# *HANDS-ON PRINT READING FOR WELDERS*

*WORKBOOK*

*Based on AWS A2.4:2012*



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Printed in the United States of America

10 9 8 7 6

ISBN 0-9624986-2-9

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# INTRODUCTION

Welding symbols and print reading are indispensable skills for the modern welder. This hands-on course was developed and fine-tuned over a ten-year period at Monroe County Community College (MI) for the Welding Technology program.

The hands-on nature of this course makes it unique among typical print reading courses. In most textbook-based courses, students simply look at numerous sample prints and answer various questions in hope that they will learn to read prints. In this course, however, building weldment models according to prints leaves no doubt as to print reading ability. Using foam instead of steel, and glue instead of filler metal, allows the student to make both simple and advanced weldments while concentrating on building print reading skills. The course finishes with three weldment samples which match the AWS Certified Entry-Level Welder test weldments. Those welding students who are part of the AWS SENSE program will find this aspect *Hands-On Print Reading for Welders* especially valuable.

# TOOLS AND SUPPLIES

For this hands-on course, you will be constructing ten weldment projects from expanded polystyrene foam board, PVC pipe, and hot-melt glue. In addition to the prints in this workbook, the following supplies and tools will be used for constructing the models in this course:

## Expendable Supplies

- 11″ x 17″ x $^{3}/_{16}$″ (5mm) expanded polystyrene foam, 4 sheets. Refer to the cutting sheet to ensure that you will be able to obtain all the needed pieces from the 4 sheets. There will be a little left over for rework if needed.
- 11″ x 17″ x $^{5}/_{8}$″ (16mm) expanded polystyrene foam, 1 sheet. For two of the projects, you will be gluing three layers of $^{5}/_{8}$″ foam together with PVA (white glue) to make a thicker block.
- ¾″ Schedule 40 PVC pipe, 7 pieces of assorted lengths.
- PVA (white glue).
- Low temperature glue sticks. Don't use high temperature glue sticks on polystyrene foam—it will melt the foam.

## Tools

- Safety Glasses. Always wear safety glasses when working with tools.
- Basic drafting kit, including compass and protractor.
- Square.
- Inch/metric tape measure.
- Cutting board. Always use the cutting board when cutting foam with a razor knife. Don't use this board for food, especially after using it in the shop.
- Razor knife.
- Hole saw. You can use the hole saw by hand to cut foam, or chuck it into a drill press (not included).
- Fine tooth saw. Good for cutting thick foam pieces.
- Low temperature glue gun. Use with the low-temperature glue sticks for "welding" the models together.

# 1.  Introduction to Welding Symbols

## Purpose of Welding Symbols

Welding symbols are used on engineering drawings to convey welding, brazing, and/or nondestructive examination requirements.  They can be simple, showing only the weld locations, or complex, showing all aspects of a weld including joint design, type of weld, extent of welding, finishing method, and even the welding process to be used. The welding symbols presented in this text are based on the most current edition of AWS A2.4, *Standard Symbols for Welding, Brazing, and Nondestructive Examination*, published by the American Welding Society.  These are the symbols used on drawings throughout the United States of America.  Welding symbols used in Europe and Asia are similar, with the major difference being in the appearance of the reference line and the use of only metric measurements.

The forward to AWS A2.4:2007 states the need for welding symbols quite clearly:

> Joining processes and examination methods cannot take their proper place as fabricating tools unless means are provided for conveying information from the designer to joining and inspection personnel.  The symbols in this publication are intended to be used to facilitate communication among the designer, fabrication, and inspection personnel.  Statements such as “to be welded throughout” or “to be completely welded,” in effect, transfer the design responsibility from the designer to production personnel, who cannot be expected to know design requirements.

What remains unfortunate in the welding industry is that while many welders study welding symbols extensively, many engineers and designers do not; and therefore it may be up to the welder to interpret the designer’s intent from often incorrectly drawn welding symbols.  A thorough understanding of proper welding symbols by both welder and designer is essential to transmit the design intent to the finished product.

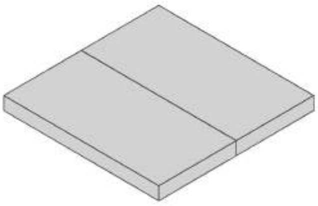
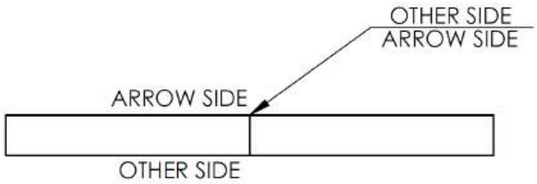
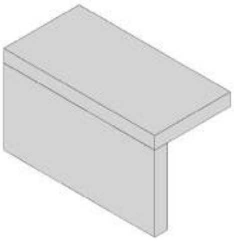
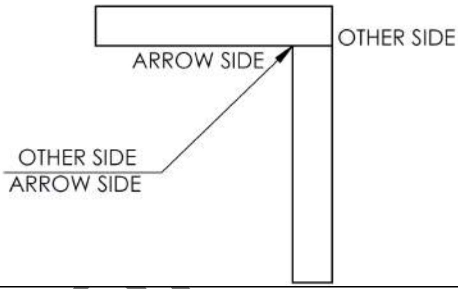
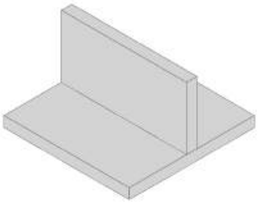
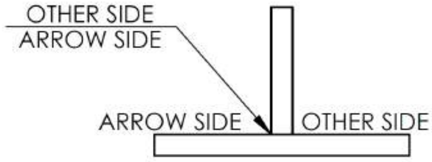
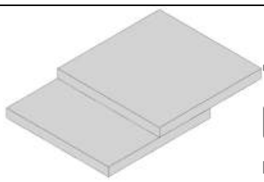
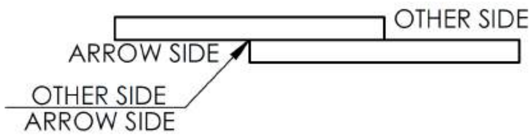
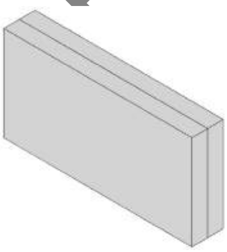
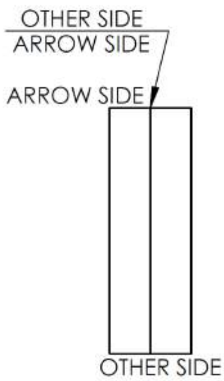


## Reference Line and Arrow

All welding symbols are based on a horizontal reference line.  On a print, the reference line is approximately 1-inch long, and is always horizontal.  An arrow is drawn from one end of the reference line to the weld joint on the drawing. There may not be arrows coming off both ends of the reference line; the end of the reference line opposite the arrow is reserved for a tail bracket (more on this in a later chapter).  The information about the weld, which is placed on the reference line, is always presented in the same order regardless of which end of the reference line the arrow is attached.

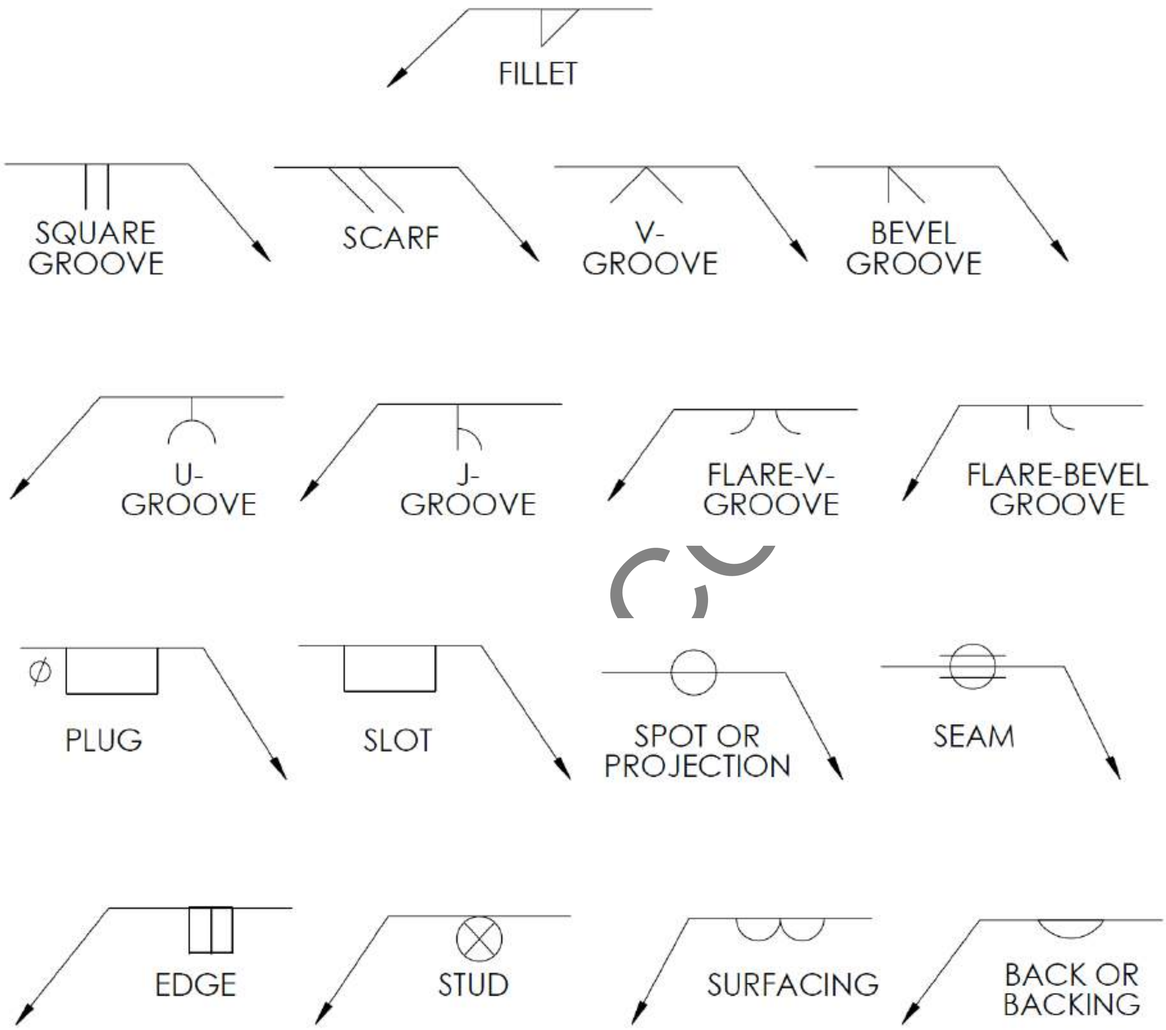
Each weld joint on a drawing will have one, and only one, welding symbol.  The welding symbol is usually shown in the drawing view that most clearly shows the weld location.

The same weld symbol is never shown in two different drawing views, just as dimensions on a drawing are never shown in two different views.  As shown in the following illustration, a weld joint has two sides: the “arrow side” (the side which the arrow is pointing at) and the “other side” (which is found by following the joint root to the side opposite the arrow.  Welding information about the “arrow side” of the joint is placed below the reference line, while information about the “other side” of the joint is place above the reference line.

| | |
|---|---|
| <br>BUTT JOINT |  |
| <br>CORNER JOINT |  |
| <br>T-JOINT |  |
| <br>LAP JOINT |  |
| <br>EDGE JOINT |  |

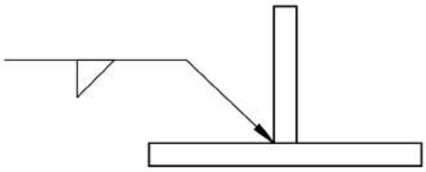
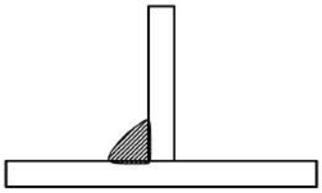
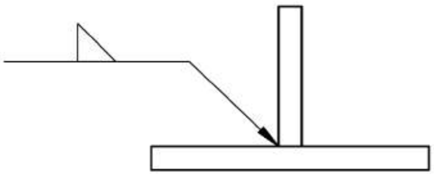
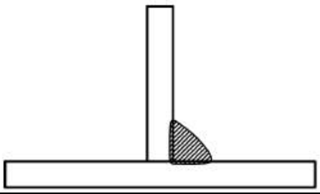
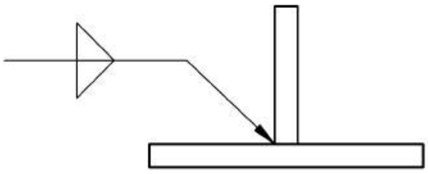
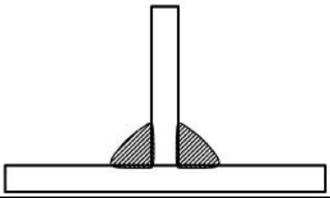
## Weld Symbols*

The most basic element of a welding symbol is the "weld symbol" itself, which tells what type of weld is required: fillet weld, groove weld, plug weld, etc. For groove welds, the type of joint preparation is specified by the weld symbol. There are 17 different weld symbols, shown in the following illustration. Through the course, we will learn them all; but for now, concentrate only on the fillet weld symbol, which looks like the cross-section of a fillet weld.

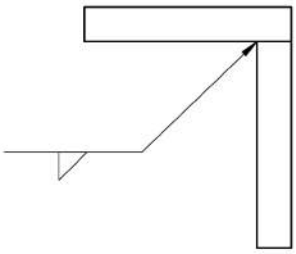
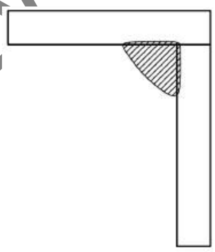
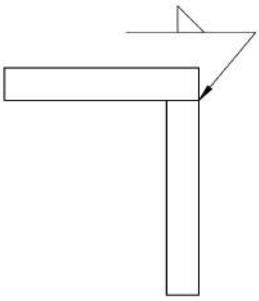
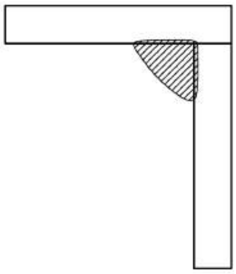


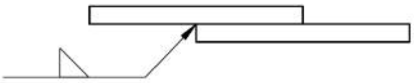
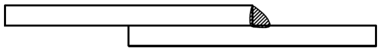
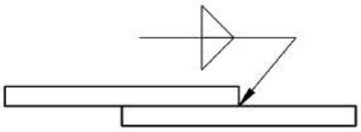
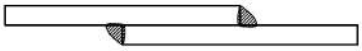
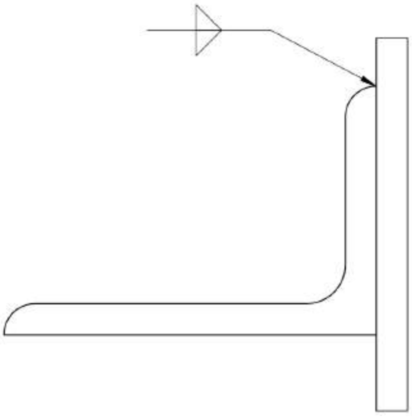
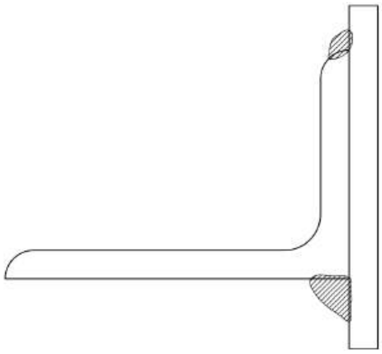
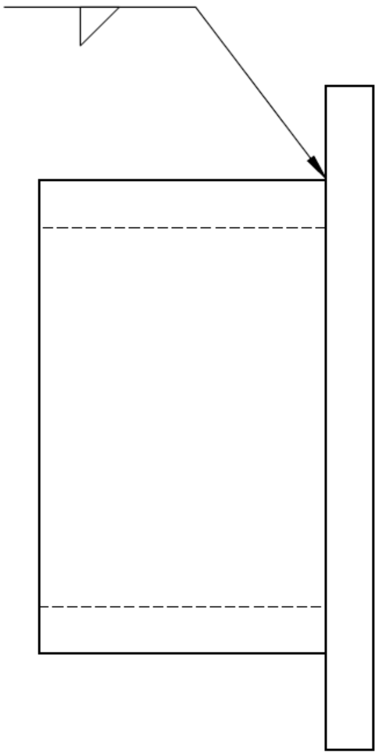
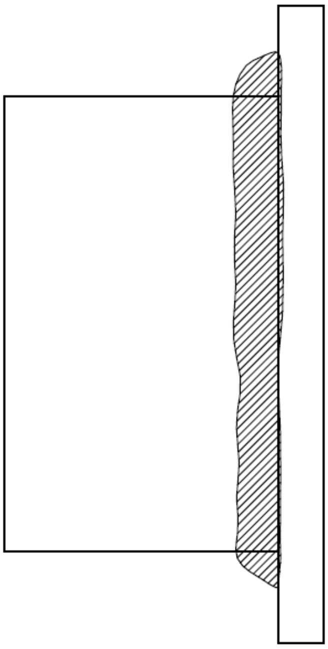
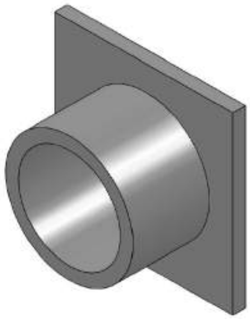

*Note that the terms "welding symbol" and "weld symbol" are different. The welding symbol is the reference line, arrow, and all the stuff associated with it, while the weld symbol is just the tiny picture of the type of weld placed on the reference line.

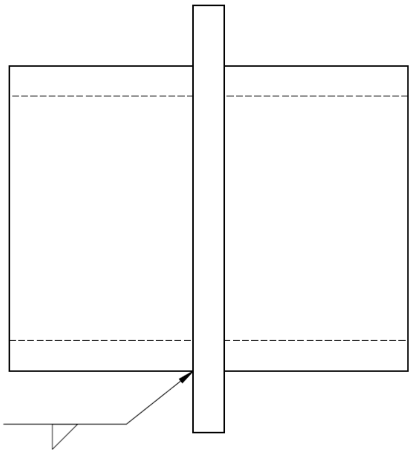
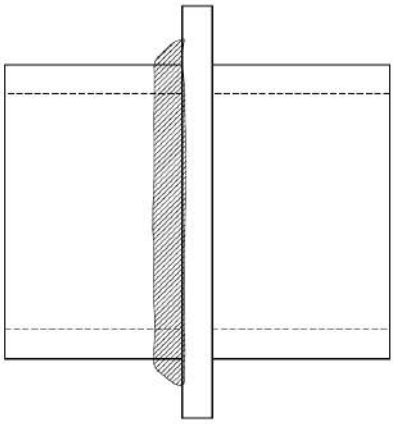
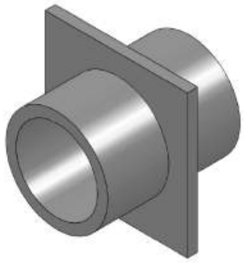
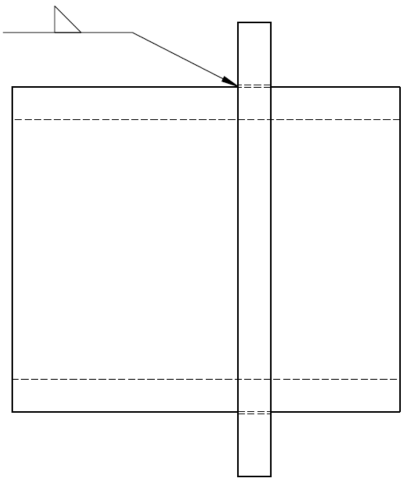
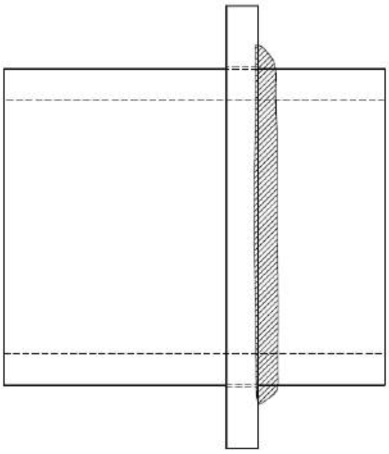
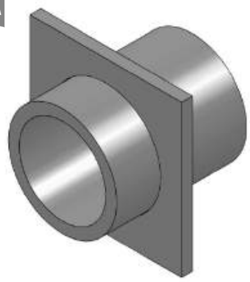
The weld symbol is placed below the reference line if the weld is to be located on the arrow side and above the reference line if the weld is to be located on the other side of the joint.  If both sides of the joint are to be welded, then two weld symbols are used, one above and one below the reference line.  The fillet weld symbol is always drawn with the left side vertical, regardless of the joint configuration or the side of the reference line with the arrow.

| PRINT | WELD EXAMPLE | COMMENTS |
|---|---|---|
|  |  | T-joint with fillet weld on arrow side. |
|  |  | T-joint with fillet weld on other side. |
|  |  | T-joint with fillet welds on both sides. |

Here are several examples welding symbols for fillet welds, showing arrow side and other side placement, in both plate and pipe.

| | | |
|---|---|---|
|  |  | Corner joint with fillet weld on arrow side. |
|  |  | Corner joint with fillet weld on other side. |

| PRINT | WELD EXAMPLE | COMMENTS |
|---|---|---|
|  |  | Lap joint with fillet weld on other side. |
|  |  | Lap joint with fillet weld on both sides. |
|  |  | Lap joint (structural angle to plate) with double-fillet welds. |
|  |  |  Fillet weld on arrow side, pipe to plate. |

| PRINT | WELD EXAMPLE | COMMENTS |
|---|---|---|
|  |  | <br>Fillet weld on arrow side, pipe to plate.<br><br>Note: this assembly has two pipes. Another welding symbol would be needed to weld the right-side pipe. The “other side” of the specified joint would be inside the pipe and usually cannot be welded unless the pipe is very short. |
|  |  | <br>Fillet weld on other side, pipe to plate.<br><br>Note: this assembly has one pipe which passes through a hole in the plate. Unlike the example above, the other side can be welded. |

**Welding Symbols Activities:**

- Chapter 1 Worksheet (page 95).

**Print Reading Lab Work:**

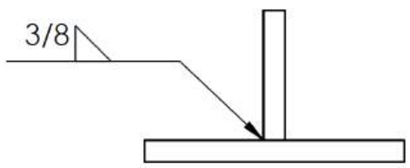
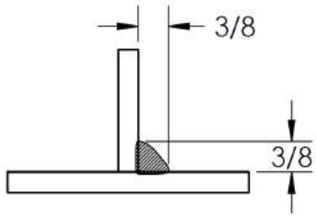
- Measuring Units and Tools Worksheet (page 157).
- Converting Measuring Units Worksheet (page 163).

## 2. Fillet Welds

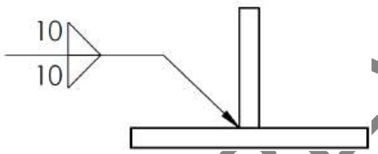
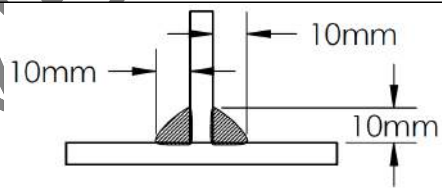
The fillet weld is the most common type of weld; for this reason we will study the fillet weld symbol and its application first. Many elements of the fillet welding symbol with carry over to the other welding symbols as well.

### Weld Size

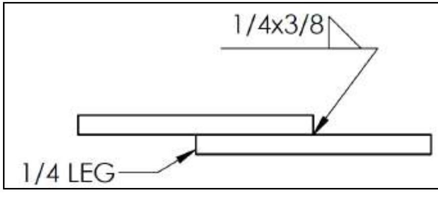
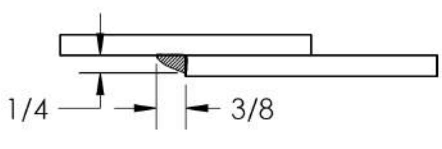
The size of the fillet weld is placed to the left of the fillet weld symbol. Weld sizes are specified on drawings using the same units as the drawing, either inches or millimeters. Inches are generally given using fractions, although decimal inches are acceptable, too. If the size of the weld is not specified on the welding symbol, then the size will usually be specified somewhere on the drawing, usually in a general note on the drawing which says something like “unless otherwise specified, all fillet welds ¼-inch.” The size may also be dimensioned in a detail drawing of the joint, although this is not a common practice. If no weld size is given on the drawing, then the welder may choose any weld size that will meet the strength and dimensional requirements of the weldment.

<table>
<tr><th>PRINT</th><th>WELD EXAMPLE</th><th>COMMENTS</th></tr>
<tr><td>
</td><td>
</td><td>T-joint with ⅜-inch fillet weld on other side.</td></tr>
</table>

On double-fillet welds, the size is given for both the arrow and other sides, even if they are the same size.

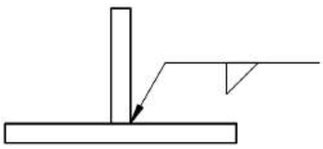
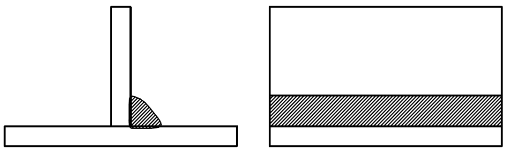
<table>
<tr><td>
</td><td>
</td><td>T-joint with 10mm fillet welds on both sides.</td></tr>
</table>

A fillet weld may have unequal legs. In this case, the sizes of both legs are given, usually the smaller leg first. The weld orientation is not specified in the welding symbol; it must be shown on the drawing or indicated by a note.

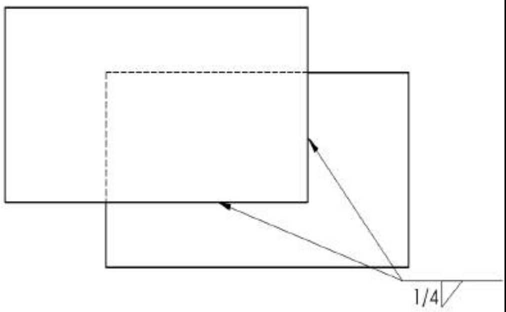
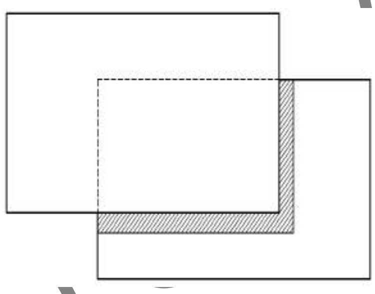
<table>
<tr><td>
</td><td>
</td><td>Lap joint with ¼x⅜ fillet weld on other side.</td></tr>
</table>

## Weld Length

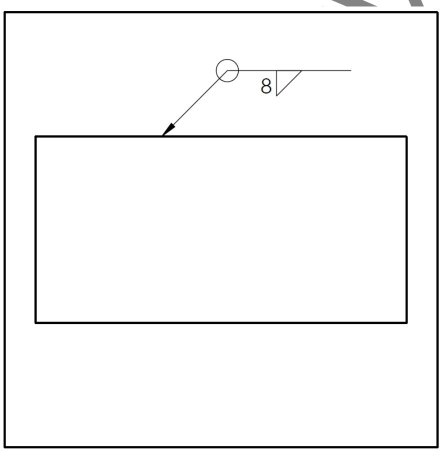
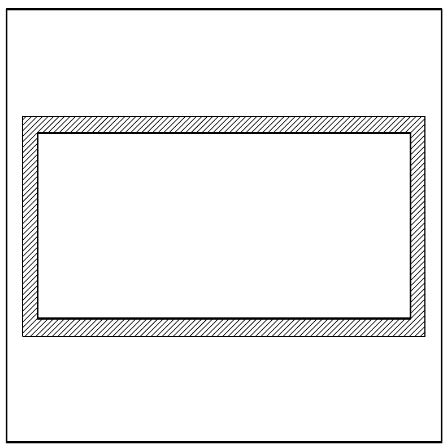
If no length of weld is given on the weld symbol, then the weld is to extend the entire length of the weld joint.

| PRINT | WELD EXAMPLE | COMMENTS |
| --- | --- | --- |
|  |  | T-joint with full-length fillet weld on arrow side. |

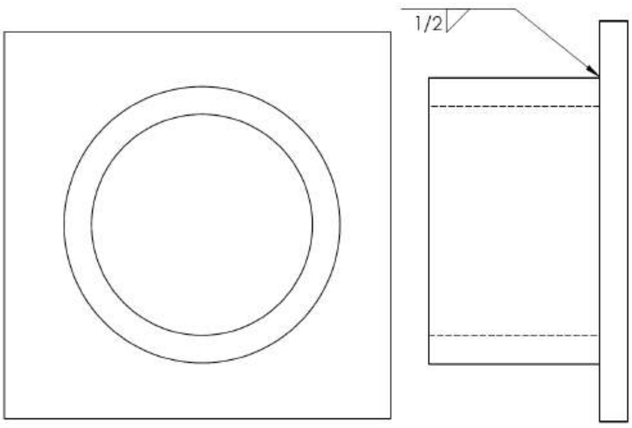
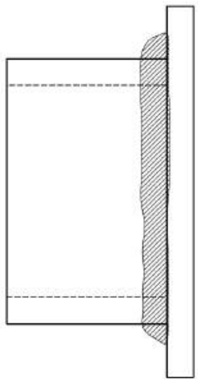
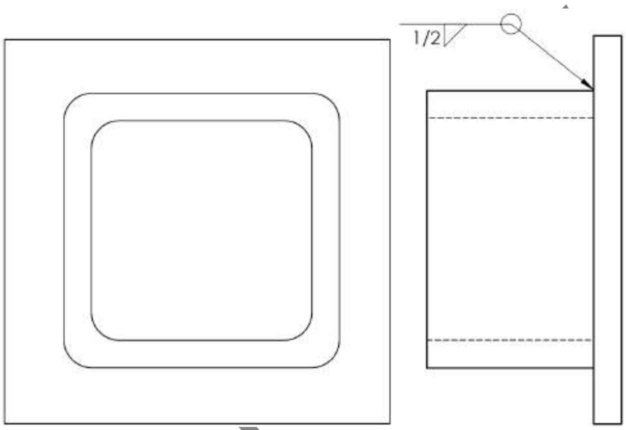
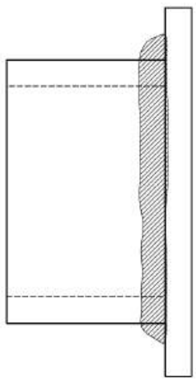
If there are abrupt changes in the direction of welding, such as when a weld turns a corner, additional welding symbols, or additional arrows on the welding symbol, are needed to show the continuing weld.

| | | |
| --- | --- | --- |
|  |  | Lap joint with ¼-inch fillet welds on arrow side. |

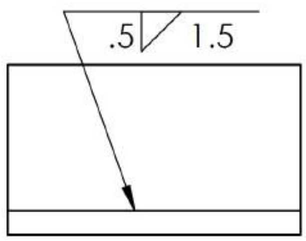
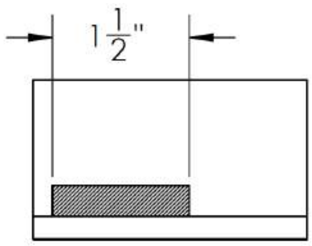
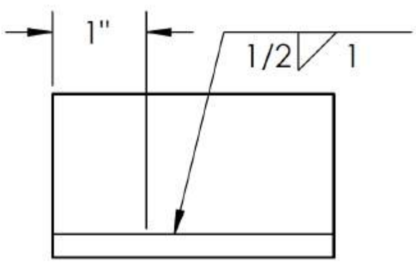
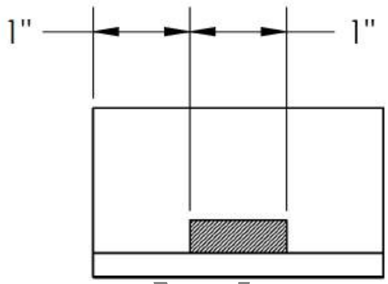
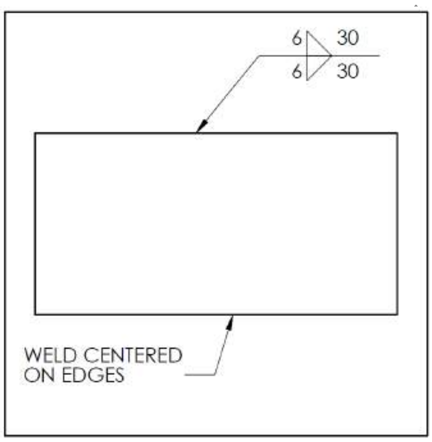
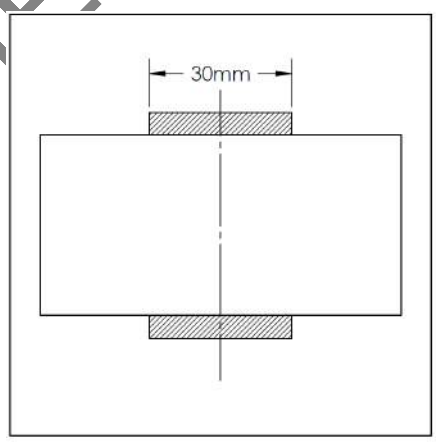
The “weld-all-around” symbol may be added to a welding symbol to indicate the weld continues all the way around a joint.

| | | |
| --- | --- | --- |
|  |  | Lap joint with 8mm fillet welds all around on arrow side. |

The weld-all-around symbol is optional on pipe and round tube, since round shapes do not change abruptly. The weld-all-around may be added just to clarify the drawing. Square and rectangular tube, however, require the weld-all-around symbol if they are to be welded all around.

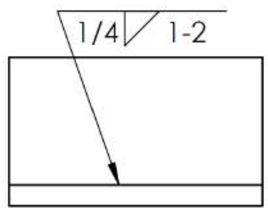
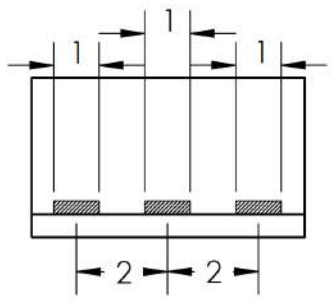
| PRINT | WELD EXAMPLE | COMMENTS |
|---|---|---|
|  |  | Round pipe with ½-inch fillet weld. |
|  |  | Square tube with ½-inch fillet weld all around. |

If the weld is not to extend the full length of the joint, but only a measured segment of weld is required, the length of the weld is placed to the right side of the weld symbol. If the location in the weld joint is important, the drawing will detail exactly where the weld is to be located, with dimensions, hatching, or notes on the drawing. If there are no specific details, then the exact location of the weld segment in the joint is not important, as long as the correct amount of weld is applied.

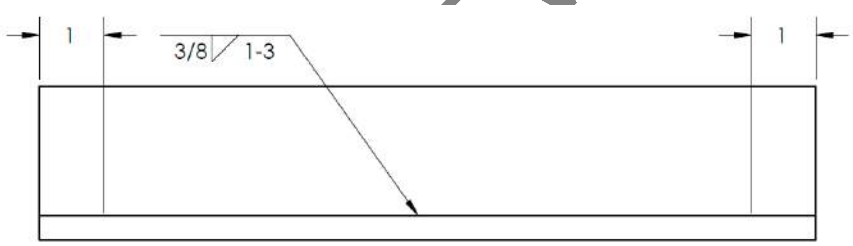
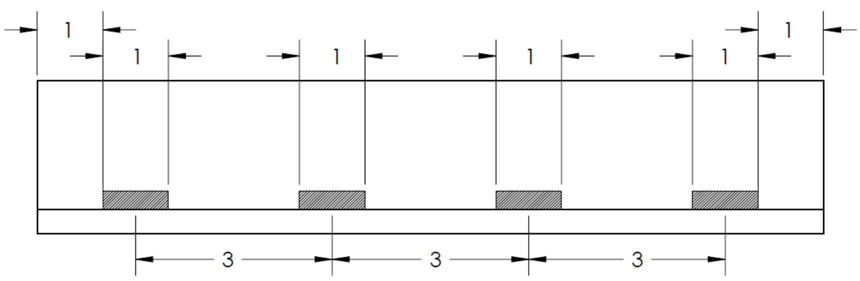
| PRINT | WELD EXAMPLE | COMMENTS |
|---|---|---|
|  |  | T-joint with 1½-inch long, ½-inch fillet weld on the arrow side.<br><br>Note: the location in the joint is not specified; therefore, the weld may be placed anywhere along the joint. |
|  |  | T-joint with 1-inch long, ½-inch fillet weld on the arrow side.<br><br>Note: the start of this weld is specified at 1-inch from the edge of the plate. |
|  |  | Lap joint with 30mm long, 6mm fillet welds on both sides.<br><br>Note: the location of these welds along the joint is specified by a note on the drawing. |

## Intermittent Fillet Welds

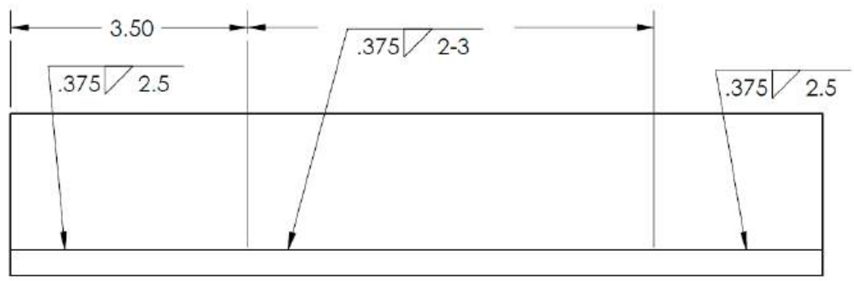
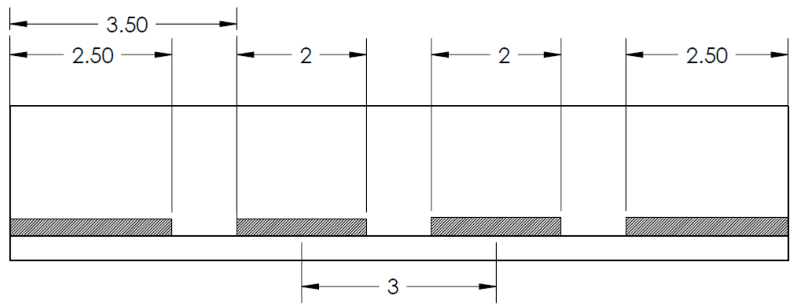
Sometimes placing a continuous weld the full length of a joint is not needed to meet the design requirements, so the drawing might specify intermittent welding to reduce welding time and filler material. To specify intermittent fillet welding, first the length of each weld increment is specified, then the pitch (center-to-center distance) from weld to weld is given, separated by a hyphen (–).

| PRINT | WELD EXAMPLE | COMMENTS |
|---|---|---|
|  |  | T-joint with ¼-inch intermittent fillet weld on arrow side. |

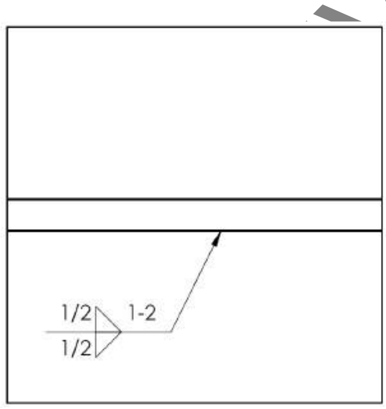
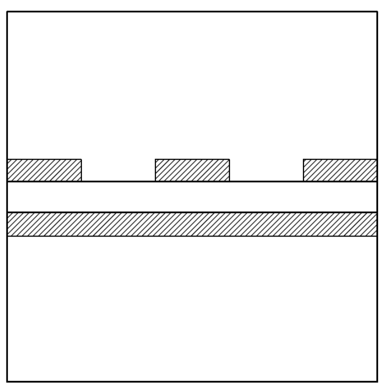
Unless specific locations are given for the intermittent weld, it will usually start at the edge of the weld joint. However, if the sum of the increments and spaces between welds do not equal the length of the joint, it may be necessary to shift the location of the weld to fit the joint. Good welding practice dictates that no weld increment should be shorter than that specified, so the intermittent weld would start out with a space, but not longer than the amount of space provided by the welding symbol. (Subtracting the increment from the pitch gives the length of space between increments.) In the example above, notice that the spaces at the ends of the weld joint are less than the distance between weld increments. A dimension may be used to locate the start of the first weld increment.

| | |
|---|---|
| <br> | T-joint with ⅜-inch intermittent fillet weld on arrow side. The starting and ending locations of the weld are indicated on the drawing. |

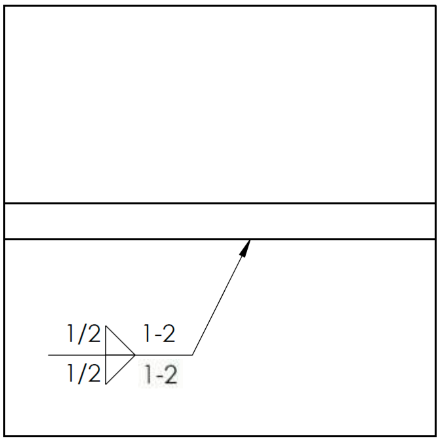
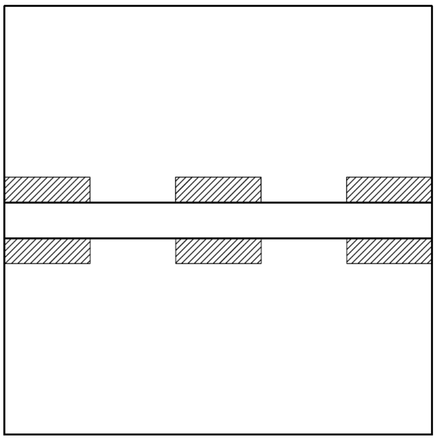
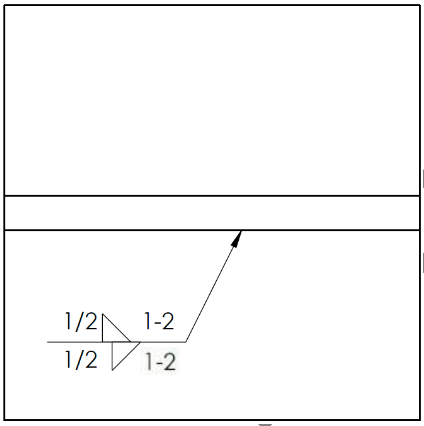
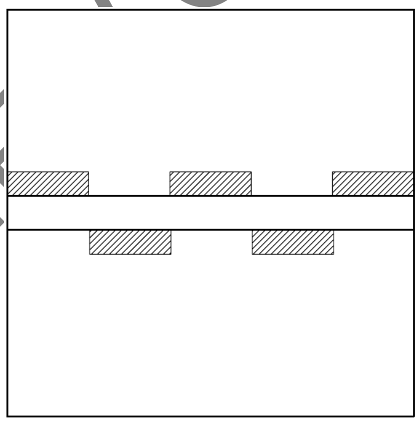
Sometimes, additional segments of continuous weld are placed before and after a section of intermittent weld to eliminate any confusion.

<table>
<tr><td>PRINT</td><td rowspan="2">COMMENTS</td></tr>
<tr><td>WELD EXAMPLE</td></tr>
<tr><td>
</td><td rowspan="2">T-joint with ⅜-inch intermittent fillet weld on arrow side.<br><br>Note: the weld joint starts and ends with a 2½-inch weld segment; a dimension specifies the start of the inter-mittent welding.</td></tr>
<tr><td>
</td></tr>
</table>

On a double-fillet weld, the weld on the opposite side is continuous if no increment or pitch is given.

<table>
<tr><td>
</td><td></td><td>T-joint with continuous ½-inch fillet weld on the arrow side and intermittent ½-inch fillet weld on the other side.</td></tr>
</table>

The weld on the opposite side may also be intermittent. There are two ways the welds may be applied, either “chain intermittent fillet welds” where the welds on the two sides of the joint are directly opposite each other, or “staggered intermittent fillet welds” where the welds alternate along the joint. If the welds are to be staggered, then the weld symbols on the reference line are also staggered as shown in the example, with the “other side” symbol shifted left and the “arrow side” symbol shifted right.

| PRINT | WELD EXAMPLE | COMMENTS |
|---|---|---|
|  |  | T-joint with chain intermittent fillet welds. |
|  |  | T-joint with staggered intermittent fillet welds. |

**Welding Symbols Activities:**

- Chapter 2 Worksheet (page 99).

**Print Reading Lab Work:**

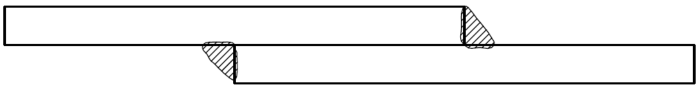
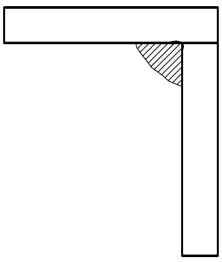
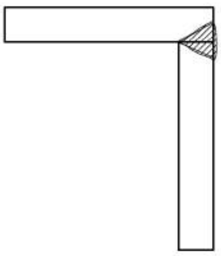
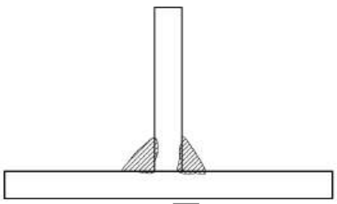
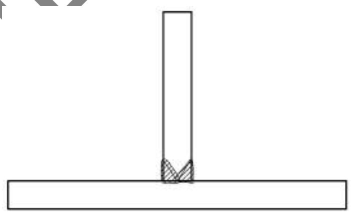
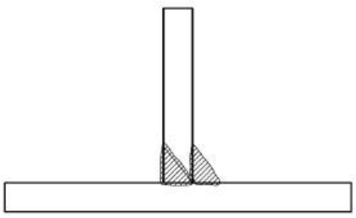
- Project 1: Intermittent Fillet Welds (page 169).

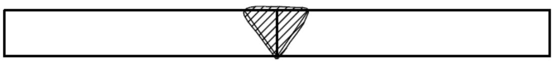
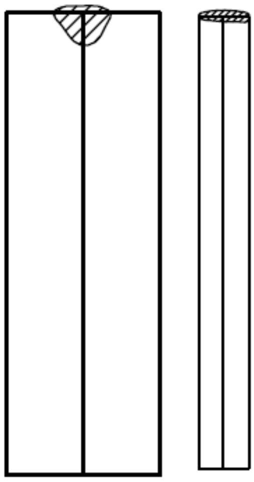
# 3. Joint Types and Square-Groove, V-Groove, and Bevel-Groove Welds

## Joint Types

So far, with the study of fillet welding symbols, we have used only T-joints. There are, however, five different joint type designations for welded construction: lap joints, T-joints, corner joints, butt joints, and edge joints.

Lap joints are usually welded with fillet welds, T-joints and corner joints may be welded with either fillet or groove welds (or both), while butt joints require groove welds. Edge joints may be welded with a groove weld if the members are thick; however, they are usually welded with edge welds (formerly called "flange welds" in previous editions of the welding symbols standard).

| WELD EXAMPLE | COMMENTS |
|---|---|
|  | Lap joint with double-fillet welds. |
|   | Corner joints welded with a fillet weld (left) and a groove weld (right). |
|   | T-joints welded with fillet welds (left) and a groove weld (right). |
|  | T-joint welded with both groove and fillet welds. |

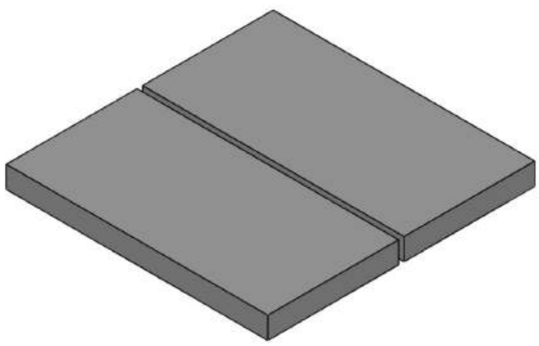
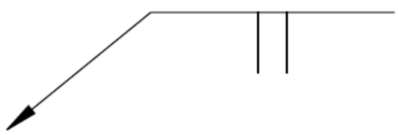
| WELD EXAMPLE | COMMENTS |
|---|---|
|  | Butt joint welded with a groove weld. |
|  | Edge joint welded with a groove weld (left) and an edge weld (right).<br><br>Note: the edge weld fuses the entire edge of the joint, while the groove weld does not. |

## Groove Welds

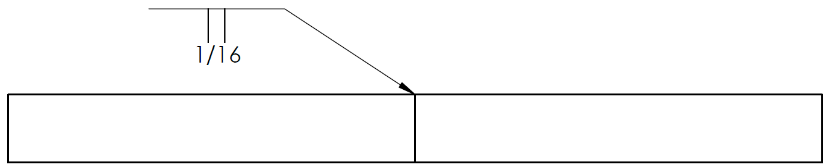
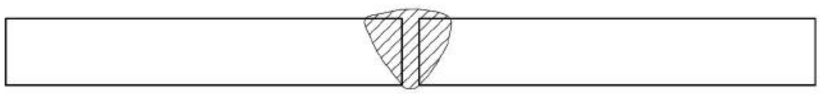
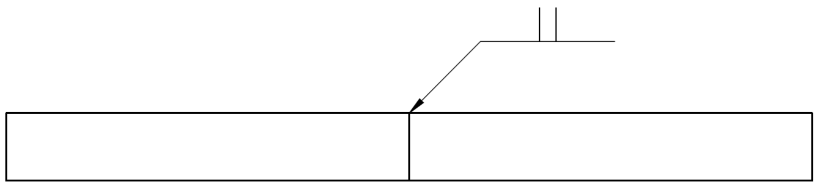
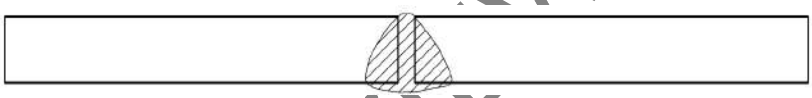
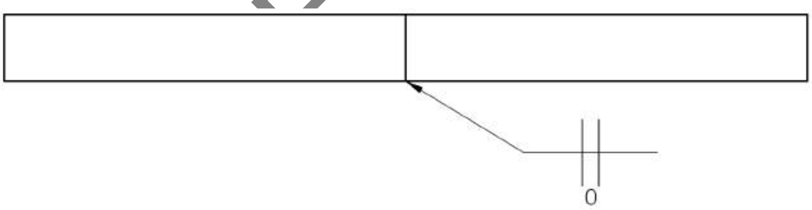
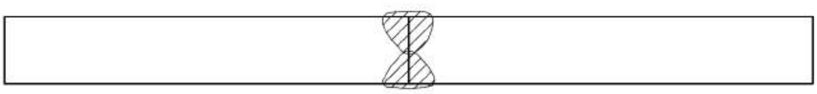
The welding symbols for the groove welds can be used to provide all the necessary details for joint geometry, including root opening, joint type, bevel angel, and groove depth.  With this detail in the welding symbol, the drawing needs to show only the joint location–the specific details of the joint do not need to be drawn.

## Square-Groove Welds

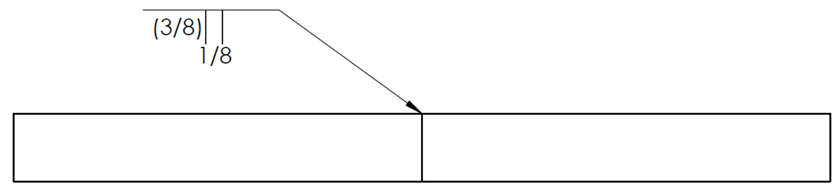
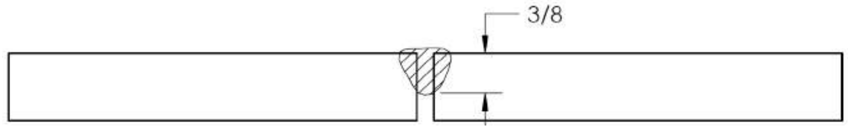
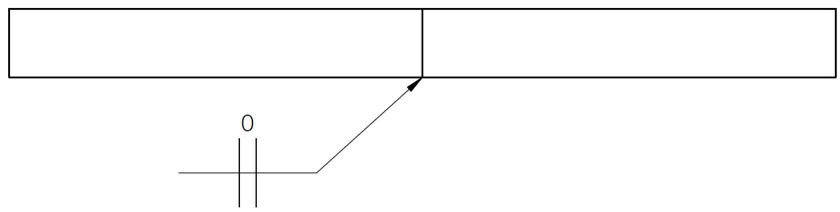
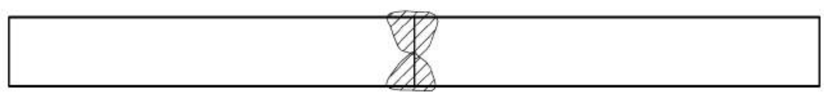
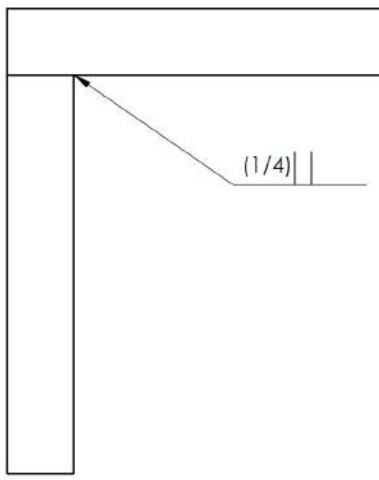
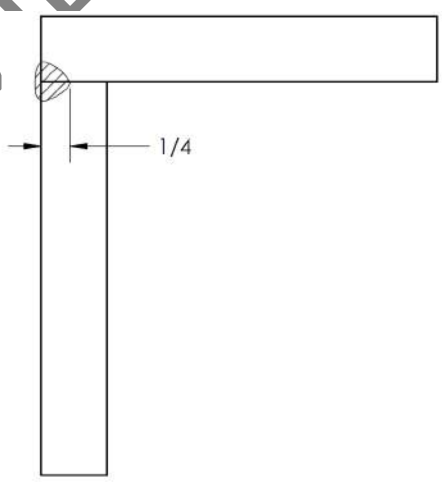
The simplest groove weld is the square-groove weld.  The joint design is simple, just the squared edges of the members to be welded.  Usually square-groove welds are specified on thinner materials or on thicker plate where complete joint penetration is not essential.  The weld symbol shows the joint design as just two squared plate ends:

| | |
|---|---|
|  |  |

The weld symbol indicates which side the weld is to be made from, the arrow side, the other side, or both sides.  Sometimes a root opening may be specified to allow deeper penetration of the square-groove weld.  When a root opening is specified, it is shown inside the weld symbol, on only one side of the reference line.  If no root opening is specified, then the welder may use any root opening that will ensure a good joint.  If no root opening is allowed, then the symbol will specify “0” for the root opening.

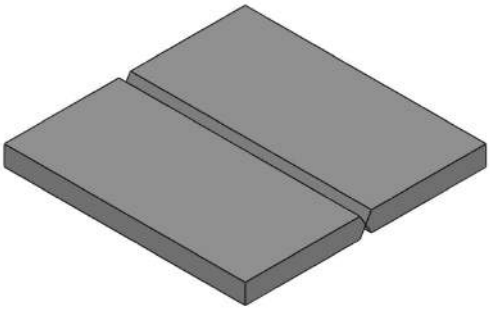
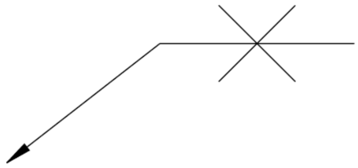
<table>
<tr><th>PRINT<br>WELD EXAMPLE</th><th>COMMENTS</th></tr>
<tr><td>
</td><td rowspan="2">Butt joint with single-square-groove weld on the arrow side. The root opening is $\frac{1}{16}$-inch.</td></tr>
<tr><td></td></tr>
<tr><td></td><td rowspan="2">Butt joint with single-square-groove weld on the other side.<br><br>Note: because the root opening is unspecified, the welder may use whatever is appropriate to make a full penetration joint.</td></tr>
<tr><td></td></tr>
<tr><td>
</td><td rowspan="2">Butt joint with double-square-groove weld. The root opening is 0.</td></tr>
<tr><td></td></tr>
</table>

A weld size may be specified for groove welds, just as for fillet welds, to the left of the weld symbol.  For groove welds, however, the weld size is enclosed in parenthesis.  If no weld size is specified, then the joint is to have complete joint penetration.

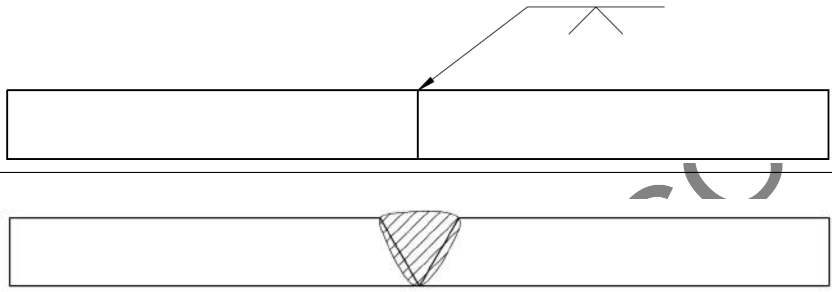
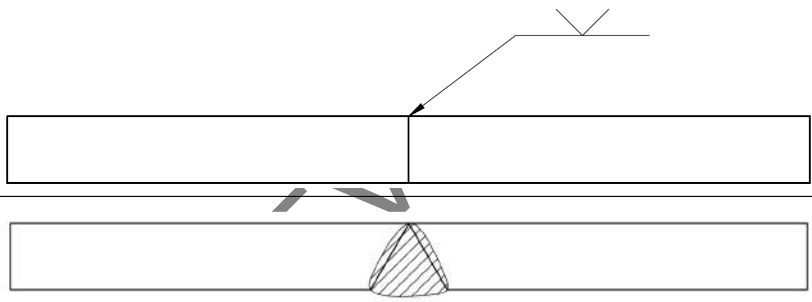
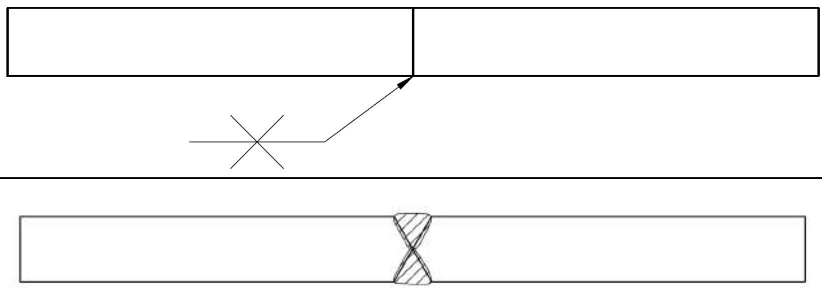
| PRINT | WELD EXAMPLE | COMMENTS |
|---|---|---|
|   |   | Butt joint with single-square-groove weld on the arrow side. The root opening is ⅛-inch and the weld size is ⅜-inch. |
|   |  | Butt joint with double-square-groove welds.  The root opening is 0. Note:  because no weld size is given, full penetration is required. |
|   |   | Corner joint with single-square-groove weld on the other side. The weld size is ¼-inch. Note: because the root opening is unspecified, the welder may use any appropriate root opening to achieve the specified weld size and maintain the weldment dimensions. |

## V-Groove Welds

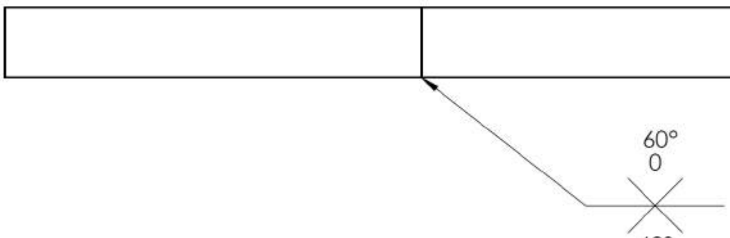
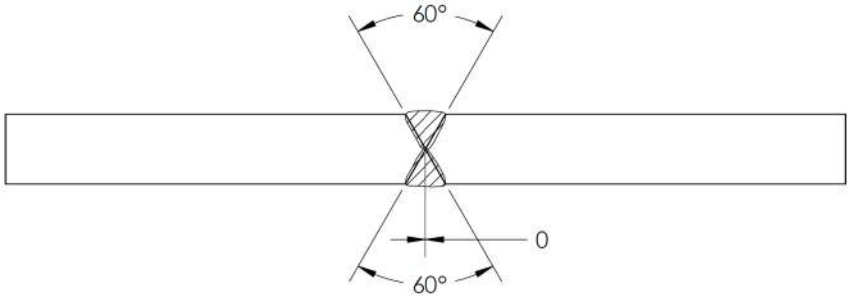
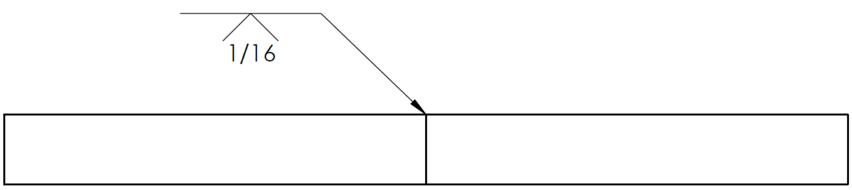
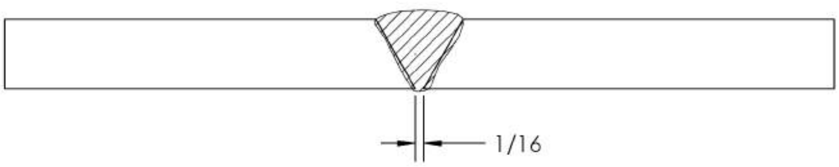
If both members are to receive a bevel, the weld is a V-groove weld.

| | |
|---|---|
|  |  |

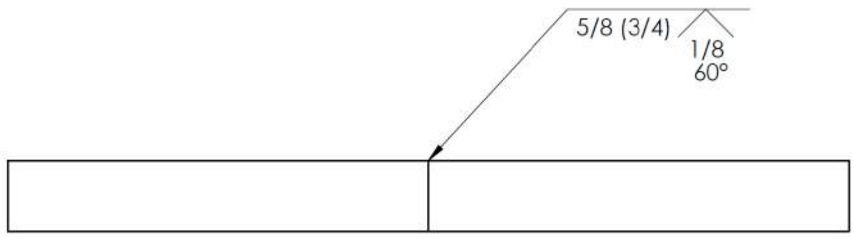
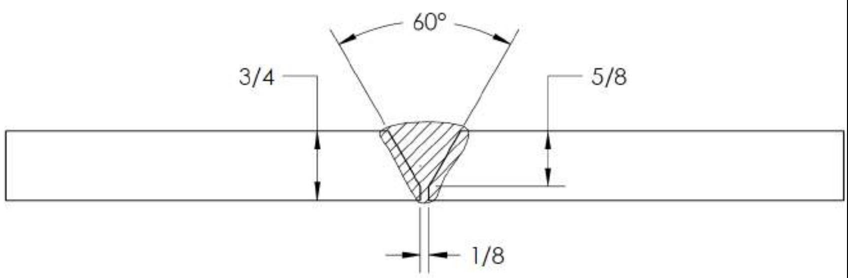
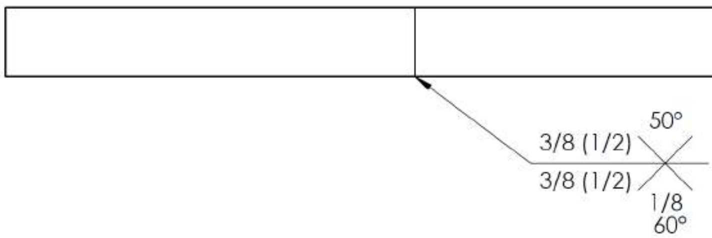
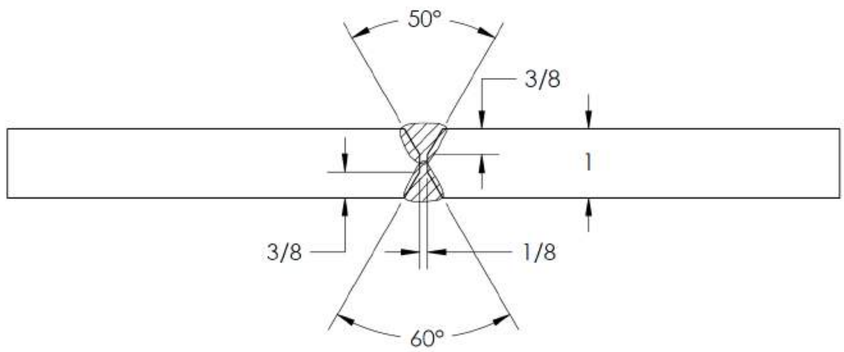
V-groove welds may be made from the arrow side, the other side, or both sides of the joint.

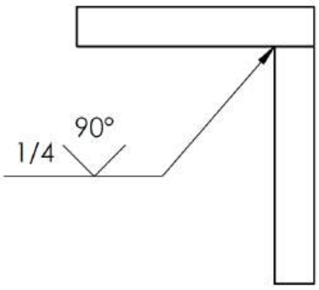
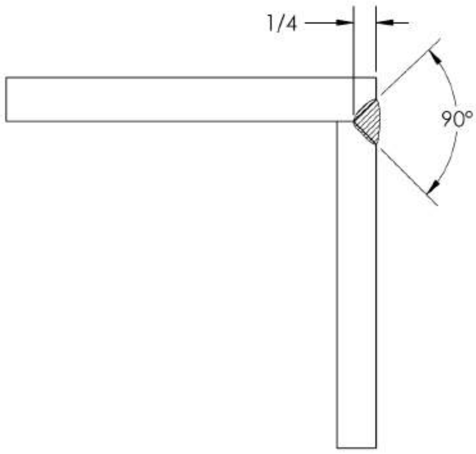
| PRINT<br>WELD EXAMPLE | COMMENTS |
|---|---|
|  | Butt joint with single-V-groove weld on the arrow side. |
|  | Butt joint with single-V-groove weld on the other side. |
|  | Butt joint with double-V-groove weld. |

A root opening may be specified; if no root opening is given then the welder may use any root opening that will make a sound weld and maintain required dimensions. The included angle of the V-groove may also be specified in the weld symbol. On a double-V-groove weld, the angle must be specified on both sides of the symbol, even if they are the same. The root opening is only specified on one side of the symbol. If no angle is given, then the welder may use any appropriate angle to make a sound weld.

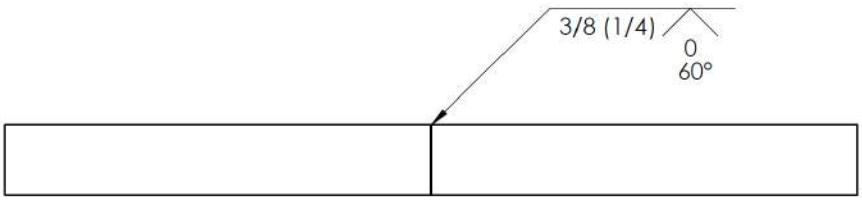
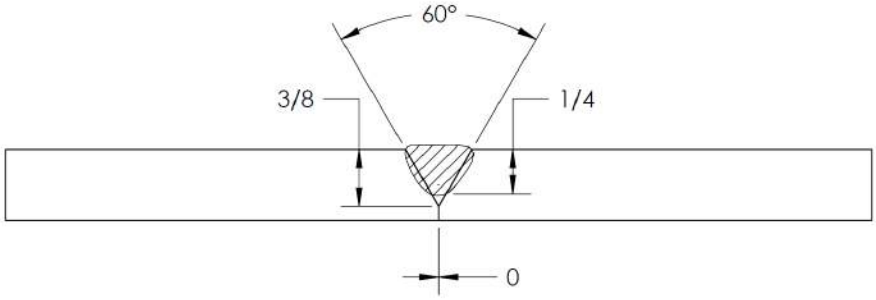
| PRINT<br>WELD EXAMPLE | COMMENTS |
|---|---|
|  | Butt joint with double-V-groove weld. The groove angle is 60° on each side, and the root opening is 0. |
|  | |
|  | Butt joint with single-V-groove weld on the arrow side. The root opening is $\frac{1}{16}$-inch.<br><br>Note: because no groove angle is given, the welder may use whatever is appropriate to make a sound weld. |
|  | |

The depth of groove and the weld size are specified to the left of the weld symbol. The weld size is always in parenthesis for a groove weld. If the depth of groove is not given, then the entire edge is beveled (for a double-bevel joint, the bevels are equal and cut to the center of the member) and there is no root face. If the weld size is not given and not specified anywhere else, then the weld is to be at least equal to the depth of groove.

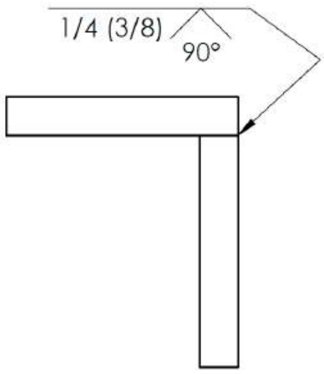
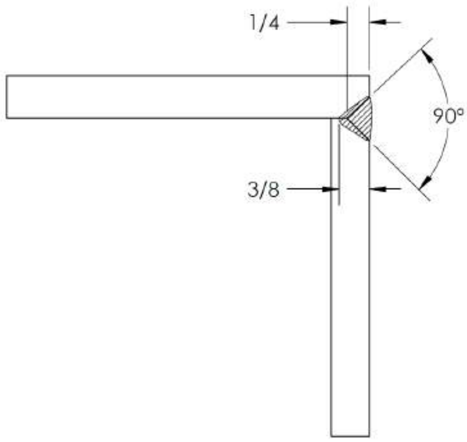
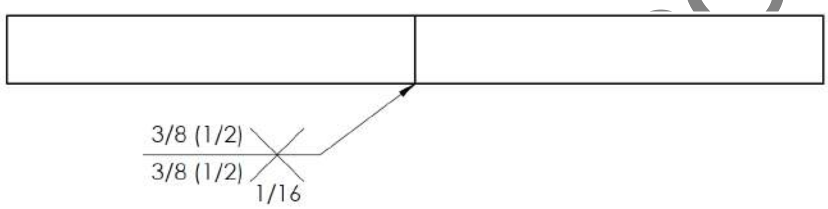
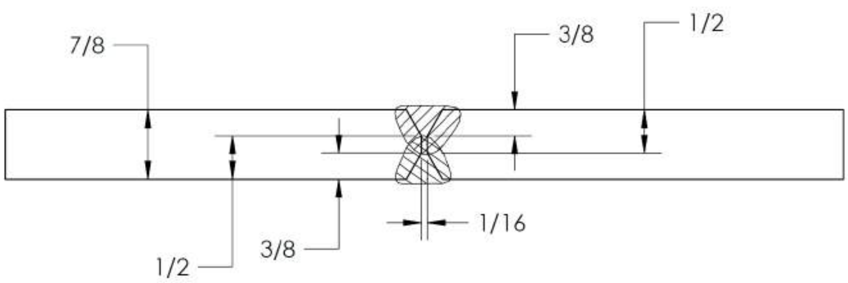
<table>
<tr><th>PRINT<br>WELD EXAMPLE</th><th>COMMENTS</th></tr>
<tr><td>
</td><td rowspan="2">Butt joint with single-V-groove weld. The groove angle is 60° and the root opening is ⅛-inch. The depth of groove is ⅝-inch (leaving a ⅛-inch root face), and the ¾-inch weld size indicates a full penetration weld of the ¾-inch thick plate.</td></tr>
<tr><td>
</td></tr>
<tr><td>
</td><td rowspan="2">Butt joint with double-V-groove weld. The bevel angle is 60° on the arrow side, 50° on the other side, and the root opening is ⅛-inch. The depth of groove is ⅜-inch on each side (leaving a ¼-inch root face), and the ½-inch weld sides indicate a full penetration weld of the 1-inch thick plate.</td></tr>
<tr><td>
</td></tr>
</table>

| PRINT | WELD EXAMPLE | COMMENTS |
|---|---|---|
|  |  | Corner joint with single-V-groove weld. The bevel angle is 90° and the depth of groove is ¼-inch.<br><br>Note: because no weld size is given, the minimum weld side is the same as the depth of groove. Because no root opening is given, the welder may use whatever root opening is appropriate for the joint, in this case 0. |

Weld sizes may be given which are not as large as the depth of groove, to produce partial penetration welds.

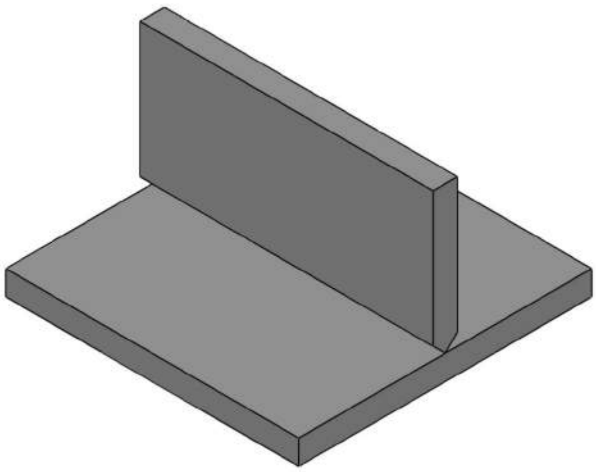
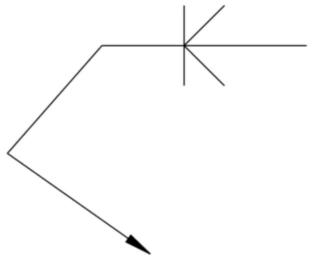
<table>
<tr><th>PRINT</th><th rowspan="2">COMMENTS</th></tr>
<tr><th>WELD EXAMPLE</th></tr>
<tr><td></td><td rowspan="2">Butt joint with single-V-groove weld. The groove angle is 60° and the root opening is 0. The depth of groove is ⅜-inch, and the ¼-inch weld size indicates a partial penetration weld.</td></tr>
<tr><td></td></tr>
</table>

Weld sizes may also be given which are greater than the depth of groove, even to the point of creating overlapping beads in the weld cross section.

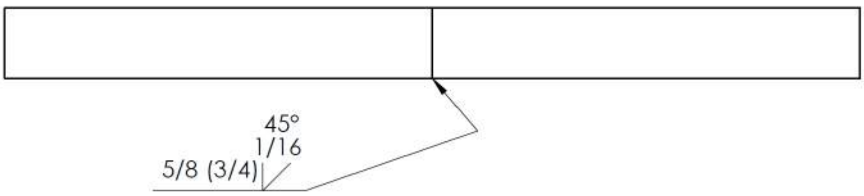
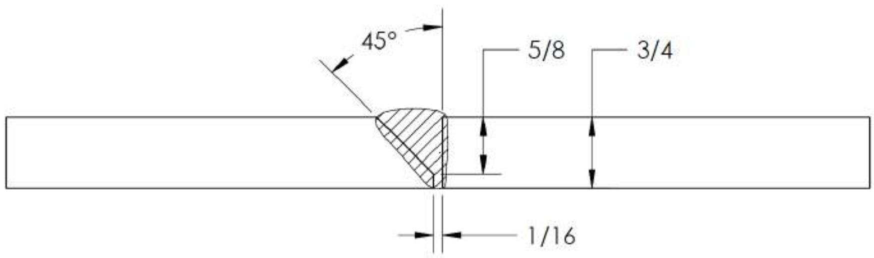
<table>
<tr><th>PRINT</th><th>WELD EXAMPLE</th><th>COMMENTS</th></tr>
<tr><td></td><td></td><td>Corner joint with single-V-groove weld. The bevel angle is 90° and the depth of groove is ¼-inch. The weld size is ⅜-inch.<br><br>Note: because no root opening is given, the welder may use whatever root opening is appropriate for the joint, in this case 0.</td></tr>
<tr><td colspan="2"></td><td rowspan="2">Butt joint with double-V-groove weld. The root opening is 1/16-inch, the depth of groove is ⅜-inch, and the ½-inch weld size indicates a full penetration weld. The total weld size is ⅞-inch—the same as the plate thickness.<br><br>Note: because no bevel angles are given, the welder may use any angle that is appropriate to produce a sound weld.</td></tr>
<tr><td colspan="2"></td></tr>
</table>

## Bevel-Groove Welds

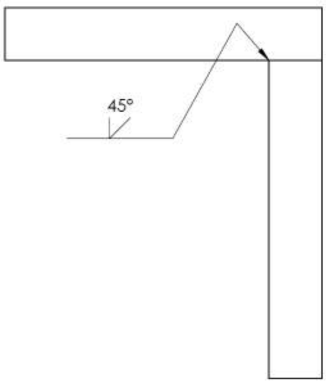
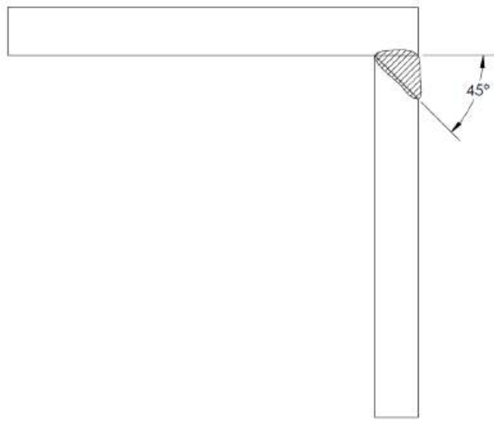
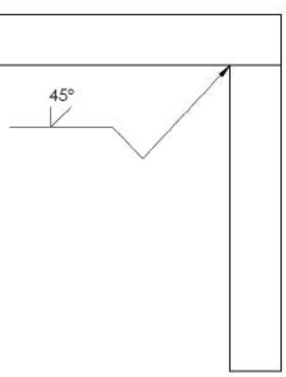
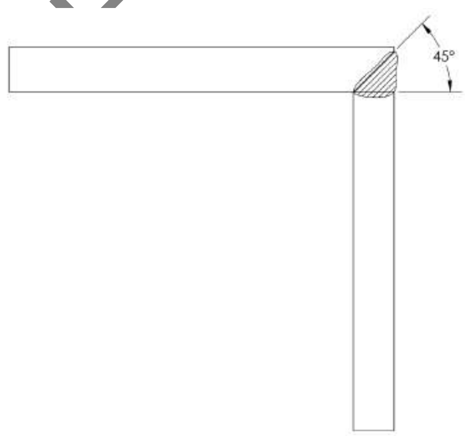
If only one member has a bevel and the other member remains square, then the joint is a bevel-groove joint. Like V-groove joints, bevel-groove joints may also be single or double.

| | |
|---|---|
|  |  |

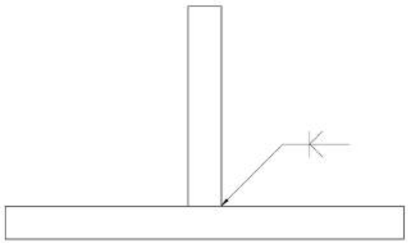
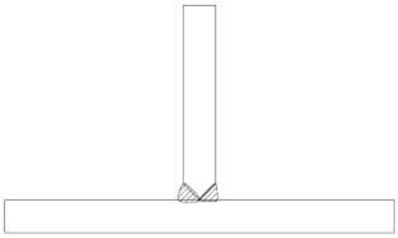
Also like V-groove joints, root opening, bevel angle, groove depth, and weld size may all be specified in the bevel-groove welding symbol.

| PRINT<br>WELD EXAMPLE | COMMENTS |
|---|---|
|  | Butt joint with single-bevel-groove weld. The groove angle is 45° and the root opening is $\frac{1}{16}$-inch. The depth of groove is ⅝-inch, and the ¾-inch weld size indicates a full penetration weld in the ¾-inch thick plate. |
|  | |

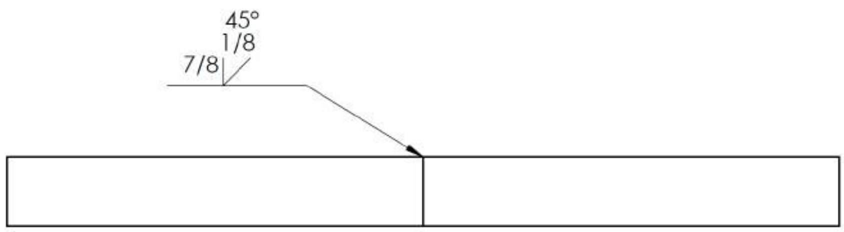
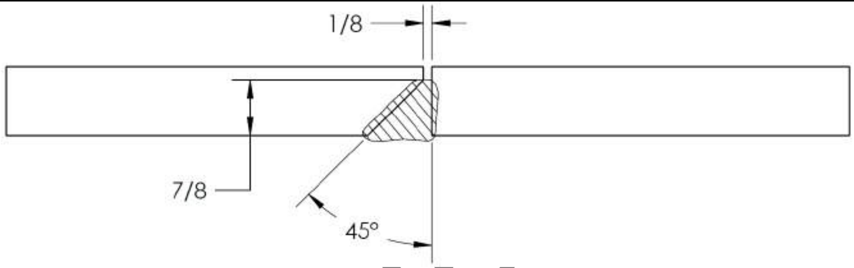
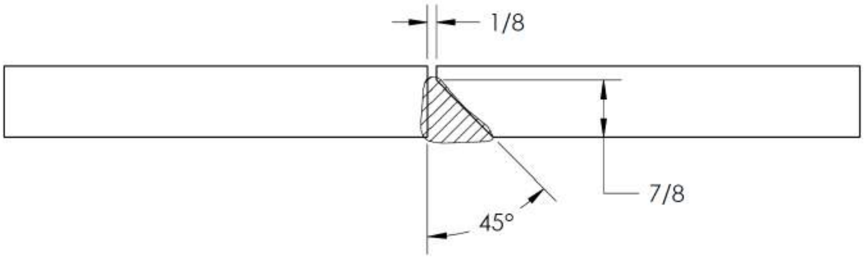
Since a bevel-groove weld is prepared on only one member, the welding symbol for a bevel-groove weld can specify which member is to receive the bevel. This is done by adding a joint in the arrow, called a broken arrow, to allow the arrow to point specifically towards the member to receive the bevel. The arrows of other types of welding symbols may be broken too, but in this case there is special meaning to the jog in the arrow.

| PRINT | WELD EXAMPLE | COMMENTS |
|---|---|---|
|  |  | Corner joint with single-bevel-groove weld. The bevel angle is 45° and the vertical member receives the bevel.<br><br>Note: because no root opening is given, the welder may use any appropriate root opening for the joint, in this case 0. Because no depth of groove or weld size is given, the full plate thickness is beveled. |
|  |  | Corner joint with single-bevel-groove weld. The bevel angle is 45° and the horizontal member receives the bevel.<br><br>Note: because no root opening is given, the welder may use any appropriate root opening for the joint, in this case 0. Because no depth of groove or weld size is given, the full plate thickness is beveled. |

The arrow does not need to be broken if it is obvious which member is to be prepared, such as in a T-joint.

| PRINT | WELD EXAMPLE | COMMENTS |
|---|---|---|
|  |  | T-joint with double-bevel-groove weld. A broken arrow is not required because it is obvious that only the vertical member can receive the bevel. |

If it does not matter which member receives the bevel, then the arrow is not broken, and the welder may choose which member to bevel.

| | |
|---|---|
|   OR  | Butt joint with single-bevel-groove weld. The groove angle is 45° and the root opening is ⅛-inch. The depth of groove is ⅞-inch.<br><br>Note: because there is no break in the arrow, either member may receive the bevel. Because the weld size is not given, the weld must be at least the depth of groove. |

**Welding Symbols Activities:**
- Chapter 3 Worksheet (page 103).

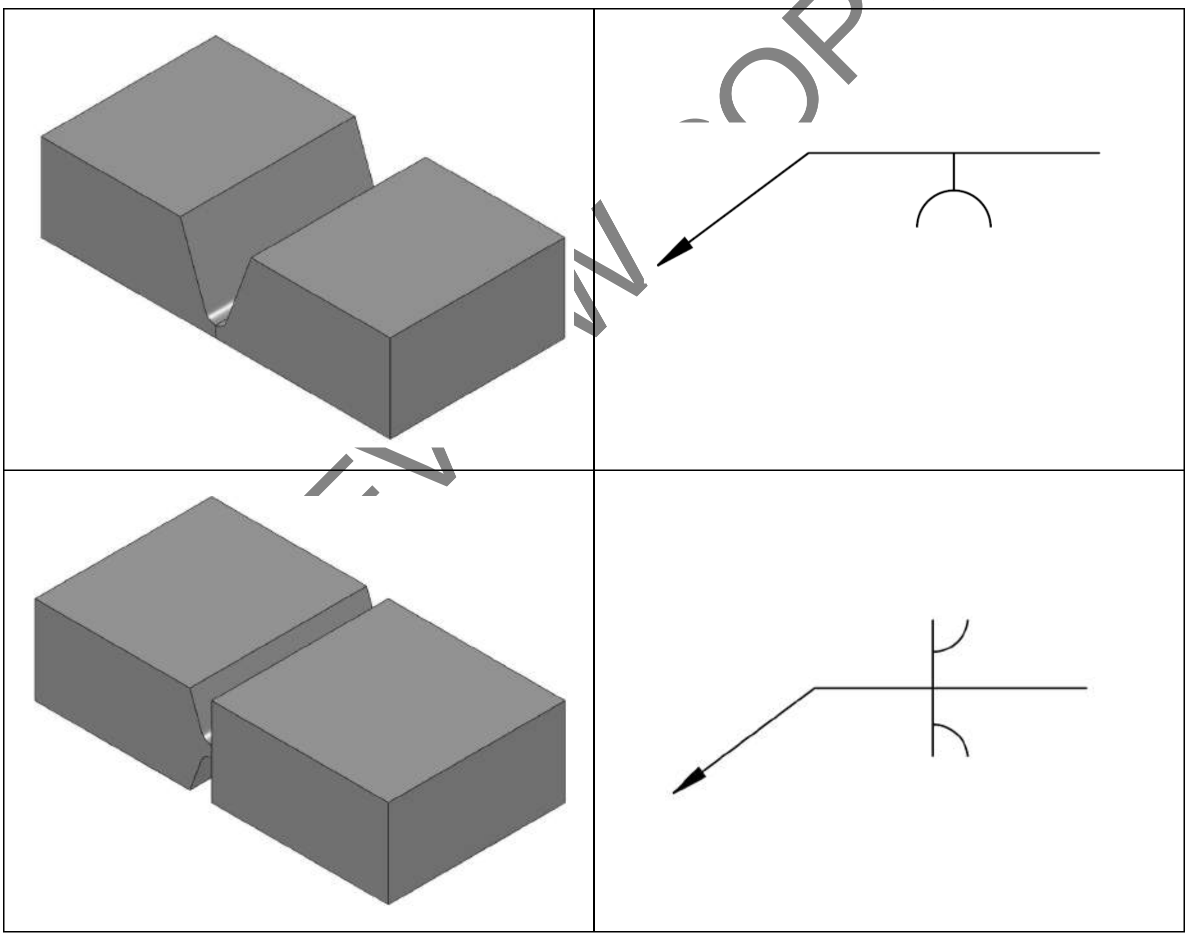
**Print reading lab work:**
- Project 2: Step Fixture Block (page 171).

# 4. Additional Groove Weld Types: U-Groove, J-Groove, and Flared-Groove; Groove Weld Lengths and Arrangement

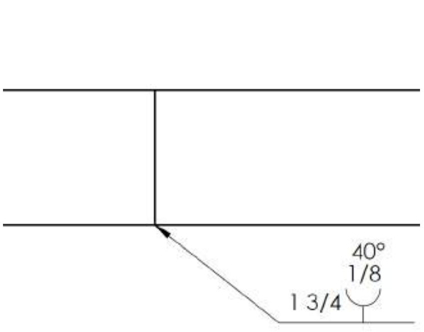
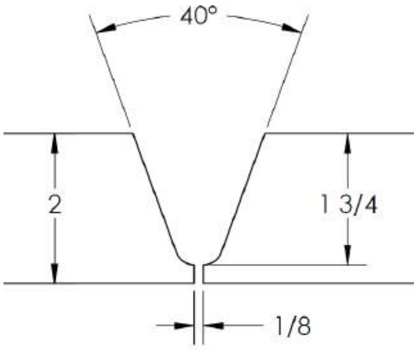
The most common groove welds were covered in Chapter 3: square-groove welds, V-groove welds, and bevel-groove welds. There are five other groove weld symbols which may be specified. These are the scarf, which will be covered in Chapter 11, U-groove and J-groove, which are used for thick materials, and flare-V-groove and flare-bevel-groove welds, which are used mainly when welding pipe and tube.

## U-Groove and J-Groove-Welds

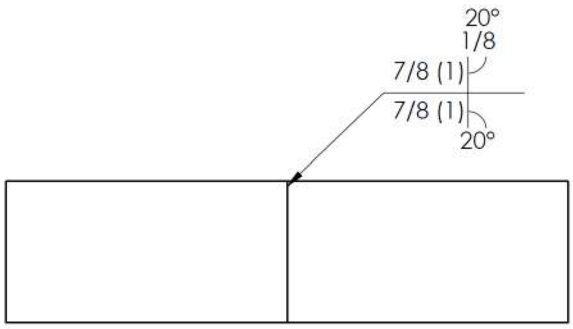
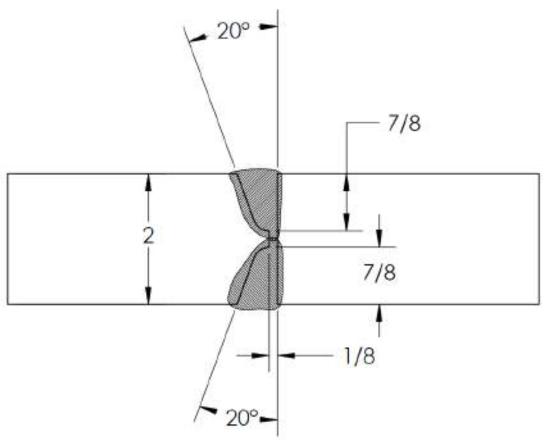
When thick materials are to be welded, typically over 1-inch when welded from one side or 2-inches when welded from both sides, V-groove and bevel-groove welds tend to take an excessive number of weld passes to complete. For this reason, V-grooves are often modified to U-grooves, and bevel-grooves are often modified to J-grooves to reduce the amount of weld metal required to complete a weld joint, while still allowing enough access to the joint to produce a sound weld.

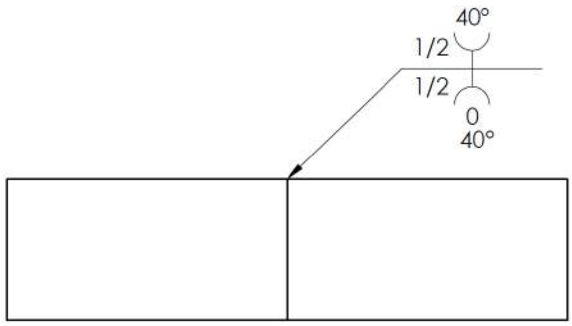
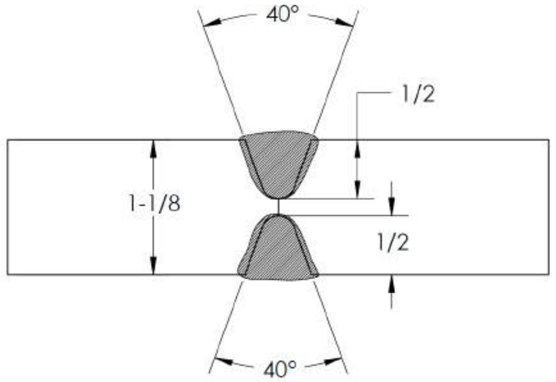


Like all the V-groove and bevel-groove welds, the depth of groove, groove angle, and root opening may all be specified in the weld symbol.  If any of these are not specified, the welder may use whatever dimension is appropriate to produce a sound weld and maintain required dimensions.

| PRINT | WELD EXAMPLE | COMMENTS |
|---|---|---|
|  |  | Butt joint with single-U-groove weld.  The groove angle is 40° and the root opening is ⅛-inch.  The depth of groove is 1¾-inch. |

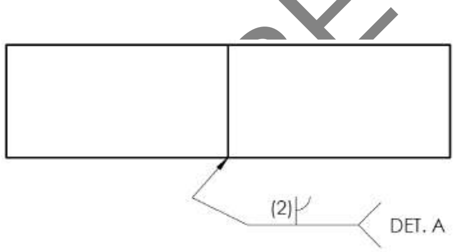
Weld size is specified in parenthesis.  If no weld size is specified, then the weld must be at least as the depth of groove.

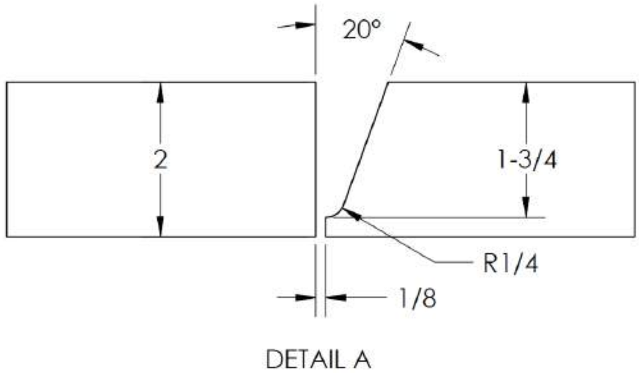
<table>
<tr><th>PRINT</th><th rowspan="2">COMMENTS</th></tr>
<tr><th>WELD EXAMPLE</th></tr>
<tr><td></td><td rowspan="2">Butt joint with double-J-groove weld.  The groove angle is 20° and the root opening is ⅛-inch.  The depth of groove is ⅞-inch on each side, and the 1-inch weld size indicates complete joint penetration of the 2-inch thick plate.<br><br>Note:  because there is no break in the arrow, either member may receive the double-J-groove preparation.</td></tr>
<tr><td></td></tr>
</table>

| PRINT<br>WELD EXAMPLE | COMMENTS |
|---|---|
| <br> | Butt joint with double-U-groove weld. The groove angle is 40° and the root opening is 0. The depth of groove is ½-inch on each side. Because no weld size is given, the weld must be at least equal to the depth of groove. |

The radius at the bottom of the U-groove or J-groove must be given in a separate detail drawing. If no detail drawing is given, then the welder may use whatever radius is appropriate to make a sound weld. A detail drawing is specified by placing a tail on the welding symbol with the appropriate information. If the detail drawing includes depth of groove and included angle dimensions, then these dimensions are not needed on the welding symbol.

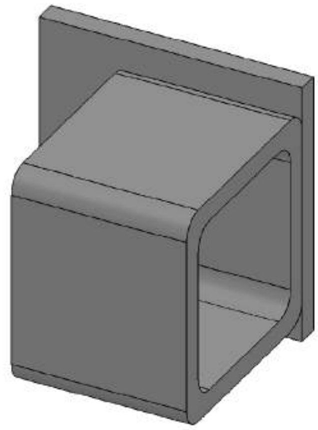
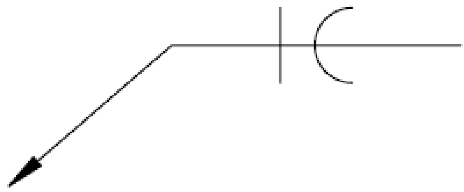
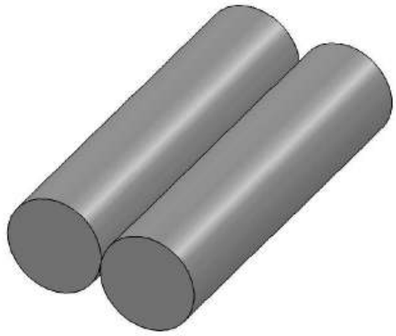
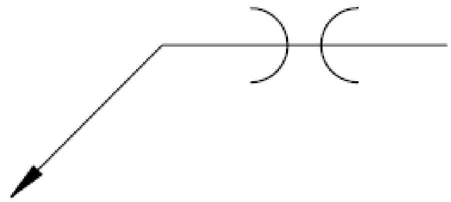




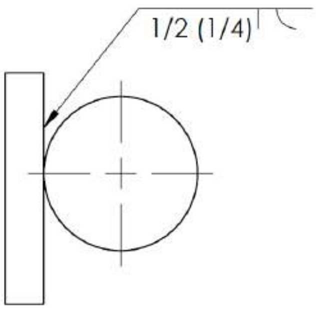
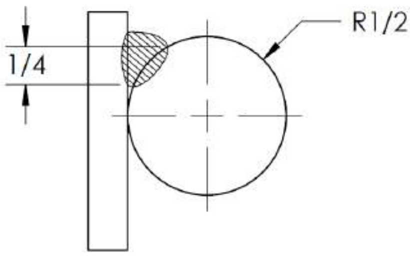
## Flared-Groove Welds

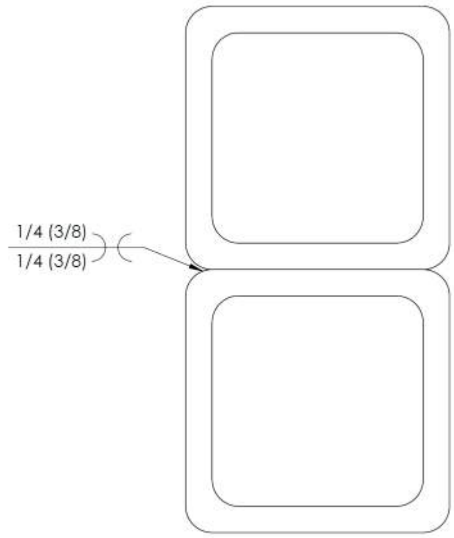
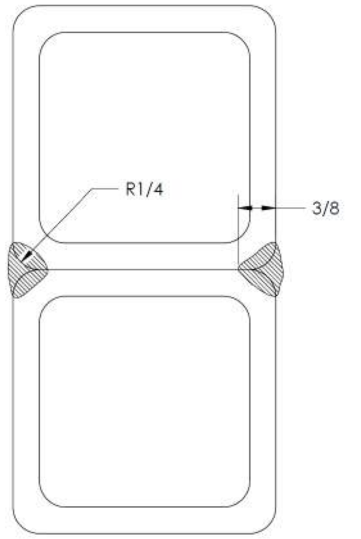
Two unique groove weld types, which appear when welding round shapes or round-corner square and rectangular tubing, are the flare-bevel-groove weld and the flare-V-groove weld.

| | |
|---|---|
|  |  |
|  |  |

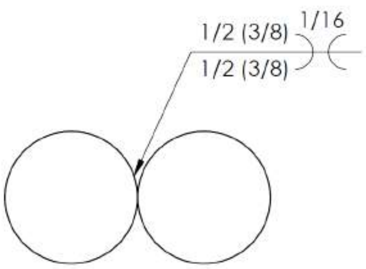
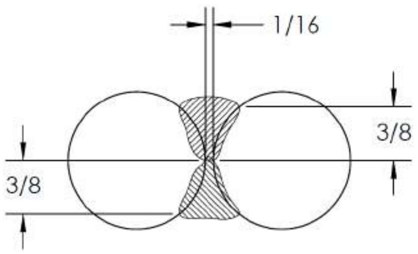
Because the geometry of the groove weld is based on the shapes of the members and cannot be controlled by the welder, the dimensions for the groove weld are applied differently.  The radius of the member is given as the depth of groove, and the groove angle is not specified.  The weld size is specified in parenthesis.  Because of the joint geometry, the weld size will often be much less that the radius; complete joint penetration is rarely obtainable.



| PRINT | WELD EXAMPLE | COMMENTS |
|---|---|---|
|   |   | Single-flare-bevel-groove weld.  The radius of the bar is given as the depth of groove. |

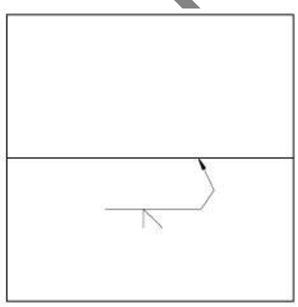
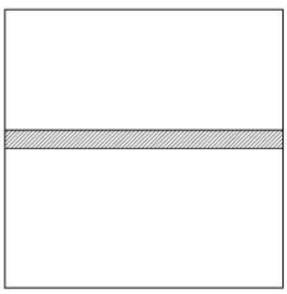
| PRINT | WELD EXAMPLE | COMMENTS |
|---|---|---|
|   |   | Double-flare-V-groove weld. The outside radius of the tube corner is given as the depth of groove. |

A root opening may be specified. If no root opening is specified then the welder may use whatever root opening is appropriate to make a sound weld and maintain required dimensions.

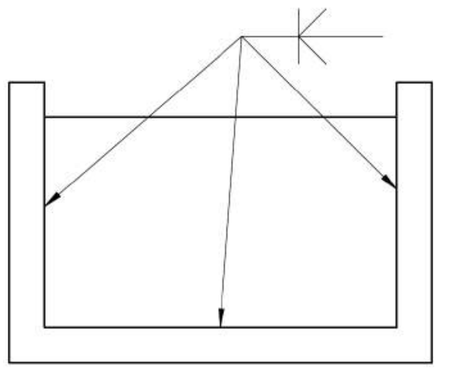
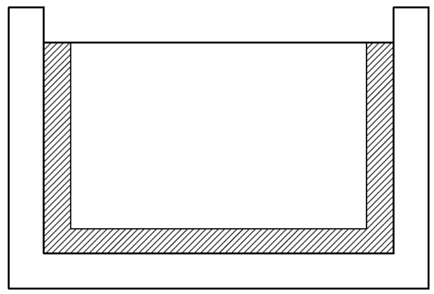
| | | |
|---|---|---|
|   |   | Double-flare-V-groove weld. The root opening is 1/16-inch. The radius of the bar is given as the depth of groove. |

## Groove Weld Lengths

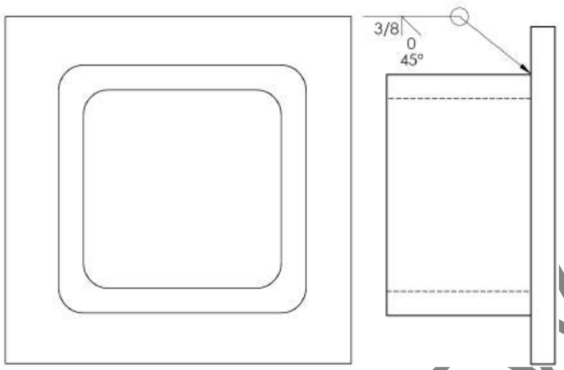
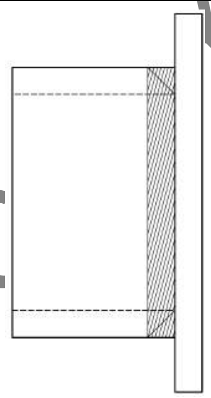
Length for a groove weld is specified to the left of the weld symbol, just as in fillet welds. The examples in this chapter show the weld length details previously covered for fillet welds in chapter 2 are applied to groove welds. If no length of weld is given on the weld symbol, then the weld is to extend the entire length of the weld joint.

| | | |
|---|---|---|
|  |  | Single-bevel-groove weld. The entire thickness of the plate is beveled; the angle of bevel is up to the welder. |

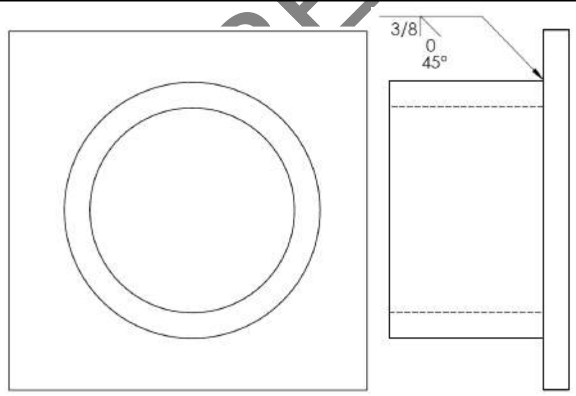
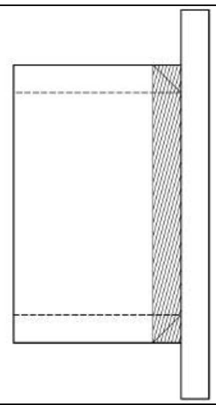
If there are abrupt changes in the direction of welding, such as when a weld turns a corner, additional welding symbols, or additional arrows on the welding symbol, are needed to show the continuing weld.

| PRINT | WELD EXAMPLE | COMMENTS |
|---|---|---|
|  |  | Double-bevel-groove weld. Broken arrows are not needed because it is obvious that the web is beveled. |

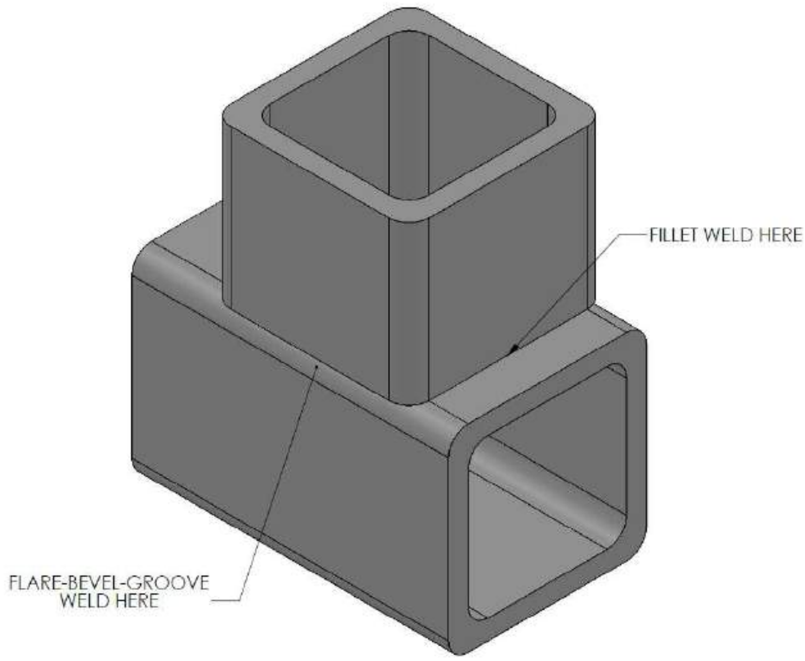
The "weld-all-around" symbol may be added to a welding symbol to indicate the weld continues all the way around a joint.

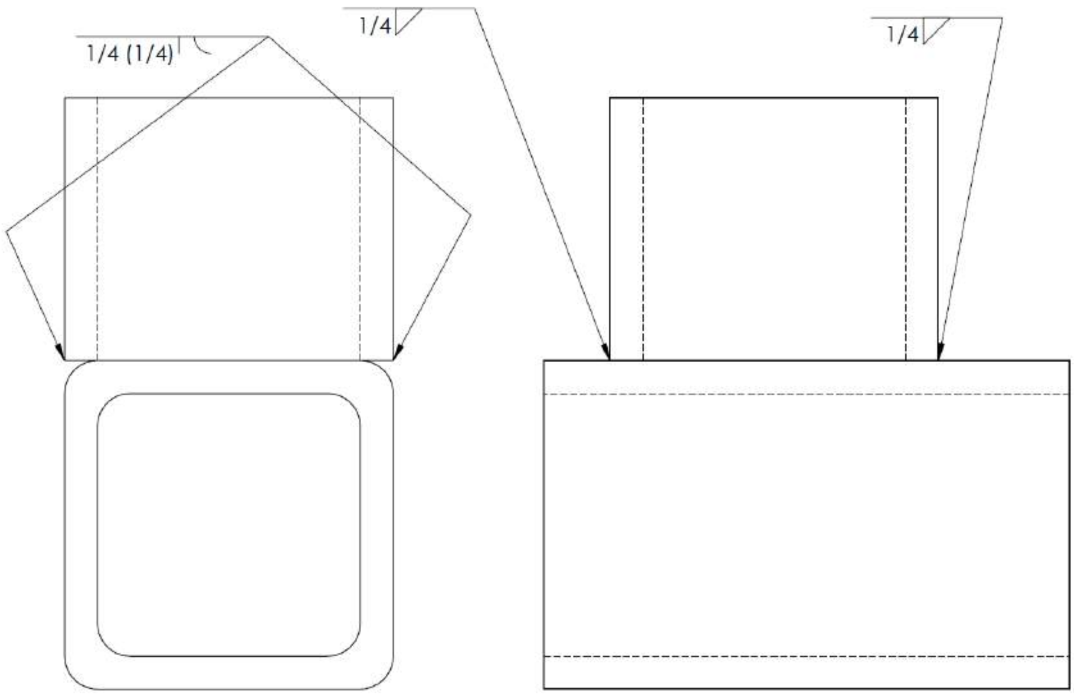
| | | |
|---|---|---|
|  |  | Single-bevel-groove weld, all around the square tube. |

The "weld-all-around" symbol is optional on pipe and round tube, since round shape do not change abruptly. Sometime it will be added as a courtesy. Square and rectangular tube, however, require the weld-all-around symbol if they are to be welded all around.

| | | |
|---|---|---|
|  |  | Single-bevel-groove weld, all around the pipe. |

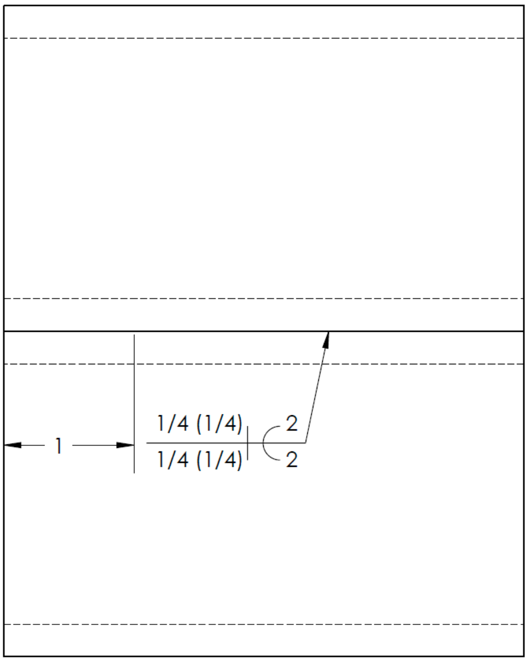
The weld-all-around symbol cannot be used for a joint where the type of weld changes from groove to filet as the weld progresses around the joint.  The most common example is a T-joint made from square or rectangular tubing.  In this joint the welds are usually flare-bevel-groove welds on two opposite sides and fillet welds on the other two opposite sides, thus two different welding symbols are required to weld the joint all the way around.



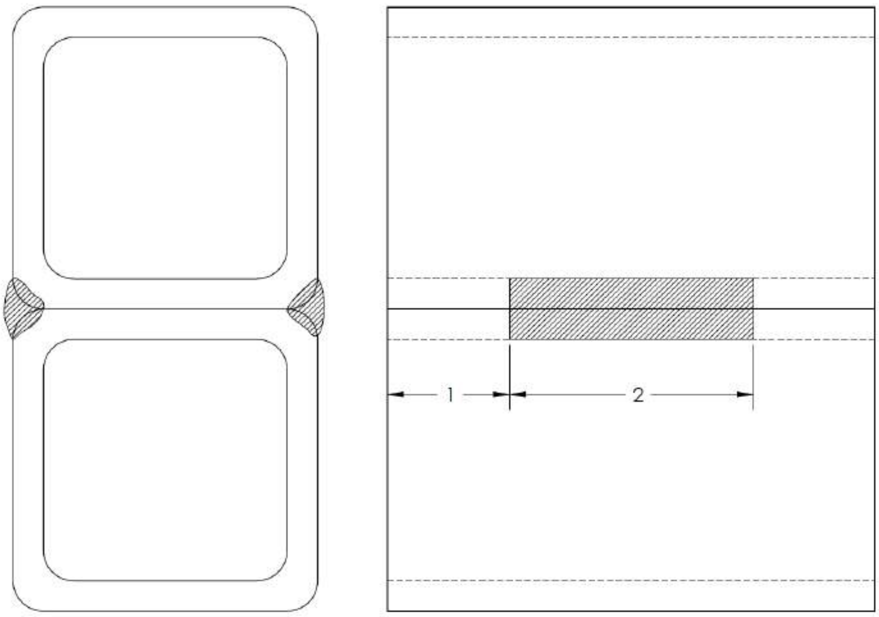



If the weld is not to extend the full length of the joint, but only a measured segment of weld is required, the length of the weld is placed to the right side of the weld symbol.  If the location in the weld joint is important, the drawing will detail exactly where the weld is to be located, with dimensions, hatching, or notes on the drawing.  If there is no specific detail, then the exact location of the weld segment in the joint is not important, as long as the correct amount of weld is applied.

<table>
<tr><th>PRINT</th><th rowspan="2">COMMENTS</th></tr>
<tr><th>WELD EXAMPLE</th></tr>
<tr><td>




</td><td rowspan="2">Double-flare-V-groove weld, ¼-inch throat, 2-inches long.</td></tr>
<tr><td>

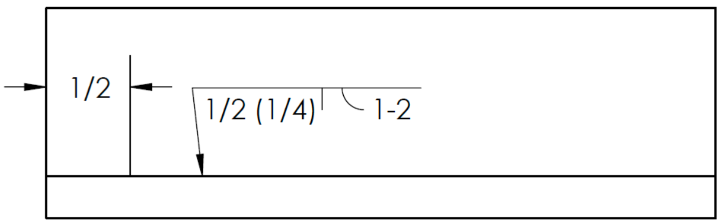
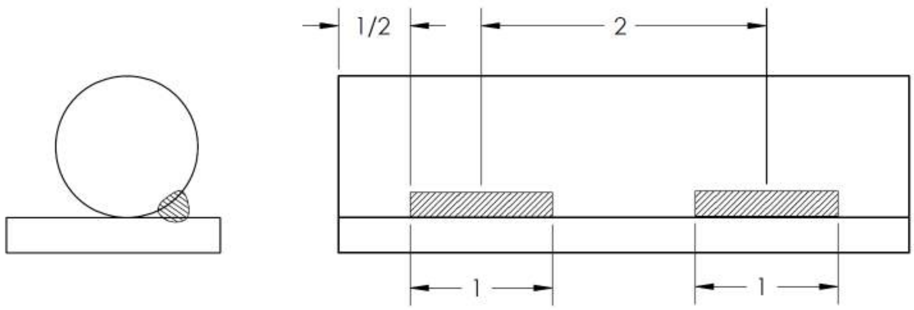



</td></tr>
</table>

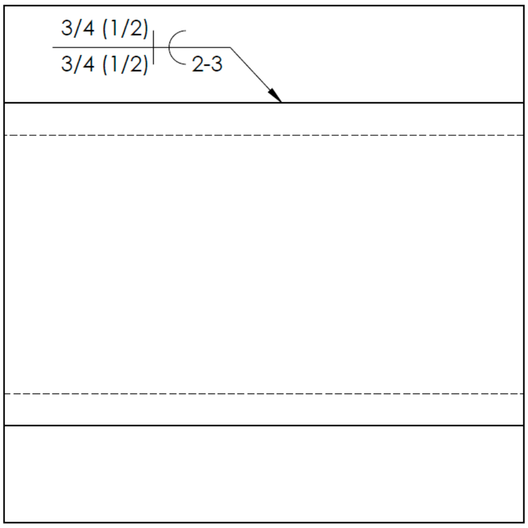
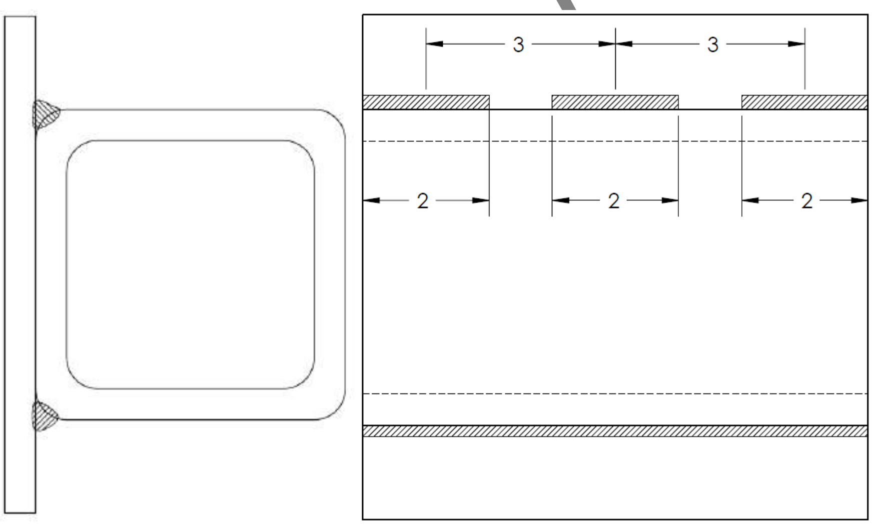
## Intermittent Groove Welds

Sometimes placing a continuous weld the full length of a joint is not needed to meet the design requirements, so the drawing might specify intermittent welding. Most often, intermittent groove welds will be specified only for square-groove, flare-V-groove, and flare-bevel-groove welds. To specify intermittent welding, first the length of each weld increment is specified, then the pitch (center-to-center distance) from weld to weld is given, separated by a hyphen (–).

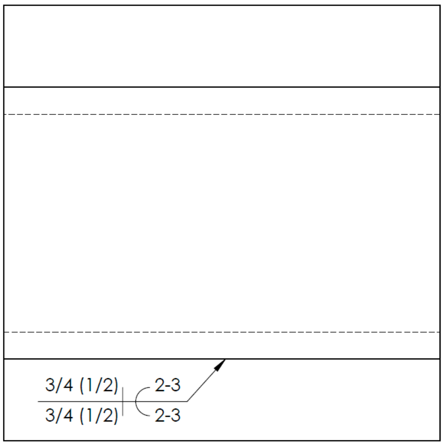
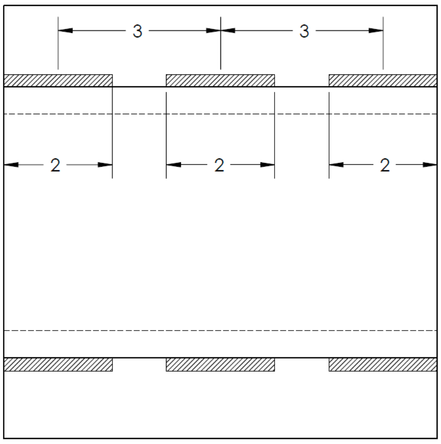
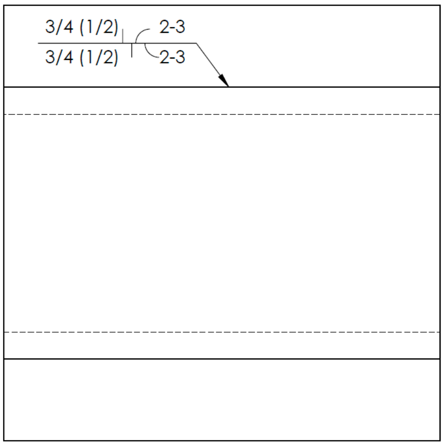
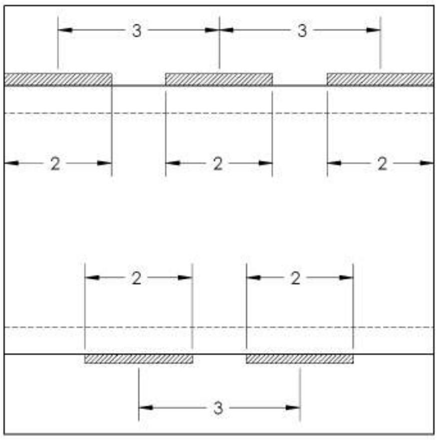
Unless specific locations are given for the intermittent weld, it will usually start at the edge of the weld joint. However, if the sum of the increments and spaces between welds do not equal the length of the joint, it may be necessary to shift the location of the weld to fit the joint. Good welding practice dictates that no weld increment should be shorter than that specified, so the intermittent weld would start out with a space, but not longer than the amount of space provided by the welding symbol. (Subtracting the increment from the pitch gives the length of space between increments.) The designer may also use a dimension locate the start of the first weld increment.

| PRINT<br>WELD EXAMPLE | COMMENTS |
|---|---|
|  | Intermittent single-flare-bevel-groove weld, ¼-inch throat, 1-inch increments with a 2-inch pitch. |
|  | |

On a double-groove weld, the weld on the opposite side is continuous if no increment or pitch is given.

| PRINT<br>WELD EXAMPLE | COMMENTS |
| --- | --- |
|  | Intermittent flare-bevel-groove weld on the arrow side; continuous flare-bevel-groove weld on the other side, ½-inch throat on both sides, 2-inch increments with a 3-inch pitch on the arrow side. |
|  | |

The weld on the opposite side may also be intermittent.  Just as for fillet welds, they may be either "chain intermittent welds" or "staggered intermittent welds."

| PRINT | WELD EXAMPLE | COMMENTS |
|---|---|---|
|   |   | Chain intermittent flare-bevel-groove weld. |
|   |   | Staggered intermittent flare-bevel-groove weld |

**Welding Symbols Activities:**
- Chapter 4 Worksheet (page 109)
- Welding Symbols Exam 1

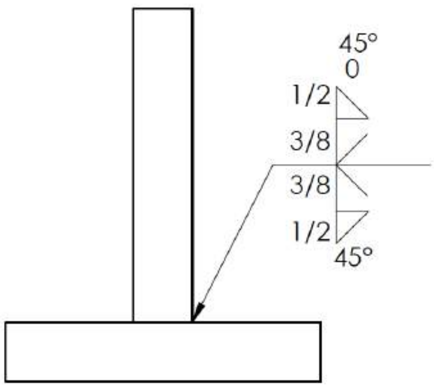
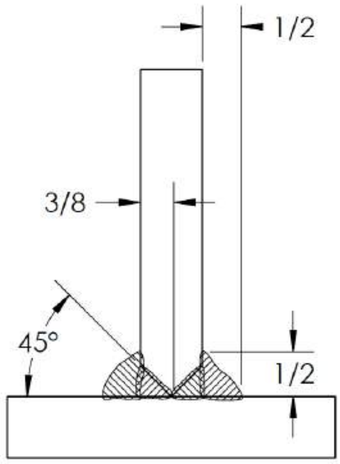
**Print Reading Lab Work:**
- Project 3:  Keyed Angle Mount (page 173)

# 5. Additional Details: Combination Welds, Multiple Reference Lines, and Tail Notes

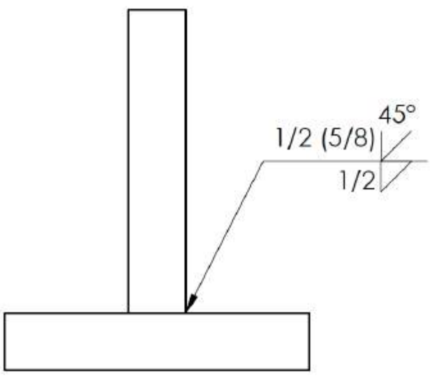
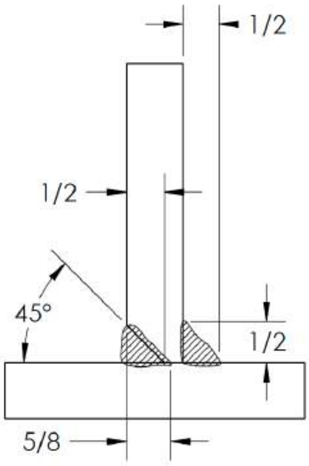
A number of additional details can be added to welding symbols to convey additional information. These details can be applied to both fillet and groove welds.

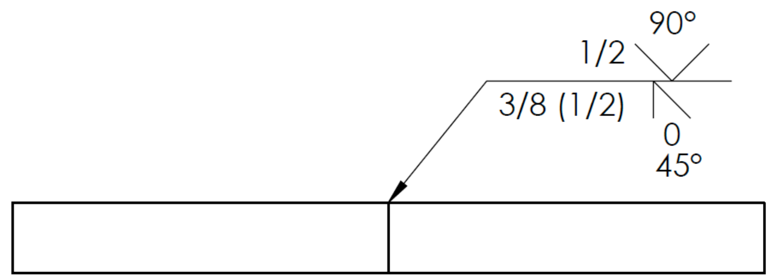
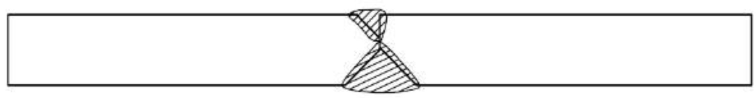
## Combination Welds

Some welded designs require more than one type of weld symbol to specify the proper weld. For example, a T-joint might be welded with a double-bevel-groove weld and reinforced with additional fillet welding, as shown below.

| PRINT | WELD EXAMPLE | COMMENTS |
|---|---|---|
|   |   | T-joint with double-bevel-groove weld reinforced with double-fillet welds. |

Different combinations of weld symbols may also be used on the welding symbol.

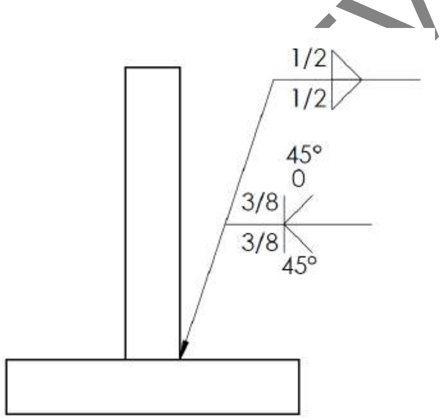
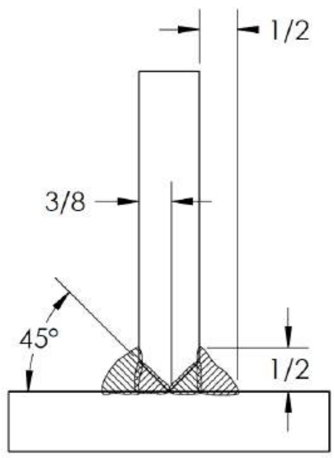
| | | |
|---|---|---|
|   |   | T-joint with fillet weld on the arrow side and single-bevel-groove weld on the other side. |

| PRINT / WELD EXAMPLE | COMMENTS |
|---|---|
|  | Butt joint with bevel-groove weld on the arrow side and V-groove weld on the other side.<br><br>Note: because the arrow is not broken, either member may be prepared with the bevel-groove. |
|  | |



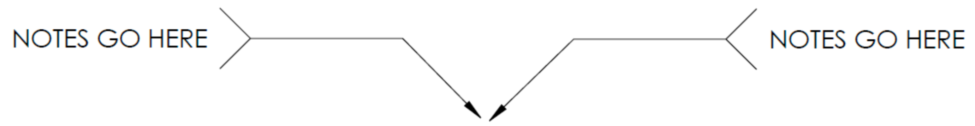
### Multiple Reference Lines

Instead of using multiple weld symbols on the same reference line, as previously discussed, multiple reference lines may be used in the welding symbol to specify a sequence of operations. The operation specified on the reference line closest to the arrow is executed first.

| PRINT | WELD EXAMPLE | COMMENTS |
|---|---|---|
|  |  | T-joint with double-bevel-groove weld reinforced with double-fillet welds. |

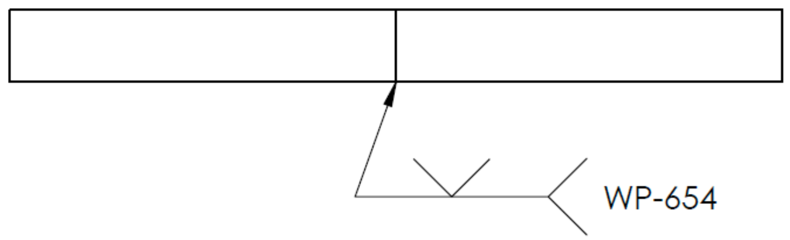
## Tail Notes

Any additional information needed for welding can be specified in a tail note.  A tail is added to the reference line opposite the arrow and the notes are written in the tail.

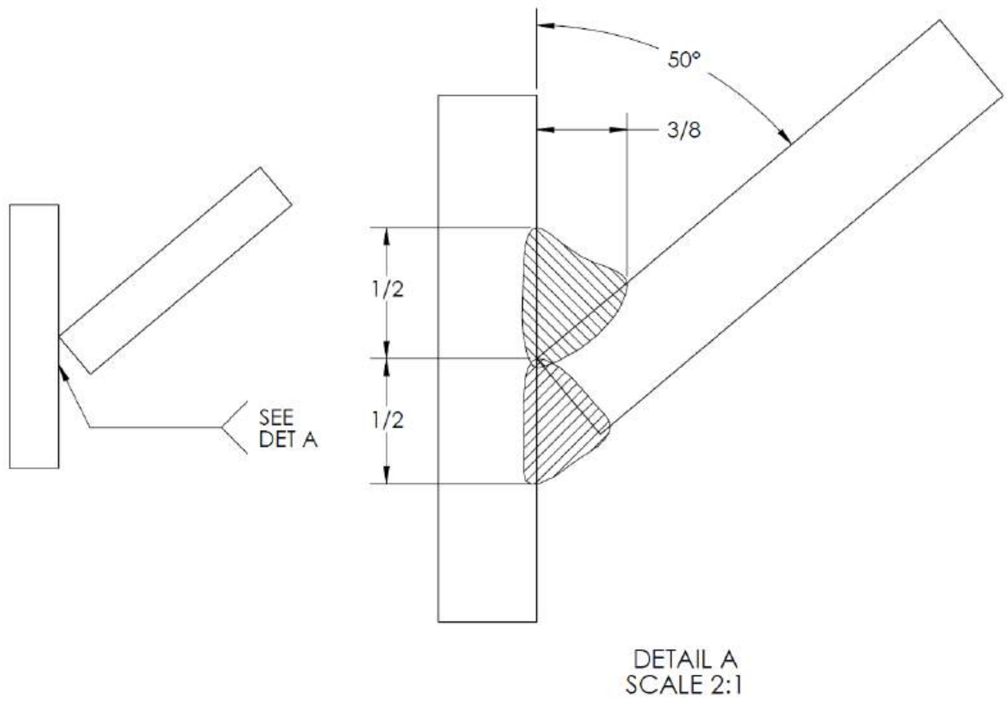



The following examples illustrate the most common uses of the tail:

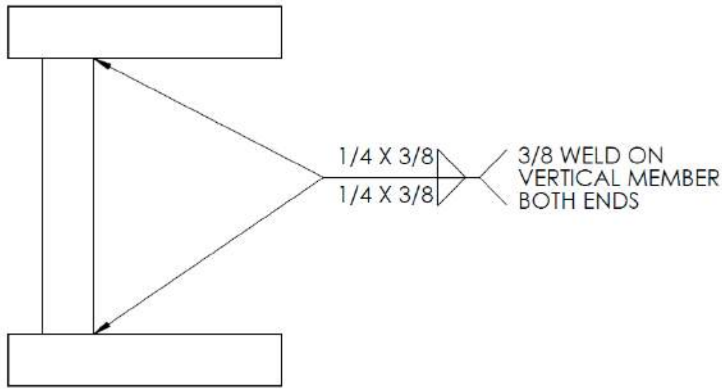
- Supplementary data, such as a welding procedure.



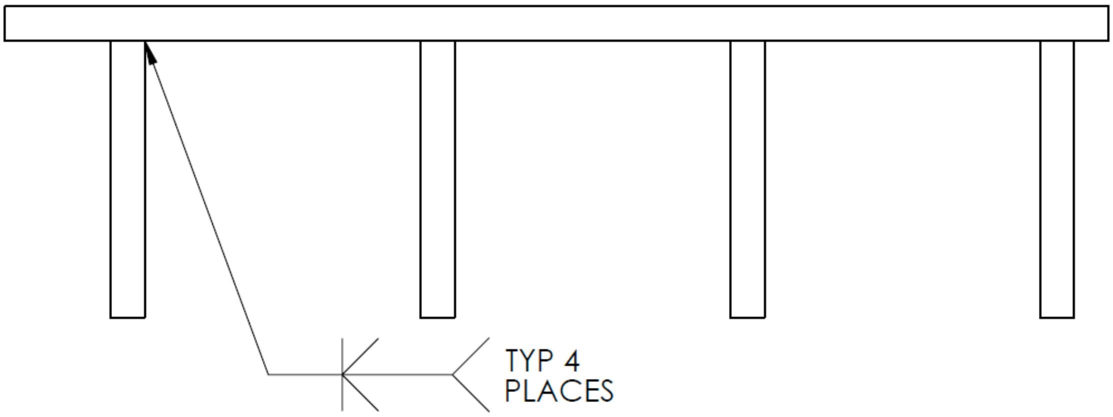

- A note referencing a detail drawing, for cases such as a skew-T joint where the weld dimensions cannot be clearly stated in the welding symbol.



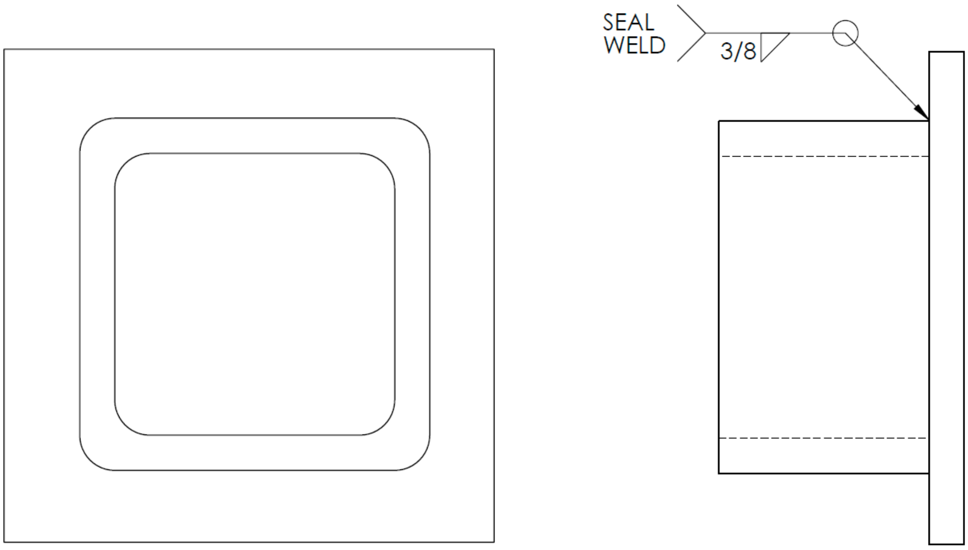
- Notes to clarify welding symbol requirements.



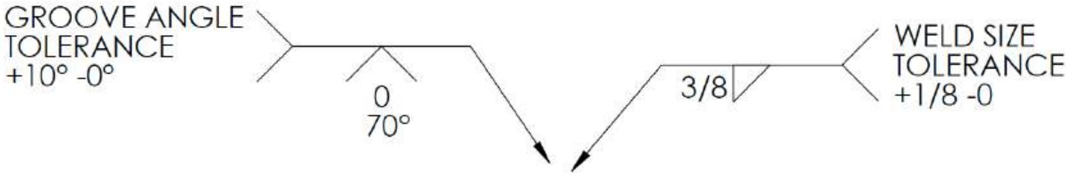

- “Typical” designation for multiple identical joints.



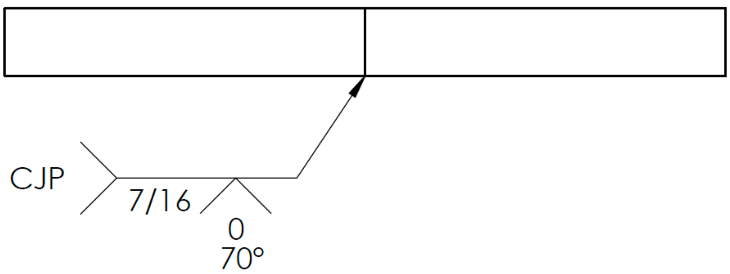

- “Seal Weld” designation when a weld’s only purpose is a sealing function.



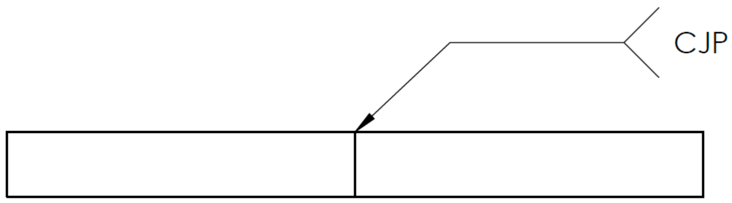
- Weld dimension tolerances.



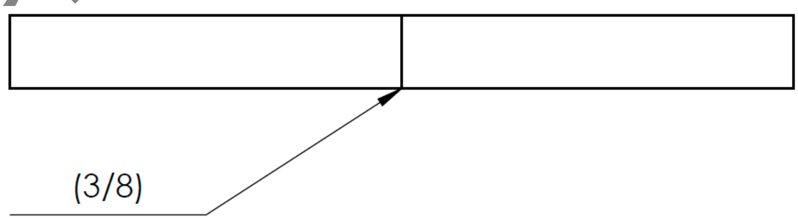

- Complete joint penetration (CJP) note, used when the depth of groove is less than the plate thickness, but complete joint penetration is required.



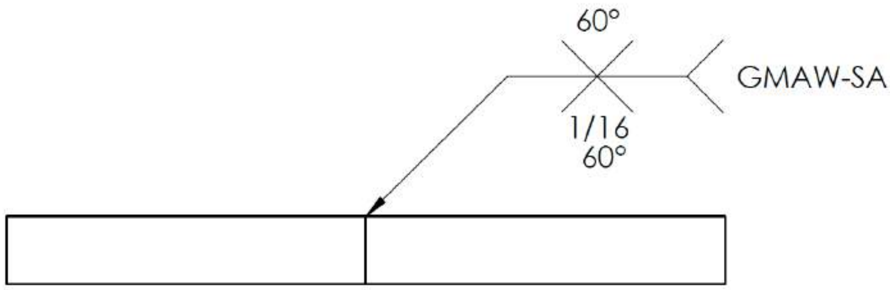

The CJP note can actually be used as the only designation on the entire welding symbol, giving the welder the freedom to use any joint geometry needed to produce a sound weld which meets all dimensional requirements of the drawing.   Using the welding symbol in this way is quite unusual, and risky for the designer, but is nevertheless allowed by the welding symbols standard.




(The standard also allows a groove weld to be specified only by the weld size, with no other geometry given.)



* Specified welding process and method.




The welding process is specified by the official AWS designation for the welding process. The table on the next page presents the common official AWS welding designations.

| WELDING PROCESS DESIGNATIONS | |
|---|---|
| SMAW | shielded metal arc welding (stick) |
| GMAW | gas metal arc welding (MIG), spray transfer is assumed unless –P or –S is specified |
| GMAW-P | pulsed gas metal arc welding |
| GMAW-S | short circuit gas metal arc welding |
| GTAW | gas tungsten arc welding (TIG) |
| FCAW | flux cored arc welding, with or without gas unless –G or –S is specified |
| FCAW-G | gas shielded flux cored arc welding |
| FCAW-S | self shielded flux cored arc welding |
| PAW | plasma arc welding |
| SAW | submerged arc welding |
| ESW | electroslag welding |
| LBW | laser beam welding |
| EBW | electron beam welding |
| PW | projection welding |
| RSW | resistance spot welding |
| RSEW | resistance seam welding |

| OPTIONAL SUFFIXES FOR WELDING PROCESS DESIGNATIONS | |
|---|---|
| MA | manual |
| SA | semi-automatic |
| ME | mechanized |
| AU | automatic |
| AD | adaptive control |
| RO | robotic |



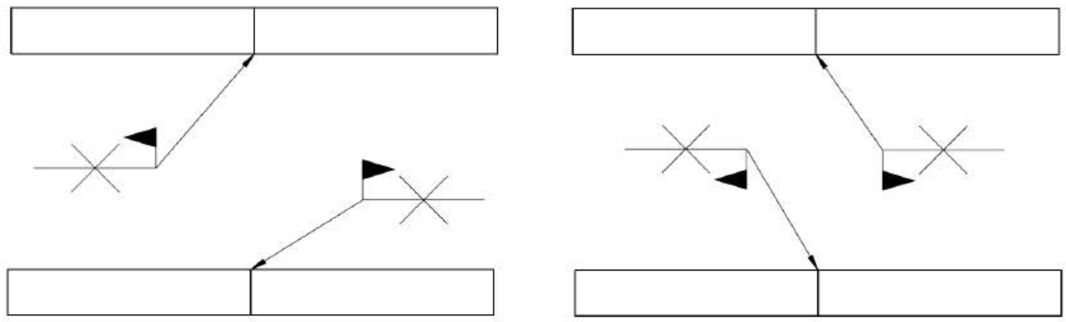
**Welding Symbols Activities:**
- Chapter 5 Worksheet (page 117)

**Print Reading Lab Work:**
- Project 4: Box Section (page 175)

# 6. Additional Details: Field Weld, Weld Contour, and Complete Joint Penetration (Melt-Through)

## Field Weld Symbol

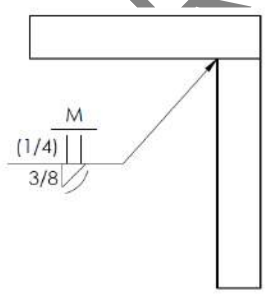
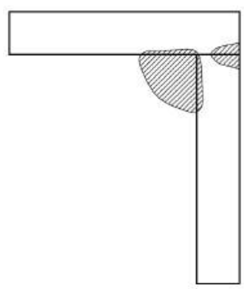
The field weld symbol is added to the welding symbol to indicate that welding will be performed outside of the welding fabrication shop. For example, a steel bridge might be fabricated by welding parts into modular sections that may be shipped by truck to the construction site. At the construction site, the sections will be moved into position and welded in place. Those welds to be made at the construction site would be designated as field welds. The flag may be on either side of the reference line and point either direction, so long as the flagpole is at a right angle to the reference line.

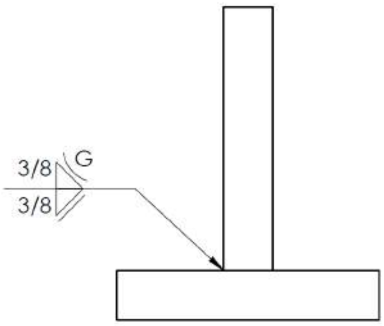
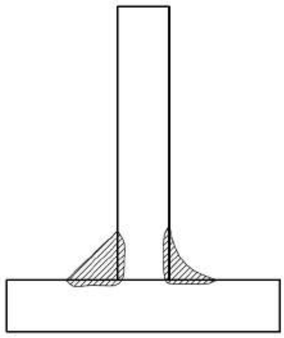


## Weld Contour Symbols

If the weld is to have a specific contour, either flush (or flat, for a fillet weld), concave, or convex, then the weld contour symbol is added. A finishing method designator may also be added when a particular process is to be used for finishing. If no method designator is added, then the weld is to be produced to the desired contour without post-weld finishing. Finishing designators are shown in the table on the next page.



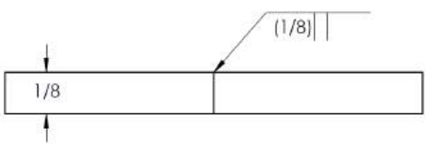
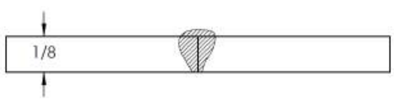
| PRINT | WELD EXAMPLE | COMMENTS |
|---|---|---|
|   |  | Corner joint with fillet weld on arrow side welded with a flat contour and a square-groove weld on the other side machined flat (flush). |

| PRINT | WELD EXAMPLE | COMMENTS |
|---|---|---|
|   |  | T-joint with double-fillet welds, welded with a flat contour on the arrow side and ground to a concave contour on other side |

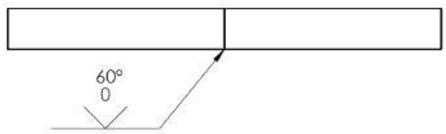
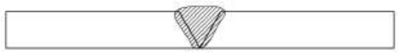
| FINISHING METHOD DESIGNATORS | |
|---|---|
| C....... Chipping<br>G....... Grinding<br>H....... Hammering<br>M ...... Machining<br>P....... Planishing | R ....... Rolling<br>U ....... method Unspecified (but some method must be used—the weld cannot be left as-welded) |

## Complete Joint Penetration (melt-through)

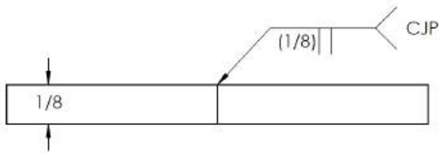
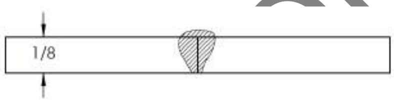
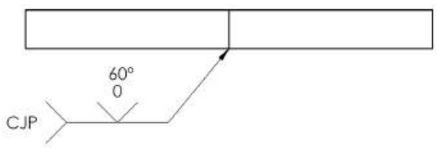
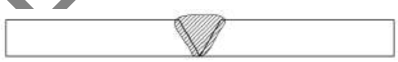
In many welding applications, complete joint penetration is required. This is ordinarily achieved by ensuring the weld size equals the thickness of the member welded.

| PRINT | WELD EXAMPLE | COMMENTS |
|---|---|---|
|   |   | Butt joint welded from the arrow side. The weld size equals the plate thickness; therefore, complete joint penetration is required. |

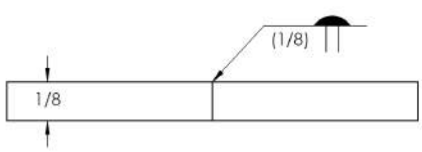
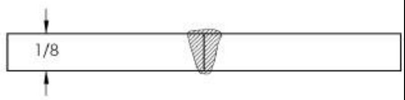
A joint will also have complete joint penetration if the depth of groove and weld size are not specified, because this indicates the full plate thickness is beveled and the weld size equals the groove depth.

| PRINT | WELD EXAMPLE | COMMENTS |
|---|---|---|
|  |  | Butt joint with single-V-groove weld. The entire thickness of the plate is beveled and the weld must be at least the depth of groove; therefore, complete joint penetration is required. |

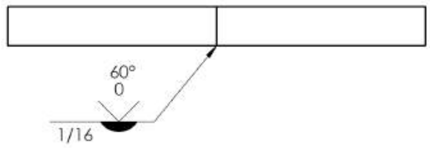
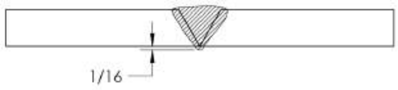
Some designers will add the tail note "CJP" to remove any doubt that complete joint penetration is required, however this is redundant. The proper use of the "CJP" tail note was covered in chapter 5.

| | | |
|---|---|---|
|  |  | Butt joint welded from the arrow side. Because the weld size equals the plate thickness, complete joint penetration is required and the tail note is redundant. |
|  |  | Butt joint with single-V-groove weld. Because the entire thickness of the plate is beveled and the weld must be at least the depth of groove, complete joint penetration is required and the tail note is redundant. |

When complete joint penetration is required ***with visible root reinforcement***, then the melt-through symbol is placed on the reference line opposite the weld symbol.

| | | |
|---|---|---|
|  |  | Butt joint with melt-through. |

The amount of root reinforcement may be specified to the left of the melt-through symbol if a certain amount of melt-through is required.

| | | |
|---|---|---|
|   |   | Single-V-groove weld with $\frac{1}{16}$-inch of melt-through. |

**Welding Symbols Activities:**

- Chapter 6 Worksheet (page 123)

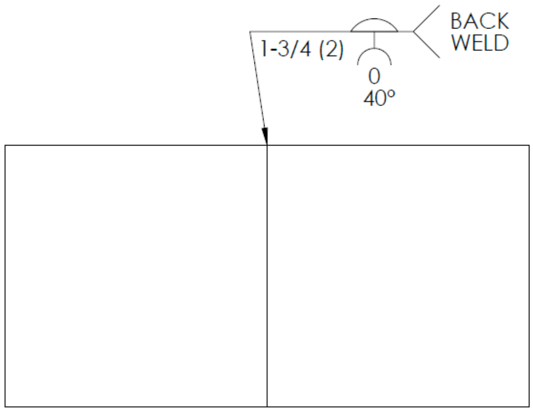
**Print Reading Lab Work:**

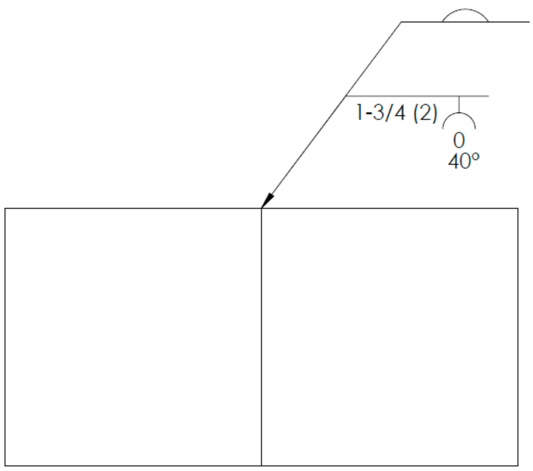
- Example 1 Worksheet: Storage Tank Platform (page 177)

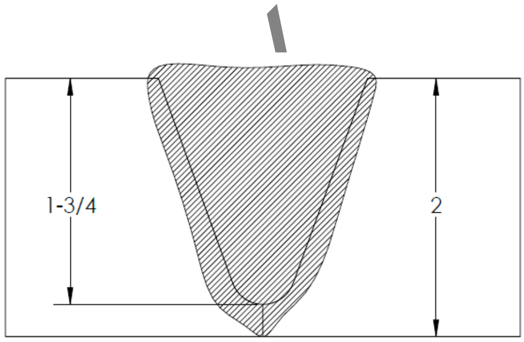
# 7. Groove Weld Details: Back and Backing Welds, and Backgouging

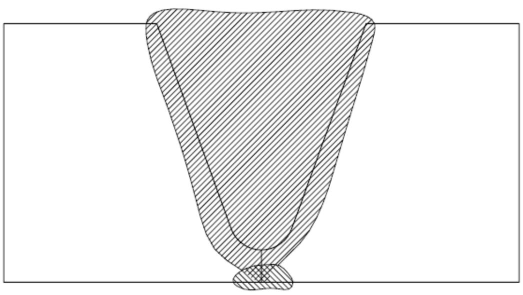
## Back Welds

After completing a groove weld from one side of the plate, it may be desirable to finish the root of the weld by applying a single weld bead over the root. This additional weld, applied after completing the primary weld, is called a back weld. The back weld symbol may be placed on the reference line opposite the groove weld symbol along with the tail note “back weld.” Alternately, the back weld symbol may be placed on an additional reference line showing the sequence of welding.

<table>
<tr><th>PRINT</th><th>WELD EXAMPLE</th></tr>
<tr><td>


<br>
OR
<br>


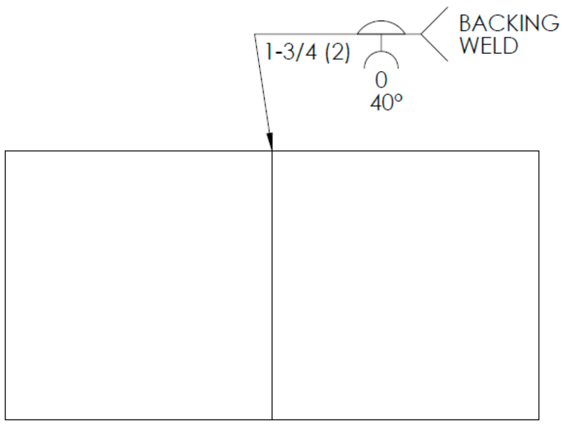
</td><td>


STEP 1, U-GROOVE WELD ARROW SIDE BEFORE BACK WELD
<br>

STEP 2, BACK WELD OTHER SIDE
</td></tr>
</table>

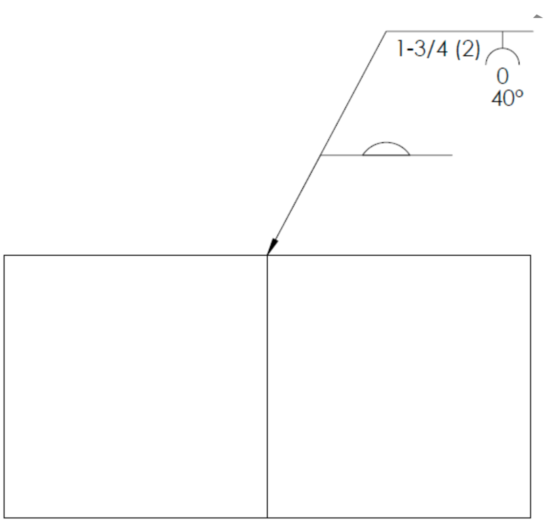
## Backing Welds

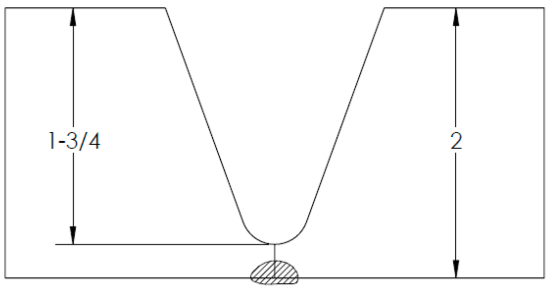
If a weld bead is placed on the reverse side of the weld joint prior to making the groove weld, then the additional weld is called a backing weld.  The backing weld symbol is the same as the back weld symbol, except that the tail note “backing weld” is used to indicate that the backing weld is applied first.  If multiple reference lines are used, then the backing weld would appear as the first weld in the sequence.

| PRINT | WELD EXAMPLE |
|---|---|

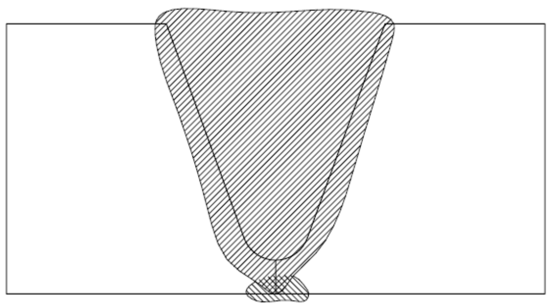



OR



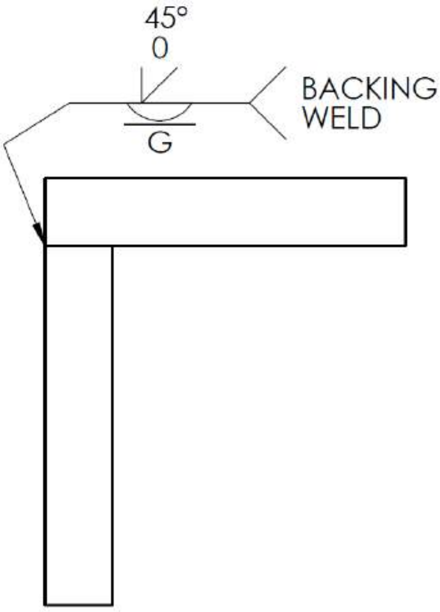
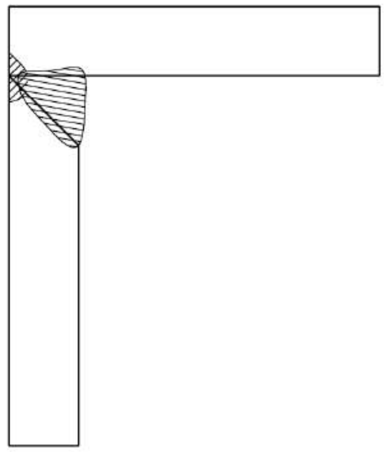




STEP 1, BACKING WELD MADE ON OTHER SIDE



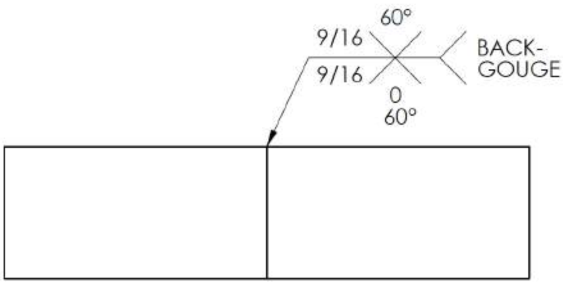
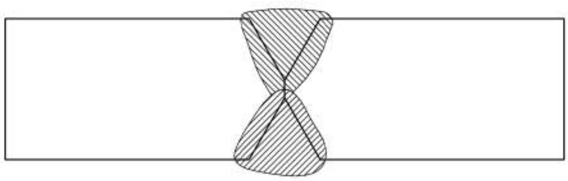
STEP 2, U-GROOVE WELD ON ARROW SIDE

Contour symbols may be applied to both back and backing welds if a particular contour is needed.

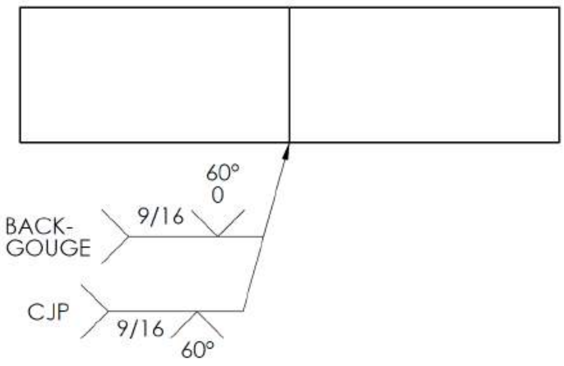
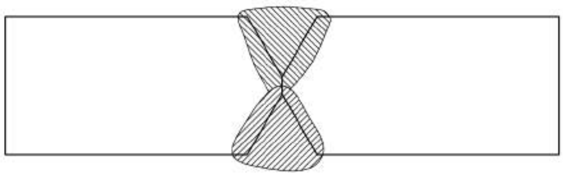
| PRINT | WELD EXAMPLE |
|---|---|
|  |  |

## Backgouging

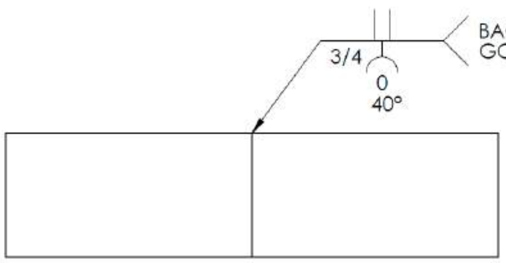
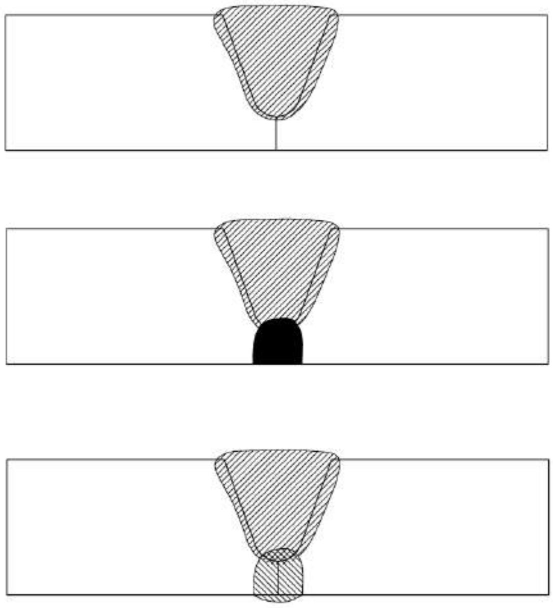
When welding a double groove weld, the root of the first side is usually backgouged by grinding, carbon-arc gouging, plasma gouging, or chipping to ensure a sound root prior to beginning the second side of the weld. The tail note “backgouge” is added to the welding symbol to require backgouging the first side prior to welding the second side.

| | |
|---|---|
|  |  |

Multiple reference lines may be used if a certain sequence of welding is required; otherwise, either side may be welded first. The “backgouge” note goes in the tail of the first-operation reference line.

| PRINT | WELD EXAMPLE |
| --- | --- |
|  |  |

The process of backgouging often changes the joint geometry during welding, especially when a square-groove joint is specified. The result of backgouging will usually be a U-groove joint; however, the change in geometry due to backgouging is not shown on the welding symbol. The symbol shows only the original joint design prior to any welding or backgouging.

| | |
| --- | --- |
|  |  |

**Welding Symbols Activities:**

- Chapter 7 Worksheet (page 129)

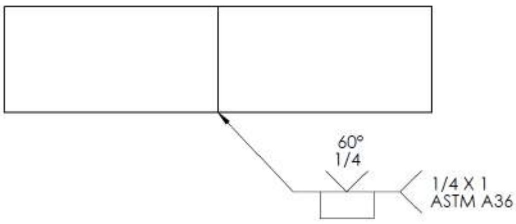
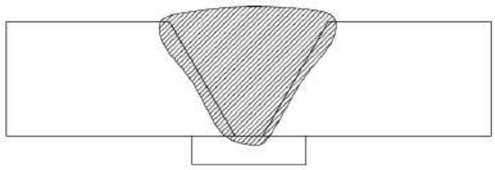
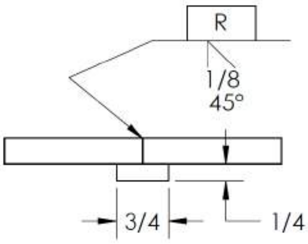
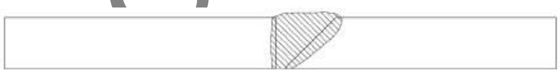
**Print Reading Lab Work:**

- Example 2: Stock Pusher Guide (page 179)

# 8. Groove Weld Details:
# Backing, Spacers, and Consumable Inserts

## Backing

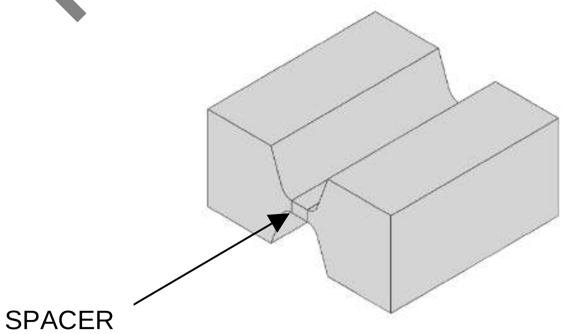
If a groove weld is to be made with a backing bar, then the backing symbol is placed on the opposite side of the groove weld symbol. If the backing is to be removed after welding, the letter "R" is placed inside the backing symbol. The dimensions of the backing bar and the material to be used may be specified in the tail of the symbol, or they may be specified on the drawing.

<table>
<tr><th>PRINT</th><th>WELD EXAMPLE</th></tr>
<tr><td>
</td><td></td></tr>
<tr><td>
</td><td></td></tr>
</table>

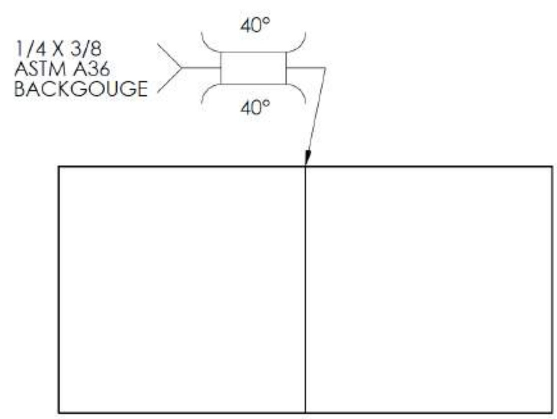
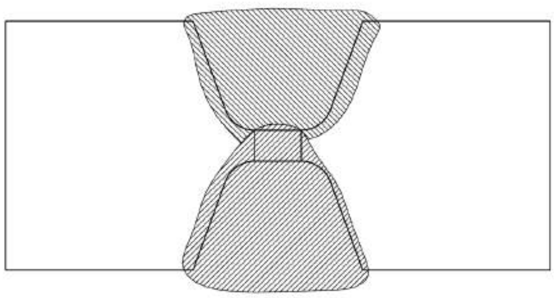


## Spacers

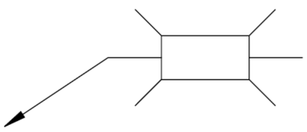
Weldments that are made from thick members, typically 1-inch thick or greater, welded with double groove welds sometimes call for spacers to assist with fit-up of the assembly. Spacers act as a backing bar for the first side welded, and maintain a proper root opening between the members. Prior to welding the second side, the joint is backgouged to remove most of the spacer until sound metal is achieved. The thickness of the spacer is usually the same as the root face.



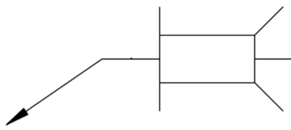
The symbol for a spacer is the same as a backing bar, but it is placed in the center of the reference line and the weld symbol is modified to accommodate the spacer symbol.  The dimensions of the spacer and the material to be used are placed in the tail of the symbol or specified on the drawing.

| PRINT | WELD EXAMPLE |
|---|---|
|  |  |

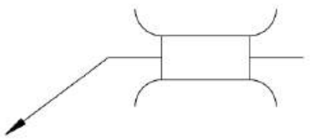
The following examples show how the various welding symbols are modified to include the spacer:



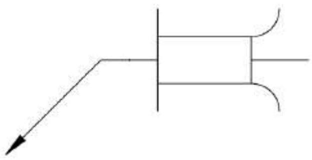
DOUBLE-V-GROOVE WELD
WITH SPACER



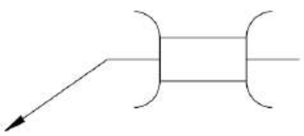
DOUBLE-BEVEL-GROOVE WELD
WITH SPACER



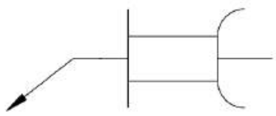
DOUBLE-U-GROOVE WELD
WITH SPACER



DOUBLE-J-GROOVE WELD
WITH SPACER



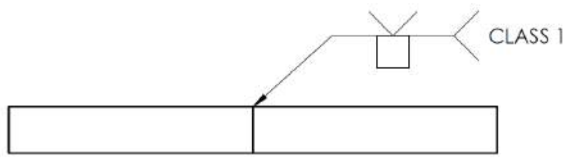
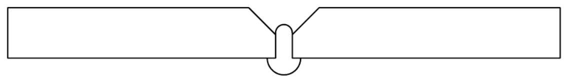
DOUBLE-FLARE-V-GROOVE WELD
WITH SPACER



DOUBLE-FLARE BEVEL-GROOVE WELD
WITH SPACER

## Consumable Inserts

If a consumable insert is required, the consumable insert symbol is placed opposite the weld symbol.  The AWS consumable insert class is placed in the tail of the welding symbol.  Contour symbols may be applied to the consumable insert symbol to indicate the desired contour after welding.

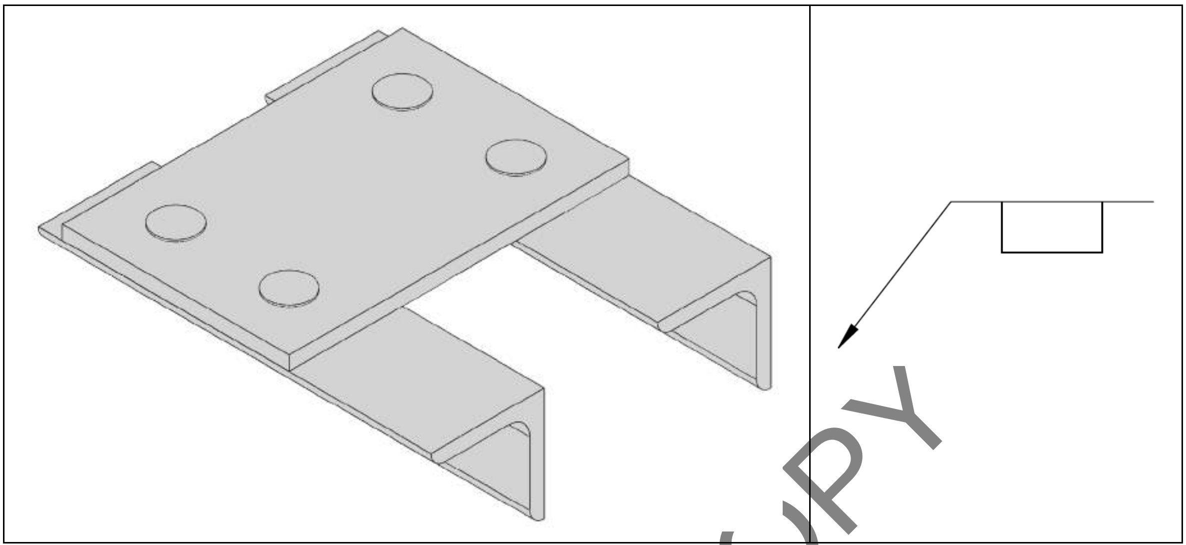
| PRINT | WELD EXAMPLE |
|---|---|
|   |  |

**Welding Symbols Activities:**
- Chapter 8 Worksheet (page 133)
- Welding Symbols Exam 2

**Print Reading Lab Work:**
- Project 5: Post Base Assembly (page 181)

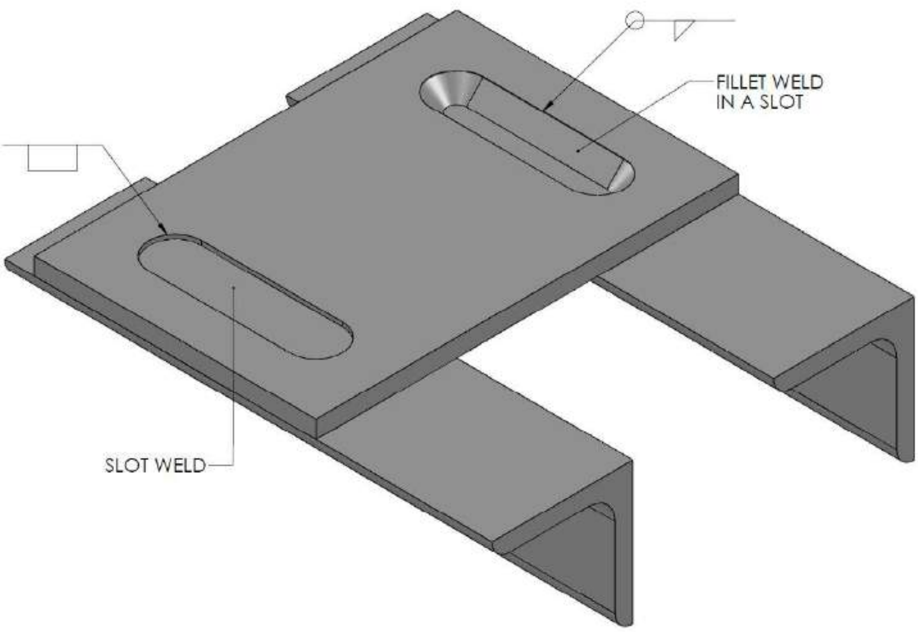
# 9. Plug and Slot Welds

Plug welds and slot welds are usually used to hold sheet or plate materials to supporting substructures by punching or drilling holes or slots in the sheet at various locations over the substructure and filling the holes or slots with weld metal. If the holes or slots are filled all the way and ground flush, the finished surface will be smooth and unbroken.



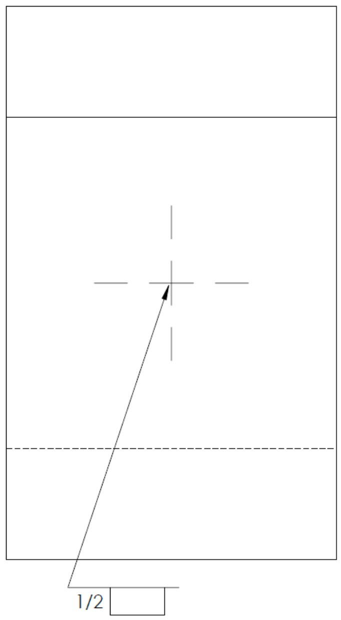
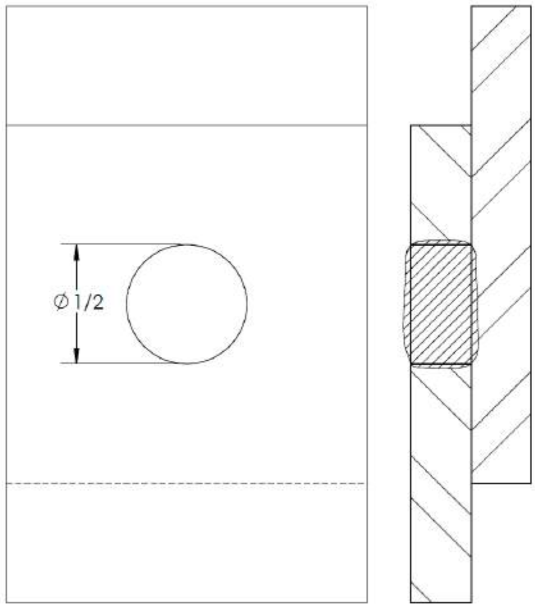
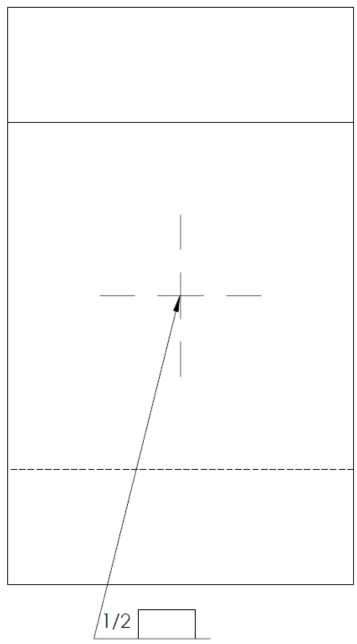
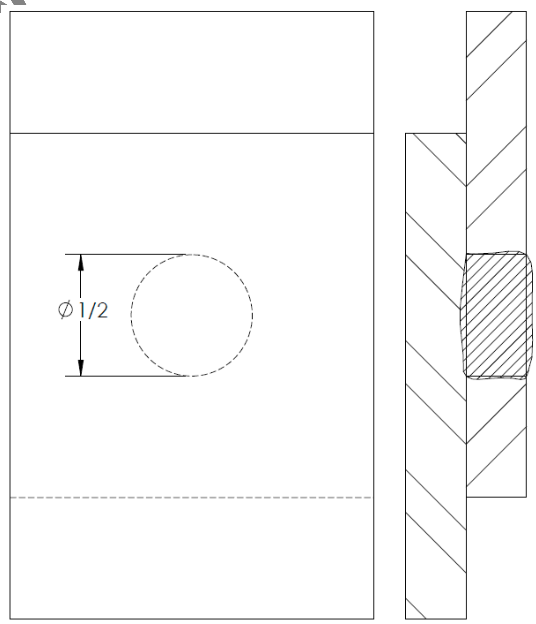


Sometimes fillet welds are placed in holes or slots, but these must not be confused with plug or slot welds because the entire hole or slot is not covered with weld metal. Welds of this type are specified with fillet weld symbols, and the holes must be detailed on the drawing.

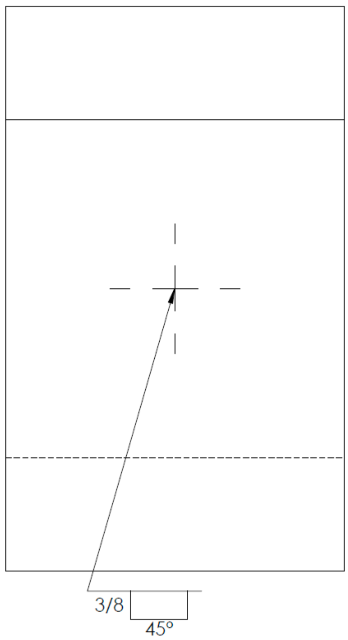
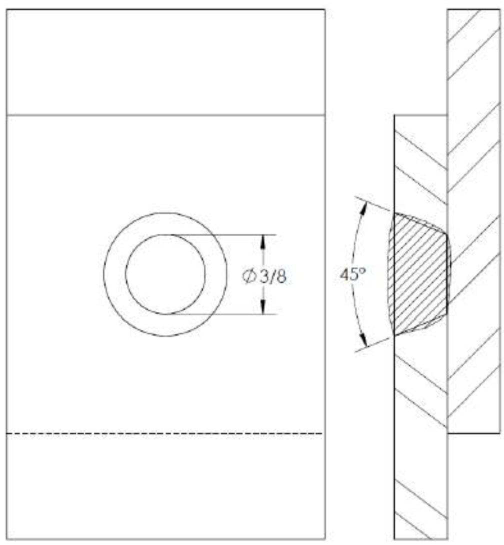


## Plug Welds

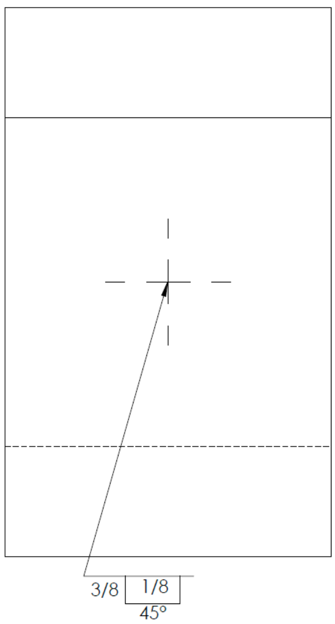
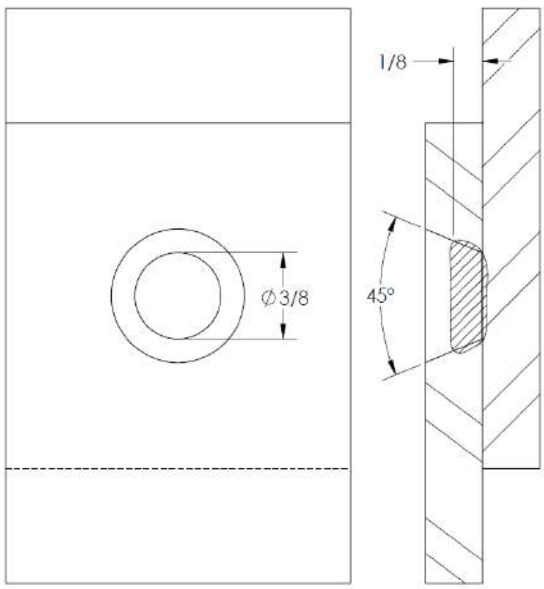
Plug welds are made in round holes. On the drawing, only the center of the plug weld will be specified; the hole itself will not usually be shown. The plug weld symbol looks just like the backing symbol for groove welds, but the addition of dimensions and the lack of a groove weld symbol differentiate it from a backing bar. Plug welds may be made from the arrow side or the other side. The diameter of the hole is specified to the left of the plug weld symbol.

| PRINT | WELD EXAMPLE |
|---|---|
|   |   |
|   |   |

The plug weld hole might be countersunk. The included angle of the countersink is specified above or below the plug weld symbol, just as the angle for groove welds was specified. When the hole is countersunk, the diameter of the plug weld is the diameter at the bottom of the hole.

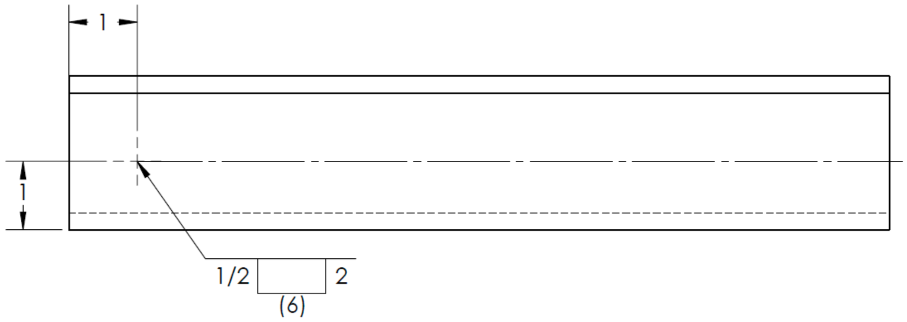
| PRINT | WELD EXAMPLE |
|---|---|
|   |   |

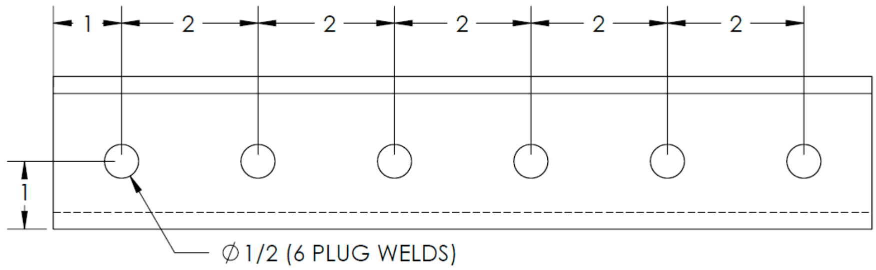
Usually, plug welds are filled completely. If the plug weld is not to be filled completely, then the thickness of the plug weld is specified inside the symbol. Note that a number like "½" means to make the plug weld ½-inch thick, not to fill the hole ½ way full.

| | |
|---|---|
|   |   |

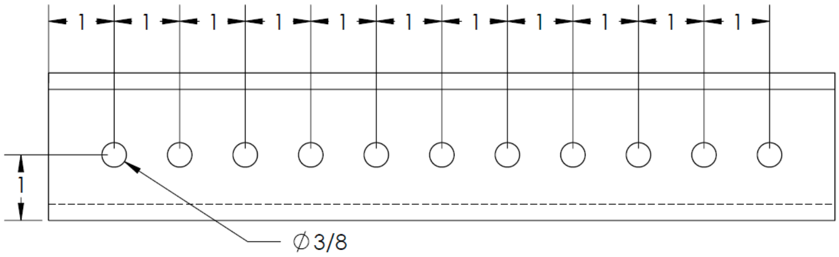
Multiple plug welds may be specified with a single welding symbol by indicating the pitch (center-to-center spacing) of the welds to the right of the weld symbol, and indicating the total number of plug welds in parentheses above or below the weld symbol, as appropriate. The drawing will show a center mark for the first plug weld, and a centerline to show where the row of plug welds is placed.

| PRINT |
| --- |
| WELD EXAMPLE |



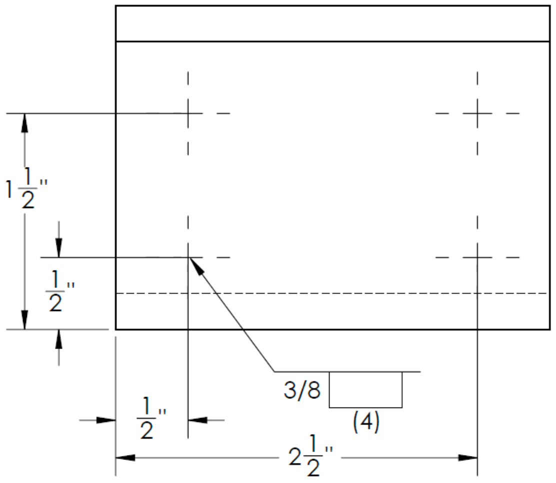



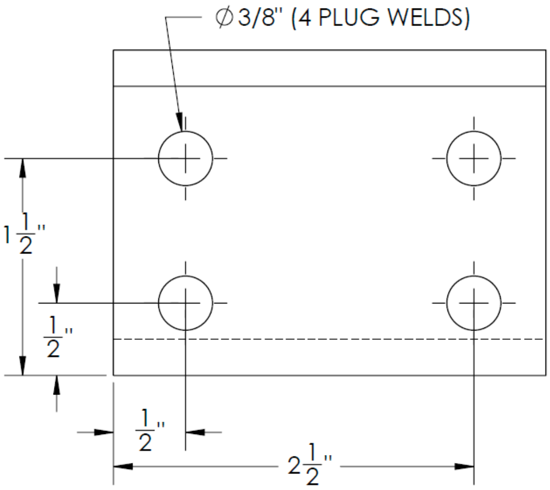

If the number of plug welds is important, but the pitch does not matter, then the pitch dimension may be left off of the symbol. Likewise, the total number of plug welds may be left off of the welding symbol if the entire joint is to be filled with plug welds at the specified pitch.

If the plug welds are placed in a pattern other than a straight line, then the drawing will show the locations of each plug weld.

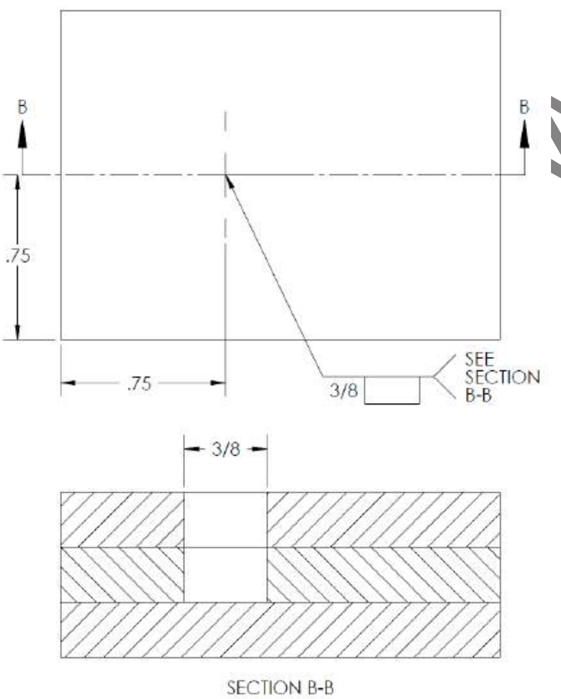
| PRINT | WELD EXAMPLE |
|---|---|

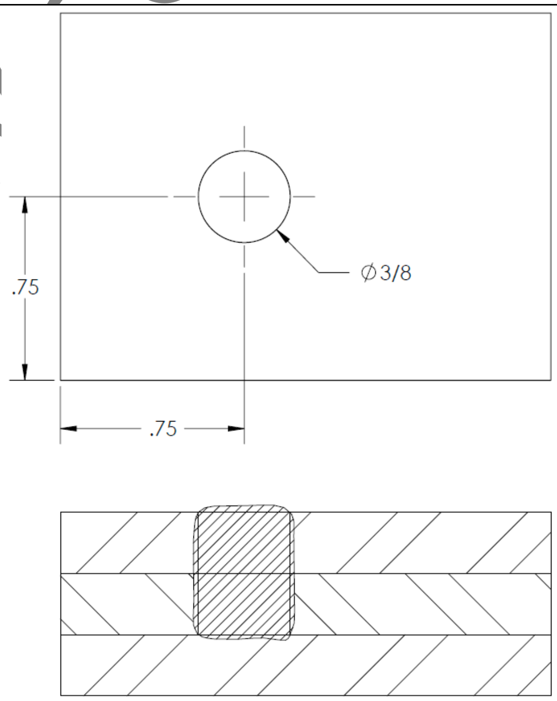


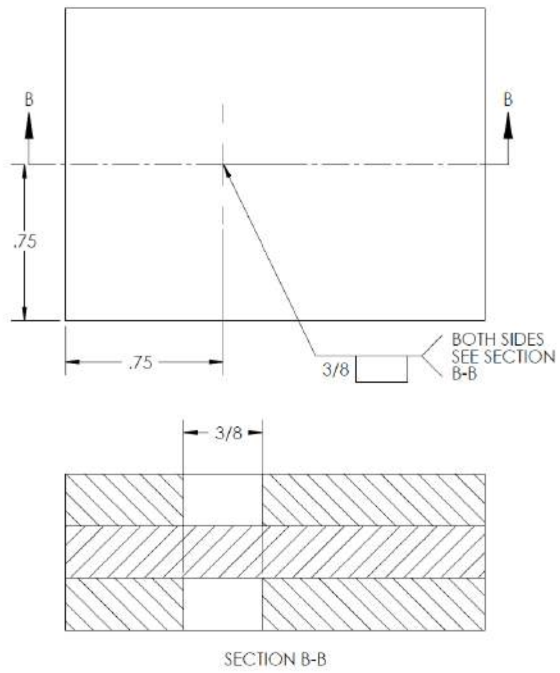
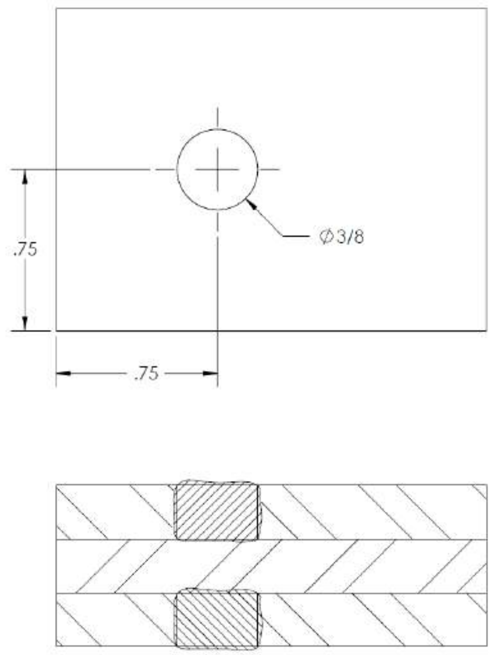




If the plug welded assembly has three or more members, then a detail drawing (usually a section view) is required to clarify exactly which member receive the hole for the plug weld.

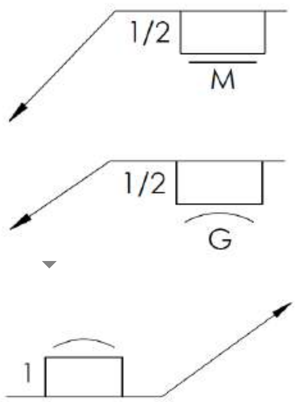




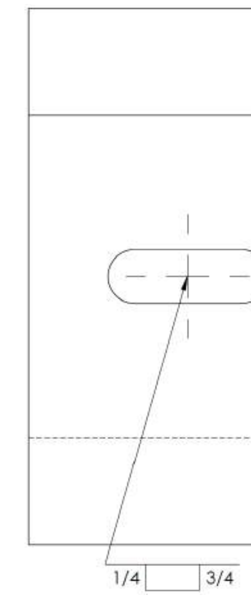
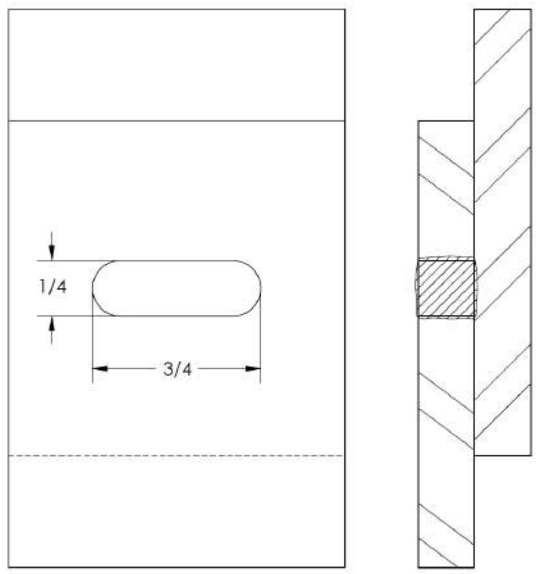
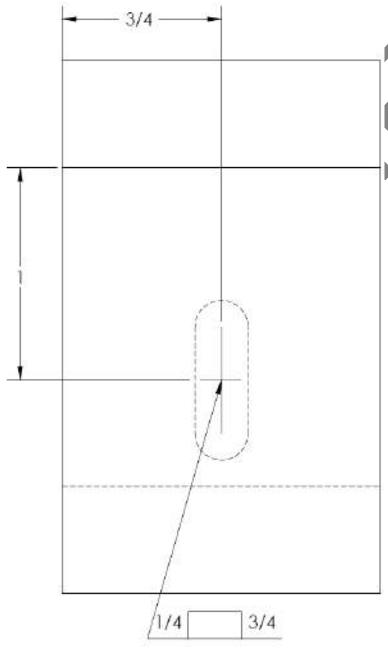
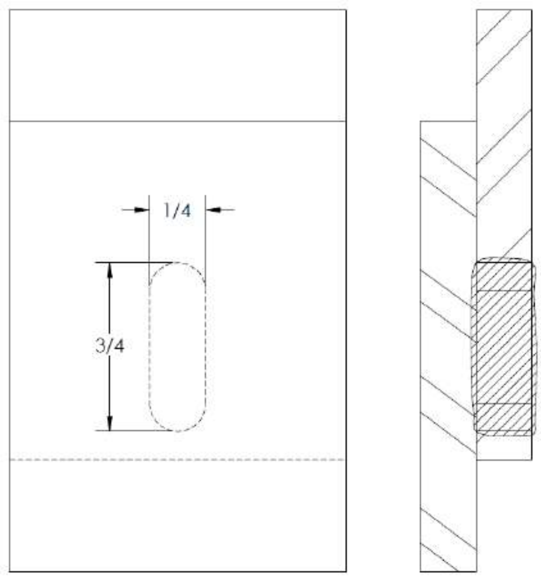
<table>
<tr><th>PRINT</th><th>WELD EXAMPLE</th></tr>
<tr><td>
</td><td>
</td></tr>
</table>

Contour symbols may be applied to plug welds as needed to specify postweld finishing.



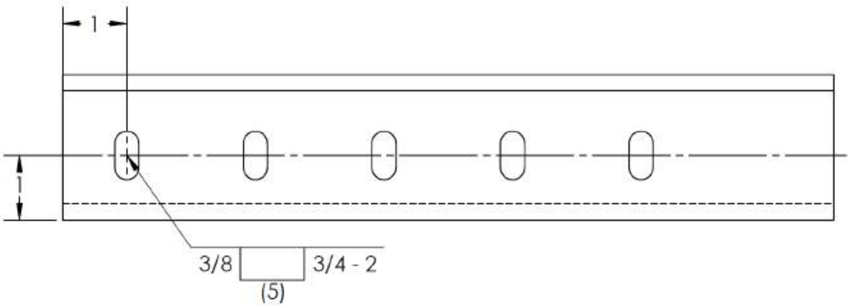
### Slot Welds

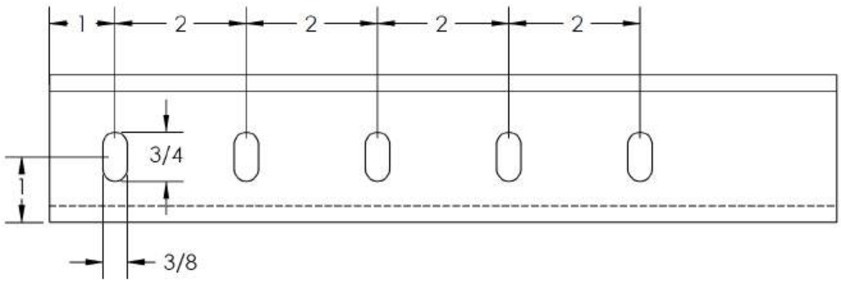
Slot welds share the same characteristics and weld symbol as plug welds, except that the width of the slot is placed to the left of the weld symbol and the length of the slot is placed to the right of the weld symbol.  The drawing will show the center of the slot and the orientation of the slot.  The slots themselves will not usually be dimensioned in the drawing.

<table>
<tr><th>PRINT</th><th>WELD EXAMPLE</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>
</td><td>
</td></tr>
</table>

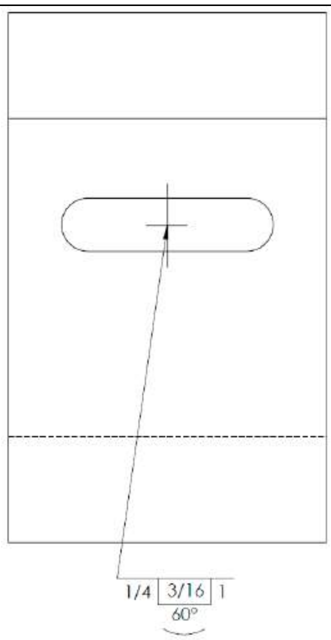
Multiple slots may be indicated by giving the pitch (center-to-center distance) between the centers of the slots to the right of the length dimension following a hyphen (–) and the number of slot welds in parentheses above or below the weld symbol as appropriate. The drawing must show the orientation of the slots.

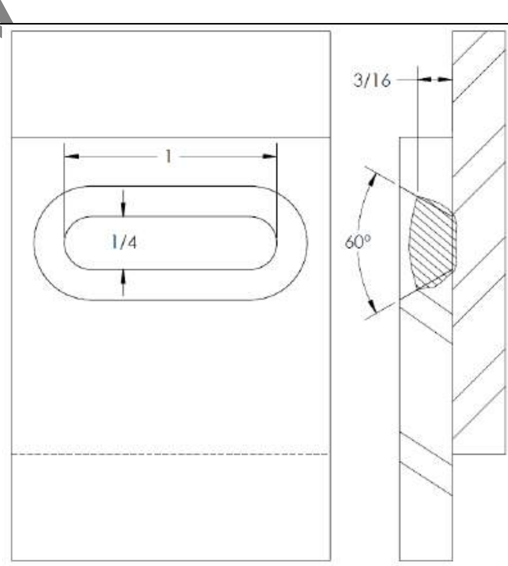
| PRINT |
| --- |
| WELD EXAMPLE |




Countersink angle, depth of fill, and weld contour may all be specified just as for plug welds.



**Welding Symbols Activities:**

- Chapter 9 Worksheet (page 137)

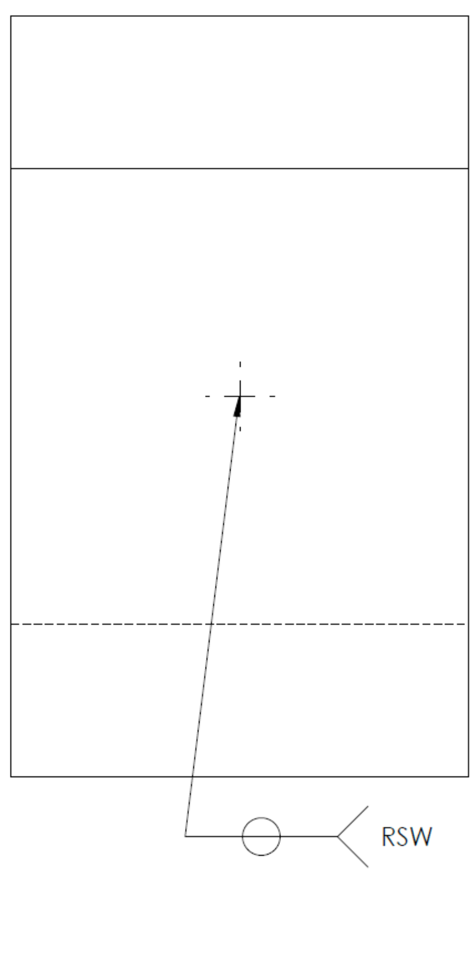
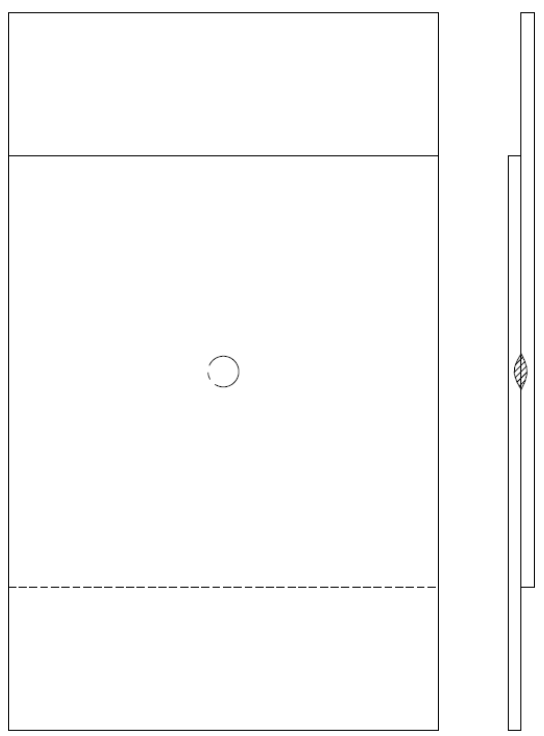
**Print Reading Lab Work:**

- Project 6: Pulley Mount Bracket Assembly (page 183)

# 10. Spot, Projection, and Seam Welds

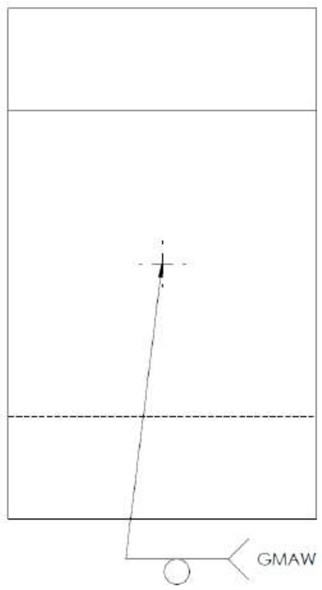
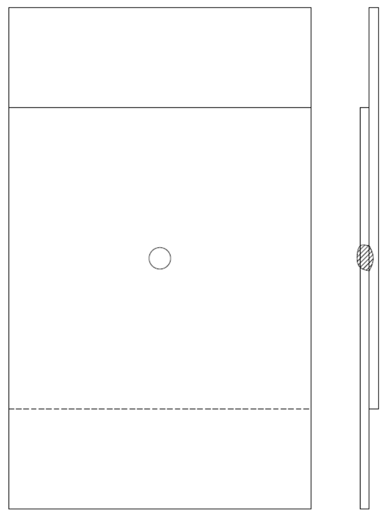
## Spot Welds

Spot welds are frequently used to join sheet metal assemblies. Most spot welds are made by RSW*, where the work is clamped between two electrodes and electric current is applied until weld fusion occurs between the members by heat from electric resistance. Since the weld forms in the center of the joint, there is no side significance and the spot weld symbol is centered on the reference line.

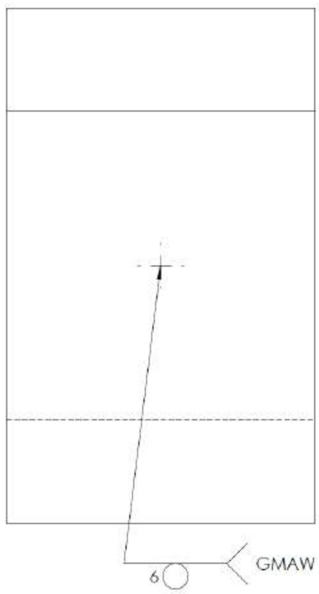
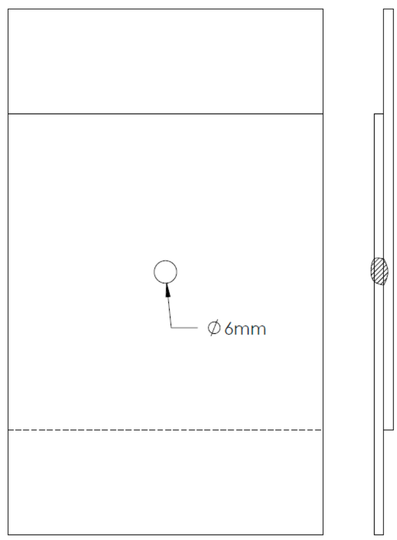
| PRINT | WELD EXAMPLE |
|---|---|
|   |  |

(*Welding process designations were covered in chapter 5)

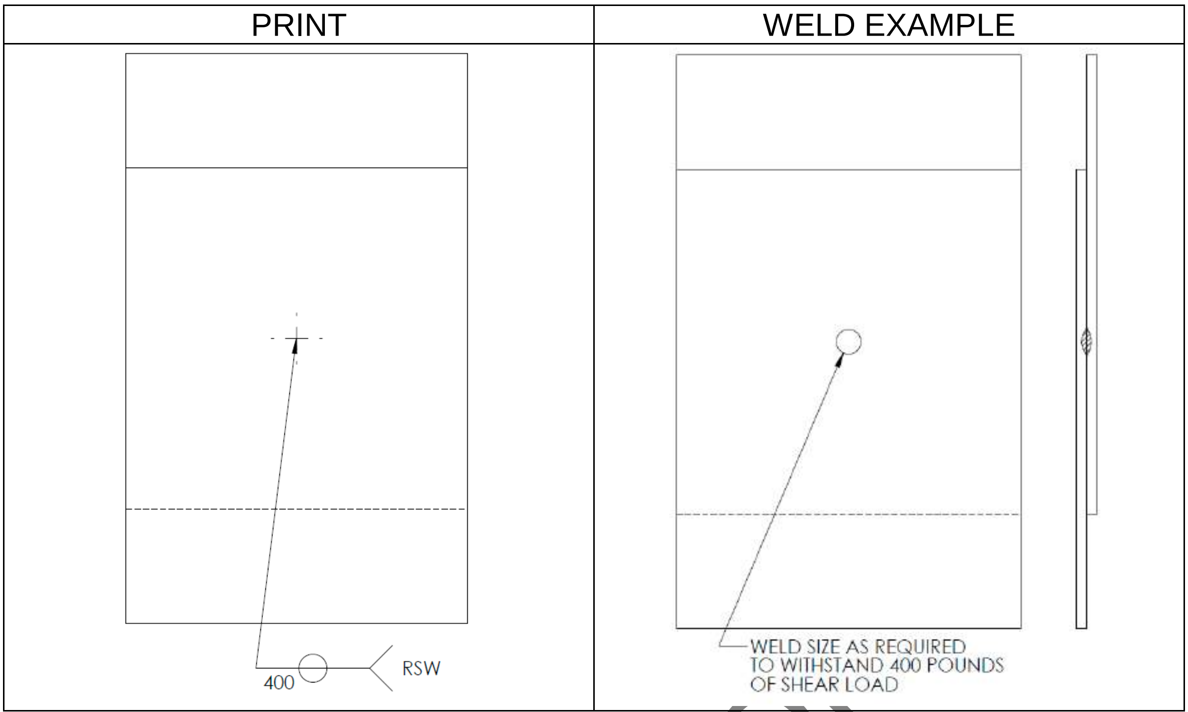
Another common method of producing a spot weld is by welding a spot from one side of the assembly by GMAW, GTAW, EBW, or LBW until the material melts through the top member into the bottom member. This is similar to plug welding, except that there is no hole in the top member. Because these welds are made from one side or the other, the symbol is placed either above or below the reference line.

| PRINT | WELD EXAMPLE |
|---|---|
|  |  |

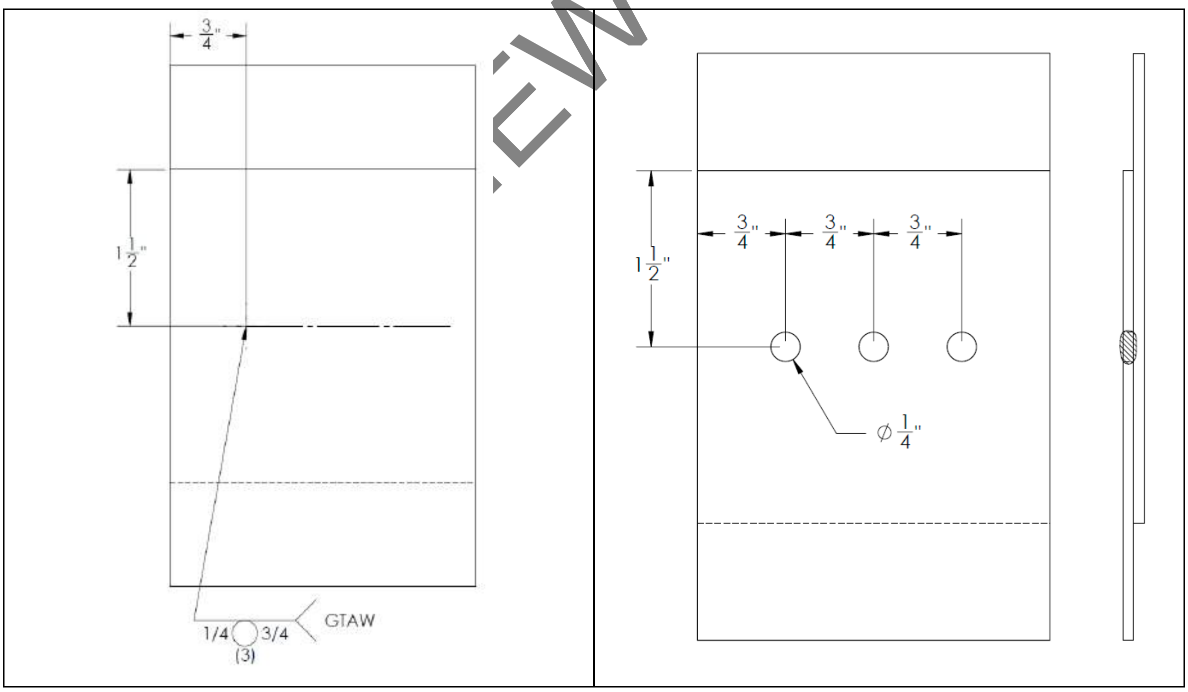
The size of the spot weld is specified to the left of the weld symbol. For RSW, it does not matter which side of the reference line has the dimension, so long as all the added information is on the same side of the welding symbol.

| | |
|---|---|
|  |  |

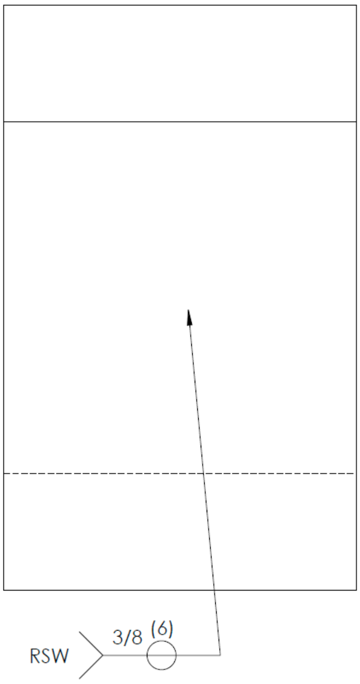
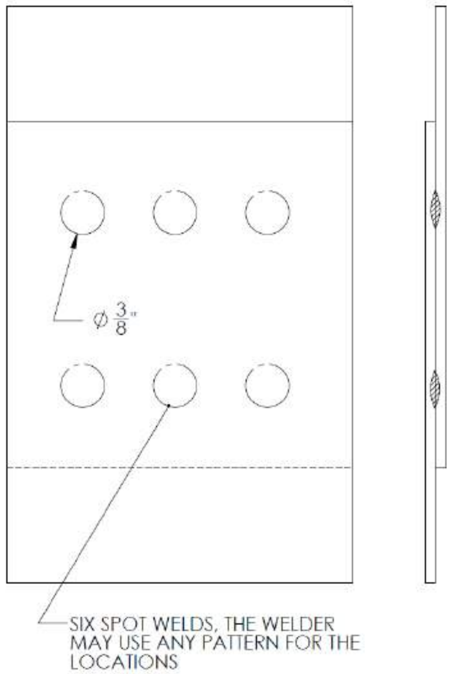
Instead of giving the size, the designer may specify the shear strength of the spot weld. This may be specified in either pounds or newtons, depending on whether the drawing units are customary or metric.



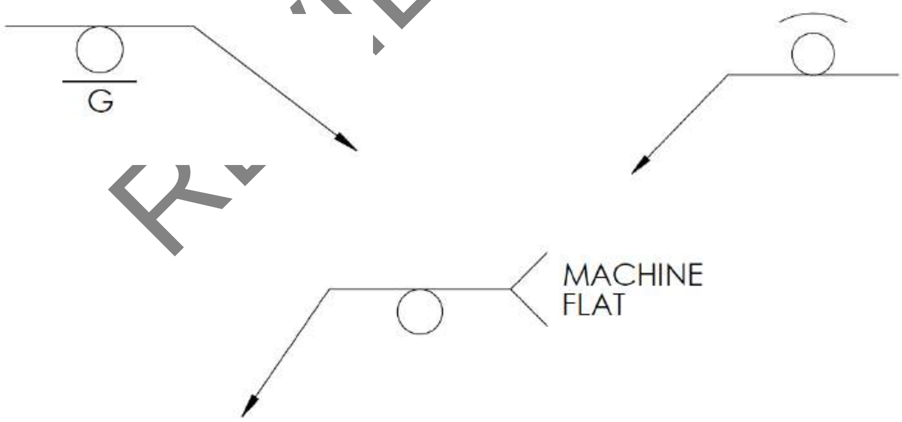

Multiple spot welds may be specified by giving the pitch (center-to-center spacing) between the welds to the right of the spot weld symbol and the number of spot welds in parenthesis above or below the spot weld symbol as appropriate.



Spot welds may also be specifically located on an assembly by print dimensions, or an area may be designated for several spot welds without giving specific locations for each spot weld.

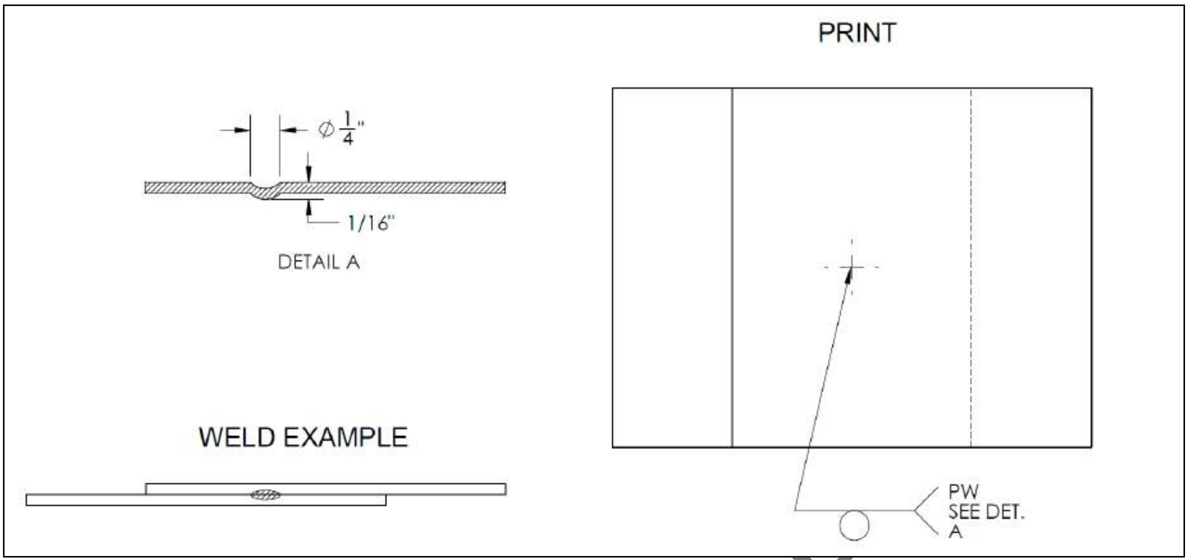
| PRINT | WELD EXAMPLE |
|---|---|
|  |  |

Spot welds with exposed surfaces, made from the arrow or other side, may have contour designations. If the desired contour is made by post-weld finishing, then the letter of the finishing method is added. If the weld is to be finished flat, but not flush to the surface, a note must be used in the tail of the welding symbol.



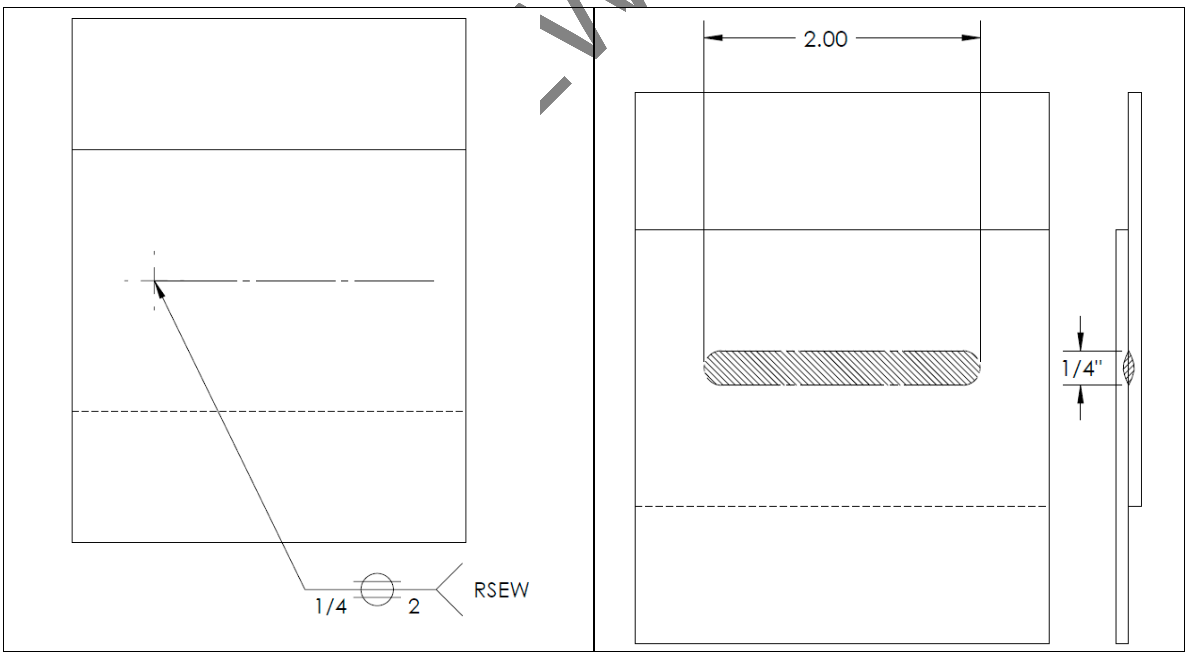
## Projection Welds

Projection welds are similar to spot welds, but require one of the members to have an embossed projection prior to welding. The spot weld symbol is placed above or below the reference line to indicate which member is embossed, and the tail will indicate "PW" and give a reference to a detail drawing showing the size of the embossed projection.

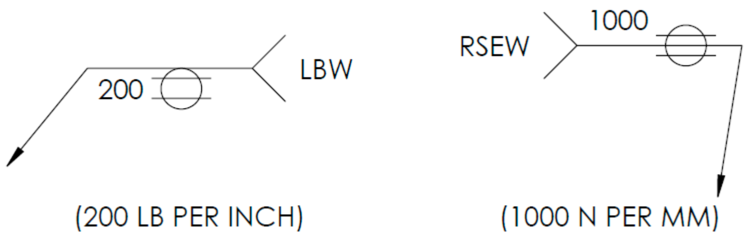



## Seam Welds

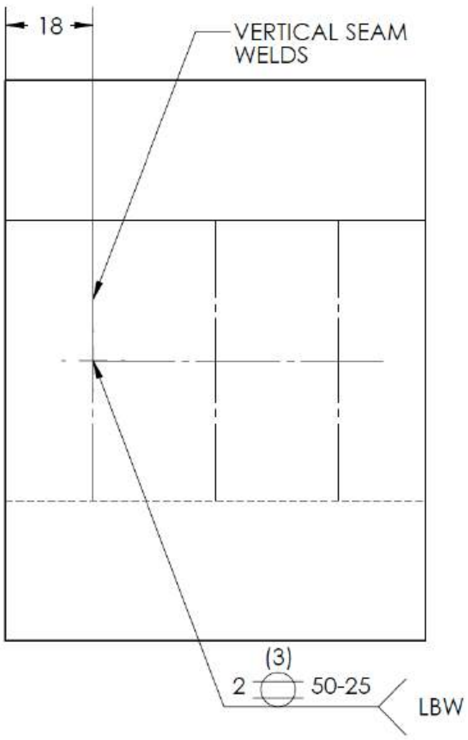
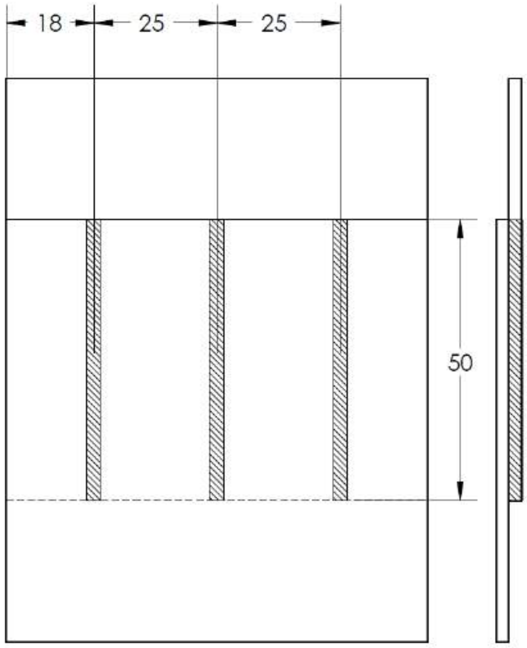
Seam welds share the same characteristics as spot welds, except that the width of the seam is placed to the left of the weld symbol and the length of the seam is placed to the right of the weld symbol. The drawing will show the centerline of the seam.



Instead of giving the width, the designer may specify the shear strength of the seam weld. This may be specified in either pounds per inch or newtons per millimeter of length, depending on whether the drawing units are customary or metric.




Multiple seams may be indicated by giving the pitch (center-to-center distance) between the centers of the seam welds to the right of the length dimension following a hyphen (–) and the number of seam welds in parentheses above or below the weld symbol as appropriate. The drawing must show the orientation of the seam welds.

| PRINT | WELD EXAMPLE |
|---|---|
|  |  |

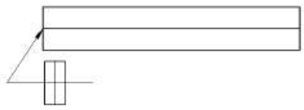
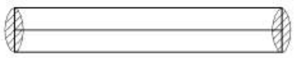
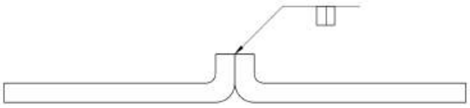
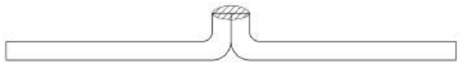
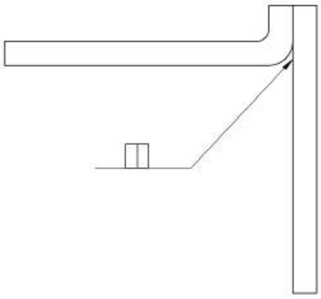
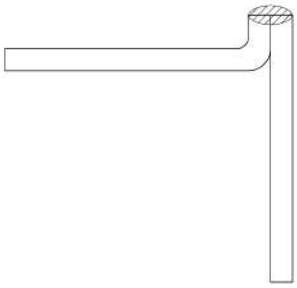
**Welding Symbols Activities:**
- Chapter 10 Worksheet (page 143)

**Print Reading Lab Work:**
- Project 7: Watertight-Door Hinge Assembly (page 185)

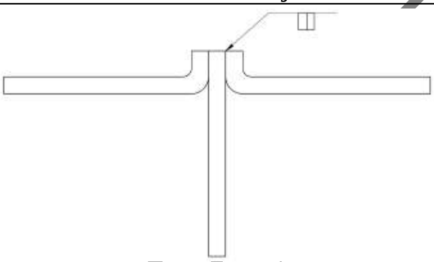
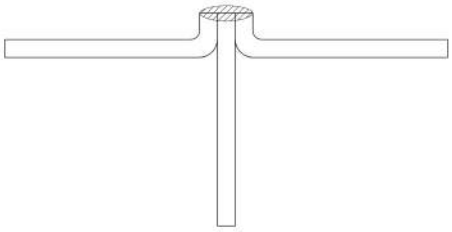
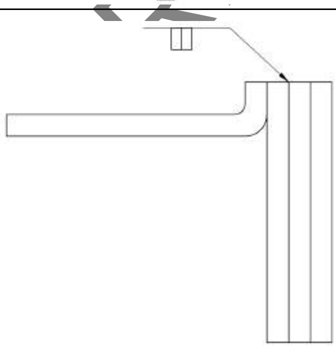
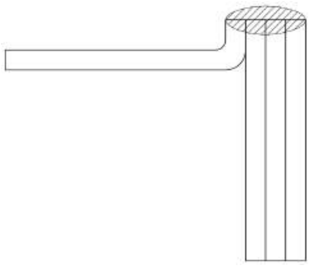
# 11. Edge Welds, Stud Welds, and Surfacing Welds

## Edge Welds

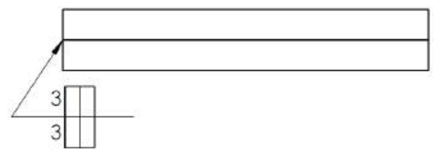
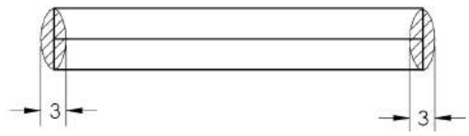
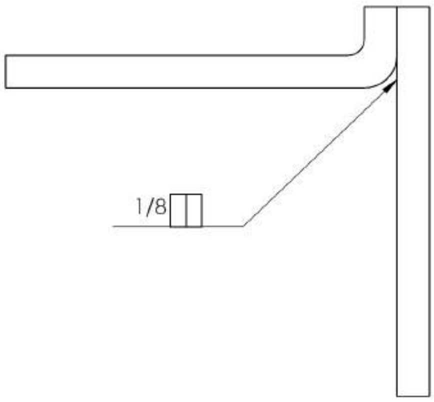
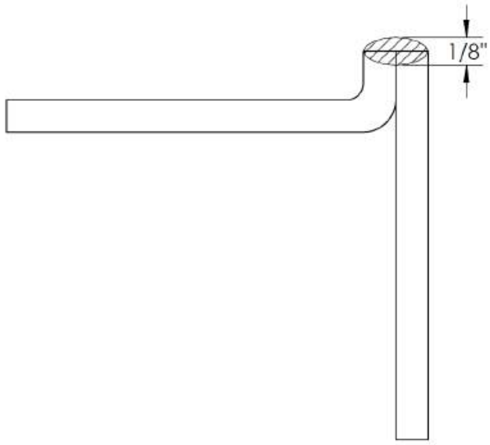
The edge weld symbol is used to indicate welds on edge joints, flanged butt joints, and flanged corner joints where the full thickness of the joint members must be fused. If the full thickness of the joint is not fused, then a groove weld symbol will be used rather than the edge weld symbol.

| PRINT | WELD EXAMPLE |
|---|---|
|  |  |
|  |  |
|  |  |

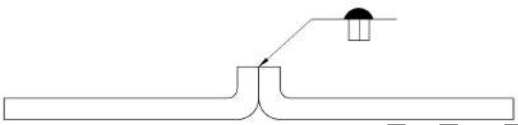
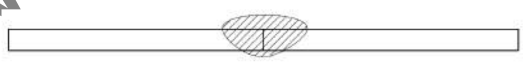
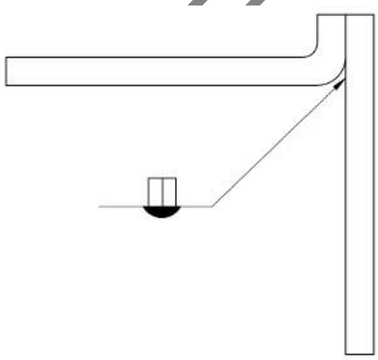
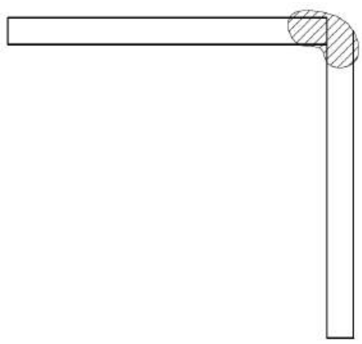
Edge joints may have two or more members; the symbol is the same regardless of the number of members in the joint.

| | |
|---|---|
|  |  |
|  |  |

The size of the edge weld may be specified to the left of the edge weld symbol.

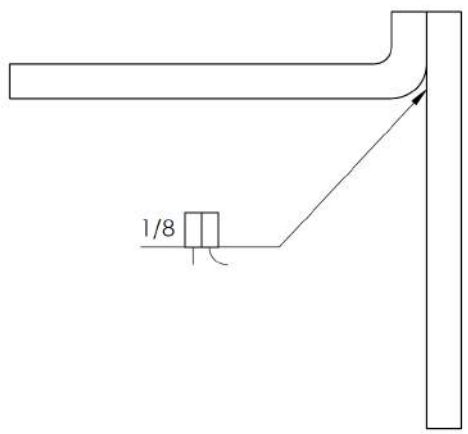
| PRINT | WELD EXAMPLE |
|---|---|
|  |  |
|  |  |

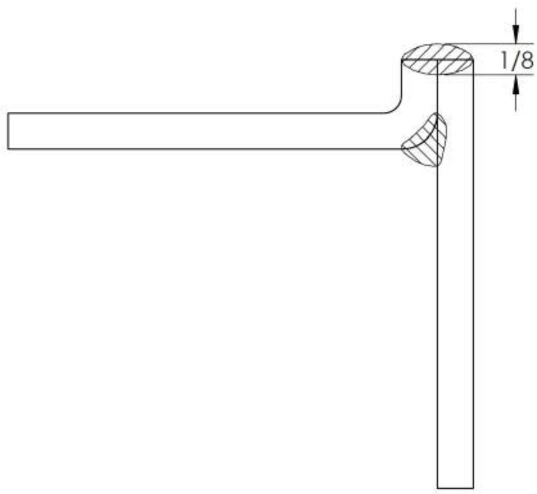
The edge weld may be combined with the melt-through symbol to ensure complete penetration. For welded flanges, the entire flange will be melted away during the welding operation.

| | |
|---|---|
|  |  |
|  |  |

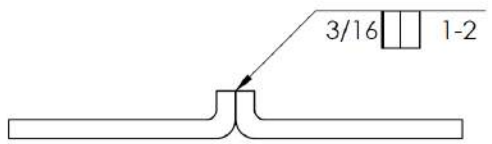
Flare-V-groove welds or flare-bevel-groove welds may be specified on the opposite side of the flange weld.

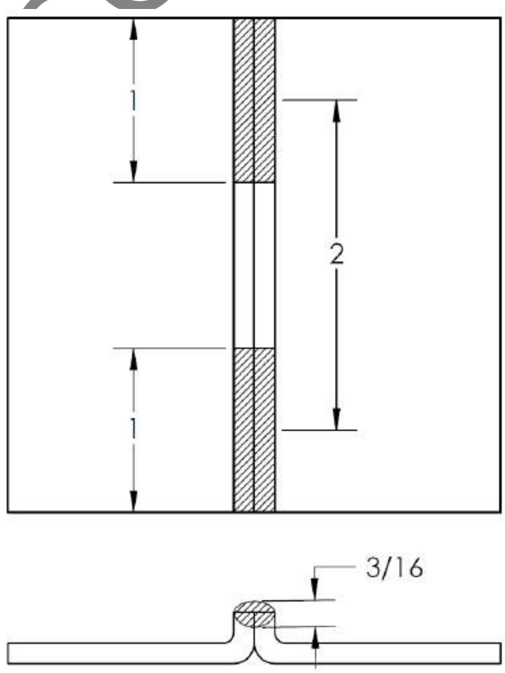
| PRINT | WELD EXAMPLE |
|---|---|



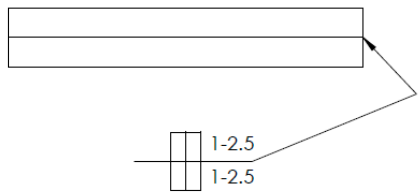
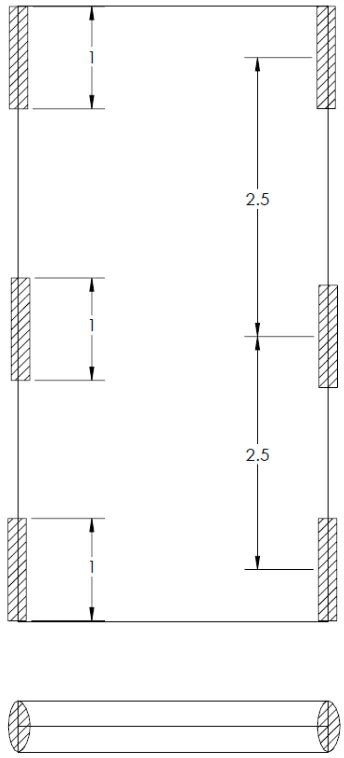
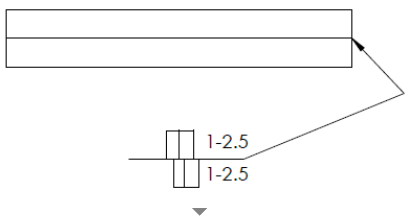
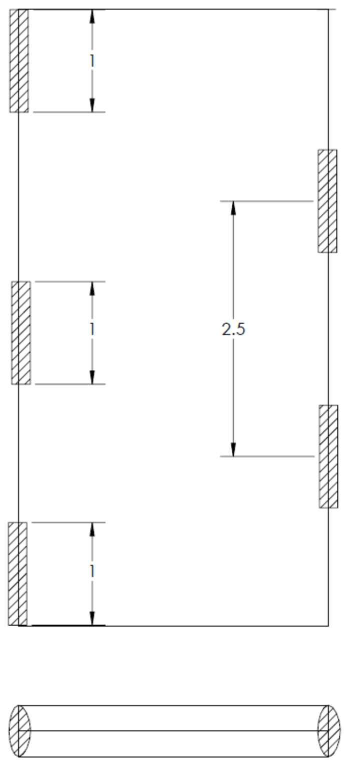




Like groove and fillet welds, length and pitch may be specified to the right of the edge weld symbol.

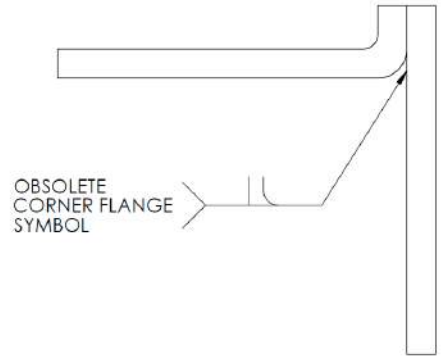


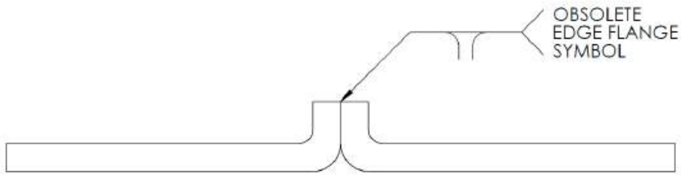



Double edge welds may be chained or staggered.

| PRINT | WELD EXAMPLE |
| --- | --- |
|   |   |
|   |   |

Prior to the 2007 Welding Symbols Standard, edge welds were called flange welds. Two weld symbols were used to indicate flange welds, the corner flange and the edge flange. Because of difficulty in properly interpreting the flange weld details, and due to confusion with other weld symbols, both flange weld symbols were replaced with the edge weld, and all joint design details are given on the drawing. Although obsolete according to the current standard, these symbols may still be found on current drawings.

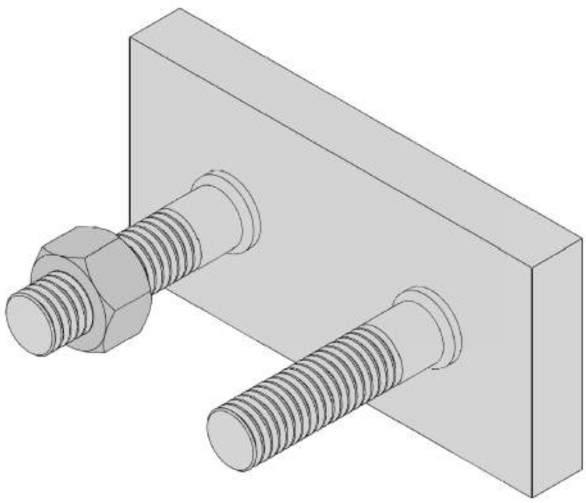


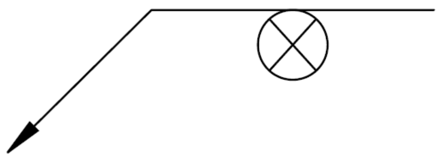





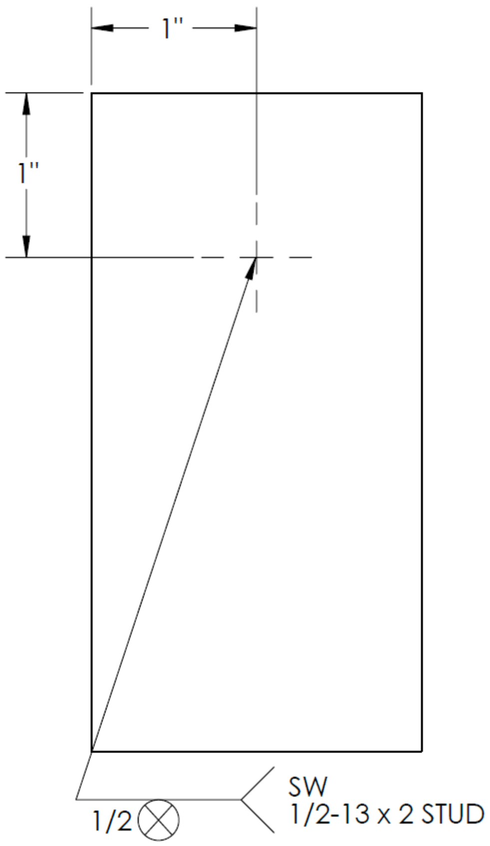

### Stud Welds

Stud welds are designated by the stud weld symbol.





Studs are always specified from the arrow side. The size of the stud is specified to the left of the stud weld symbol. The drawing will show the center location of the studs.

<table>
<tr><th>PRINT</th><th>WELD EXAMPLE</th></tr>
<tr><td>


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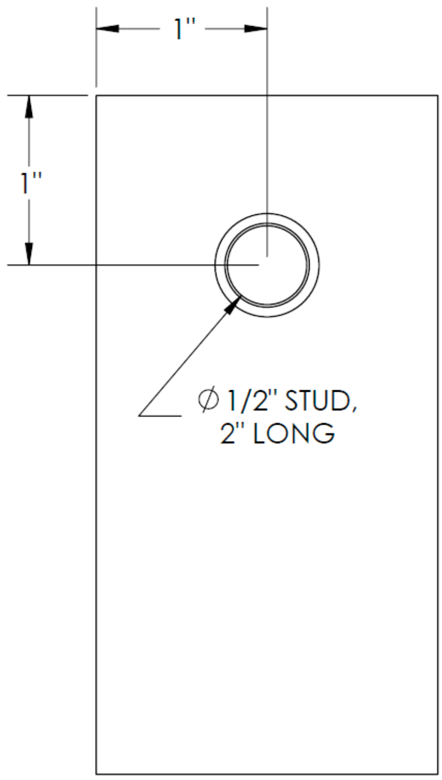
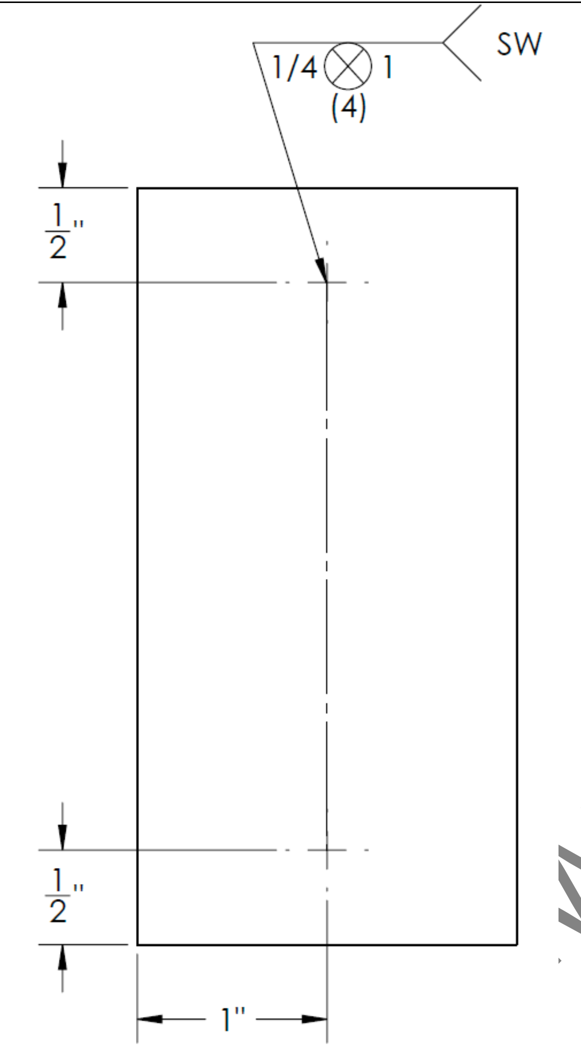
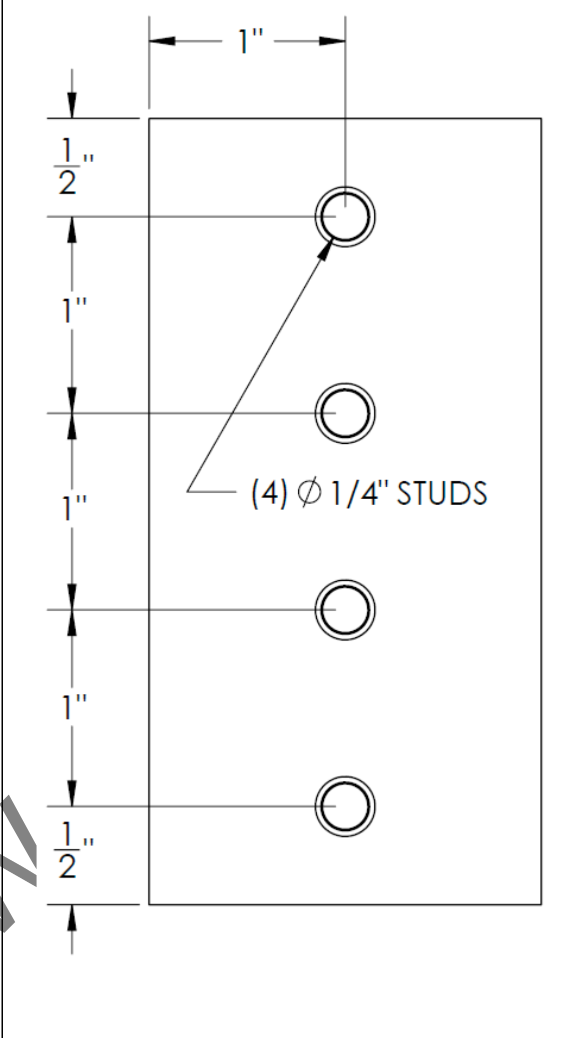


</td></tr>
</table>

For multiple studs, the pitch (center-to-center distance) between the studs is specified to the right of the symbol, and the number of studs is specified below the stud weld symbol. The drawing will show the center locations of the first and last stud in the line of studs.

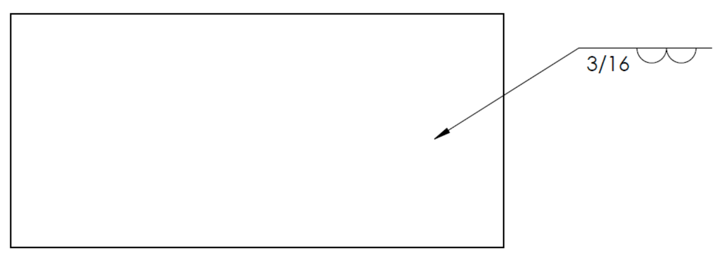
| PRINT | WELD EXAMPLE |
|---|---|
|  |  |

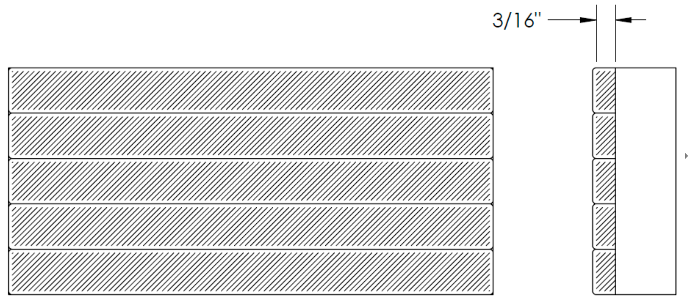
## Surfacing Welds

Surfacing welds are specified by the surfacing weld symbol. Surfacing is always applied from the arrow side. The minimum thickness of the surfacing may be specified to the left of the weld symbol.

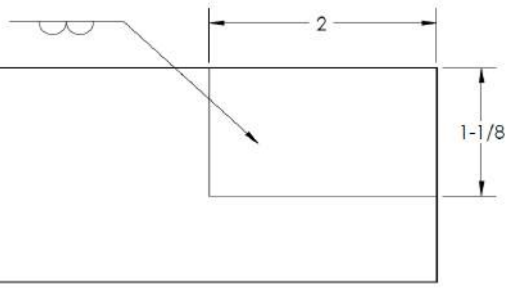
PRINT

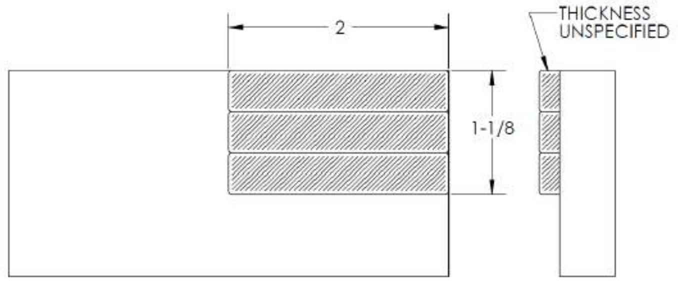
WELD EXAMPLE



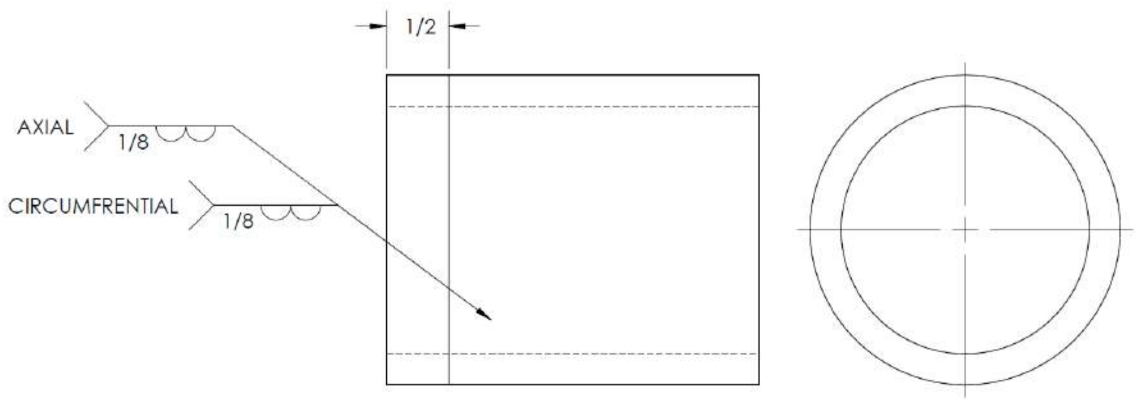

If the entire surface is not to be surfaced, the drawing will show what area is to be surfaced.

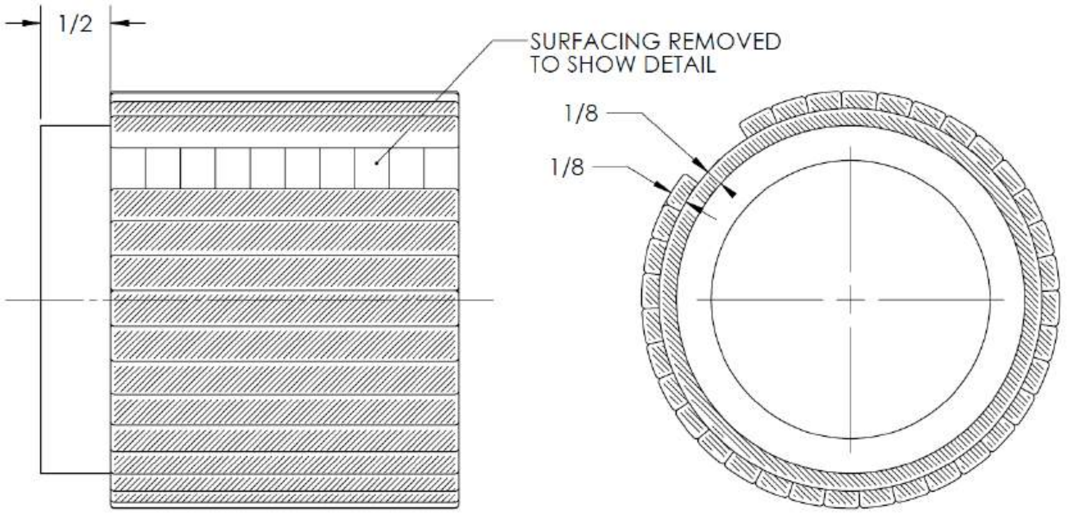


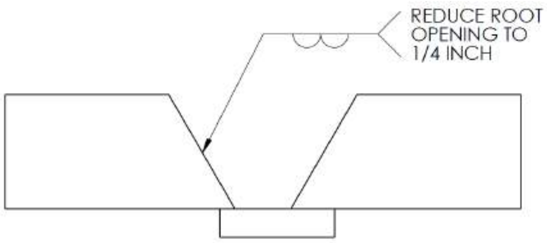
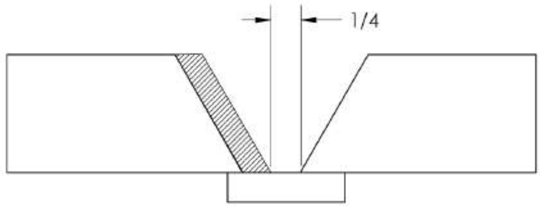
Multiple layers of surfacing may be indicated by multiple reference lines and tail notes.

| PRINT |
|---|
| WELD EXAMPLE |

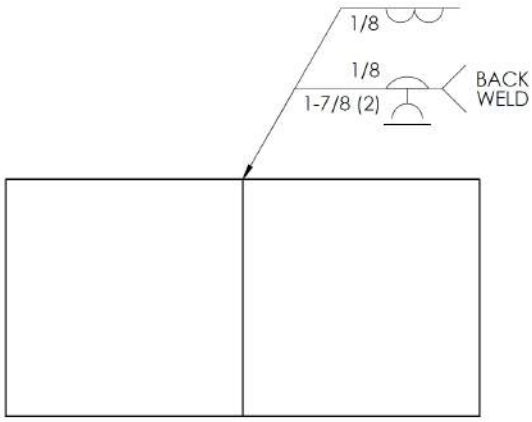
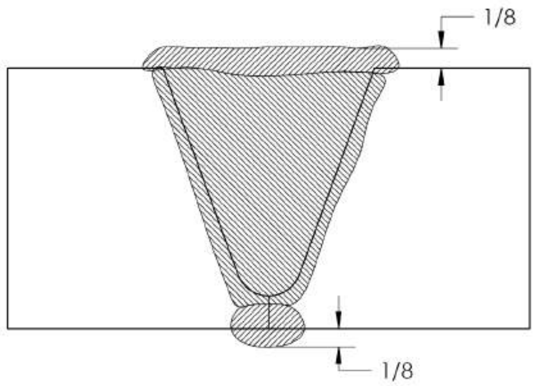


Surfacing may also be applied to joints to correct weld fit-up problems such as excessive root opening.

<table>
<tr><th>PRINT</th><th>WELD EXAMPLE</th></tr>
<tr><td>
</td><td>
</td></tr>
</table>

Surfacing may also be applied over a previously made weld.

<table>
<tr><td>
</td><td>
</td></tr>
</table>



**Welding Symbols Activities:**

- Chapter 11 Worksheet (page 147)

**Print Reading Lab Work:**

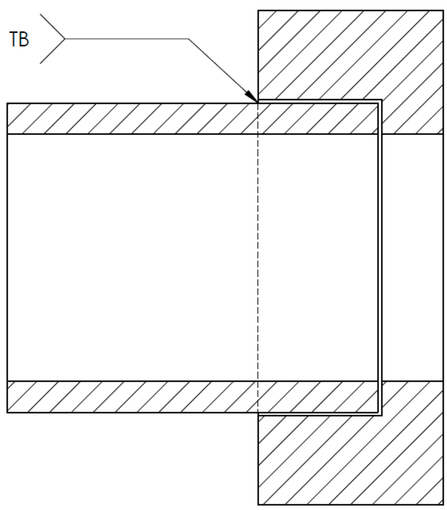
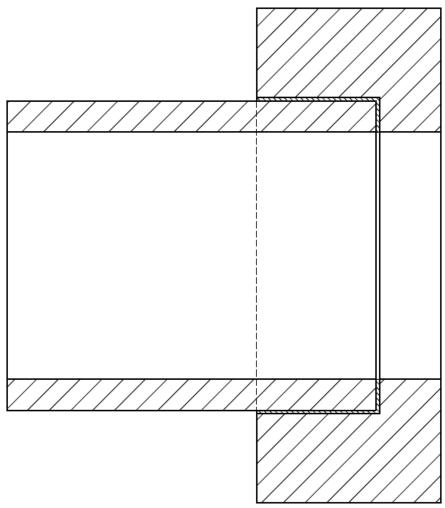
- Projects 8 and 9: Test Weldments 1 and 2 (page 187)

# 12. Brazing Symbols and Nondestructive Examination Symbols

## Brazing Symbols

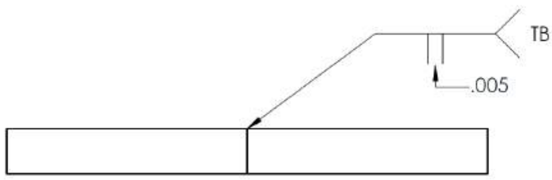
Brazing symbols are used like welding symbols to convey the designer's intent for brazements. Many of the same elements are used, with modifications specific to the brazing process.

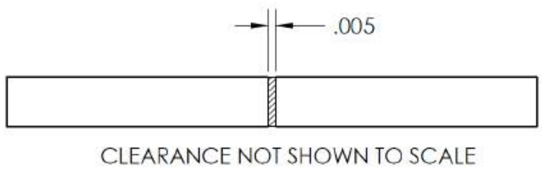
If the drawing indicates all dimensional information for the joint, then only the location of the braze and the method of brazing is specified.

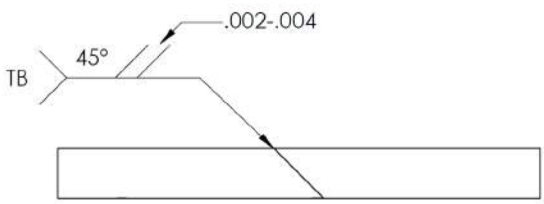
| PRINT | BRAZE EXAMPLE |
| --- | --- |
|  |  |

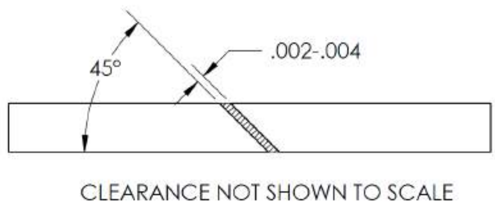


Brazed butt joints use either the scarf or square-groove symbol. The angle of the scarf is indicated to the left of the scarf symbol, and the clearance is given with a small arrow. A tolerance for clearance may also be given.

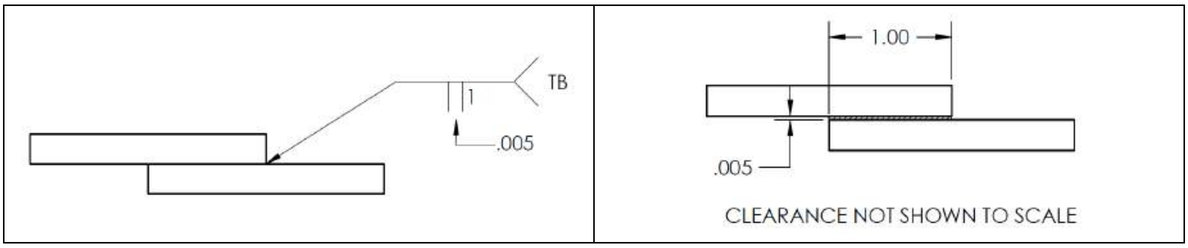


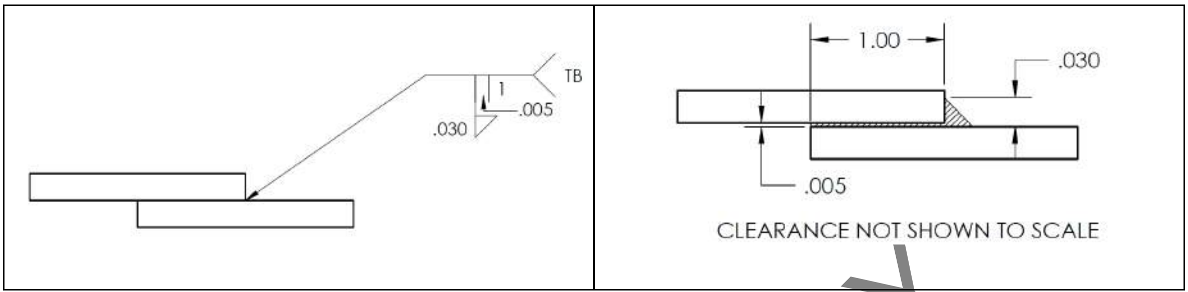



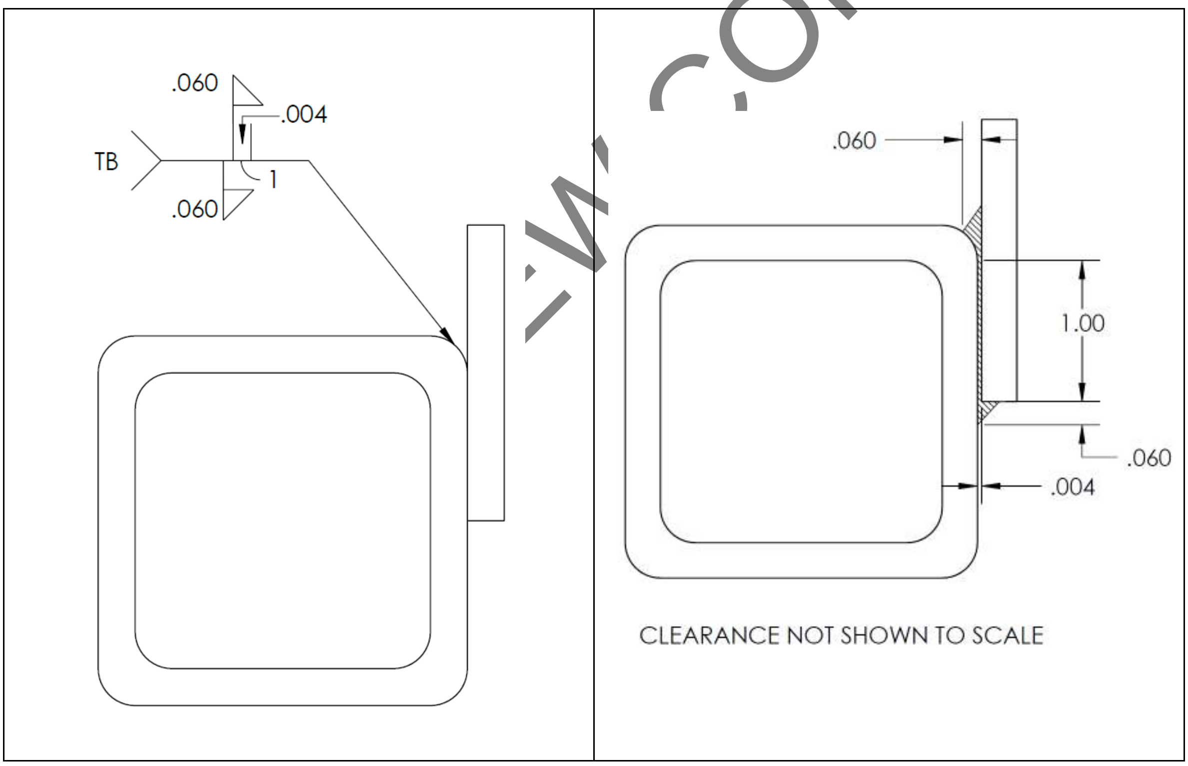
Brazed lap joint symbols give the clearance and the length of overlap.




Brazed fillets may be added to the joint if the brazement is torch brazed; however, the size of the fillet is nearly impossible to control due to the nature of brazing.




Flare-bevel and flare-V-grooves may be brazed as well.

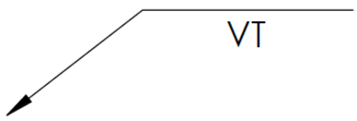
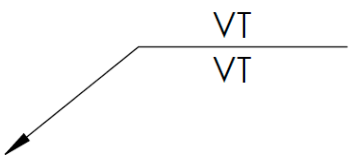


## Nondestructive Examination Symbols

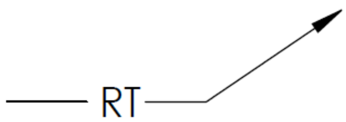
Nondestructive Examination (NDT) symbols are quite similar to welding symbols, but with the weld symbol itself replaced with an examination method letter designation. The designations for the various NDT methods are as follows:

| NDT METHOD DESIGNATIONS |
|---|
| VT ............ visual testing<br>MT ........... magnetic particle testing<br>PT ............ penetrant testing<br>UT ............ ultrasonic testing<br>RT ............ radiographic testing<br>ET ............ electromagnetic (eddy current) testing<br>LT ............ leak testing<br>NRT ......... neutron radiographic testing<br>AET.......... acoustic emission testing<br>PRT ......... proof testing |

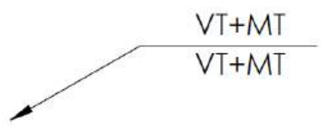
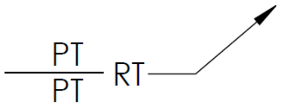
Examination may be made from the arrow side, the other side, or both sides.

| PRINT | COMMENTS |
|---|---|
|  | Visual inspection on the arrow side of the weld joint. |
|  | Magnetic particle inspection on the other side of the weld joint. |
|  | Visual inspection on both sides of the weld joint. |

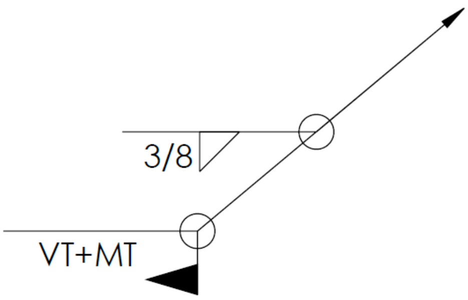
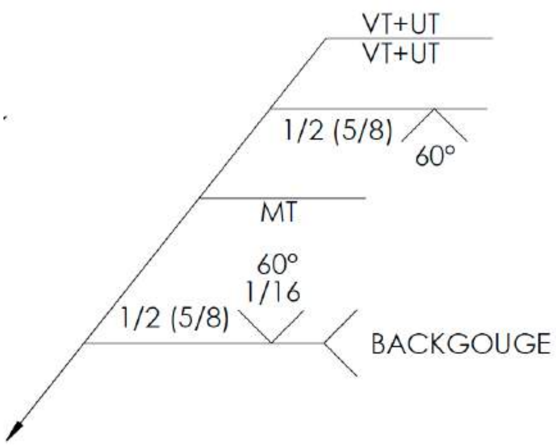
Some methods do not have side significance, or there may not be a specified preference.

| | |
|---|---|
|  | Radiographic inspection (no side significance). |

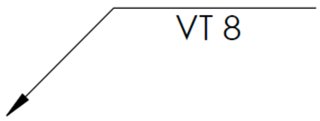
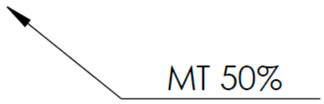
Multiple examination methods may be specified on the same reference line.

| PRINT | COMMENTS |
|---|---|
|   | Visual inspection and magnetic particle inspection on both sides of the weld joint. |
|   | Penetrant inspection and radiographic inspection on both sides of the weld joint. |

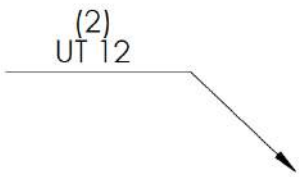
NDT symbols may be combined with welding symbols, and use supplementary symbols such as “examine-all-around” and “field examination.”

| | |
|---|---|
|   | First operation:<br>⅜-inch fillet weld on the arrow side, all around the joint, performed at the welding facility.<br><br>Second operation:<br>Visual and magnetic particle inspection on the arrow side, all around, performed in the field. |
|   | First operation:<br>First half of a double-V-groove weld on the other side, ½-inch depth of groove, 60° groove angle, 1/16-inch root opening, ⅝-inch weld size. Backgouge the root (from the arrow side) after welding.<br><br>Second operation:<br>Magnetic particle inspection of the backgouged root on the arrow side.<br><br>Third operation:<br>Complete the double-V-groove weld from the arrow side. The bevel would normally be prepared at the same time as the other side.<br><br>Fourth operation:<br>Visual and Ultrasonic inspection on both sides of the weld joint. |

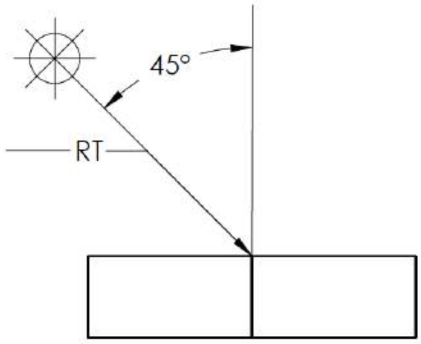
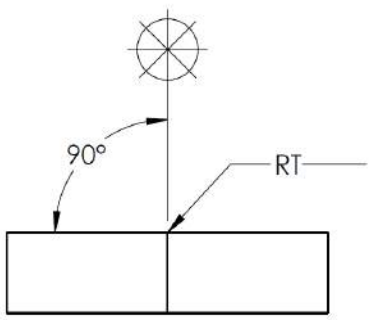
If less then full examination is required then the length of weld to be examined or a percentage of the weld to be examined is given to the right of the designation.

| PRINT | COMMENTS |
|---|---|
|   | Visual inspection on the arrow side of the weld joint. Inspect an 8” length of weld. |
|   | Magnetic particle inspection on the other side of the weld joint. Inspect 50% of the total weld joint. |

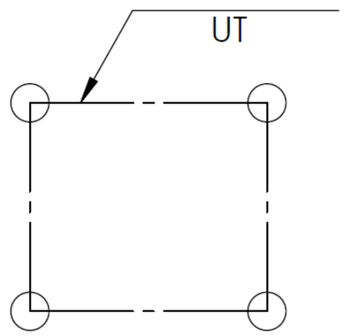
A certain number of examinations may be specified.

| | |
|---|---|
|   | Ultrasonic inspection on the other side of the weld joint. Inspect two 12-inch length of the weld joint. |

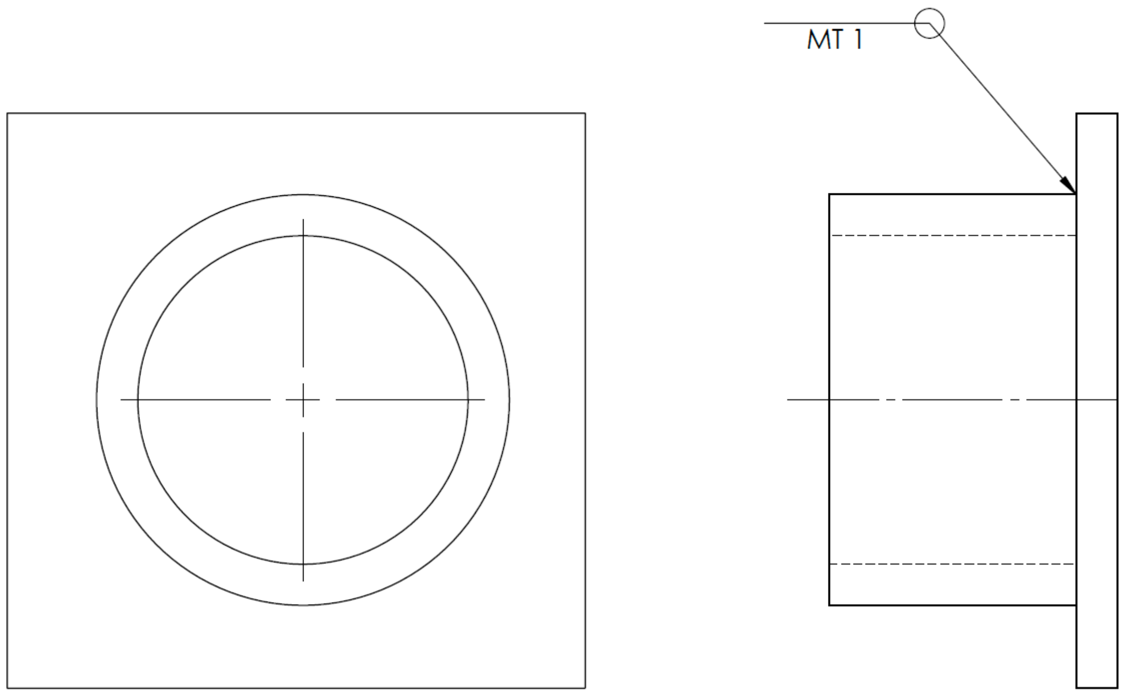
For radiographic examination, the location of the radiation source may be specified with the radiation direction symbol.

| | |
|---|---|
|   | Radiographic inspection of the weld joint. The radiation source is placed at an angle of 45° with respect to the weld joint. |
|   | Radiographic inspection of the weld joint. The radiation source is placed at an angle of 90° with respect to the weld joint. |

An area may be specified for examination on the drawing.  The area is defined using a dashed-line boundary with small circles marking each change in direction of the boundary.  The boundary may be any size and shape, and dimensions on the print are used to define the size and shape of the boundary.

| PRINT | COMMENTS |
|---|---|
|  | Ultrasonic inspection on the arrow side of the weld joint.  Inspect the area enclosed by the boundary. |

For round parts, areas of revolution may be identified in a section view with the “examine-all-around” symbol.  A number to the right of the designation tells how wide the inspection area will be, and the inspect-all-around symbol tells that an area of revolution is to be inspected.




Magnetic particle inspection on the arrow side.
Inspect a 1-inch wide portion of the joint, all the way around the pipe.

**Welding Symbols Activities:**

- Chapter 12 Worksheet (page 153)
- Welding Symbols Exam 3

**Print Reading Lab Work:**

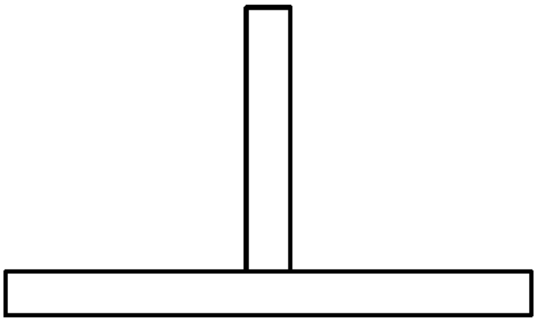
- Project 10: Test Weldment 3 (page 187)

# CHAPTER 1–INTRODUCTION TO WELDING SYMBOLS

1. What is the AWS standard for welding symbols? ________________________________

2. T or F Welding symbols follow the same standard throughout the world.

3. Draw a reference line and arrow pointing to the left side of the T-joint. Label the "arrow side" and "other side" of the joint on the figure.

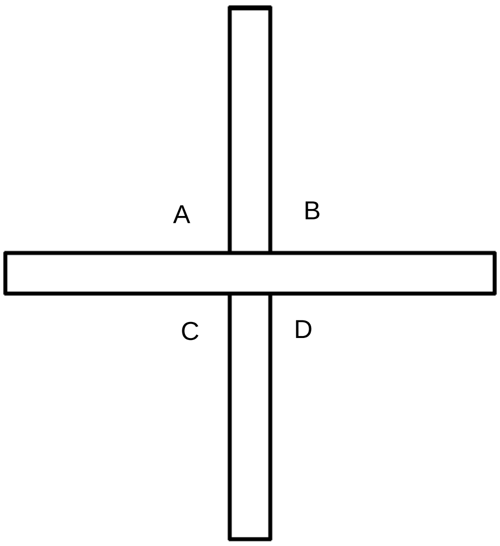


4. How many separate weld joints are shown in the figure? __________

5. Draw reference lines and arrows pointing to the joint at letter B and and at letter C.

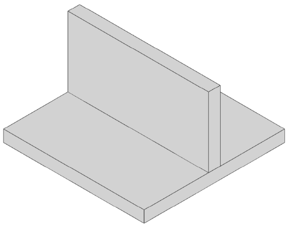
6. For the reference line and arrow pointing at B, the arrow side is labeled ____ and the other side is labeled ____.

7. For the reference line and arrow pointing at C, the arrow side is labeled ____ and the other side is labeled ____.

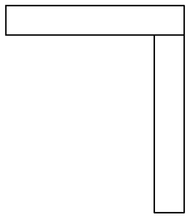


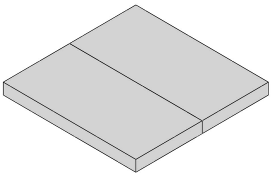

8. *Circle the correct word.* Information about the arrow side of the joint is placed (above/below) the reference line, while information about the other side of the joint is placed (above/below) the reference line.

Matching:  Connect the joint type listed in the center column with the proper figures in the right and left columns.

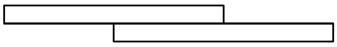


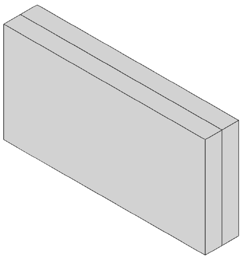
9. Butt Joint



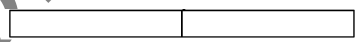


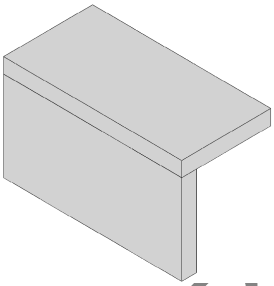
10. Corner Joint



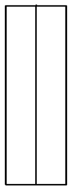


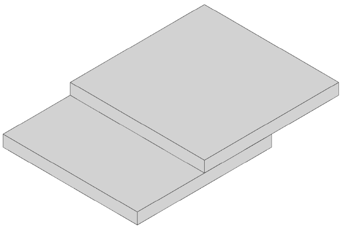
11. T-Joint



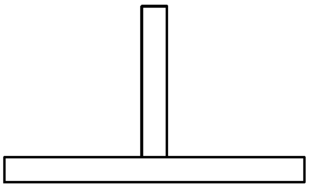


12. Lap Joint



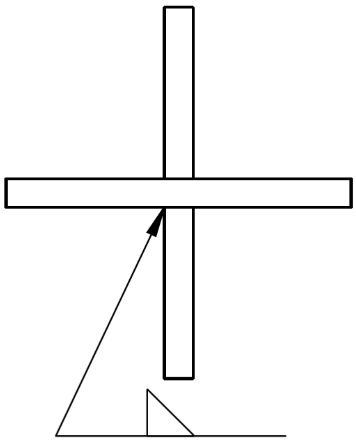


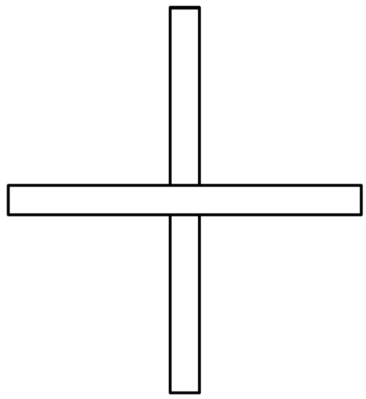
13. Edge Joint



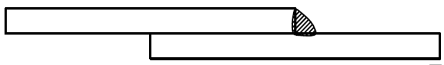
14. Draw a weld symbol for a fillet weld on the other side.

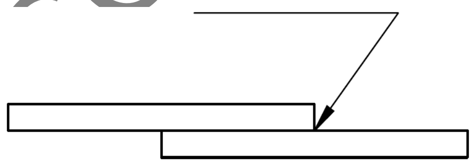
15. Sketch the weld indicated by the welding symbol shown below:



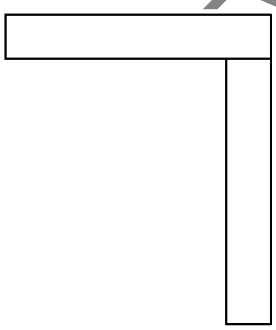


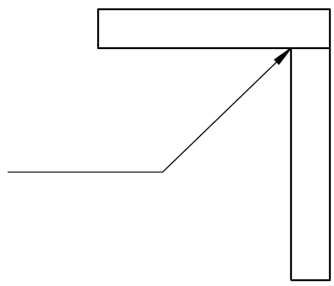
16. Draw the weld symbol for the weld shown in the drawing below:



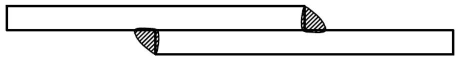


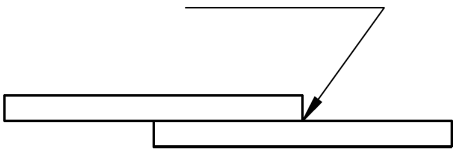
17. Sketch a fillet weld in the joint below, then draw the weld symbol on the drawing:



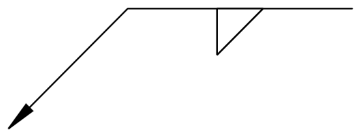


18. Draw the weld symbol for the weldment shown below:





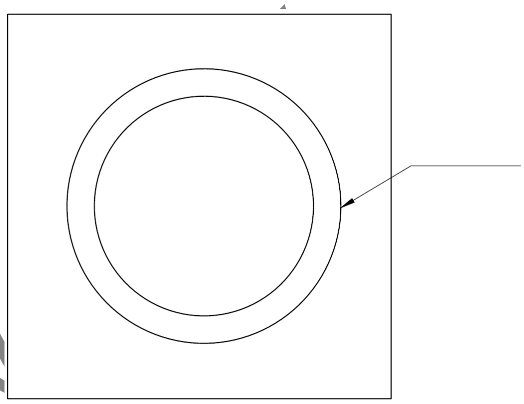
19. What weld is specified (type and location):



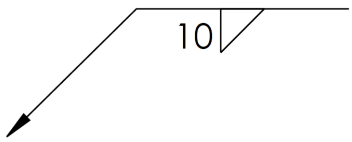
______________________________

______________________________

20. Draw the weld symbol to place a fillet weld around the outside of the pipe.



## CHAPTER 2–FILLET WELDS

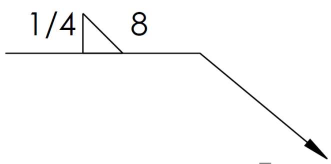



1. What type of weld is required? ______________________________

2. Where is the weld located? ______________________________

3. What is the weld size? ______________________________

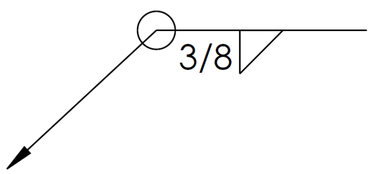
4. What is the length of the weld? ______________________________




5. Where is the weld located? ______________________________

6. What is the weld size? ______________________________

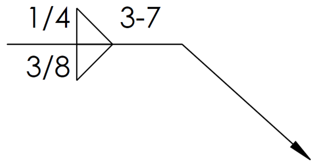
7. What is the length of the weld? ______________________________




8. Where is the weld located? ______________________________

9. What is the weld size? ______________________________

10. What does the circle mean? ______________________________




11. What is the weld size on the arrow side? ______________________________

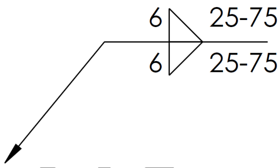
12. What is the length of weld on the arrow side? ______________________________

13. What is the weld size on the other side? ______________________________

14. What type of weld is on the other side? ______________________________

15. What is the length of each intermittent weld increment? ______________________________

16. What is the pitch of the weld increments? ______________________________



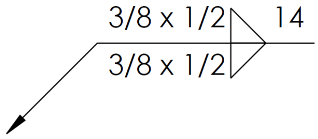

17. What is the weld size on the arrow side? ______________________________

18. What is the weld size on the other side? ______________________________

19. What type of weld is shown, chain intermittent or staggered intermittent fillet welds? ______________________________

20. What is the length of each weld increment? ______________________________

21. What is the pitch? ______________________________



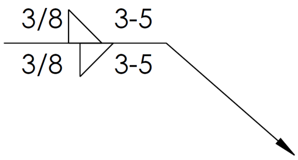

22. What is the weld size on the arrow side? ______________________

23. How long is the weld on the arrow side? ______________________

24. What is the weld size on the other side? ______________________

25. How long is the weld on the other side? ______________________

26. How does the welder know which joint member receives the ⅜” leg?
    a) It doesn’t matter which member receives the ⅜” leg.
    b) A note on the drawing will indicate which member receives which size leg.
    c) The thicker member always receives the larger size leg.
    d) The welder may place the weld either way, using good judgement.




27. What is the weld size on the arrow side? ______________________

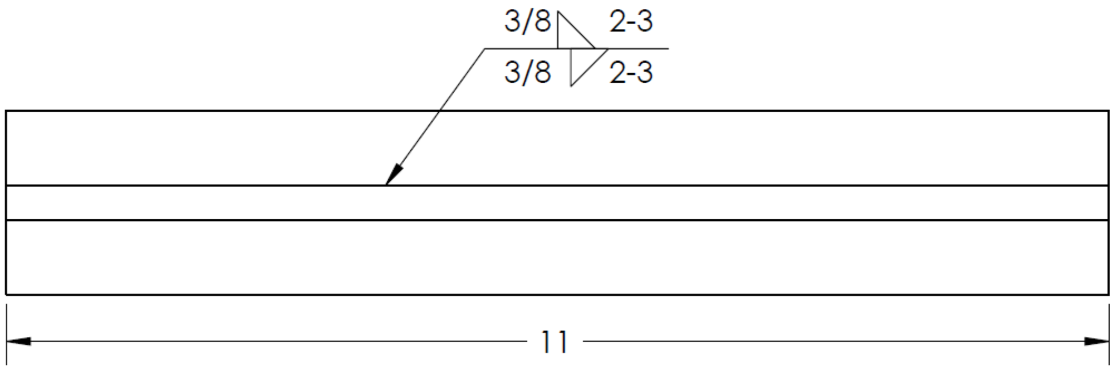
28. What is the weld size on the other side? ______________________

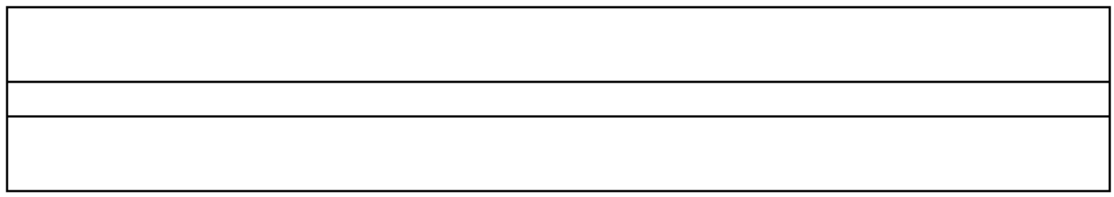
29. What type of weld is shown, chain intermittent or staggered intermittent fillet welds? ______________________

30. What is the length of each weld increment? ______________________

31. What is the pitch? ______________________

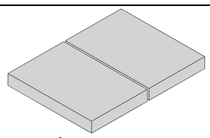
32. Sketch and dimension the staggered intermittent fillet weld on the drawing below:



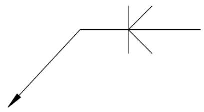



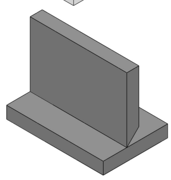
## CHAPTER 3–JOINT TYPES AND SQUARE-GROOVE, V-GROOVE, AND BEVEL-GROOVE WELDS

Matching: Connect the groove weld type listed in the center column with the proper figures in the right and left columns.

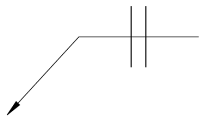


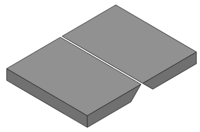
1. Single-V-Groove Weld



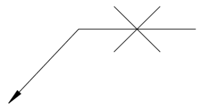


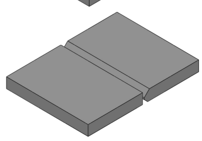
2. Single-Bevel-Groove Weld



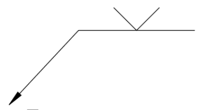


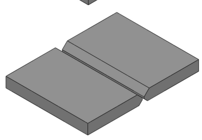
3. Double-Square-Groove Weld



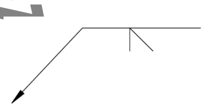


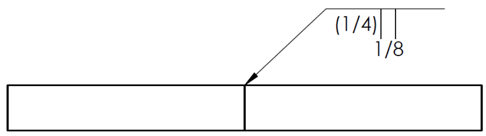
4. Double-V-Groove Weld



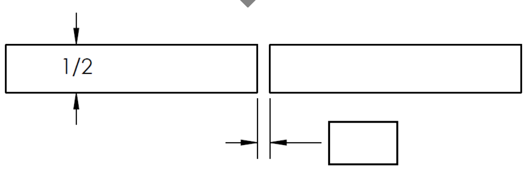


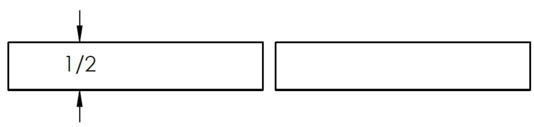
5. Double-Bevel-Groove Weld

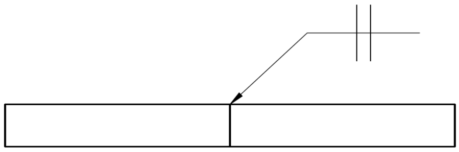





6. What type of weld is required? ______________________
7. Where is the weld located? ______________________
8. What is the weld size? ______________________
9. What is the root opening? ______________________
10. Dimension the joint sketch below left, and sketch the weld into the drawing below right.





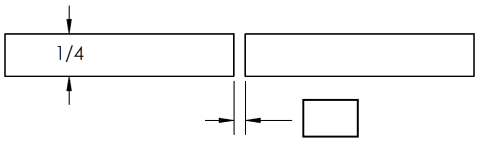
11. What type of weld is required? ____________________

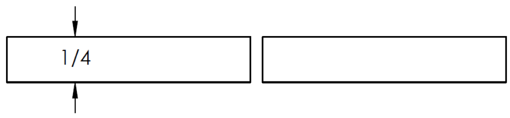
12. Where is the weld located? ____________________

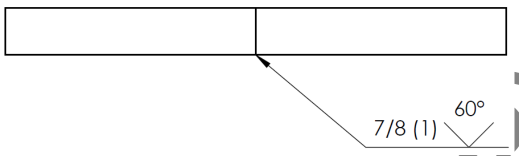
13. What is the total weld size? ____________________

14. What is the root opening? ____________________

15. Dimension the joint sketch below left, and sketch the weld into the drawing below right.




16. What type of weld is required? ____________________

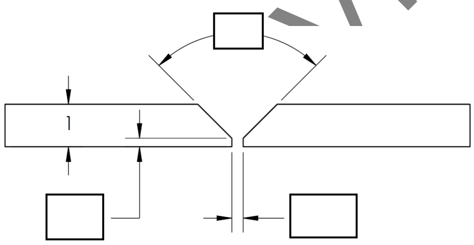
17. What is the root opening? ____________________

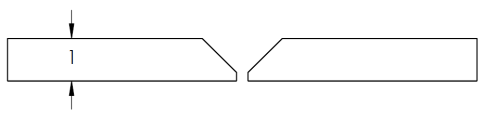
18. What is groove angle? ____________________

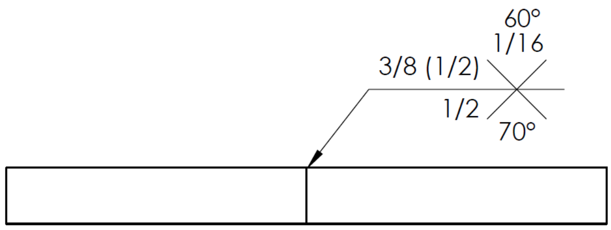
19. What is the depth of preparation? ____________________

20. What is the weld size? ____________________

21. Dimension the joint sketch below left, and sketch the weld into the drawing below right.






22. What type of weld is required? ______________________

23. What is the root opening? ______________________

24. What is the bevel angle on the arrow side? ______________________

25. What is the depth of groove on the arrow side? ______________________

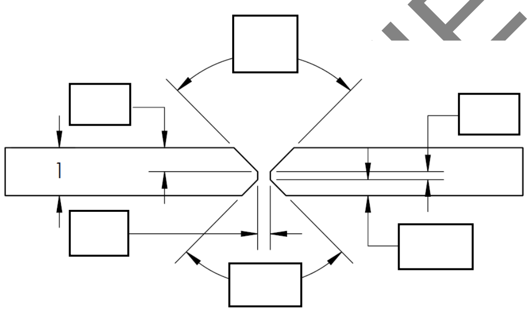
26. What is the weld size on the arrow side? ______________________

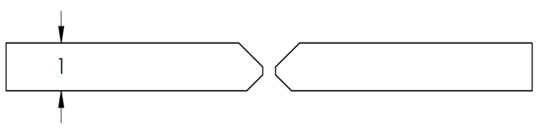
27. What is the bevel angle on the other side? ______________________

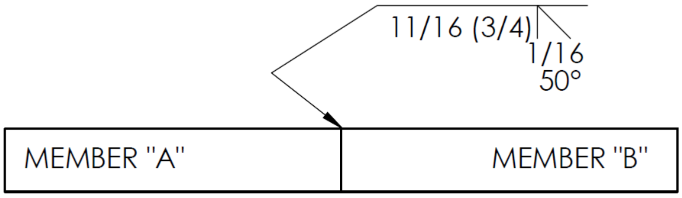
28. What is the depth of groove on the other side? ______________________

29. What is the weld size on the other side? ______________________

30. Dimension the joint sketch below left, and sketch the weld into the drawing below right.






31. What type of weld is required? ________________

32. Which member receives the bevel? ________________

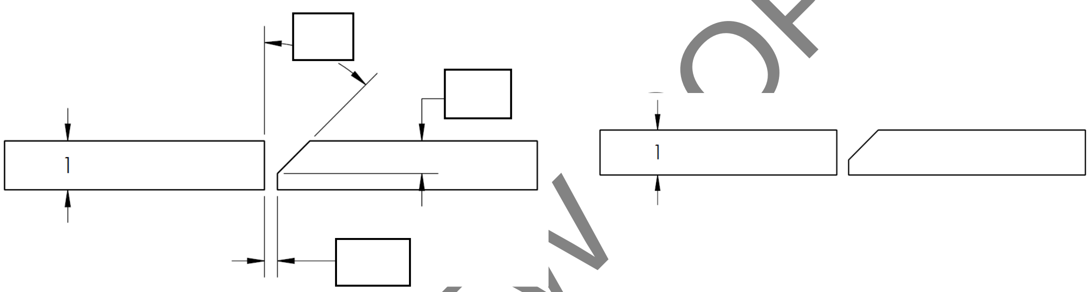
33. What is the root opening? ________________

34. What is the bevel angle? ________________

35. What is the depth of groove? ________________

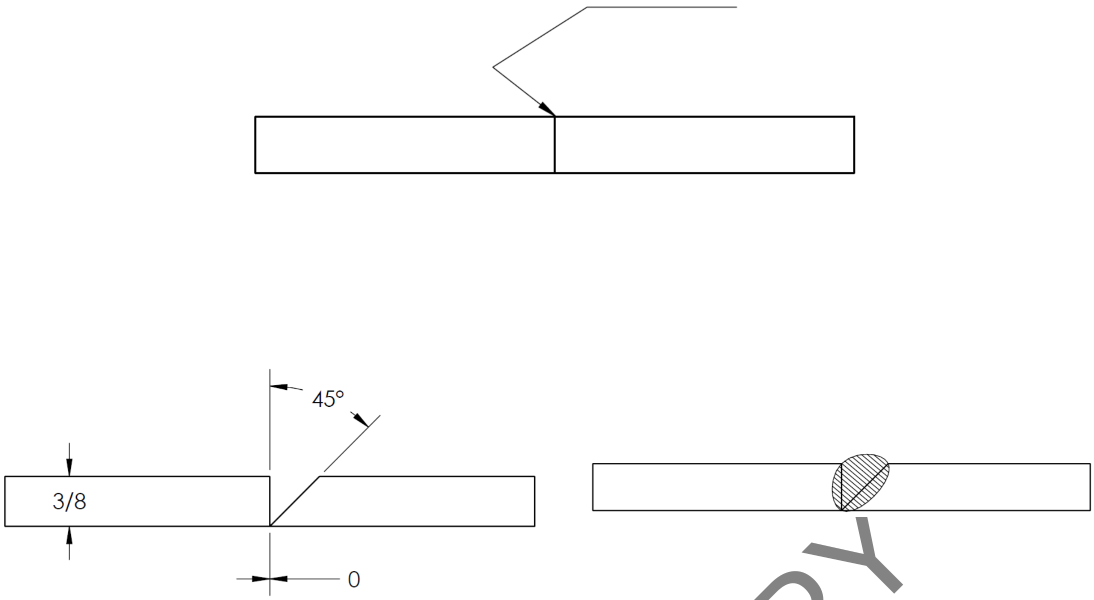
36. What is the weld size? ________________

37. Dimension the joint sketch below left, and sketch the weld into the drawing below right.

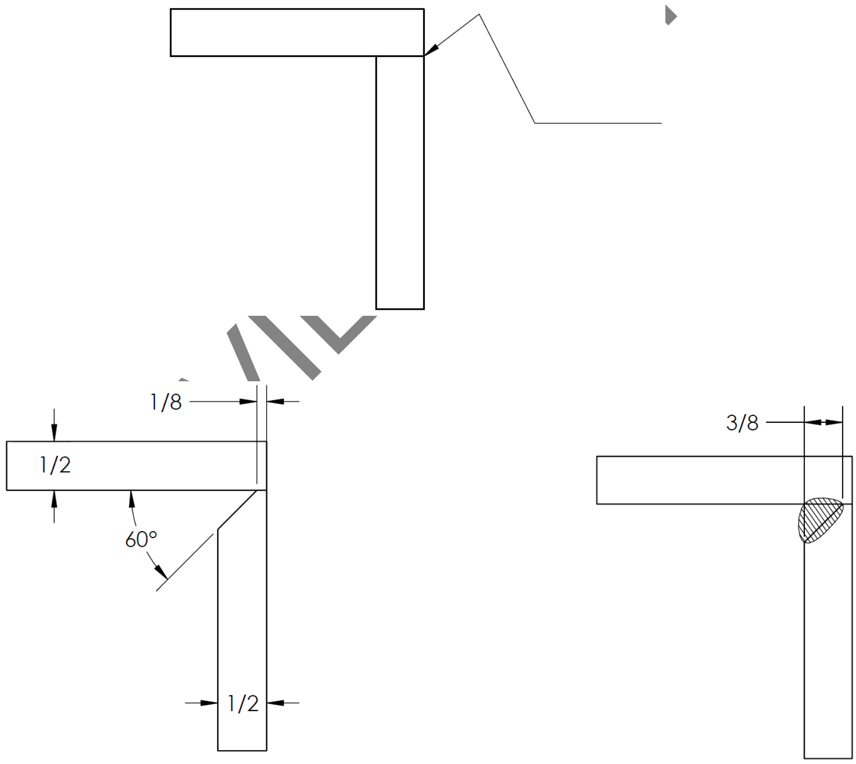


Sketch the weld symbols for the following weld joints:

38.

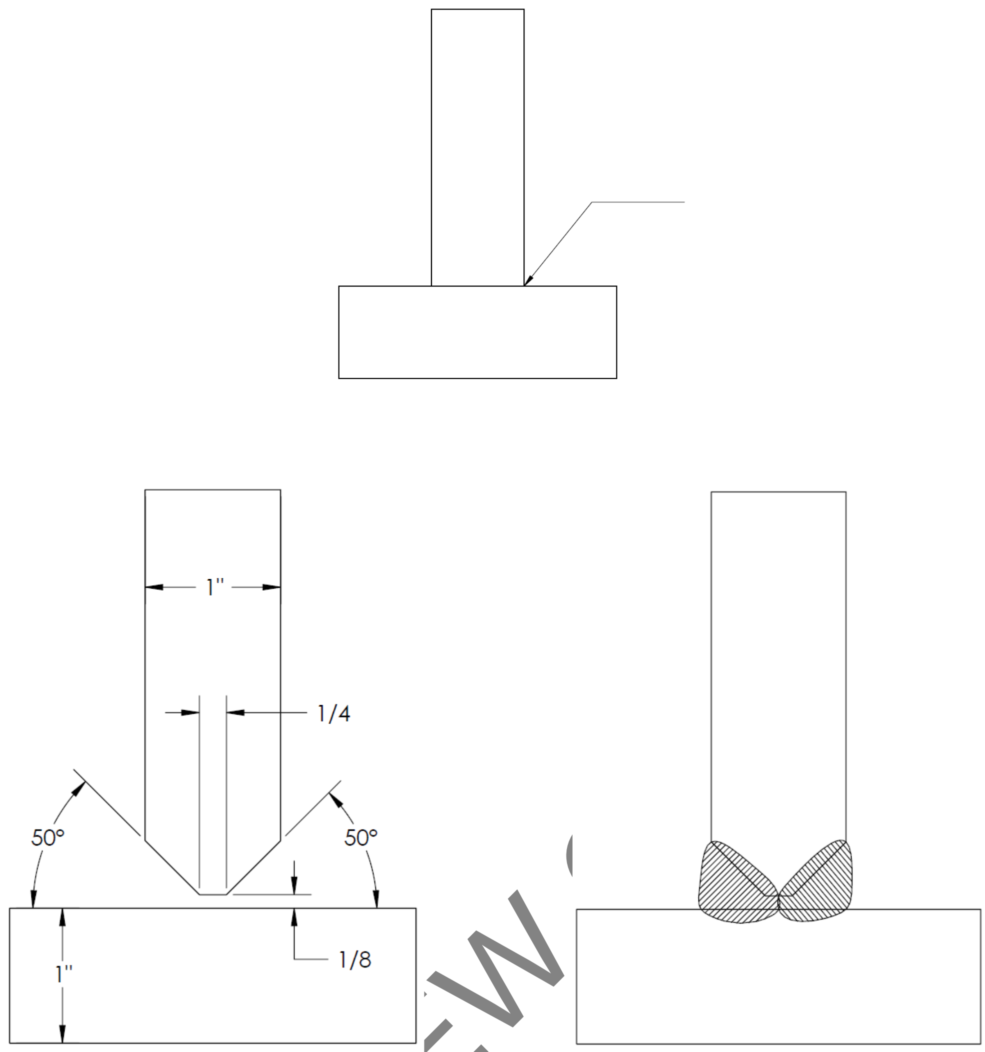



39.



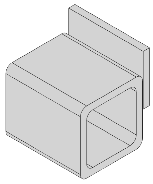
Sketch the weld symbols for the following weld joints:

40.

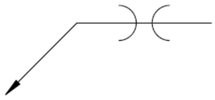


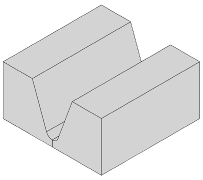
# CHAPTER 4–ADDITIONAL GROOVE WELD TYPES: U-GROOVE, J-GROOVE, AND FLARED-GROOVE; GROOVE WELD LENGTHS AND ARRANGEMENT

Matching: Connect the groove weld type listed in the center column with the proper figures in the right and left columns.

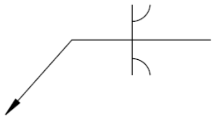


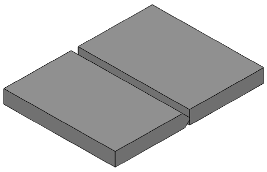
1. Single-U-Groove Weld



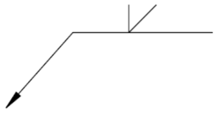


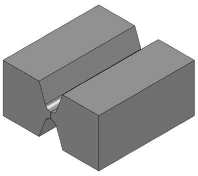
2. Single-J-Groove Weld



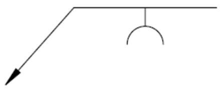


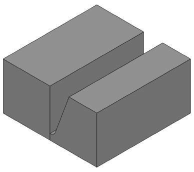
3. Single-Flare-Bevel-Groove Weld



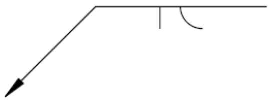


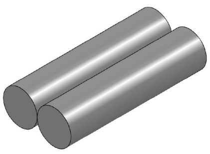
4. Single-Bevel-Groove Weld



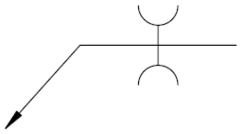


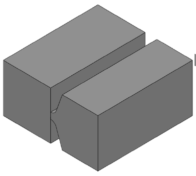
5. Double-U-Groove Weld



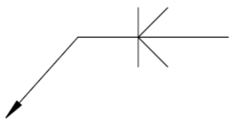


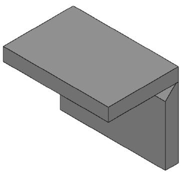
6. Double-J-Groove Weld



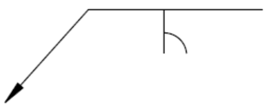


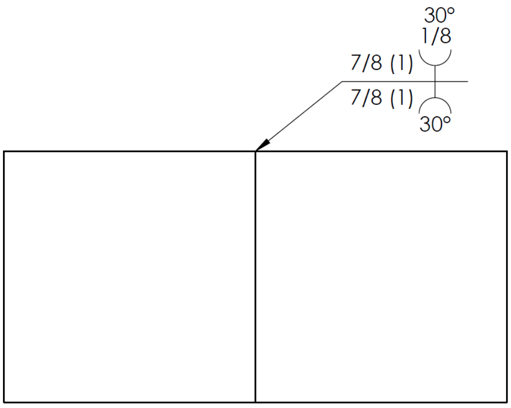
7. Double-Flare-V-Groove Weld





8. Double-Bevel-Groove Weld






9. What type of weld is required? ______________________

10. What is the root opening? ______________________

11. What is the bevel angle on the arrow side? ______________________

12. What is the depth of groove on the arrow side? ______________________

13. What is the weld size on the arrow side? ______________________

14. What is the bevel angle on the other side? ______________________

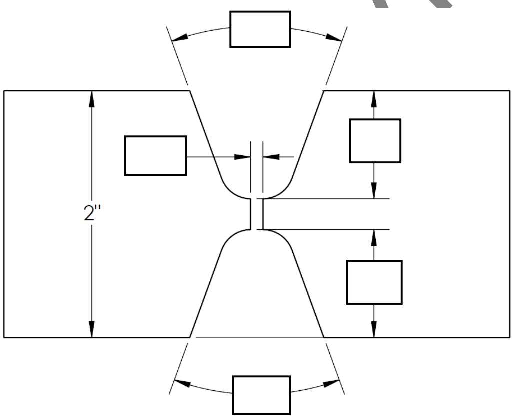
15. What is the depth of groove on the other side? ______________________

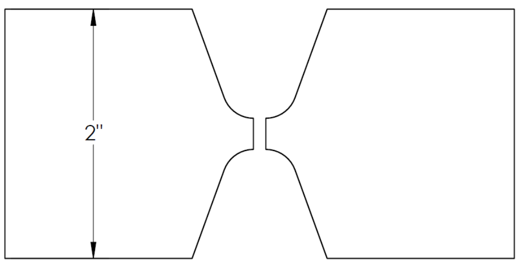
16. What is the weld size on the other side? ______________________

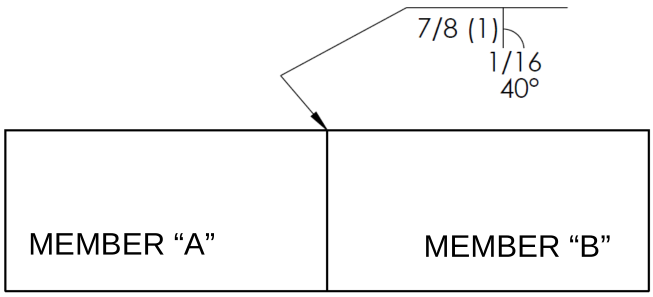
17. What is the radius at the bottom of the grooves? ______________________

18. Dimension the joint sketch below left, and sketch the weld into the drawing below right.








19. What type of weld is required? ______________________________

20. Which member receives the preparation? ______________________________

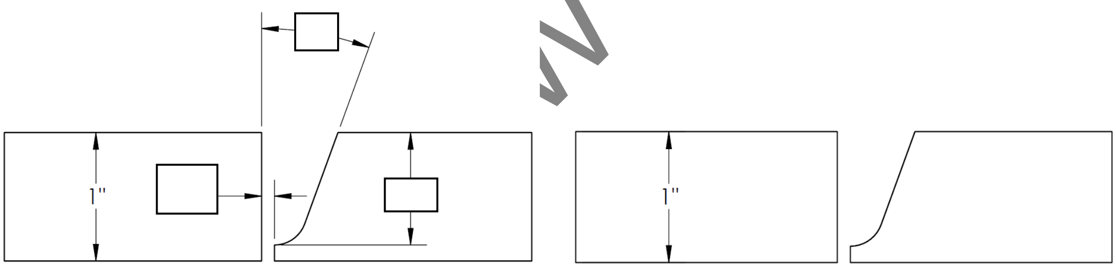
21. What is the root opening? ______________________________

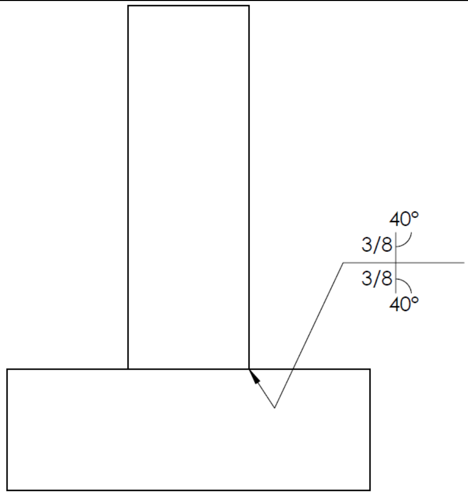
22. What is the bevel angle? ______________________________

23. What is the depth of groove? ______________________________

24. What is the weld size? ______________________________

25. Dimension the joint sketch below left, and sketch the weld into the drawing below right.






26. What type of weld is required? ______________________

27. Which member receives the preparation? ______________________

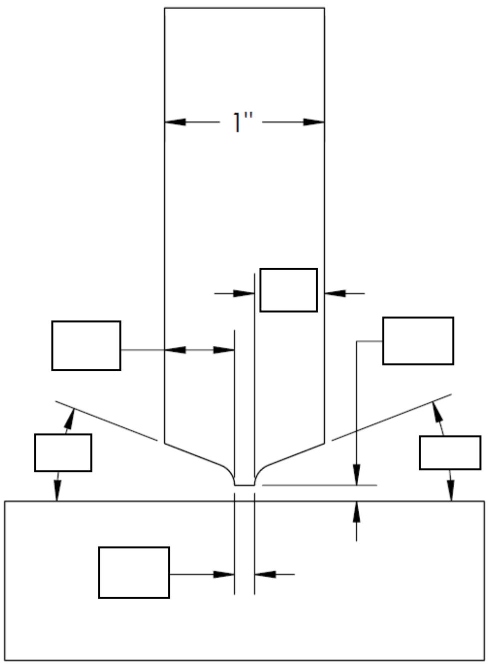
28. What is the root opening? ______________________

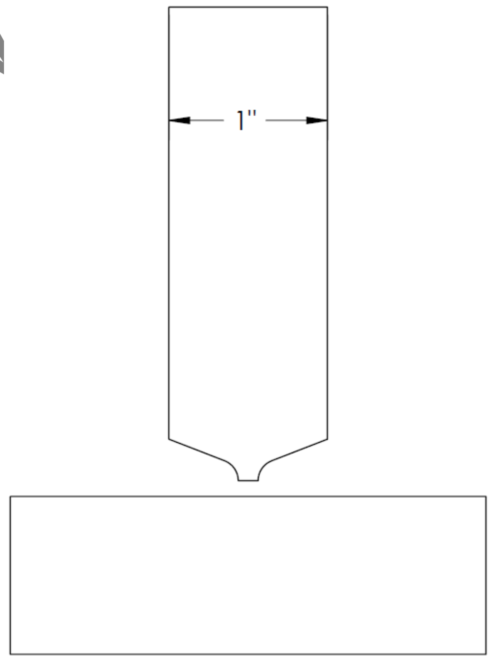
29. What is the bevel angle? ______________________

30. What is the depth of groove on each side? ______________________

31. What is the weld size on each side? ______________________

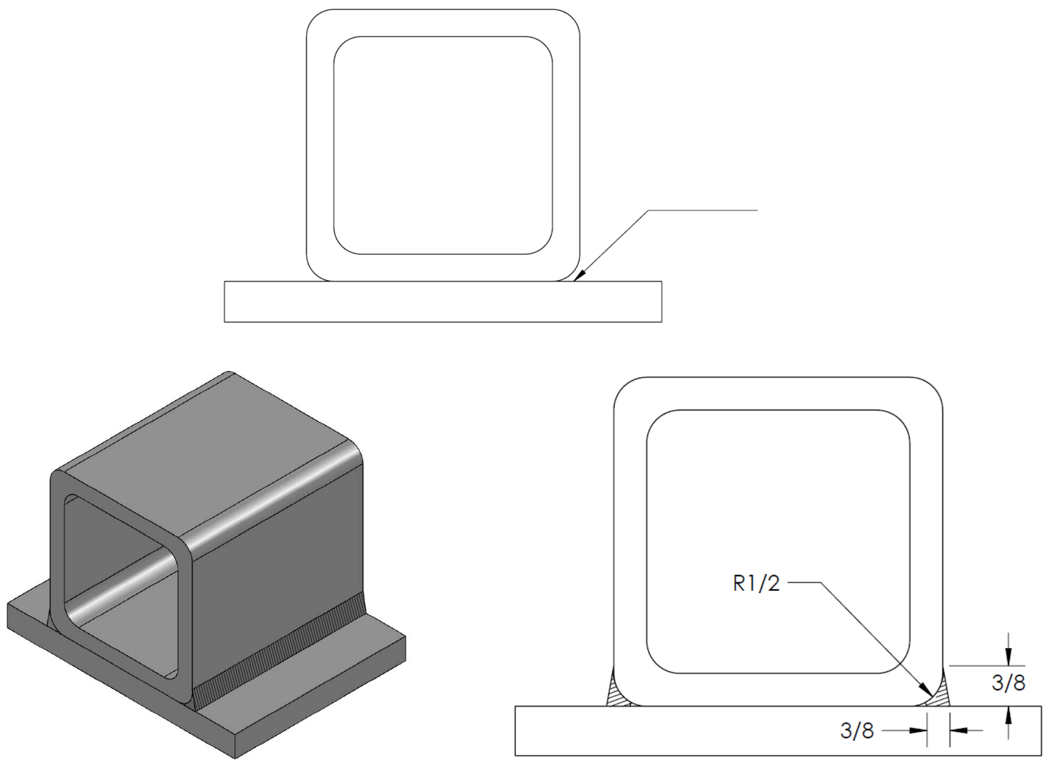
32. Dimension the joint sketch below left, and sketch the weld into the drawing below right.



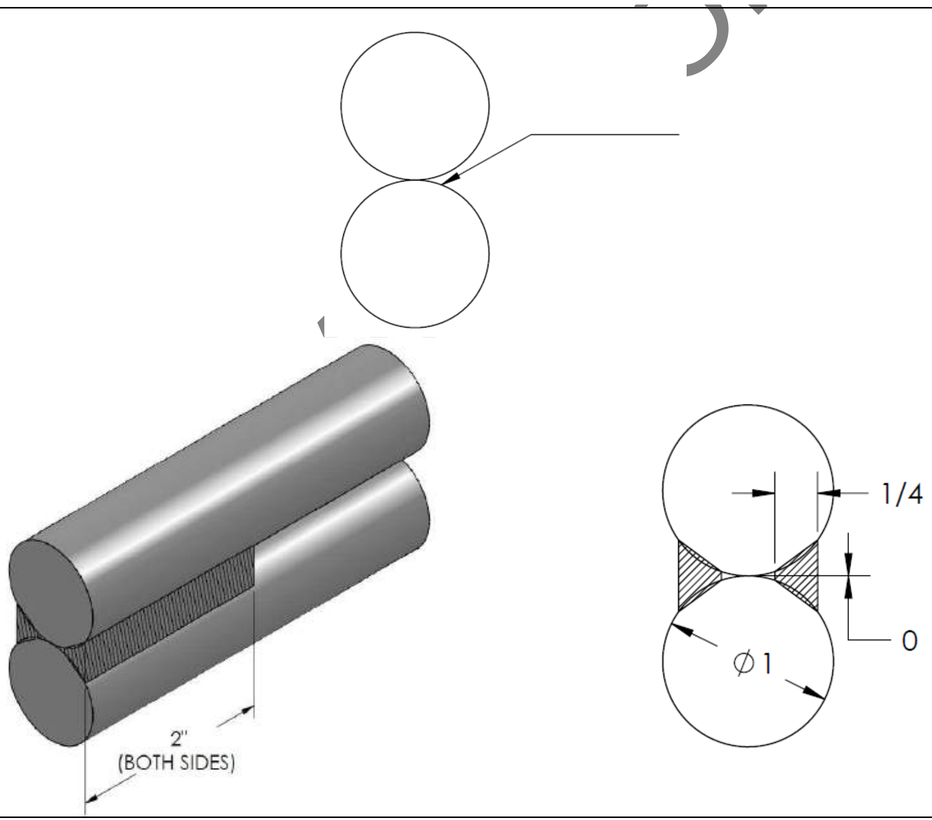



Sketch the weld symbols for the following weld joints:

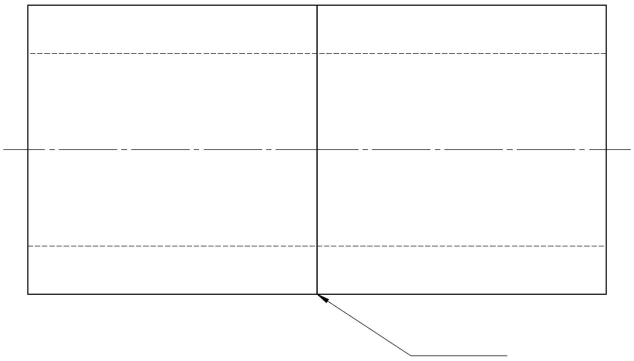
33.

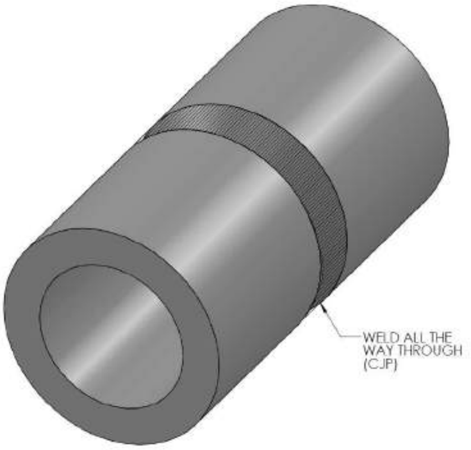


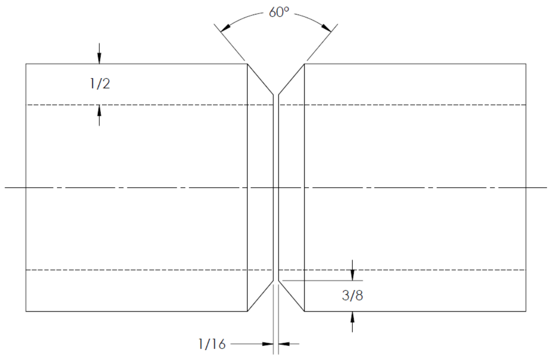

34.



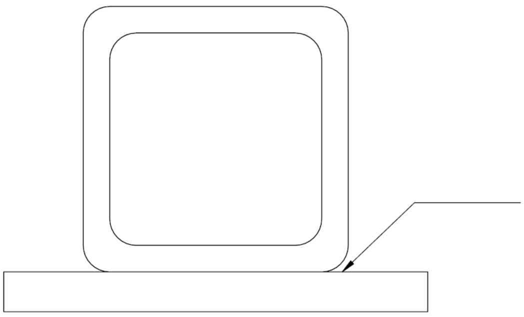
35.

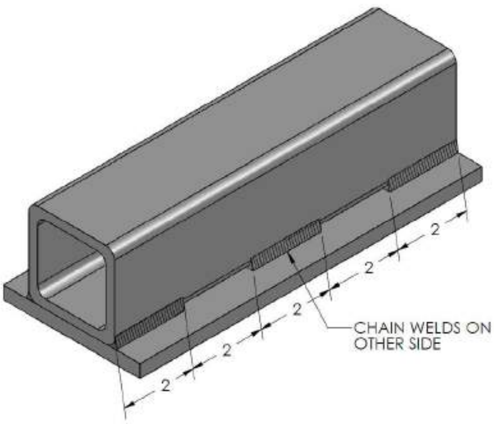


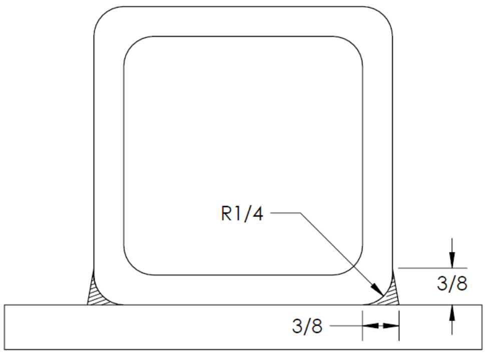

WELD ALL THE
WAY THROUGH
(CJP)


60°
1/2
3/8
1/16

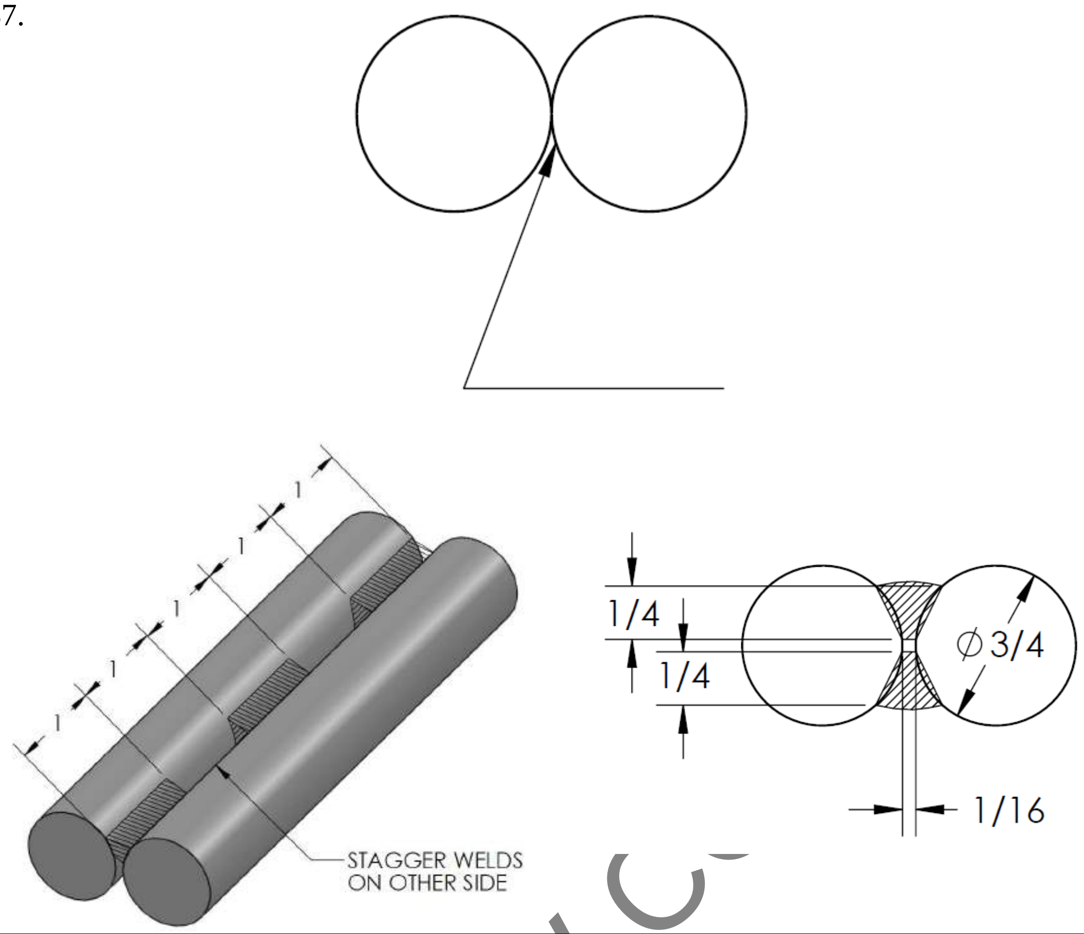
36.



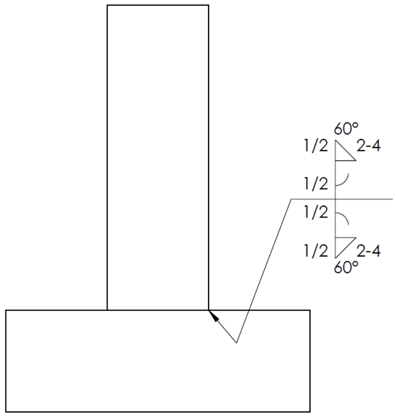

2
2
2
2
2
CHAIN WELDS ON
OTHER SIDE


R1/4
3/8
3/8

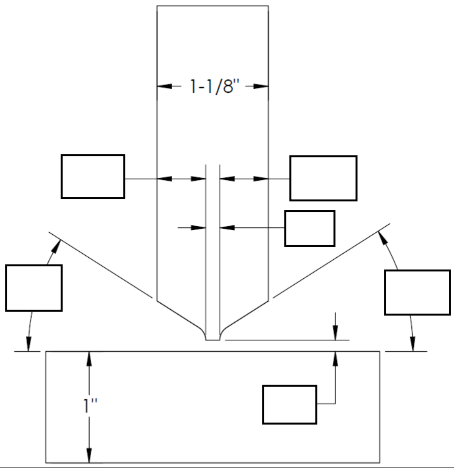
37.

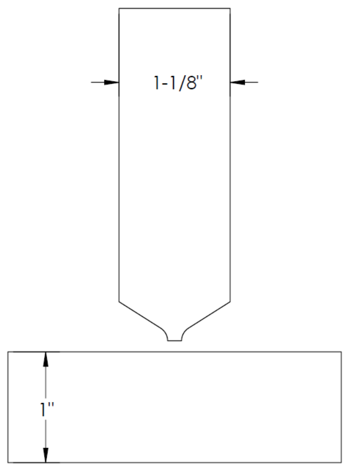


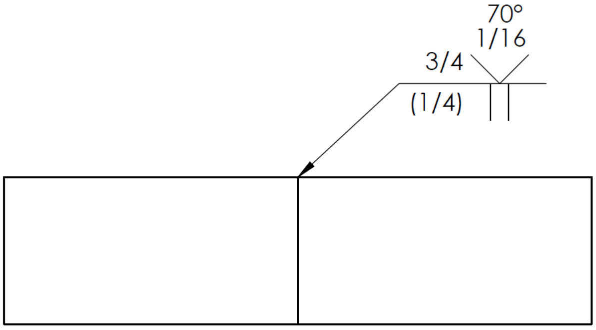
# CHAPTER 5–ADDITIONAL DETAILS: COMBINATION WELDS, MULTIPLE REFERENCE LINES, AND TAIL NOTES



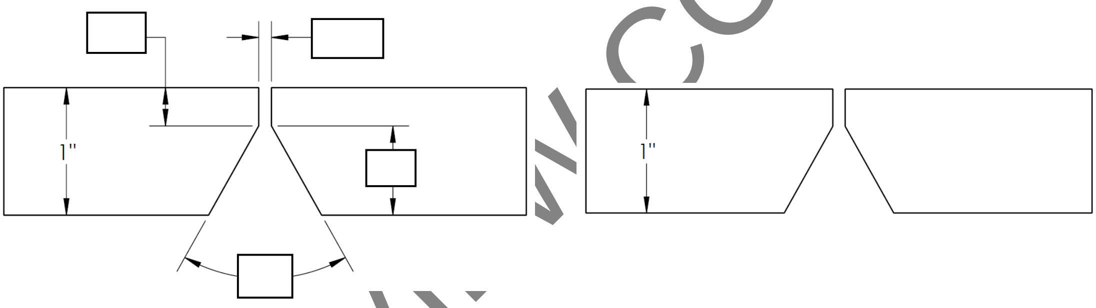

1. What type of groove weld is required? ______________________
2. What is the root opening? ______________________
3. What is the bevel angle? ______________________
4. What is the depth of groove? ______________________
5. What is the groove weld size on the arrow side? ______________________
6. What is the length of the groove weld? ______________________
7. What type of fillet weld is applied over the groove weld? ______________________
8. What is the size of the fillet weld? ______________________
9. What is the length of each fillet weld increment? ______________________
10. What is the pitch of the fillet welds? ______________________
11. Dimension the joint sketch below left, and sketch the weld into the drawing below right.

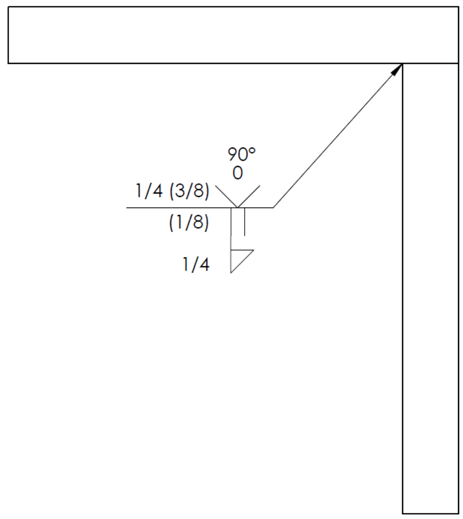


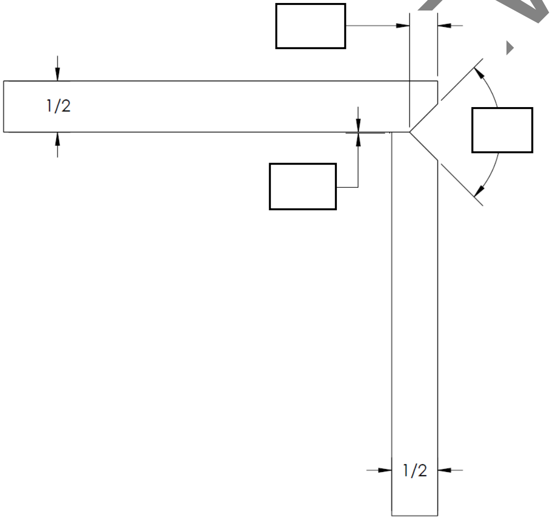


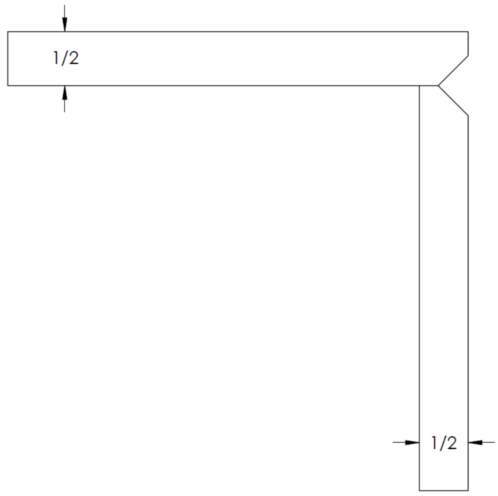

12. What type of weld is required on the arrow side? ______________________
13. What is the root opening? ______________________
14. What is the weld size on the arrow side? ______________________
15. What type of weld is required on the other side? ______________________
16. What is the bevel angle? ______________________
17. What is the depth of groove? ______________________
18. What is the weld size on the other side? ______________________
19. Dimension the joint sketch below left, and sketch the weld into the drawing below right.

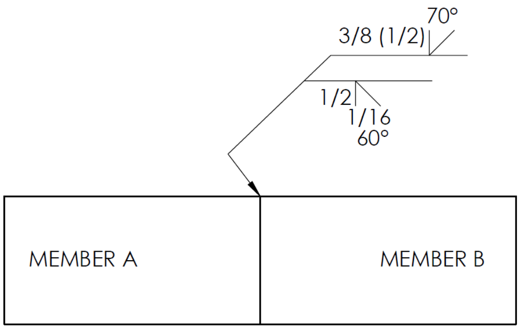





20. What type of weld is required on the arrow side? ____________________
21. What is the root opening? ____________________
22. What is the groove weld size on the arrow side? ____________________
23. What is the fillet weld size on the arrow side? ____________________
24. What type of weld is required on the other side? ____________________
25. What is the bevel angle? ____________________
26. What is the depth of groove? ____________________
27. What is the weld size on the other side? ____________________
28. Dimension the joint sketch below left, and sketch the weld into the drawing below right.






29. Which member receives the bevel? ____________________

30. Which side is welded first? ____________________

31. What is the root opening? ____________________

32. What is the bevel angle on the arrow side? ____________________

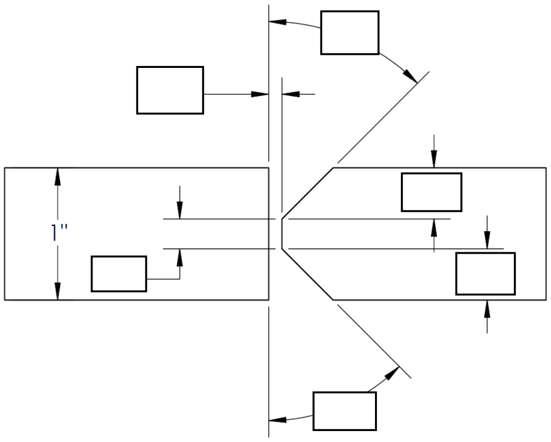
33. What is the depth of groove on the arrow side? ____________________

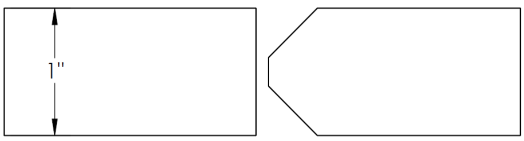
34. What is the bevel angle on the other side? ____________________

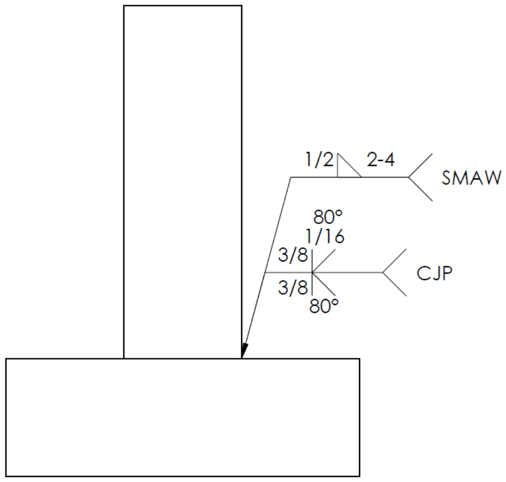
35. What is the depth of groove on the other side? ____________________

36. What is the weld size on the other side? ____________________

37. Dimension the joint sketch below left, and sketch the weld into the drawing below right.






38. What is the groove weld type? ____________________

39. What is the root opening? ____________________

40. What is the bevel angle? ____________________

41. What is the depth of groove? ____________________

42. What is the additional fillet weld size? ____________________

43. What is depth of joint penetration? ____________________

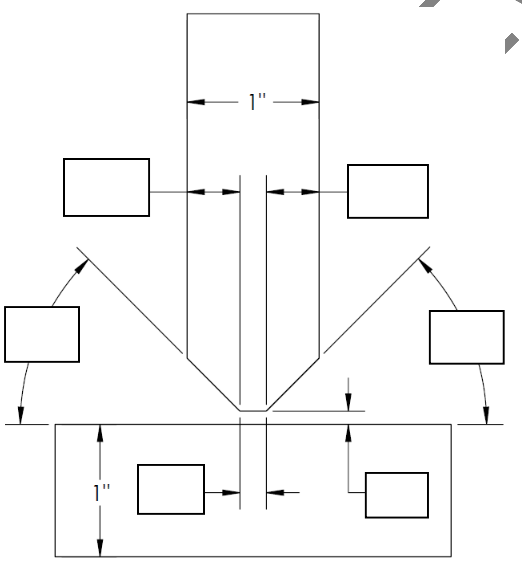
44. What is the welding process for the fillet weld? ____________________

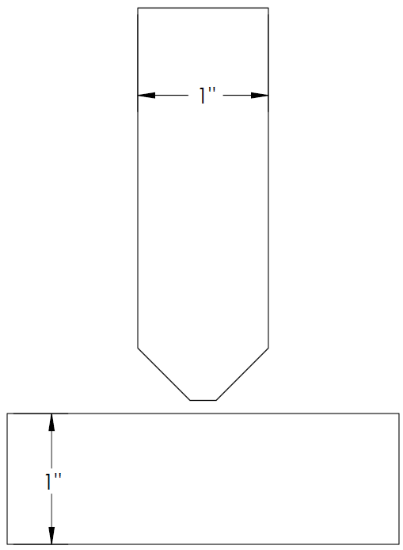
45. What is the length of the groove weld? ____________________

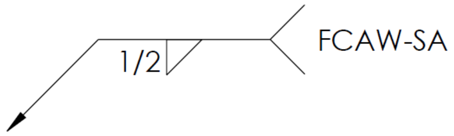
46. What is the length of each fillet weld increment? ____________________

47. Dimension the joint sketch below left, and sketch the weld into the drawing below right.





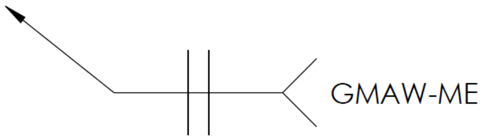






48. What is the weld type and location? ____________________

49. What is the weld size? ____________________

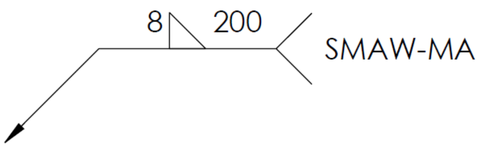
50. What is welding process and application method? ____________________




51. What is the weld type and location? ____________________

52. What is the weld size? ____________________

53. What is the welding process and application method? ____________________




54. What is the type and location? ____________________

55. What is the weld size? ____________________

56. What is the weld length? ____________________

57. What is the welding process and application method? ____________________

Define:

58. EBW____________________

59. RSEW____________________

60. GTAW____________________

61. SAW____________________

Give the abbreviation for:

62. Robotic laser beam welding

____________________

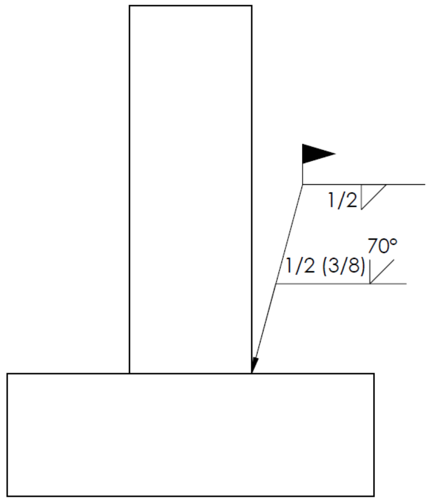
63. Manual gas tungsten arc welding

____________________

64. Automatic resistance spot welding

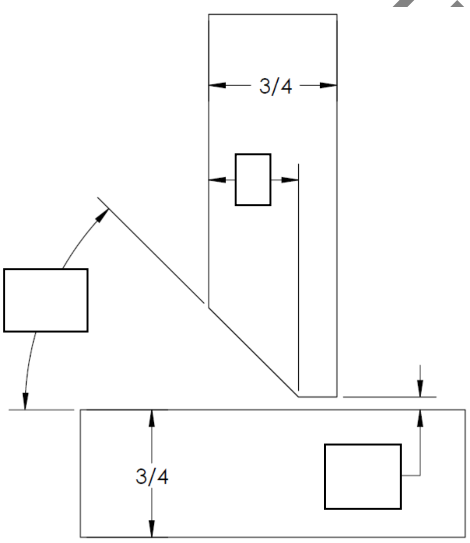
____________________

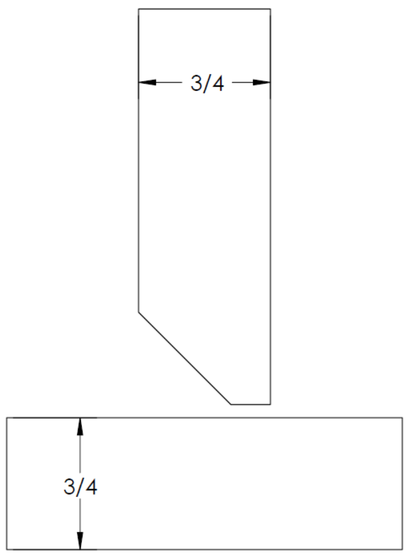
## CHAPTER 6–ADDITIONAL DETAILS: FIELD WELD, WELD CONTOUR, AND COMPLETE JOINT PENETRATION (MELT-THROUGH)




1. What type of weld is specified on the arrow side? ____________________
2. What type of weld is specified on the other side? ____________________
3. What is the bevel angle? ____________________
4. What is the depth of groove? ____________________
5. What is the groove weld size? ____________________
6. What is the fillet weld size? ____________________
7. Which weld is the field weld? ____________________

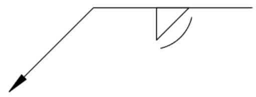
8. Dimension the joint sketch below left, and sketch the weld into the drawing below right.



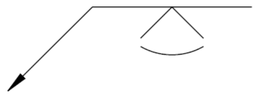



Matching:  Match the weld symbol to the description.

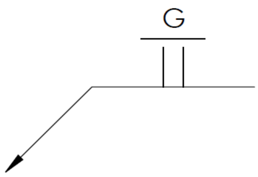
9. Flat contour-
as-welded



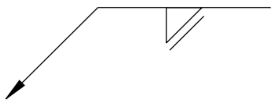
10. Concave contour-
by chipping



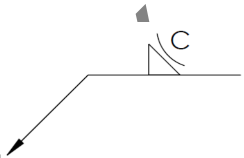
11. Convex contour-
as-welded, fillet weld



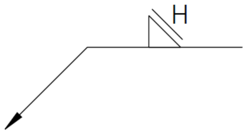

12. Flat (flush) contour-
unspecified finish method



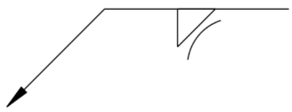
13. Concave contour-
as welded, fillet weld



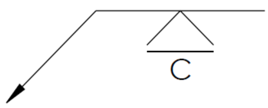

14. Flat contour-
by chipping



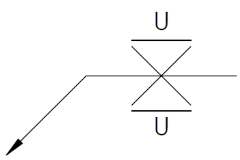

15. Convex contour-
as welded, groove weld



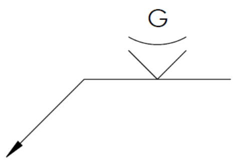
16. Flat contour-
by hammering




17. Concave contour-
by grinding

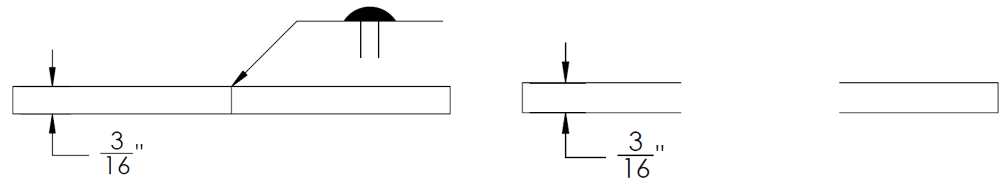



18. Flat (flush) contour-
by grinding

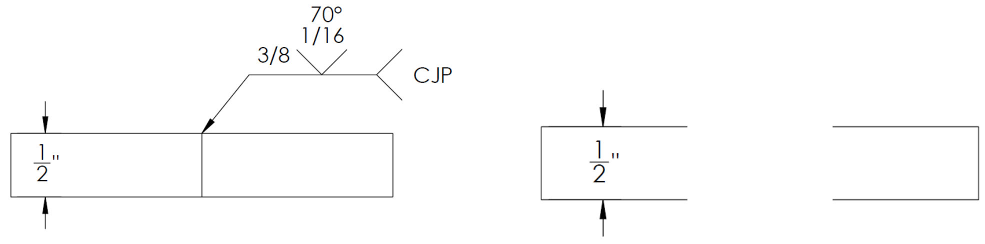


For each example, indicate complete joint penetration (CJP) or partial joint penetration (PJP) and sketch the weld

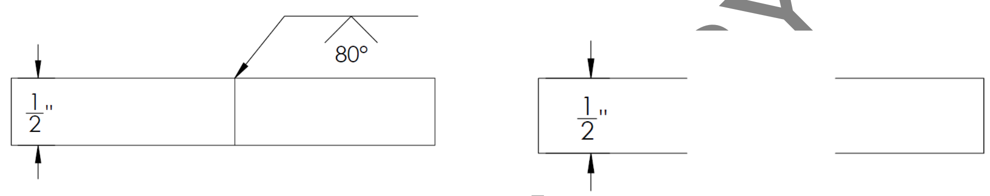
19. CJP PJP



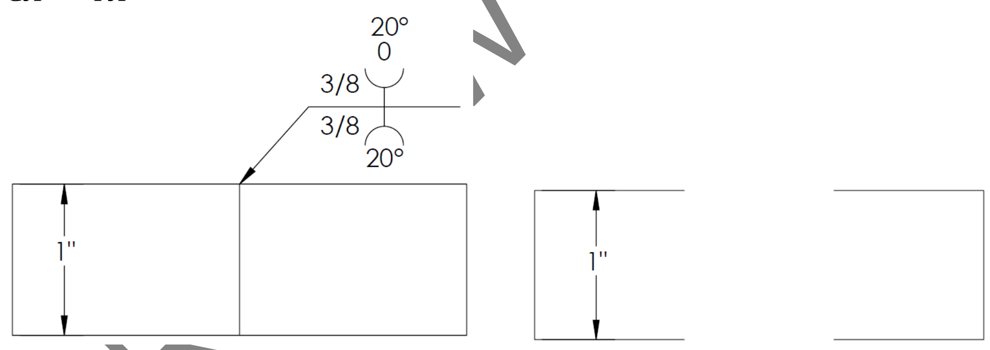

20. CJP PJP




21. CJP PJP

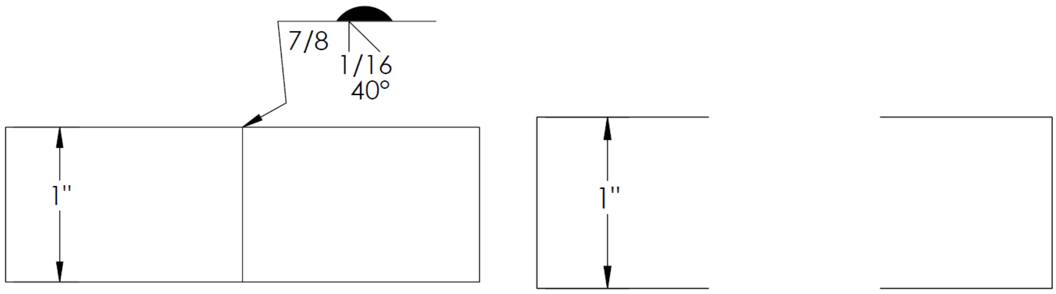



22. CJP PJP

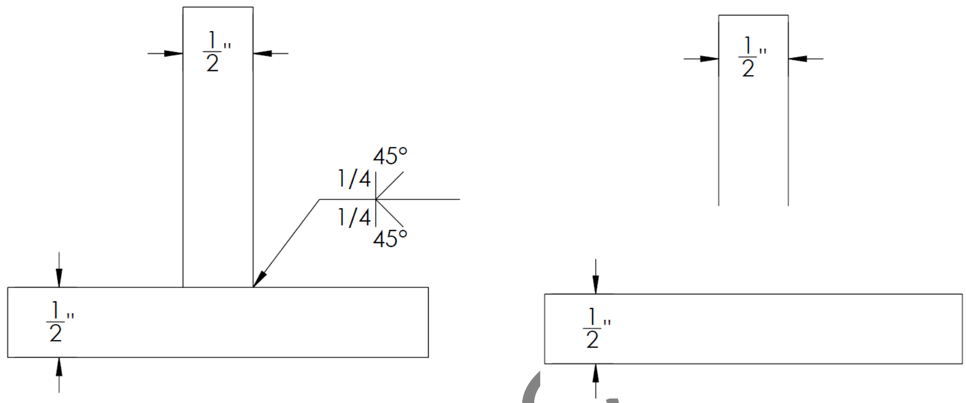


For each example, indicate complete joint penetration (CJP) or partial joint penetration (PJP) and sketch the weld

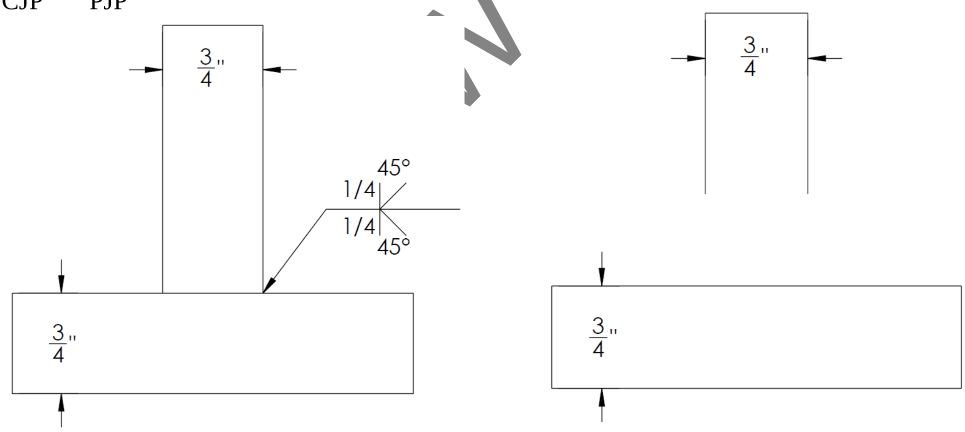
23. CJP PJP




24. CJP PJP

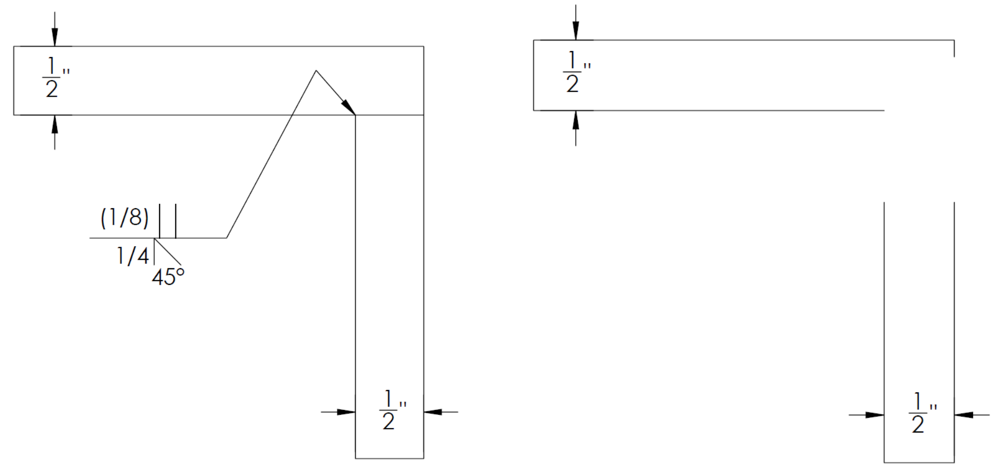



25. CJP PJP

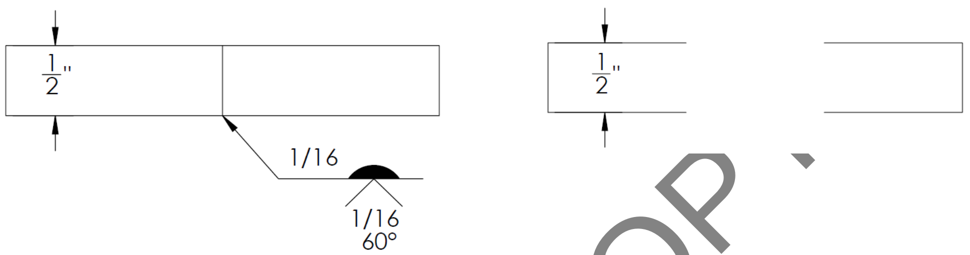


For each example, indicate complete joint penetration (CJP) or partial joint penetration (PJP) and sketch the weld

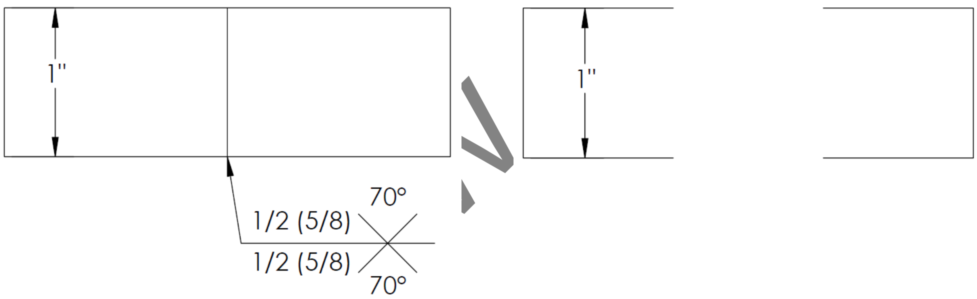
26. CJP PJP




27. CJP PJP

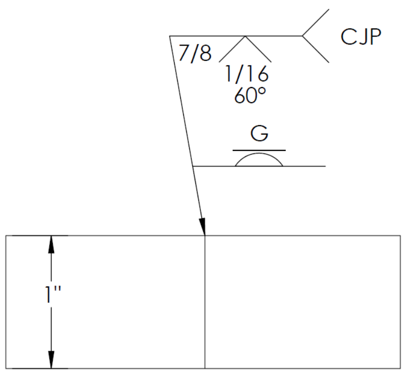



28. CJP PJP



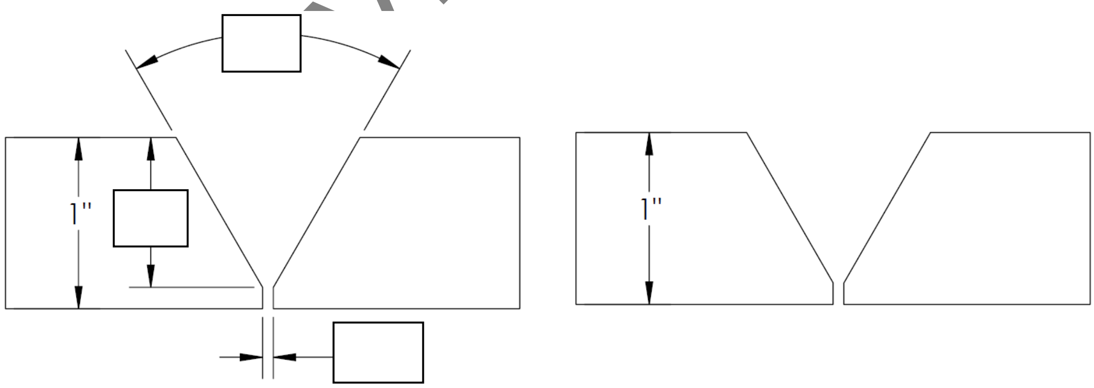
# CHAPTER 7–GROOVE WELD DETAILS: BACK AND BACKING WELDS, AND BACKGOUGING

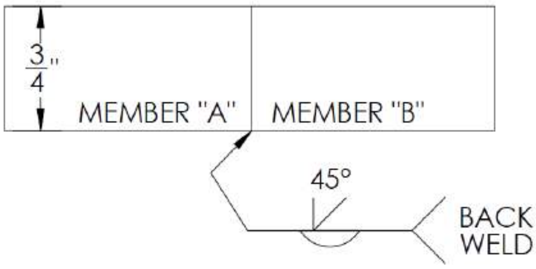
1. *(circle correct answer)* A back weld is applied (before/after) the main weld, while a backing weld is applied (before/after) the main weld.



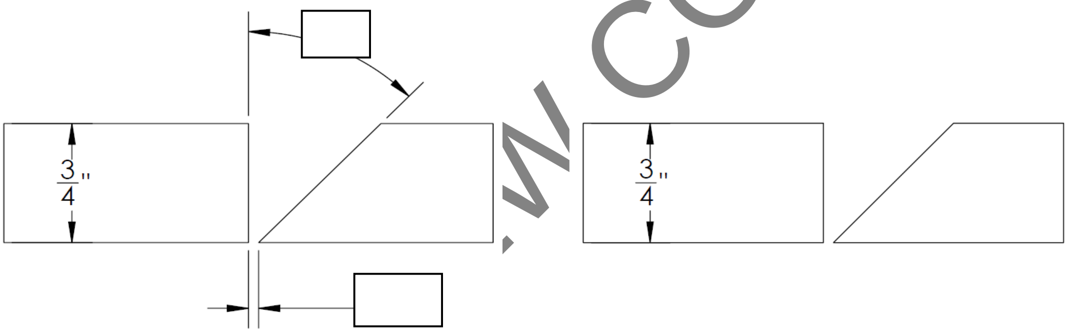

2. What type of weld is required on the arrow side? ____________________
3. What is the contour and finish method on the arrow side? ____________________
4. What type of weld is required on the other side? ____________________
5. What is the contour and finish method on the other side? ____________________
6. What is the root opening? ____________________
7. What is the bevel angle? ____________________
8. What is the depth of groove? ____________________
9. What is the weld size? ____________________

10. Dimension the joint sketch below left, and sketch the weld into the drawing below right.





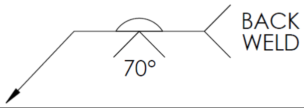
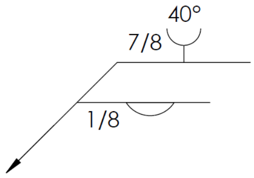
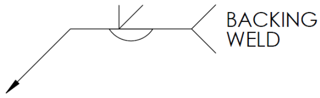
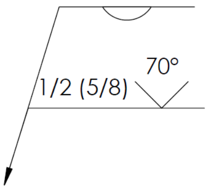

11. What type of weld is required on the arrow side? ____________________
12. What type of weld is required on the other side? ____________________
13. What is the root opening? ____________________
14. What is the bevel angle? ____________________
15. What is the depth of groove? ____________________
16. What is the weld size? ____________________
17. Which member receives the bevel? ____________________
18. Dimension the joint sketch below left, and sketch the weld into the drawing below right.



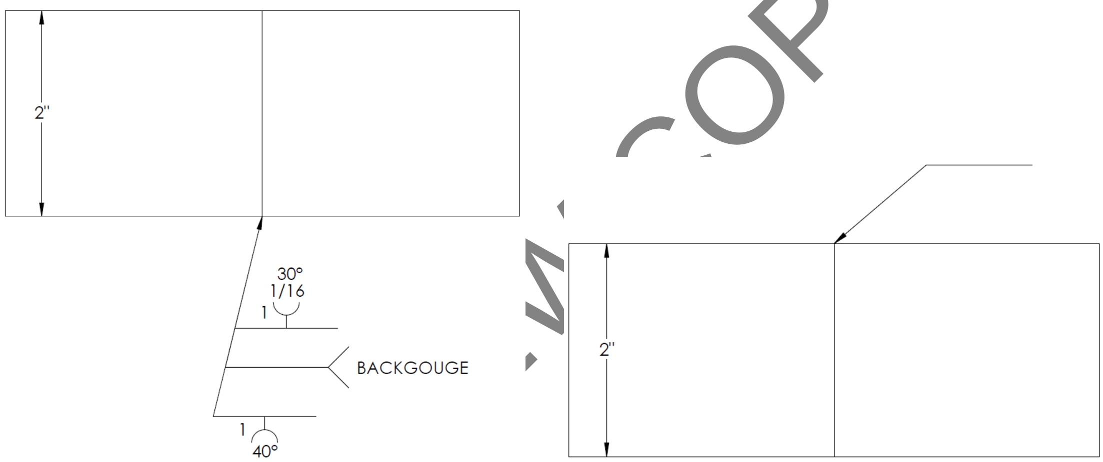

19. Draw the welding symbol for the following weld and joint description:

- Double bevel groove weld
- $^{1}/_{16}$” root opening
- 50° bevel angle on both sides
- $^{7}/_{16}$” depth of groove on both sides
- ½” weld size on both sides
- Backgouge before welding second side

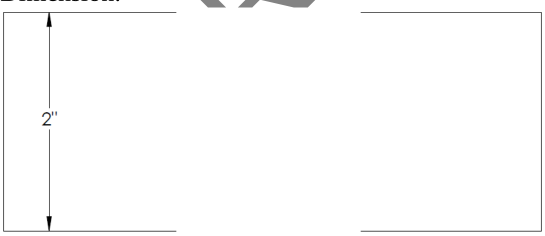
Identify each of the following symbols as using a back weld or a backing weld:

| | |
|---|---|
| 20. Back Weld Backing Weld |  |
| 21. Back Weld Backing Weld |  |
| 22. Back Weld Backing Weld |  |
| 23. Back Weld Backing Weld |  |

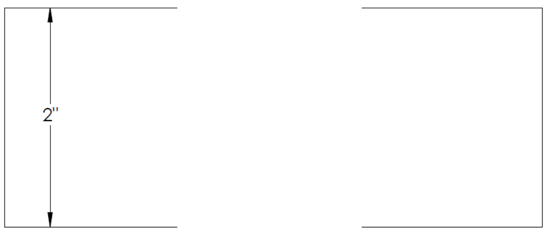
24. Combine the following multiple-reference-line welding symbol into a single welding symbol on the given reference line:

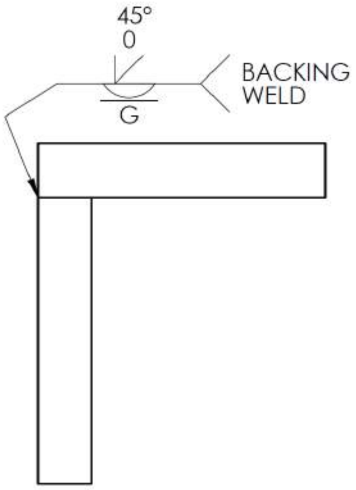



Dimension:

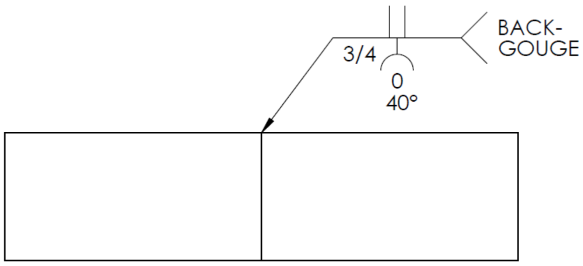



Sketch Weld:



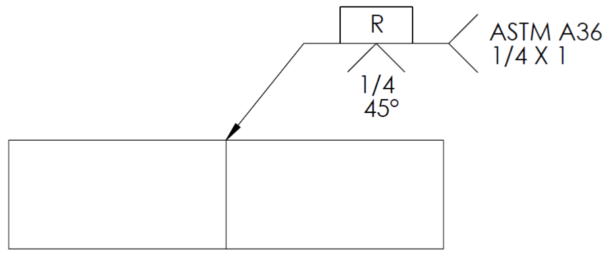



25. What type of weld is required on the arrow side? ____________________
26. What is the weld contour and finish method on arrow side? ____________________
27. What type of weld is required on the other side? ____________________
28. What is the root opening? ____________________
29. What is the bevel angle? ____________________
30. What is the depth of groove? ____________________



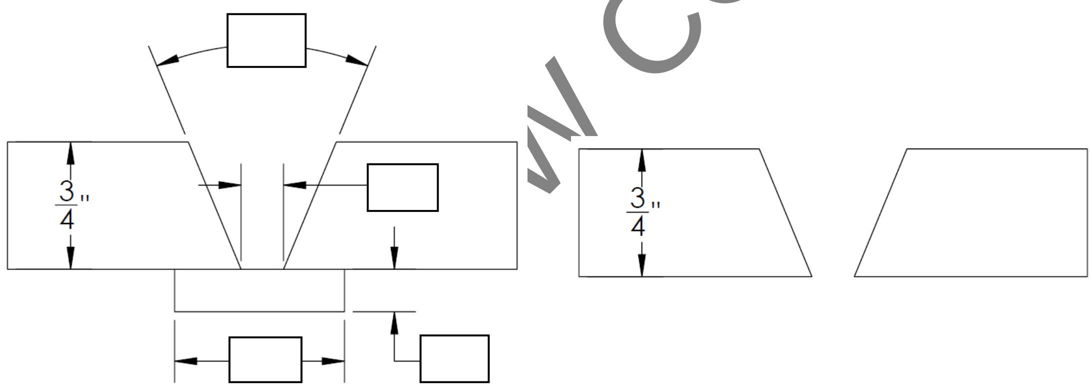

31. What type of weld is required on the arrow side? ____________________
32. What is the root opening? ____________________
33. What is the bevel angle? ____________________
34. What is the depth of groove? ____________________
35. What type of weld is required on the other side? ____________________
36. What must be done before welding the other side? ____________________

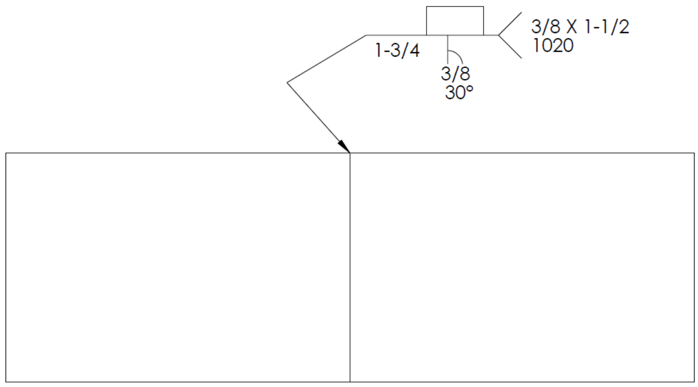
## CHAPTER 8–GROOVE WELD DETAILS: BACKING, SPACERS, AND CONSUMABLE INSERTS




1. What type of weld is required? ____________________
2. What is the root opening? ____________________
3. What is the bevel angle? ____________________
4. What is the depth of groove? ____________________
5. What is the weld size? ____________________
6. What does the "R" mean? ____________________
7. What material is the backing bar? ____________________

8. Dimension the joint sketch below left, and sketch the weld into the drawing below right.






9. What type of weld is required? ______________________

10. What is the root opening? ______________________

11. What is the groove angle? ______________________

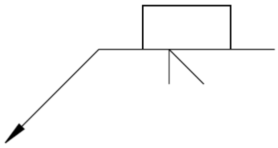
12. What is the depth of groove? ______________________

13. What is the material for the backing bar? ______________________

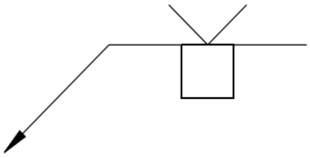
14. Dimension the joint sketch below.

Identify each of the following symbols as using a backing bar (B), a spacer (S), or a consumable insert (CI):

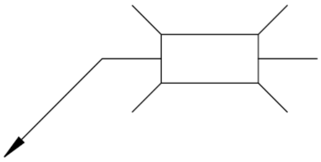
15. B S CI Type of weld________



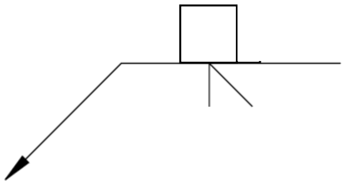
16. B S CI Type of weld________



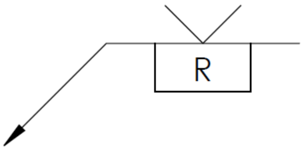
17. B S CI Type of weld________

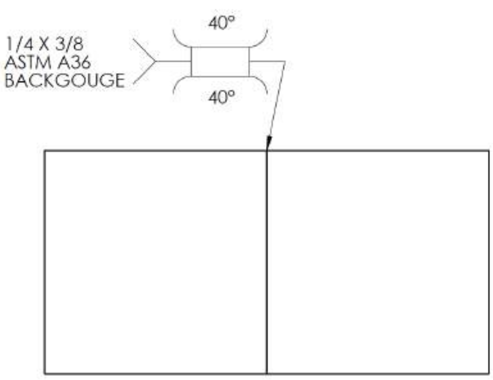


18. B S CI Type of weld________



19. B S CI Type of weld________




20. What type of weld is required? ____________________

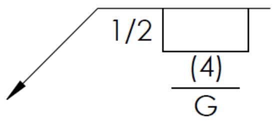
21. What is the root opening? ____________________

22. What is the bevel angle? ____________________

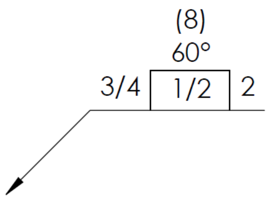
23. What material is the spacer? ____________________

24. What must be done before welding the second side? ____________________

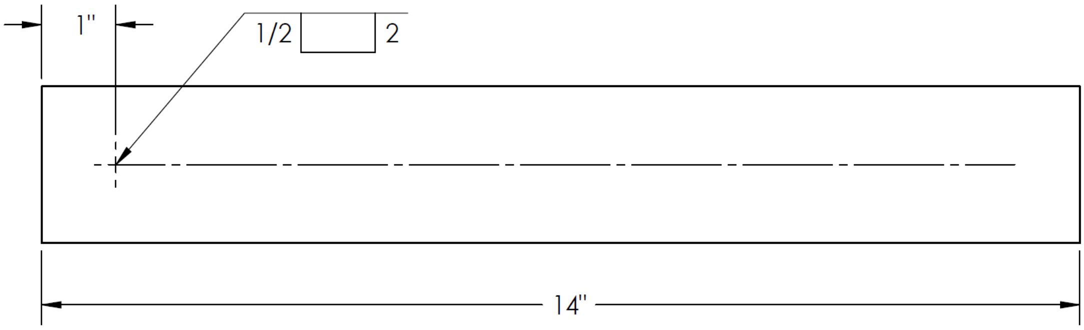
# CHAPTER 9–PLUG AND SLOT WELDS




1. What type of weld is required?
2. What is weld location?
3. What is the diameter?
4. What is the countersink angle?
5. What is the depth of fill?
6. What is the contour and finish method?
7. How many welds are required?




8. What type of weld is required?
9. What is weld location?
10. What is the diameter?
11. What is the countersink angle?
12. What is the depth of fill?
13. How many welds are required?
14. What is the spacing of the welds?




15. How many welds will be made? ______________________

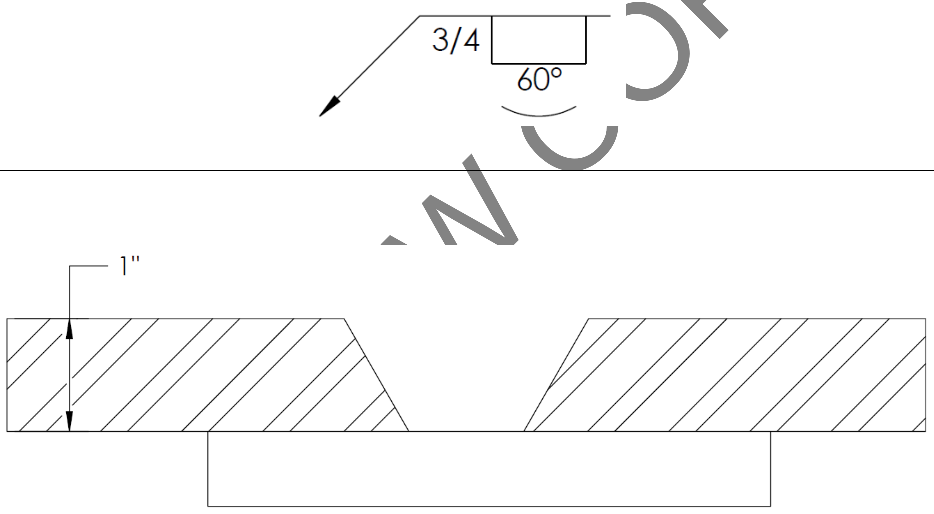
16. What is the diameter? ______________________

17. What is the location? ______________________

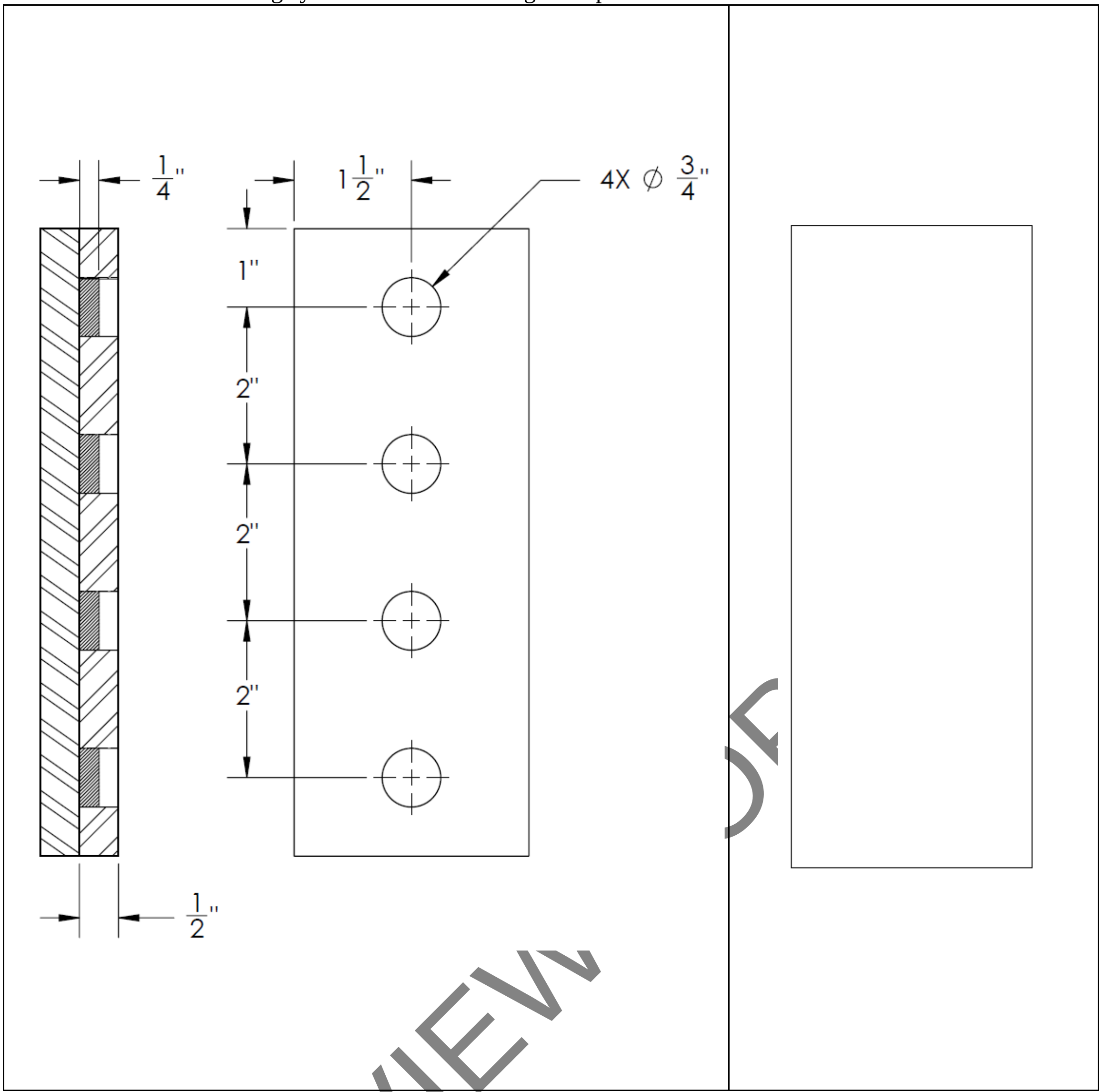
18. What is the countersink angle? ______________________

19. What is the depth of fill? ______________________

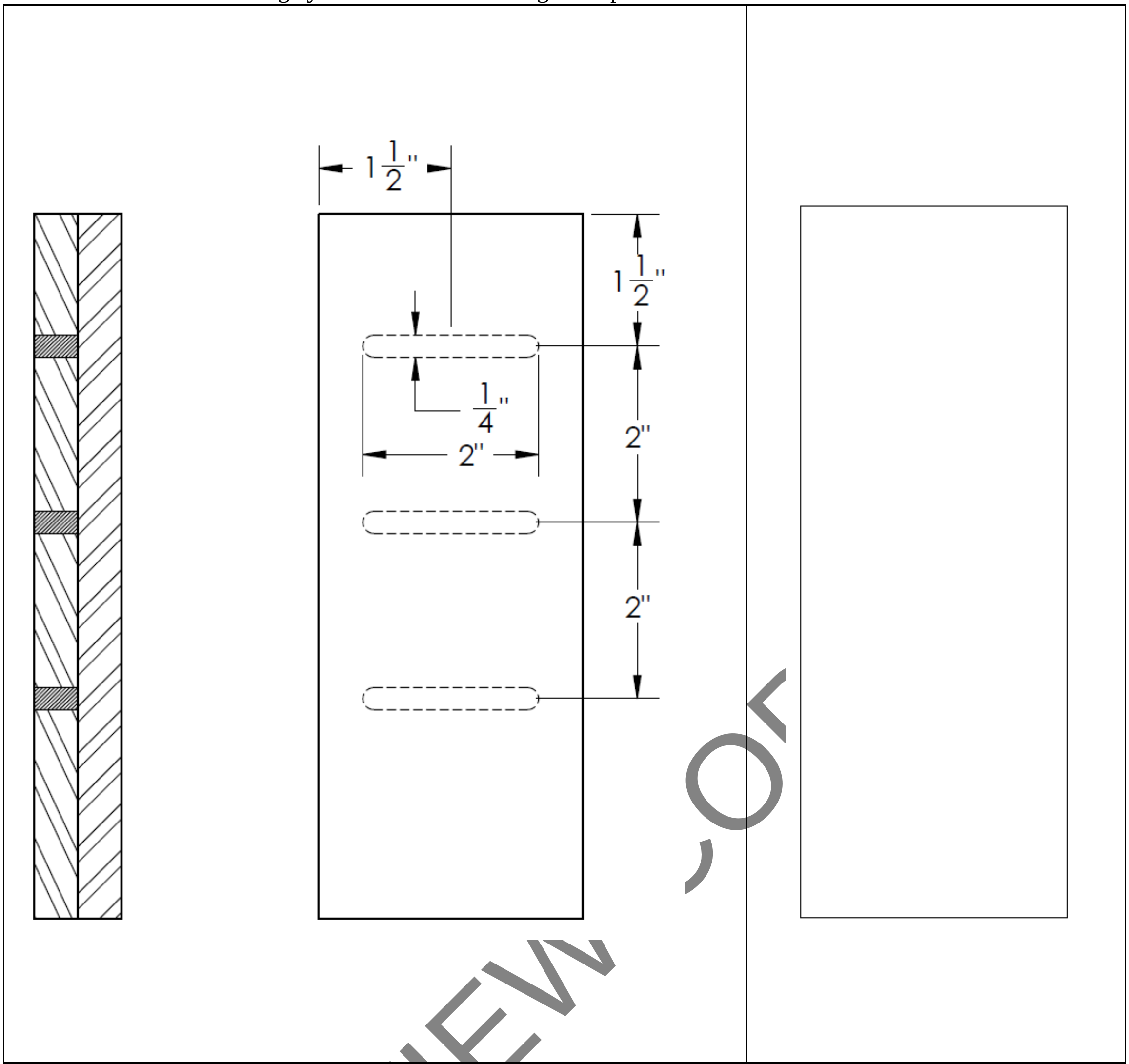
20. Dimension the figure and sketch the plug weld:

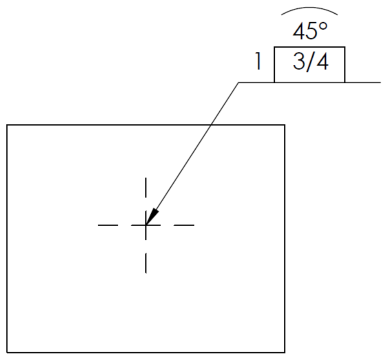


21. Draw the welding symbol for the following example:



22. Draw the welding symbol for the following example:






23. What type of weld is required? ____________________

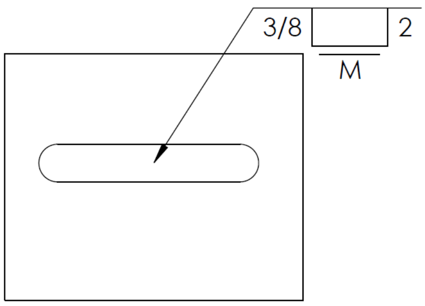
24. What is the location? ____________________

25. What is the diameter? ____________________

26. What is the countersink angle? ____________________

27. What is the depth of fill? ____________________

28. What is the contour and finish method? ____________________




29. What type of weld is required? ____________________

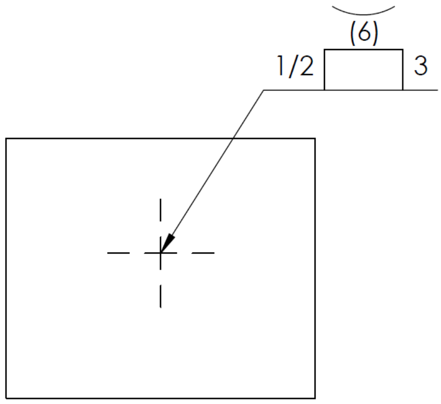
30. What is the location? ____________________

31. What is the width? ____________________

32. What is the length? ____________________

33. What is the depth of fill? ____________________

34. What is the contour and finish method? ____________________




35. What type of weld is required? ______________________

36. What is the location? ______________________

37. What is the diameter? ______________________

38. What is the countersink angle? ______________________

39. What is the depth of fill? ______________________

40. What is the contour and finish method? ______________________

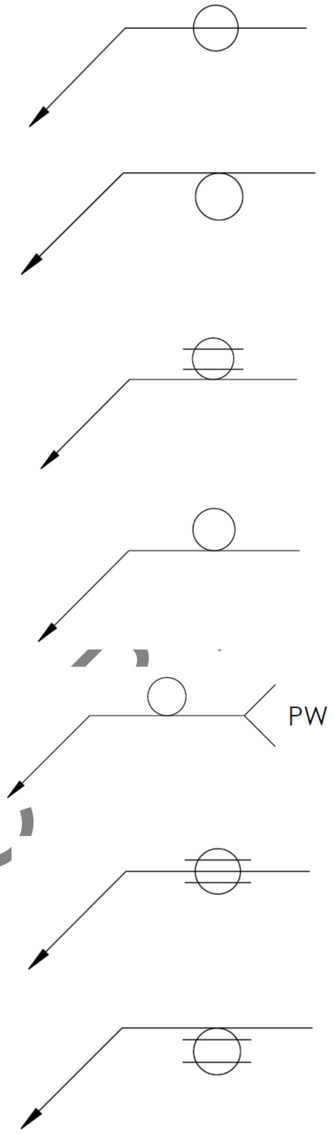
41. How many welds are required? ______________________

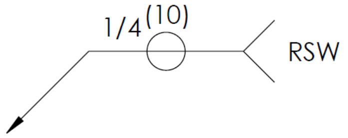
42. What is the pitch? ______________________

# CHAPTER 10–SPOT, PROJECTION, AND SEAM WELDS

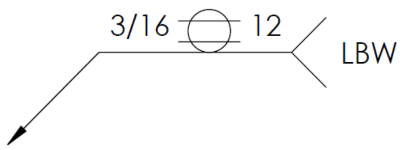
Matching:

1. Spot weld, arrow side
2. Projection weld
3. Spot weld, other side
4. Seam weld, no side significance
5. Spot weld, no side significance
6. Seam weld, other side
7. Seam weld, arrow side

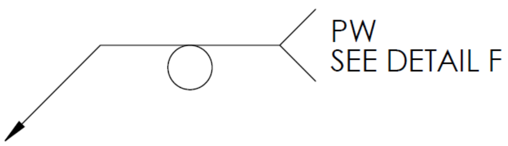




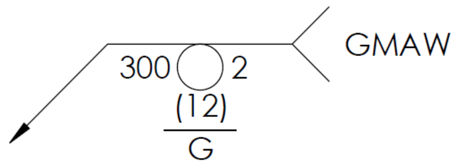

8. What type of weld is required? ______________________
9. What is the welding process? ______________________
10. What is the weld diameter? ______________________
11. How many welds are required? ______________________




12. What type of weld is required? ______________________
13. What is location? ______________________
14. What is the welding process? ______________________
15. What is the weld width? ______________________
16. What is the weld length? ______________________




17. What type of weld is required? ______________________
18. What is location of the projection? ______________________
19. What is the diameter and height of the projection? ______________________




20. What type of weld is required? ______________________

21. What is the location? ______________________

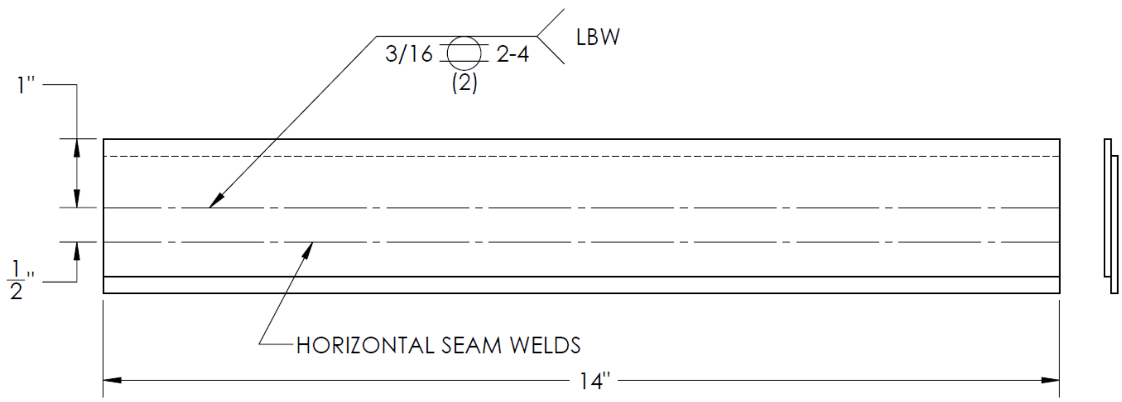
22. What is the welding process? ______________________

23. What is the strength of each spot? ______________________

24. How many welds are required? ______________________

25. What is the pitch? ______________________

26. What is the contour and finish method? ______________________




27. What type of weld is required? ______________________

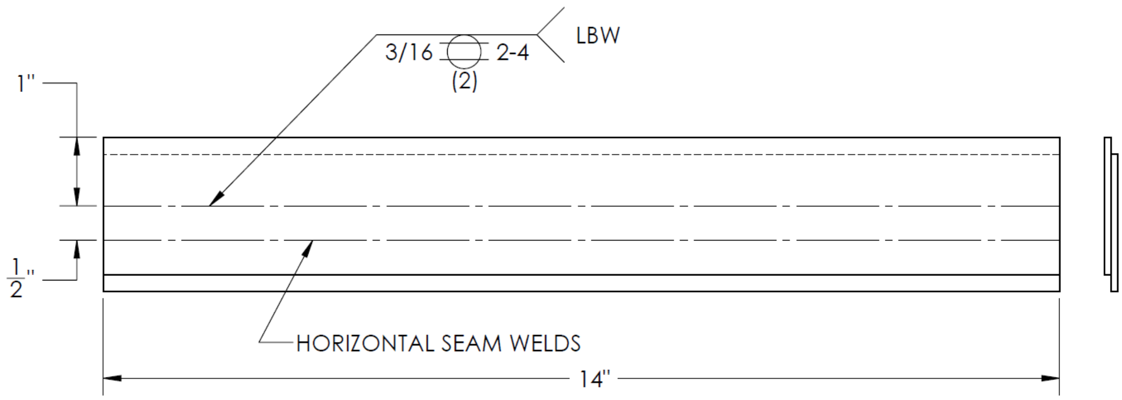
28. What is the location? ______________________

29. What is the welding process? ______________________

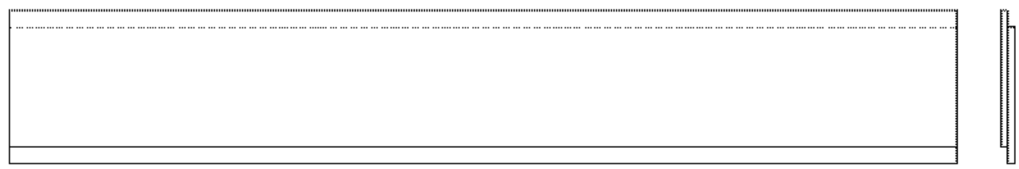
30. What is the width of the weld? ______________________

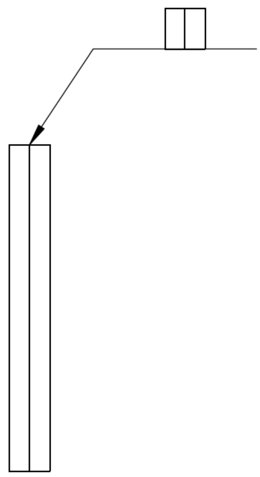
31. What is the length of each weld increment? ______________________

32. What is the pitch? ______________________



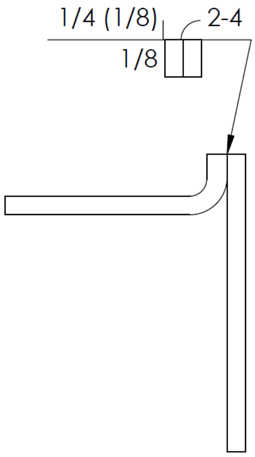

33. Sketch and dimension the seam weld shown above.





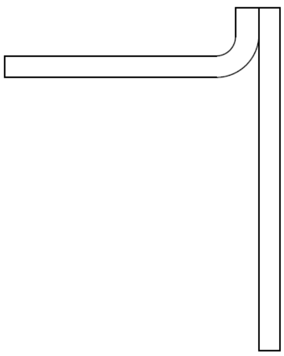
1. What type of weld is required? ________________
2. What is the weld location? ________________
3. What is the weld size? ________________
4. What is the weld length ________________

Sketch the weld:



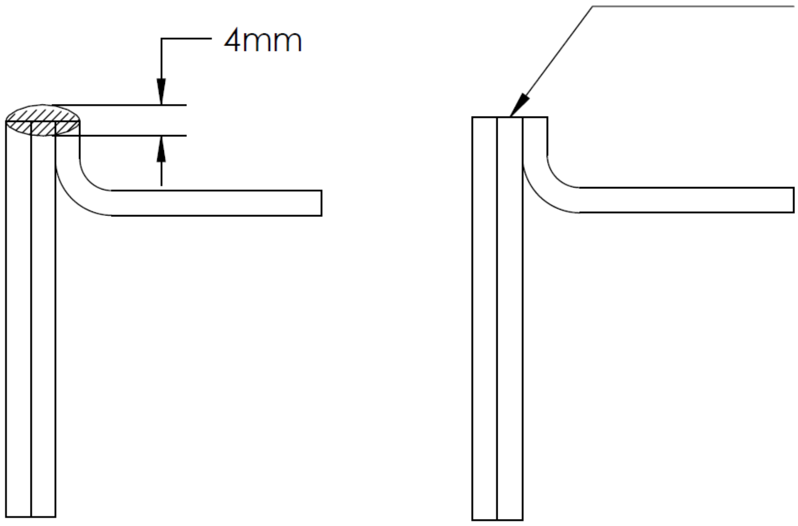

5. What type of weld is required on the arrow side? __________
6. What is the weld size on the arrow side? __________
7. What type of weld is required on the other side? __________
8. What is the radius of the groove? __________
9. What is the weld size? __________
10. What is the length of each increment? __________
11. What is the pitch? __________

Sketch the weld:

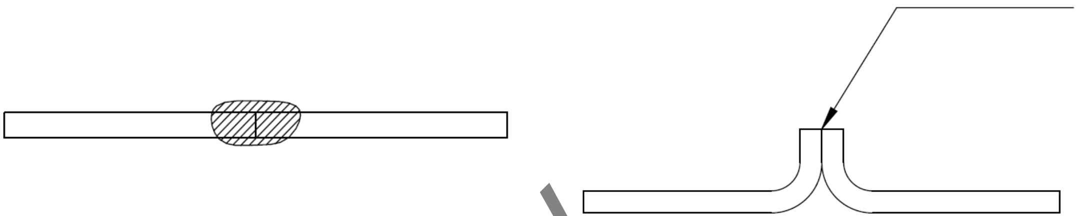


Sketch the weld symbol for each example:

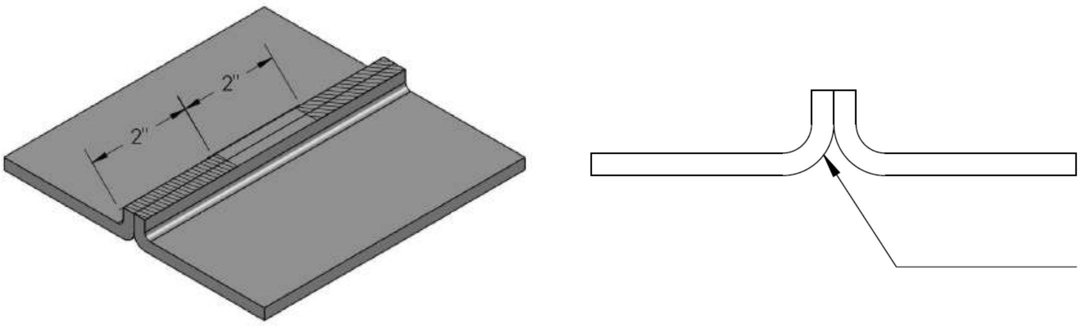
12. Example 1:




13. Example 2:

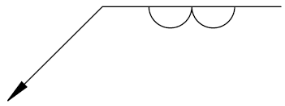


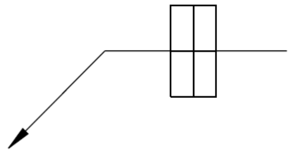
14. Example 3:

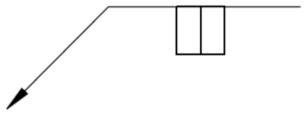


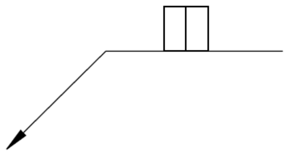
Matching:

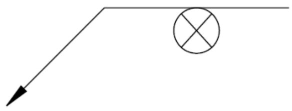
15. Edge weld on arrow side
16. Surfacing weld
17. Edge weld on other side
18. Stud weld
19. Edge weld on both sides

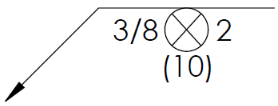




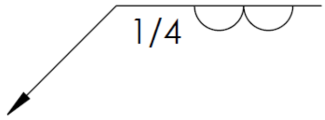




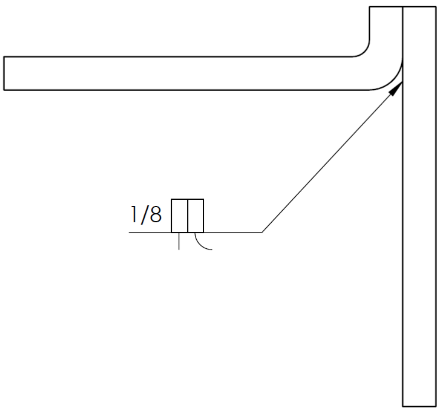





20. What type of weld is specified? ______________________
21. What is the diameter of each stud? ______________________
22. How many studs are required? ______________________
23. What is the pitch? ______________________

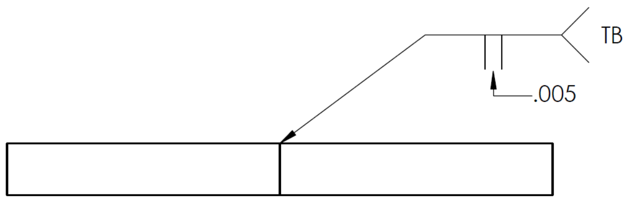



24. What type of weld is specified?
25. What is the thickness?

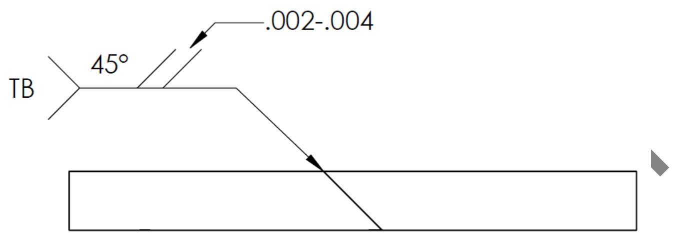



26. What type of weld is specified on the arrow side?
27. What type of weld is specified on the other side
28. What is the weld size on the arrow side?
29. What is the weld size on the other side?
30. What is the length of the edge weld?

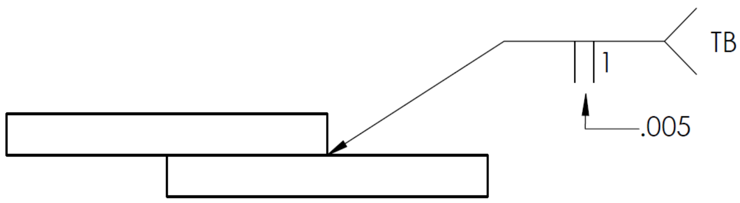
# CHAPTER 12–BRAZING SYMBOLS AND NONDESTRUCTIVE EXAMINATION SYMBOLS



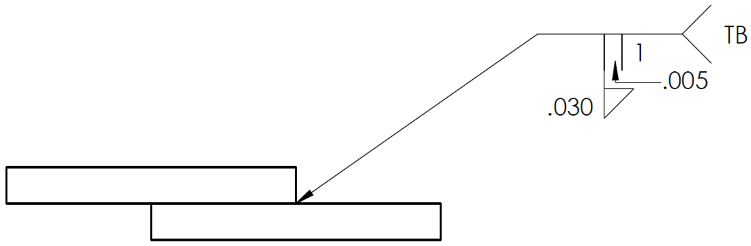

1. What type of braze joint is specified? ____________________
2. What is the location (side to braze from)? ____________________
3. What is the clearance? ____________________



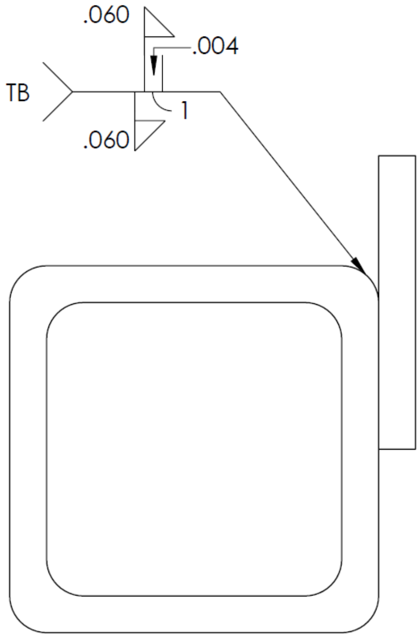

4. What type of braze joint is specified? ____________________
5. What is the location (side to braze from)? ____________________
6. What is the clearance? ____________________
7. What is the scarf angle? ____________________




8. What type of braze joint is specified? ____________________
9. What is the location (side to braze from)? ____________________
10. What is the clearance? ____________________
11. What is the length of overlap ____________________
12. What is the method of brazing ____________________



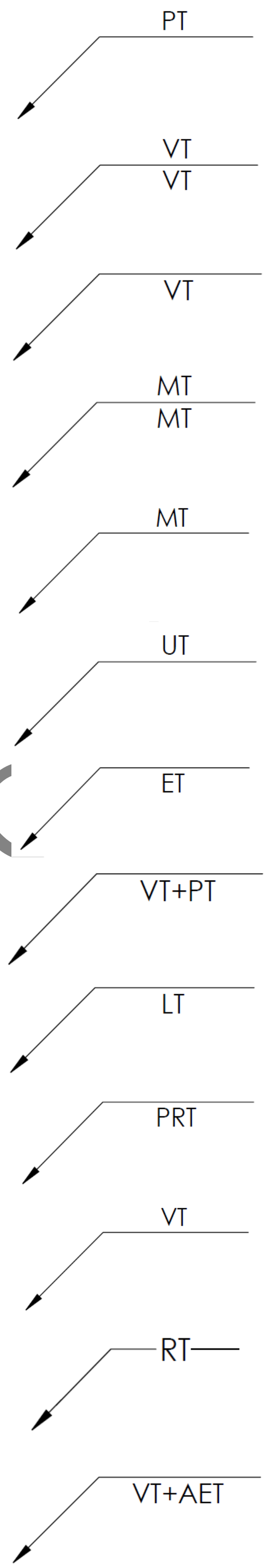

13. What type of braze joint is specified? ______________________
14. What is the location (side to braze from)? ______________________
15. What is the clearance? ______________________
16. What is the length of overlap? ______________________
17. What is the braze fillet size? ______________________




18. What type of braze joint is specified on the arrow side? ______________________
19. What is the clearance? ______________________
20. What is the length of overlap? ______________________
21. What type of braze joint is specified on the other side? ______________________
22. What is the braze fillet size? ______________________

Matching:

23. Visual test arrow side
24. Magnetic particle test other side
25. Eddy current test arrow side
26. Penetrant test other side
27. Visual and penetrant test arrow side
28. Visual test both sides
29. Magnetic particle test both sides
30. Ultrasonic test other side
31. Proof test arrow side
32. Radiographic test
33. Leak test arrow side
34. Visual and acoustic emission test arrow side
35. Visual test other side



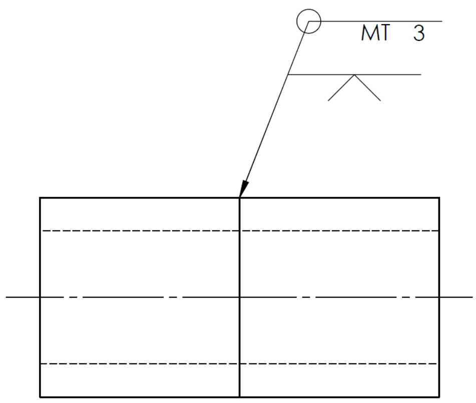
36. Draw the symbol for the following:
    •Radiograph
    •Visual test both sides

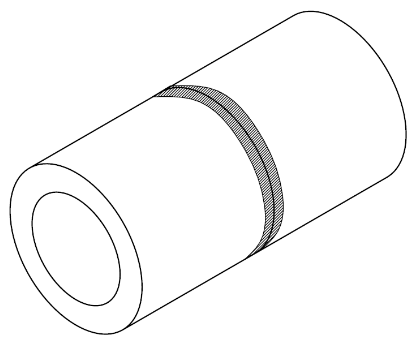
37. Draw the symbol for the following:
    •Penetrant test four 8” lengths of weld

38. Draw the symbol for the following:
    •Radiograph 50% of the joint in the field

39. Draw the symbol for the following:
    •1st operation: single U-groove on the other side, then backgouge
    •2nd operation: MT backgouge
    •3rd operation: single U-groove on the arrow side
    •4th operation: VT and MT both sides

40. On the welded pipe, shade and dimension the inspection area:

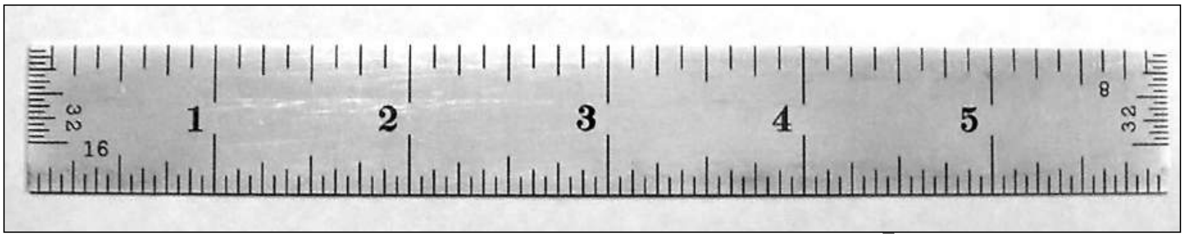


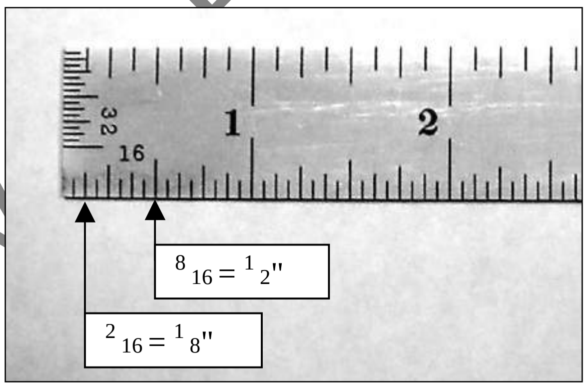
<u>MEASURING UNITS AND TOOLS WORKSHEET</u>

The three most common measuring systems used to dimension prints are fractional inches, decimal inches, and millimeters. Fractional inches and millimeters will be used most often by welders, while decimal inches are used mostly by machinists. Prints for large structures may be dimensioned in feet and inches or in meters. When building assemblies according to a print, it is important to have the proper measuring tools graduated in the same units used on the print. If a print is dimensioned in millimeters, it is far better to use measuring tools graduated in millimeters rather than try to convert all the units to inches. For those who insist on converting units, this is covered in the section on Converting Measuring Units.

## Fractional Inch Rule

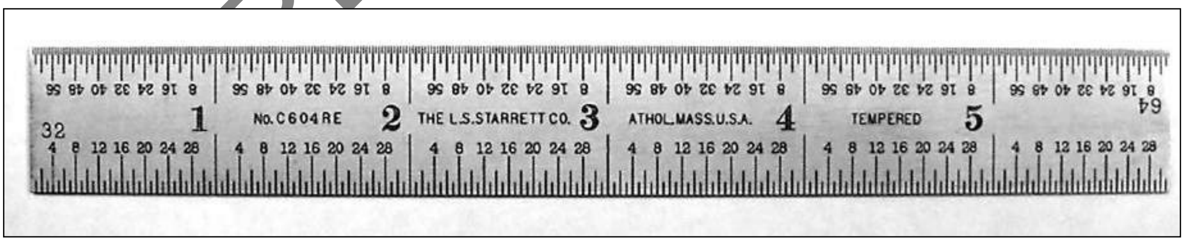



The fractional inch rule is graduated by $^{1}/_{8}$, $^{1}/_{16}$, $^{1}/_{32}$, or $^{1}/_{64}$ inch increments, depending on the rule style. The rule illustrated above is graduated by $^{1}/_{8}$ inch graduations on the upper scale, and $^{1}/_{16}$ inch graduations on the lower scale. Note the graduation is often, but not always, indicated by a small number near the start of the rule. Fractional measurements are always reduced to the lowest terms (that is, the numerator is always an odd number). For example, a measurement of $^{8}/_{16}$ would be read as $^{1}/_{2}$ inch (divide both the top and bottom numbers by 8), and a measurement of $^{2}/_{16}$ would be read as $^{1}/_{8}$ inch (divide both the top and bottom numbers by 2).





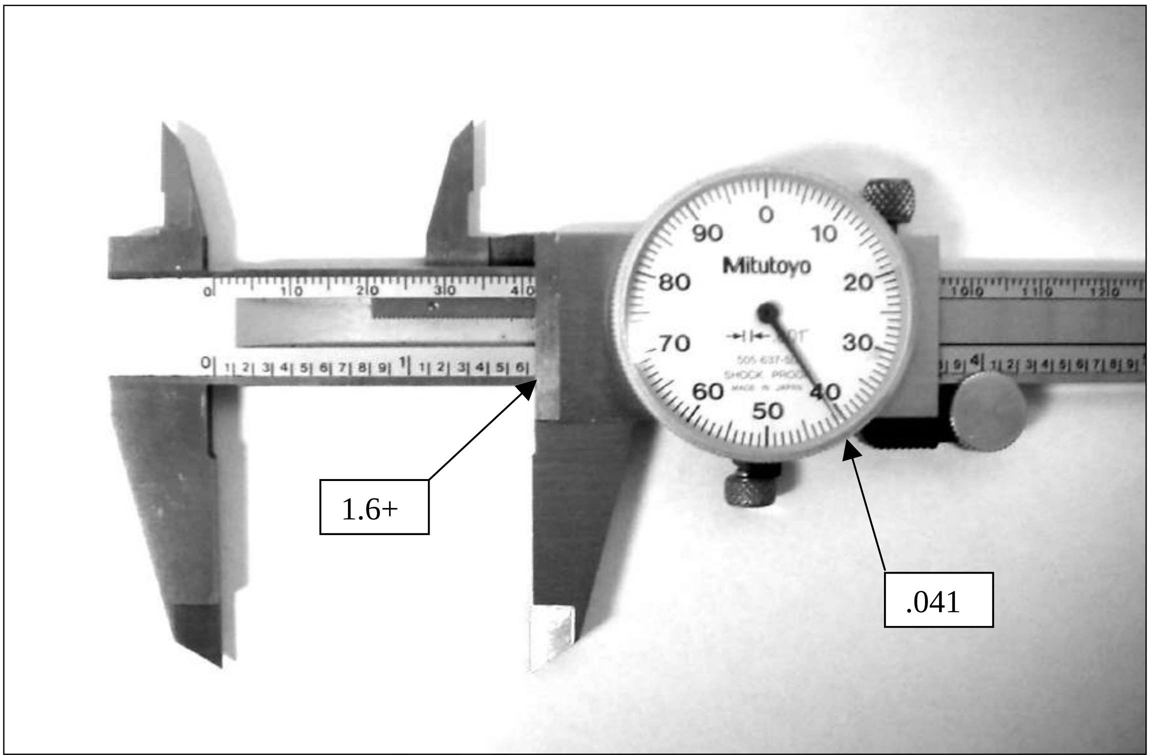

The other side of the rule shown above has graduations of $^{1}/_{32}$ and $^{1}/_{64}$ inch:




These graduations are too small to be of much use in welding; however, machinists use them occasionally. More often, when high precision measurements are needed, decimal inches will be used rather than fractions.

## Decimal Inch Caliper

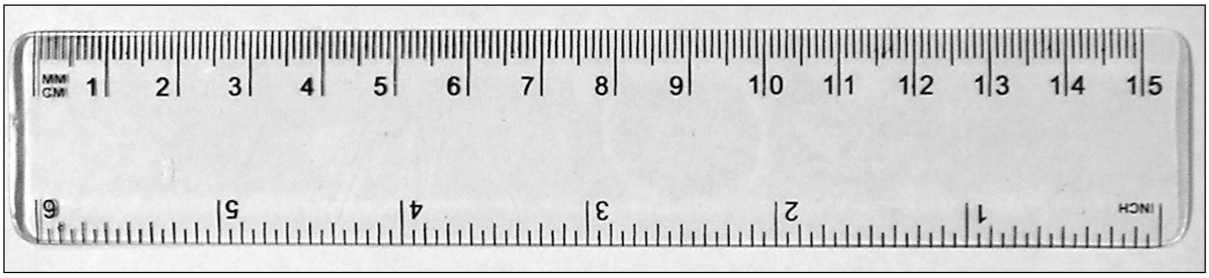
For high precision measurements such as those needed by machinists, decimal inches are the preferred unit of measure. Most often, measurements will be made to the nearest $^{1}/_{1000}$ inch, referred to as “thousandths” by machinists, and expressed as a decimal with three decimal places. Zeros are added to make 3 decimal places, even if they are not needed for the measurement. Thus, ½ inch would be expressed as .500″ as a decimal, and 2⅜ inches would be expressed as 2.375″ as a decimal. Notice there is no leading zero on the one-half inch dimension; leading zeros are only used on metric prints. Although rules are available with decimal inch graduations, most machinists use calipers and micrometers for measuring to the nearest thousandth of an inch.



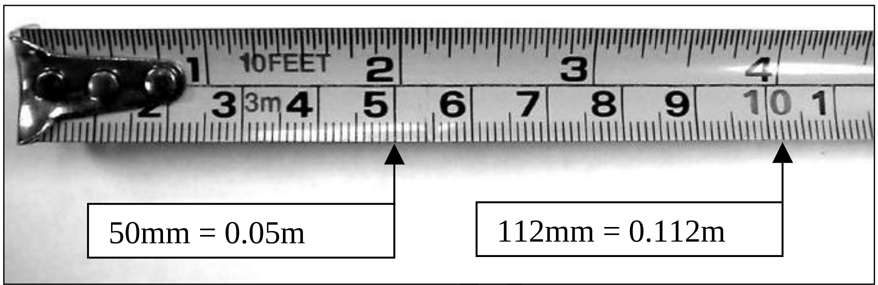

The dial caliper in the picture above has a millimeter scale on top (reading approximately 41.5mm) and a decimal inch scale on the bottom (reading 1.6+ inches). The dial shows 41 thousandths of an inch, for a total reading of 1.641 inches. Dial calipers with metric dials are available, and electronic digital calipers can be switched between inch and metric units.

Decimals may be converted to fractions, but with some loss of precision since the smallest fraction ever used is $^{1}/_{64}$ inch (which converts to .016″). Likewise, converting fractions to decimals is not precise either because many fractions must be rounded off to the desired number of decimal places. The section on Converting Measuring Units will show how to convert decimals to fractions and fractions to decimals.

## Metric Rule



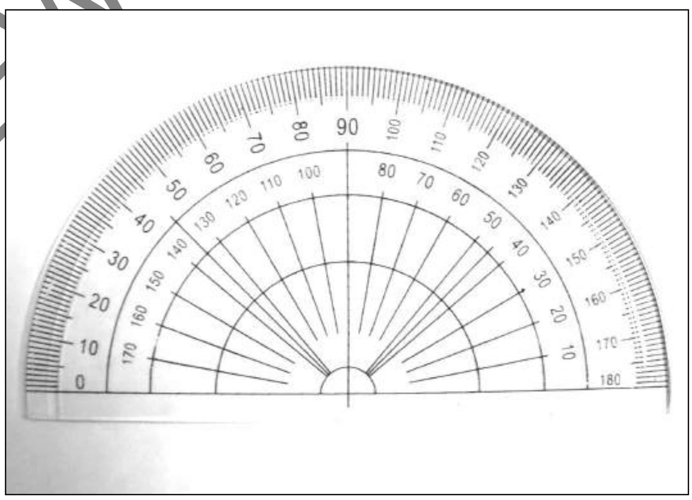
A metric rule is graduated in millimeters (thousandths of a meter) and occasionally half-millimeters. On most rules, every centimeter (hundredth of a meter or 10 millimeters) is numbered. On engineering drawings, dimensions are given in millimeters, with no decimal places unless needed.




For large structures such as buildings and bridges, units of meters with three decimal places may be used (for example, 112mm = 0.112m). Notice in the example that a leading zero is used on the 0.454m dimension to differentiate the dimension from inch units. Also, unlike decimal inch dimensions, extra zeros are not added to decimals—only the number of decimal places actually needed is used on the dimension.

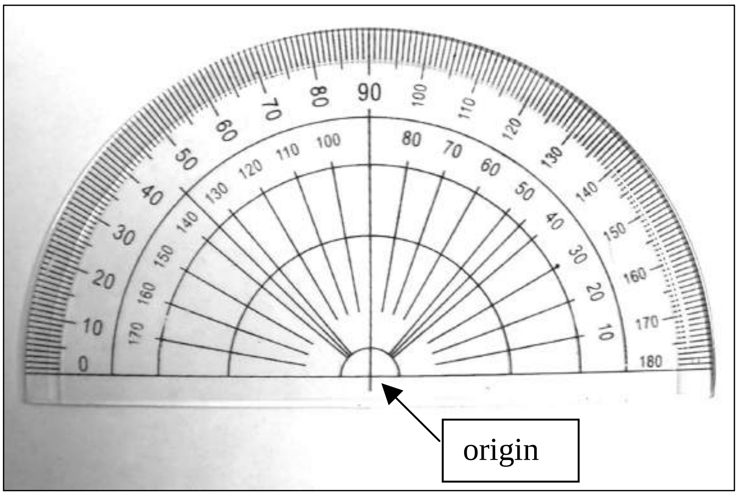


## Protractor

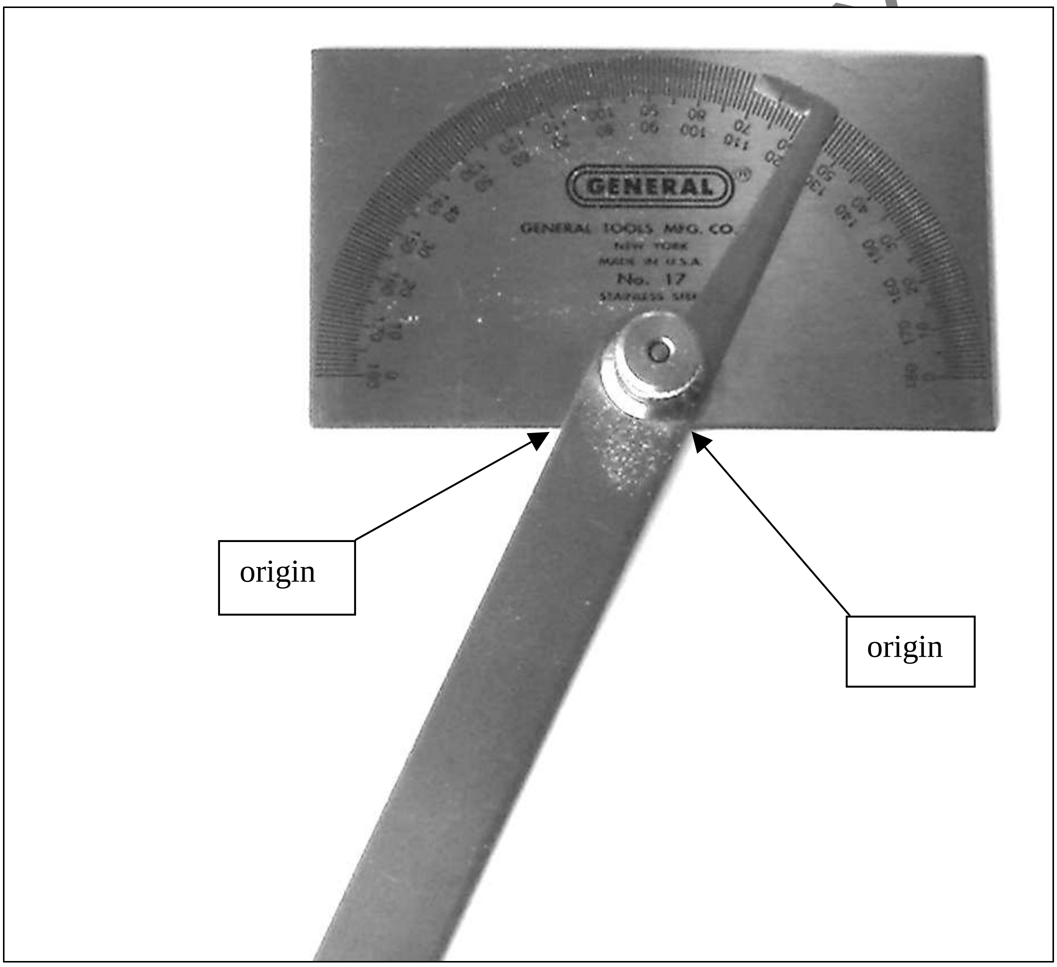


The protractor is used to measure angles. If angles are given on a print, regardless of whether the print is inch or metric, the angles will be dimensioned in degrees (°). Dimensions which are more precise than 1° are given in minutes (60'=1°) and seconds (60"=1'), or in decimal degrees; however, this is pretty uncommon. Protractors may have two scales of 0-180° like the one shown, or may have two scales 0-90°, or just one scale 0-180°. Metal protractors with moving measuring arms are good for welding work because they don't melt in the shop.

It is very important to line up the origin of the protractor properly with the angle being measured.  On drafting protractors, the origin is usually not at the very bottom edge, but printed a little up from the bottom.

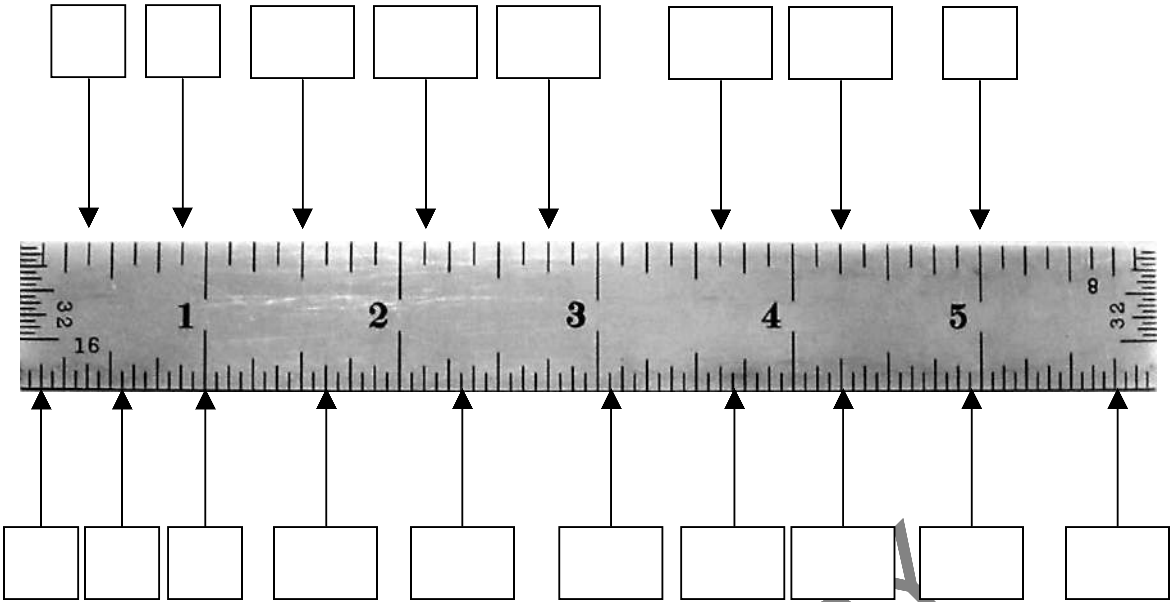



Metal shop protractors, on the other hand, usually have their origins at the bottom center, like the one shown below.

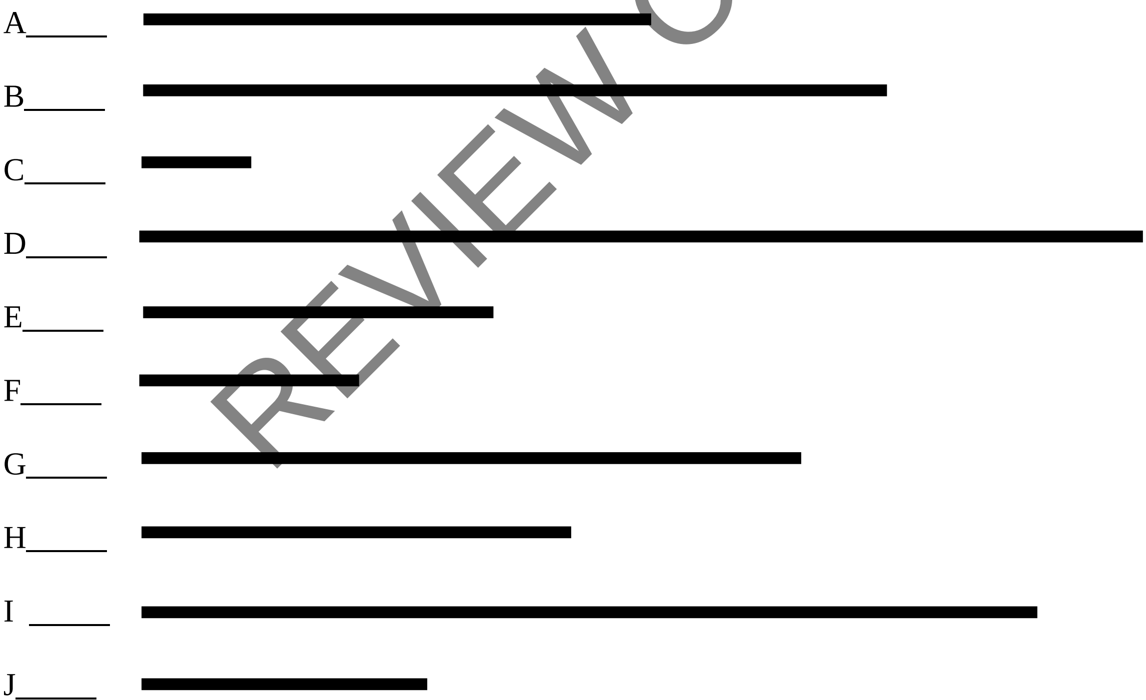


## Fractional Rule Exercises

Place the correct fractional reading for each measurement in the space provided. Reduce fractions to their lowest terms; for example: $\frac{10}{16} = \frac{5}{8}''$

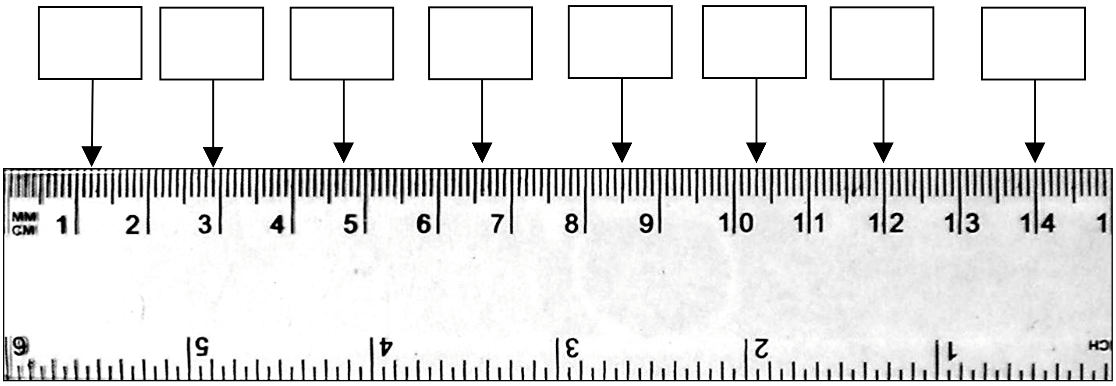



Using a fractional inch rule, measure the length of each of the following lines to the nearest $\frac{1}{16}$ inch and place your answer in the space provided.



## Metric Rule Exercises

Place the correct millimeter reading for each measurement in the space provided.




Using a metric rule, measure the length of each of the following lines to the nearest millimeter and place your answer in the space provided.

A_____

B_____

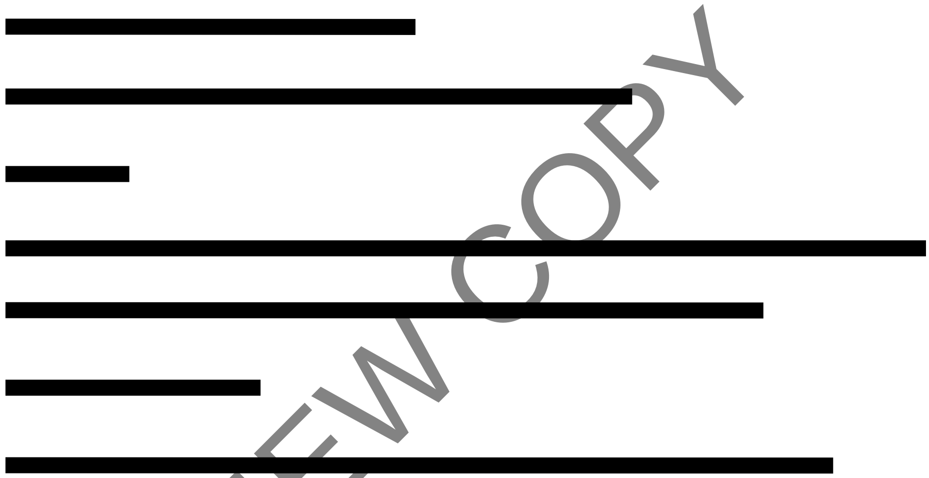
C_____

D_____

E_____

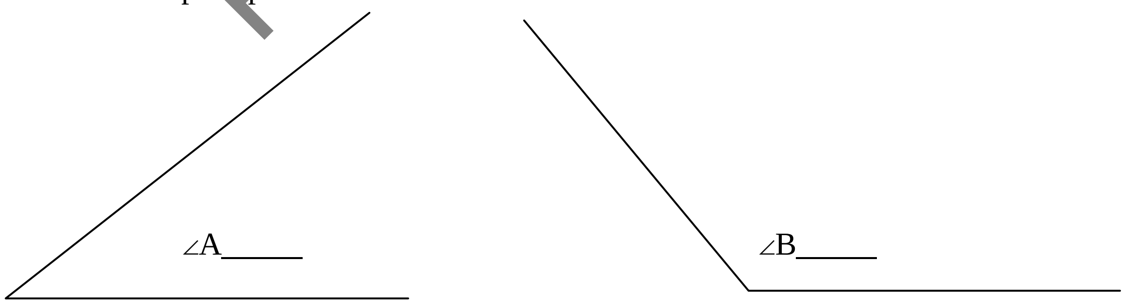
F_____

G_____



## Protractor Exercises

Using a protractor, measure each of the following angles to the nearest 1° and place your answer in the space provided.



∠A_____ ∠B_____

# CONVERTING MEASURING UNITS WORKSHEET

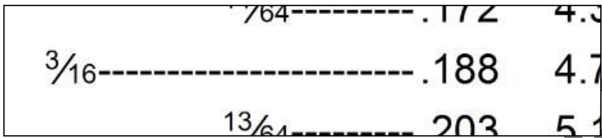
Units of fractional inches, decimal inches, and millimeters may be converted from one to another as the need arises, generally when the proper measuring tools are not available. For example, most steel tape measures are graduated in fractional inches rather than decimal inches. Units may be converted either mathematically or by using conversion tables. A conversion table is located at the end of this section on page 167.

## Converting Fractional Inches to Decimal Inches

Fractional inches may be converted to decimal inches by simply dividing the upper number (numerator) by the lower number (denominator), then rounding the answer to an appropriate number of decimal places (usually 3 or less). For example:

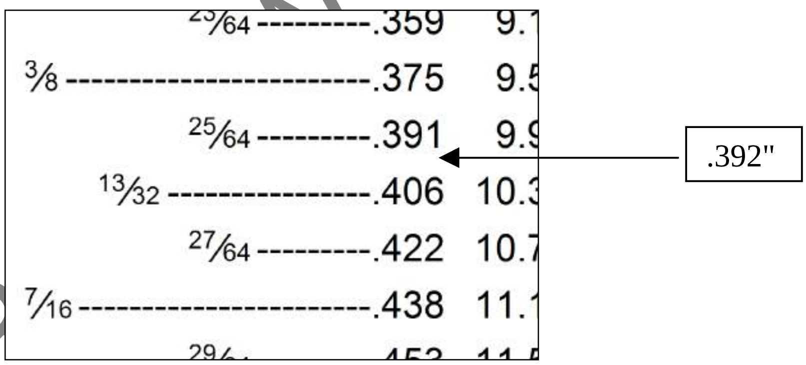
$$3/16 = 3 \div 16 = .1875 \quad \textit{which rounds to} \quad .188$$

Fractions may also be converted by using a conversion table such as the one at the end of this section. For example:




## Converting Decimal Inches to Fractions

The easiest way to convert decimal inches to fractions is to look up the nearest fraction on a conversion chart. For example, if the decimal to be converted is .392″ then we find where it would be on the chart and pick the closest fraction with the desired denominator:




- To convert to the nearest $\frac{1}{64}$ we select $\frac{25}{64}$ since .392 is closer to $\frac{25}{64}$ than to $\frac{13}{32}$
- To convert to the nearest $\frac{1}{32}$ we select $\frac{13}{32}$ since .392 is closer to $\frac{13}{32}$ than to $\frac{3}{8}$
- To convert to the nearest $\frac{1}{16}$ we select $\frac{3}{8}$ since .392 is closer to $\frac{3}{8}$ than to $\frac{7}{16}$
- To convert to the nearest $\frac{1}{8}$ we select $\frac{3}{8}$ since .392 is closer to $\frac{3}{8}$ than to $\frac{1}{2}$

Converting decimal inches to fractions mathematically can be done using the following method:

1. Choose the desired denominator, and multiply the decimal by that number.
2. Round the result to the nearest whole number.
3. Write out the fraction with the result as the numerator and the number you multiplied by as the denominator. Simplify the fraction by dividing top and bottom by 2 if needed.

For example:

To convert .392 to the nearest $^{1}/_{64}$: $.392 \times \frac{64}{64} = \frac{25.088}{64} = \frac{25}{64}$

To convert .392 to the nearest $^{1}/_{32}$: $.392 \times \frac{32}{32} = \frac{12.544}{32} = \frac{13}{32}$

To convert .392 to the nearest $^{1}/_{16}$: $.392 \times \frac{16}{16} = \frac{6.272}{16} = \frac{6}{16} = \frac{3}{8}$

To convert .392 to the nearest $^{1}/_{8}$: $.392 \times \frac{8}{8} = \frac{3.136}{8} = \frac{3}{8}$

## Converting Inches to Millimeters

To convert inches to millimeters, multiply inches by 25.4 and round off to the appropriate number of decimal places (usually one or less). For example:

$$4.375\,inches \times 25.4 = 111.125\,mm \;\; which\,rounds\,to\,111.1\,mm$$

Fractions may be converted to millimeters by looking at the conversion table, or by first converting the fraction to a decimal by dividing the numerator by the denominator.

## Converting Millimeters to Inches

To convert millimeters to inches, divide millimeters by 25.4 and round off to the appropriate number of decimal places (usually three or less). For example:

$$350\,mm \div 25.4 = 13.779527\,inches \;\; which\,rounds\,to\;13.780\,inches$$

## Unit Conversion Exercises

Complete the following table using any appropriate method.

| | Fractional Inches to Nearest $\frac{1}{32}$ | | Decimal Inches to 3 places | | Millimeters to 1 place |
|---|---|---|---|---|---|
| Sample | $\frac{3}{16}$ | = | .188 | = | 4.8 |
| 1. | $\frac{15}{32}$ | = | ______ | = | ______ |
| 2. | ______ | = | .438 | = | ______ |
| 3. | ______ | = | ______ | = | 18 |
| 4. | $1\frac{5}{8}$ | = | ______ | = | ______ |
| 5. | ______ | = | .200 | = | ______ |
| 6. | ______ | = | ______ | = | 100.5 |
| 7. | $7\frac{5}{16}$ | = | ______ | = | ______ |
| 8. | ______ | = | 9.250 | = | ______ |
| 9. | ______ | = | ______ | = | 25.4 |
| 10. | $2\frac{1}{8}$ | = | ______ | = | ______ |
| 11. | ______ | = | .910 | = | ______ |
| 12. | ______ | = | ______ | = | 57 |

# FRACTIONS TO DECIMALS & MILLIMETERS

| FRACTION | DECIMAL | MM |
|---|---|---|
| 1/64 | .016 | 0.40 |
| 1/32 | .031 | 0.79 |
| 3/64 | .047 | 1.19 |
| 1/16 | .062 | 1.59 |
| 5/64 | .078 | 1.98 |
| 3/32 | .094 | 2.38 |
| 7/64 | .109 | 2.78 |
| 1/8 | .125 | 3.18 |
| 9/64 | .141 | 3.57 |
| 5/32 | .156 | 3.97 |
| 11/64 | .172 | 4.37 |
| 3/16 | .188 | 4.76 |
| 13/64 | .203 | 5.16 |
| 7/32 | .219 | 5.56 |
| 15/64 | .234 | 5.95 |
| 1/4 | .250 | 6.35 |
| 17/64 | .266 | 6.75 |
| 9/32 | .281 | 7.14 |
| 19/64 | .297 | 7.54 |
| 5/16 | .312 | 7.93 |
| 21/64 | .328 | 8.33 |
| 11/32 | .344 | 8.73 |
| 23/64 | .359 | 9.13 |
| 3/8 | .375 | 9.53 |
| 25/64 | .391 | 9.92 |
| 13/32 | .406 | 10.32 |
| 27/64 | .422 | 10.72 |
| 7/16 | .438 | 11.11 |
| 29/64 | .453 | 11.51 |
| 15/32 | .469 | 11.91 |
| 31/64 | .484 | 12.30 |
| 1/2 | .500 | 12.70 |

| FRACTION | DECIMAL | MM |
|---|---|---|
| 33/64 | .516 | 13.10 |
| 17/32 | .531 | 13.19 |
| 35/64 | .547 | 13.89 |
| 9/16 | .562 | 14.29 |
| 37/64 | .578 | 14.68 |
| 19/32 | .594 | 15.08 |
| 39/64 | .609 | 15.48 |
| 5/8 | .625 | 15.88 |
| 41/64 | .641 | 16.27 |
| 21/32 | .656 | 16.67 |
| 43/64 | .672 | 17.07 |
| 11/16 | .688 | 17.46 |
| 45/64 | .703 | 17.86 |
| 23/32 | .719 | 18.26 |
| 47/64 | .734 | 18.65 |
| 3/4 | .750 | 19.05 |
| 49/64 | .766 | 19.45 |
| 25/32 | .781 | 19.84 |
| 51/64 | .797 | 20.24 |
| 13/16 | .812 | 20.64 |
| 53/64 | .828 | 21.03 |
| 27/32 | .844 | 21.43 |
| 55/64 | .859 | 21.83 |
| 7/8 | .875 | 22.23 |
| 57/64 | .891 | 22.62 |
| 29/32 | .906 | 23.02 |
| 59/64 | .922 | 23.42 |
| 15/16 | .938 | 23.81 |
| 61/64 | .953 | 24.21 |
| 31/32 | .969 | 24.61 |
| 63/64 | .984 | 25.00 |
| 1 | 1.000 | 25.40 |

## PROJECT 1—INTERMITTENT FILLET WELDS

### Introduction:

In welded construction, fillet welds are the most popular method of joining lap and tee joints. Sometimes the welds are continuous for the full length of the joint (as indicated by the lack of length, pitch, or increment numbers), but often in structural welding the welds are intermittent; that is, short increments (or lengths) of weld are placed at a specified pitch (center-to-center distance). If the specified weld is a double weld, then the increments of weld may be chained or staggered as indicated by the weld symbol.

### Construction:

- Refer to the Project 1 prints.
- Cut 4 pieces of $^{3}/_{16}$″ foam to a size of 3″ x 6″ each.
- Tack the pieces into tee joints.
- Lay out the chain and staggered intermittent fillet welds using a pen or marker.
- When the layout is complete, make the welds using the glue gun.

### Assembly Notes:

When laying out intermittent fillet welds, always mark off the pitch by measuring from the start of the joint, rather than measuring from weld to weld. If you lay out the welds by chaining from one weld to the next, a little error on each increment and pitch can add up over a long distance. Also, remember that pitch, although described as the center-to-center distance between welds, is the same as the start-to-start distance from increment to increment. As a double check for the layout, check the distance between increments — it’s the pitch minus the increment.

### Worksheet Questions:

1. On the Chain Intermittent Fillet Weld model, how many weld increments will be needed on each side for the 6″ weld length? ________________

2. On the Staggered Intermittent Fillet Weld model, how many weld increments will be needed on the Arrow Side? On the Other Side? ________________

3. What is the scale of the drawings? ________________

4. What is the tolerance on the $^{3}$ $_{16}$″ dimension? ________________

5. Sketch a weld symbol for the following joint:
   • Arrow side: ¼″ continuous fillet weld.
   • Other side: ¼″ intermittent fillet weld with 2-inch increments and 3 inches from the end of one increment to the beginning of the next increment.

## PROJECT 2—STEP FIXTURE BLOCK

### Introduction:
The step fixture block illustrates the basics of orthographic projection, using front view, top view, and right-hand side view. All of the common line types are illustrated, including object lines, hidden lines, center lines, extension lines, and dimension lines. Dimensions are given in fractional inches. The small pictorial view in the upper right of the print is to help you visualize the object—it would not normally be placed on a print.

### Construction:
- Refer to the Project 2 print.
- Layout and cut the project from ⅝″ foam board.

### Assembly Notes:
It is best to start out with a rectangular blank 3″ x 4″ then lay out and saw the notch. Since you have a holesaw to make the hole, only the center of the hole needs to be located before cutting the hole.

### Worksheet Questions:
1. On the drawing, sketch the left-hand side view in the location indicated. What is different on the left-hand side view compared to the right-hand side view? ____________________

2. Could this part have been adequately shown in only two views? Explain. ____________________

3. Could this part have been adequately shown in only one view? Explain. ____________________

4. What are the dimensions of the "notch" in decimal inch units? ____________________

1. Assume a 10-foot long aluminum extrusion is produced having a cross section as shown in the front view. If a saw cut is ⅛-inch wide, how many parts could be cut from the 10-foot bar? ____________________

# PROJECT 3—KEYED ANGLE MOUNT

## Introduction:

The keyed angle mount illustrates the use of an auxiliary view to show details not otherwise seen at “true size” or “true shape” in the front, top, or side view. The auxiliary view is set up to look perpendicular to the sloped surface of the part, and it is common to leave hidden lines off the view if they do not help with visualizing the part. Sometimes, the auxiliary view will only be a partial view, showing only the sloping surface. The “weld all around” sign on the fillet weld symbol is optional since the weld is being made on a round tube. The small pictorial view in the lower left of the print is to help you visualize the object—it would not normally be placed on a print.

## Construction:

- Refer to the Project 3 print.
- Layout and construct the part as shown in the print. Dimensions are given in millimeters.

## Assembly Notes:

Before starting, glue together three pieces of 80mm x 100mm x 16mm foam to make the block needed. Start with a rectangular block, and use your saw to cut the details.

The 25mm piece of pipe for this model was cut from ¾″ Schedule 40 PVC pipe. The ¾″ dimension refers to the nominal inside diameter which is roughly ¾″ while the “Schedule 40” indicates the strength of the pipe. In actual use, for any given pipe size the outside diameter is maintained constant so the pipe fittings will fit, and the wall thickness is varied by the Schedule designation to obtain the required strength. Thus the inside dimension may vary up or down from the nominal dimension depending on the pipe material and required strength.



## Worksheet Questions:

1. What is the width of the bottom key-way in millimeters? ____________________
2. What are the dimensions of the inclined surface shown in the auxiliary view? ____________________
3. According to the print, what is the wall thickness of the tube? ____________________
4. What is the width of the narrow keyway? ____________________
5. In the auxiliary view, what is the distance from the edge of the part to the outer edge of the tube? ____________________

# PROJECT 4—BOX SECTION

## Introduction:

The box section illustrates the use of sectioning to show internal details. In this part, a section view is used in place of the front view to show the inside cavity. Also, a corner of the top view has been broken out to show the wall thickness. Dimensions are given in millimeters. The small pictorial view in the upper right of the print is to help you visualize the object—it would not normally be placed on a print.

## Construction:

- Refer to the Project 4 print.
- Layout and construct the part from three pieces of 16mm foam board.

## Assembly Notes:

Cut each layer according to the print and then glue them together to complete the model. Note that this project was designed solely for illustrating section views, and a real part built in this manner would be actually be represented using assembly and detail drawings, to be introduced later in the course.

## Worksheet Questions:

1. Cut away the upper corner of the model to reveal the internal detail shown by the broken out section in the top view. Draw section lines on the cut surface of the model to match the print. (no answer required) __________

2. Saw the model along the line designated Section A-A in the top view. Draw section lines on the cut surface of the model to match the print. (no answer required) __________

3. What are the internal dimensions of the square part of the cavity? __________

4. How deep is the 10mm x 16mm hole? __________

5. According to the top view, what is the minimum distance from the side of the part to the edge of the ø25mm hole? __________

## EXAMPLE 1—STORAGE TANK PLATFORM

### Introduction:

The storage tank platform example illustrates structural welding drawings such as those using for buildings, bridges, and large fabrications. There are six sheets in this example, including an assembly view, a weldment cut list, a detailed part drawing, and three detail assembly drawings. The dimensions are given in feet and inches, with fractional inches as needed. Standard structural shapes (channels, tube, beams, etc.) are described by their depth and weight in pounds per foot of length. Detail drawings are provided only for parts which cannot be described adequately in the weldment cut list. The application for this platform is to support a 5,000 gallon storage tank.

### Worksheet Questions:

1. What are the overall dimensions of the storage tank platform assembly (L x W x H)? __________

2. Complete the “QTY” column of the weldment cut list (Sheet 2). (answer on Sheet 2 and/or on next page) __________

3. How much does each leg (part 1) weigh? __________

4. What is the total length and weight of structural channel used (parts 4 and 5)? __________

5. In addition to the channel, tube, and bar, what thickness of steel plate will be needed? __________

1\. What is the total length of ø1″ steel bar that will be needed (parts 10 and 11)? __________

7\. Holes are provided in the base plates for hold-down bolts. What diameter bolts should be used? __________

8\. When was the gusset plate size revised? __________

9\. How many double flare-bevel groove welds will be required to build the platform? __________

10\. What type of weld is used to attach the gusset plates to the legs? __________

Graphic for Question 2:

| ITEM | QTY | DESCRIPTION | SIZE/LENGTH |
|---|---|---|---|
| 1 | | 4"X21.63 SQ TUBE ASTM A500, GR B | 6'-0" |
| 2 | | 4"X21.63 SQ TUBE ASTM A500, GR B | 5'-8" |
| 3 | | 4"X21.63 SQ TUBE ASTM A500, GR B | 3'-8" |
| 4 | | 6"X16.3 CHANNEL ASTM A36 | 5'-8" |
| 5 | | 6"X16.3 CHANNEL ASTM A36 | 3'-8" |
| 6 | | BASE PLATE ASTM A36 | 1/2" X 5" X 8" LG |
| 7 | | LEG CAP ASTM A36 | 1/4" X 3-1/2" X 3-1/2" |
| 8 | | GUSSET PLATE ASTM A36 | 1/2" X 6" X 6" |
| 9 | | TOP PLATE ASTM A36 | 3/4" X 8" X 2'-4" LG |
| 10 | | 1" DIA BAR ASTM A36 | 6'-8-5/8" |
| 11 | | 1" DIA BAR ASTM A36 | 5'-3" |

# EXAMPLE 2—STOCK PUSHER GUIDE

## Introduction:

The stock pusher guide example illustrates a precision assembly which uses both welding and mechanical fasteners. There are five sheets in this example, including an assembly view, a bill of materials (BOM), and three detailed part drawings. The dimensions are given in decimal inches for machining and fractional inches for weld details and fastener sizes. On the BOM, the tube is identified by its outside dimension and wall thickness, the channel by its depth and weight in pounds per foot of length, and the threaded fasteners by their nominal diameter, thread series (UNC), pitch (number of threads per inch), and length. Detail drawings are provided for parts which cannot be described adequately on the BOM. In the assembly, socket head cap screws are used to strengthen the assembly of parts 2 and 5 since a fillet weld is not allowed on the inside corner. The fasteners are installed prior to welding the $^{3}/_{16}$″ fillet welds.

## Worksheet Questions:

1. Why must part 1 and 2 be welded together before any other assembly is done? ____________
2. What is the purpose of the designation “CS” in the side view of sheet 1? ____________
3. On sheet 1, instead of a top view, what is the third view? ____________
4. On sheet 1, what is the tolerance of the 1″ dimension? ____________
5. In the BOM, what is the size of the screws holding parts 2 and 4 together? ____________
6. What is the inside dimension of the square tube? ____________
7. On part 2, what is the distance between the hole centers? ____________
8. On part 4, what is the purpose of the counterbores? ____________
9. On sheet 4 in the front view, what is the distance from the center of the hole to the right edge of the part? ____________
10. On sheet 5, what is the tolerance on the 1.500 dimension? ____________

# PROJECT 5—POST BASE ASSEMBLY

## Introduction:

This assembly drawing illustrates the use of revolution when features are arranged radially about a center axis. The top view shows the actual number and orientation of the ribs and holes, while the front view revolves one rib and one hole so that they appear true size, although not necessarily in their correct position. For this assembly, detail drawings have not been prepared—all fabrication information may be obtained from the assembly drawing. If detail drawings were used, then the assembly drawing would not give the part dimension, it would only give dimension needed for assembly. Dimensions are given in decimal inches.

## Construction:

- Refer to the Project 5 print.
- Layout and construct the assembly from foam board and PVC pipe.

## Assembly Notes:

Tack-weld the assembly prior to final welding. If the tube were welded to the base prior to fitting the ribs, the weld would be in the way of the ribs.

## Worksheet Questions:

1. On the bill of materials (BOM), fill in the quantity and size for each part, and convert the sizes to metric. (answer on the BOM and/or on next page) ____________________
2. What type of view is used for the front view? ____________________
3. What is the distance from the top edge of the rib to the top of the tube? ____________________
4. What is the overall height of the assembly? ____________________
5. According to the top view, what is the distance from the right edge of the base to the edge of the right rib? ____________________

Graphic for Question 1:

| PART | QTY | DESCRIPTION | SIZE (INCHES) | SIZE (MILLIMETERS) |
|---|---|---|---|---|
| 1 | | BASE | | |
| 2 | | TUBE | | |
| 3 | | RIB | | |

# PROJECT 6—PULLEY MOUNT BRACKET ASSEMBLY

## Introduction:
This assembly drawing includes detail drawings. Dimensions are given in meters.

## Construction:
- Refer to the Project 6 print.
- Layout and construct the assembly from foam board and PVC pipe.

## Assembly Notes:
Tack-weld the assembly prior to final welding. Observe the orientation of the single bevel groove welds—since the weldment is symmetrical, the weld faces will be to the outsides of the assembly.

## Worksheet Questions:

1. On the BOM, fill in the quantity and size for each part (in millimeters), and convert the sizes to inches to the nearest ⅛ inch. (answer on BOM and/or on next page) ____________
2. In the front view, what is the distance from the bottom of part 1 to the centerline of part 3? ____________
3. In the front and top views, what is the space between the bearings? ____________
4. What is the overall height of the assembly? ____________
5. What is the tolerance on the hole in the web? ____________

Graphic for Question 1:

| PART | QTY | DESCRIPTION | SIZE (MILLIMETERS) | SIZE (INCHES) |
|---|---|---|---|---|
| 1 | | BASE | | |
| 2 | | SUPPORT | | |
| 3 | | TUBE | | |
| 4 | | WEB | | |

# PROJECT 7—WATERTIGHT-DOOR HINGE ASSEMBLY

## Introduction:
This assembly drawing includes detail drawings. Dimensions are given in millimeters.

## Construction:
- Refer to the Project 7 print.
- Layout and construct the assembly from foam board and PVC pipe.

## Assembly Notes:
Study the assembly print and determine a sequence for welding that will allow all welds to be completed, then tack-weld the assembly prior to final welding. A pair of 20mm thick “parallel bars” cut from the left-over ⅝″ foam board could be useful during assembly to support the model.

## Worksheet Questions:

1. On the BOM, fill in the quantity and size for each part (in millimeters), and convert the sizes to inches to the nearest ⅛ inch. (answer on BOM or and/or on next page) ____________________
2. In the top view, what is the vertical distance from the top of part 1 to the centerline of part 2? ____________________
3. What is the center-to-center distance between parts 5? ____________________
4. What type of weld joins parts 3 and 5? ____________________
5. What is the tolerance on the angles on part 3? ____________________

Graphic for Question 1:

| ITEM NO. | QTY | DESCRIPTION | SIZE (MILLIMETERS) | SIZE (INCHES) |
|---|---|---|---|---|
| 1 | | BACK PLATE | | |
| 2 | | HINGE TUBE | | |
| 3 | | WEB | | |
| 4 | | RIB | | |
| 5 | | SOCKET RECEIVER | | |

# PROJECTS 8, 9, and 10—TEST WELDMENTS

## Introduction:

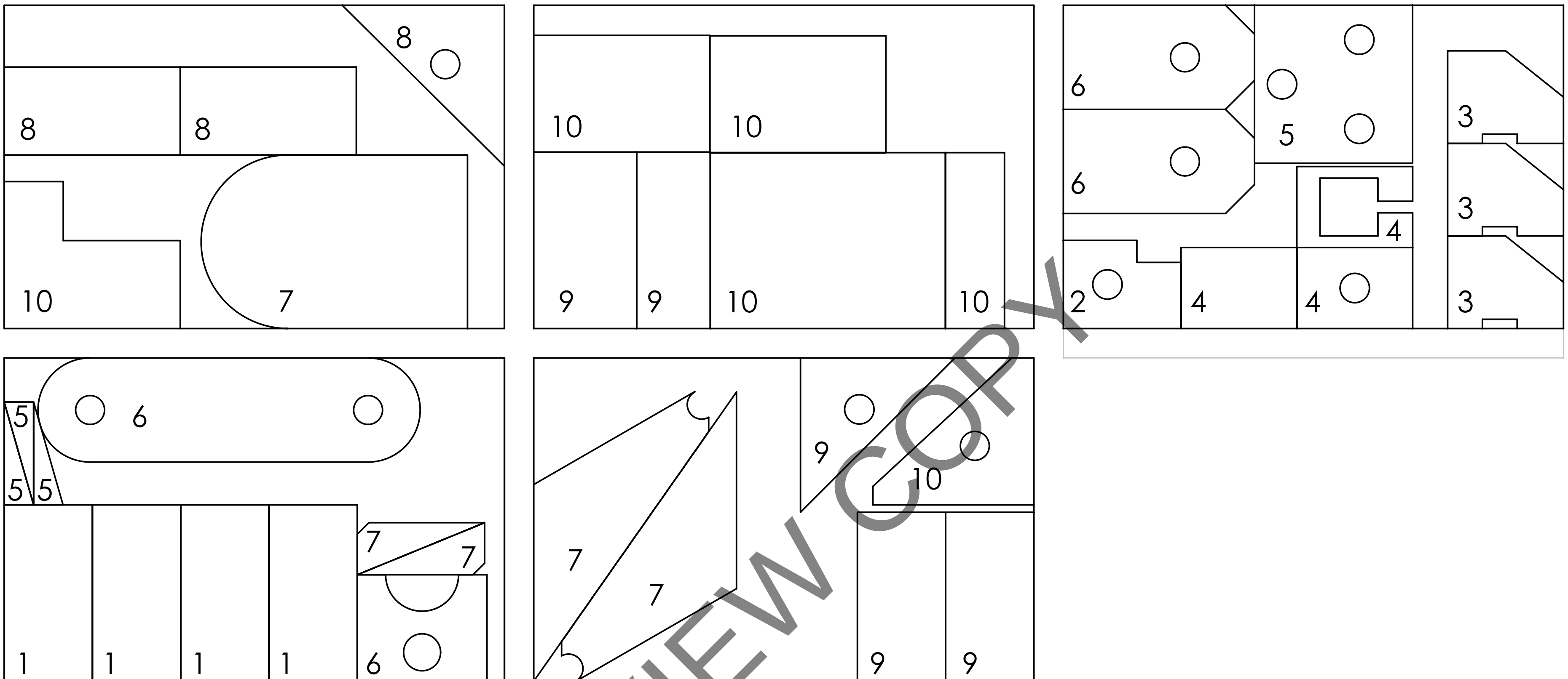
These assemblies are examples of the test weldments used for the AWS Certified Entry-Level Welder program. The configurations of the weldments provide for a variety of welding positions and weld types. Dimensions are in fractional inches for Test Weldment 1 and Test Weldment 3, and in millimeters for Test Weldment 2M.

## Construction:

- Refer to the Project 8, 9 and 10 prints.
- Layout and construct the assemblies from $^{3}/_{16}$″ (5mm) foam board.

## Assembly Notes:

Before beginning assembly or cutting parts, complete the BOM for each weldment. The dimensioning used on the prints is not standard; the assemblies have been dimensioned in a manner which requires careful interpretation and math calculations to properly cut and fit the parts.






**Technology Education Resources, LLC**

TITLE:

# CUTTING SKETCH

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±1/16
ANGULAR: MACH ±1 BEND ±1
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.005

INTERPRET GEOMETRIC
TOLERANCING PER: ANSI Y14.5-09

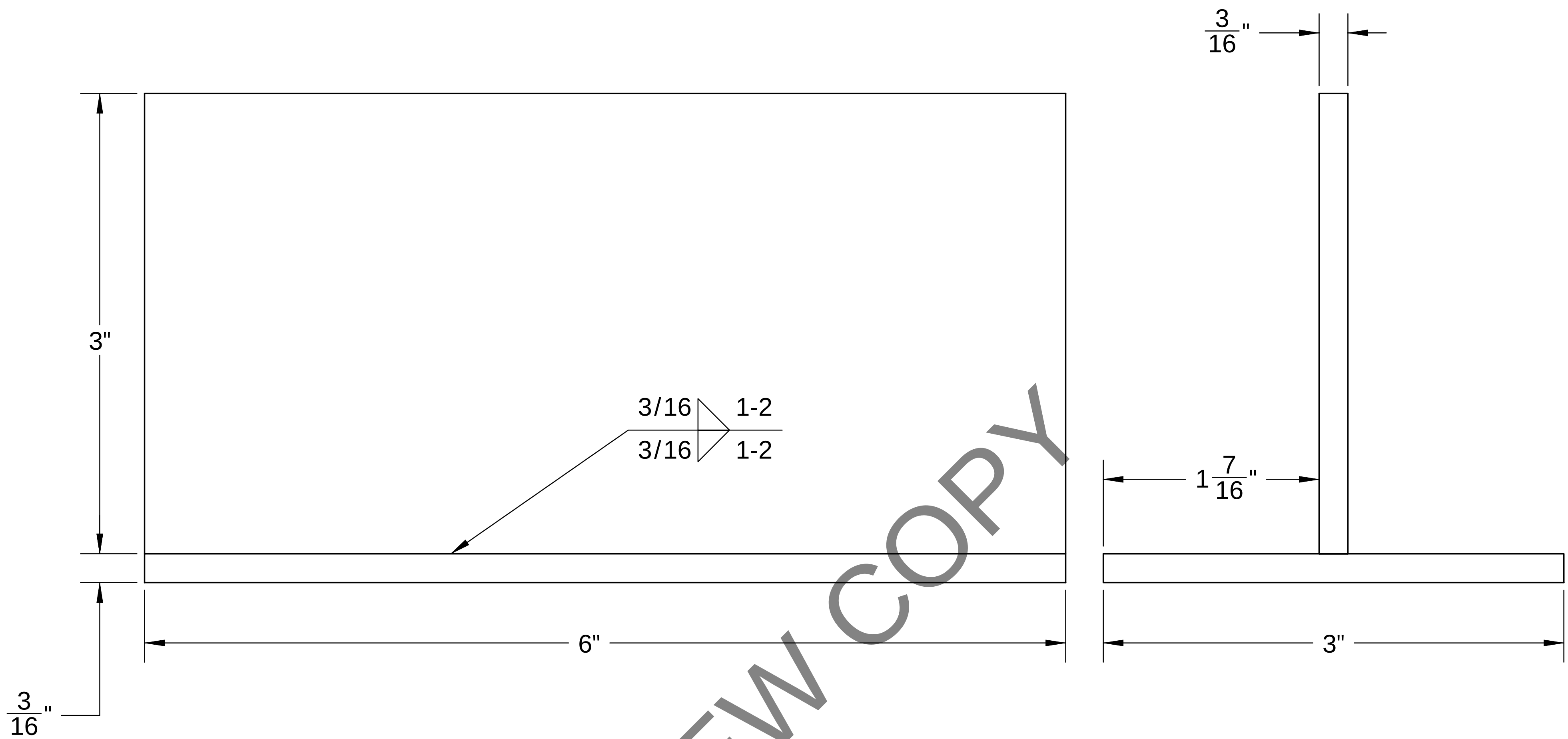
DO NOT SCALE DRAWING

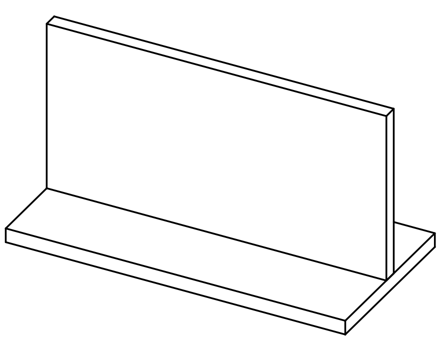


| SIZE | DWG. NO. | REV |
|---|---|---|
| A | Foam Panel | |

| SCALE: None | WEIGHT: | SHEET 1 OF 1 |
|---|---|---|

5 4 3 2 1





**Technology Education Resources, LLC**

TITLE:

# CHAIN INTERMITTENT FILLET WELD

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±1/16
ANGULAR: MACH ±1 BEND ±1
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.005

INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14.5-09

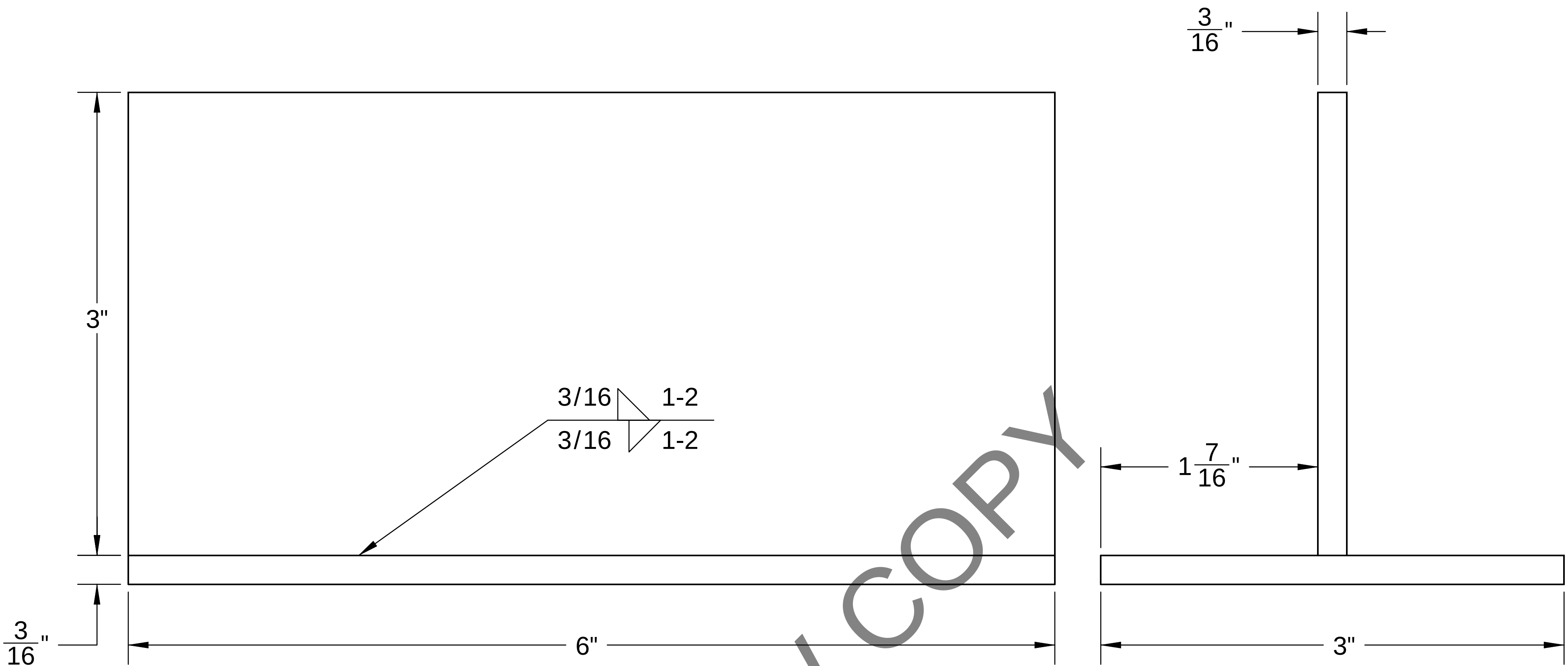
DO NOT SCALE DRAWING

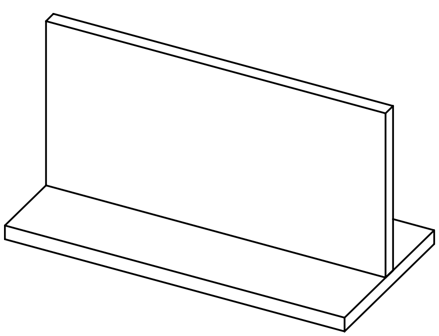


| SIZE | DWG. NO. | REV |
|---|---|---|
| A | Project 1 | 0 |

| SCALE: 1:1 | WEIGHT: | SHEET 1 OF 2 |
|---|---|---|

5 4 3 2 1





**Technology Education Resources, LLC**

TITLE:

STAGGERED INTERMITTENT FILLET WELD

| SIZE | DWG. NO. | REV |
|---|---|---|
| A | Project 1 | 0 |

| SCALE: 1:1 | WEIGHT: | SHEET 2 OF 2 |
|---|---|---|

UNLESS OTHERWISE SPECIFIED:

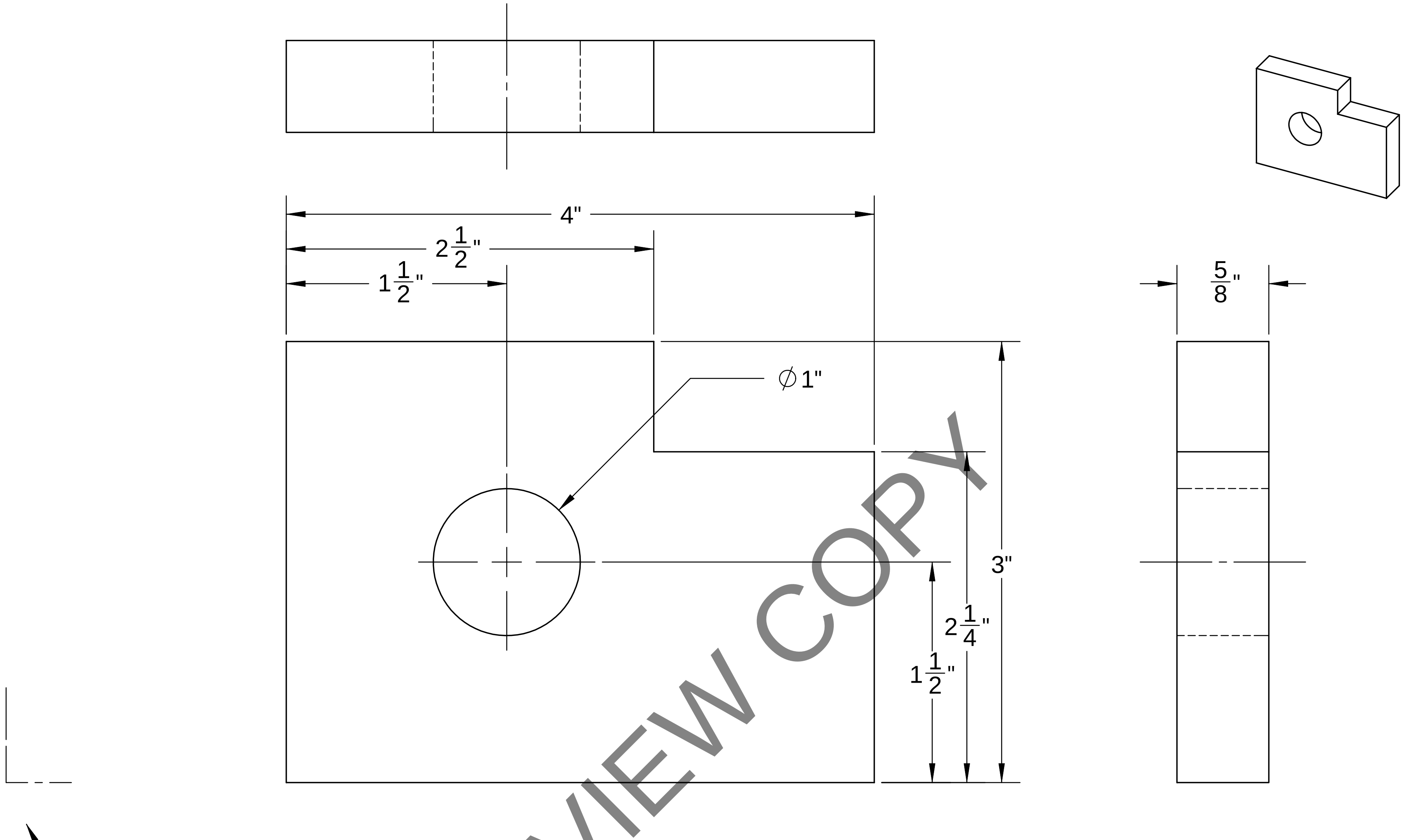
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±1/16
ANGULAR: MACH ±1 BEND ±1
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.005

INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14.5-09

DO NOT SCALE DRAWING



5 4 3 2 1




Sketch left side view here (worksheet question 1).



**Technology Education Resources, LLC**

TITLE: STEP FIXTURE BLOCK

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±1/16
ANGULAR: MACH ±1 BEND ±1
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.005

INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14.5-09

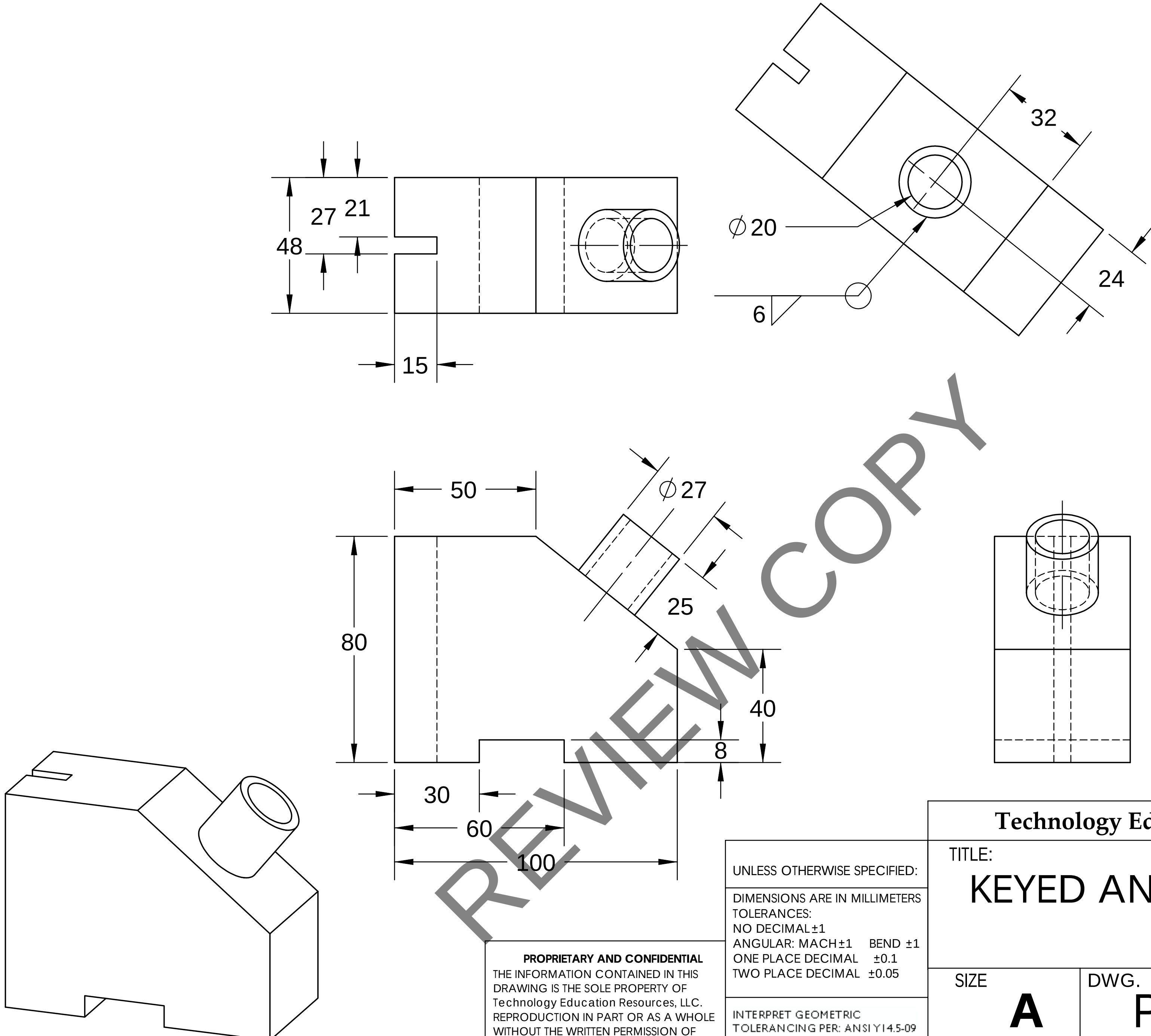
DO NOT SCALE DRAWING



| SIZE | DWG. NO. | REV |
|---|---|---|
| A | Project 2 | |

| SCALE: 1:1 | WEIGHT: | SHEET 1 OF 1 |
|---|---|---|
| | | |

5 4 3 2 1






**Technology Education Resources, LLC**

TITLE:

KEYED ANGLE MOUNT

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN MILLIMETERS
TOLERANCES:
NO DECIMAL ±1
ANGULAR: MACH ±1 BEND ±1
ONE PLACE DECIMAL ±0.1
TWO PLACE DECIMAL ±0.05

INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14.5-09

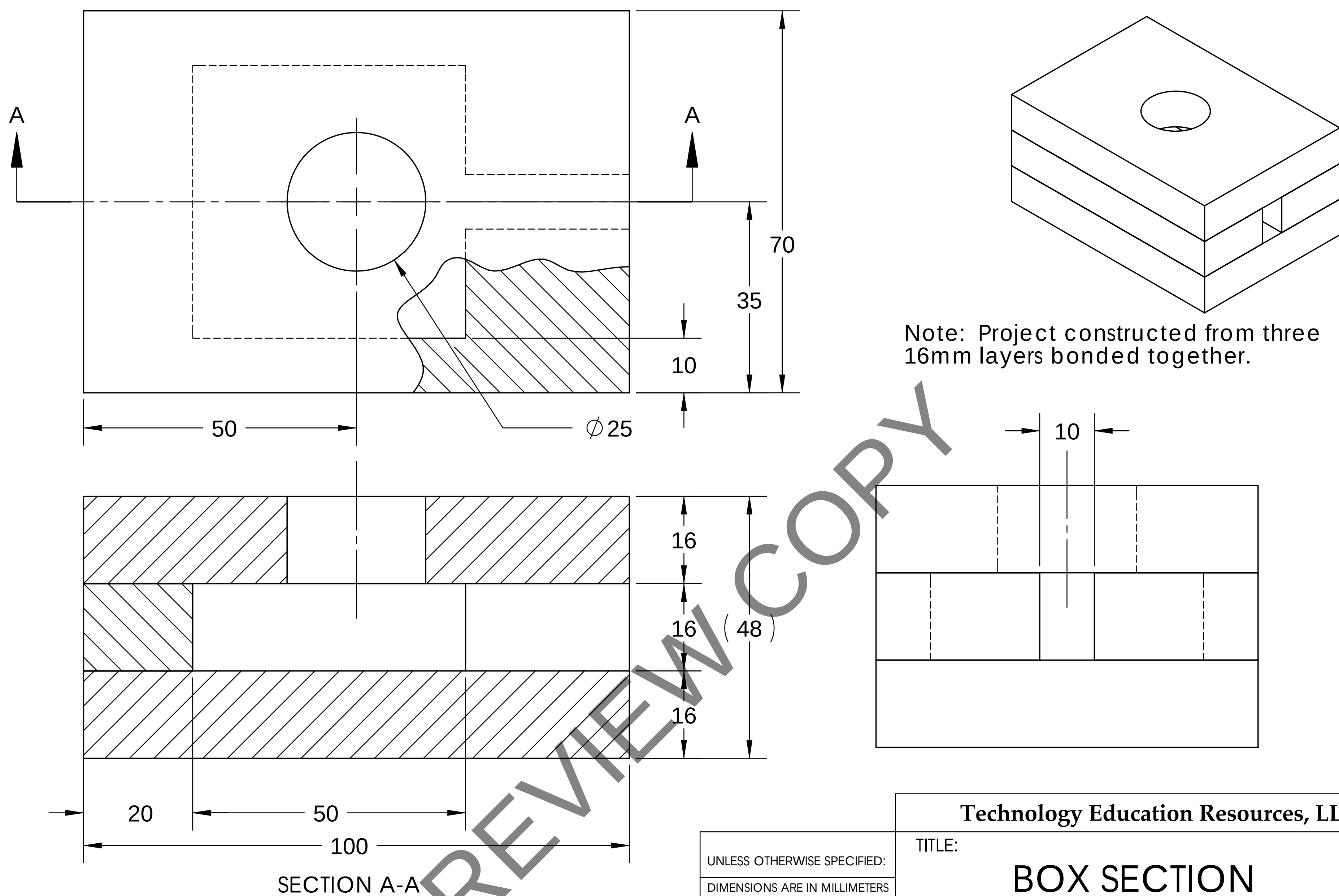
DO NOT SCALE DRAWING



| SIZE | DWG. NO. | REV |
|---|---|---|
| A | Project 3 | |

| SCALE: 1:2 | WEIGHT: | SHEET 1 OF 1 |
|---|---|---|

5 4 3 2 1




**Technology Education Resources, LLC**



UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN MILLIMETERS
TOLERANCES:
NO DECIMAL ±1
ANGULAR: MACH ±1 BEND ±1
TWO PLACE DECIMAL ±0.1
THREE PLACE DECIMAL ±0.01

INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14.5-09

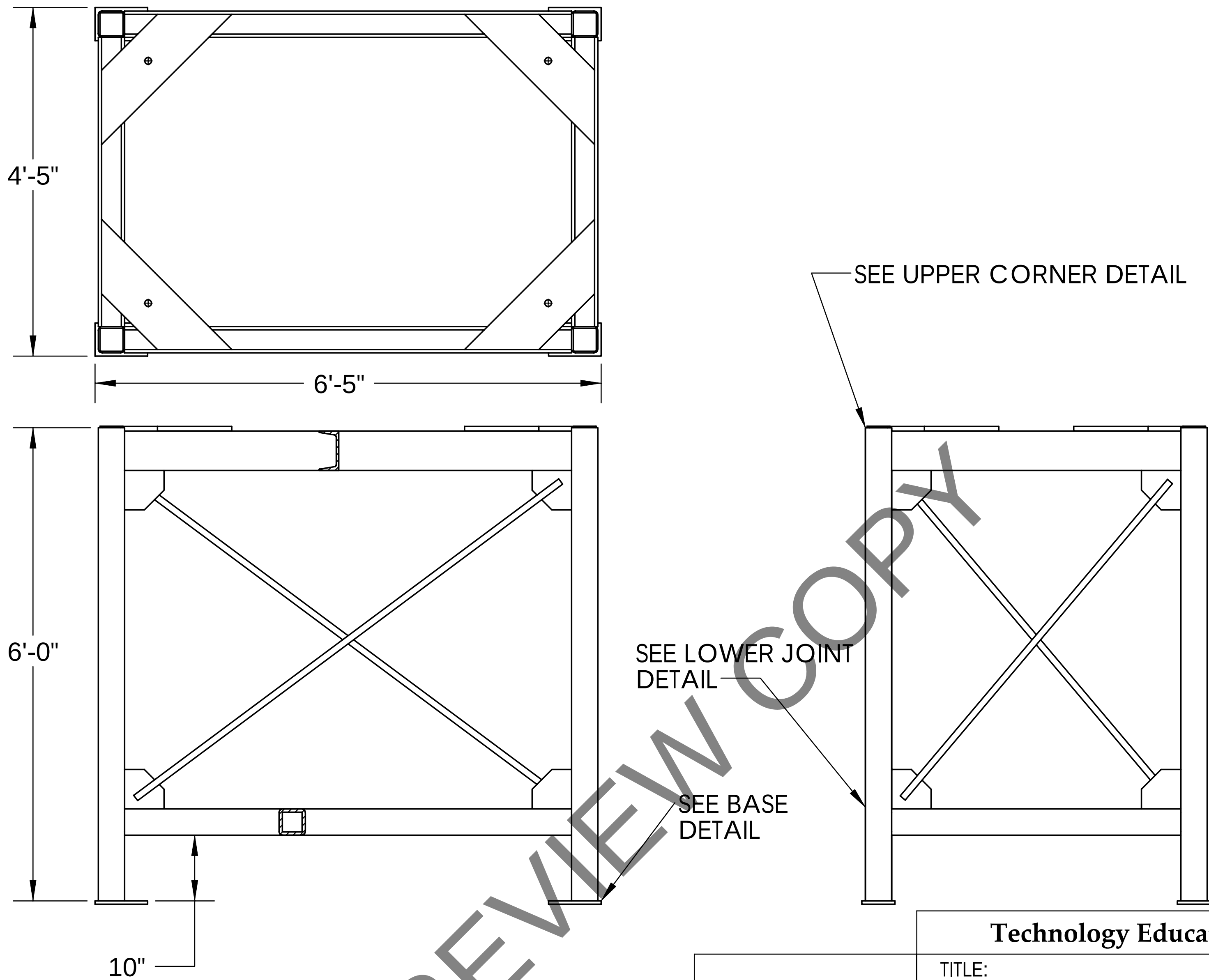
DO NOT SCALE DRAWING

TITLE:
# BOX SECTION

| SIZE | DWG. NO. | REV |
|---|---|---|
| A | Project 4 | |

| SCALE: 1:1 | WEIGHT: | SHEET 1 OF 1 |
|---|---|---|

5 4 3 2 1






**Technology Education Resources, LLC**

TITLE:

# STORAGE TANK PLATFORM ASSEMBLY VIEW

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±1/16
ANGULAR: MACH ±1  BEND ±1
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.005

INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14.5-09

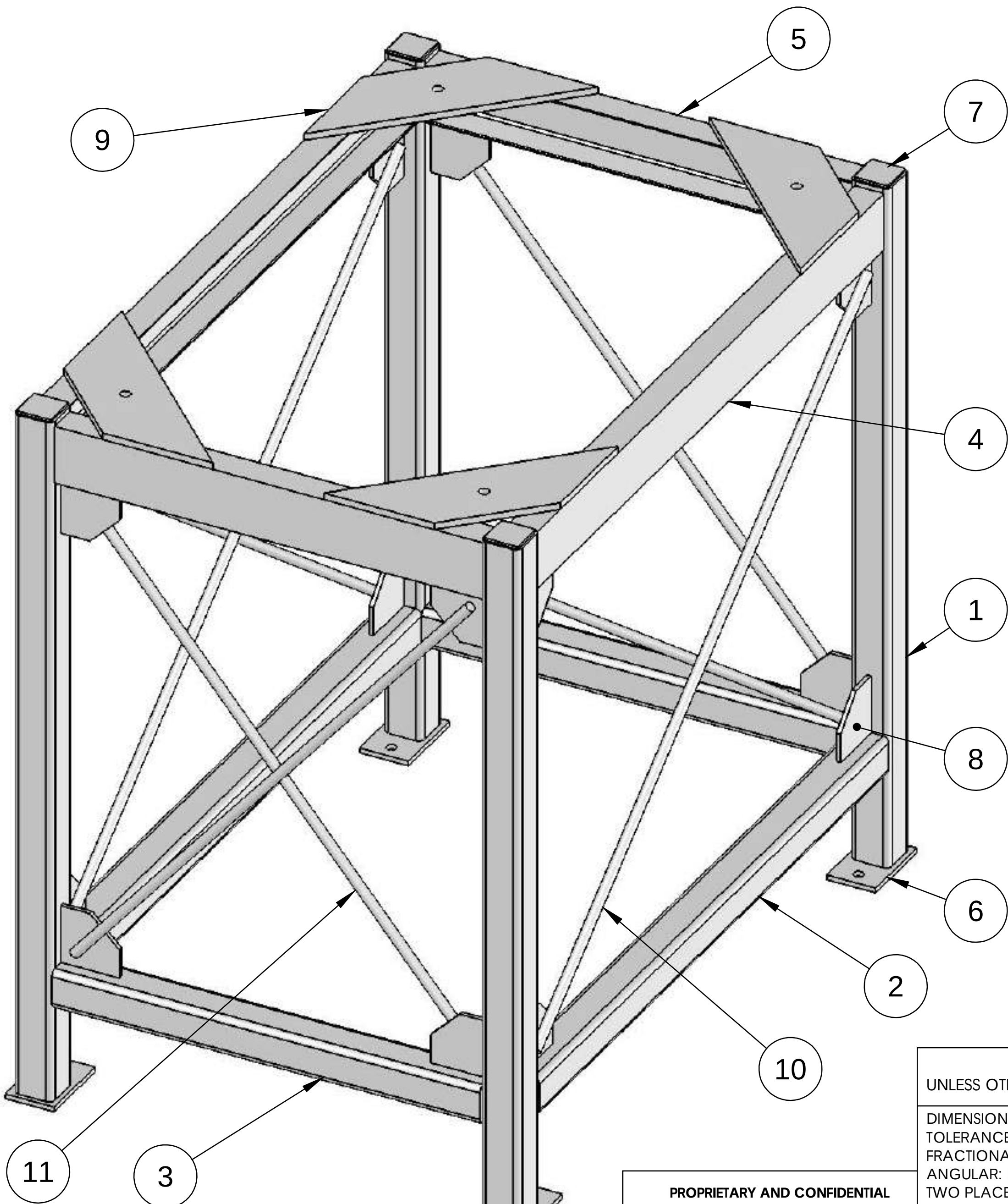
DO NOT SCALE DRAWING



| SIZE | DWG. NO. | REV |
|---|---|---|
| A | Example 1 | |

| SCALE: 1/2" = 1' | WEIGHT: | SHEET 1 OF 6 |
|---|---|---|

5 4 3 2 1




| ITEM | QTY | DESCRIPTION | SIZE/LENGTH |
|---|---|---|---|
| 1 | | 4"X21.63 SQ TUBE ASTM A500, GR B | 6'-0" |
| 2 | | 4"X21.63 SQ TUBE ASTM A500, GR B | 5'-8" |
| 3 | | 4"X21.63 SQ TUBE ASTM A500, GR B | 3'-8" |
| 4 | | 6"X16.3 CHANNEL ASTM A36 | 5'-8" |
| 5 | | 6"X16.3 CHANNEL ASTM A36 | 3'-8" |
| 6 | | BASE PLATE ASTM A36 | 1/2" X 5" X 8" LG |
| 7 | | LEG CAP ASTM A36 | 1/4" X 3-1/2" X 3-1/2" |
| 8 | | GUSSET PLATE ASTM A36 | 1/2" X 6" X 6" |
| 9 | | TOP PLATE ASTM A36 | 3/4" X 8" X 2'-4" LG |
| 10 | | 1" DIA BAR ASTM A36 | 6'-8-5/8" |
| 11 | | 1" DIA BAR ASTM A36 | 5'-3" |



UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±1/16
ANGULAR: MACH ±1 BEND ±1
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.005

INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14.5-09

DO NOT SCALE DRAWING

**Technology Education Resources, LLC**

TITLE:

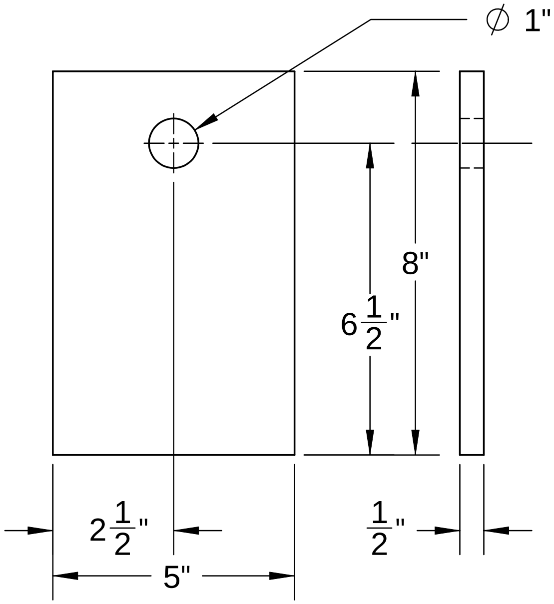
# STORAGE TANK PLATFORM WELDMENT CUT LIST

| SIZE | DWG. NO. | REV |
|---|---|---|
| A | Example 1 | |

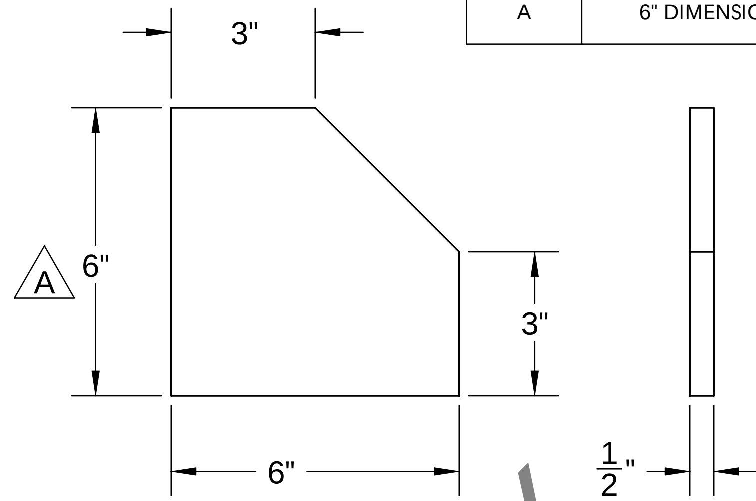
| SCALE: NONE | WEIGHT: | SHEET 2 OF 6 |
|---|---|---|
| | | |

5 4 3 2 1

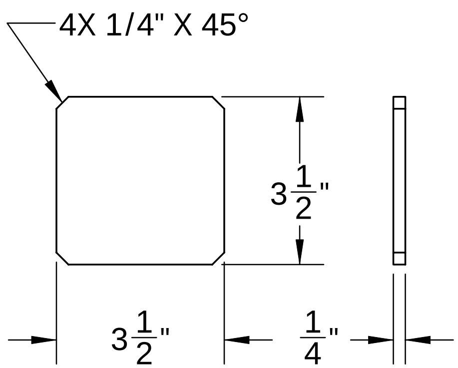
| REVISIONS | | | |
|---|---|---|---|
| REV. | DESCRIPTION | DATE | APPROVED |
| A | 6" DIMENSIONS WERE 4" | 6/27/2008 | MEM |



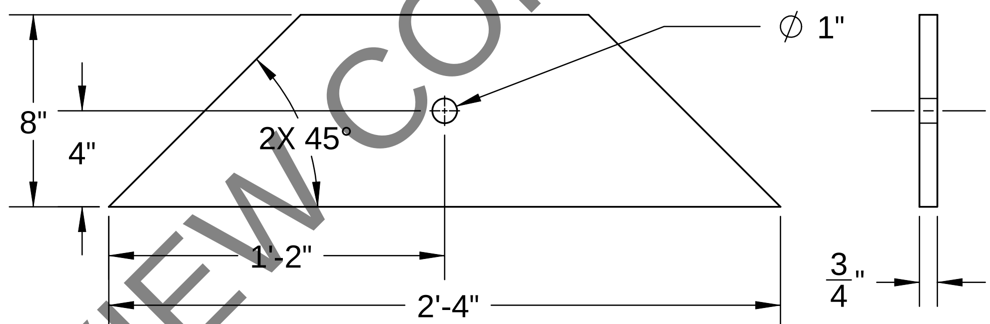

ITEM 6. BASE PLATE




ITEM 8. GUSSET PLATE




ITEM 7. LEG CAP




ITEM 9. TOP PLATE
SCALE 1:8



**Technology Education Resources, LLC**

TITLE:

# STORAGE TANK PLATFORM FABRICATED PARTS DETAIL

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±1/16
ANGULAR: MACH ±1 BEND ±1
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.005

INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14.5-94

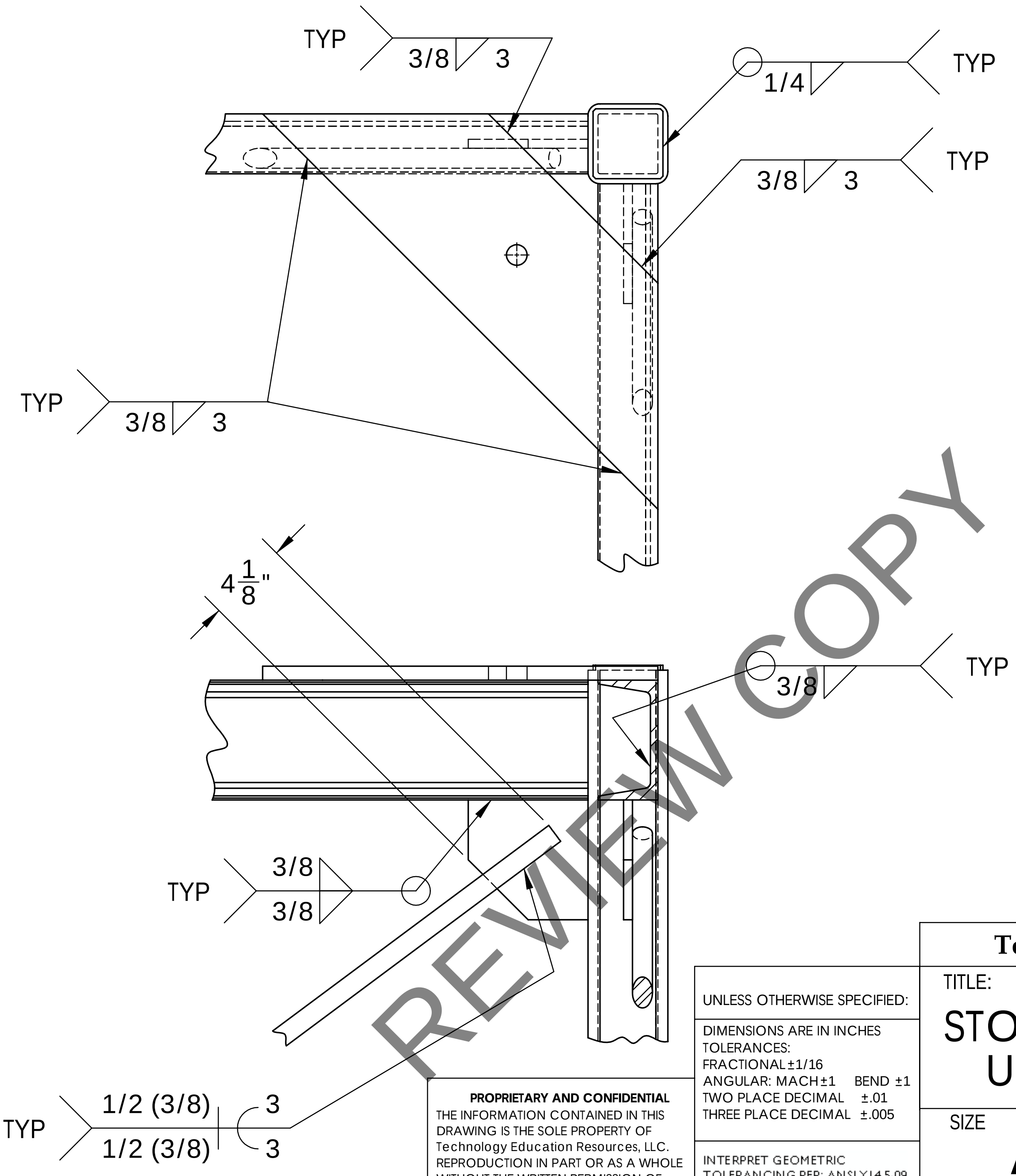
DO NOT SCALE DRAWING



| SIZE | DWG. NO. | REV |
|---|---|---|
| A | Example 1 | A |

| SCALE: 1:4 | WEIGHT: | SHEET 3 OF 6 |
|---|---|---|

5 4 3 2 1






**Technology Education Resources, LLC**

TITLE:

# STORAGE TANK PLATFORM UPPER CORNER DETAIL

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±1/16
ANGULAR: MACH ±1 BEND ±1
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.005

INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14.5-09

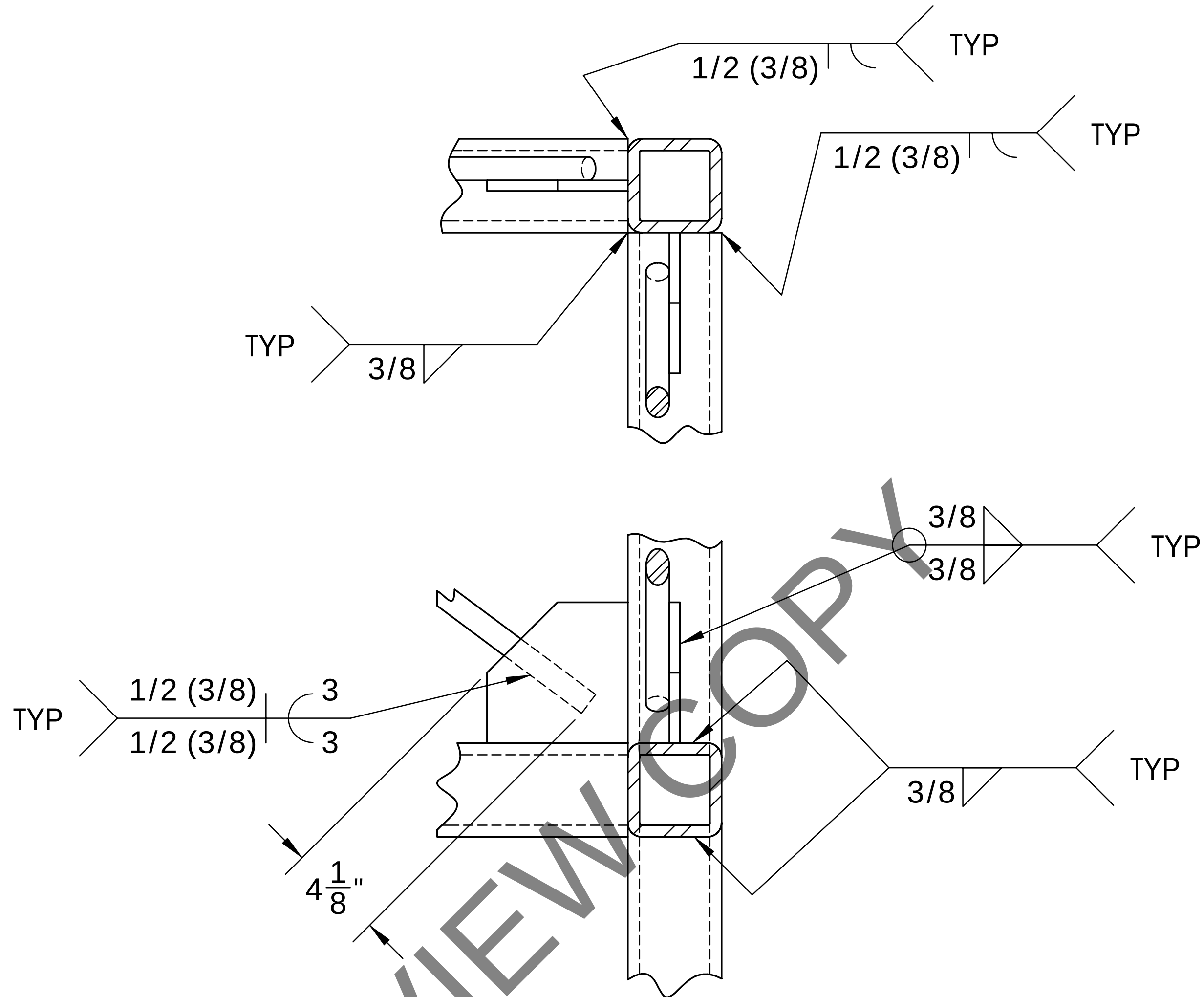
DO NOT SCALE DRAWING



| SIZE | DWG. NO. | REV |
|---|---|---|
| A | Example 1 | |

| SCALE: 1:8 | WEIGHT: | SHEET 4 OF 6 |
|---|---|---|

5 4 3 2 1






**Technology Education Resources, LLC**

TITLE:

# STORAGE TANK PLATFORM LOWER JOINT DETAIL

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±1/16
ANGULAR: MACH ±1 BEND ±1
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.005

INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14.5-09

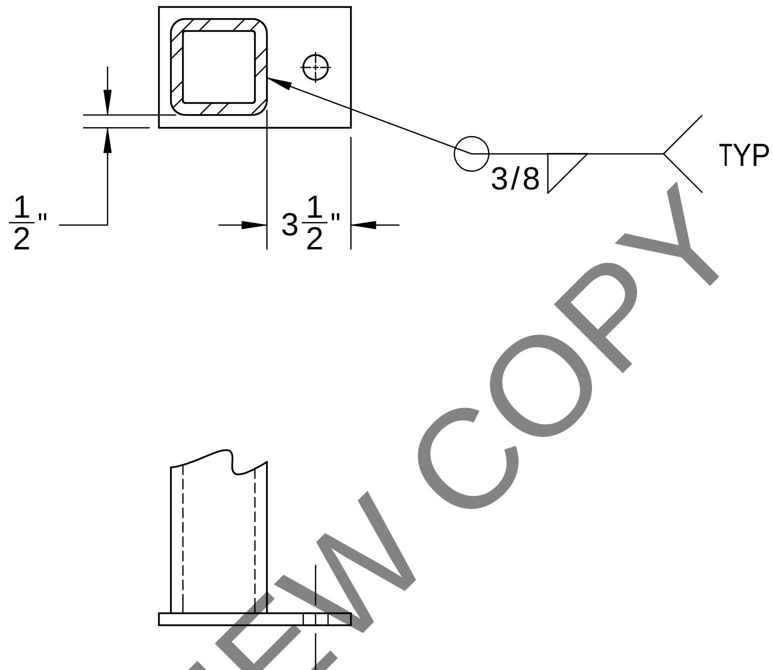
DO NOT SCALE DRAWING



| SIZE | DWG. NO. | REV |
|---|---|---|
| A | Example 1 | |

| SCALE: 1:8 | WEIGHT: | SHEET 5 OF 6 |
|---|---|---|

5 4 3 2 1








UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±1/16
ANGULAR: MACH ±1 BEND ±1
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.005

INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14.5-09

DO NOT SCALE DRAWING

**Technology Education Resources, LLC**

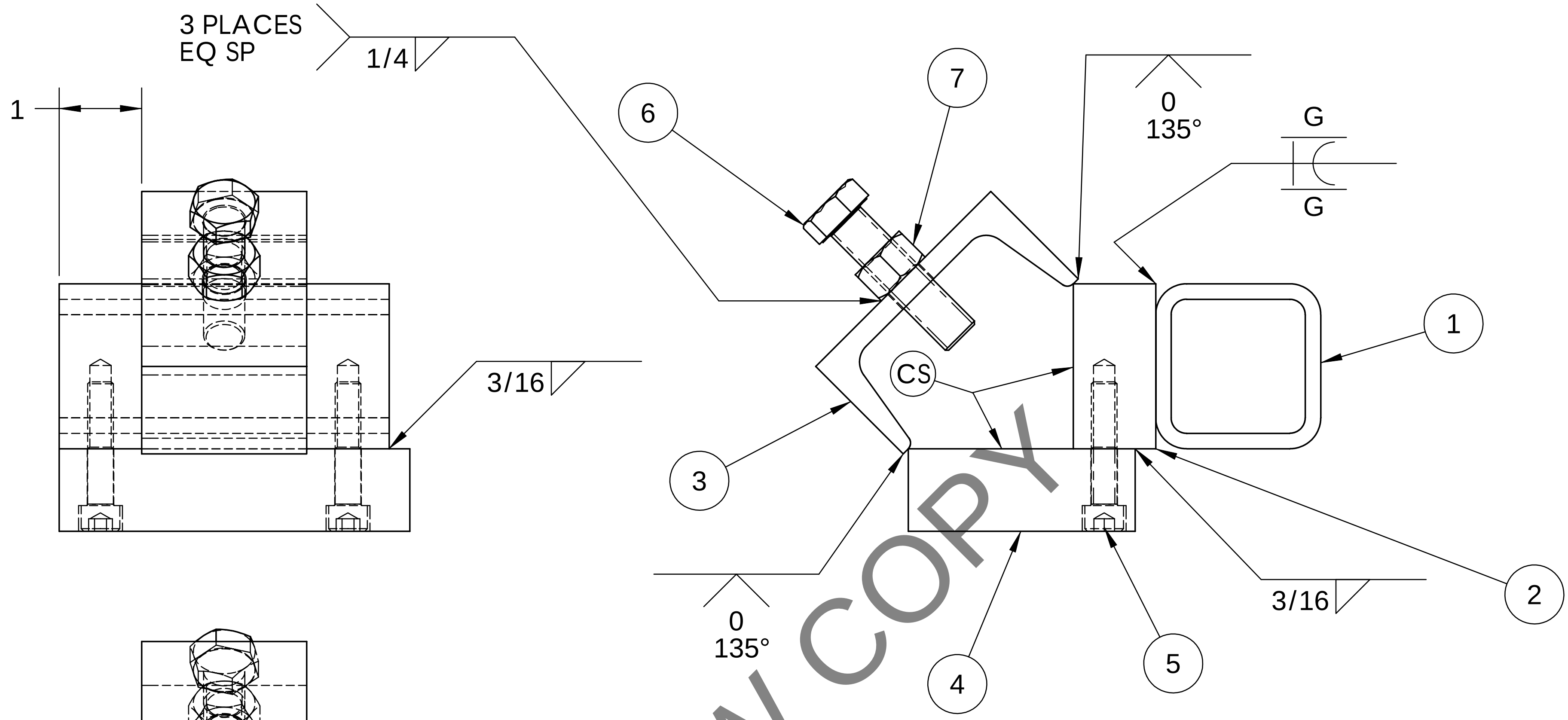
TITLE:

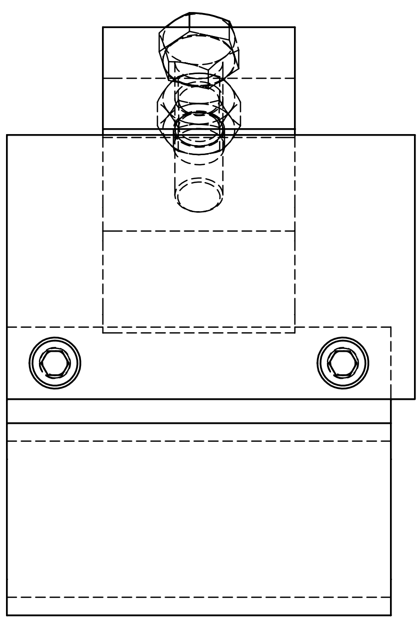
# STORAGE TANK PLATFORM BASE DETAIL

| SIZE | DWG. NO. | REV |
|---|---|---|
| **A** | Example 1 | |

| SCALE: 1:8 | WEIGHT: | SHEET 6 OF 6 |
|---|---|---|

5 4 3 2 1



NOTE: SURFACES MARKED CS MUST BE CLEAN OF WELD SPATTER.





UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±1/16
ANGULAR: MACH ±1 BEND ±1
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.005

INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14.5-09

DO NOT SCALE DRAWING

**Technology Education Resources, LLC**

TITLE:
# STOCK PUSHER GUIDE ASSEMBLY

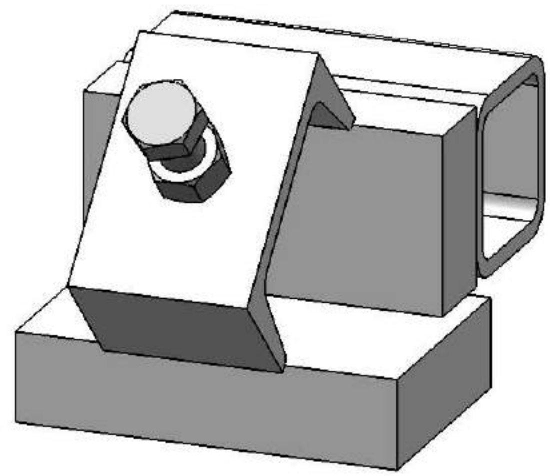
| SIZE | DWG. NO. | REV |
|---|---|---|
| **A** | Example 2 | |

| SCALE: 1:2 | WEIGHT: | SHEET 1 OF 5 |
|---|---|---|

5 4 3 2 1

## BILL OF MATERIALS

| ITEM NO. | QUANTITY | DESCRIPTION | SIZE/LENGTH |
|---|---|---|---|
| 1 | 1 | 2" X 3/16" WALL SQ. TUBE<br>ASTM A500, GRADE B | 4.00" |
| 2 | 1 | REAR MOUNT BLOCK<br>ASTM A36 | 1" X 2" X 4.00" LONG |
| 3 | 1 | 3" X 4.1 STRUCTURAL CHANNEL<br>ASTM A36 | 2.00" |
| 4 | 1 | BOTTOM MOUNT BLOCK<br>ASTM A36 | 1" X 2.75" X 4.25" LONG |
| 5 | 2 | SOCKET HEAD CAP SCREW<br>ANSI/ASME B18.3 GRADE 8 | 5/16 UNC 18 X 1.5 |
| 6 | 1 | HEX HEAD CAP SCREW<br>ANSI/ASME B18.3 GRADE 5 | 1/2 UNC 13 X 2 |
| 7 | 1 | HEX NUT<br>GRADE 8 PLAIN STEEL | 1/2 UNC 13 |





UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±1/16
ANGULAR: MACH ±1 BEND ±1
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.005

INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14.5-09

DO NOT SCALE DRAWING

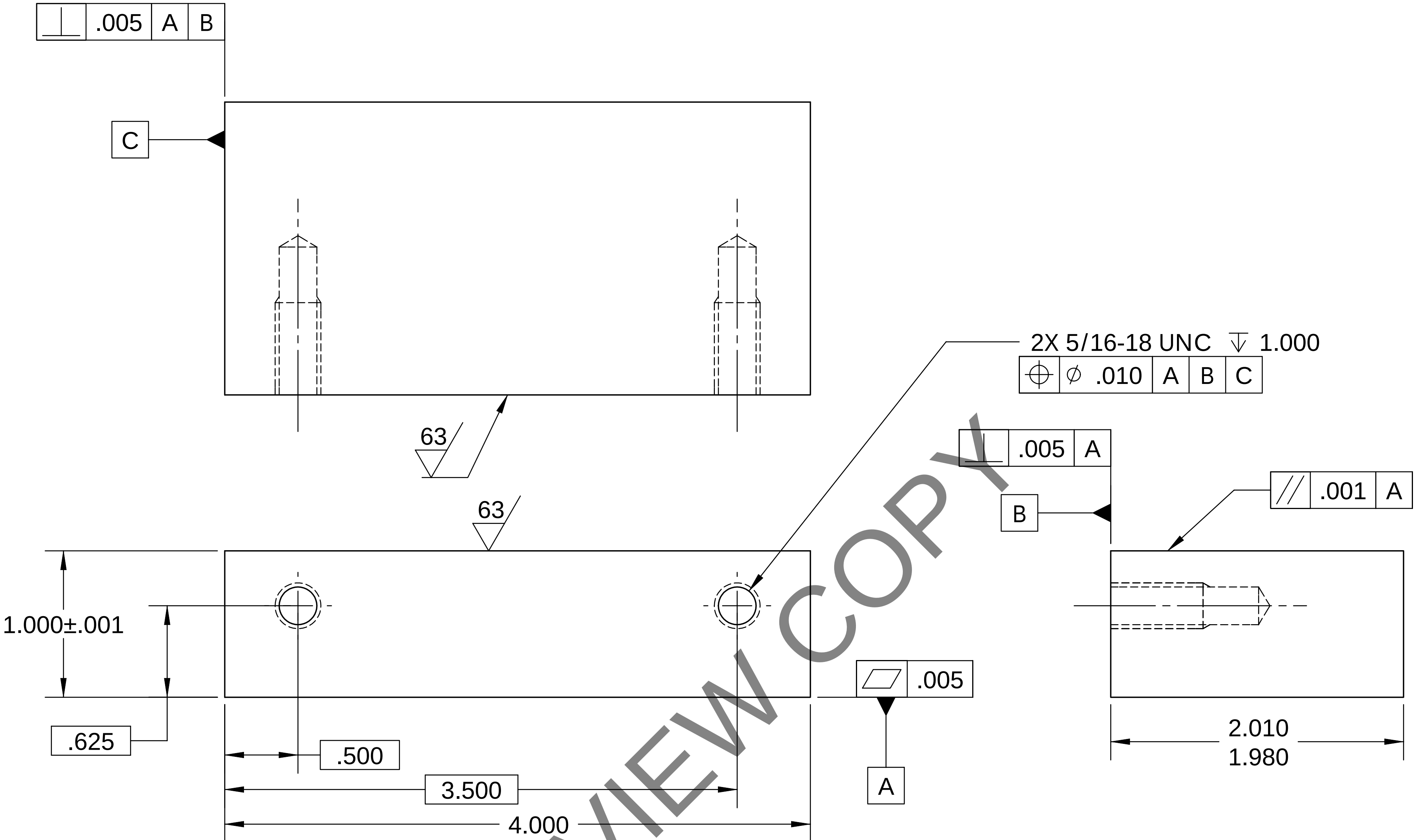
Technology Education Resources, LLC

TITLE:
STOCK PUSHER GUIDE
BILL OF MATERIALS

SIZE: A
DWG. NO. Example 2
REV

SCALE: NONE
WEIGHT:
SHEET 2 OF 5

5 4 3 2 1






**Technology Education Resources, LLC**

TITLE:

STOCK PUSHER GUIDE
REAR MOUNT BLOCK DETAIL

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±1/16
ANGULAR: MACH ±1  BEND ±1
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.005

INTERPRET GEOMETRIC
TOLERANCING PER: ANSI Y14.5-09

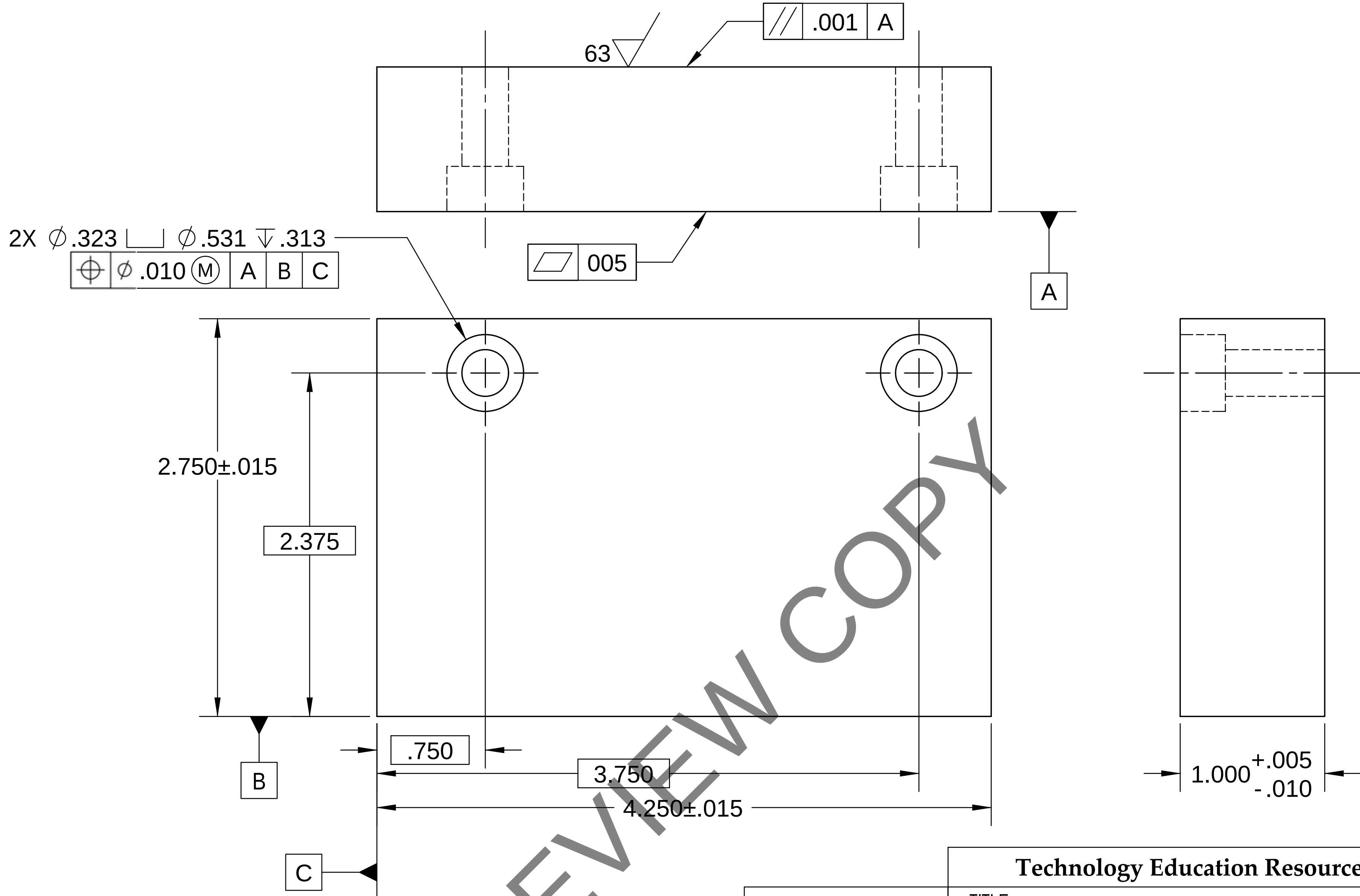
DO NOT SCALE DRAWING



| SIZE | DWG. NO. | REV |
|---|---|---|
| **A** | Example 2 | |

| SCALE: 1:1 | WEIGHT: | SHEET 3 OF 5 |
|---|---|---|

5 4 3 2 1






**Technology Education Resources, LLC**

TITLE:

STOCK PUSHER GUIDE
BOTTOM MOUNT BLOCK DETAIL

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±1/16
ANGULAR: MACH ±1 BEND ±1
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.005

INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14.5-09

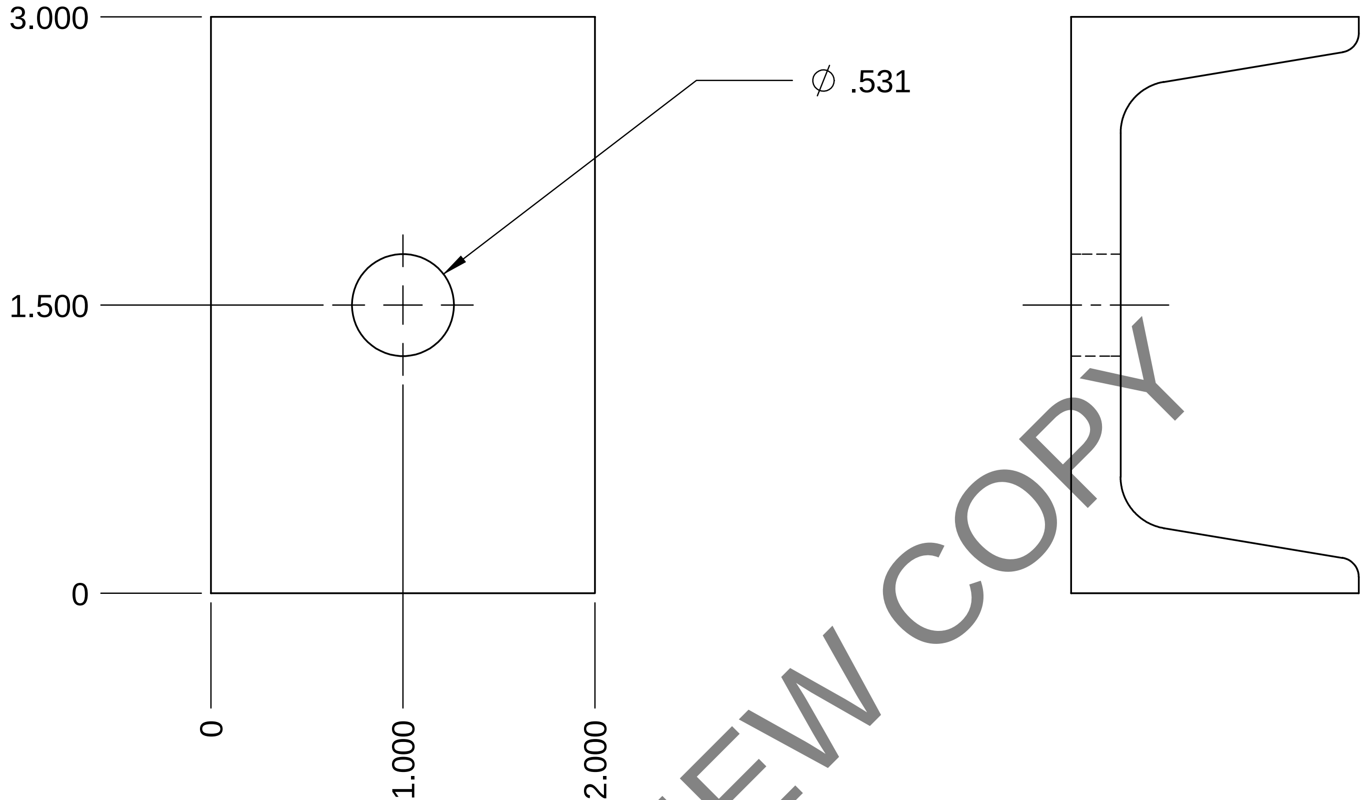
DO NOT SCALE DRAWING



| SIZE | DWG. NO. | REV |
|---|---|---|
| A | Example 2 | |

| SCALE: 1:1 | WEIGHT: | SHEET 4 OF 5 |
|---|---|---|

5 4 3 2 1






**Technology Education Resources, LLC**

TITLE:

STOCK PUSHER GUIDE CHANNEL DETAIL

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±1/16
ANGULAR: MACH ±1 BEND ±1
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.005

INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14.5-09

DO NOT SCALE DRAWING

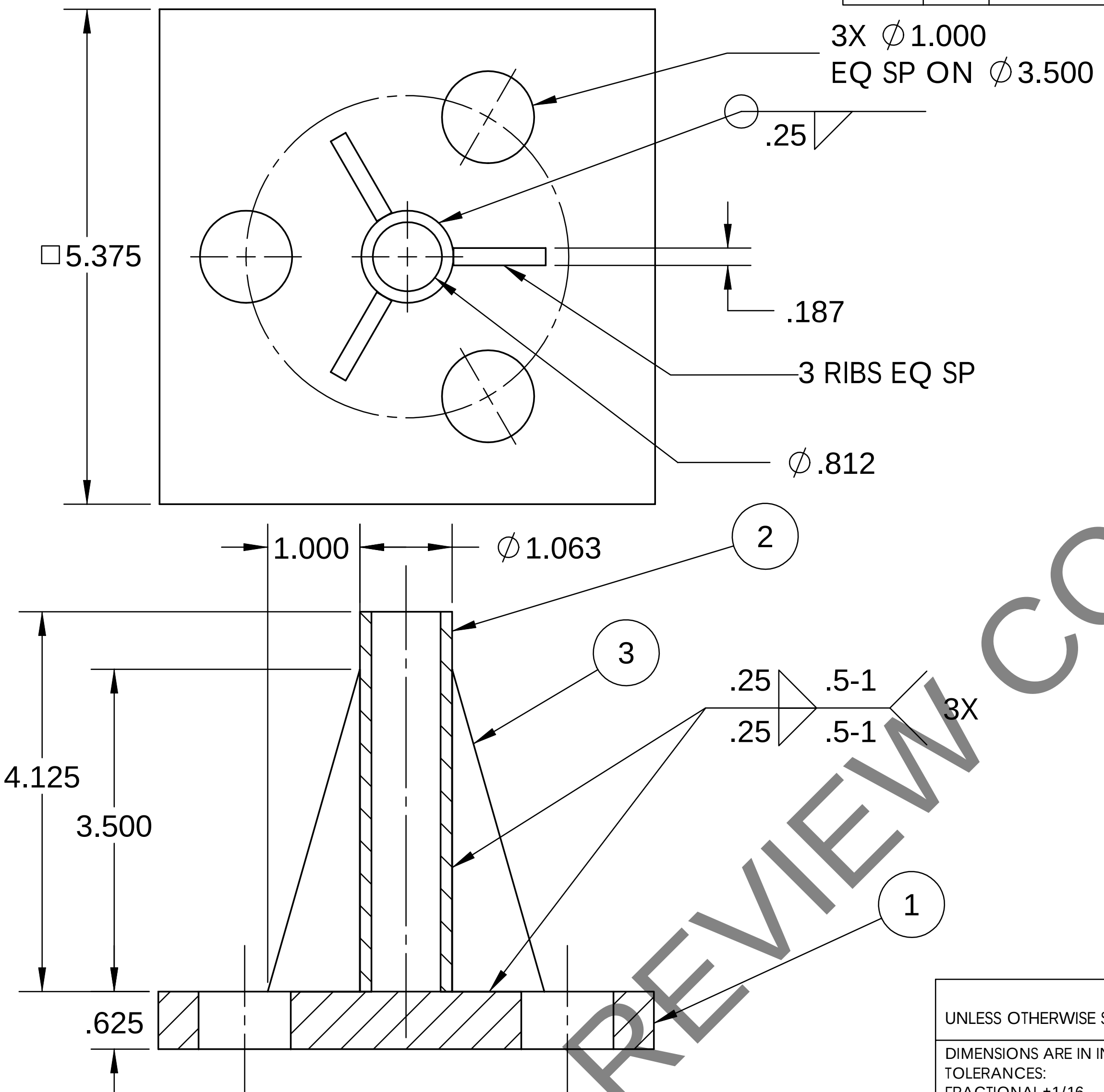


| SIZE | DWG. NO. | REV |
|---|---|---|
| A | Example 2 | |

| SCALE: 1:1 | WEIGHT: | SHEET 5 OF 5 |
|---|---|---|

5 4 3 2 1

| PART | QTY | DESCRIPTION | SIZE (INCHES) | SIZE (MILLIMETERS) |
|---|---|---|---|---|
| 1 | | BASE | | |
| 2 | | TUBE | | |
| 3 | | RIB | | |






**Technology Education Resources, LLC**

TITLE: POST BASE ASSEMBLY

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±1/16
ANGULAR: MACH ±1 BEND ±1
TWO PLACE DECIMAL ±.05
THREE PLACE DECIMAL ±.031

INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14.5-09

DO NOT SCALE DRAWING

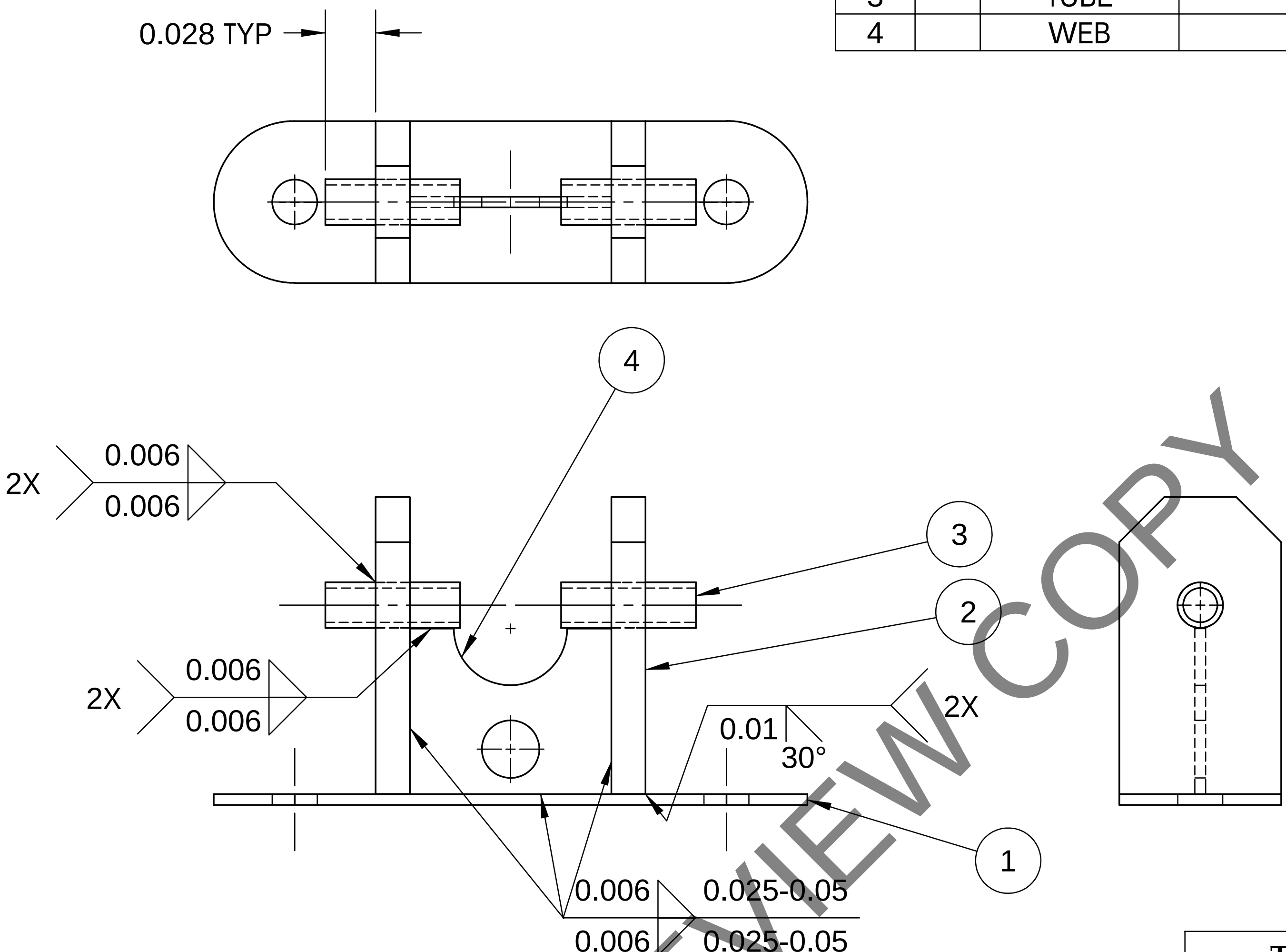


SIZE: A | DWG. NO.: Project 5 | REV

SCALE: 1:2 | WEIGHT: | SHEET 1 OF 1

5 4 3 2 1

| PART | QTY | DESCRIPTION | SIZE (MILLIMETERS) | SIZE (INCHES) |
|---|---|---|---|---|
| 1 | | BASE | | |
| 2 | | SUPPORT | | |
| 3 | | TUBE | | |
| 4 | | WEB | | |






NOTE: ASSEMBLY SYMMETRICAL
ABOUT VERTICAL CENTERLINE



UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN METERS
TOLERANCES:
ONE PLACE DECIMAL ±0.1
ANGULAR: MACH ±1 BEND ±1
TWO PLACE DECIMAL ±0.01
THREE PLACE DECIMAL ±0.001

INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14.5-09

DO NOT SCALE DRAWING

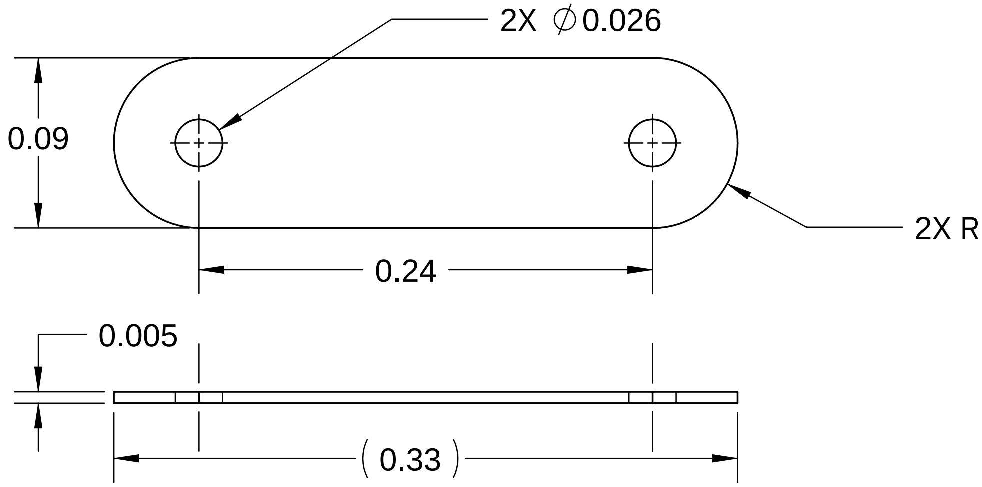
**Technology Education Resources, LLC**

TITLE:
PULLEY MOUNT BRACKET ASSEMBLY

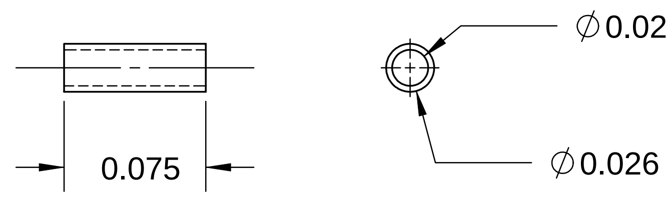
| SIZE | DWG. NO. | REV |
|---|---|---|
| A | Project 6 | |

| SCALE: 1:4 | WEIGHT: | SHEET 1 OF 2 |
|---|---|---|

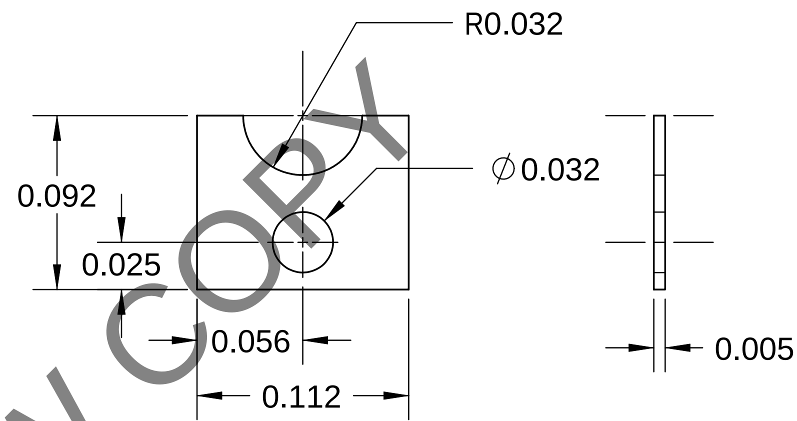
5 4 3 2 1



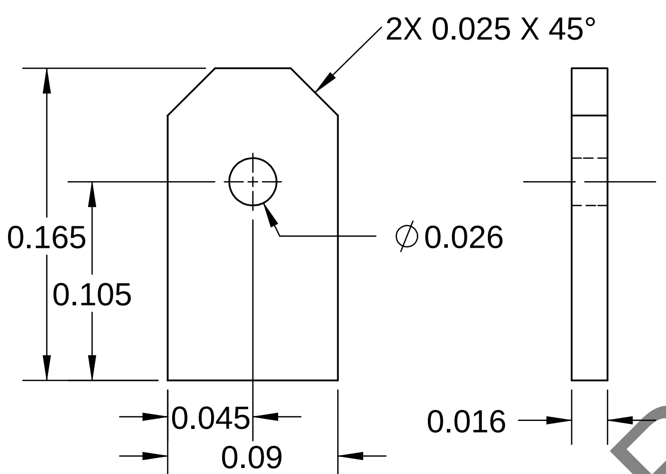

PART 1. BASE
0.09 X 0.33 X 0.005 PLATE
1 REQD




PART 3. TUBE
0.026 OD X 0.02 ID X 0.075 LONG TUBE
2 REQD




PART 4. WEB
0.092 X 0.112 X 0.005 PLATE
1 REQD




PART 2. SUPPORT
0.09 X 0.165 X 0.016 PLATE
2 REQD





UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN METERS
TOLERANCES:
ONE PLACE DECIMAL ±0.1
ANGULAR: MACH ±1 BEND ±1
TWO PLACE DECIMAL ±0.01
THREE PLACE DECIMAL ±0.001

INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14.5-09

DO NOT SCALE DRAWING

**Technology Education Resources, LLC**

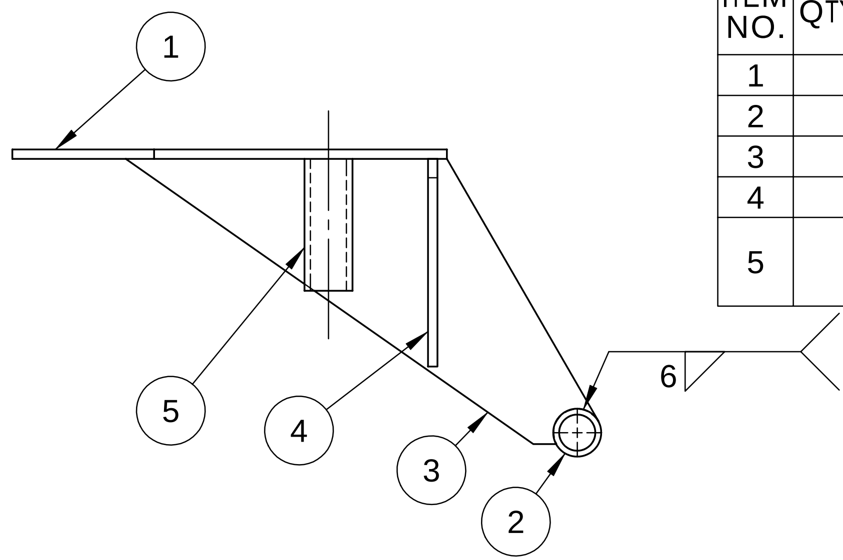
TITLE:
PULLEY MOUNT BRACKET DETAIL DRAWINGS

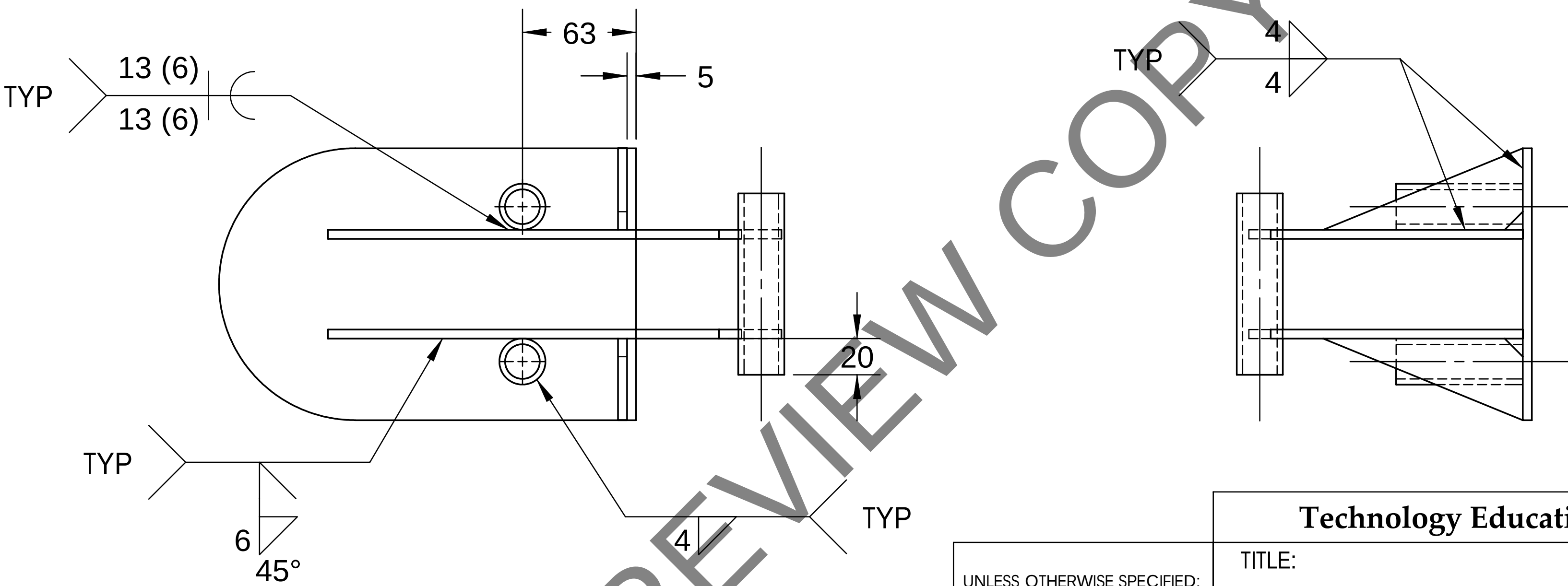
| SIZE | DWG. NO. | REV |
|---|---|---|
| A | Project 6 | ' |

| SCALE: 1:4 | WEIGHT: | SHEET 2 OF 2 |
|---|---|---|

5 4 3 2 1

| ITEM NO. | QTY | DESCRIPTION | SIZE (MILLIMETERS) | SIZE (INCHES) |
|---|---|---|---|---|
| 1 | | BACK PLATE | | |
| 2 | | HINGE TUBE | | |
| 3 | | WEB | | |
| 4 | | RIB | | |
| 5 | | SOCKET RECEIVER | | |






**Technology Education Resources, LLC**

TITLE:

# WATERTIGHT DOOR HINGE ASSEMBLY

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN MILLIMETERS
TOLERANCES:
NO DECIMAL ±1
ANGULAR: MACH±1 BEND ±1
ONE PLACE DECIMAL ±.1
TWO PLACE DECIMAL ±.05

INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14.5-09

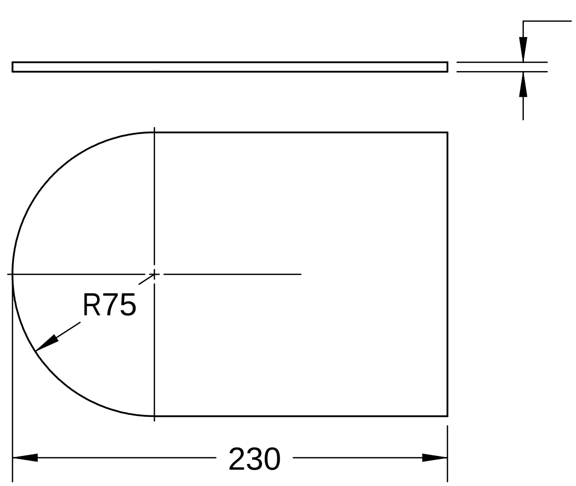
DO NOT SCALE DRAWING



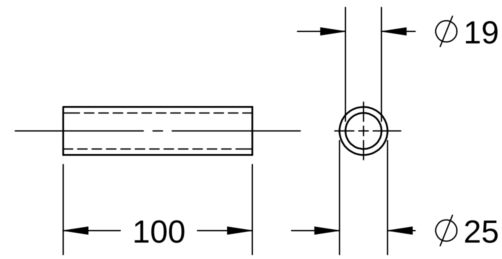
SIZE A | DWG. NO. Project 7 | REV

SCALE: 1:4 | WEIGHT: | SHEET 1 OF 2

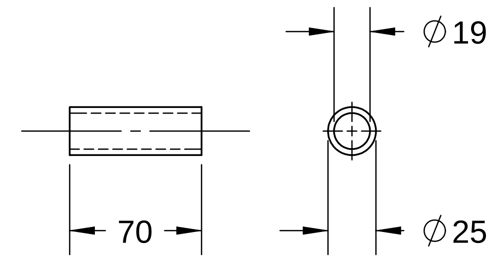
5 4 3 2 1



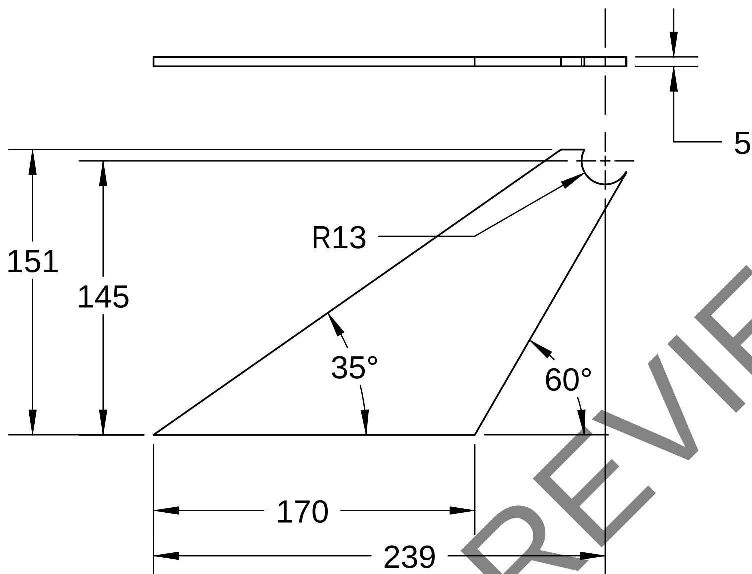

<u>ITEM 1 - BACK PLATE</u>
230 X 150 X 5 PLATE
1 REQD.



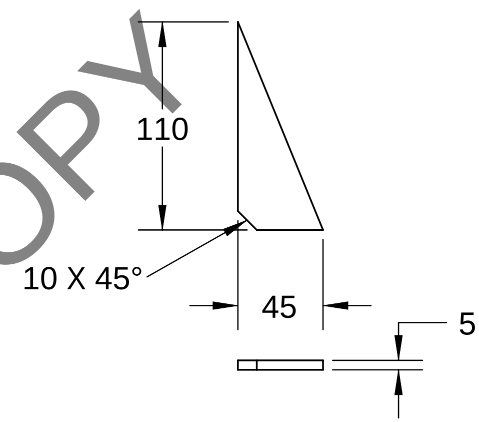

<u>ITEM 2 - HINGE TUBE</u>
19 ID x 25 OD x 100 LONG
1 REQD.




<u>ITEM 5 - SOCKET RECEIVER</u>
19 ID X 25OD X 70 LONG
2 REQD.




<u>ITEM 3 - WEB</u>
250 X 151 X 5 PLATE
2 REQD.




<u>ITEM 4 - RIB</u>
110 X 45 X 5 PLATE
2 REQD.





UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
TOLERANCES:
NO DECIMAL ±1
ANGULAR: MACH±1 BEND ±1
ONE PLACE DECIMAL ±.1
TWO PLACE DECIMAL ±.05

INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14.5-09

DO NOT SCALE DRAWING

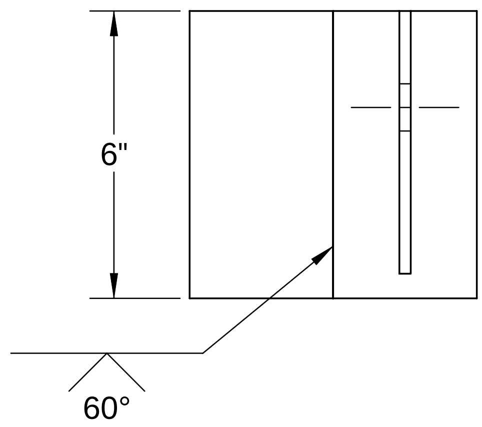
**Technology Education Resources, LLC**

TITLE:
# WATERTIGHT DOOR HINGE DETAIL PARTS

| SIZE | DWG. NO. | REV |
|---|---|---|
| A | Project 7 | |

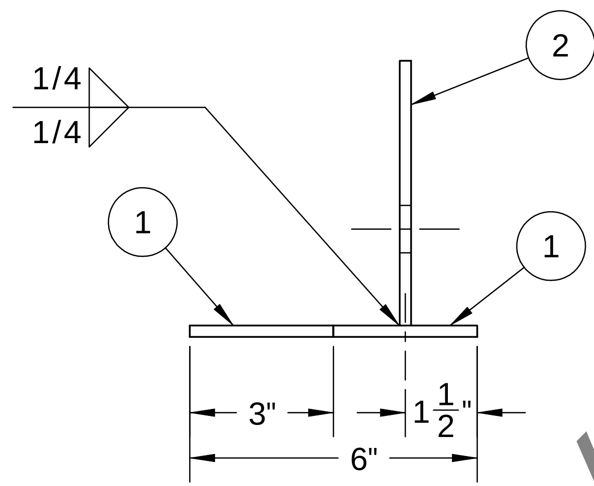
SCALE: 1:4 | WEIGHT: | SHEET 2 OF 2

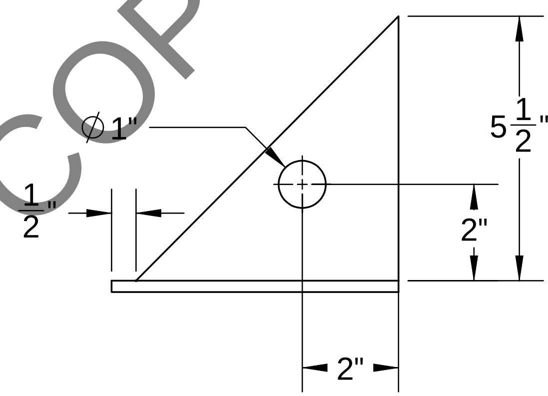
| PART | No. REQD | SIZE | METRIC CONVERSION |
|---|---|---|---|
| 1 | | | |
| 2 | | | |
| | | | |
| | | | |
| | | | |
| | | | |




NOTES:

1. COMPLETE B.O.M. IN STANDARD INCH UNITS.
2. CONVERT ALL B.O.M. DIMENSIONS TO SI UNITS TO NEAREST MILLIMETER.
3. MANUFACTURE FROM 3/16" THICK MATERIAL.






**Technology Education Resources, LLC**

TITLE:

TEST WELDMENT 1

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±1/16
ANGULAR: MACH ±1 BEND ±1
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.005

INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14.5-09



SIZE **A**

DWG. NO. Project 8

REV

DO NOT SCALE DRAWING

SCALE: 1:4

WEIGHT:

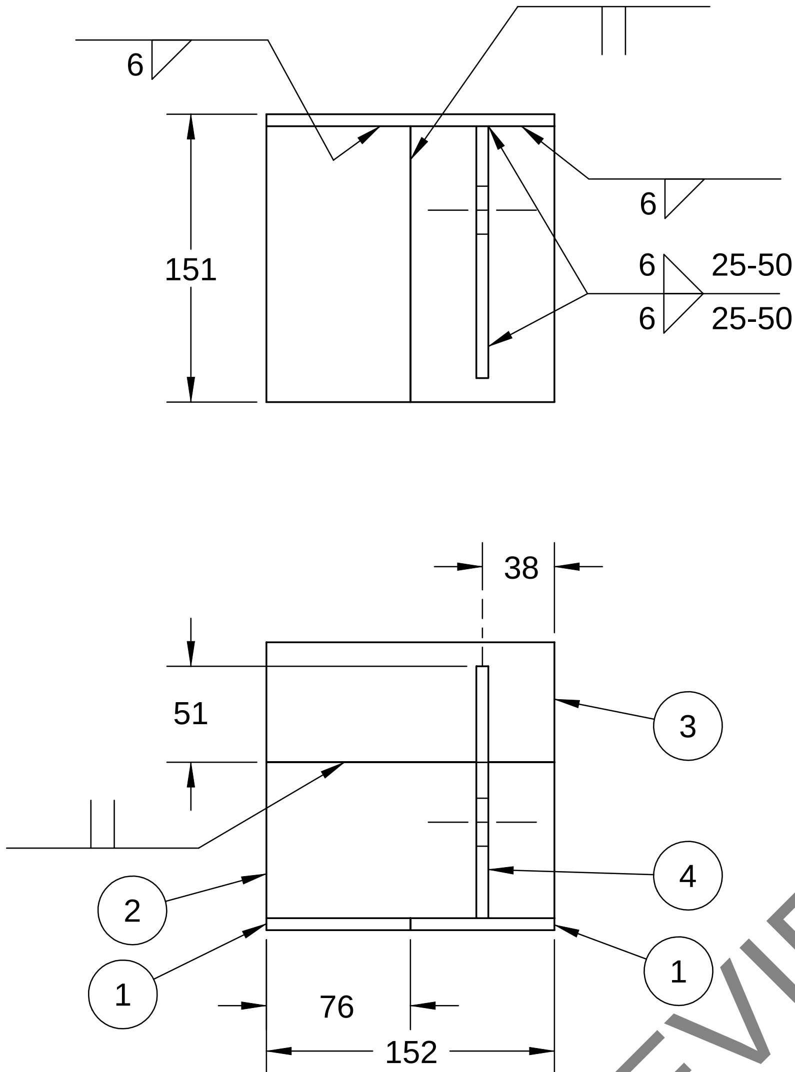
SHEET 1 OF 1

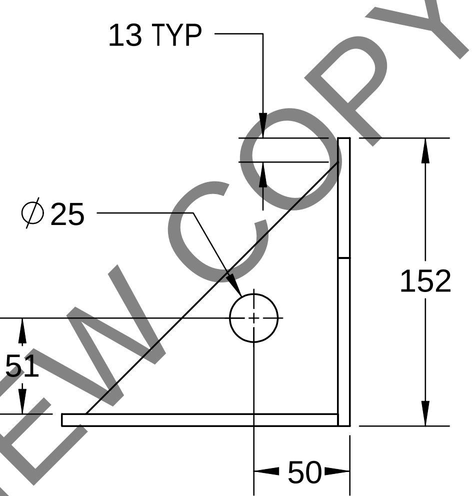
5 4 3 2 1

| PART | No. REQD | SIZE | INCH CONVERSION |
|---|---|---|---|
| 1 | | | |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| | | | |
| | | | |

NOTES:

1. COMPLETE B.O.M. IN SI UNITS
2. CONVERT ALL B.O.M. DIMENSIONS TO STANDARD INCH TO THE NEAREST 1/16"
3. MANUFACTURE FROM 5mm MATERIAL






Technology Education Resources, LLC

TITLE:
TEST WELDMENT 2M

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN MILLIMETERS
TOLERANCES:
NO DECIMAL ±1
ANGULAR: MACH ±1 BEND ±1
ONE PLACE DECIMAL ±0.1
TWO PLACE DECIMAL ±0.01

INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14.5-09

DO NOT SCALE DRAWING

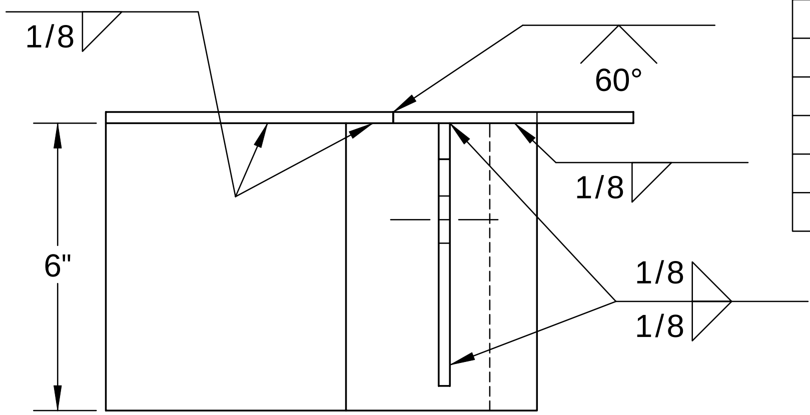


SIZE A | DWG. NO. Project 9 | REV

SCALE: 1:4 | WEIGHT: | SHEET 1 OF 1

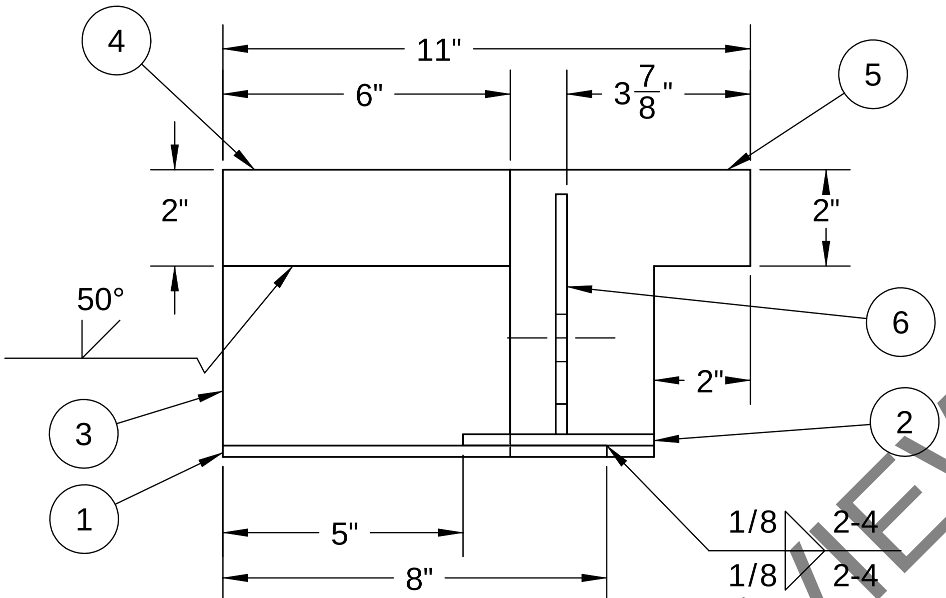
5 4 3 2 1

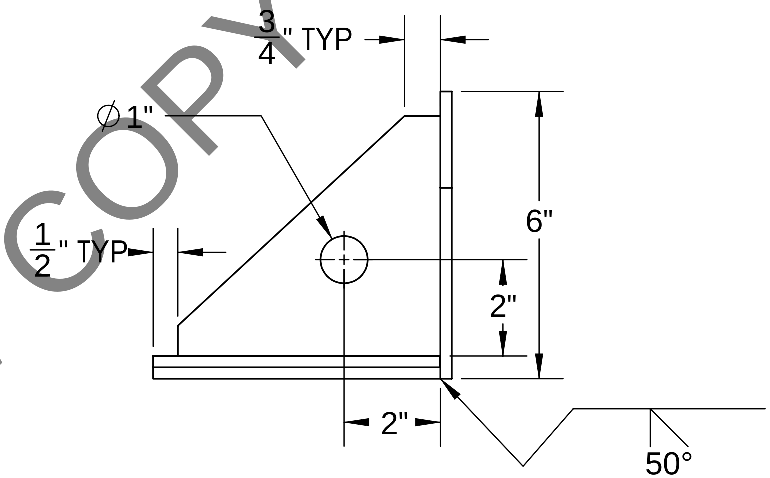
| PART | No. REQD | SIZE | METRIC CONVERSION |
|---|---|---|---|
| 1 | | | |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |
| 6 | | | |




NOTES:

1. COMPLETE B.O.M. IN STANDARD INCH UNITS.
2. CONVERT ALL B.O.M. DIMENSIONS TO SI UNITS TO NEAREST MILLIMETER.
3. MANUFACTURE FROM 3/16" THICK MATERIAL.






**Technology Education Resources, LLC**

TITLE:

TEST WELDMENT 3

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±1/16
ANGULAR: MACH ±1 BEND ±1
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.005

INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14.5-09

DO NOT SCALE DRAWING



| SIZE | DWG. NO. | REV |
|---|---|---|
| A | Project 10 | |

SCALE: 1:4 | WEIGHT: | SHEET 1 OF 1

5 4 3 2 1