This workbook has been created to accompany the Standardized Welding Curriculum and Testing for Shipyards National Shipbuilding Research Program’s Panel Project.
Table of Contents

Why are you here? .................................................................................................................................................. 5
Current Naval Standard ............................................................................................................................................ 5
Module 1: Introduction ............................................................................................................................................. 7
First Time Quality (FTQ) ....................................................................................................................................... 8
Group Activity .......................................................................................................................................................... 11
Module 2: Welding ................................................................................................................................................... 15
Importance of Welding ............................................................................................................................................. 16
Weld Size: Is Bigger Better? .................................................................................................................................... 17
Weld Distortion ........................................................................................................................................................ 18
What causes distortion? ......................................................................................................................................... 19
Types of Distortion .................................................................................................................................................. 19
  Knowledge Check .................................................................................................................................................. 23
Why is Distortion Control Important? .................................................................................................................. 24
Thin Steel Welding Implementation Items .......................................................................................................... 25
Weld Positions ....................................................................................................................................................... 26
Welding Processes .................................................................................................................................................. 30
SMAW ...................................................................................................................................................................... 31
GTAW ..................................................................................................................................................................... 31
GMAW ..................................................................................................................................................................... 32
FCAW ..................................................................................................................................................................... 32
Common Problems ............................................................................................................................................... 33
Overwelding ............................................................................................................................................................ 33
Measuring Tools ..................................................................................................................................................... 34
  Knowledge Check .................................................................................................................................................. 37
Proper Fillet Welding/Equipment Adjustments .................................................................................................... 38
Clamping ................................................................................................................................................................ 40
  Knowledge Check .................................................................................................................................................. 41
Structural Strong-Backs ........................................................................................................................................... 43
Tractor Welding ....................................................................................................................................................... 44
Pipe Welding ........................................................................................................................................................... 47
Tacking and Temporary Welds ............................................................................................................................... 50
Common Problems with Building Welds on Poor Quality Tacks ............................................................... 52
Distortion Control Tack Technique ........................................................................................................... 55
Distortion Control ...................................................................................................................................... 56
Distortion Correction ................................................................................................................................. 57
Module 3: Shipfitting Plates and Inserts ............................................................................................... 59
Cutting and Fitting .................................................................................................................................. 60
Poor Fit-Up ............................................................................................................................................. 65
Sequencing .............................................................................................................................................. 70
Back-step Welding .................................................................................................................................. 71
Back Gouging ......................................................................................................................................... 71
Module 4: Quality Inspection .................................................................................................................. 73
Quality .................................................................................................................................................. 74
Group Activity ....................................................................................................................................... 75
Looking to the Future ............................................................................................................................... 83
**Why are you here?**

Despite its advantages of being an economical way to join metal parts, welding can lead to structural problems such as distortion.

Reworking is necessary to remove distortion, which results in additional costs in:

1. __________________________
2. __________________________

Additionally, reworking leads to project time delays.

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.

**Current Naval Standard**

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
- Meets operational objectives and improves 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
Thin steel designs cause significant fabrication difficulties such as:

(1) ________________________________

(2) ________________________________

(3) ________________________________
Module 1: Introduction

Topics

• What does quality mean?
• Why is quality important?

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
First Time Quality (FTQ)

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

- This is a key element in the effort to exceed the expectations of both _____________ and _____________ customers.

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

1. identify opportunities for continuous improvement
2. reducing costs
3. the ability to monitor process stability
4. providing added value to customers by demonstrating and documenting measurable performance
5. helps provide guidance on training shipbuilders in order to have the highest probability of success based on demonstrated FTQ history
Take a moment to think about why quality is important to you.

Video Clip Notes:

___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________

9
Group Activity

Read the case study of the USS Thresher below. As you read the case study examine the incidents that led to the structural breakdown and demise of the submarine and her crew. Answer the questions following the case study and prepare for a group discussion.

Case Study - The Loss of the USS Thresher (SSN-593)

The USS Thresher was the lead ship of a class of 3700-ton nuclear-powered attack submarines that was commissioned in August of 1961. She was considered “state of the art” and had many new technological features and weapons aboard her; therefore, lengthy sea trials were conducted. Completion of numerous sea trials and dockside tests resulted in only minor issues that were addressed during her routine post-test overhaul. Upon completion of the overhaul, she set sail for her post-overhaul trials. On April 10, 1963, having completed a series of diving trials the previous day, the USS Thresher had prepared for her scheduled deep-dive tests. The submarine was accompanied by the submarine rescue ship USS Skylark. The Skylark carried a McCann submarine rescue chamber that with the assistance of her divers could rescue crew from a depth of 850 feet in the event of a disaster. This method was the Navy’s only submarine rescue system at the time. Communication between the ship and the submarine although available would have not been very good since the only method available at that time was the UQC, a rudimentary underwater radio. The Thresher’s test depth was approximately 1,300 feet with a collapse depth of approximately 1,900 feet. She had previously been to her test depth on 40 previous dives before her recent overhaul so there would not have been much concern as she began her deep dive tests among her seasoned crew.

As the Skylark listened, garbled reports of a “minor difficulty” were received from the submarine as it descended to about 1,000 feet. Sadly, it turned out to be anything but a “minor difficulty” as the crew of a rescue ship heard the ominous words of “exceeding test depth”. Silent filled the air as they continued to listen. The Thresher had disintegrated under the crushing pressure of the sea and 129 men lost their lives. What happened? Why did they think it was a “minor difficulty”?
Investigation into the cause of the loss of the ship has been filled with controversy throughout the years but the Navy felt that a brazed joint on an interior pipe had burst – anything but minor. It is further believed that seawater from the burst joint sprayed on an electrical panel, shorting it out and causing an emergency shutdown of the nuclear reactor. From pieces of the radio transmission that could be understood it was further determined that the valiant crew of the Thresher worked feverishly to empty ballast tanks, which if functioning properly would have forced the submarine to surface. The Skylark stood by helplessly as the efforts of the Thresher’s crew failed to bring her to the surface. She continued her descent below crush depth. It is believed that the Navy crewmembers and civilian technicians onboard would have understood their dire situation and scrambled to close valves in an attempt to stem the flooding. It is further believed that the ballast system was disabled by ice resulting in the failure of that system as well. Restarting the failed reactor was impossible since it was a 20-minute process. Death for the 129 men was instantaneous in the violent implosion that occurred. Remnants of the submarine came to rest on the ocean floor at a depth of 8,500 feet. The divers on the Skylark could do nothing to help the doomed crew.

Answer the following questions:

• 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?

___________________________________________________________________
___________________________________________________________________
___________________________________________________________________

___________________________________________________________________
The quality of welds and the adjoining materials are vital to the safety of the vessel and its crew. An excellent example is that of the USS Thresher (SSN-593). Her loss is still to this day considered the world’s worst submarine disaster in terms of lives lost.

You may not be among the shipbuilders who build submarines but disaster can strike any vessel and result in loss of life.

---

_Ink It While You Think It!_

___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________

___________________________________________________________________
Take a few moments to jot down at least 4 things you learned in this module.

(1)

(2)

(3)

(4)
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 what it means to have 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

List 3 reasons why welding is important:

(1) ______________________________________
(2) ______________________________________
(3) ______________________________________

Ink It While You Think It!
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________

16
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 ________ and the ________ as well as specify the amount and size of weld actually required.

Welders and shipfitters should follow the specification given by the designer as ____________ so the overall project is successful.

- On thin material, _________ welds can actually have increased strength due to better penetration
- ________________________ on thin plate or creating an additional pass can harm the strength of the joint and surrounding base material since more heat is added and slight material degradation is created

Despite common belief by some that bigger is better, the cost of over and under welding both add ____________ as time and labor are drastically impacted.

Cumulative Fillet Weld Time Based on 100ft of Weld

<table>
<thead>
<tr>
<th>Weld Size</th>
<th>Weld Passes</th>
<th>Flat (16 ft/hr)</th>
<th>Vertical (8 ft/hr)</th>
<th>Overhead (4 ft/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/16”</td>
<td>1</td>
<td>6.25</td>
<td>12.5</td>
<td>25</td>
</tr>
<tr>
<td>3/8”</td>
<td>2</td>
<td>13.5</td>
<td>27</td>
<td>54</td>
</tr>
<tr>
<td>5/8”</td>
<td>3</td>
<td>20.5</td>
<td>41.5</td>
<td>83</td>
</tr>
</tbody>
</table>

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

What is weld distortion?

• The alteration of the original shape (or other characteristic) of an object

What is distortion control?

• The process of minimizing the potential distortion in an object, such as controlling the stress distribution from welding

Examine the picture and prepare for a class discussion on what you see in this image. What do you think was the main catalyst that caused this problem?

___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________

What is residual stress?

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

• When the finished weldment cools, some areas cool and contract more than others 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.
What causes distortion?

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

What does HAZ mean? ____________________________________________

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

Cause

Prevention Measures

Correction Measures

Longitudinal Shrinkage

Cause

Prevention Measures

Correction Measures
Angular Distortion

Cause

Prevention Measures

Correction Measures

Bowing or Dishing

Cause

Prevention Measures

Correction Measures
Buckling

Cause

Prevention Measures

Correct ion Measures

_Ink It While You Think It!_
Knowledge Check

Match the following types of distortion by drawing a line from the image to the name of the distortion shown. Try not to look back in your workbook!

- Bowing Distortion
- Buckling Distortion
- Longitudinal Shrinkage
- Transverse Shrinkage
- Angular Distortion
Why is Distortion Control Important?

Employees taking a proactive approach to distortion control are important to the company’s _________________.

Why would you say it is important to reduce costs?

___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
Thin Steel Welding Implementation Items

Increase fitter/welder communication and feedback:

- Cost: Negligible
- Process Time: 10 minutes per work piece
- Benefits: Increased final weld quality and part weldability as well as increased workmanship and accountability

_Ink It While You Think It!_
Weld Positions

Four basic positions of welding that are employed in structural fabrication:

(1) These are two examples of ____________________________ position.
These are two examples of _________________ position.
(3) These are two examples of ________________ position.
(1) These are two examples of ________________ position.
Welding Processes

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

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)
**SMAW**

List three advantages:

(1) 
(2) 
(3) 

List three disadvantages:

(1) 
(2) 
(3) 

**GTAW**

List three advantages:

(1) 
(2) 
(3) 

List three disadvantages:

(1) 
(2) 
(3)
GMAW

List three advantages:

(1) ______________________________________________
(2) ______________________________________________
(3) ______________________________________________

List three disadvantages:

(1) ______________________________________________
(2) ______________________________________________
(3) ______________________________________________

FCAW

List three advantages:

(1) ______________________________________________
(2) ______________________________________________
(3) ______________________________________________

List three disadvantages:

(1) ______________________________________________
(2) ______________________________________________
(3) ______________________________________________
Common Problems

List three common problems seen in manual and semi-automatic processes:

(1) __________________________________________
(2) __________________________________________
(3) __________________________________________

Overwelding

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 _______ and _______ of a fillet weld
- The size of the actual weld is checked by using one or more gauges to compare the _______ of the weld to the _______ of the individual gauges
- 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

![Theoretical Throat Diagram]

- It is commonly used incorrectly. Why?

________________________________________________________
________________________________________________________
________________________________________________________
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.
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 ___________ and ___________ legs must be checked.

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

Would this convex fillet weld be considered good or bad?
__________________________________________________________________________________________
__________________________________________________________________________________________
__________________________________________________________________________________________

Why?
__________________________________________________________________________________________
__________________________________________________________________________________________
__________________________________________________________________________________________
### Proper Fillet Welding/Equipment Adjustments

<table>
<thead>
<tr>
<th></th>
<th>SAW</th>
<th>FCAW</th>
<th>GMAW (Pulse)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1/8” (3mm)</td>
<td>3/16” (5mm)</td>
<td>1/4” (6mm)</td>
</tr>
<tr>
<td>Current (Amps)</td>
<td>330</td>
<td>330</td>
<td>205-210</td>
</tr>
<tr>
<td>Voltage (Volts)</td>
<td>29</td>
<td>25</td>
<td>200</td>
</tr>
<tr>
<td>Travel Speed (in/min)</td>
<td>48</td>
<td>32.5</td>
<td>16.5</td>
</tr>
</tbody>
</table>

### Fillet Weld Size

<table>
<thead>
<tr>
<th></th>
<th>1/8” (3mm)</th>
<th>3/16” (5mm)</th>
<th>1/4” (6mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current (Amps)</td>
<td>205</td>
<td>205-210</td>
<td>210-220</td>
</tr>
<tr>
<td>Voltage (Volts)</td>
<td>25</td>
<td>25</td>
<td>25-27</td>
</tr>
<tr>
<td>Travel Speed (in/min)</td>
<td>37.5</td>
<td>16.5</td>
<td>13-14</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>1/8” (3mm)</th>
<th>3/16” (5mm)</th>
<th>1/4” (6mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current (Amps)</td>
<td>N/A</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>Voltage (Volts)</td>
<td>N/A</td>
<td>24</td>
<td>24</td>
</tr>
<tr>
<td>Travel Speed (in/min)</td>
<td>N/A</td>
<td>19.5</td>
<td>13</td>
</tr>
</tbody>
</table>
### Fillet Weld Size

<table>
<thead>
<tr>
<th>GMAW (Aluminum)</th>
<th>1/8” (3mm)</th>
<th>3/16” (5mm)</th>
<th>1/4” (6mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current (Amps)</td>
<td>230</td>
<td>230</td>
<td>230</td>
</tr>
<tr>
<td>Voltage (Volts)</td>
<td>23.5</td>
<td>23.5</td>
<td>23.7</td>
</tr>
<tr>
<td>Travel Speed (in/min)</td>
<td>75</td>
<td>57</td>
<td>47</td>
</tr>
</tbody>
</table>

**PLEASE NOTE:** THESE ARE ONLY RECOMMENDED AS A BASE LINE. Settings may differ depending on individual skills and different machines.

---

**Ink It While You Think It!**

__________________________________________
__________________________________________
__________________________________________
__________________________________________
__________________________________________
__________________________________________
__________________________________________
__________________________________________
__________________________________________

---

39
Clamping

• Clamps should be placed as _______ the seams being welded as possible

• Stresses causing distortion are distributed out into the plate from ___________________ therefore clamping near the HAZ is the most ________ area

• Clamps placed around the plate ________ will reduce the amount of distortion

• Clamps should remain attached until the welded area and plate edges cool below _______ or ______ after the welding is completed
Knowledge Check
Without clamping this example of a tee beam is clearly distorted:

What type of distortion is this an example of? ________________________
Distortion is dramatically ______________ when clamping is used properly.
• Clamps are used around the panel _________________ and along the edge of _________________

• Beam restraints are placed along the __________________________ prior to welding

Knowledge Check

Why did clamping aid in controlling distortion?

________________________________________________________________________________________

________________________________________________________________________________________

________________________________________________________________________________________
**Structural Strong-Backs**

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

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?

- 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

The proper settings to use in tractor welding depend 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 routine procedure changes
- Tracking control and self-steering in most applications allows the operator to be free for quality control, joint cleaning and flux handling
Tractor welding reduces weld size, which results in decreased process time.

- The reduction of ____________ and __________ of process time make increasing use of tracks for thin deck plate and large bulkhead applications a recommended practice.

Common problems associated with Tractor Welding:

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

Common pipe welding problems include:
Melt/Burn Through

- Occurs when pool 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

Label the Melt/Burn Through Drawing:

Word Bank:

Electric, Arc, Internal Pressure, Pipe Wall, Bulge
Ovality and Alignment Issues

- In the manufacturing process of pipe bends it is difficult to avoid:
  - __________ on the internal side
  - __________ on the external side
- The cross section of the bend also becomes non-circular due to the bending process
- As the pipe becomes __________, alignment issues arise when joining sections of pipe
- Ovality is measured as the variation between the __________ and the ____________ dimension of the pipe in one location

**Formula for Ovality:**

\[ \frac{(A-B)}{C} = X \text{ maximum} \]

**Notes:**
- \( X \) = industry standard
- \( A \) = maximum measurement
- \( B \) = minimum measurement

- 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**”

**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
- 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 ___________ as permanent welds

• Tack-welds, holding elements in place, must be easily ___________ for adjusting weldment construction

• It is _____________ to leave arc strikes as they can lead to __________ of the material later on in the life of the vessel

Important Note: Although the tacks seen in this photograph are messy and not quality work, the main point of failure is the arc strikes as these can affect the future structural integrity of the vessel.
Tack welds are commonly incorporated into the final weld therefore the tacker should always weld tacks with this in mind.

Common Problems with Building Welds on Poor Quality Tacks

- Oversized tacks often drive an increase in weld size to cover tacks
- Minimizing tack size to 1/16” below the weld size helps to eliminate overwelding and reduce welding induced distortion
- Large tacks also make the use of semi-automatic equipment difficult causing ___________ process time and ___________ larger welds
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

(1) Why should the quality of a tack be the same as the quality of the final weld?

(2) Tacks should be ____________ than the size of the final weld.

(3) What are some of the disadvantages of tack that are too large?

(4) What two steps can be take to retain the strength of a tack when using a 3/32 electrode?

(5) What must be done to all tacks before releasing a complete unit to the welding customer?
Distortion Control Tack Technique

- A good quality tack of proper size does not require grinding
- 3/32” electrode needs to be used on plate 3/8” thick and below
- Slag must be removed from tacks prior to release

Ink It While You Think It!
Distortion Control

*Spot Flaming Straightening Method*

The thin material is repaired using minimal propylene gas pressure, increased oxygen, and a #2 size torch tip. The spot flame straightening 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 originally to be cut out and reinserted due to major damage to the outside shell, but was saved with the spot flaming method. When proper distortion control techniques are followed, this non-value added step can be minimized or eliminated.
Flame Straightening Example

*Steps for Straightening ¼” Plate*

**Step 1:** All stiffeners are heated in the general area of distortion/deflection, with a staggered spot pattern

**Step 2:** If unacceptable distortion/deflection still exists, Step 1 is repeated using an opposite spot pattern from step 1

**Step 3:** If unacceptable distortion/deflection still exists, heat all stiffeners in the general area of distortion/deflection with line heat along the stiffener

**Step 4:** If unacceptable distortion/deflection still exists, contact supervisor before proceeding

*After Repairs Using Heat Straightening*
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 techniques

This is how:

• We will discuss fit quality and important 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 __________ 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

• 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 ___________________ and are ________________ before fitting

• Relay issues to a supervisor if a part is out of tolerance or if any inaccuracy trends are noticed

• Trimming ________ be done on insert plates that otherwise would create a forced-tight fit in order to maintain 1-2mm root opening

STOP AND THINK

If an insert must be force-fit into a deck plate, will this induce or reduce residual stress?
Shown below is an insert that was forced-fit into deck plate (shown on radius)

• There is no room for thermal expansion when welded, __________ significant residual stress into plate

• Distortion will radiate __________ from inserts fit this way and cause process ______ and ________ for every subsequent process

Poor Fit-up:

• Requires additional ______________________

• _____________ weld size

• Can induce severe heat input and ____________ if weld “buttering” is needed on excessive root gaps
Due to mill rolling procedures, residual stress is non-uniform. Following the proper cut sequence will account for:

(1) ______________________________________________________
(2) ______________________________________________________
(3) ______________________________________________________
Effects of Edge Trimming on Residual Stress Re-Distribution

Before Trimming

Without Trimming

With Trimming

After Trimming
Ink It While You Think It!

Correct Root Openings (tight fit-ups)

Excessive Root Opening

Plan View

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:

(1) ____________________________________________
(2) ____________________________________________
(3) ____________________________________________
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 heat induced, which increases distortion.
**Plate/Insert Fitting**

What is an Insert?

Inserts are thicker plates installed into thinner base plates to give localized reinforcement where needed. Inserts are the number one driver of welding induced distortion. All other welding attributed distribution drivers are amplified on inserts. Ensuring fit quality and following insert weld procedures is the easiest way to reduce rework and cost.

![Insert Image](image)

Common issues with plate/insert fitting are:

**Inconsistent Root Gaps**

- When fitting inserts, the thicker member should not be forced-fit into the cutout
- If forced-fit, residual stress is locked within the plate
- The residual stress gets released when welded and creates panel buckling
- An enlarged gap induces overwelding.
- Optimal root gap size is 1-2mm
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
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

Radii Fitting

• The radius is an insert feature, which creates the _________ rework and currently is where ___________ 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 _________________ when welded
• Straight sections when fit overly tight or with a larger than 2mm gap may generate a shrinkage force or angular distortion but poorly fit radii will result in much more buckling distortion

• The Radii on thin steel is best left 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

**Sequencing**

• Minimizing welding induced

• Plate walking occurs with heat input

• Back-Step Process prevents “walking” and distortion

• When used correctly sequencing can also be used as a self contained
Back-step Welding

• Potential sequence step to avoid plate walking and prevent ______________ of weld metal

• When used correctly can also be used as a way to utilize weld sequencing as a __________________________

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 ______________ is reached. This process is done prior to welding the back of the insert.

• Often times this is __________ and in some cases up to 80% of the plate thickness gouged with a large gap. The gap needs to be completely ______________________ with weld metal and generates an enormous amount of avoidable overwelding.
Welders should be conscious about the effect enlarged back gouging has on the weld size.

- The optimal root gap is __________ to achieve proper weld sizing on thin plate
- Reaching __________ weld metal is a priority but steps can be taken to make sure this is achieved with minimal gouging

This is an example of a back gouge of __________ inches or __________ mm.
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 and process time

This is how:

- We shall discuss what is meant by quality work
- We shall examine the affects 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:

(1) Is this the very best work I can do?

_____________________________________________________________

_____________________________________________________________

_____________________________________________________________

(2) Can I change anything to help produce a better product?

_____________________________________________________________

_____________________________________________________________

_____________________________________________________________

(3) 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 ______________, provided things such as amperage, travel speed, and the wire or rod size are correct
• Discontinuities in welds do not occur by ______________
• Proper fit-up is ______________ to a quality product
Group Activity

The following images are examples of the effects of distortion. Look closely as we examine 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: ____________________________________________
(2) Probable cause: ____________________________________________
(3) Could it have been avoided? _________________________________
(4) If so, how? ________________________________________________

_____________________________________________________________
_____________________________________________________________
Distortion – Example 2

(1) Type of distortion: ___________________________________________
(2) Probable cause: ______________________________________________
(3) Could it have been avoided? ________________________________
(4) If so, how? ________________________________________________

______________________________________________________________

______________________________________________________________
Distortion – Example 3

(1) Type of distortion: ________________________________________________
(2) Probable cause: _________________________________________________
(3) Could it have been avoided? ______________________________________
(4) If so, how? _____________________________________________________
...........................................................................................................
Distortion – Example 4

(1) Type of distortion: ____________________________________________
(2) Probable cause: ______________________________________________
(3) Could it have been avoided? ____________________________________
(4) If so, how? ____________________________________________________
__________________________________________________________________
Distortion – Example 5

(1) Type of distortion: ________________________________
(2) Probable cause: ________________________________
(3) Could it have been avoided? ______________________
(4) If so, how? ________________________________

_________________________________________________

_________________________________________________
Distortion – Example 6

(1) Type of distortion: ________________________________
(2) Probable cause: ________________________________
(3) Could it have been avoided? _____________________
(4) If so, how? ________________________________

_________________________________________________
_________________________________________________
Trickle Down Effect of Distortion

Look at the following image. If left uncorrected, what affect will this have when it reaches the next workstation?
Trickle Down Effect of Distortion

One more example, look at the following image. If left uncorrected, what affect will this have when it reaches the next workstation?
Looking to the Future

Hybrid Laser Arc Welding (HLAW)

• ______ travel speed and _______________ weld profile due to deep penetration

• Potential to ______ heat input and distortion by at least ______ over the current techniques

• Further comparison of heat distortion between HLAW and SAW processes can be seen in this example:
Transient Thermal Tensioning (TTT)

- Introduces additional heat source applied at a ______________ distance from weld
- Tensile bands created to counter ______________ and minimize distortion
In conclusion, we must all do our part to minimize weld distortion by making it our goal to produce quality work.

Remember:

You **CAN** make a difference!

We challenge you to make that difference