA has strict guidelines regarding fall protection, **Table 2-3**. Businesses and industries can enact stricter fall protection regulations, but they may not allow workers to violate the OSHA minimum standards.

It is important to be proactive to reduce the hazards on a work site that might contribute to a fall. Employers are required to provide a workplace that is free from any known hazards. Floors must be clear of obstructions, such as building materials and scrap, and also kept dry when possible. Some of the things that must be done to prevent falls include:

Fall Protection Requirements

Workplace or Type of Work	Potential Fall Distance
General industry workplaces	4 feet
Shipyards	5 feet
Construction industry	6 feet
Longshoring operations	8 feet
Working over dangerous Equipment and machinery	At any height, no matter how small

TABLE 2-3 When Fall Protection Is Required

- Guard every floor hole into which a worker can accidentally walk with a railing with a toeboard and/or a floor hole cover, **Figure 2-3**.
- Provide a guardrail and toeboard around every elevated floor and open-sided platform or runway.
- Regardless of the elevation in question, if a worker can fall into or onto dangerous machines or equipment (such as a vat of acid or a conveyor belt), employers must provide guardrails and toeboards to prevent workers from getting injured.

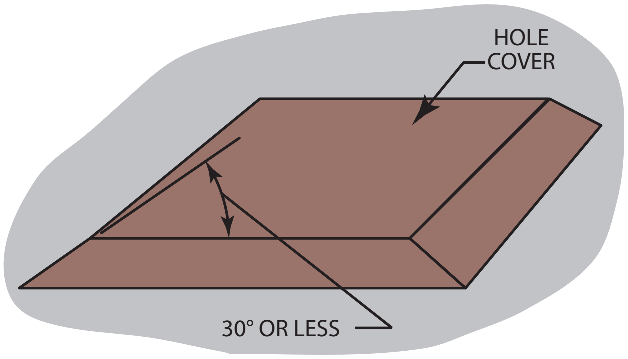


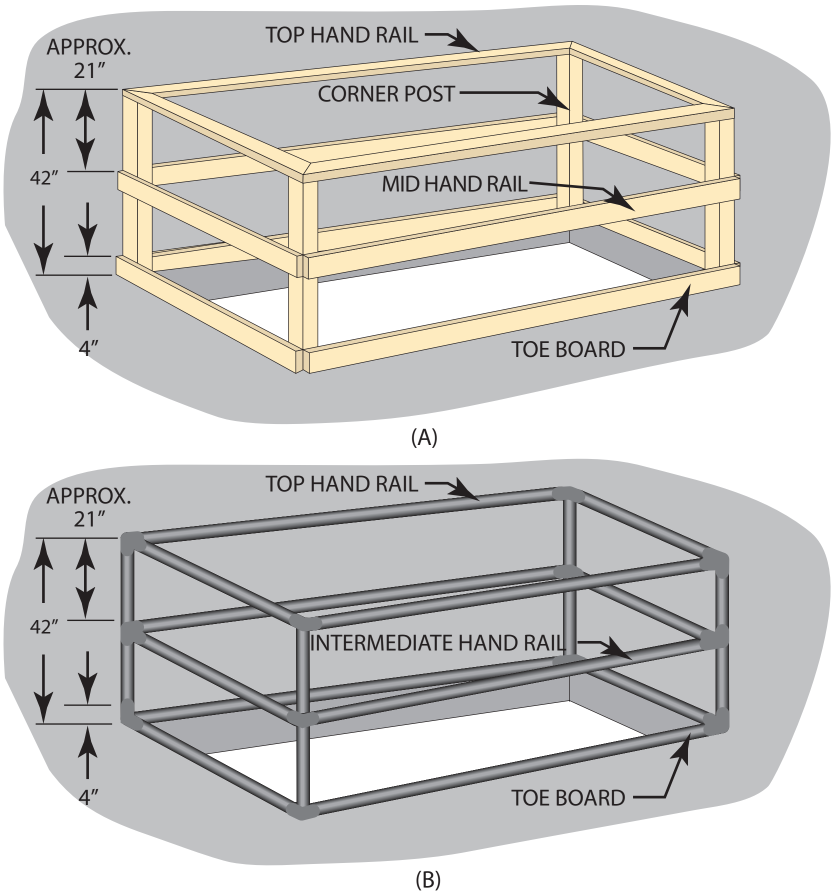
FIGURE 2-3 Specifications for a hole cover.

Guardrails must have a top handrail that is 42 in. (1 m) [plus or minus 3 in. (8 cm)] above the floor, have a midrail that is approximately halfway between the top handrail and floor (around 21 in), and a toeboard, **Figure 2-4**.

NOTE

To protect against falls, workers must be provided any required PPE and fall protection training.

Some of the other ways of providing worker protection from fall-related injuries include safety harnesses and line and safety nets.



TOP HAND RAIL shall be 39 to 45 in. above the walkway or working level and be able to support at least 200 lbs of force.

MID HAND RAIL (intermediate hand rail) shall be installed between the top rail and walkway or working level around 21 in. and able to support at least 150 lbs of force.

TOE BOARD shall be at least three in. wide and be able to withstand at least 50 lbs of force.

CORNER POST shall be anchored to withstand a force of 200 lbs when applied to the top rail in any direction once the guard rail is completed.

FIGURE 2-4 Specifications for a hole guardrail.

Scaffolding

Scaffolding, sometimes called *staging*, consists of temporary structures (usually constructed of pipe) that are used to support people or material. The most commonly used scaffolding consists of two end frames that are joined together by cross brace tubes, **Figure 2-5**. To make a taller scaffold, the scaffolding frames can be stacked vertically, with one on top of the other, using scaffolding insert pins. The frames may also be joined horizontally with interlocking cross brace tubes to make a longer scaffold, **Figure 2-6**. The legs of the scaffold frame may be set in flat base plates, casters or leveling jacks.

The safety guidelines for fall protection and guardrails as discussed above also apply to scaffolding. Some of the additional safety concerns for scaffolding are:

- **Footing**—It is important that the scaffolding is set on a solid base that is capable of bearing the load of the scaffold.
- **Platforms**—These must be fully supported, capable of supporting the load, and fully cover the deck area.
- **Training**—Anyone working on scaffolding must complete training on the hazards involved.

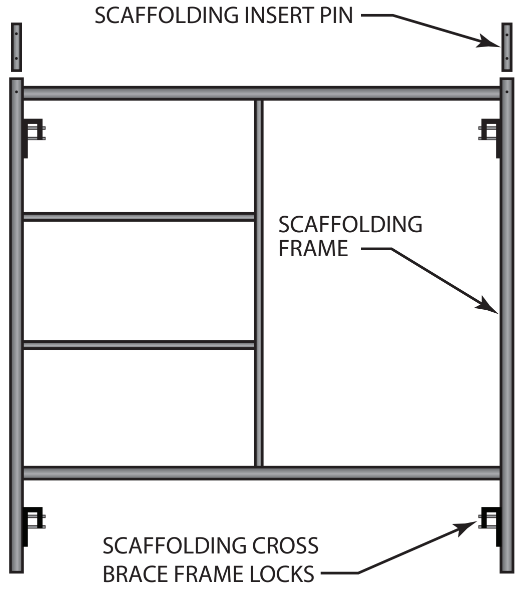


FIGURE 2-5 Scaffolding part identification.

- **Inspection**—All scaffolding must be inspected before each shift begins work.
- **Erecting and dismantling**—All fall protections must be followed as scaffolding is erected and disassembled.

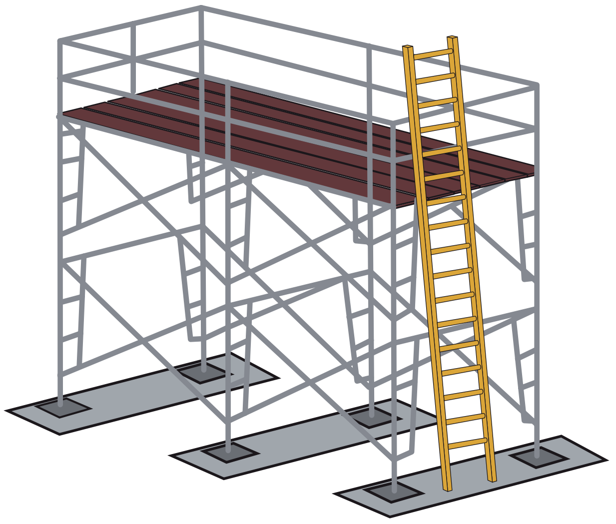


FIGURE 2-6 Suggested way that scaffolding can be set up.

FIGURE 2-7 Stepladder.

Ladder Safety

Falls from portable ladders are major causes of occupational fatalities and injuries, so it is important to know how to use them properly and safely. Often pipe welding is done up on scaffolding or down in ditches, so there are times that a ladder must be used to reach the work area, or even to weld from. Even a fall from a small step stool can cause injury. Often people feel that when a ladder starts to fall, they can just jump free; however, there is nothing solid under your feet, so you cannot do this. If someone falls onto debris or equipment, the injuries can be compounded; so it is important to keep the area around the base of a ladder clear.

Some of the things that must never be done with a ladder include:

- Never place a ladder on anything such as boxes to increase its reach.
- Never move a ladder with anyone on it.
- Never overload a ladder with more weight than it is rated for.
- Never use a stepladder unless it is fully opened, or use it as a straight ladder.
- Never stand on the top two rungs.

Types of Ladders

The two major types of ladders used for welding are stepladders and straight ladders. **Stepladders** prop open and are self-supporting, **Figure 2-7**. **Straight ladders** must be leaned against a stable surface, and they are available as fixed-length ladders or **extension ladders**, **Figure 2-8**.

Ladders can be made from wood, aluminum, or fiberglass. Each type has its advantages and disadvantages,

FIGURE 2-8 Straight (left) and extension ladders.

Table 2-4. When choosing a ladder for a job, consider the height required for the job and how much load (weight) it must carry. Look for the **American National Standards Institute (ANSI)** or **Underwriters Laboratories (UL)** label to ensure that the ladder is constructed to a standard of safety.

Ladder Inspection

Always inspect a ladder prior to using it. Over time, ladders can become worn or damaged. Look for loose or damaged steps, rungs, rails, braces, and safety feet. Check to see that all the hardware is tight, including the hinges, locks, nuts, bolts, screws, and rivets. Wooden ladders must be checked

Ladder Materials		
Materials	**Advantages**	**Disadvantages**
Wood	Electrically nonconductive	Long-term exposure to weather will cause rotting
Aluminum	Lightweight Weather resistant	Electrically conductive Shakier than wood or fiberglass
Fiberglass	Electrically nonconductive Weather resistant	Heavier than aluminum and wood Fiberglass splinters

TABLE 2-4 Types of Ladder Material and Their Advantages and Disadvantages

for cracks, rot, or wood decay. Never use a defective ladder. Make any necessary repairs before it is used; or, if it cannot be repaired, replace it.

Rules for Ladder Use

Read the entire ladder manufacturer's list of safety rules before using the ladder for the first time. Stepladders must be locked in the full-open position with the spreaders. Straight or extension ladders must be used at the proper angle; either too steep or too flat is dangerous, **Figure 2-9**.

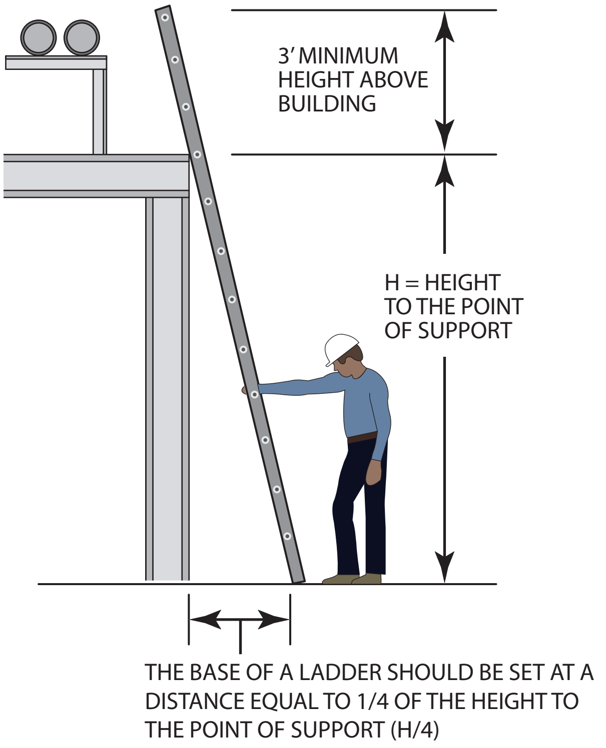


FIGURE 2-9 Proper setup for using a straight ladder.

The following are general safety and usage rules for ladders:

- Follow all recommended practices for safe use and storage.
- Avoid electrical hazards! Look for overhead power lines before handling a ladder. Metal ladders should never be used near power lines or exposed energized electrical equipment.
- Do not exceed the manufacturer's recommended maximum weight limit for the ladder.
- Before setting up a ladder, make certain that it will be erected on a level, solid surface.
- Never use a ladder in a wet or muddy area where water or mud will be tracked up the ladder's steps or rungs. Only climb or descend ladders with clean, dry shoes.
- The proper angle for setting up a straight or extension ladder is to place its base a quarter of the working length of the ladder from the wall or other vertical surface.
- Tie the ladder securely in place.
- Always maintain a three-point (two hands and a foot, or two feet and a hand) contact on the ladder when climbing. Keep your body near the middle of the step and always face the ladder while climbing.
- Do not carry tools and supplies in your hand as you climb or descend a ladder. Use a rope to raise or lower the items once you are safely in place.
- Wear well-fitting shoes or boots.

CAUTION

Never use ladders near live electrical wires. Turn the power off to any wires that will be near your ladder when working. Never move a ladder in the upright position near any electrical wires, even if you think the power on the line is off.

EXCAVATIONS

Because many pipelines are buried beneath the Earth's surface, pipe welders must often work in some type of excavation to access these pipes. All work being done in an excavation poses unique safety issues not normally associated with other work areas. The term *excavation* is very broad; OSHA defines an **excavation** as "any man-made

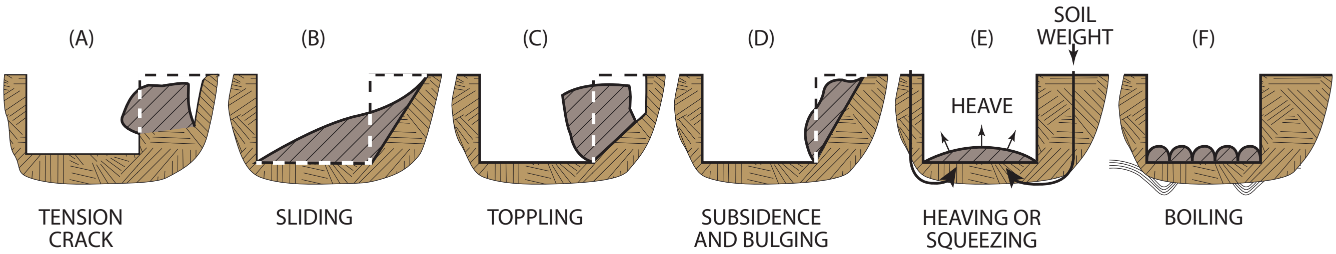


FIGURE 2-10 Types of excavation wall and floor failures.

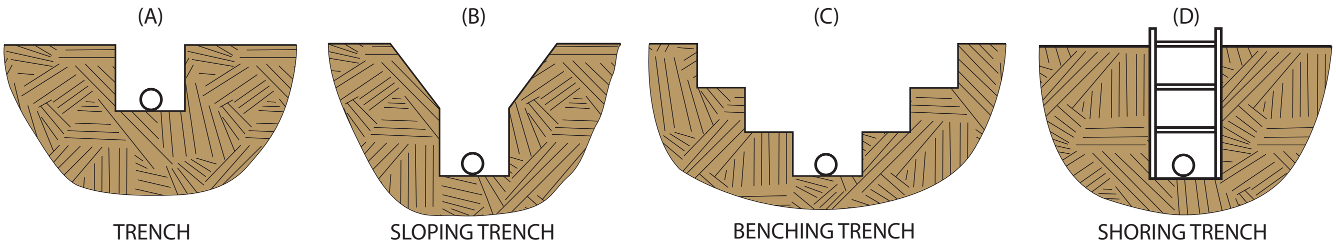


FIGURE 2-11 Recommended methods for opening an excavation.

cut, cavity, trench, or depression in the earth's surface formed by earth removal." OSHA defines the related term **trench** as "a narrow underground excavation that is deeper than it is wide, and no wider than 15 feet (4.5 meters)."

CAUTION

Never begin an excavation until the site has been surveyed for underground utilities. Most states have laws that require contractors to call a published phone number for their "Call Before You Dig" service, which will make sure that all the required utility companies have been contacted prior to beginning the excavation. Failure to do this can result in fines and make you liable for any damage caused by the excavation.

Cave-ins

One of the most serious safety hazards to workers in excavations is **cave-ins**, **Figure 2-10**. Excavation cave-ins result in the most serious injuries and too often result in work site fatalities.

One of the first things that an engineer must do at a proposed excavation site is a soil analysis. There are many different types of soil; some types, such as clay soils, are less prone to cave-ins than sandy soils. In addition, many excavation sites may have more than one soil type, or different soil types layered on top of each other. The analysis is used to determine the type of soil and the appropriate excavation wall design, **Figure 2-11**. The dirt removed from a trench is referred to as *spoil*, **Figure 2-12**.

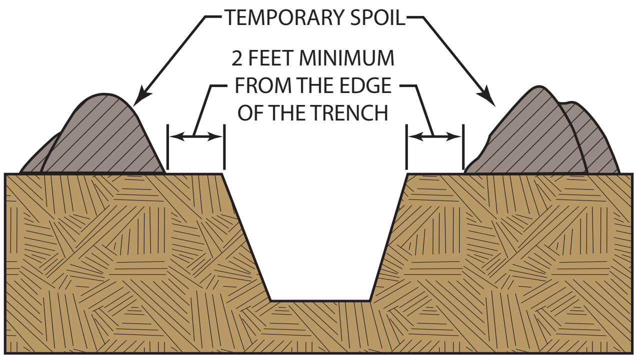


FIGURE 2-12 Safe way to place dirt when digging.

Excavation Walls

There are a number of ways to prevent cave-ins, including:

- **Sloping**—The angle of the sloped wall of an excavation is determined by the soil type, **Figure 2-13**. Less stable soil types and layered soil types require a much shallower slope angle than the more stable soil types.
- **Benching**—Stair steps cut into the wall of an excavation can make it a little easier to get in and out of it, **Figure 2-14**. It's also possible to combine **sloping** and **benching** with some soil types, **Figure 2-15**.

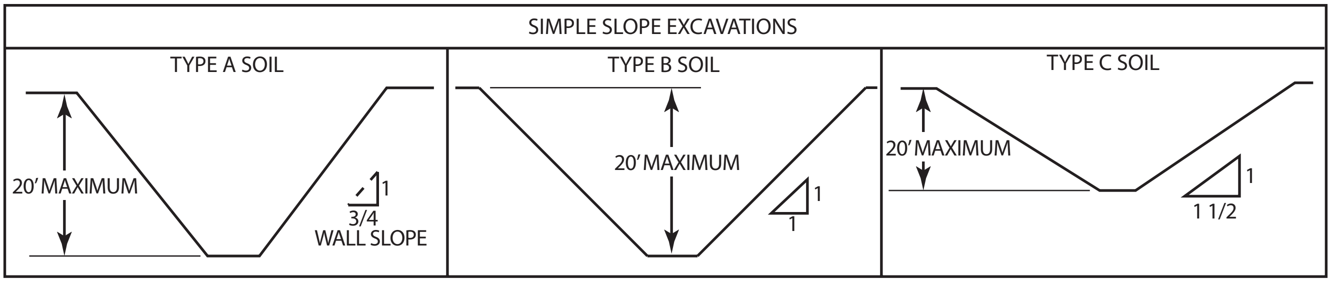


FIGURE 2-13 Sloping for different types of soil.

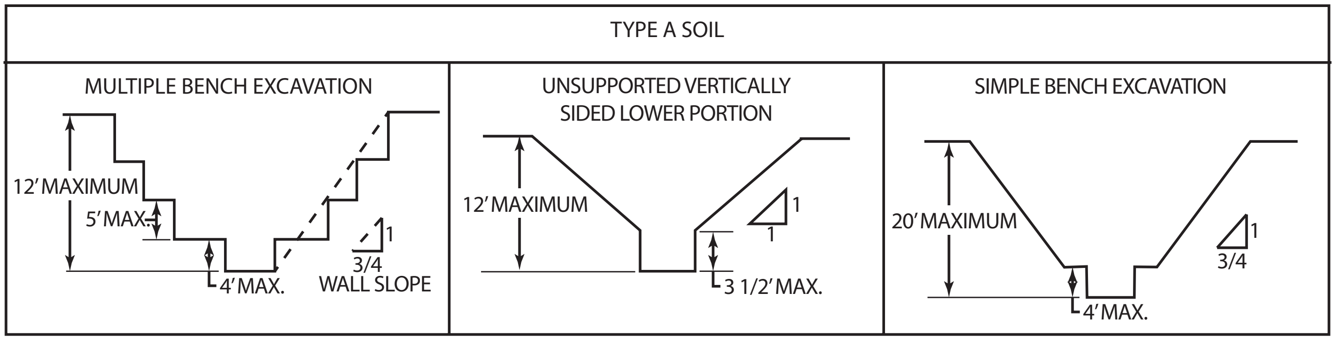


FIGURE 2-14 Benching for different depths of excavations.

FIGURE 2-15 Example of benching (on the left wall) and sloping (on the right wall).

- **Shoring**—Because trenches are a narrower type of excavation, these walls can be secured against cave-ins by bracing them with one of several types of **shoring**, **Figure 2-16**.
- **Shielding**—One of the most commonly used methods of protecting against cave-ins in trenches are trench boxes, **Figure 2-17**. Metal trench boxes can be easily moved along a trench or from one excavation site to another. The space between the trench wall and the wall of the trench box should be kept as small as possible.

Other Excavation Hazards

Welders must be alert for other safety hazards while working in or around an excavation, including:

- **Falls**—Pay very close attention while walking around open excavations to avoid accidentally stepping into them.
- **Slipping**—Often the dirt in and around an excavation can turn into mud, which greatly increases the potential of slipping. Slipping and sliding can cause strained or pulled muscles and can result in a fall.
- **Falling loads**—Be alert to loads that may be moving overhead. Although nothing should ever be moved over workers who are in an excavation, crane or lift operators may not be able to see that someone is working in an excavation.

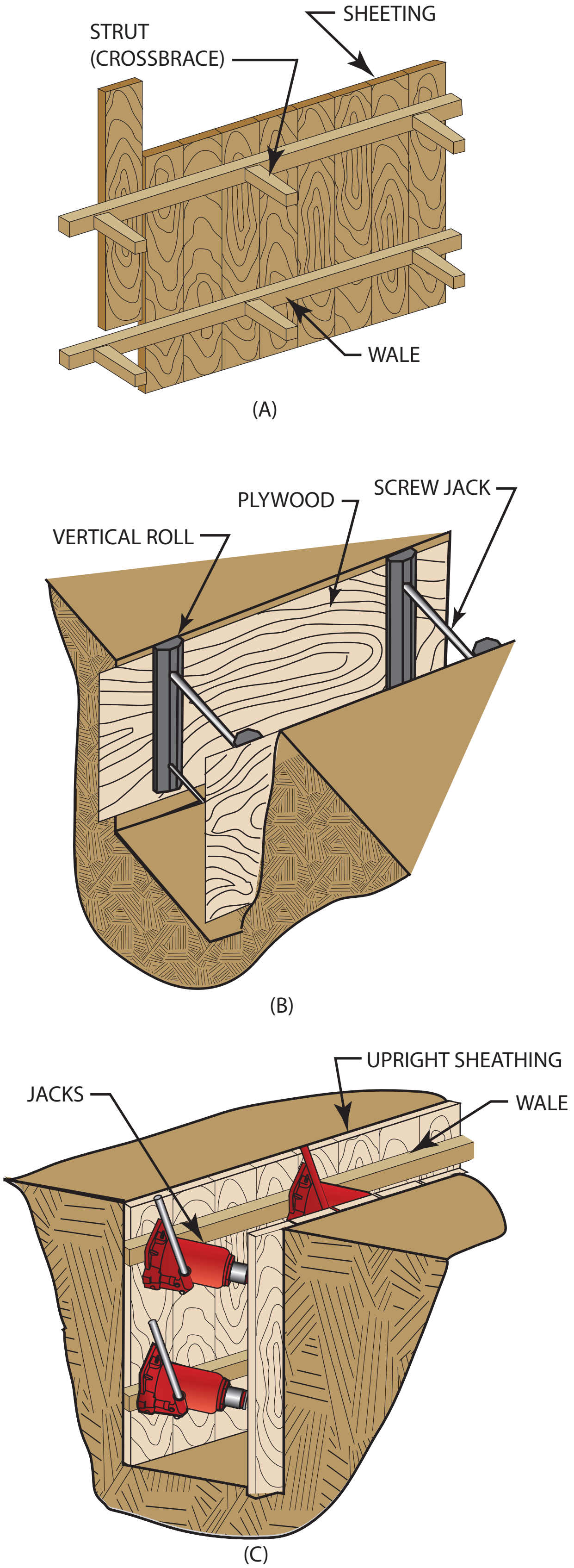


FIGURE 2-16 Methods of securing an excavation wall from cave-ins. (A) Vertical planking, (B) plywood, and (C) hydraulic jacks can be used to replace cross bracing and screw jacks.

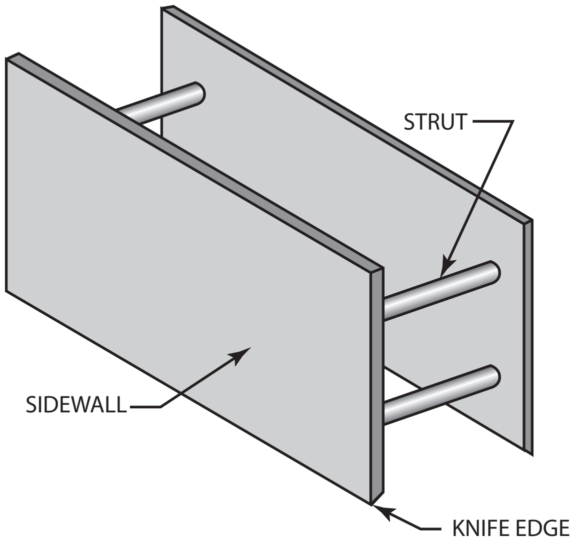


FIGURE 2-17 A metal trench box is a good way of securing the walls of excavations.

- **Hazardous atmosphere**—Many hazardous gases, such as carbon monoxide from equipment exhaust, are heavier than air and can collect inside an excavation.
- **Mobile equipment**—Drivers and equipment operators my accidentally drive into an excavation.
- **Underground utilities**—There is a wide variety of utilities that may be located in a proposed excavation site, such as telecommunication cables, wires, and fiber optics; pipes for water, gas, and sewer; and wires for power. It is the responsibility of the excavation equipment operator to locate these underground utilities before any digging begins. Damaging underground utilities such as electrical cables, gas pipes, and water lines can be deadly.

ELECTRICAL SAFETY

The best way to avoid an electrical shock is not to come in contact with electricity in the first place. There are many factors that affect exactly how much electricity it takes to be fatal. However, it is generally accepted that it only takes around 0.03 amperes (amps) to kill a person. To put this in perspective, a 60-watt incandescent light bulb uses around 0.5 amps—16 times higher than the fatal dose.

These are some general electrical safety steps that can be taken to minimize your risk of an electrical shock and possible death:

- Do not work on equipment that is still plugged into a power source.
- Repair or discard all worn or damaged electric power tools.

- Do not continue working if you think that you are not safe.
- Do not continue working with electrical equipment if there are electrical storms in the area because a lightning strike miles away can be carried by power wires to your job site.
- Complete a cardiopulmonary resuscitation (CPR) course and encourage others to do so too.

Extension Cord Safety

Because much pipe welding is done on location, it is necessary to use extension cords for lighting, grinders, fans, drills, and other portable tools. Because of the potential of electrical shock or electrocution posed by extension cords, they must have three wires and have a **ground-fault circuit interrupter (GFCI)**as part of the cord or be attached to a GFCI at the power source. In fact, it is a violation of federal safety rules not to have a three-wire extension cord and not to use a GFCI.

When a high current draw is required through an extension cord, there will be some degree of drop in the voltage. This voltage drop is much like the drop in water pressure when a long extension hose is used. As the voltage drop increases, you will experience a loss in power in drills, saws, and other motor-driven tools. The real problem is not the loss of power, but that the voltage drop will cause additional heat buildup in the motor. Too much heat buildup will result in the motor burning out. Keeping an extension cord as short as possible and making sure it can safely carry the current will help reduce voltage drop. **Table 2-4** shows the correct size extension cord to use based on cord length and nameplate amperage rating. If in doubt, use the next larger size. The smaller the gauge number of an extension cord, the larger the cord.

Extension cords should be checked frequently while in use to detect unusual heating. Any cable that feels more than slightly warm to a bare hand placed outside the insulation should be checked immediately for overloading.

Safety Rules for Portable Electric Tools

Portable electric tools such as grinders, drills, motorized pipe beveling cutters, fans, and lights are commonly needed on pipe welding jobs. They are often plugged into portable welding machines, and the chance of a fatal electrical shock is just as real as if they were plugged into an electrical outlet in the shop.

Following are a few safety precautions that should be observed. These general rules apply to all power tools, and they should be strictly obeyed to avoid injury to the operator and damage to the power tool:

- Know the tool. Learn the tool's applications and limitations, as well as its specific potential hazards by reading the manufacturer's literature.
- Ground the portable power tool unless it is double insulated. If the tool is equipped with a three-prong plug, it must be plugged into a three-hole electrical receptacle. If an adapter is used to accommodate a two-pronged receptacle, the adapter wire must be attached to a known ground. Never remove the third prong.
- Do not expose the power tool to rain or wet locations.
- Keep the work area well lit.
- Avoid chemical or corrosive environments.
- Because electric tools spark, portable electric tools should never be started or operated in the presence of propane, natural gas, gasoline, paint thinner, acetylene, or other flammable vapors that could cause a fire or explosion.
- Power tools will do the job better and more safely if operated at the rate for which the tool was designed; do not force a tool to operate beyond its limits.
- Use the right tool for the job. Never use a tool for any purpose other than that for which it was designed.
- Wear eye protectors such as safety glasses or goggles while you operate power tools.
- Wear a dust mask if the operation creates dust.
- Never carry a tool by its cord or yank it to disconnect it from the receptacle.
- Secure your work with clamps. It is safer than using your hands, and it frees both hands to operate the tool.
- Keep proper footing and balance at all times. Do not overreach when operating a power tool.
- Maintain power tools. Follow the manufacturer's instructions for lubricating and changing accessories. Replace all worn, broken, or lost parts immediately.
- Disconnect the tools from the power source when they are not in use.
- Form the habit of checking to see that any keys or wrenches are removed from the tool before turning it on.

- Avoid accidental starting. Do not carry a plugged-in tool with your finger on the switch. Be sure that the switch is off when plugging in the tool.
- Be sure that any accessories and cutting bits are attached securely to the tool.
- Do not use tools with cracked or damaged housings.
- When operating a portable power tool, give it your full and undivided attention; avoid dangerous distractions.

GENERAL WORK CLOTHING

Because of the amount and temperature of hot sparks, your general work clothes should be made of 100% cotton. When working in a cold environment, make sure that any jacket or coat is not made with or does not contain synthetic materials, such as nylon, rayon, or polyester. These materials are easily melted, and they produce a hot, sticky ash; some produce poisonous gases to boot. The clothing must also stop ultraviolet light from passing through it. This is accomplished if the material chosen is a dark color, thick, and tightly woven.

The following are some guidelines for selecting work clothing:

- Shirts must be long-sleeved to protect the arms, have a high-buttoned collar to protect the neck, be long enough to protect the waist, and have flaps on the pockets to keep sparks out (or have no pockets), as shown in **Figure 2-18**.

Larry Jeffus

FIGURE 2-18 Welders and welding helpers must wear appropriate general work clothing.

- Pants must have legs long enough to cover the tops of the boots and must be without cuffs that could catch sparks.
- Boots must have high tops to keep out sparks, steel toes to prevent crushed toes, **Figure 2-19**, and smooth tops to prevent sparks from being trapped in seams.

FIGURE 2-19 Steel toe safety boots are required on most job sites.

- Caps should be thick enough to prevent sparks from burning the top of a welder's head.

Clothing must be relatively tight-fitting in order to prevent excessive folds or wrinkles that might trap sparks. Also, clothing must be free of frayed edges, which might easily catch fire from welding sparks.

Butane lighters and matches may catch fire or explode if they are subjected to welding heat or sparks. There is no safe place to carry these items when welding.

Special Protective Clothing

In addition to general work clothing, extra protective clothing is often needed for many welding jobs. Leather is often the best material to use for such garments, as it is lightweight, flexible, resists burning, and is readily available. Ready-to-wear leather protection includes capes, jackets, aprons, sleeves, gloves, caps, pants, kneepads, and spats, among other items. Synthetic insulating materials are also available.

FIRE PROTECTION

Too often, we read in the news that a "welder's torch" started a fire. No one wants to be the center of a lead story about a fire started by a welder, so we need to do everything to prevent accidental fires from being started. Fire is a constant danger in all welding situations, but it is a special problem for pipe welding outdoors, such as welding on cross-country pipelines. Fires can spread quickly in materials such as dried grass, farm crops, underbrush, and woodlands, especially during a drought or in the winter when plants die back and dry out. The possibility of accidental fires being started can be decreased by removing vegetation and other flammable materials 35 ft (10.7 m) or more from the welding area.

It is not always possible to remove all combustible materials when welding outside. If you must work around combustible materials, wet the area first, and then keep a bucket of water and a fire extinguisher handy and use a fire watch, **Figure 2-20**.

FIGURE 2-20 A fire watch has both a water sprayer and a fire extinguisher. A fire safety officer does not have to see a fire happen; the burned grass on a site may be enough to shut down welding.

Fire Watch

A **fire watch** can be provided by any person who knows how to sound the alarm and use a fire extinguisher. The fire extinguisher must be the type required to put out a fire of the type of combustible materials near the welding. Combustible materials that cannot be removed from the welding area should be soaked with water or covered with sand or noncombustible insulating blankets, whichever is available.

CAUTION

Never weld or cut in a dry area or any area that has been posted by the county or state as fire restricted, **Figure 2-21.** You could be held legally responsible if you ignore this warning and a fire starts.

FIGURE 2-21 In most areas, it is the welder's responsibility to know if there are fire restrictions, so call before you weld.

PLANNED MAINTENANCE

Follow the manufacturer's routine schedule of equipment maintenance. Small problems, if fixed in time, can prevent the loss of valuable time due to equipment breakdown or injury.

Any maintenance beyond routine external maintenance should be referred to a trained service technician. In most areas, it is against the law for anyone but a factory-trained repair technician to work on pressure regulators. Electrical shock and exploding regulators can cause serious injury or death.

Hoses

Hoses should be kept out of the direct line of sparks. Any leaking or bad joints must be repaired.

Cables

Welding cables and extension cords can be damaged by welding and cutting sparks, as well as becoming scraped and gouged as they are pulled around a job site. So it is important to inspect them for damage that might create a safety hazard.

Hand Tools

Tools that are used outside and exposed to damp conditions need to be cleaned and well oiled to prevent rusting. Keep knives and other cutting tools sharpened.

Work Area

The work area in welding shops should be kept picked up and swept clean. Collections of steel, welding electrode stubs, wire, hoses, and cables are difficult to work around and easy to trip over, **Figure 2-22**. Keeping the work area clean is important not only for safety, but also because antilitter laws can be broken if food wrappers, Styrofoam™ cups, cardboard, and other trash are not disposed of