Ingalls Shipbuilding
A Division of Huntington Ingalls Industries

NSRP Standardized Welding Curriculum and Testing for Shipyards

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Why are you here?

Despite its advantages of being an economical way to join metal parts, inadequate fitting and welding can lead to structural problems such as distortion. Rework is necessary to remove distortion, which results in additional costs in manpower and materials. Additionally, rework leads to project time delays.

As a shipbuilder, it is important for you to understand:

- structural problems and their associated costs
- best practice methods to avoid problems such as distortion
- how to correct distortion when it cannot be avoided

Why are you here?

The main topic of this course is distortion control.

It is critical to your job knowledge and the quality of our ships.

The goal of this course is to aid you in understanding what distortion is and how to help control and reduce it.

Modern Design Construction of Naval Surface Combatants

Thin steel hulls have become a standard in Naval Surface Combatant designs

- Incorporates thinner and higher strength steel panels and structures
- Designs increasingly becoming more light weight to increase mission capabilities
- Meet operational objectives and improve vessel performance
- Counteracts increase in weight due to automated equipment and weaponry

Naval vessels will increasingly trend toward use of thinner, light weight/higher strength steel designs

Modern Design Construction of Naval Surface Combatants

Thin steel designs create new challenging production environment and fabrication difficulties such as:

- Distortion due to high heat input on thin steel
  - From traditional ship production processes
- Panel shrinkage and dimensional control issues
- Workforce unfamiliarity with techniques needed to ease construction difficulties

Distortion and Issues with Thin Steel

Distortion can be caused by almost every manufacturing process. This course will focus on distortion caused by locked-in residual (or left over) stresses that can come from four major sources:

- Steel mills rolling process, material handling, shipping and storage
- Poor fit-up caused by inadequate nesting (Engineering) and inaccurate cutting
- Over-welding, inadequate welding process and erection sequences
- Unrestrained, inadequate clamping and fixturing

Distortion and Issues with Thin Steel

- Thin steel is difficult to weld because it is more prone to buckling distortion as plate thickness decreases
- Flame straightening is commonly used to remove distortion
- Improper flame straightening has been found as the triggering mechanism for damage to many hull structures in NSC, LPD, DDG and LHD contracts

Over heating could lead to crippled structures!

Course Lesson Plan

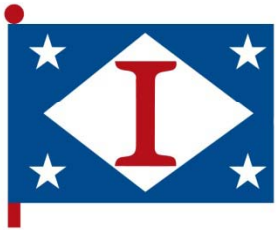
- Day 1: First Time Quality

  Cost of Rework and Process Delays
- Day 2: Basic Welding Concepts

  Weld Joint Designs, Weld Sizes, Introduction to Distortion
- Day 3: Welding Distortion

  Manual and Semi-Automatic Welding, Clamping, Tractor Welding, Pipe Welding, Tacking
- Day 4: Shipfitting and Insert Fitting/Welding

  Layout, plate and insert fitting and welding, root gaps
- Day 5: Mockup Activities



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Module 1

INTRODUCTION

Topics

- What is Residual Stress?
- What does quality mean?

Objectives

After this module, you will be able to:

- Explain why it is important to learn about welding distortion
- Discuss why quality is important

This is how:

- We shall discuss why quality is important through class discussion and by watching a short video clip

Is 99.9% Called Success?

First Time Quality (FTQ): What does it mean?

Things done right the first time!

The result of FTQ is companies can better identify methods and processes to streamline production to ensure a higher quality product in a more cost-efficient manner.

What is First Time Quality?

- FTQ can further be defined as a lean metric that indicates to what extent work is done correctly the first time without need for costly rework or replacement

- FTQ is an important tool in any Quality Management System toolbox to deliver a high quality product— built right, the first time

- FTQ is a key element in the effort to exceed the expectations of both internal and external customers

What is First Time Quality?

A well-strategized FTQ system offers a multitude of benefits, including:

- the ability to identify opportunities for continuous improvement
- reducing costs
- providing added value to customers by demonstrating and documenting measurable performance
- Providing guidance on training shipbuilders in order to have the highest probability of success based on demonstrated FTQ history

What is First Time Quality?

How success is measured means different things to different people.

Is 99.9 percent good enough? It sounds good, but is it good enough when lives are at risk?

The number of welds in a Navy vessel would be overwhelming to try to count. The quality of those welds is vital to the safety of the vessel and its crew therefore we must strive to produce the best and safest vessel possible.

Why is Quality Important?

Video

Group Activity

Read the case study of the USS Thresher in your workbook.

Prepare for Case Discussion:

- **What are some of the factors that may have led to this disaster?**

- **What best welding practices would have aided in eliminating the problems leading up to this disaster?**

What is First Time Quality?

Was a 99.9 percent FTQ rate considered successful?

Absolutely not!

The work we do as shipbuilders requires we strive for a FTQ of 100 percent **EVERY TIME.**

What is First Time Quality?

Welders are responsible for his/her work, not the foreman or QA inspector

Achieving FTQ and taking ownership of the quality of work you perform not only affects your workstation, but is amplified on every following workstation

Poor quality “snowballs” as the work moves downstream.

Ensuring a quality end product starts with YOU!

It's Not a Test!

We just want to establish the knowledge level of the class in order to tailor the course better to meet the needs of the participants.

It's Not a Test!

1. T As a shipbuilder, it is important for you to understand structural problems, their associated costs, best practice methods to avoid problems such as distortion, and how to correct it when it cannot be avoided.

2. F Naval Surface Combatant designs are moving away from thin panel designs because they are weaker structurally but the transition will take several years so we must continue to work with thin panel and distortion.

3. F We should never set a quality goal that cannot be reached by all shipbuilders.

It's Not a Test!

4. T Welders and shipfitters should follow the specifications given by the designer as closely as possible so the overall project is successful.

5. F The size and type of weld is determined by the welder after he/she evaluates the work to be done.

6. F Weld size and joint designs do not affect the project cost but impact the structural integrity of the ship.

7. T Each additional welded pass adds additional heat and creates slight material degradation.

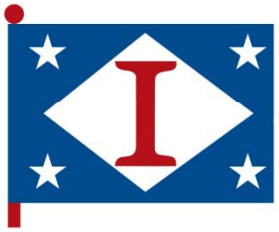
It's Not a Test!

8. F Residual stress is the stress that can be removed through the flame straightening method of distortion control.

9. F Fillet weld gauges are used only by the foremen and quality inspectors to check the angle of the weld.

10. T The root cause of welding distortion is high heat input.

Take a 10 minute break!



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Module 2

WELDING

Topics

- Weld Sizes: Is Bigger Better?
- Overwelding vs. Underwelding
- Welding Distortion
- Problems with Building Welds on Poor Quality Tacks
- Manual/Semi-Automatic Welding
- Track Welding
- Pipe Welding
- Tacking

Objectives

After this module, you will be able to:

- Define distortion control and explain how it applies to shipbuilding

This is how:

- We shall discuss the affects of distorted material
- We shall explain the importance of distortion control
- We shall identify the five (5) specific types of weld distortion
- We shall discuss the process of distortion control

Importance of Welding

Why is welding important?

Weld Size: Is Bigger Better?

It is easier for designers to see the whole picture whereas welders and shipfitters normally only see the area in which they are working.

Therefore, in designing welded connections designers should consider the work necessary for the shipfitter and the welder as well as specify the amount and size of weld actually required per design specifications.

Welders and shipfitters should follow the engineering drawings and instructions as closely as possible so the overall project is successful and meets expected financial goals. This is important for the company and competition for future work.

Weld Size: Is Bigger Better?

Almost any weld can be made in any material in any position. A number of factors can affect the cost of producing a weld. Welding to the design specified size is one major way to control welding cost.

Reducing the groove angle can decrease the welding filler metal required to complete the weld as well as decrease the time required to fill the larger groove opening.

Weld Size: Is Bigger Better?

- On thin material, smaller welds can actually have increased strength because the weld cools faster which means harder weld metal in higher strength

- Overwelding on thin plate or creating an additional pass adds heat and distortion without improving the strength of the plate

Overwelding vs. Underwelding

Overwelding and under welding each present their own set of problems. In the following section, we will examine both and their overall effects on the cost and quality of the project.

Despite common belief by some that more is better, the cost of over and under welding both add non-valve as time and labor are drastically impacted. Labor is the most significant of the cost.

Cumulative Fillet Weld Time (hrs) Based on 100ft of Weld

Weld Size	Weld Passes	Flat (16 ft/hr)	Vertical (8 ft/hr)	Overhead (4 ft/hr)
3/16”	1	6.25	12.5	25
3/8”	2	13.5	27	54
5/8”	3	20.5	41.5	83

Note: Weld prep for additional pass ≈ 15% weld time

Weld Distortion

What is weld distortion?

- The alteration of the design shape (or other characteristic) of an object

What is distortion control?

- The process of controlling the potential distortion in an object, such as distortion in a weldment caused by welding

Weld Distortion

What is residual stress?

- Stress that remains after the original cause of the stresses has been removed.

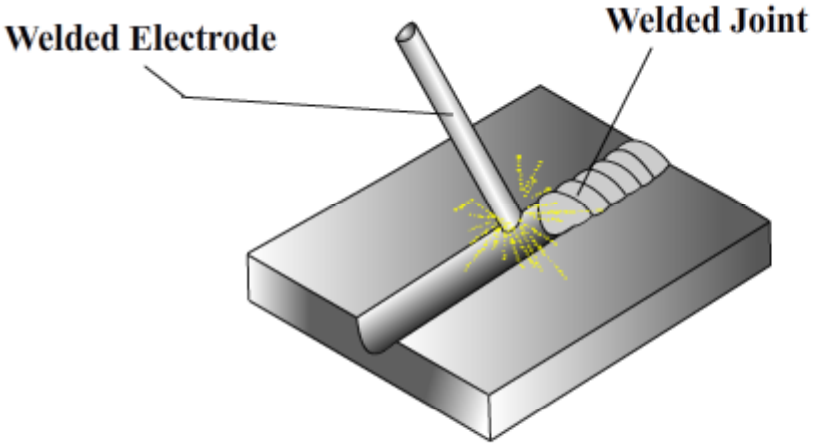
- Due to the moving heat of a welding arc, the plate heats and cools at different rates in certain areas, leaving residual stresses in the material

- Distortion is closely related to the amount of residual stress and the degree of joint restraint during the welding process

Weld Distortion

What causes distortion?

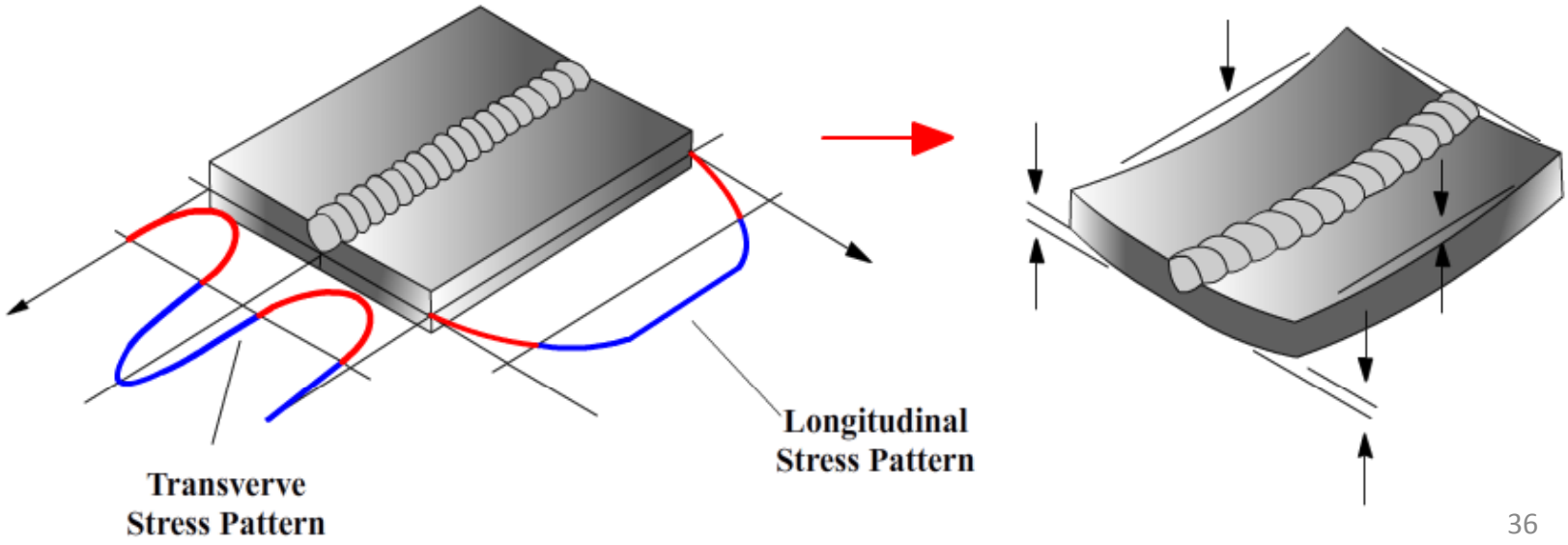
- As welding heats the material, joints fuse together causing a highly localized heated area. This results in non-uniform stresses setting up in the material because of the expansion and contraction of the heated material



Weld Distortion

What causes distortion?

Initially, stresses are created in the surrounding cold metal when the weld pool is formed as the heat affected zone (HAZ) next to the weld pool expands. Additional stresses occur during the contraction of the weld metal and the cooling of the HAZ is resisted by the bulk of the cold metal.

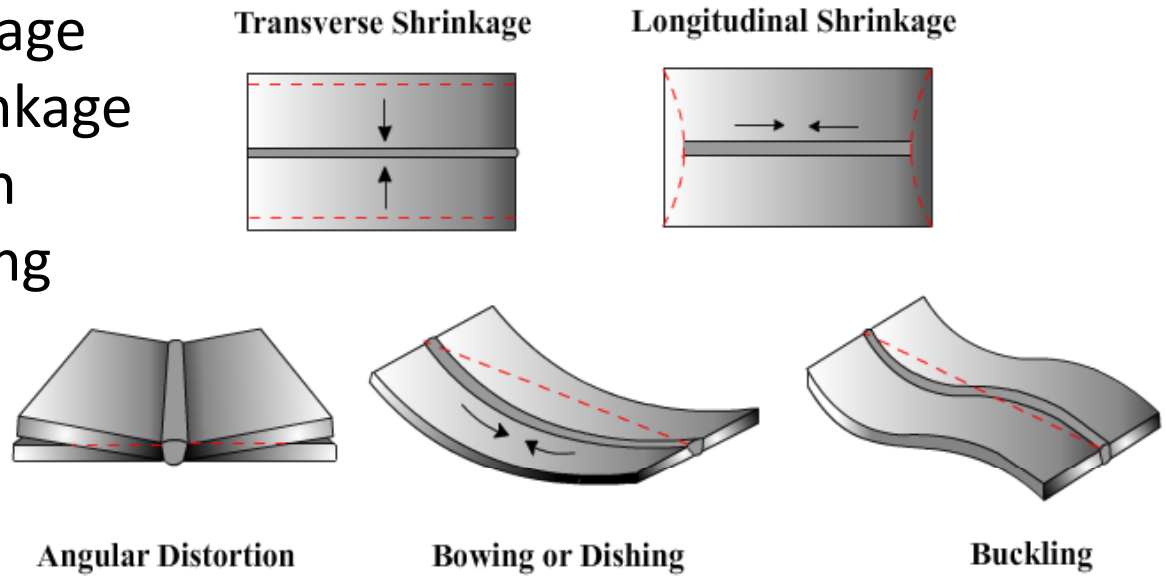


Types of Distortion

There are five forms of distortion. Two or more types of distortion may occur at the same time.

The types of distortion are:

- Transverse shrinkage
- Longitudinal shrinkage
- Angular distortion
- Bowing and dishing
- Buckling

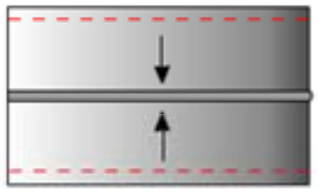


Transverse Shrinkage

What causes transverse shrinkage?

- The majority of transverse shrinkage is caused by welding in the longitudinal direction
- This type of distortion is primarily dependent on the cross-sectional area of the joint.
- The bigger the weld, the greater the shrinkage

Transverse Shrinkage

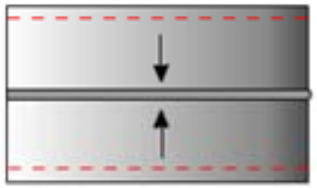


Transverse Shrinkage

What prevention measures can be taken?

- Lower heat input (reduce weld size, increase travel speed) will reduce the amount of shrinkage
- Cannot be totally avoided but it isn't necessary bad if it is controlled
- Balanced heat input using recommended weld sequences

Transverse Shrinkage



Transverse Shrinkage

What correction measures are necessary?

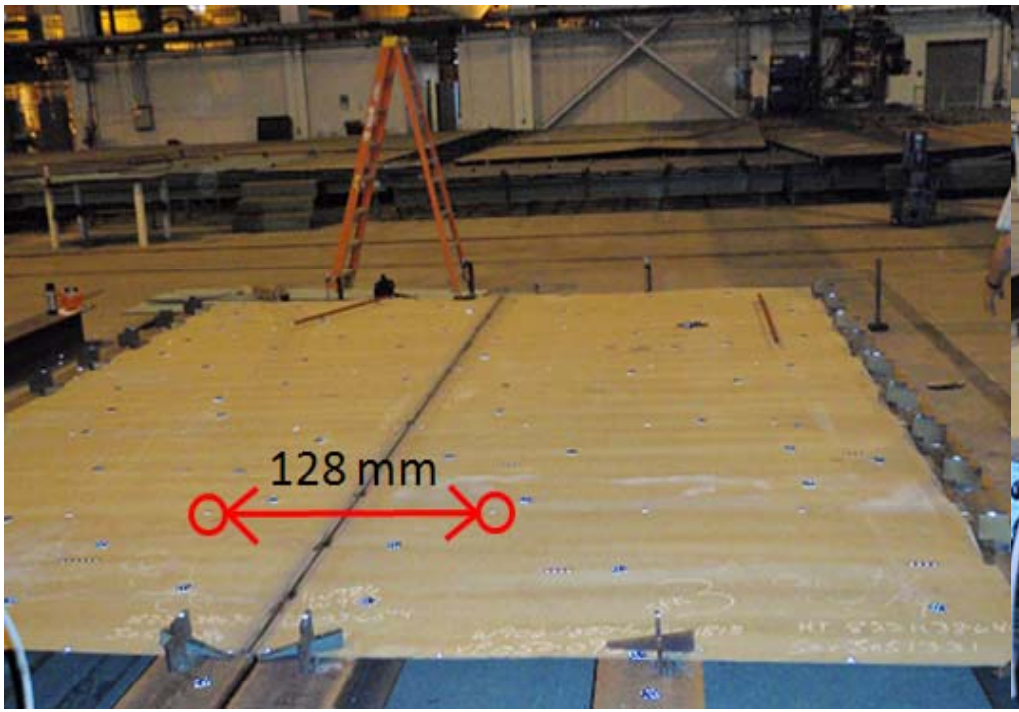
- If the amount of shrinkage exceeds the amount of stock left to account for shrinkage, costly rework may be necessary
- If the overall dimensions are shorter than the design tolerance, weld buttering (cladding) may be needed to make up the gap difference
- Severe cases may require insert pieces added at the end joint, often late in construction

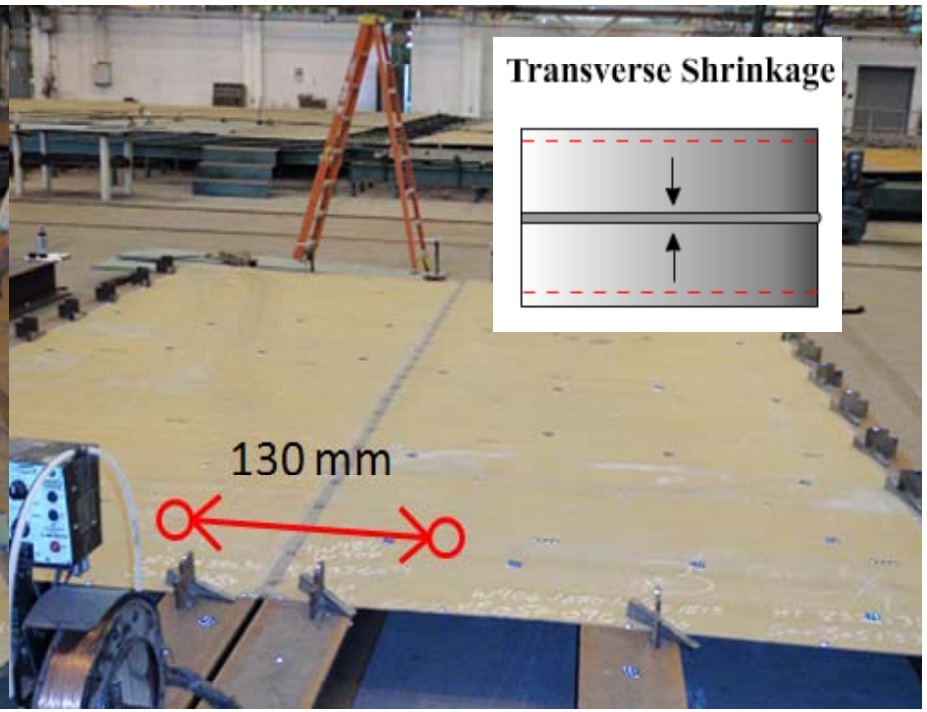
Goal for controlling shrinkage

- Achieve “Neat Construction.” Account for shrinkage values and avoid the need to add and trim excess stock

These corrections are extremely costly and decrease quality

Transverse Shrinkage





After Seam Fitting and Tack Welds

After Seam Welding

2 mm transverse shrinkage across longitudinal seam after welding
(Welded with double sided SAW tractor)

Longitudinal Shrinkage

What causes longitudinal shrinkage?

- Majority of longitudinal shrinkage is shrinkage along the length of the weld
- Shrinkage that occurs parallel with the weld
- This type of weld distortion is dependent on the length as well as the cross sectional area of the plate structure

Longitudinal Shrinkage

Longitudinal Shrinkage

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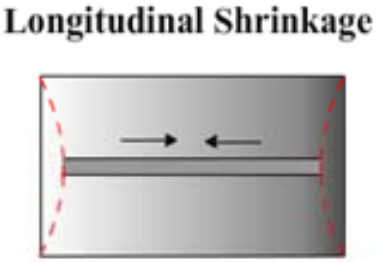

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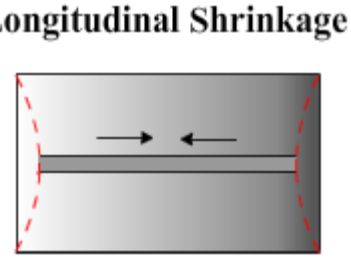
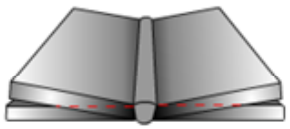


Angular Distortion

What causes angular distortion?

- The weld cross-section is not balanced on the weldment perimeter causing features in the section to rotate with respect to each other

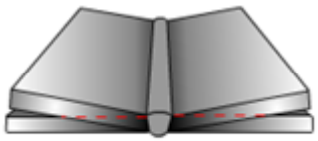


Angular Distortion

Angular Distortion

What prevention measures can be taken?

- Using tack welds to set up and maintain the joint gap
- Identical components welded in a sequence that is balanced about the neutral axis
- Process and technique should aim to deposit the weld metal as quickly as possible
- Use of proper clamping

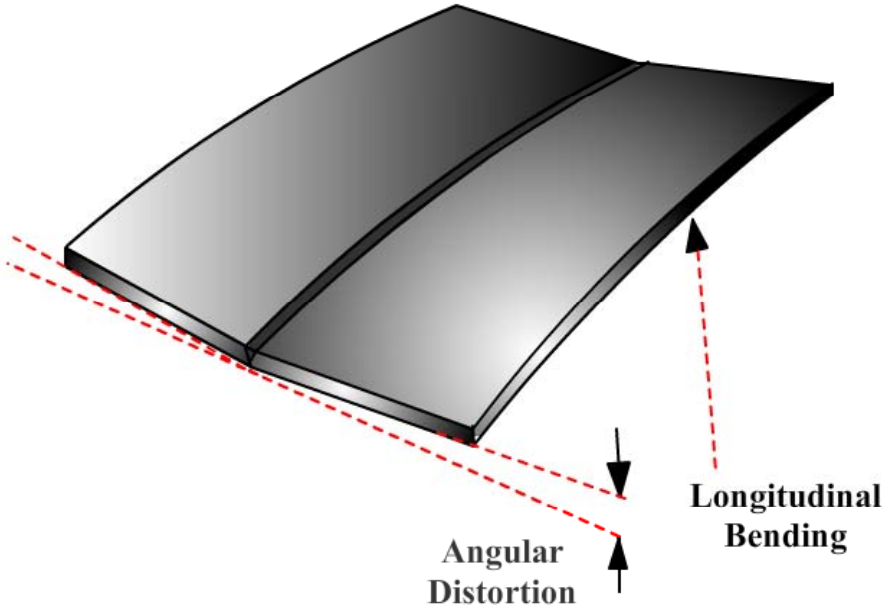


Angular Distortion

Angular Distortion

What correction measures are necessary?

- Mechanical straightening by adding strongbacks or other supports where needed
- Flame straightening

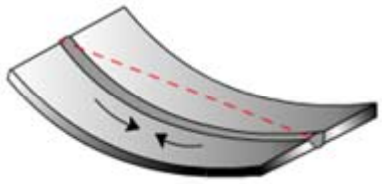


Angular Distortion

Bowing Distortion

What causes bowing distortion?

- Bowing distortion occurs when the weld is not balanced with respect to the neutral axis of the cross section affecting the straightness of the weldment so that longitudinal shrinkage in the welds bends the section into a curved shape



Bowing or Dishing

Bowing Distortion

What prevention measures can be taken?

- Weld sequencing and back-step welding should be used to minimize bowing
- Adequate plate restraint prior to welding

Bowing Distortion

What correction measures are necessary?

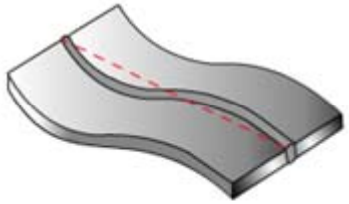
- Correction measures can be mechanical or thermal
  - Mechanical is preferable when shrinkage from flame straightening is a concern. However, cracking formation need to be prevented
  - Mechanical straightening requires using force (wedge, pneumatic ram, etc.) to push the bowing area flat and a strongback or header is welded to hold the panel flat when the force is released
  - In the case of severe bowing on a T beam, the distortion needs to be corrected thermally with flame straightening as mechanically straightening it would cause a T beam to ripple and become unstable

Bowing and Dishing

Buckling Distortion

What causes buckling distortion?

- It is the most violent of the out-of-plane distortions
- Is extremely sensitive to initial stress conditions
- Buckling distortion is usually more prevalent in thin metal structures

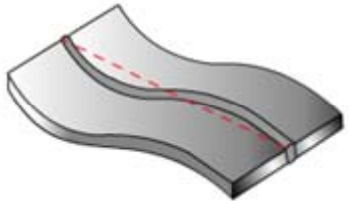


Buckling

Buckling Distortion

What prevention measures can be taken?

- Following proper welding sequences (In general, weld steps should be progressed from the center of the work outward)
- Adequate clamps/restraints on the panel edge and near welding area PRIOR to welding
- Achieving proper fit-up to ensure weld size control and limit residual stress
- WELDING TO DESIGN SIZE

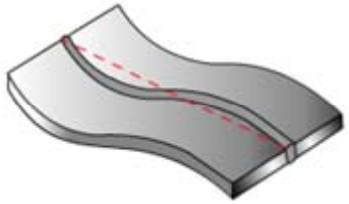


Buckling

Buckling Distortion

What correction measures are necessary?

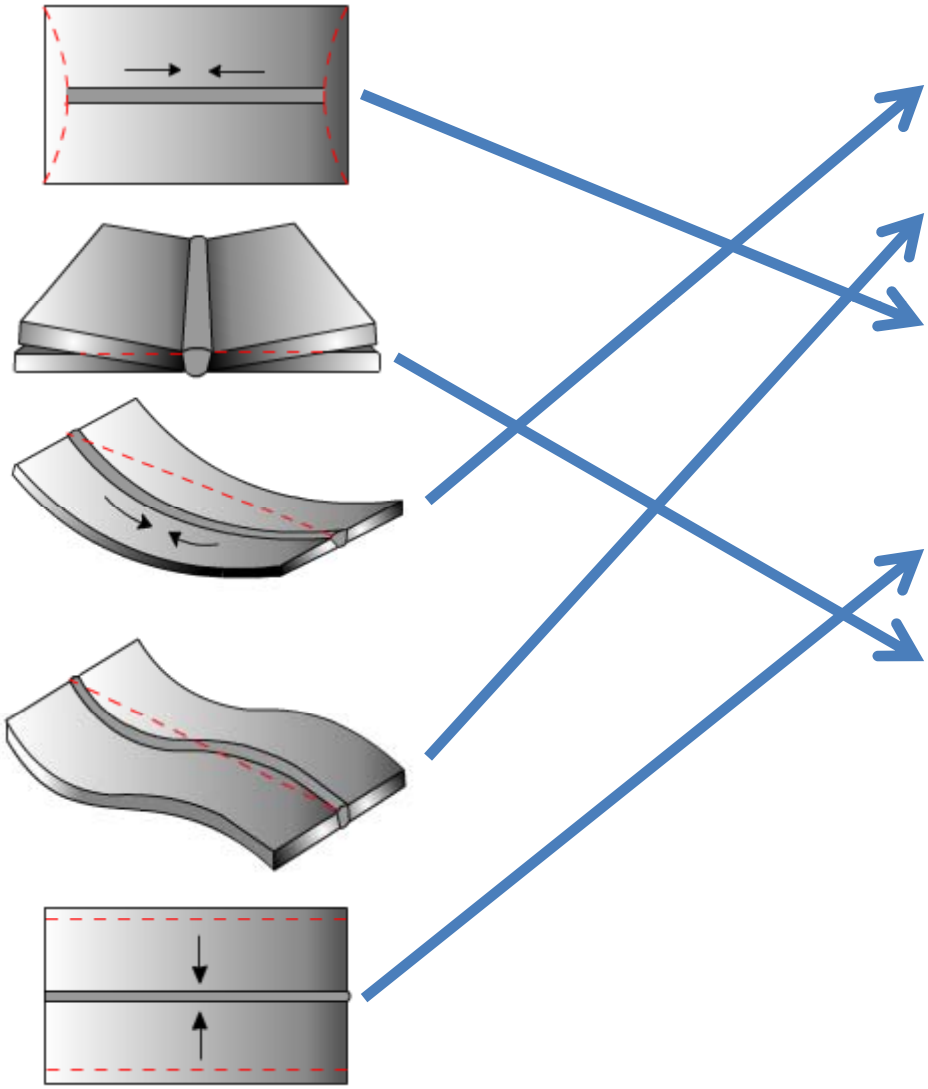
- Thermal (Flame Straightening) works by inducing additional heat into the steel to generate a shrinkage force that will pull the distortion out
- Displacement in buckling mode are not always repeatable, so rework is usually the necessary remedy



Buckling

Buckling Distortion

Knowledge Check

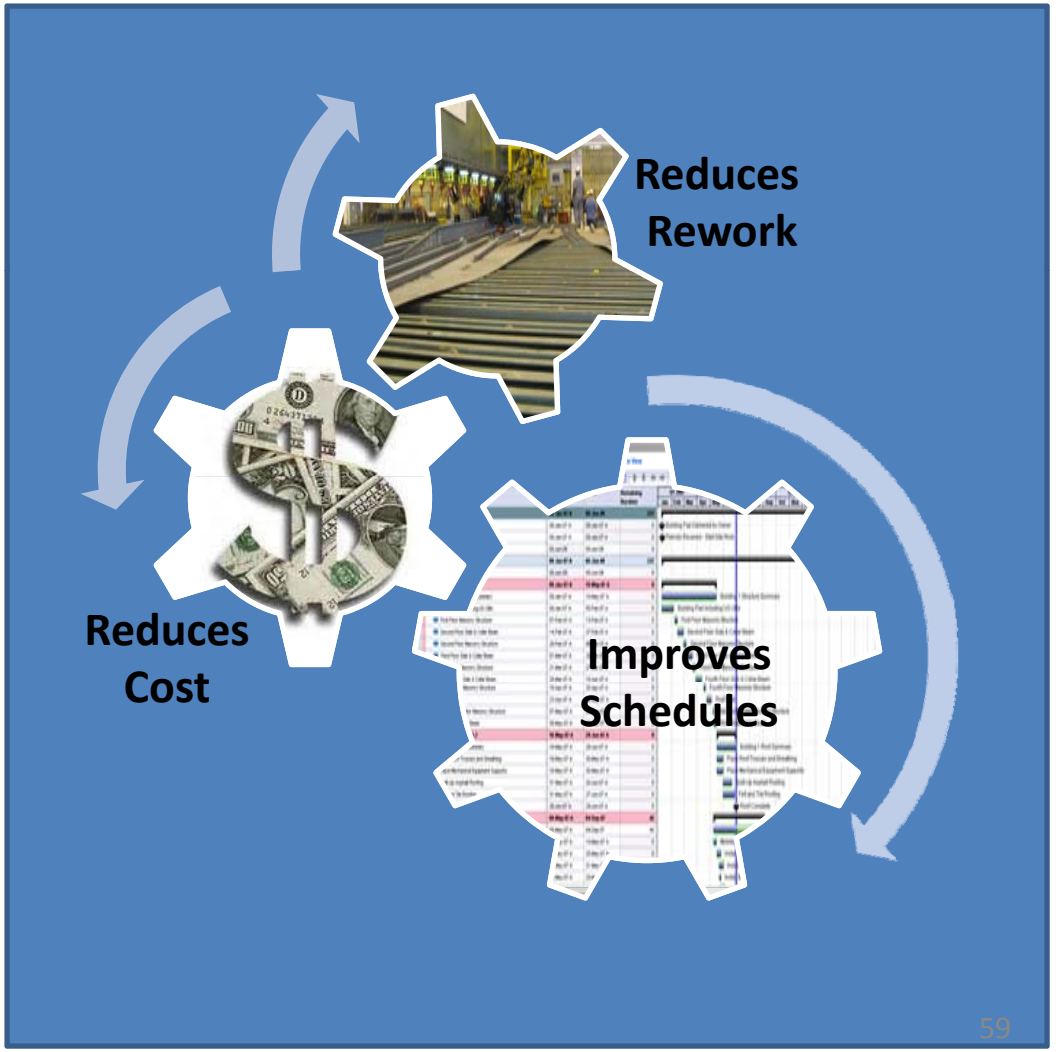


- Bowing Distortion
- Buckling Distortion
- Longitudinal Shrinkage
- Transverse Shrinkage
- Angular Distortion

Why is Distortion Control Important?

Employees taking a proactive approach to distortion control reduces production costs

Why would you say it is important to reduce costs?



Thin Steel Welding Implementation Items

Increase fitter/welder communication and feedback:

- Benefits:
  - Increased final weld quality and part weldability
  - Increased workmanship and accountability
  - Remedy problems created by others that may unknowingly cause problems downstream

Thin Steel Welding Implementation Items

Increase welding automation:

- Benefits:
  - Superior weld quality, improved process time
  - More consistent control of welding parameters
  - Automated welding is generally faster than manual

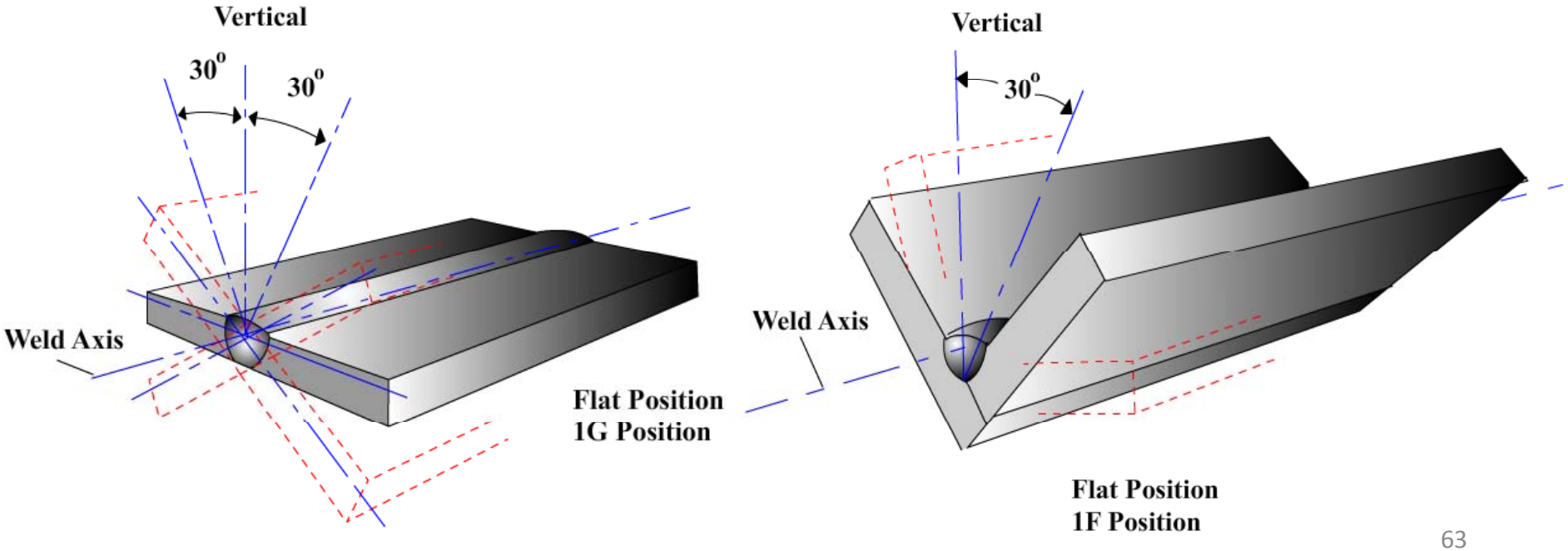
Thin Steel Welding Implementation Items

Incorporate weld size into welder certification process:

- Benefits:
  - Incorporating a weld-to-design tolerance prior to being released to the field promotes a weld size conscious approach from the start
  - **MIL-STD-1628 Rev B** will have an underweld tolerance and is awaiting final approval

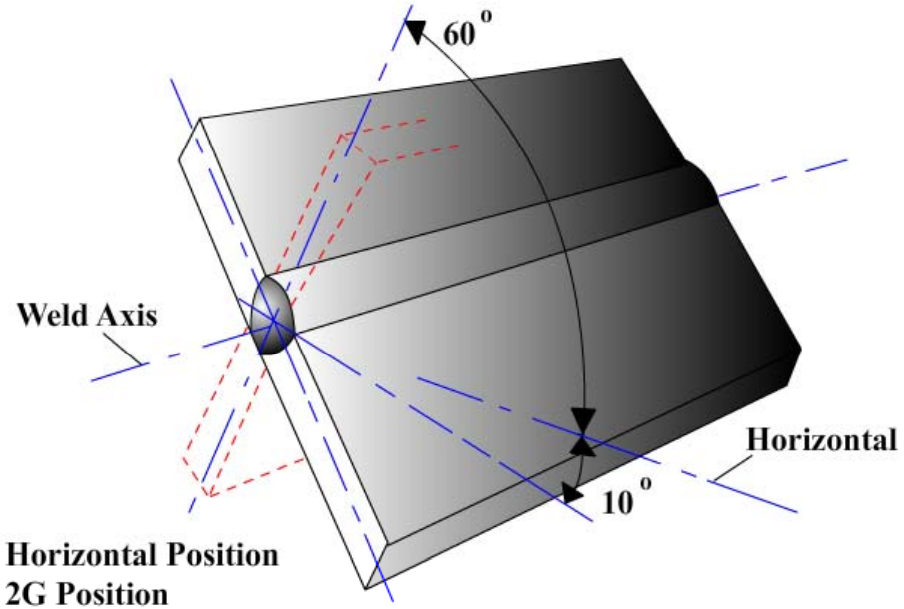
Weld Positions

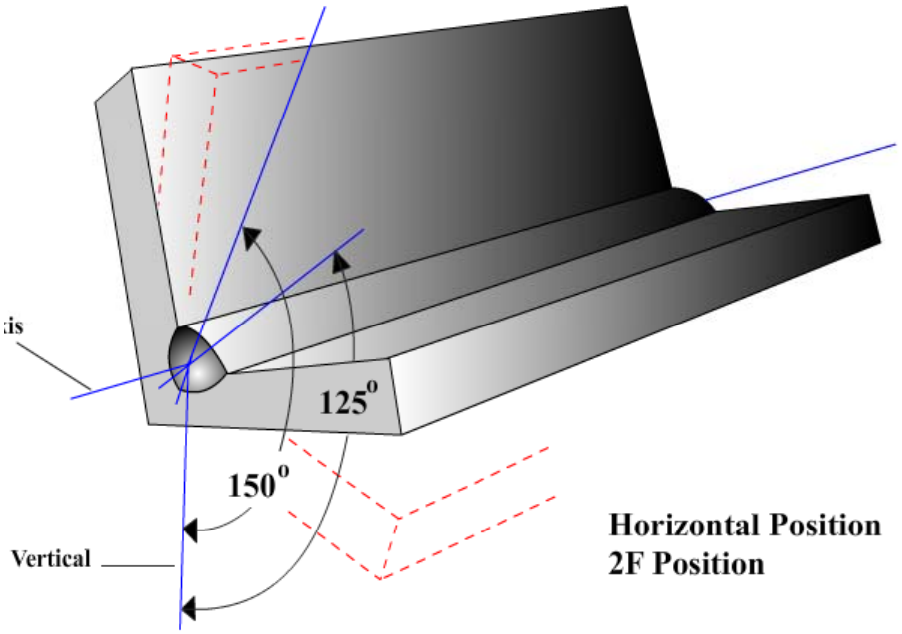
- There are four basic positions of welding that are employed in structural fabrication.
- Flat position – used to weld from the upper side of the joint – the face of the weld is approximately horizontal.



Weld Positions

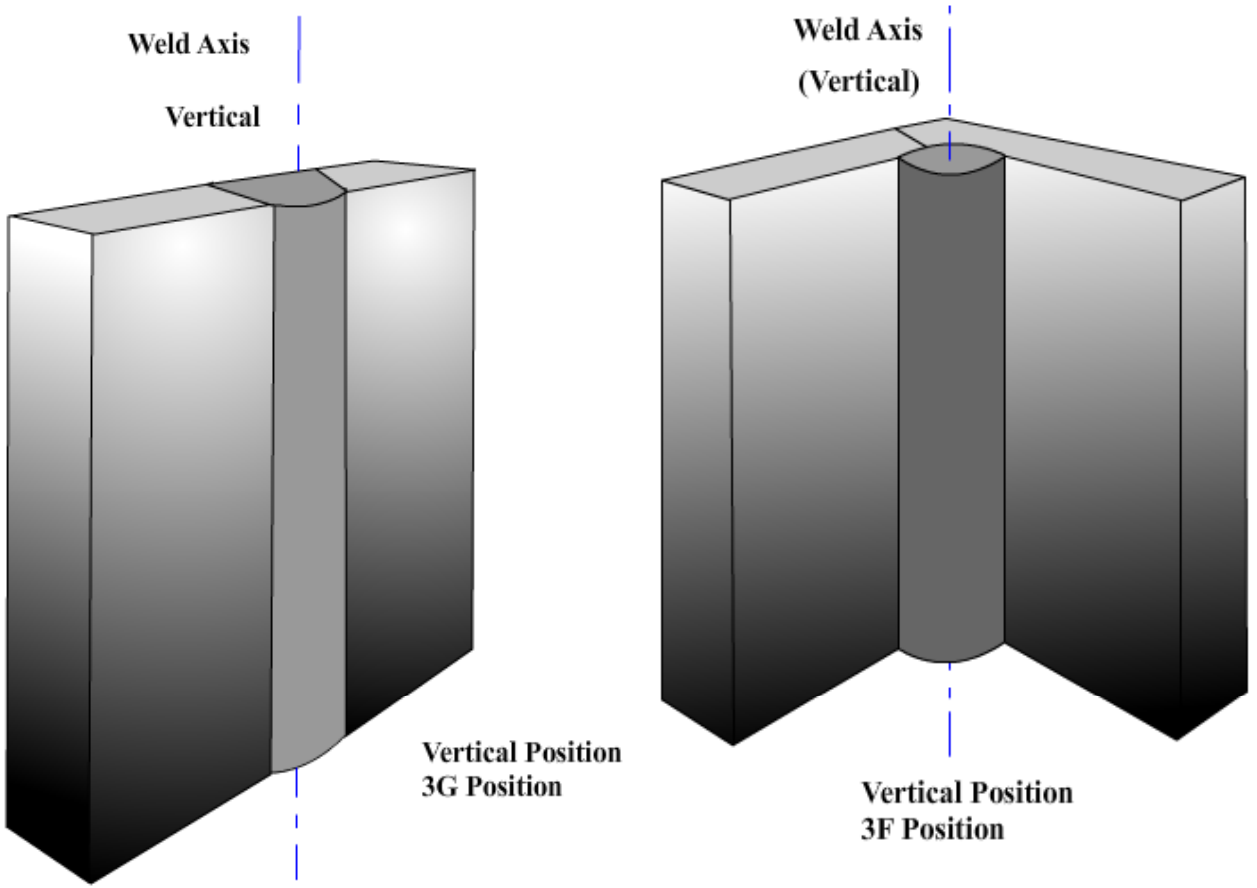
- Horizontal Position – used when welding is performed on the upper side of an approximately horizontal surface and against an approximately vertical surface.





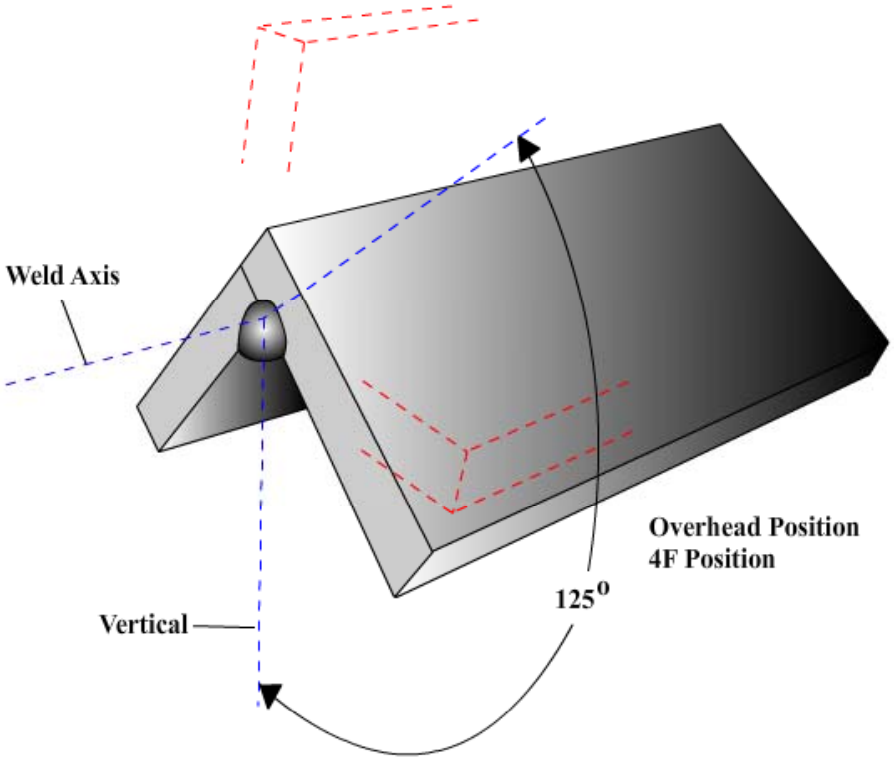
Weld Positions

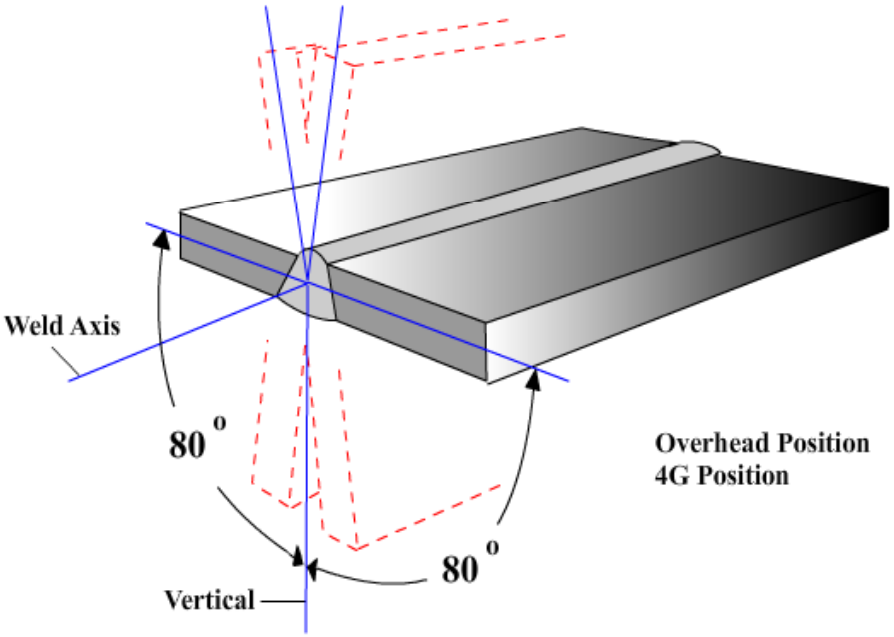
- Vertical Position – in structural welding, the position of welding in which the axis of the weld is approximately verti



Weld Positions

- Overhead Position – the position in which welding is performed from the underside of the joint





Which Welding Process to Use?

The type of weld process used is normally a decision made by the foreman but the welder should understand why a particular process was chosen.

Welding Processes

Manual welding processes include:

- SMAW (stick welding)
- GTAW (TIG) welding

Semi-automatic welding processes include:

- GMAW (MIG)
- Flux-Core

Machine Welding processes include:

- Flux-core
- Sub-arc welding (SAW)

Shielded Metal Arc (SMAW)

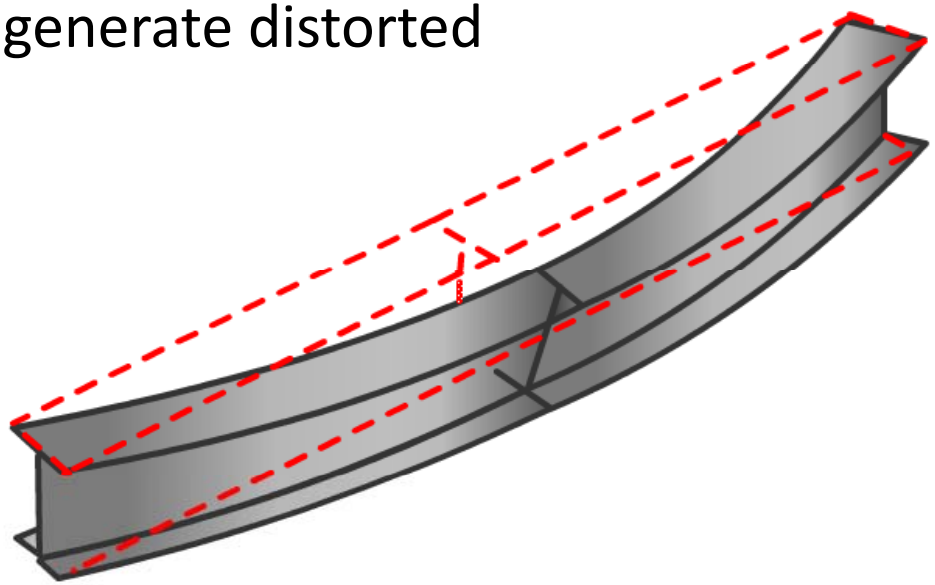
Advantages

- Versatility – readily applied to a variety of applications and a wide choice of electrodes
- Completely Manual
- Low cost
- Suitable for out-of-position welding
- Not very sensitive to environmental conditions

SMAW (Stick Welding)

Disadvantages

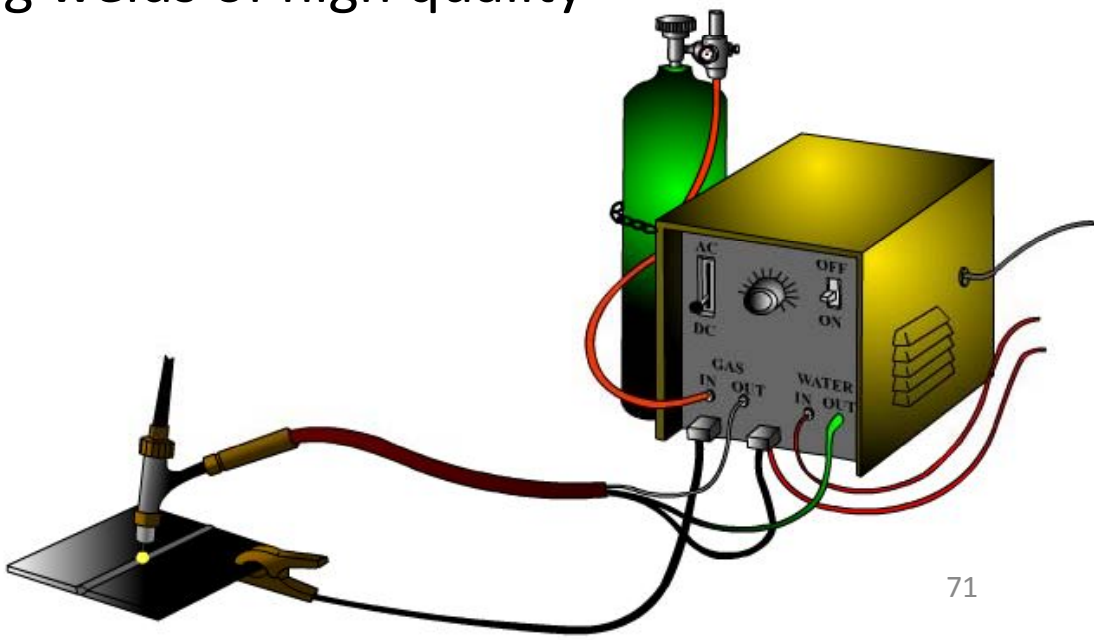
- Welding thin materials may be difficult even for skilled welders
- Many starts and stops for the length of weld
- Slow travel speed will generate distorted members



Gas Tungsten Arc (GTAW)

Advantages

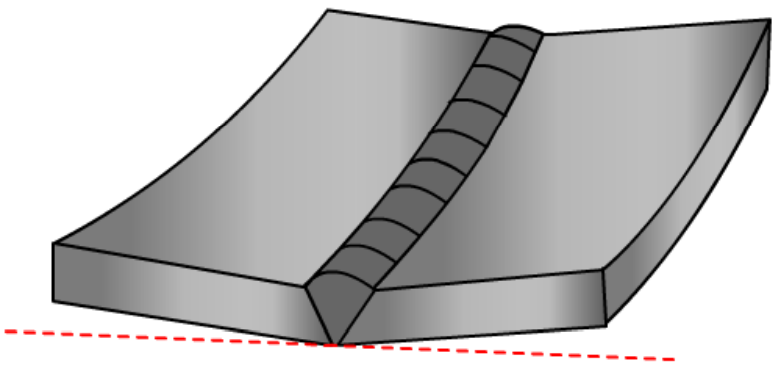
- Applicable to a very wide range of materials
- Especially good for welding thin section pipes and sheetmetal applications
- Capable of producing welds of high quality and appearance



Gas Tungsten Arc (GTAW)

Disadvantages

- Very slow travel speed
- Very low deposition rate
- Can generate large amounts of distortion if used for thicker parts



Gas Metal Arc Welding (GMAW)

Advantages

- Higher productivity due to time saved by not having to constantly change electrodes or chip away slag
- Clean and efficient
- Versatile
- Faster Welding Speed

  than SAW or GMAW

GMAW (MIG Welding)

Disadvantages

- Costly
- Limited positions fluidity of the welding puddle and the high heat rule it out for vertical and overhead welding
- Unsuitable for outdoor welding
- Fast cooling rates since not covered by slag

FCAW (Flux-core)

Advantages

- Versatility – suitable for a variety of positions and applications
- Enables “one process” operation for individual projects – simplifies training, supervision and logistics
- Capable of relatively high deposition

FCAW Process

Disadvantages

- Incorrect selection of consumables and parameters may lead to lower weld toughness
- Fume extraction may be required

Common Problems

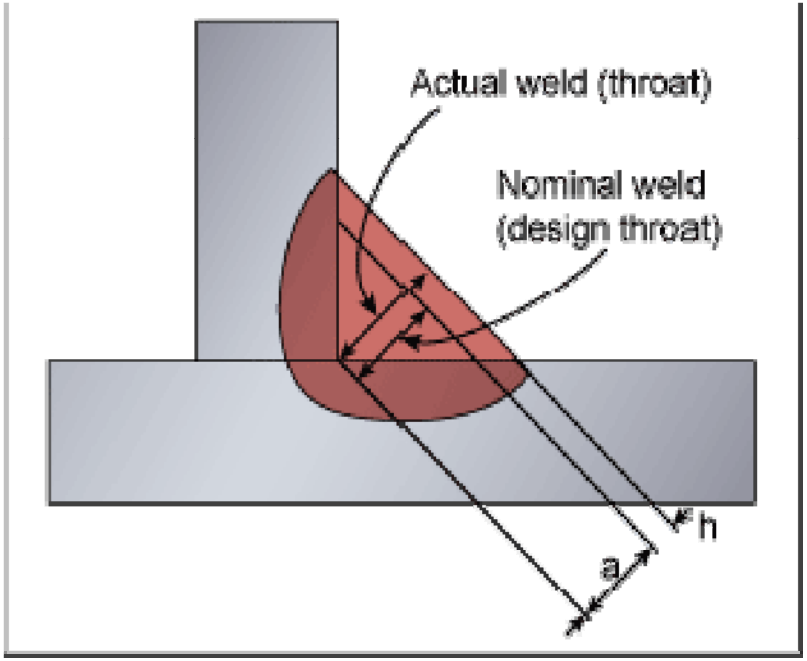
Common Manual/Semi-Automatic problems

- Overwelding
- Weld Gauge Use and Misuse
- Proper Welding and Equipment Adjustments

Over Welding

Common causes are:

- Poor fit quality
- High welding current
- Slow travel speeds
- Some are supervision related (e.g. *'to be safe make this fillet weld bigger by x mm')*

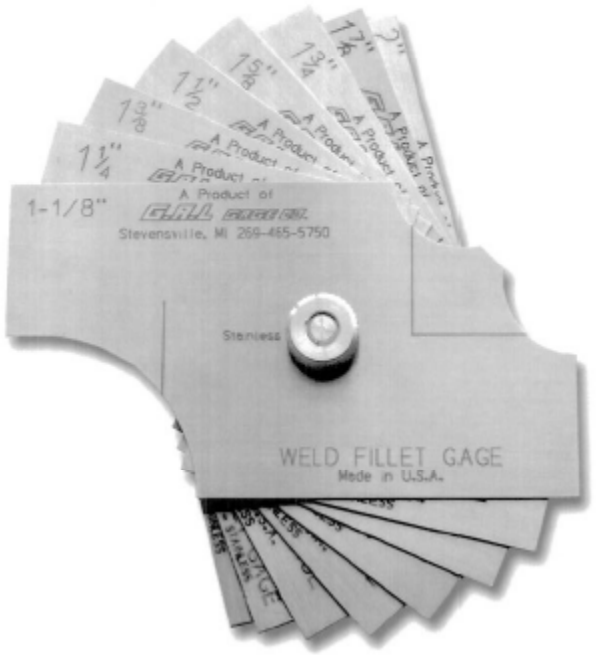


Avoidance:

- Adhere to the specified welding procedure and parameters
- Do not add to the specified weld size
- Where possible use automated welding processes

Measuring Tools

- The fillet weld gauge is one of the most often used measuring devices to measure the throat and leg of a fillet weld
  - The size of the actual weld is checked by using one or more gauges to compare the size of the weld to the size of the individual gauges.
  - It is commonly used incorrectly

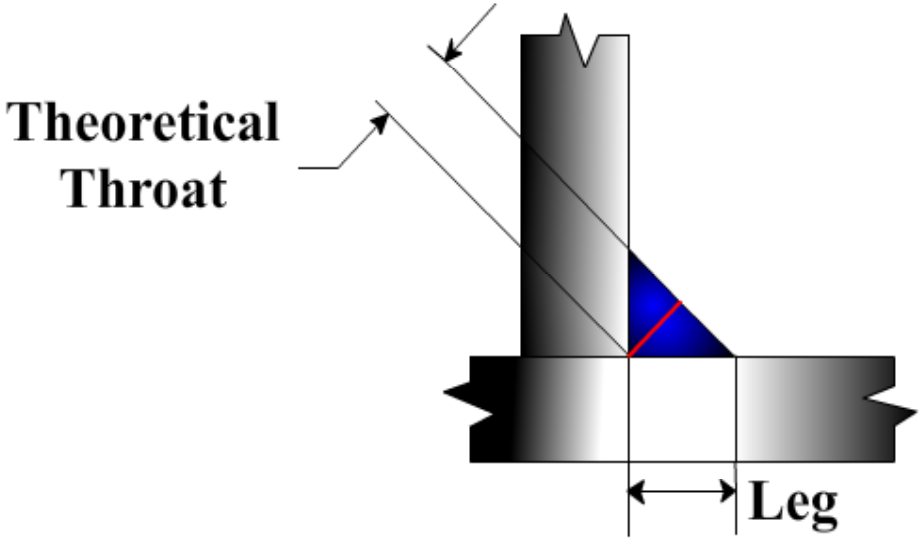


Leaf Style Fillet Gauge

Video

Measuring Tools

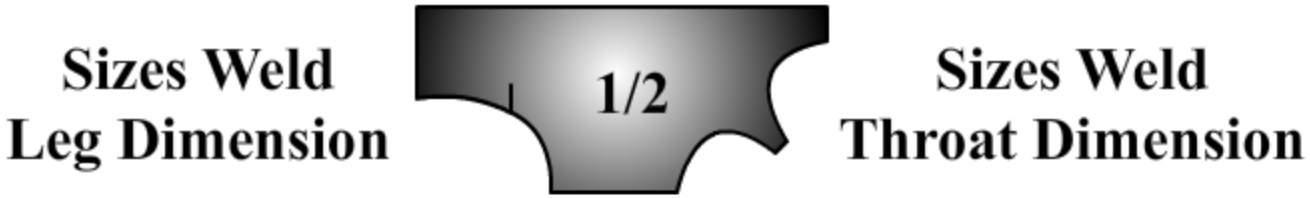
- Fillet welds have a cross section that is essentially a triangle.
- If the two members being joined are at right angles to each other, the cross section of the fillet weld resembles a right triangle



When possible the fillet weld gauge should be read at eye level as size readings look different depending on the angle at which they are being read.

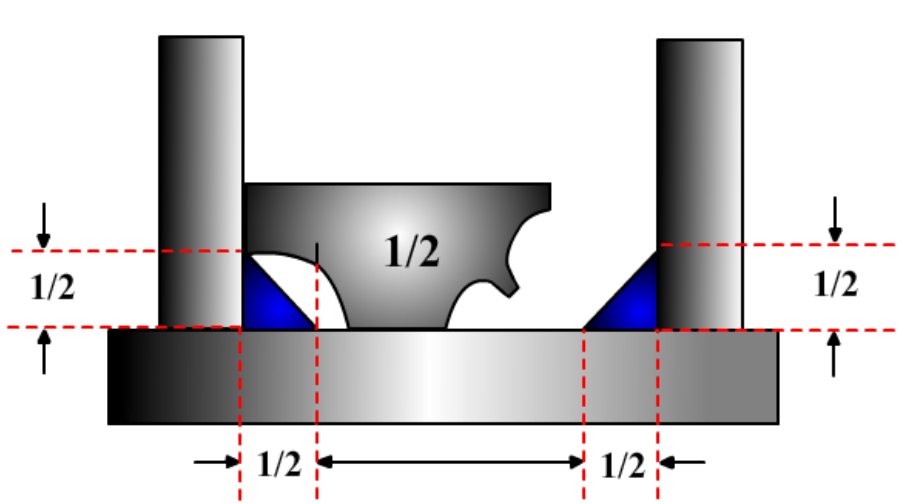
Measuring Tools

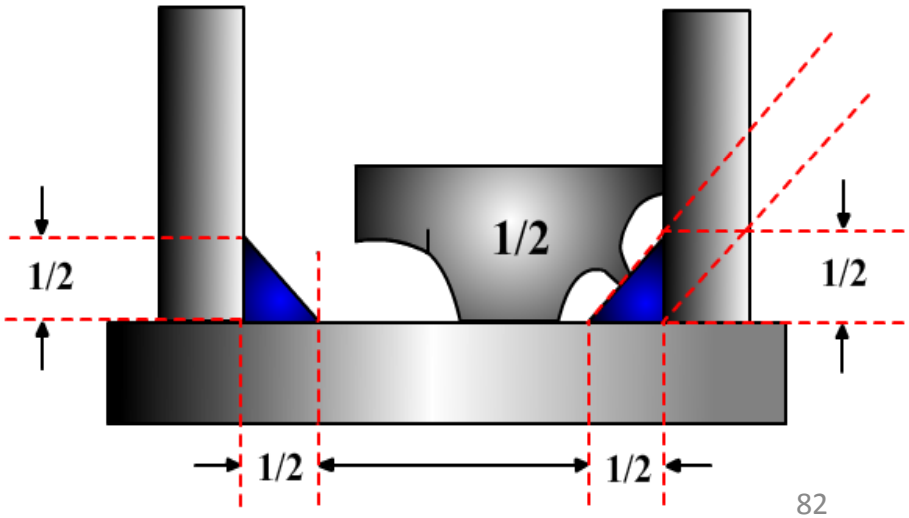
- A leaf style fillet weld gauge is commonly used to measure the size of the fillet weld
- Leaf style fillet weld gauges typically come in 1/16 inch increments for weld sizes 1/2 inch and smaller, and in 1/8 inch increments for sizes 5/8 inch and larger
- The basic leaf style fillet gauge has two ends, one for sizing the weld leg and the other for sizing the throat (based on the equivalent leg size for the right triangle)



Measuring Tools

For this example, ideally both the weld legs would be exactly 1/2 inch while the throat would measure exactly 0.354 inch. The manufacturers print 1/2 inch on the right end of the gauge because the fillet throat is the proper size for a fillet weld with 1/2 inch legs. That saves the time needed to calculate the required throat dimension for each leg dimension.

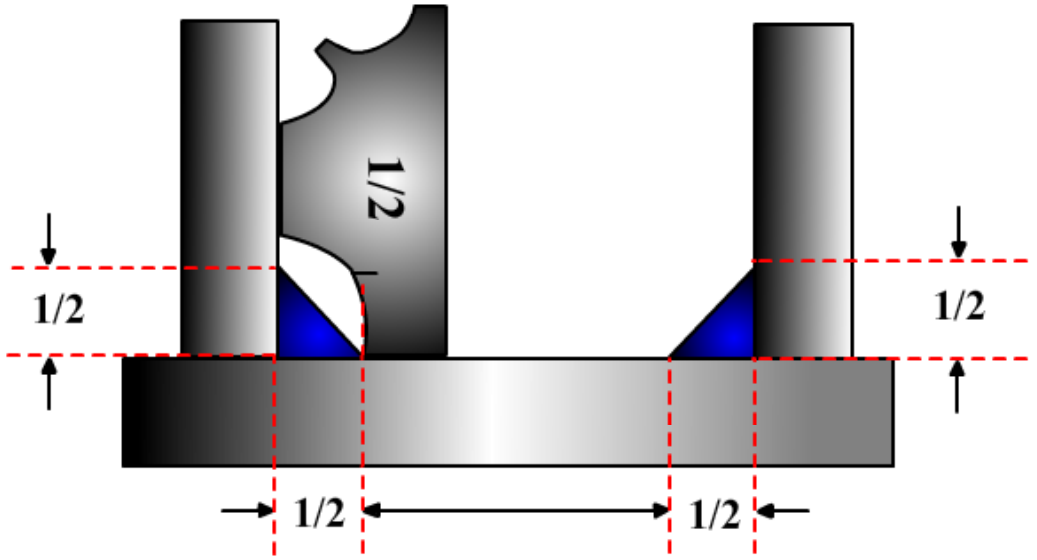




Measuring Tools

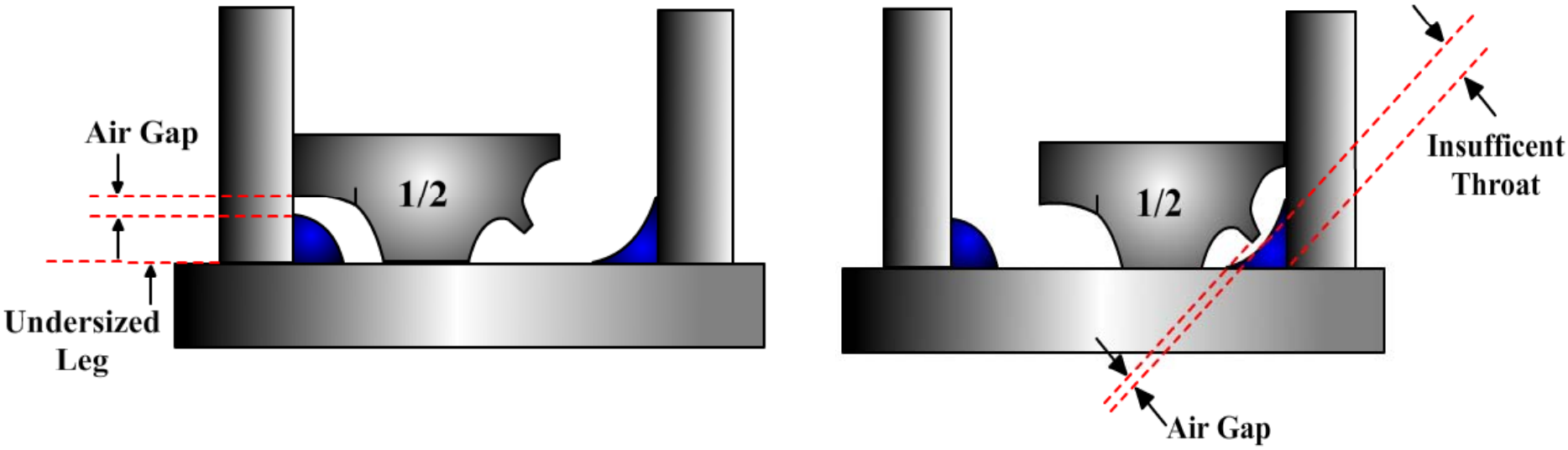
To measure a vertical fillet leg the gauge has to be turned to verify the horizontal fillet leg is the proper size.

Do not assume the two legs are the same size by design or as dictated by the welder's skill, both horizontal and vertical legs must be checked.



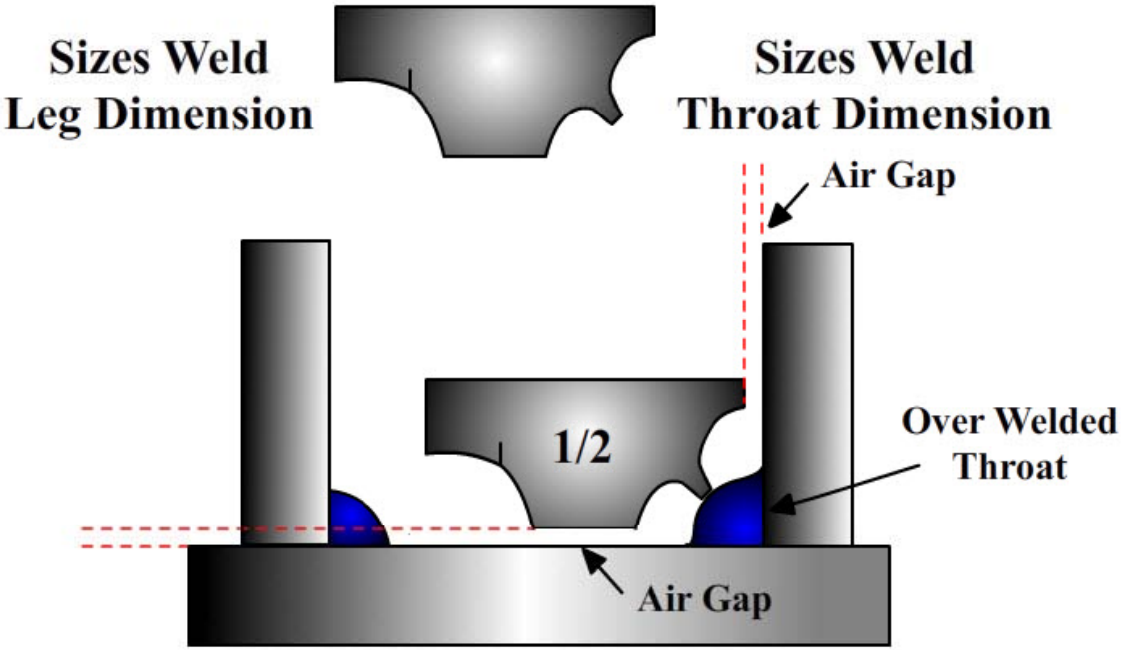
Measuring Tools

Checking the perfect weld is easy, but things get a little more complicated when dealing with fillet welds that are convex or concave or a combination of both.



Measuring Tools

Welders should check for oversized welds and plan a way to reduce the amount of overwelding on future work. Oversized welds add no additional strength and can cause excessive rework.

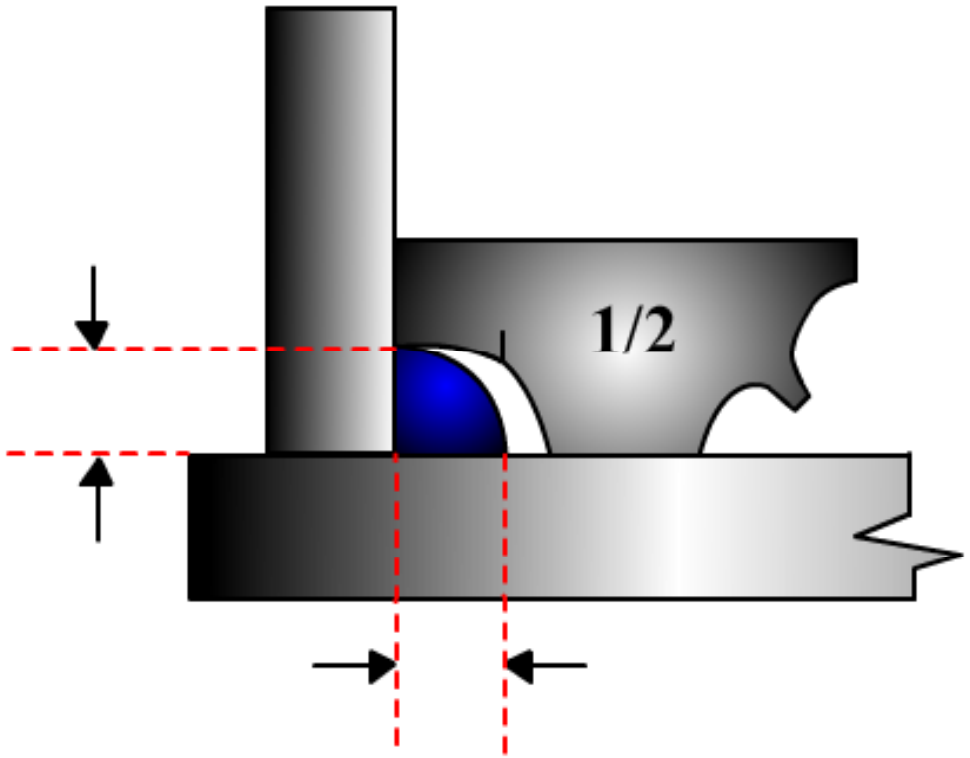


Knowledge Check

Would this convex fillet weld be considered good or bad?

If you said that it is a good fillet weld you are correct.

Good Job!



Proper Fillet Welding/Equipment Adjustments

	Fillet Weld Size		
SAW	**1/8” (3mm)**	**3/16” (5mm)**	**1/4” (6mm)**
Current (Amps)	330	330	330
Voltage (Volts)	29	29	29
Travel Speed (in/min)	48	32.5	30

PLEASE NOTE: These adjustments are only recommended as a base line for fillet welds. Settings may differ depending on individual skills and different machines

Proper Fillet Welding/Equipment Adjustments

	Fillet Weld Size		
FCAW	**1/8” (3mm)**	**3/16” (5mm)**	**1/4” (6mm)**
Current (Amps)	205	205-210	210-220
Voltage (Volts)	25	25	25-27
Travel Speed (in/min)	37.5	16.5	13-14

PLEASE NOTE: These adjustments are only recommended as a base line for fillet welds. Settings may differ depending on individual skills and different machines

Proper Fillet Welding/Equipment Adjustments

	Fillet Weld Size		
GMAW (Pulse)	**1/8” (3mm)**	**3/16” (5mm)**	**1/4” (6mm)**
Current (Amps)	N/A	200	200
Voltage (Volts)	N/A	24	24
Travel Speed (in/min)	N/A	19.5	13

PLEASE NOTE: These adjustments are only recommended as a base line for fillet welds. Settings may differ depending on individual skills and different machines

Proper Fillet Welding/Equipment Adjustments

	Fillet Weld Size		
GMAW (Aluminum)	**1/8” (3mm)**	**3/16” (5mm)**	**1/4” (6mm)**
Current (Amps)	230	230	230
Voltage (Volts)	23.5	23.5	23.7
Travel Speed (in/min)	75	57	47

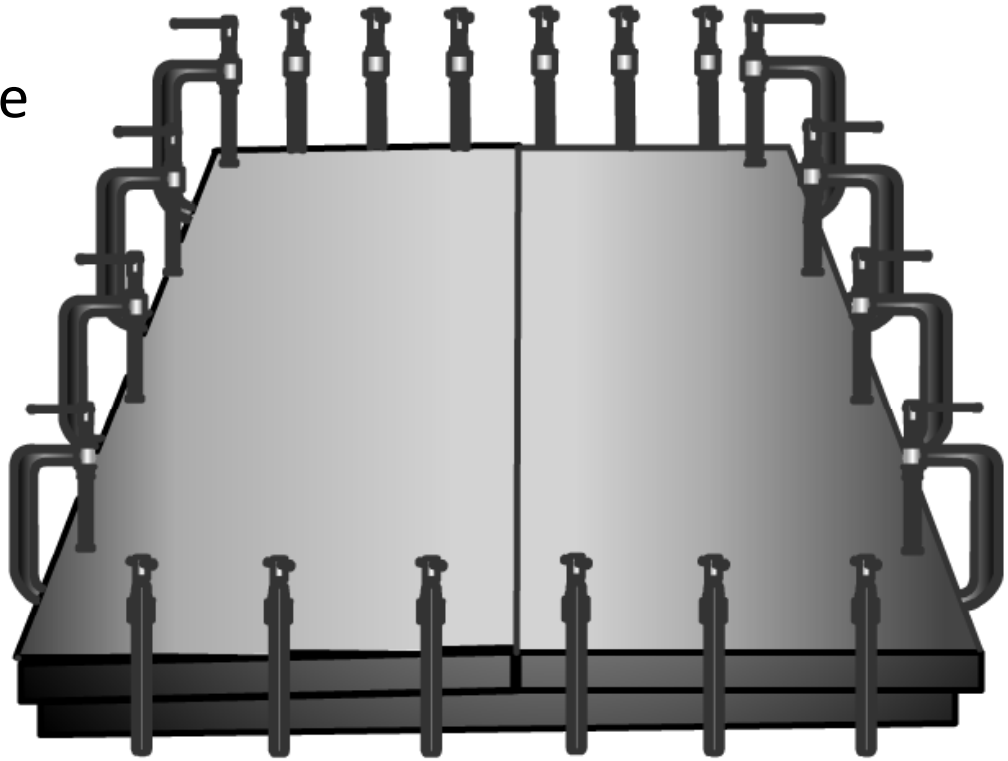
PLEASE NOTE: These adjustments are only recommended as a base line for fillet welds. Settings may differ depending on individual skills and different machines

Clamping

- Clamps should be placed as near the seams being welded as possible (ideally 2”)
- The further away a clamp is placed from the weld, the less support it provides in resisting welding distortion

Clamping

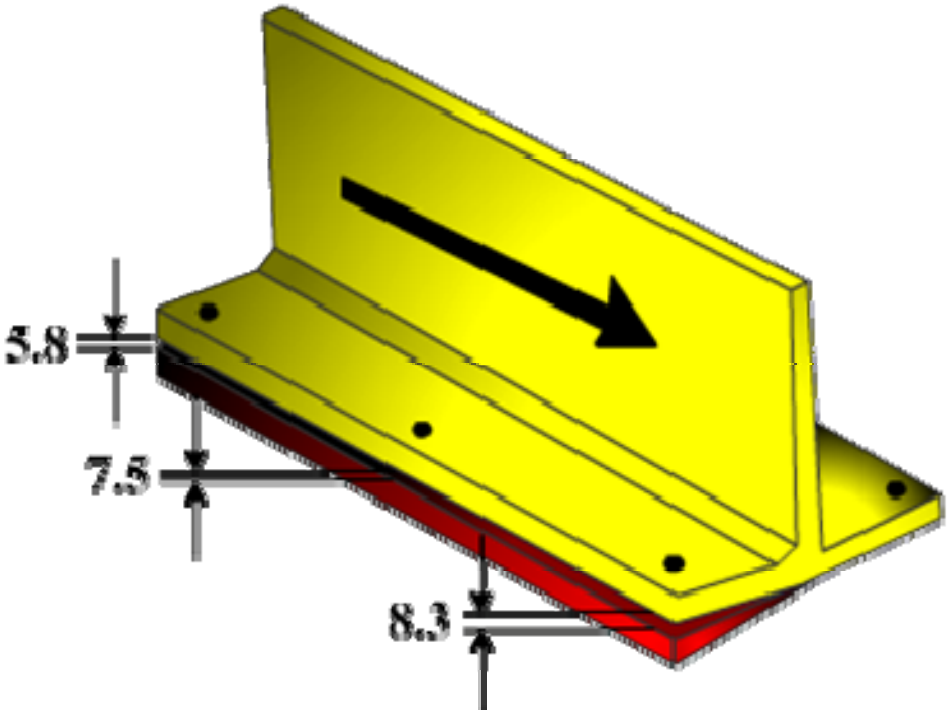
- Clamps placed around the plate perimeter will reduce the amount of edge distortion
- Clamps should remain attached until the welded area and plate edges cool below 150° F or 20 min after the welding is completed



Clamping

- Without clamping this example of a tee beam is clearly distorted:

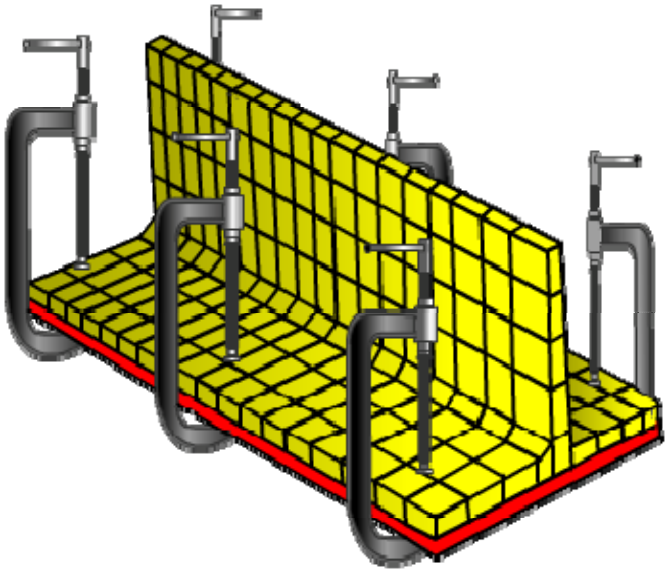
- What type of distortion is this an example of?

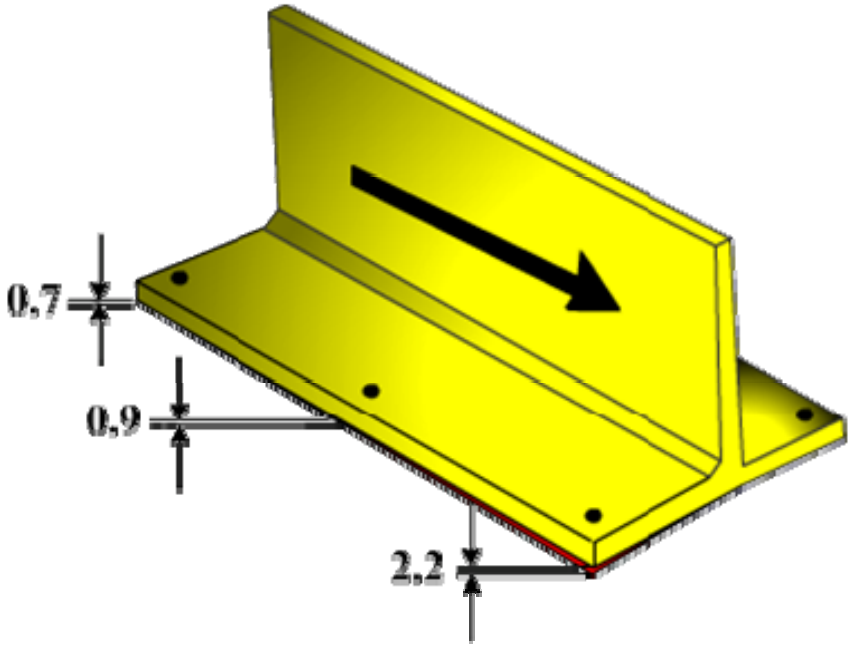


Angular Distortion

Clamping

- Distortion is dramatically reduced when clamping is used properly

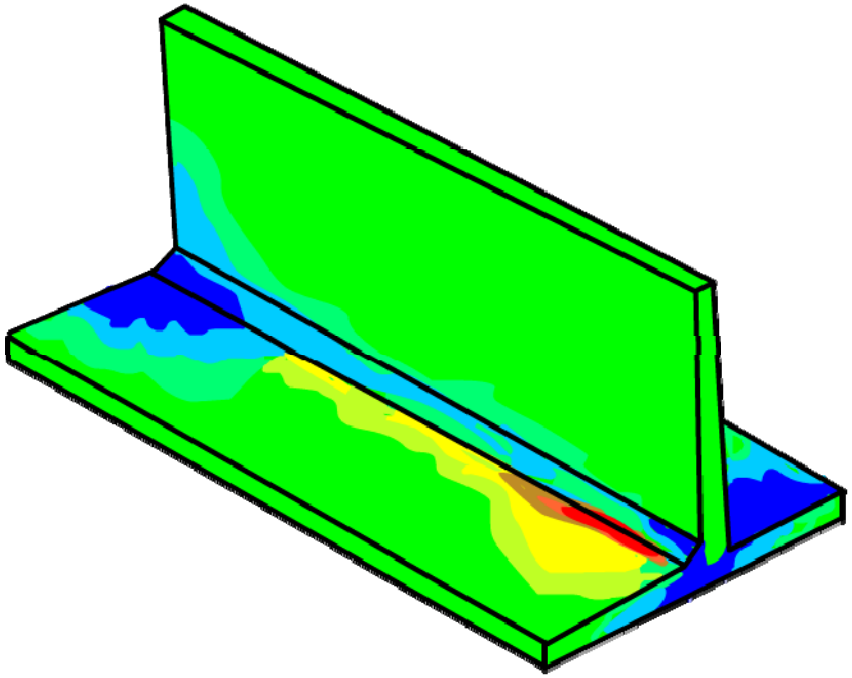




Clamping

Why did the clamping aid in controlling distortion?

- Distortion was less due to a lower final residual stress



Clamping

- Clamps are used around the panel perimeter and along the edge of cutouts
- Beam restraints are placed along the longitudinal seams prior to welding

Structural Strong-Backs

- Use externally placed stud attached fairing tools to eliminate any welding and repair to outside shell
- Improved access/reduced clean up and reusable tooling
- Effective in most locations

Structural Strong-Backs

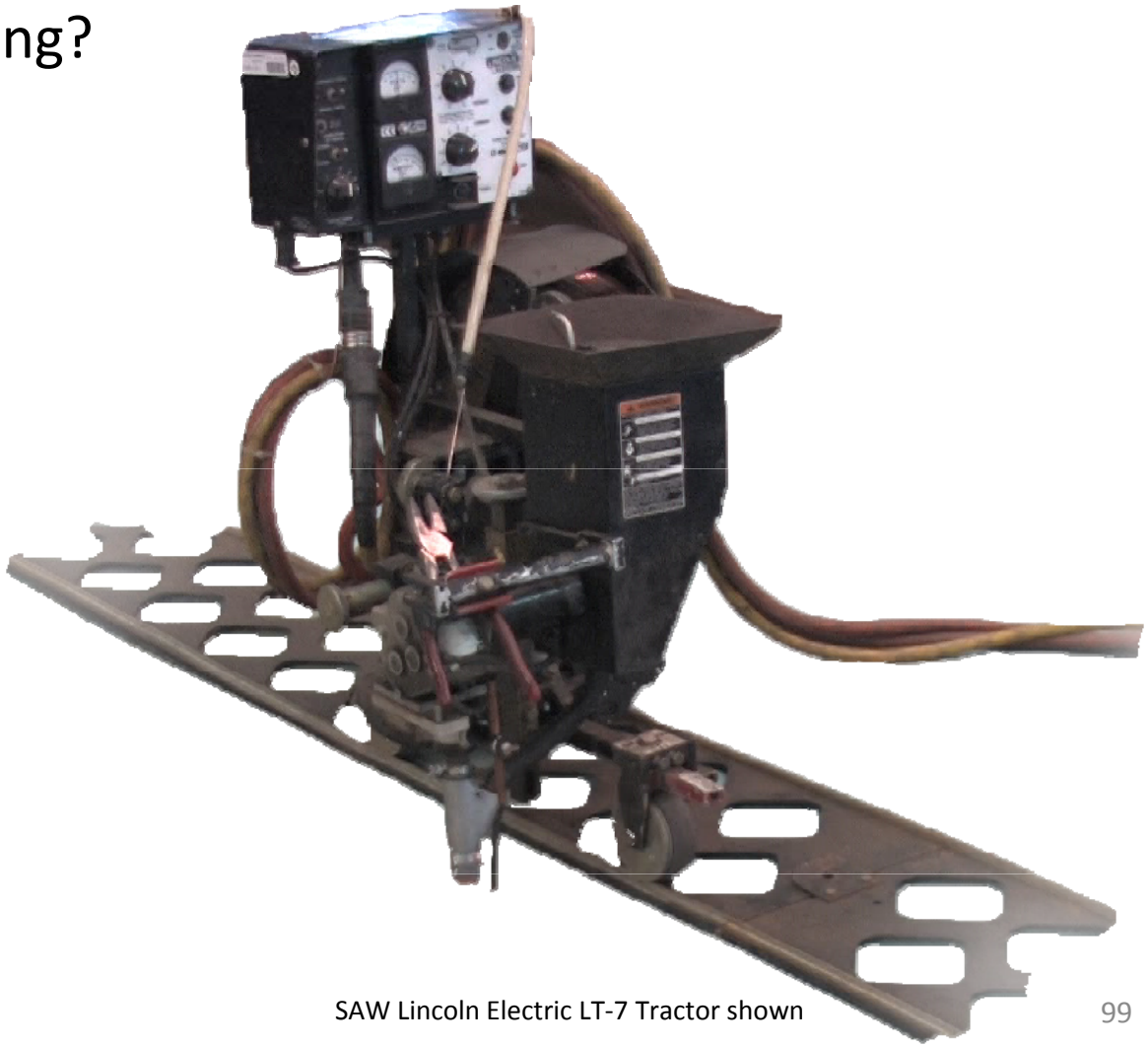
Example of Extensive Rework Needed

- Strong back could not hold the plate at the hard frames
- Plate puckered requiring back gouging of the weld and realignment of the plate

Tractor Welding

What is tractor welding?

- Advantages
- Disadvantages
- Limitations



SAW Lincoln Electric LT-7 Tractor shown

Tractor Welding

What is tractor welding?

- Tractor welding uses a self-propelled mechanized wire fed tractor that is designed for the submerged arc process

- The tractor moves along sections of track that are easily moved to the area requiring welding

Tractor Welding

The proper settings used in tractor welding depends largely on the specific application

- Welds butts, horizontal fillets and lap joints
- On most tractors, the control box is mounted to the tractor eliminating the need to return to the power source for setting adjustments
- Tracking control and self-steering in most applications allows the operator free for quality control, joint cleaning and flux handling

Lincoln Electric LT-7 Tractor Control Box

Video

Tractor Welding

- Tractor welding reduces weld size, which results in decreased process time
- The reduction of weld size and decrease of process time make increasing use of tracks for thin deck plate and large bulkhead applications a recommended practice

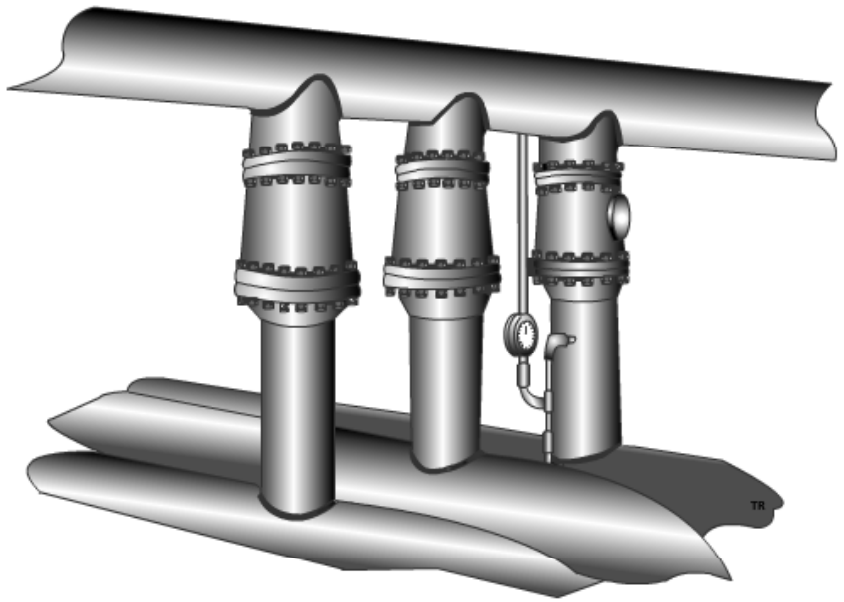
Tractor Welding

Common problems

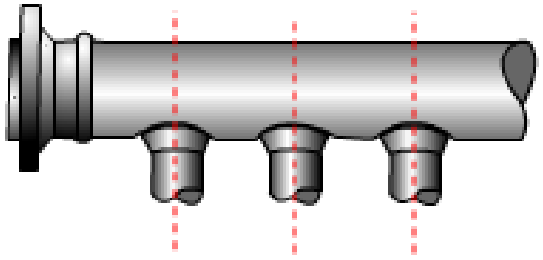
- Best suited in flat position but many tractors will weld up to 50 degrees on either side
- Equipment and tracks can make clamping near a seam difficult
- Proper fit-up required for minimizing root gap variance
- There is an increased importance on clamping when using SAW tractors

Pipe Welding

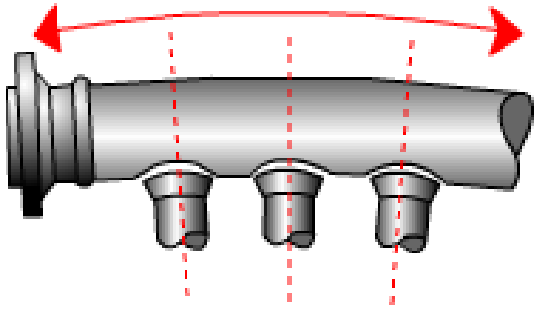
Distortion caused by welding can seriously affect the alignment and location accuracy of a pipe installation unless preventive measures are taken to avoid potential problems



Typical Fabrication



Without Distortion



With Distortion

Pipe Welding

Common pipe welding problems include:

- Melt/Burn Throughs
- Ovality Issues

Melt/Burn Through

Ovality Issue

Pipe Welding - Melt/Burn Through

Melt/Burn Through

- Occurs when puddle melts through to the inside of pipe due to excessive heat
- Is caused by using too high amperage or too slow travel speed
- Results in burn through with oxidation

Pipe Welding- Ovality/Alignment Issues

Ovality and Alignment Issues

- Ovality in pipe can occur during the manufacturing process, which causes issues when fit to other members
- Ovality can also occur during pipe bending

Pipe Welding- Ovality/Alignment Issues

Ovality and Alignment Issues

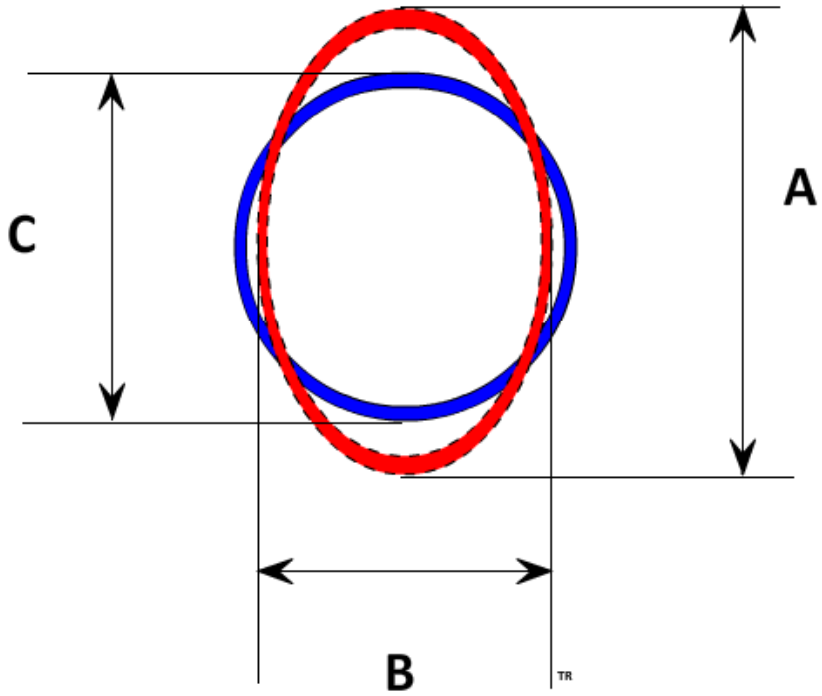
- In the manufacturing process of pipe bends it is difficult to avoid:
  - thinning on the internal side
  - thickening on the external side
- The cross section of the bend also becomes non-circular due to the bending process
- As the pipe becomes non-circular, alignment issues arise when joining sections of pipe

Pipe Welding- Ovality Issue

Ovality is measured as the variation between the maximum and the minimum dimension of the pipe in one location

Formula for Ovality:
(A-B)/C = X maximum

Notes:
X = industry standard
A = maximum measurement
B = minimum measurement
C = nominal diameter



Pipe Welding- Ovality Issue

- The permissible variations for industry standards vary as does the size and types of pipe

- Examples of some industry standards for steel or stainless steel are:

  "Seamless and Welded – the minimum wall thickness at any point shall not be more than 12.5% under the nominal wall thickness specified."

  "Forged and Bored, and Cast – The inside diameter shall not vary under that specified by more than 1/16 in. There shall be no variation over the specified inside diameter."

Formula for Ovality:

(A-B)/C = X maximum

Notes:

X = industry standard

A = maximum measurement

B = minimum measurement

C = nominal diameter

Be aware of the approved standards to which you work!

Tacking and Temporary Welds

As stated by the American Welding Society (AWS),

- Tacking is defined as "welds made to hold the parts of a weldment in proper alignment until the final welds are made“
- Similar are "Temporary welds“ which are defined as welds "made to attach a piece or pieces to a weldment for temporary use in handling, shipping, or working on the weldments“
- In both cases, one must remember these types of welds, if improperly made, may have negative influence on the quality of permanent welds

Tacking

- It is very important to minimize the risks associated with poor tack welding as they must not interfere with or degrade the quality of the completed welded structure
- Short tack welds require limited heat input which aids in minimizing distortion therefore it is better to have more short tacks than fewer long tacks
- Tacks and temporary welds should be held to the same standards as permanent welds
- Tack-welds, holding elements in place, must be easily removable for adjusting weldment construction

Tacking

- It is prohibited to leave arc strikes as they can lead to failure of the material later on in the life of the ship

- Tacks seen in this photograph are messy and not quality work

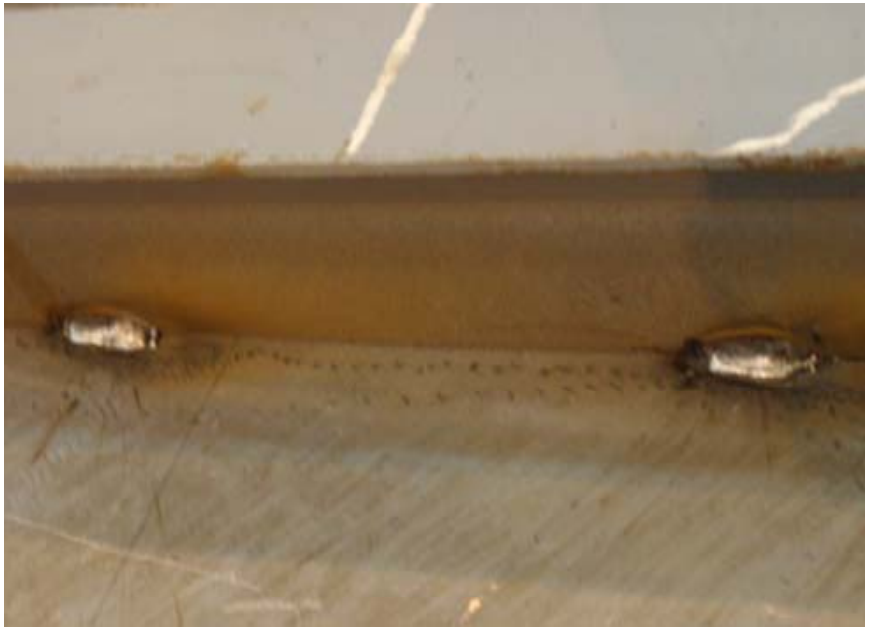
Tacking

- Tack welds are commonly incorporated into the final weld therefore the tacker should always weld tacks with this in mind

Shown to the right are examples of good and bad tacks

Common Problem with Building Welds on Poor Quality Tacks

- Oversize tacks often drive an increase in weld size to cover tacks
- Minimizing tack size eliminate overwelding and reduce welding induced distortion



- Large tacks also make the use of semi-automatic equipment difficult causing longer process time and larger welds

Common Problem with Building Welds on Poor Quality Tacks

Fitter/Welders should never be permitted to check out two different types of electrodes but it is common for them to be allowed to check out different sizes of the same type of electrode and store them in the same can!

What can you see as a potential problem in this scenario?

Knowledge Check

Why should the quality of a tack be the same quality of the final weld?

The tack should be the same quality of the final weld because the tack is made to be able to incorporate it into the final weld.

Knowledge Check

Tacks should be _____smaller_____ than the size of the final weld.

Knowledge Check

What are some of the disadvantages of tacks that are too large?

- Large tacks result in added distortion to the unit
- Large tacks create difficulty in using tractors to mechanically weld
- Large tacks increase the need for repairs to be made using grinders

Knowledge Check

What two steps can be taken to retain the strength of a tack when using a 3/32 electrode?

- Increase the length of the tack
- Increase the frequency of the tacks

Knowledge Check

What must be done to all tacks before releasing a completed unit to the welding customer?

The slag must be removed from all tacks prior to release.

Distortion Correction
Spot Flame Straightening Method

The thin material is repaired using minimal propylene gas pressure, increased oxygen, and a #2 size torch tip.

The spot heating method is performed by creating 1- 1/4 inch spots along both sides of the weld seam and/or along both sides of the Tee's.

Distortion Correction
Repairing Excessive Heat Damage

- This unit was repaired by creating 1-1/4 inch spots along the area damaged by excessive heat
- The entire highlighted area was repaired using the spot heating method
- When proper distortion control techniques are followed, this costly non-value added step can be minimized or eliminated

Flame Straighten Example
Steps for Straightening 1/4” Plate

Step 1: Heat all stiffeners in a general area with distortion/deflection with a spot pattern

- 1 to 1 ¼” spots 2” apart
- 950 to 1000 degrees
- Stagger spots on each side of the stiffener

Step 2: If unacceptable distortion/deflection still exists, repeat Step 1

- Use an opposite spot pattern compared to Step 1

Flame Straighten Example
Steps for Straightening 1/4” Plate

Step 3: If unacceptable distortion/deflection still exists, line heat all stiffeners in a general area with distortion/ deflection with continuous running of the stiffener.

- Heat entire length of stiffeners
- 950 to 1000 degrees
- Supervision should be notified prior to performing this step

Flame Straighten Example
Steps for Straightening 1/4” Plate

Step 4: If unacceptable distortion/deflection still exists, heat distorted areas of the panel with spot pattern

- 1 to 1 ¼” spots 2” apart
- 950 to 1000 degrees
- Stagger spots between stiffeners, across the distorted areas of the panel
- Only high spots are to be heated to pull slack from the low spots
- Supervision should be notified prior to performing this step

After Repairs Using Heat Straightening

Ingalls Shipbuilding
A Division of Huntington Ingalls Industries

Module 3

SHIPFITTING PLATES AND INSERTS

Topics

- Cutting and Fitting
- Fit Quality
- Plate/Insert Fit-Up and Welding
- Back-Step Process

Objectives

After this module, you will be able to:

- Explain what is meant by fit quality
- Discuss proper plate/insert fit-up and welding
- Identify proper weld sequences and back gouging sequences

This is how:

- We will discuss fit quality and importance points to remember to ensure a quality fit
- Examine proper plate/insert fit-up and welding points
- Identify the proper weld sequence and back gouging procedures

Cutting and Fitting

- Achieving proper fit-up for weld size control begins with the accuracy of parts coming off the cutting machines
- Eliminating rework or process delays starts by accepting a quality product from the customer (internal or external)
- Parts cut on the plasma cutters need to be properly nested by Engineering. All kerf and travel directions must be maintained per Engineering's specifications

Cutting and Fitting

- Proper PM procedures for plasma cutters must be followed and any issues reported to your supervisor and maintenance

- As a fitter, it is important that the part dimensions received are consistent with design specs and are checked before fitting
  - Relay issues to a supervisor if a part is out of tolerance or if any inaccuracy trends are noticed
  - Trimming **MUST** be done on insert plates that otherwise would create a forced-tight fit in order to maintain 1-2mm root opening

Cutting and Fitting

Insert was forced-fit into deck plate (shown on radius)

- There is no room for thermal expansion when welded, induces significant residual stress into plate
- Distortion will radiate outwards from inserts fit this way and cause process delays and rework for every subsequent process

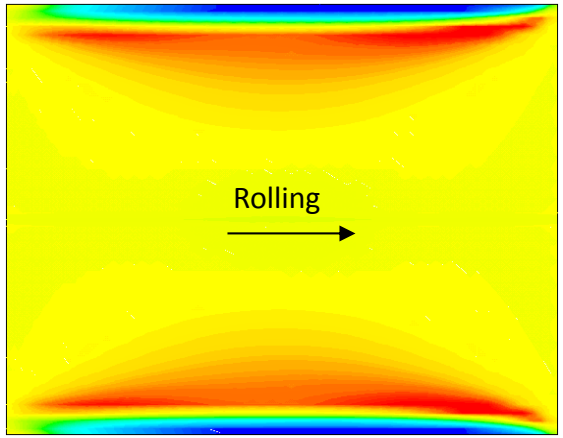
Cutting and Fitting

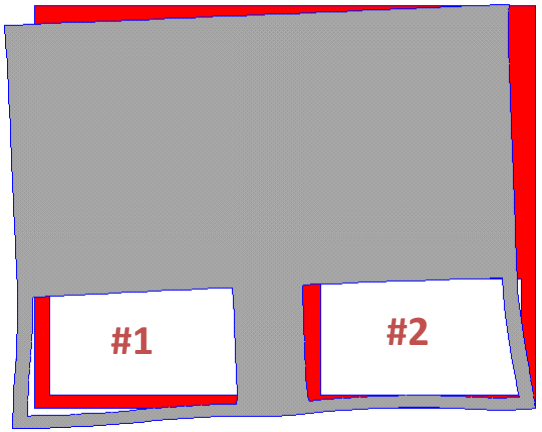
Poor Fit-up:

- requires additional process time
- Increases weld size
- Can induce severe heat input and distortion if weld “buttering” is needed on excessive root gaps

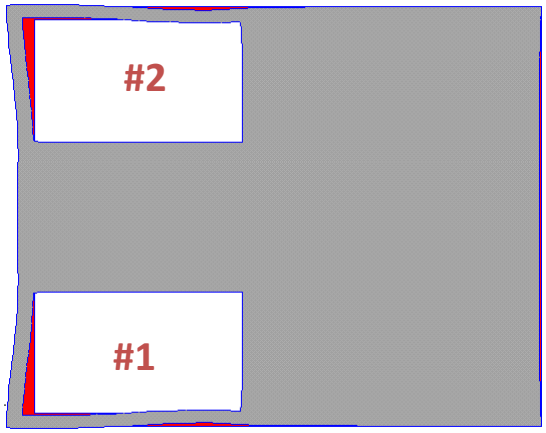
Cutting and Fitting

Longitudinal Residual Stress in Plate Received from the Mill





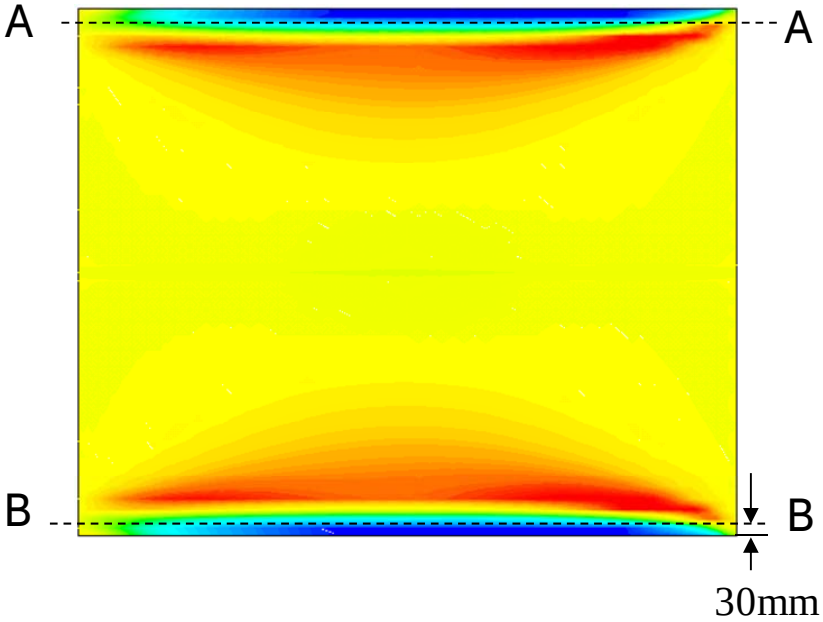
Sequence I



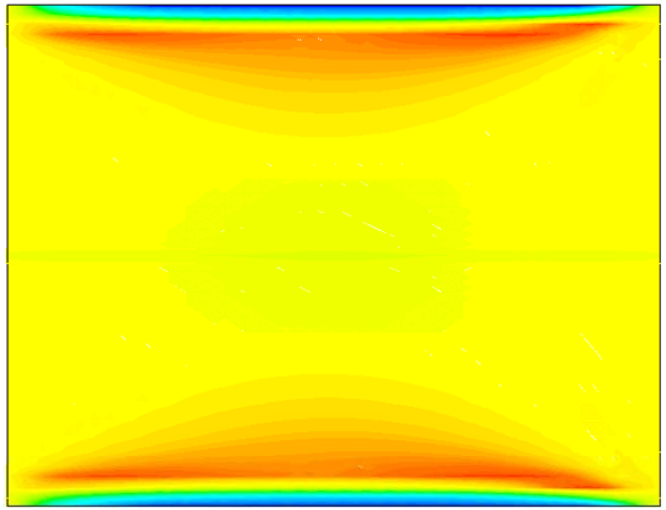
Sequence II

Cutting and Fitting

Effects of Edge Trimming on Residual Stress Re-Distribution



Before Trimming

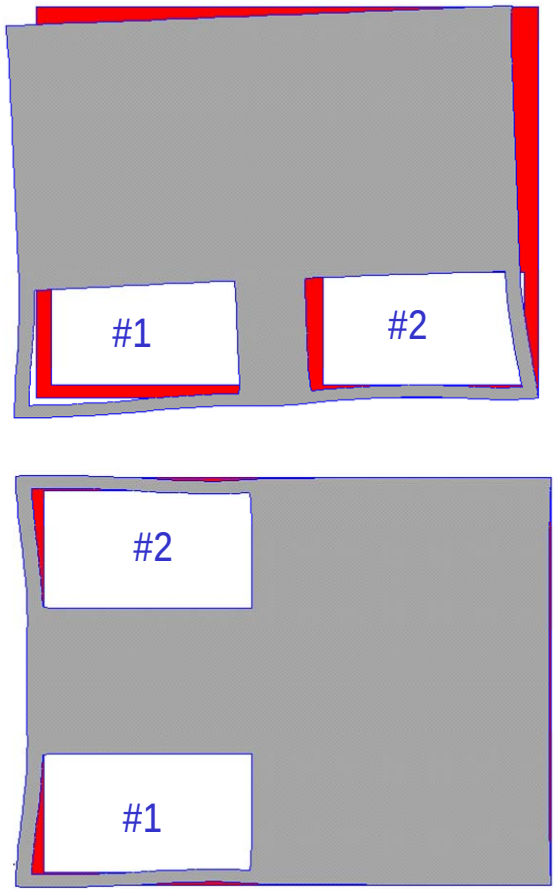


After Trimming

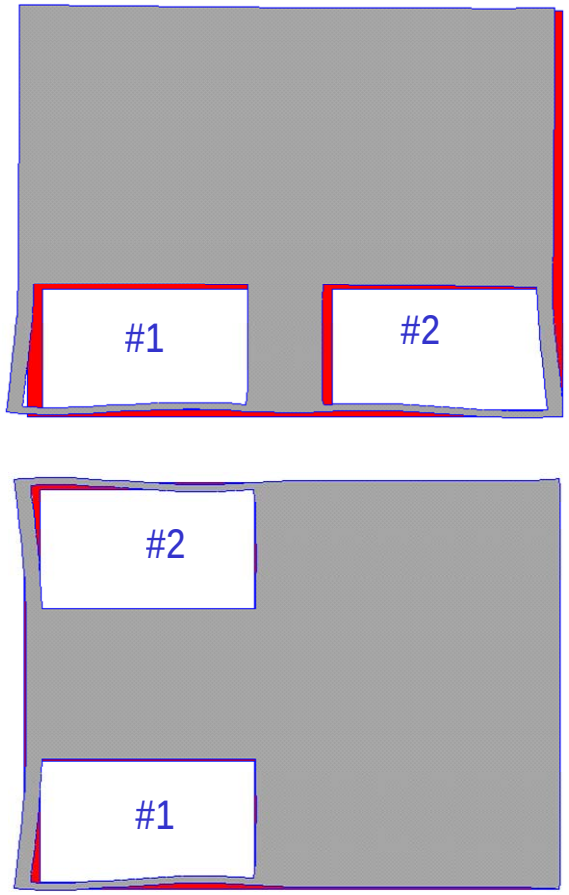
Cutting and Fitting

Magnification Factor: 30

Without Trimming



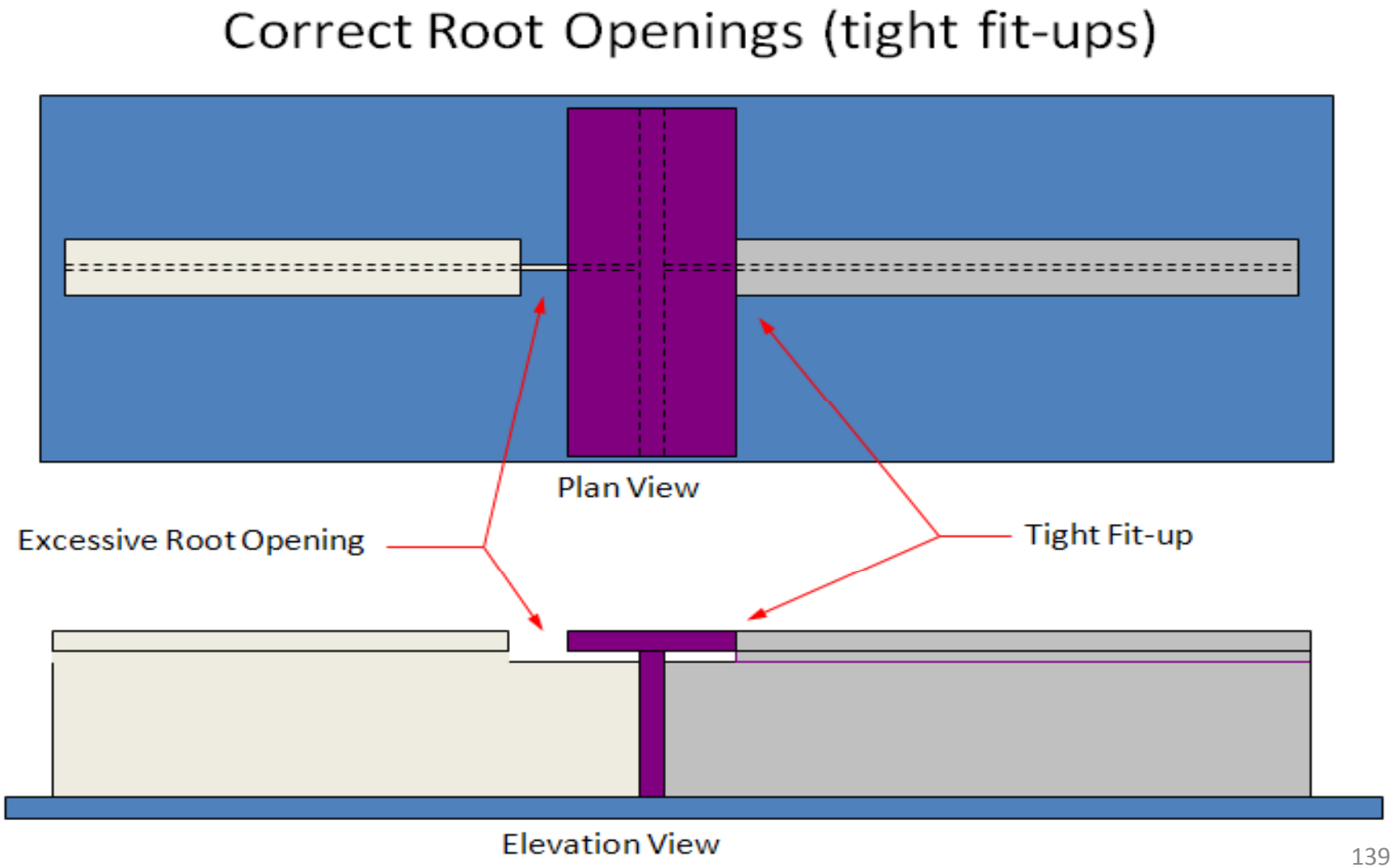
With Trimming



Fit Quality

- Due to mill rolling procedures, residual stress is non-uniform
- Following the proper cut sequence will account for:
  - The residual stresses
  - Limit cutting inaccuracies
  - Make proper fit quality easier to achieve

Fit Quality


Correct Root Openings (tight fit-ups)
Plan View
Excessive Root Opening
Tight Fit-up
Elevation View

Poor Fit-Up

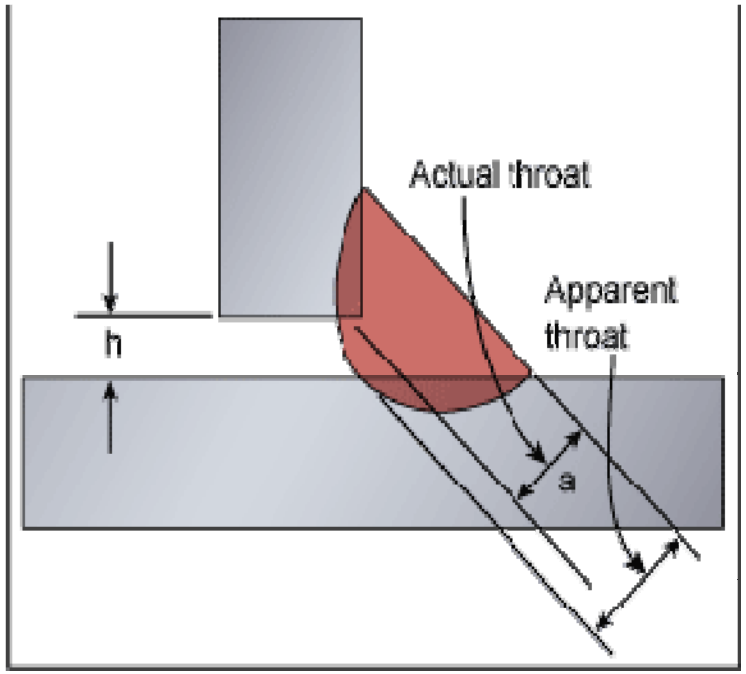
- Weld quality is driven by the fit quality
- Overwelding and other rework are required when the fit quality is poor

Common causes of poor fit quality are:

- Poor workmanship practice
- Poor dimensioning
- Tolerance dimensions on drawings

Poor Fit-Up

- As seen here, the gap results in a reduction in the leg length and results in a reduction in the throat thickness of the joint

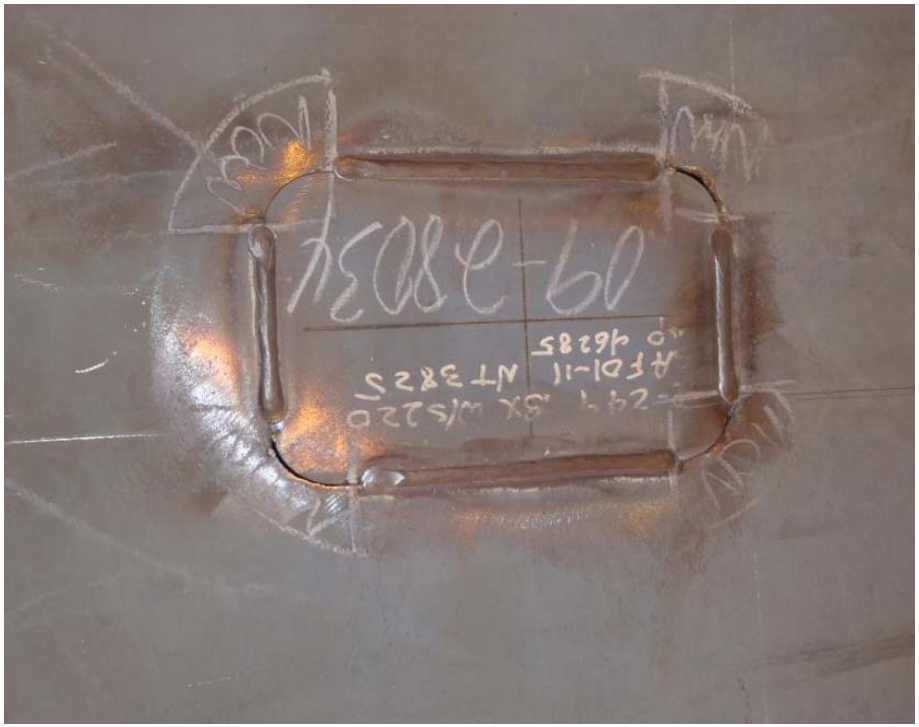


The fillet weld must then be increased to compensate for a large gap. This in turn adds to the amount of weld, which increases distortion.

Plate/Insert Fitting

What is an insert?

- Designed inserts are thicker plates installed into thinner base plates to give localized reinforcement where needed



Plate/Insert Fitting

- Inserts are the number one driver of welding induced distortion
- All other welding attributed distribution drivers amplified on inserts
- Ensuring fit quality and following insert weld procedures is the easiest way to reduce rework and cost

Plate/Insert Fitting

Common issues with plate/insert fittings are:

- Inconsistent Root Gaps
  - When fitting inserts, the thicker member should not be force-fitted into the cutout
  - If force-fitted, residual stress is locked within the plate
  - The residual stress gets released when welded and creates panel buckling
  - Overwelding due to large root gaps
  - Optimal root gap size is 1-2mm

Plate/Insert Fitting

- Inserts
  - Residual stress and buckling distortion

Inserts - Welding

Insert Radius Corners WITHIN 36 inches of the plate edge

- **All Plate Thicknesses**

Initial install

Smooth Side – Tack-only any radius corner, weld straight sections

Stiffener Side – Tack-only any radius corner, weld straight sections

After stiffeners

Stiffener Side – After longitudinal and transverse stiffener installation, weld radius corners

First Ship Shape Position

Smooth Side – Weld radius corners and complete any NDT requirements

Inserts - Welding

Insert Radius Corners MORE than 36 inches from the plate edge

- **Plate 7/16” thick or LESS**

Initial install

Smooth Side – Weld corner radius and straights sections

Stiffener Side – Weld straight sections only

After stiffeners

Stiffener Side – After longitudinal and transverse stiffeners installed, gouge and weld radius corners and accomplish any NDT requirements

- **Plate ½” thick or GREATER**

Initial install

Smooth Side – Weld radius and straights sections complete

Stiffener Side – Prior to stiffener installation, Weld radius and complete any NDT requirements

- ***use proper ‘back-step’ weld procedures on radius corners***

Plate/Insert Fitting

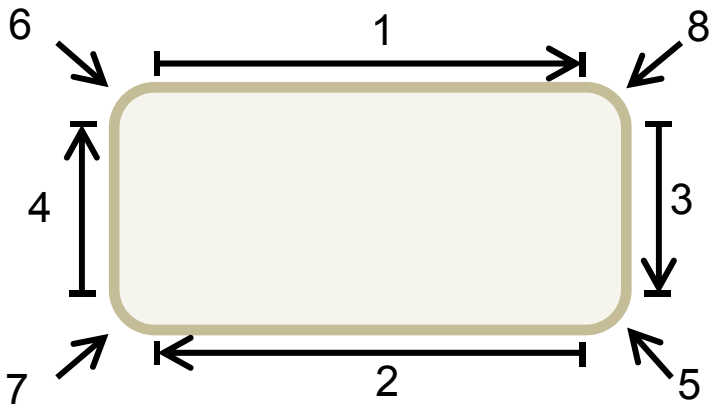
- Inserts
  - Radii Fitting
    - The radius is an insert feature, which creates the most rework and currently is where most fit issues occur
    - Cannot force-fit these areas as the stress distribution initiated from this practice spreads around the curvature of the radii and causes severe buckling when welded
    - Straight sections when fit overly tight or with a larger than 2mm gap may generate a greater shrinkage force or angular distortion but poorly fit radii will result in much more buckling distortion

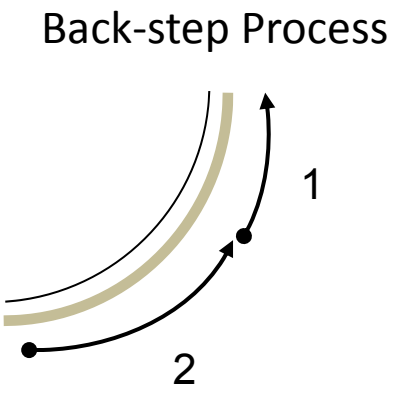
Plate/Insert Fitting

- Inserts
  - Radii Welding
    - The Radii on thin steel is best left unwelded until the plate is strengthened with stiffeners, headers or frames, in order to enhance internal buckling resistance
    - Optimal gap is 1.5 mm and should be consistent around the insert

Plate/Insert Fitting

- Inserts
  - Sequencing
    - Minimizing welding induced distortion
    - Plate walking (shifting) occurs with unbalanced heat input
    - Back-step process prevents “walking” and minimizes distortion
  - When used correctly can also be used as a self contained restraint mechanism





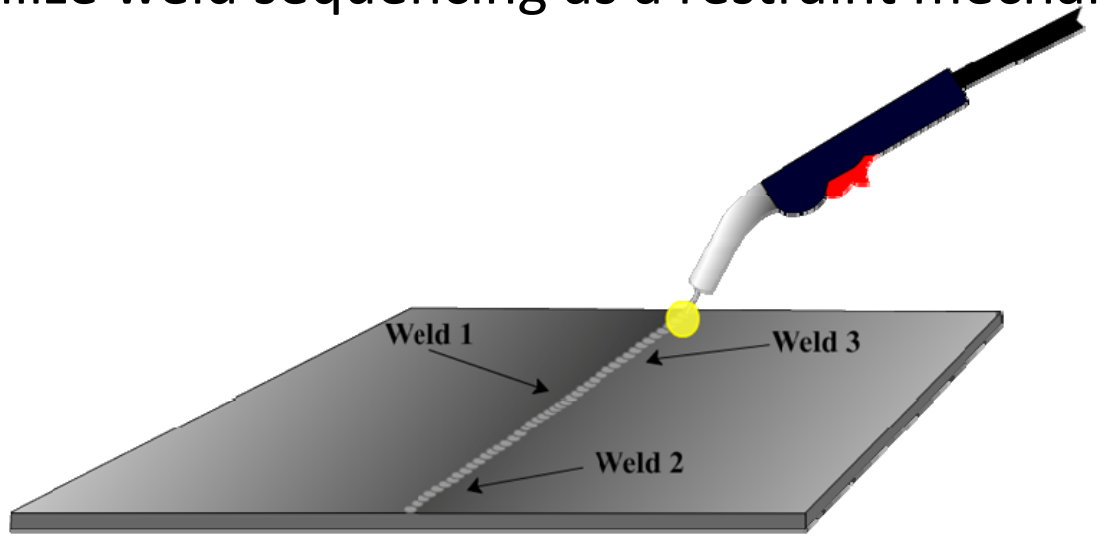
Note: Back-stepping radii is recommended on root pass and first cap

Plate/Insert Fitting

Back-step Welding

- Potential sequence step to avoid plate walking and prevent uneven distribution of weld metal

- When used correctly can also be used as a way to utilize weld sequencing as a restraint mechanism



Back-Step Process (Shown on Radius)

Plate/Insert Fitting

Back Gouging

- Process used when the top side of an insert is welded and the panel has been flipped to weld the backside. The weld is gouged until sound metal is reached. This process is done prior to welding the second side of the insert

- Often times this is overdone and in some cases up to 80% of the plate thickness gouged with a large joint opening. It needs to be completely filled back up with weld metal and generates an enormous amount of avoidable overwelding

Fit Quality

Welders should be conscious about the effect enlarged back gouging has on the weld size

- Reaching sound weld metal is a priority but steps can be taken to make sure this is achieved with minimal gouging

Example shown of a back gouge of ½” (12 mm)

Ingalls Shipbuilding
A Division of Huntington Ingalls Industries

Module 4

QUALITY INSPECTION

Topics

- Identifying common types of distortion
- The “trickle down” effects of distortion

Objectives

After this module, you will be able to:

- Identify common types of distortion, their probable cause, whether or not the distortion could be avoided and if so how it could have been avoided
- Discuss how your quality effort not only effects your work but every following work station's quality

This is how:

- We shall discuss what is meant by quality work
- We shall examine the effects of distortion as we follow pieces of plate and witness the fit issues experienced as it passes from work station to work station

Quality

Ask yourself:

- Is this the very best work I can do?
- Can I change anything to help produce a better product?
- When I send my work down the line to the next workstation, will it be received as quality work?

Remember:

- The quality of a completed weld is predictable, provided things such as amperage, travel speed, and the wire or rod size are correct
- Discontinuities in welds do not occur by mere chance
- Proper fit-up is critical to a quality product

Class Activity

The following images are examples of the effects of distortion.

Look closely at each image and determine the following:

(1) Type of distortion

(2) Probable cause

(3) Could it have been avoided?

(4) If so, how?

Distortion - Example 1

(1) Type of distortion?

Bowing

(2) Probable cause?

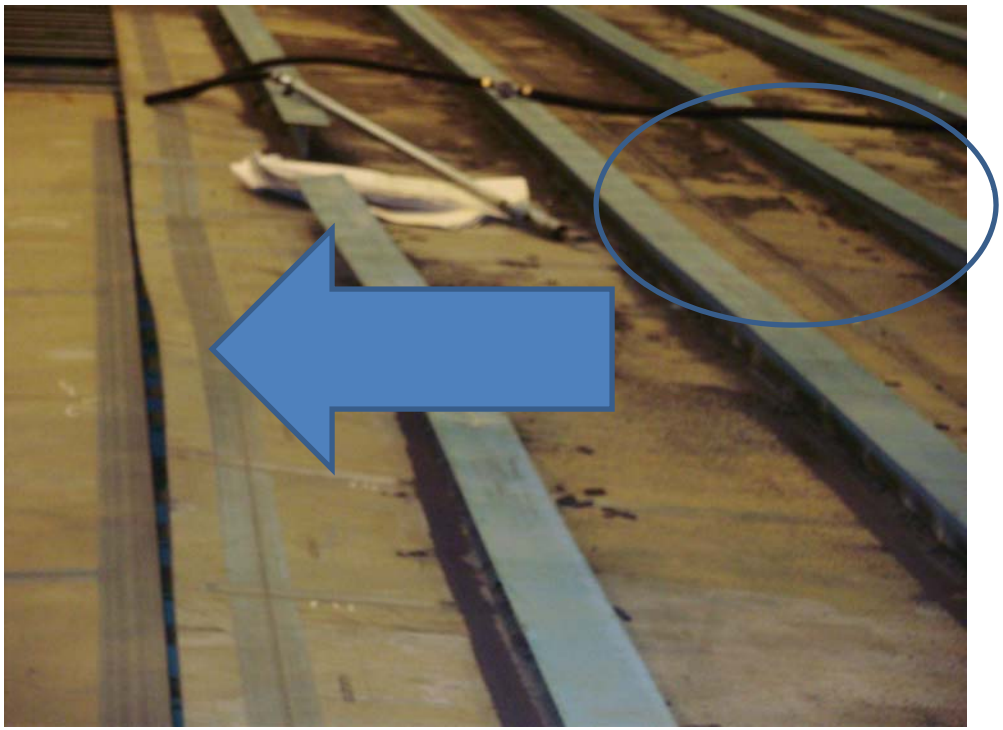
- *Excessive heat damage from fillets*
- *Insert*

(3) Could it have been avoided?

Yes

(4) If so, how?

- *Edge restraints while welding insert*
- *Proper insert fit-up and weld sequence*



Distortion - Example 2

(1) Type of distortion?

Buckling

(2) Probable cause?

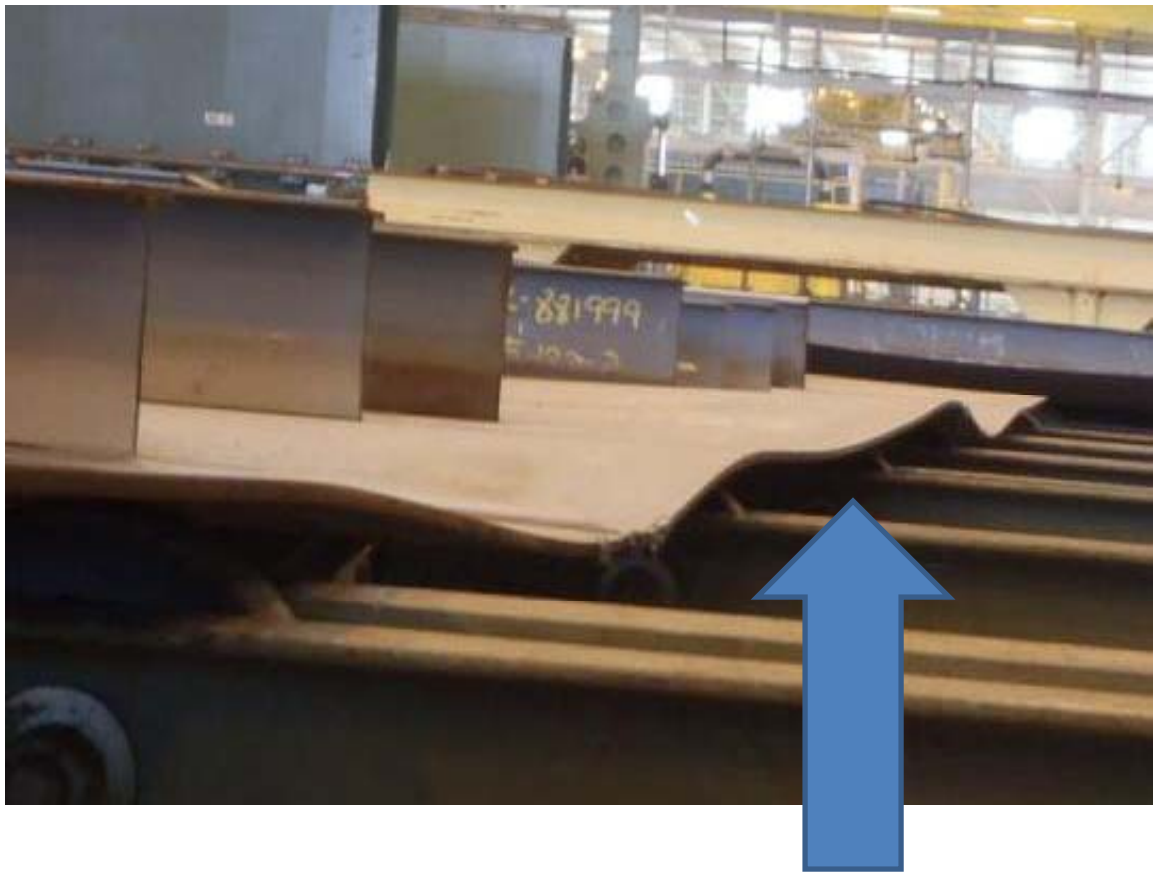
Lack of restraint/insert

(3) Could it have been avoided?

Yes

(4) If so, how?

Clamping between stiffeners before welding



Distortion - Example 3

(1) Type of distortion?

Buckling

(2) Probable cause?

Uneven heat distribution from differing stiffener lengths near edge

(3) Could it have been avoided?

Yes

(4) If so, how?

- *Use center-out stiffener weld sequence*
- *Edge restraints*

Distortion - Example 4

(1) Type of distortion?

Buckling

(2) Probable cause?

Excessive weld size and heat to remove seam and temporary attachments

(3) Could it have been avoided?

yes

(4) If so, how?

Smaller welds and lower, more concentrated heat to remove temporary attachments

Distortion - Example 5

(1) Type of distortion?

Angular

(2) Probable cause?

Lack of support while welding

(3) Could it have been avoided?

Yes

(4) If so, how?

Increase strongback usage prior to welding

Distortion - Example 6

(1) Type of distortion?

Buckling

(2) Probable cause?

Insert and its proximity to panel edge

(3) Could it have been avoided?

Yes

(4) If so, how?

- *Leaving radii unwelded*
- *Beam use when welding insert*

Example: Distortion Trickle Down Effect

Look at this image.

If left uncorrected,

what affect will this have when it reaches the next workstation?

Example:
Trickle Down Effect of Distortion

Look at this image.

If left uncorrected,

what affect will this have when it reaches the next workstation?

Example: Distortion Trickle Down Effect

Over straightening from excessive distortion caused tripped members. What is necessary/affected to correct the damage?

- **Engineering**
- **Planning**
- **Industrial Engineering**
- **Production Control**
- **Materials**
- **Cranes**
- **Outfitting**
- **Shipfitters**
- **Welders**
- **Paint**
- **Quality**
- **Schedule**
- **Consumables**

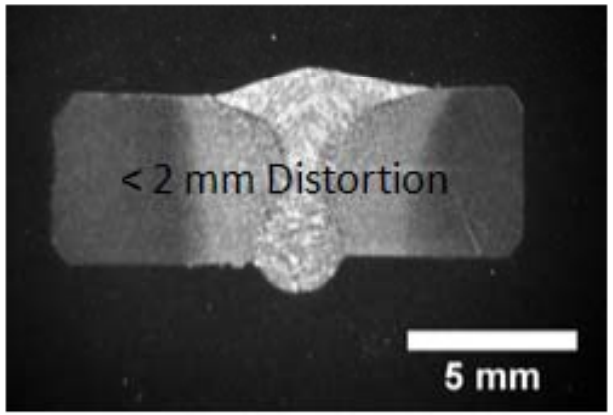
Looking to the Future

Hybrid Laser Arc Welding (HLAW)

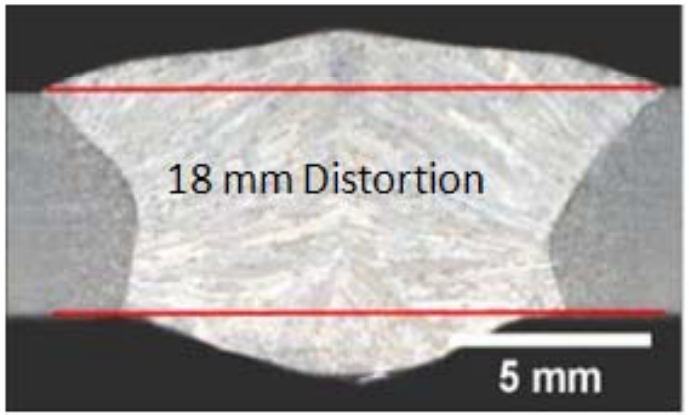
- High travel speed and small weld profile due to deep penetration

- Potential to reduce heat input and distortion by at least 71% over the current techniques

Solution
Single-Pass Hybrid Weld



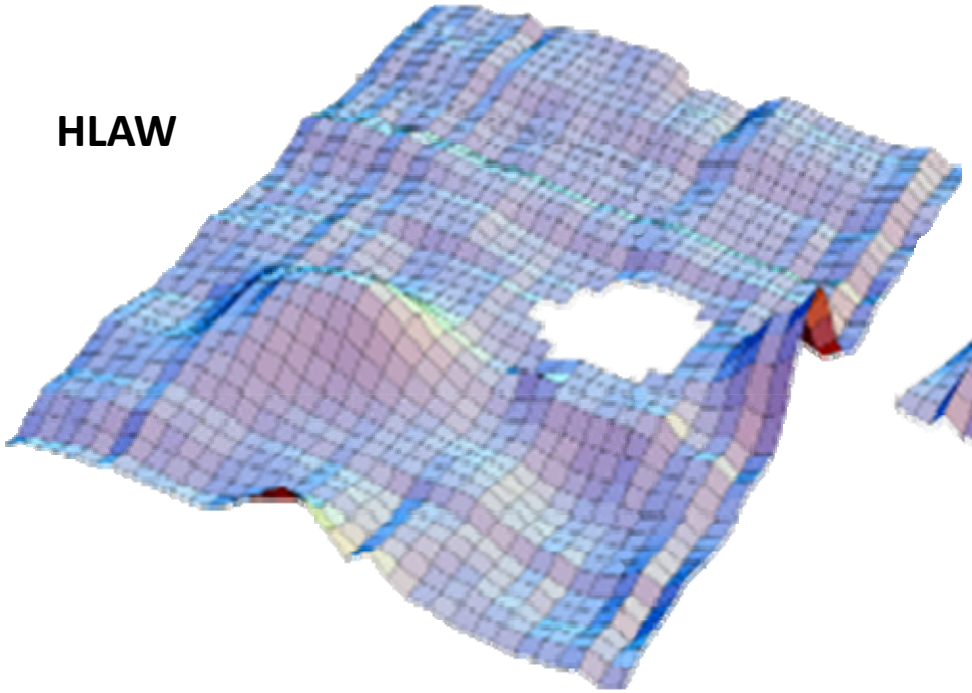
Conventional
Single-Sided Tandem SAW



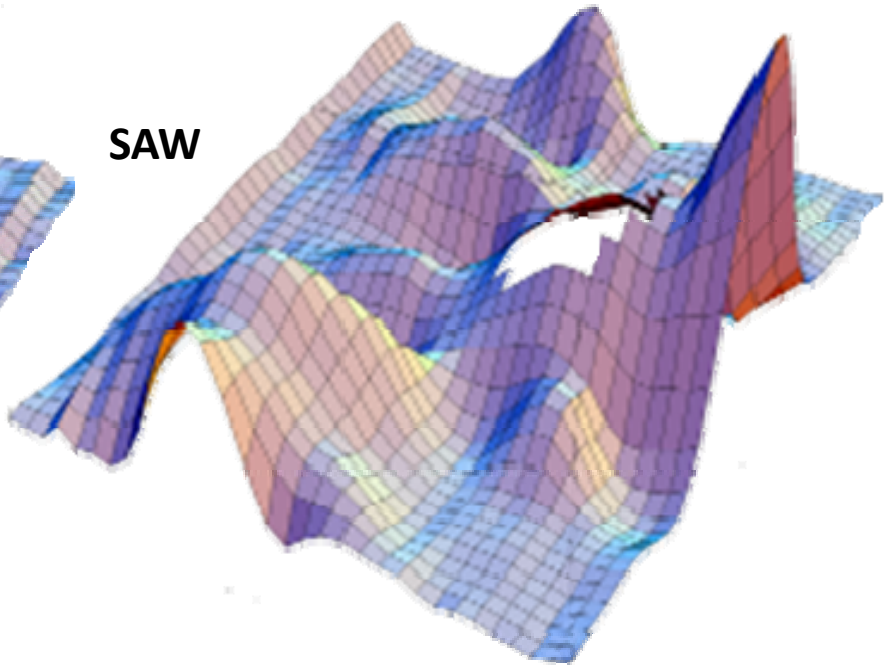
Looking to the Future

Further comparison of heat distortion between HLAW and SAW processes can be seen in this example:

HLAW



SAW

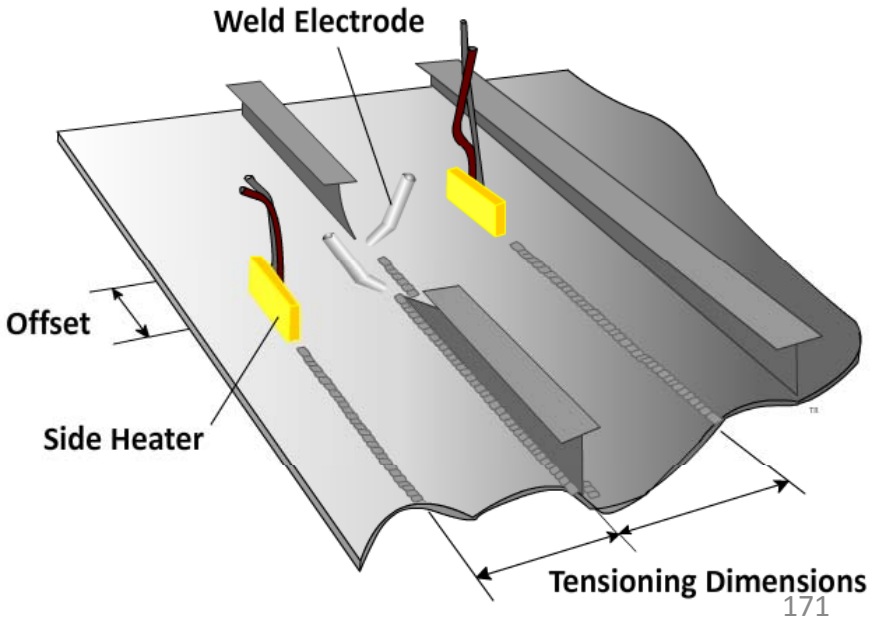


Looking to the Future

Transient Thermal Tensioning (TTT)

- Introduces additional heat source applied at a pre-determined distance from weld

- Tensile bands created to counter compressive stresses and minimize distortion



In Conclusion…

We must all do our part to minimize weld distortion by making it our goal to produce quality work.

You **CAN** make a difference!

We challenge you to make that difference

Thank you