

Preface

Today's students and instructors need to do more in less time than ever before. *Welding* was written from the ground up to be both comprehensive and concise. Each chapter is cleanly designed and covers exactly what students need to know to enter the workforce. The material is presented with striking images, easy-to-read reference charts and tables, and detailed step-by-step procedures.

NEW TO THIS EDITION

Based on peer review several major changes were made to the text as outlined below:

- An introductory pipe welding chapter has been added. Topics covered include joint preparation, weld joint fit-up, tack welds, root pass welding, fill pass welding, cap pass welding, and technique. The chapter closes with welding tables that, when used in conjunction with the welding process chapters, act as a step-by-step guide for welding pipe.
- Welding Alloys has been expanded into two separate chapters- Welding Ferrous Alloys and Welding Nonferrous Alloys. Information was reorganized, for a more practical approach to setting up and completing welds with individual metal alloys.
- Components of Welding Design have been relocated to the end of Metals and Welding Metallurgy, adding an unique, practical, and measurable view of metal warpage and distortion.
- The Welding Codes and Testing chapter is divided into two separate chapters- Welding Codes and Weld Testing. This logical division makes information easier to find and aides instructors in course design.
- The Welding Costs chapter has been streamlined into easy to use tables in Appendix F. Tables are structured in a simple manner that students can more easily understand.

STORY OF THE BOOK

The authors have experience both in industry and in the classroom. Their industry experience brings together knowledge of welding and manufacturing, welding inspection and quality control, training, weld code testing, power source design,

troubleshooting, and customer service. Those collective industry experiences and more than 60 years of combined instructional expertise have inspired the writing of this textbook. As instructors, the authors wanted to produce an accessible book that covers welding in a clear and concise manner. After an introduction to welding and to welding safety, they gave each major welding process its own chapter so they could easily be discussed in the classroom. Following the weld processes, their chapters focus on critical topics, such as codes, destructive and non-destructive weld testing, welding symbols, welding metallurgy, welding ferrous and nonferrous alloys, and welding power sources. Most textbooks do not cover smaller diameter electrodes well. *Welding* does. The authors' goal was to create a text suitable for high schools and postsecondary schools, for industrial use, or by the home hobbyist, and they have done just that with *Welding*.

ORGANIZATION

First, the book orients students with basic information on welding careers and welding safety. Then, welding chapters follow, with uniquely detailed step-by-step weld setups and techniques. The authors devote an entire chapter to each of the common weld processes. Within those chapters they take the weld setup and break it down into its most important steps, providing students with instructions and photos. Students are visual learners, and this step-by-step format makes the material easier to learn and easier to reference later in the semester and even later in students' careers. The chapters cover important information with easy-to-read technical tables.

Next, the chapters turn to metallurgy and alloys, codes and costs, and other critical welding topics. Finally, the appendices cover additional topics, such as troubleshooting, conversion, and pipes and beams.

A SOLID FOUNDATION FOR LEARNING

CHAPTER LEARNING OBJECTIVES Each chapter begins with clearly stated objectives that enable students to focus on what they should achieve and know by the end of the chapter.

LEARNING OBJECTIVES

In this chapter, the reader will learn how to:

1. Use the Gas Tungsten Arc Welding process safely.
2. List what types of power sources and other peripheral components make up the Gas Tungsten Arc Welding process.
3. Identify the characteristics and correctly use the various controls on power sources.
4. Determine which polarity is best for the base metal used and desired outcome.
5. Select the correct electrode for the base metal used and the desired outcome.
6. Select the correct shielding gas.
7. Properly set up for Gas Tungsten Arc Welding by adjusting the filler addition amount, travel speed, work angles, and electrode-work distance.

CHAPTER KEY TERMS Each chapter opens with a list of key terms with page references for the chapter. This provides for quick access and easy review by students.

KEY TERMS

| | |
|------------------------|----------------------|
| Air-Cooled Torch 171 | Inert Gas 183 |
| Water-Cooled Torch 171 | Asphyxiant 184 |
| Torch Body 174 | Venire Control 185 |
| Cup 174 | Postflow 186 |
| Collet 174 | Preflow 186 |
| Collet Body 174 | Cathodic Etching 188 |
| Back Cap 175 | High-Frequency 190 |
| Tungsten Electrode 178 | Autogenous Weld 190 |

CHAPTER INTRODUCTION

These introductions provide a general overview of the chapter content. They are a preview of the essential content, which often includes historical information, that will be featured in the coming pages.

INTRODUCTION

Gas Tungsten Arc Welding (GTAW) is an extremely useful welding process that uses a nonconsumable tungsten electrode to conduct welding current. Base metal and arc gap resistance to current flow creates heat, causing the base metal to melt, forming a molten weld pool. The weld can then be finished by blending base metal pools together or by manually adding filler metal. **FIGURE 6-1** shows a typical GTAW torch and welding arc. In the past, this welding process was called TIG welding. TIG stands for Tungsten Inert Gas. While the acronym TIG is not entirely inaccurate, GTAW is the universally acceptable acronym for this welding process.

CHAPTER QUESTIONS/ASSIGNMENTS

Great for study review and comprehension checks, these end-of-chapter questions help students assess their understanding of the material.

CHAPTER QUESTIONS/ASSIGNMENTS

MULTIPLE CHOICE

1. What is another common name for GTAW?
 - a. Gas Arc Welding (GAW)
 - b. Manual Filler Welding (MFW)
 - c. Tungsten Inert Gas (TIG)
 - d. Tungsten Electrode Welding (TEW)
4. The air-cooled welding torch uses what to remove heat?
 - a. Carbon dioxide shielding gas
 - b. Cooled water
 - c. Argon shielding gas
 - d. 75% argon/25% carbon dioxide shielding gas mixture

FILL IN THE BLANK

12. The tungsten electrode is a _____ electrode that is used to conduct welding current.
13. A constant _____ power source is the type used for GTAW.
19. _____ is the process in which positive ions are released from the electrode and strike the oxides on the surface of the aluminum. The loose oxides are then lifted away by the current flow from the aluminum to tungsten.

SAFETY Critical for every welding program, safety considerations/tables are clearly highlighted at the start of each of the welding process chapters.

SAFETY

TABLES 6-1 and 6-2 show some basic safety considerations related to workplace environments. TABLE 6-1 shows the basic safety considerations and TABLE 6-2 shows recommended lens shade.

| Head | Body | Hands | Feet |
|----------------------------------|--|---------------------------|---------------------------------------|
| Safety glasses Welding helmet | Flame-resistant wool or cotton pants and shirt | Leather welding gloves | High-top leather safety work boots |

TABLE 6-1

Read "Chapter 2: Safety in Welding" for detailed discussion of safety related to workplace environment, workplace hazards, personal protective equipment, electrical consideration, gases and fumes, ventilation, fire prevention, explosion, and compressed cylinders and gases.

| Arc Current | Suggested Shade |
|-------------|-----------------|
| < 50 | 8 |
| 50-150 | 10 |
| 150-250 | 12 |
| 250-400 | 14 |

TABLE 6-2

STEP-BY-STEP PROCEDURES

Procedures including instruction, safety, and photos make material easy to understand.

SMAW Setup

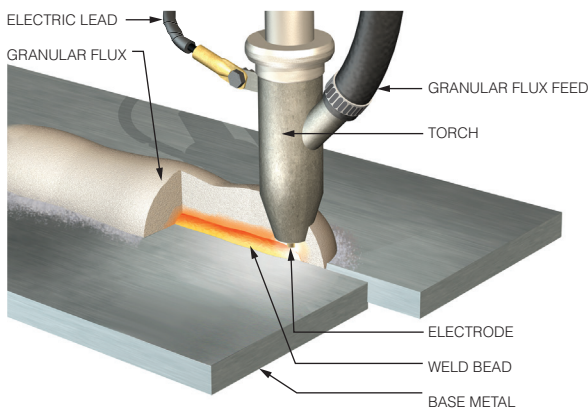
STEP-BY-STEP

1 Select a power source (DC inverter).
CAUTION: Make sure the power is off.

2a Connect the work lead to the power source.
CAUTION: Wear dry welding gloves when handling electrode leads.

RICH ART THROUGHOUT

Striking art and photos are large and detailed to reach visual learners.



SUPPLEMENTS

Supplements are a crucial part of any book these days, and *Welding* includes a unique package for both students and instructors. To access supplementary materials online, instructors need to request an instructor access code. Go to **www.pearsonhighered.com/irc** to register for an instructor access code. Within 48 hours of registering, you will receive a confirming e-mail including an instructor access code. Once you have received your code, locate your text in the online catalog and click on the Instructor Resources button on the left side of the catalog product page. Select a supplement, and a login page will appear. Once you have logged in, you can access instructor material for all Pearson Education textbooks. If you have any difficulties accessing the site or downloading a supplement, please contact Customer Service at **<http://247pearsoned.custhelp.com>**.

INSTRUCTOR'S RESOURCE MANUAL The *Instructor's Resource Manual* (ISBN-10: 0-13-401645-9) includes chapter-by-chapter assistance through modifiable lesson plans, a sample syllabus, objectives, and answers to the end-of-chapter review questions.

POWERPOINT PRESENTATION The PowerPoint Presentation (ISBN-10: 0-13-401706-4) features a lecture outline format with key talking points. It includes art from the textbook to enhance the classroom experience and to help instructors prepare for class.

TESTGEN This electronic question bank (ISBN-10: 0-13-401637-8) can be used to develop customized quizzes, tests, and/or exams.

STUDENT'S WELDING LAB MANUAL (PRINT) A printed *Student Welding Lab Manual* (ISBN-10: 0-13-407007-0) is also available. With more than 170 labs in all, this outstanding resource includes challenging lab exercises for the more common welds that students are likely to encounter.

Chapter 7

PIPE WELDING

LEARNING OBJECTIVES

In this chapter, the reader will learn how to:

1. Identify the challenges of welding pipe positions compared to plate welding.
2. Determine how to correctly prepare and clean a weld joint.
3. Understand the importance of fit up and its relationship to the weld keyhole.
4. Properly place and clean up tack welds.
5. Distinguish the differences in making root passes on several base metal types.
6. Describe the importance of fill pass layer thickness and width to ensure a successful weld.
7. Identify several criteria that determine the success of a cap pass.
8. Select a welding procedure for a specific welding process and welding position.

KEY TERMS

Tack Weld 219

Keyhole 218

Root Pass 220

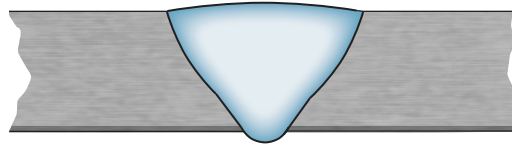
Hot Pass 222

Fill Pass 222

Cap Pass 222

INTRODUCTION TO PIPE WELDING AND POSITIONS

Using advanced welding processes and techniques requires both an understanding of basic welding fundamentals and the skills required to perform welds in multiple positions. The skills used to perform the pipe procedures described here are not beginning welding skills. They require that the welder already can perform welds successfully in the 1G, 2G, 3G, and 4G positions. Since pipe welding most often requires open root welding, open root plate welding in all positions is good preparation to acquire the skill needed to produce complete joint penetration (**FIGURE 7-1**) welds on pipe. Both the 5G and 6G pipe welding positions require the ability to weld in multiple positions. For example, the 5G encompasses welding in the flat, vertical, and overhead positions, and the 6G involves welding in all positions. While producing fillet welds on pipe present some difficulty compared to plate welding, the discussion here is focused on groove welding.



COMPLETE JOINT PENETRATION

FIGURE 7-1 Complete Joint Penetration.

WHAT ARE THE FACTORS THAT MAKE PIPE WELDING BOTH DIFFERENT AND MORE CHALLENGING THAN WELDING PLATE MATERIALS?

Pipe welding entails maintaining welding angles around the circumference of pipes. Rather than welding in one linear direction, the welder must constantly adjust the welding travel angle to account for the curvature of the pipe. Maintaining visibility of the weld pool is also complicated for welding fixed position pipe. **FIGURE 7-2** shows common AWS pipe welding positions for groove joints.

JOINT DESIGN Where fillet welds are common on plate welding design, groove welds are more common in pipe applications where complete joint penetration is needed. Open root groove designs have variations of those elements—groove or bevel angle, root face, and root opening—shown in **FIGURE 7-3**. A good practice for selecting a groove design is to follow recommendations from a welding code or standard directly related to the pipe welding being done. Welding codes, such as *AWS D1.1 Structural Welding Code-Steel*, and *ASME Boiler and Pressure Vessel Code, Section IX: Welding and Brazing Qualifications*, contain recommended practices and requirements for welding carbon steel pipe.

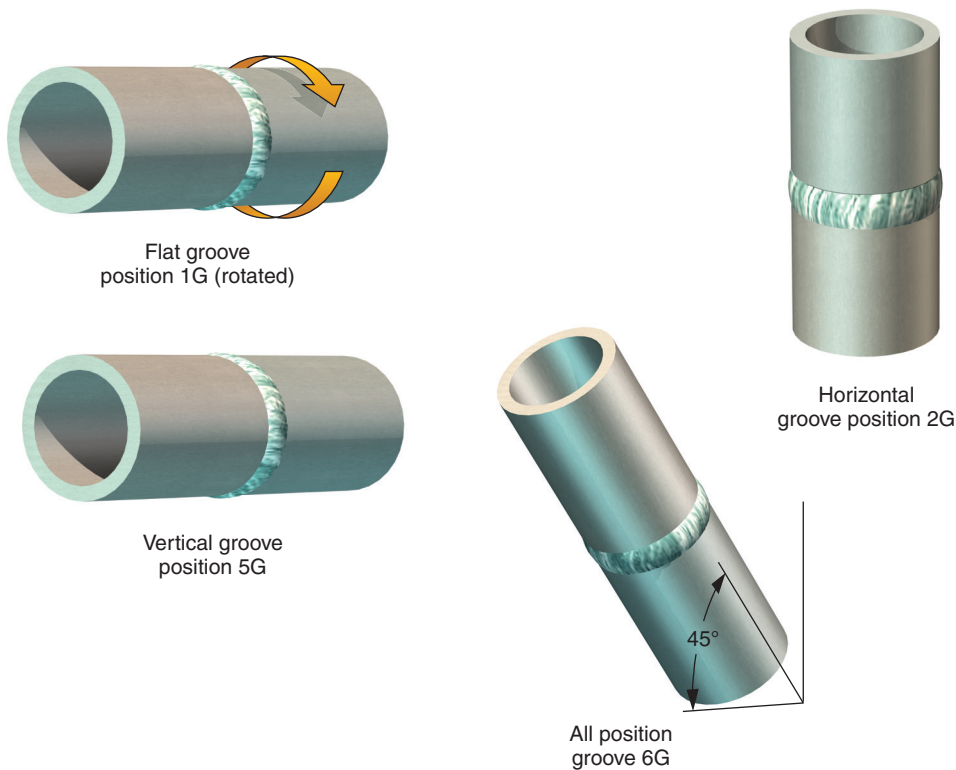


FIGURE 7-2 Common pipe welding positions.

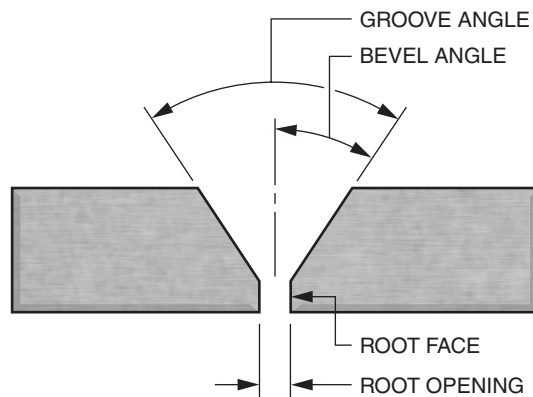


FIGURE 7-3 Groove joint design.

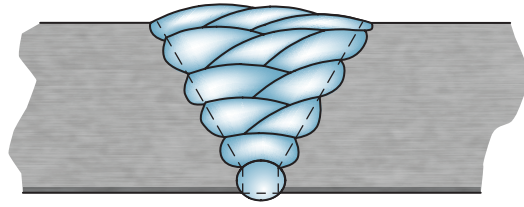
JOINT PREPARATION

WHAT ARE THE MINIMUM REQUIREMENTS FOR JOINT PREPARATION BEFORE ASSEMBLING PARTS FOR WELDING?

The first step for joint preparation is to determine specific dimensions for the groove design. The groove angle and root opening must be sufficient enough to allow for access of the electrode to ensure complete joint penetration and to allow for fusion to the groove faces and between all weld passes and layers (**FIGURE 7-4**). For larger nozzle diameters used with GMAW and GTAW, the included angle may be as much as 70 degrees on v-groove joints. If the joint root is easily accessible, an included angle of 60 degrees may be used.

EDGE PREPARATION The bevel angle should be prepared by machining within the tolerances of an established welding procedure specification. The root face can be machined or ground after beveling. In some cases, the bevel angle, root

FIGURE 7-4 Weld layers in groove weld.



face, and inside surface of the pipe are prepared in one operation with a pipe beveling machine equipped with multiple cutting tools. The inside edges of the pipe must be in alignment to ensure complete joint penetration throughout the full weld length.

FINAL CLEANING Before setting up for welding, the pipe must be cleaned sufficiently to ensure fusion and to eliminate any form of contamination entering the weld zone. Mill scale, varnish, paint, rust, or other contaminants must be removed prior to joint fit-up to a distance of 1 inch (2.54 cm) from the bevel edge. These possible contaminants can be removed by mechanical means such as grinding. Further, any oils or fluids from cutting or storage must be removed with a cleaning solvent approved for welding operations to eliminate porosity or unwanted metallurgical effects. With aluminum base metals, oxide removal is necessary immediately prior to welding, for each weld pass, to ensure proper fusion.

WELD JOINT FIT UP

HOW ARE PIPE PIECES HELD IN PLACE FOR WELDING? The pipe pieces must be secured in a manner that keeps the root edges in alignment, while maintaining a consistent root opening. If the inside edges of the pipe are not aligned, it will be difficult to maintain complete joint penetration through the full length of the weld. At the same time, if the root opening is narrower on one side of the pipe and wider on the other, it is difficult to control both fusion in the narrow opening and to eliminate excessive melt-through of the wider opening.

To ensure proper alignment on the job, one technique uses pipe clamps. These allow for precise alignment, fitting up the pipe for welding. Many commercial styles of both internal and external pipe clamps are available. These are often cost prohibitive in small schools shops. In this case, other alternatives exist. Angle iron or channel iron can be used for alignment, with the addition of a clamping mechanism (**FIGURE 7-5**).



FIGURE 7-5 Channel Iron Used for alignment.

WHAT ARE THE FIRST STEPS IN ENSURING A SUCCESSFULLY WELDED PIPE JOINT? Before welding begins, and this applies to all or any single weld pass or layer, equipment must be set properly, allowing for ease of weld starts. All welds with all processes must have arc initiation within the weld groove, where subsequent weld passes will melt out the effects of initiating the arc (arc starts).

The next factor for success is to develop and maintain a **keyhole** at the leading edge of the weld pool in the joint root. A keyhole is a small circular hole

| Problem | Causes | Solutions |
|--|----------------------------|-----------------------|
| Keyhole too big Excessive melt-through | Amps too high | Decrease amps |
| | Root opening too big | Reduce root opening |
| | Root face too small | Increase root face |
| | Starting to push electrode | Correct drag angle |
| Keyhole too small Incomplete root fusion | Amps too low | Increase amps |
| | Root opening too small | Increase root opening |
| | Root face too large | Reduce root face |
| | Too steep drag angle | Increase to push |

TABLE 7-1

Troubleshooting keyhole and root fusion.

through the joint root, at the leading edge of the weld pool, on tack and root pass welds. It is desired to ensure fusion through the joint root. A properly shaped and sized keyhole (**FIGURE 7-6**) will melt both root faces and ensure adequate root fusion. Too large a keyhole will cause excessive melt through which is difficult to repair. However, if the keyhole closes, root fusion may be lost, which is equally unacceptable. **TABLE 7-1** lists some causes and solutions regarding problems encountered maintaining a keyhole on all welds in the joint root.



FIGURE 7-6 Keyhole size and shape—both beveled pipe edges are melted.

MAKING AND PLACEMENT OF TACK WELDS

WHAT IS THE FIRST STEP IN WELDING AFTER JOINT PREPARATION AND FIT-UP ARE COMPLETE?

Once fit-up is complete, it is time for placement of **tack welds**. A tack weld is a permanent weld used to fit up and hold the weld joint in place for welding. Tack welds are an integral part of the weld assembly. They must have complete joint penetration, and be large enough to hold the pipe rigidly in place to withstand expansion and contraction forces introduced during placement of the root pass. Otherwise, the weld joint will not stay properly aligned, or the root opening may close preventing fusion through the root of the joint.

Positioning of tack welds, both in number and location, is imperative to success in achieving complete joint penetration, meeting strength, and code requirements. Tack welds spaced equal distance and centered at the four quadrants of the pipe circumference as shown in **FIGURE 7-7** are sufficient for most small diameter pipe applications. For larger diameter pipe, more tack welds may be placed at intervals frequent enough to eliminate closing of the root opening. When welding pipe for procedure qualification or welder qualification, tack welds maybe placed at positions other than were test pieces are taken.

The final steps for finishing of tack welds are to clean by chipping and brushing, followed by grinding. Grind the weld to feather it out to a uniform, smooth contour. It is important to smooth out cold weld starts, where build-up is convex and likely too thick to accept fusion through the root of the subsequent root pass.

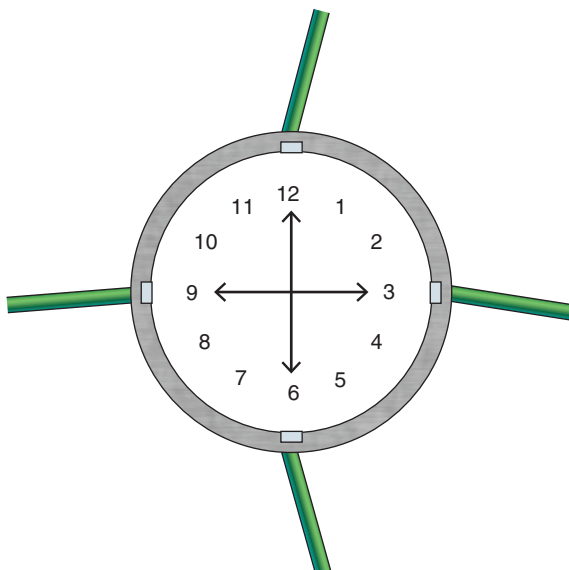


FIGURE 7-7 Placement of tack welds relative to clock positions.

At the same time, the welder must take care not to overgrind and remove too much of the tacks weld. This may result in melting the tack weld completely out and the root faces pulling together, reducing root fusion.

In the case of welding aluminum, GTAW tack welds are preferred over GMAW tack welds. Cold starts can be a problem with GMAW and this may obstruct fusion in the root pass. Use of a welding power source with a “hot start” function can help to reduce this problem.

ROOT PASS WELDING

The **root pass** is the initial pass deposited after the pipe is fit-up and tack-welded together. Where final visual inspection is concerned, the root pass and the cover or cap-pass are the decisive factors for determining whether or not welding was successful. If the pipe has been prepared with the correct groove design, and fit-up and the tack welding have been done correctly, welding the root pass can proceed.

It is important to start the initial weld of the root pass by starting the arc at least $\frac{1}{4}$ inches back (overlapping) on the tack weld and progress forward from there. This will allow the weld pool to develop, creating enough heat to cause proper melt through and fusion with the tack weld and tie into the keyhole. This same method must be repeated with each tie-in (restart) to complete the root pass.

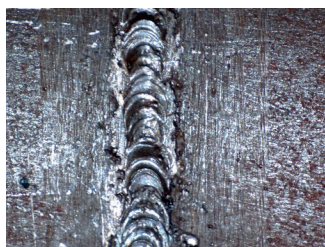


FIGURE 7-8 Fusion on the root side—both beveled pipe edges are melted.

Remember, the goal is to finish the root pass with complete fusion, both on the root side (**FIGURE 7-8**) and the fusion face and toes of the weld (**FIGURE 7-9**). **TABLE 7-1** lists the causes and solutions to problems encountered with root fusion. The factors the welder controls that influence fusion are amperage, travel and work angles, arc length, and travel speed. One other factor is the position of the weld. For example, vertical down-welding requires higher travel speeds and is limited to thinner pipe thicknesses. Vertical up-welding may be done with smaller diameter electrodes to allow for both proper root fusion and weld pool control.



FIGURE 7-9 Fusion on weld face and toes.

Root pass procedures vary with some alloys other than carbon steel. In the case of stainless steels, open root welding is accomplished by back purging the inside of the pipe with either argon or nitrogen gases. As an alternative, one of various types of consumable inserts (**FIGURE 7-10**), backing rings, or backing tape can be used to prevent the root from oxidizing effects of atmospheric oxygen. Consumable inserts are commercially available for most common base metal alloys.

When welding aluminum alloys, it is a common practice to use backing rings that fit inside the pipe and act as a backing bar. In addition, the extended-land bevel joint may be used (**FIGURE 7-11**). This design eliminates the need for a backing ring.

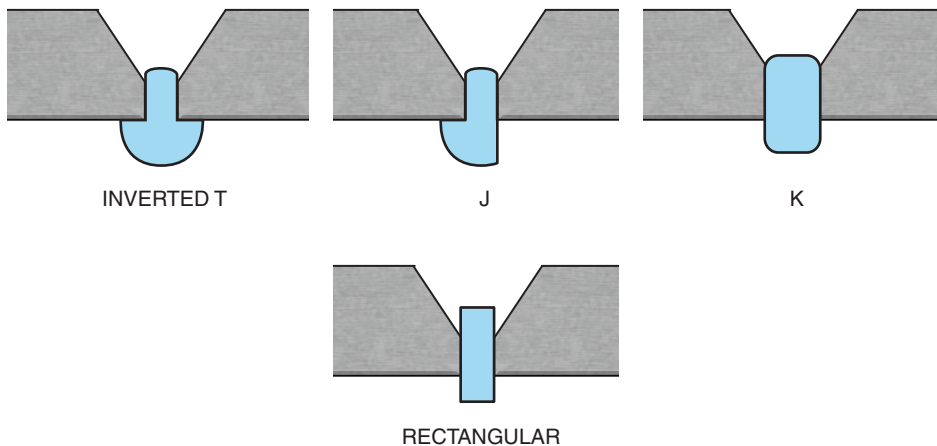


FIGURE 7-10 Consumable inserts for open root welding.

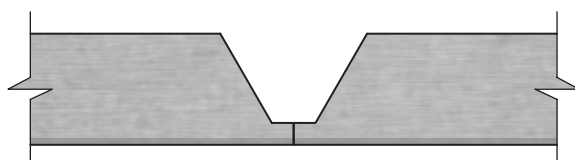


FIGURE 7-11 Extended land.
 Source: AWS D1.2/D1.2M:2003, Figure 3.31 reproduced with permission of the American Welding Society, Miami, Florida.

FILL PASS WELDING

OTHER THAN ADJUSTING THE POWER SOURCE AND SELECTING AN ELECTRODE, WHAT ELSE CAN THE WELDER DO TO IMPROVE WELD QUALITY?

Once the root pass is completed, it must be cleaned thoroughly to ensure that any slag, cold starts, or any other irregularity, which may reduce fusion in the next passes, are removed. Interpass cleaning—chipping, wire brushing, and grinding are necessary steps in producing sound welds.

When using EXX10 and EXX11 class electrodes with SMAW, a **hot pass** may be used after brushing and grinding. Due to the turbulent nature of the arc, electrode manipulation, and narrow groove faces of the joint root, these electrodes tend to leave a weld face that can be more difficult to clean than those of welds made with low-hydrogen-type electrodes. A hot pass is a second pass, at higher welding currents, used to help eliminate and float out any difficult to remove slag particles.

After the root pass and hot pass (if needed) are completed, the groove is filled by layering with overlapping weld beads. **Fill passes** are used to complete the interior portion of multipass groove welds. Fill passes are used to nearly fill the groove, leaving only enough space for the cap passes, the final weld layer. It is necessary to maintain an even layer-by-layer approach at this stage.

WHAT LIMITS EXIST FOR WELD BEAD WIDTH OR THICKNESS?

Whether using stringer or weave beads, code requirements must be met. Some codes set limits on bead width and layer thickness (**FIGURE 7-12**) for qualified procedures. *AWS D1.1 Structural Welding Code-Steel-2010*, e.g., limits a fill pass layer thickness for SMAW. It also limits single pass layer width for GMAW and FCAW processes.

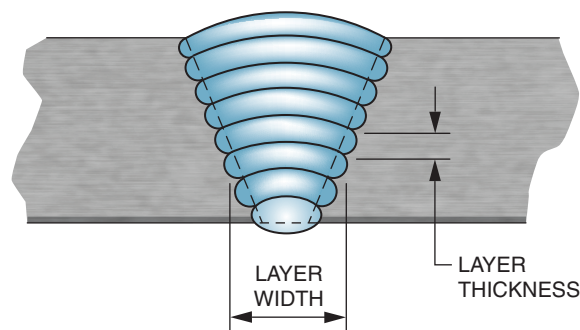


FIGURE 7-12 Example of layer thickness and width.

CAP PASS WELDING

The **cap pass** is the final visible weld layer on a multipass groove weld. Several factors must be met for the final weld and weld layer to be acceptable. First of all, the weld penetration including reinforcement has a minimum thickness equal to the base metal thickness. Second, the reinforcement height cannot exceed code requirements, and in most cases, this is 1/8" maximum. The cap pass width should be as narrow as possible while filling the groove completely. Finally, the weld must have a smooth transition to the base metal at the weld toes. **FIGURE 7-13** shows a

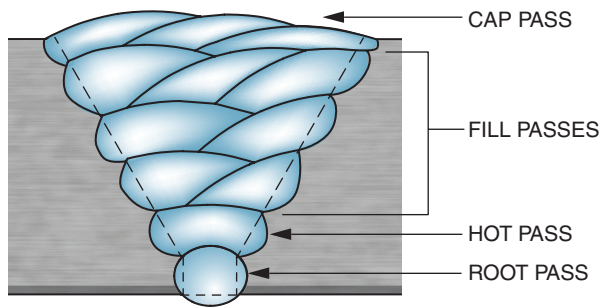


FIGURE 7-13 completed groove weld and layers (stringer bead technique).

completed groove joint filled with multipass stringer weld beads and all layers: root pass, hot pass, fill passes, and cap pass.

WELDING PROCESSES AND PROCEDURES

WHAT PROCESSES AND PROCEDURES ARE USED FOR PIPE WELDING?

For shielded metal arc welding, the EXX10 and EXX11 electrode classifications are commonly used for welding the root pass on carbon steel pipe. These electrodes have an arc characteristic that provides good root penetration and fusion while minimizing slag entrapment, where the low-hydrogen-type electrodes like the EXX18 fail to produce the desired results for root pass welding. The EXX10 and EXX11 electrodes can be used exclusively, or they may be used for the root pass, with remaining fill and cap passes completed with the low-hydrogen electrodes.

Gas tungsten arc welding provides superior weld quality in food-grade applications and for pipe welding, where nondestructive examination such as ultrasonic and radiographic testing may be required. The use of argon shielding without fluxes, and with the aid of remote amperage technology, allows a great degree of arc control for open root welding. These factors make GTAW a good choice for small diameter, thin walled pipe. In addition to thin walled pipe, GTAW can be a good choice for root pass welding, while completing the remaining fill and cap passes with a higher deposition process like GMAW or with low-hydrogen SMAW.

Given the more complicated application, heating with the torch and the manual addition of filler metal, a couple illustrations will help review techniques unique to GTAW. **FIGURE 7-14** demonstrates the addition of the filler metal in relation to the pipe base metal and the torch travel angle. Too steep of a travel angle,

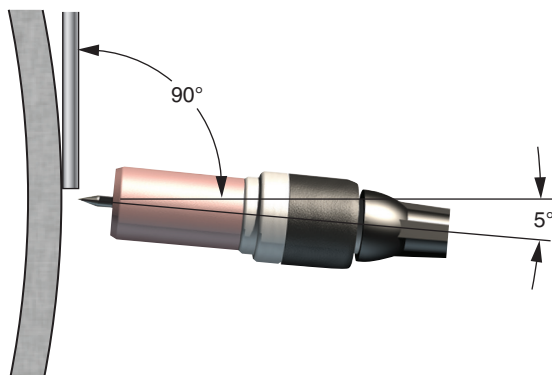
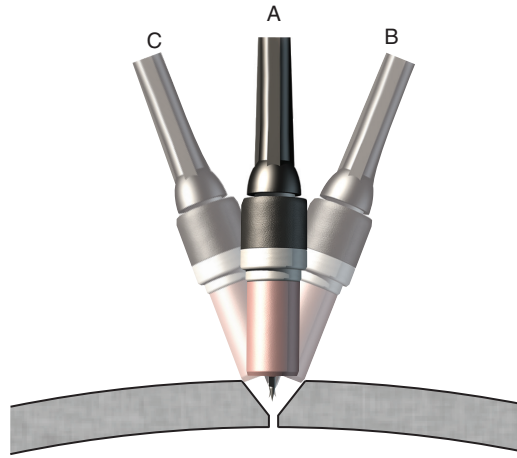


FIGURE 7-14 GTAW torch and filler metal positions.

FIGURE 7-15 Torch position and work angle view (when walking the cup, rest the nozzle on the groove face and use appropriate travel angle).



one that directs the arc toward the filler metal and away from the base metal will cause the filler metal to ball up and reduce fusion.

The work angle for 1G and 5G welds holds the torch directly perpendicular to the work surface as shown in torch position “A” in **FIGURE 7-15**. Positions “B” and “C” show alternate torch positions for walking the cup along the groove faces, which provides good control of the weld pool and produces a good weld bead profile.

Finally, GMAW can be used where advantageous for pipe welding. While short circuit transfer has its limits when heavy wall pipe applications are concerned, it has its place on thin-walled pipe and for welding root passes where it performs well, especially with vertical down-welding progression. In addition, new advances in welding power source and process design allow a very high degree of control for root pass welding and bridging gaps.

Use the following **Tables 7-2** through **7-13**, and recommendations as a basic step-by-step instruction along with the techniques sections of Chapter 3 Shielded Metal Arc Welding, Chapter 4 Gas Metal Arc Welding and Chapter 6 Gas Tungsten Arc Welding. **FIGURES 7-18** through **7-41** demonstrate travel angles and work angles for each process and welding position. **FIGURE 7-16** shows recommended bevel angle, root opening, and root face dimensions. **FIGURE 7-17** shows the various welding progressions associated with the 5G pipe position. Welding progressions for 6G pipe are similar to that of 5G pipe, with some horizontal progression included.

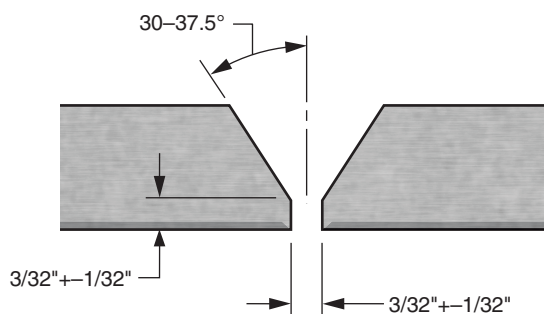
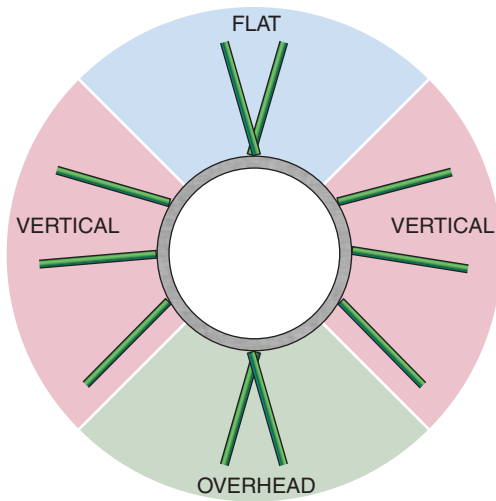


FIGURE 7-16 Groove design.



WELDING PROGRESSIONS ASSOCIATED WITH THE 5G PIPE POSITION

FIGURE 7-17 Welding progressions associated with the 5G pipe position.

| SMAW pipe | |
|--|--|
| 1G Flat groove position | |
| | |
| <p>FIGURE 7-18 Travel angle.</p> | |
| | |
| <p>FIGURE 7-19 Work angle.</p> | |
| Instructions (refer to Chapter 3 techniques) | |
| Base metal | Carbon Steel |
| Current | DCEP |
| Root pass | EXX10 or EXX11 classification electrodes <ul style="list-style-type: none"> ▪ Backhand stringer, straight step whipping |

TABLE 7-2

| SMAW pipe | | |
|-------------------------|---|--|
| 1G Flat groove position | | |
| Hot pass | As needed | |
| Fill passes | Option 1 | Option 2 |
| | EXX10 or EXX11 classification electrodes <ul style="list-style-type: none"> ▪ Backhand stringer, straight step whipping, or circular weave | EXX18 classification electrode <ul style="list-style-type: none"> ▪ Stringer bead |
| Cover pass | Option 1 | Option 2 |
| | EXX10 or EXX11 classification electrodes <ul style="list-style-type: none"> ▪ Backhand stringer, straight step whipping, or circular weave | EXX18 classification electrode <ul style="list-style-type: none"> ▪ Stringer bead |
| Comments | Use as little weave as possible | |

TABLE 7-2 Continued

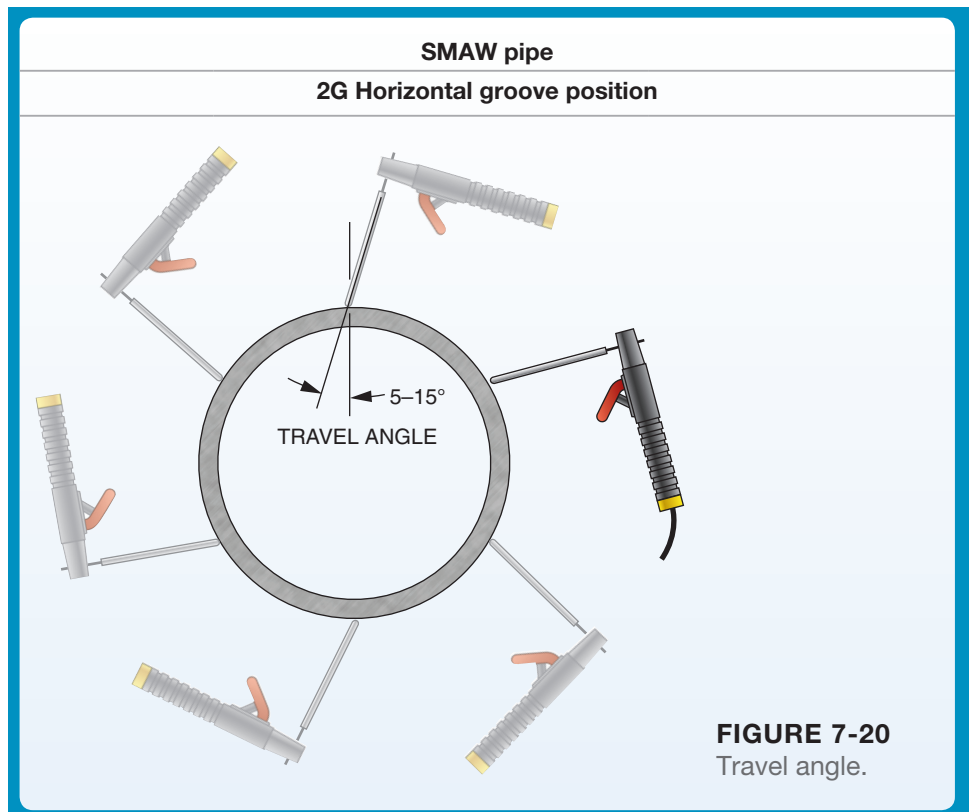


TABLE 7-3

SMAW pipe

2G Horizontal groove position

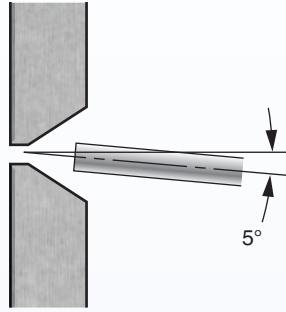


FIGURE 7-21 Work angle.

Instructions (refer to Chapter 3 techniques)

| | | |
|-------------|---|--|
| Base metal | Carbon steel | |
| Current | DCEP | |
| Root pass | EXX10 or EXX11 classification electrodes <ul style="list-style-type: none"> ▪ Backhand stringer, straight step whipping | |
| Hot pass | As needed | |
| Fill passes | Option 1 | Option 2 |
| | EXX10 or EXX11 classification electrodes <ul style="list-style-type: none"> ▪ Backhand stringer, straight step whipping, or circular weave | EXX18 classification electrode <ul style="list-style-type: none"> ▪ Stringer bead |
| Cover pass | Option 1 | Option 2 |
| | EXX10 or EXX11 classification electrodes <ul style="list-style-type: none"> ▪ Backhand stringer, straight step whipping, or circular weave | EXX18 classification electrode <ul style="list-style-type: none"> ▪ Stringer bead |
| Comments | <ul style="list-style-type: none"> ▪ The work angle on this horizontal progression weld requires a slight upward angle to compensate for the effects of gravity on the weld pool. Usually about a 5 degree angle is sufficient. ▪ Use as little weave as possible | |

TABLE 7-3 Continued

SMAW pipe

5G Vertical groove position

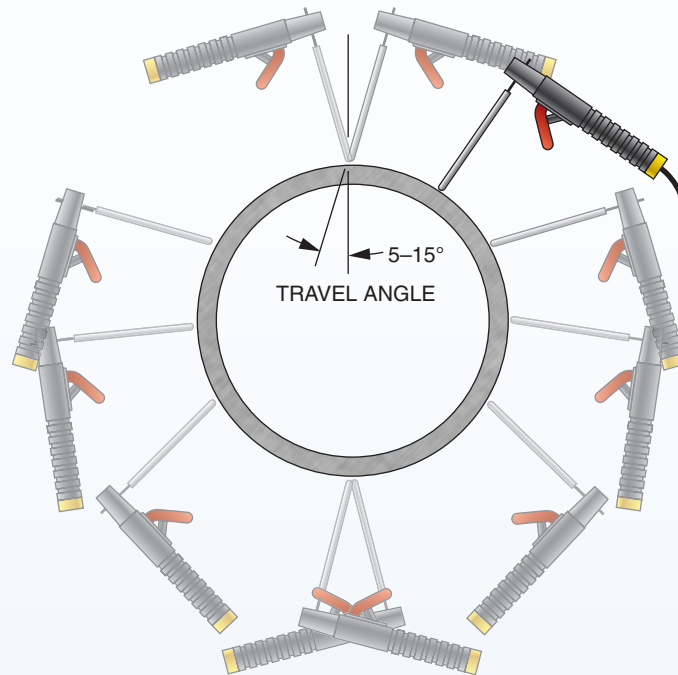


FIGURE 7-22
Travel angle.

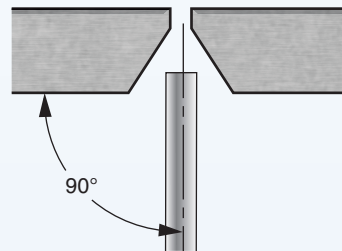


FIGURE 7-23 Work angle.

Instructions (refer to Chapter 3 techniques)

| | |
|-------------|---|
| Base Metal | Carbon Steel |
| Current | DCEP |
| Progression | Vertical down |
| Root pass | EXX10 or EXX11 classification electrodes <ul style="list-style-type: none"> ▪ Backhand stringer, straight step whipping |
| Hot pass | As needed |
| Fill passes | EXX10 or EXX11 classification electrodes <ul style="list-style-type: none"> ▪ Backhand stringer, straight step whipping |
| Cover pass | EXX10 or EXX11 classification electrodes <ul style="list-style-type: none"> ▪ Backhand stringer, straight step whipping |
| Progression | Vertical up |
| Root pass | EXX10 or EXX11 classification electrodes <ul style="list-style-type: none"> ▪ Backhand stringer, straight step whipping, or circular weave |

TABLE 7-4

| SMAW pipe | | |
|-----------------------------|---|--|
| 5G Vertical groove position | | |
| Hot pass | As needed | |
| | Option 1 | Option 2 |
| Fill passes | EXX10 or EXX11 classification electrodes <ul style="list-style-type: none"> ▪ Backhand stringer, straight step whipping, or circular weave | EXX18 classification electrode <ul style="list-style-type: none"> ▪ Stringer or weave |
| Cover pass | EXX60 classification electrodes <ul style="list-style-type: none"> ▪ Backhand stringer, straight step whipping, or circular weave | EXX18 classification electrode <ul style="list-style-type: none"> ▪ stringer or weave |
| Comments | Use as little weave as possible | |

TABLE 7-4 Continued

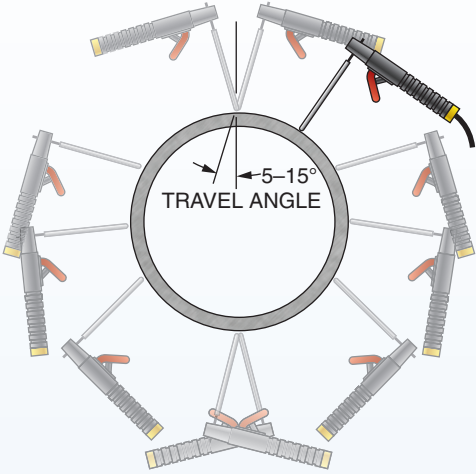
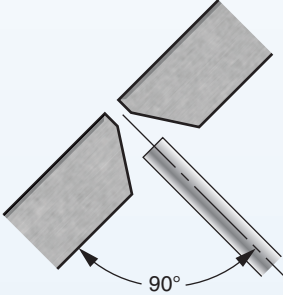
| SMAW pipe | |
|---|--|
| 6G Vertical groove position | |
|  | |
| <p>FIGURE 7-24 Travel angle.</p> | |
|  | |
| <p>FIGURE 7-25 Work Angle.</p> | |
| Instructions (refer to Chapter 3 techniques) | |
| Base Metal | Carbon Steel |
| Current | DCEP |
| Progression | Vertical down |
| Root pass | EXX10 or EXX11 classification electrodes <ul style="list-style-type: none"> ▪ Backhand stringer, straight step whipping |

TABLE 7-5

| SMAW pipe | | |
|-----------------------------|--|--|
| 6G Vertical groove position | | |
| Hot pass | As needed | |
| Fill passes | EXX10 or EXX11 classification electrodes <ul style="list-style-type: none"> ▪ Backhand stringer, straight step whipping | |
| Cover pass | EXX10 or EXX11 classification electrodes <ul style="list-style-type: none"> ▪ Backhand stringer, straight step whipping, or circular weave | |
| Progression | Vertical up | |
| Root pass | EXX10 or EXX11 classification electrodes <ul style="list-style-type: none"> ▪ Backhand stringer, straight step whipping, or circular weave | |
| Hot pass | As needed | |
| | Option 1 | Option 2 |
| Fill passes | EXX10 or EXX11 classification electrodes <ul style="list-style-type: none"> ▪ Backhand stringer, straight step whipping, or circular weave | EXX18 classification electrode <ul style="list-style-type: none"> ▪ Stringer or weave |
| Cover pass | <ul style="list-style-type: none"> ▪ EXX10 or EXX11 classification electrodes ▪ Backhand stringer, straight step whipping, or circular weave | EXX18 classification electrode <ul style="list-style-type: none"> ▪ Stringer or weave |
| Comments | Use as little weave as possible | |

TABLE 7-5 Continued

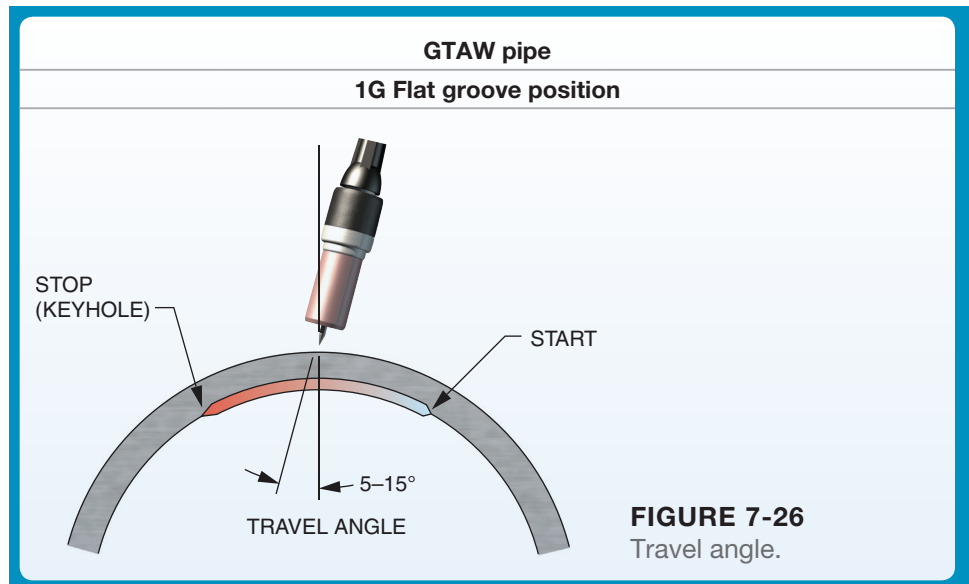


TABLE 7-6

GTAW pipe

1G Flat groove position

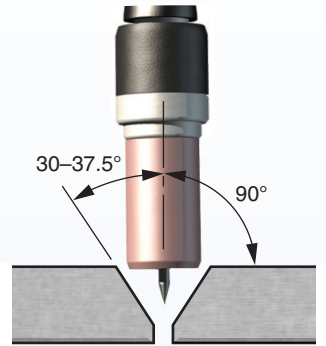


FIGURE 7-27 Work angle.

Instructions (refer to Chapter 6 techniques)

| | | |
|---------------------------|--|---------------------|
| Base Metal | Carbon Steel | |
| Current | <ul style="list-style-type: none"> ▪ DCEN | |
| Shielding | <ul style="list-style-type: none"> ▪ Argon (100%) | |
| Root pass | ER70S-2 classification electrodes <ul style="list-style-type: none"> ▪ Use forehand stringer, circular weave, or walk the cup | |
| Second pass and Fill pass | Option 1: Used for thin wall pipe or tubing | |
| | ER70S-2 classification electrodes <ul style="list-style-type: none"> ▪ Use forehand stringer, circular weave, or walk the cup | |
| Cover pass | ER70S-2 classification electrodes <ul style="list-style-type: none"> ▪ Use forehand stringer, circular weave, or walk the cup | |
| Fill passes | Option 2 | Option 3 |
| | Use SMAW Procedures | Use GMAW Procedures |
| Cover pass | Use SMAW Procedures | Use GMAW Procedures |
| Comments | <ul style="list-style-type: none"> ▪ Pulsed GTAW can be substituted on the root pass for superior weld pool and keyhole control. ▪ Use as little weave as possible | |

TABLE 7-6 Continued

GTAW pipe

2G Horizontal groove position

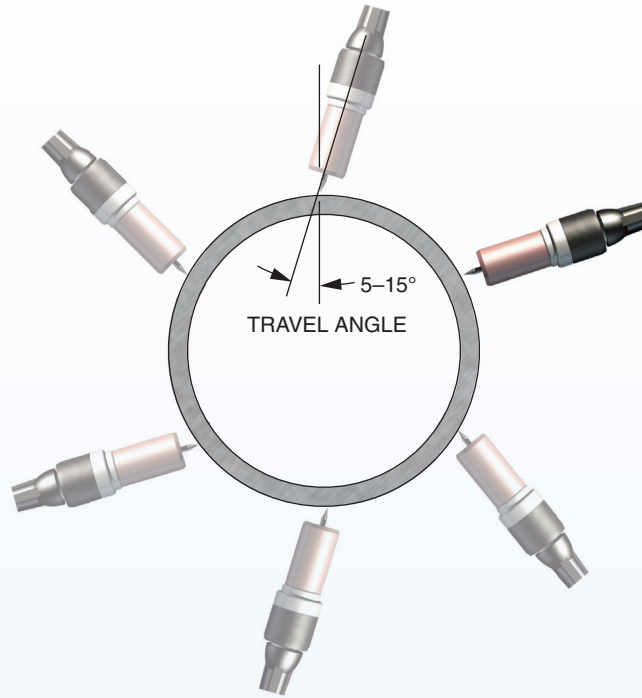


FIGURE 7-28
Travel angle.

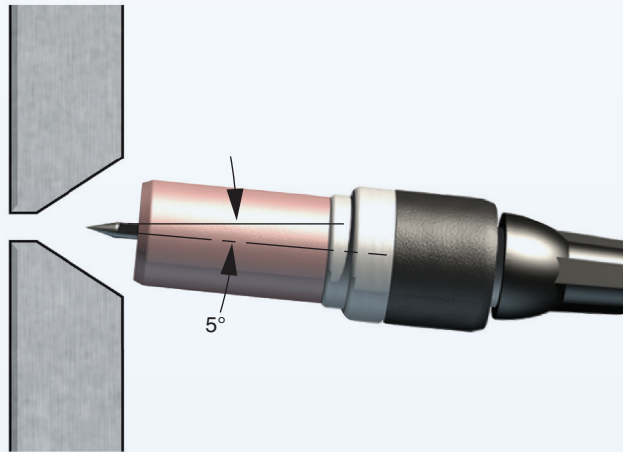


FIGURE 7-29
Work Angle.

| | Instructions (refer to Chapter 6 techniques) |
|---------------------------|--|
| Base Metal | Carbon Steel |
| Current | <ul style="list-style-type: none"> ▪ DCEN |
| Shielding | <ul style="list-style-type: none"> ▪ Argon (100%) |
| Root pass | <ul style="list-style-type: none"> ▪ ER70S-2 classification electrodes ▪ Use forehand stringer, circular weave, or walk the cup |
| Second pass and Fill pass | Option 1: Used for thin wall pipe or tubing <ul style="list-style-type: none"> ▪ ER70S-2 classification electrodes Use forehand stringer, circular weave, or walk the cup |
| Cover pass | ER70S-2 classification electrodes Use forehand stringer, circular weave, or walk the cup |

TABLE 7-7

| GTAW pipe | | |
|-------------------------------|--|---------------------|
| 2G Horizontal groove position | | |
| Fill passes | Option 2 | Option 3 |
| | Use SMAW procedures | Use GMAW procedures |
| Cover pass | Use SMAW procedures | Use GMAW procedures |
| Comments | <ul style="list-style-type: none"> ▪ The work angle on this horizontal progression weld requires a slight upward angle to compensate for the effects of gravity on the weld pool. Usually about a 5 degree angle is sufficient. ▪ Pulsed GTAW can be substituted on the root pass for superior weld pool and keyhole control. ▪ Use as little weave as possible | |

TABLE 7-7 Continued

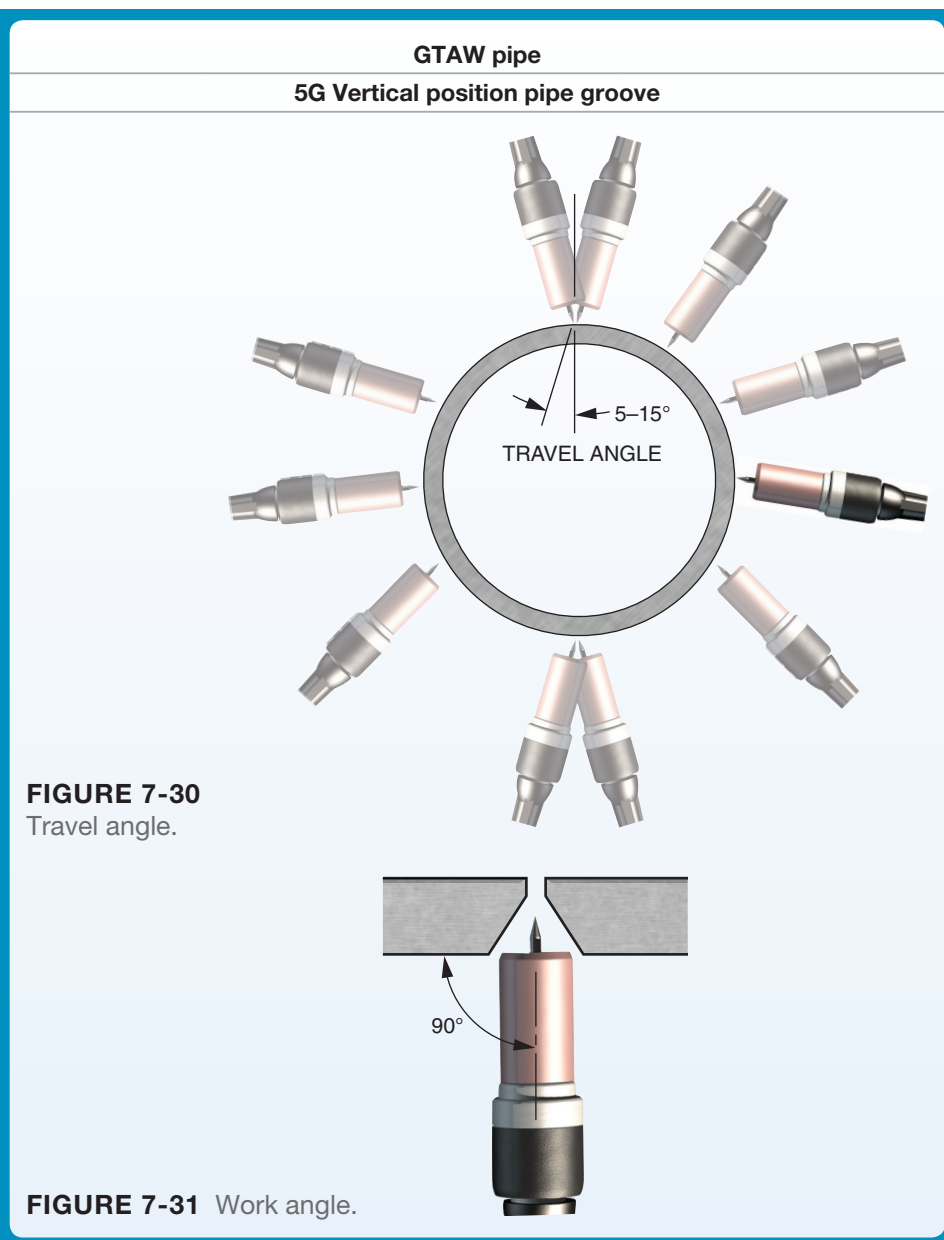


FIGURE 7-30
Travel angle.

FIGURE 7-31 Work angle.

TABLE 7-8

| GTAW pipe | | |
|----------------------------------|--|---------------------|
| 5G Vertical position pipe groove | | |
| | Instructions (refer to Chapter 6 techniques) | |
| Base Metal | Carbon Steel | |
| Current | DCEN | |
| Shielding | Argon (100%) | |
| Progression | Vertical up | |
| Root pass | ER70S-2 classification electrodes <ul style="list-style-type: none"> Use forehand stringer, circular weave, or walk the cup | |
| Second pass and Fill pass | Option 1: Used for thin wall pipe or tubing | |
| | ER70S-2 classification electrodes <ul style="list-style-type: none"> Use forehand stringer, circular weave, or walk the cup | |
| Cover pass | ER70S-2 classification electrodes Use forehand stringer, circular weave, or walk the cup | |
| Fill passes | Option 2 | Option 3 |
| | Use SMAW procedures | Use GMAW procedures |
| Cover pass | Use SMAW procedures | Use GMAW procedures |
| Comments | <ul style="list-style-type: none"> Pulsed GTAW can be substituted on the root pass for superior weld pool and keyhole control. Use as little weave as possible | |

TABLE 7-8 Continued

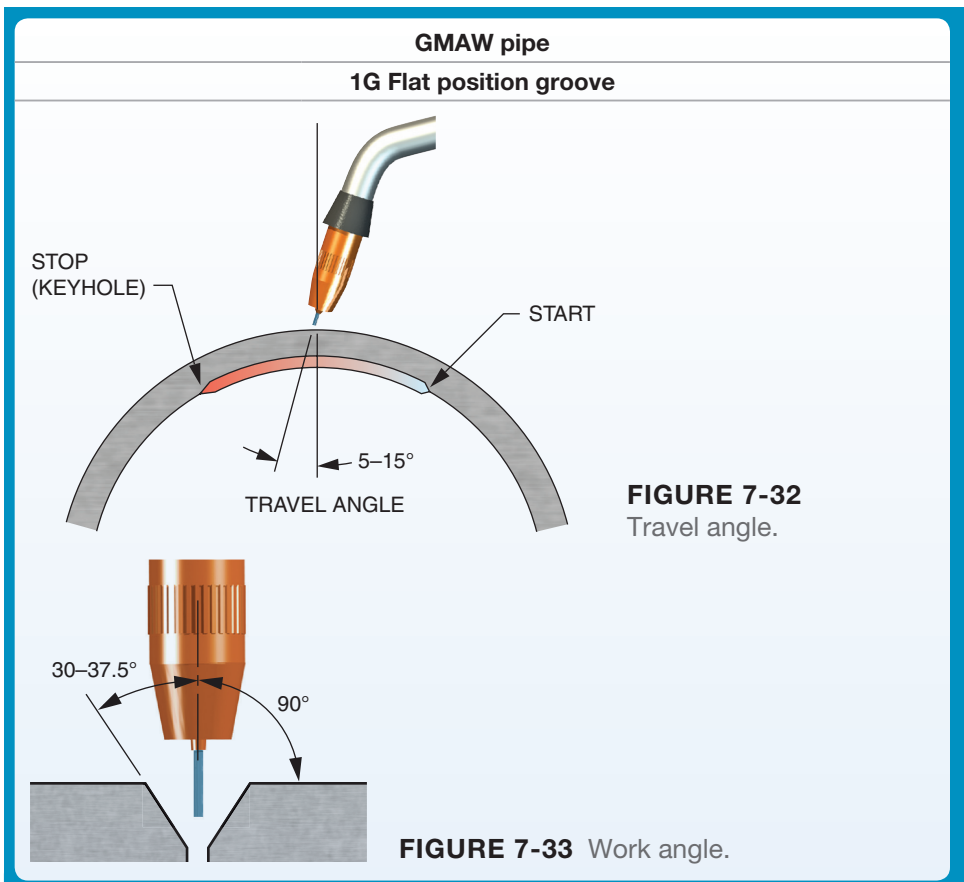


TABLE 7-9

| GMAW pipe | |
|--|---|
| 1G Flat position groove | |
| Instructions (refer to Chapter 4 techniques) | |
| Base Metal | Carbon Steel |
| Current | DCEP |
| Shielding | Argon/carbon dioxide |
| Electrode classification | ER70S-6 or ER70S-3 |
| Root pass | Backhand stringer or forehand stringer bead, or weave |
| Fill passes | Backhand stringer or forehand stringer bead, or weave |
| Cover pass | Backhand stringer or forehand stringer bead, or weave |
| Comments | Use as little weave as possible |

TABLE 7-9 Continued

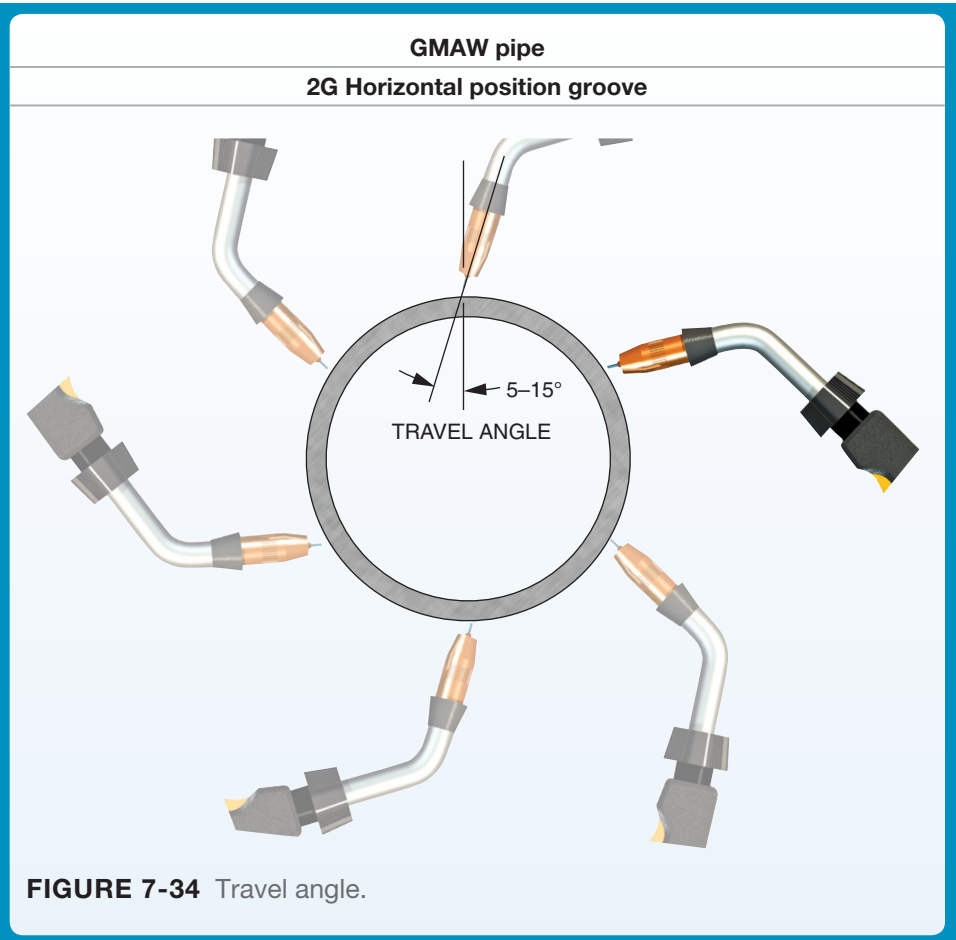


TABLE 7-10

GMAW pipe

2G Horizontal position groove

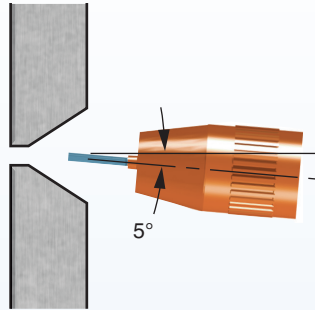


FIGURE 7-35 Work angle.

Instructions (refer to Chapter 4 techniques)

| | |
|--------------------------|---|
| Base Metal | Carbon Steel |
| Current | DCEP |
| Shielding | Argon/carbon dioxide |
| Electrode classification | ER70S-6 or ER70S-3 |
| Root pass | Backhand stringer or forehand stringer bead, or weave |
| Fill passes | Backhand stringer or forehand stringer bead, or weave |
| Cover pass | Backhand stringer or forehand stringer bead, or weave |
| Comments | <ul style="list-style-type: none"> ▪ The work angle on this horizontal progression weld requires a slight upward angle to compensate for the effects of gravity on the weld pool. Usually about a 5 degree angle is sufficient. ▪ Use as little weave as possible |

TABLE 7-10 Continued

GMAW pipe

5G Vertical groove position

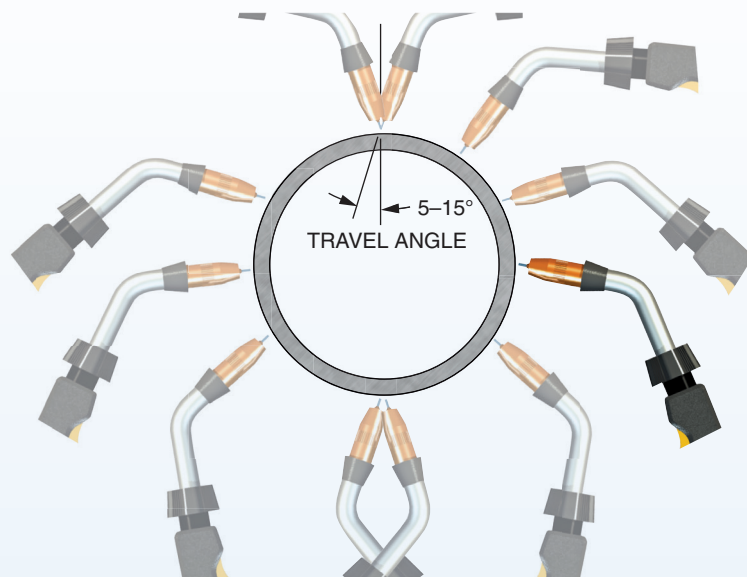


FIGURE 7-36 Travel angle.

TABLE 7-11

GMAW pipe

5G Vertical groove position

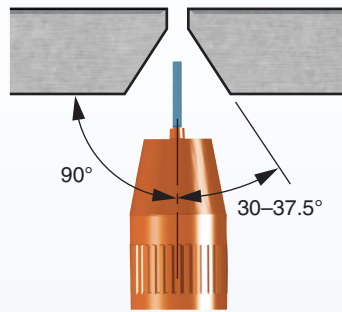


FIGURE 7-37 Work angle.

Instructions (refer to Chapter 4 techniques)

| | |
|--------------------------|---|
| Base Metal | Carbon Steel |
| Current | DCEP |
| Shielding | Argon/carbon dioxide |
| Electrode classification | ER70S-6 or ER70S-3 |
| Progression | Vertical down |
| Root pass | Backhand stringer or weave |
| Fill passes | Backhand stringer or weave |
| Cover pass | Backhand stringer or weave |
| Progression | Vertical up |
| Root pass | Root pass only vertical down—backhand stringer or weave |
| Fill passes | Forehand stringer bead, or tight weave |
| Cover pass | Forehand stringer bead, or tight weave |
| Comments | Use as little weave as possible |

TABLE 7-11 Continued

GTAW pipe

1G Flat groove position

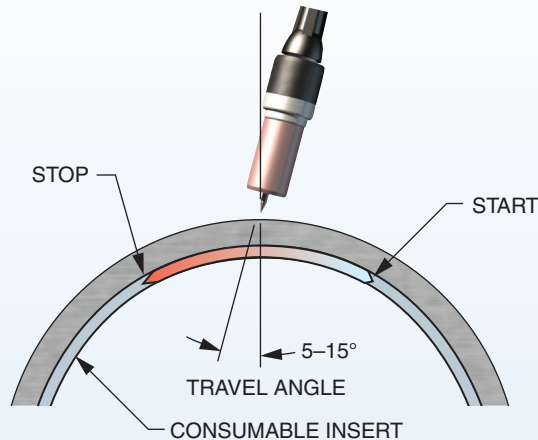


FIGURE 7-38 Travel Angle.

TABLE 7-12

GTAW pipe

1G Flat groove position

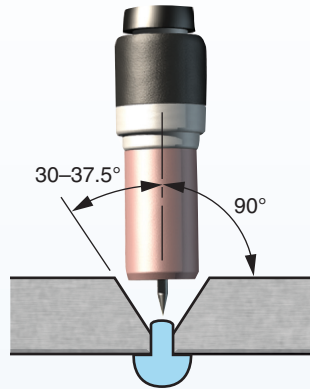


FIGURE 7-39 Work angle.

Instructions (refer to Chapter 6 techniques)

| | |
|--------------|--|
| Base metal | Stainless steel—304L |
| Current | DCEN |
| Shielding | Argon (100%) |
| Electrode | EWCe-2, sharpen to point |
| Insert | Stainless steel—304L |
| Filler metal | ER308L |
| Root pass | Use forehand stringer, circular weave, or walk the cup |
| Fill passes | Use forehand stringer, circular weave, or walk the cup |
| Cover pass | Use forehand stringer, circular weave, or walk the cup |
| Comments | Back purge with argon or nitrogen, use as little weave as possible |

TABLE 7-12 Continued

GMAW pipe

1G Flat groove position

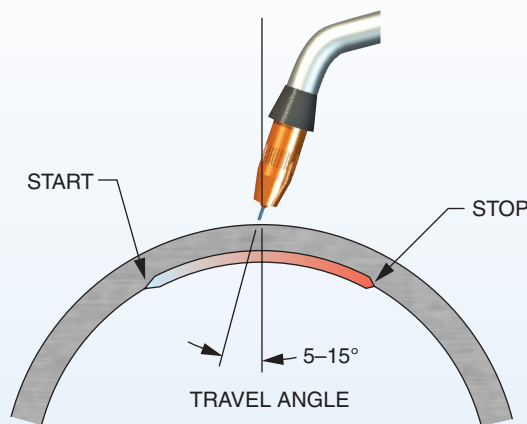


FIGURE 7-40 Travel angle.

TABLE 7-13

GMAW pipe

1G Flat groove position

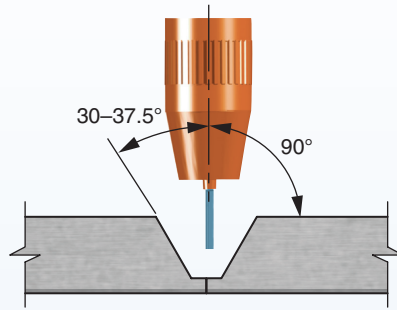


FIGURE 7-41 Work angle.

Instructions (refer to Chapter 4 techniques)

| | |
|-------------|-------------------------|
| Base metal | Aluminum -6061 |
| Current | DCEP |
| Shielding | Argon (100%) |
| Electrode | ER4043 |
| Root pass | Use forehand stringer |
| Fill passes | Use forehand stringer |
| Cap pass | Use forehand stringer |
| Comments | Use GTAW to Tack/fit-up |

TABLE 7-13 Continued

CHAPTER QUESTIONS/ASSIGNMENTS

MULTIPLE CHOICES

- Which welding position includes welding in flat, horizontal, and overhead progressions?
 - 1G
 - 2G
 - 4G
 - 5G
- Which electrodes classification is commonly used for welding the root pass on carbon steel pipe?
 - EXX10
 - EXX12
 - EXX14
 - EXX18
- What is the work angle for 2G pipe?
 - 5 degrees
 - 37 ½ degrees
 - 45 degrees
 - 60 degrees
- Which process works well with thin walled pipe in the vertical down position?
 - GTAW
 - FCAW
 - GMAW
 - SMAW
- Which of the following is used to float out any difficult to remove slag particles?
 - Root pass
 - Hot pass
 - Fill pass
 - Cap pass

FILL IN THE BLANK

6. Rather than welding in one linear direction the welder must constantly adjust the welding _____ to account for the curvature of the pipe.
7. The _____ is the initial pass deposited after the pipe is fit-up and tack welded together.
8. For larger _____ diameters used with _____ and GTAW the included angle may be as much as 70 degrees
9. Tack welds must have _____ joint penetration, and be large enough hold the pipe rigidly in place to withstand _____ and _____ forces introduced during placement of the root pass.
10. If the inside edges of the pipe are not _____ it will be difficult to maintain _____ joint penetration through the full length of the weld.

SHORT ANSWER

11. Mill scale, varnish, paint, rust, or other contaminants must be removed prior to joint fit-up to a distance of how much?
12. What will a properly shaped and sized keyhole do?
13. Where does arc initiation need to take place for all weld starts?
14. How are pipe pieces kept in alignment prior to tack welding?
15. Why must the root pass is completed be thoroughly cleaned?
16. How much space is left to fill in the groove after fill passes are complete?

TRUE/ FALSE

17. The cap pass should be as wide as possible.
18. The use of argon shielding without fluxes, and with the aid of remote amperage technology allow great degree of arc control for open root welding.
19. Tack welds are an integral part of the weld assembly.
20. If the keyhole closes fusion will be complete.
21. Four tack welds are usually sufficient for small diameter pipe.