Ship Design and Construction Training Module

NSRP Joint Panel Meeting

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Outline

- Introduction
- Thin Steel Design and Construction Difficulties
- Preferred Construction Methods
- Distortion Mitigation Techniques
- Proper Administration of Correction Techniques
  - Flame Straightening, Reduced Heat
- Summary

Introduction to Thin Steel Design

- Thin steel hulls have become a current trend 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/high strength steel designs

- Thin steel designs cause significant fabrication difficulties
  - Distortion due to high heat input on thin steel
  - Panel shrinkage and dimensional control issues
  - Workforce unfamiliar with techniques needed to mitigate thin steel construction difficulties
  - Reluctance of changing to newer unfamiliar technology that can drastically aid in reducing the difficulties of thin steel fabrication

Design Effects on Optimal Construction Effort

Eliminate Unnecessary Welding

Distortion Prior to Butt Welding

Additional Transverse Seams on Thin Plate (3/16”)

The “best practice” for eliminating overwelding is not welding at all

With the ongoing effort to reduce distortion in thin plates and implementation of “best practices,” design engineers need to be conscious of distortion and eliminate designs that create problems for controlling distortion on the production side.

Design Effects on Optimal Construction Effort
Eliminate Unnecessary Welding

Increased Plate Distortion from Added Seams

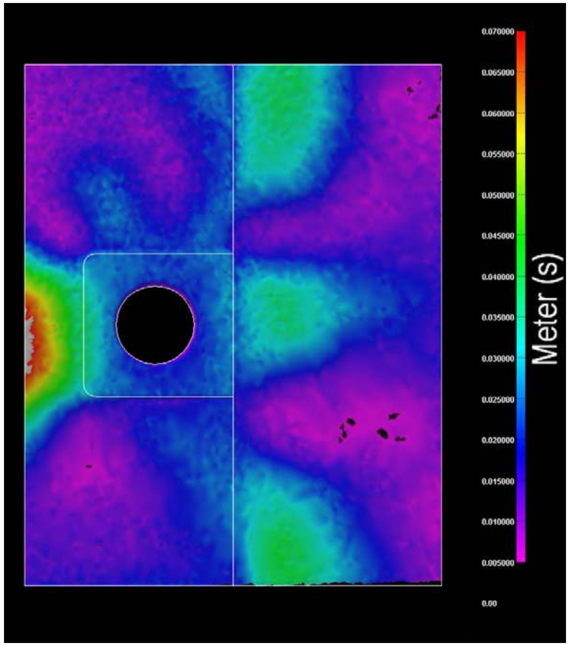
Fairness of Entire Panel Effected

Craft is doing their part to implement distortion reducing “best practices” by reducing weld size and increasing restraints during butt welding, but the “best practice” of all would be to eliminate unnecessary welds altogether

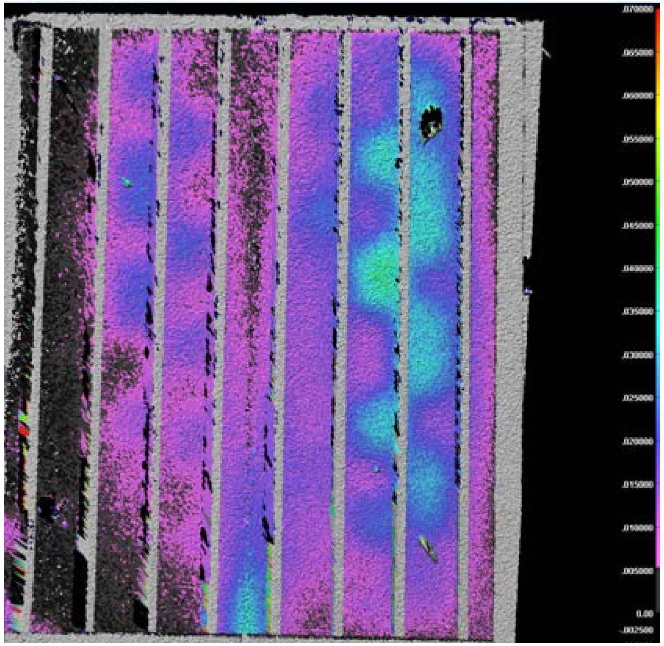
Design Effects on Optimal Construction Effort

Reduce Thick to Thin Transitions

LIDAR distortion scan of panel with insert



LIDAR distortion scan of panel without insert

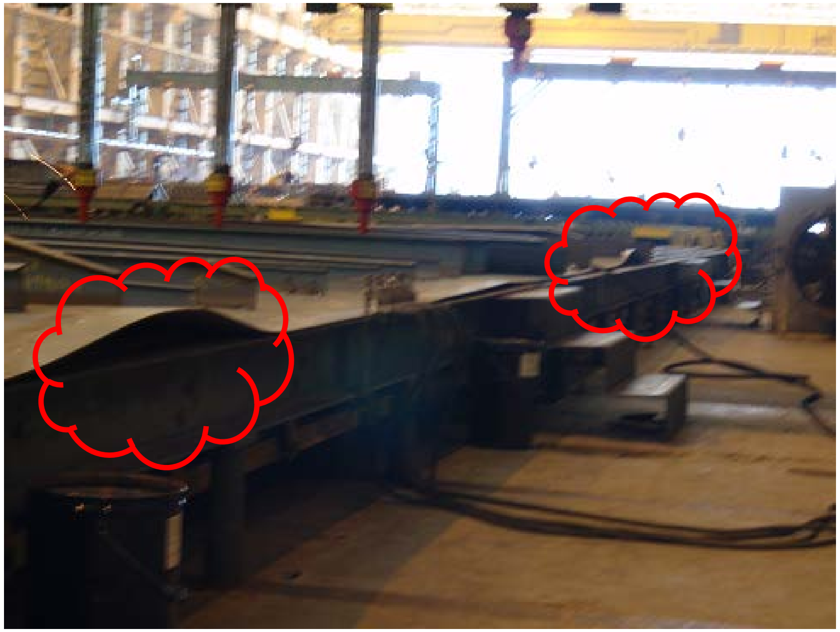


Designs which create seams with differing plate thicknesses cause numerous distortional difficulties.

- Fit-up issues (Forced fit which locks in residual stress, enlarged gap which causes overwelding)
- Although these concerns are being addressed by production, cases where inserts can be eliminated, or moved away from plate edge will greatly reduce distortion

Design Effects on Optimal Construction Effort

Increased Construction Difficulties with Inserts



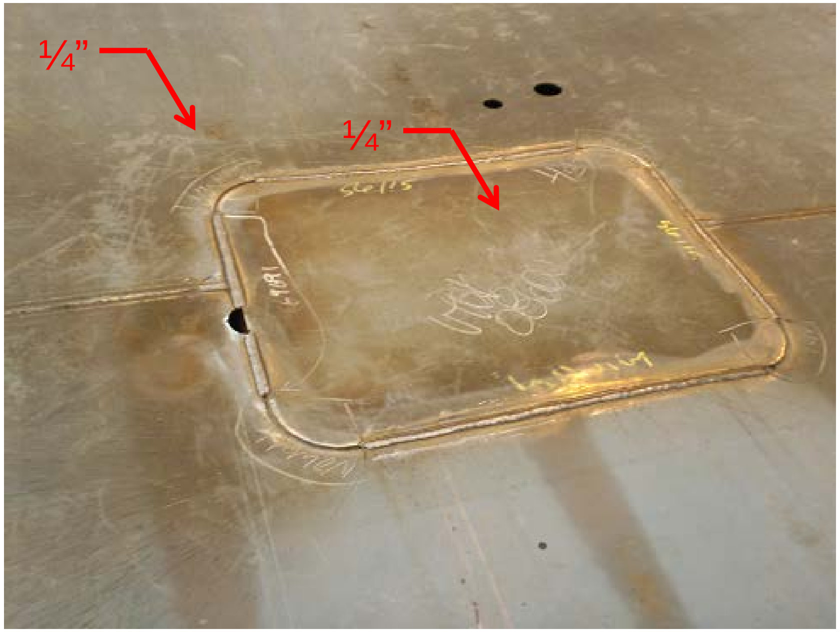
Identical Inserts on port and starboard sides. The size of weld and amount of heat required to weld these insert plates caused major distortion throughout unit

- All alternative designs that eliminate the need for inserts on thin steel panels should be exhausted before adding these inserts to the design

- It is evident from the picture on the right that these inserts, being so close the panel edge, caused significant and symmetrical unstable distortion on this unit

Design Effects on Optimal Construction Effort

Increased Construction Difficulties with Inserts



Several same thickness inserts were put in the design on this unit to account for manholes which intersect a longitudinal butt seam

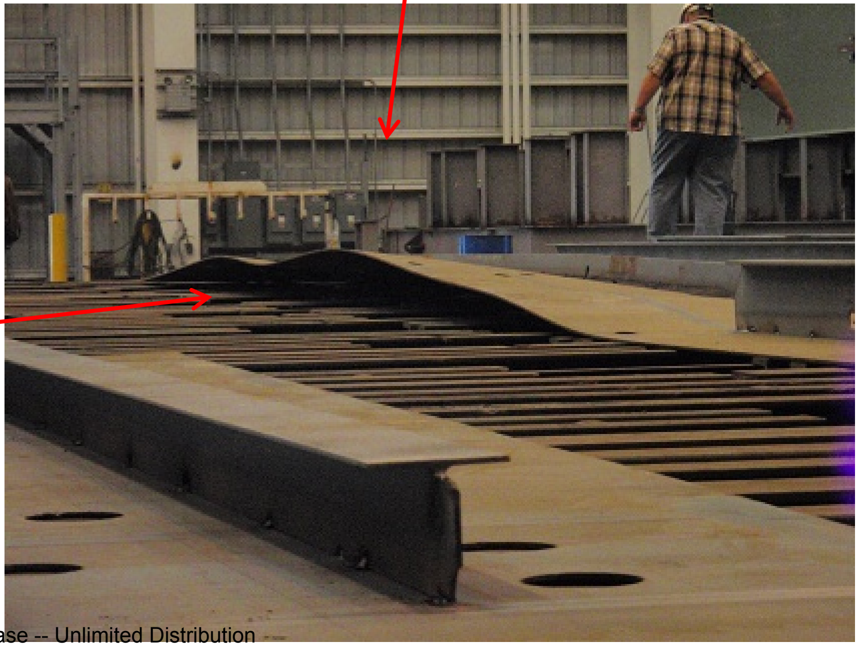
- Because of the increased heat from a weld size of 1”+ (as shown above) this unit has severe unstable distortion throughout

- Welding to the manhole cutout (similar to the partial penetration shown on the insert) should be used to eliminate these inserts and the resulting distortion

Typical Construction Problems - An Actual Thin Plate Production Panel

Panel complexity and welding methods, combined with material condition prior to welding caused excessive distortion throughout panel

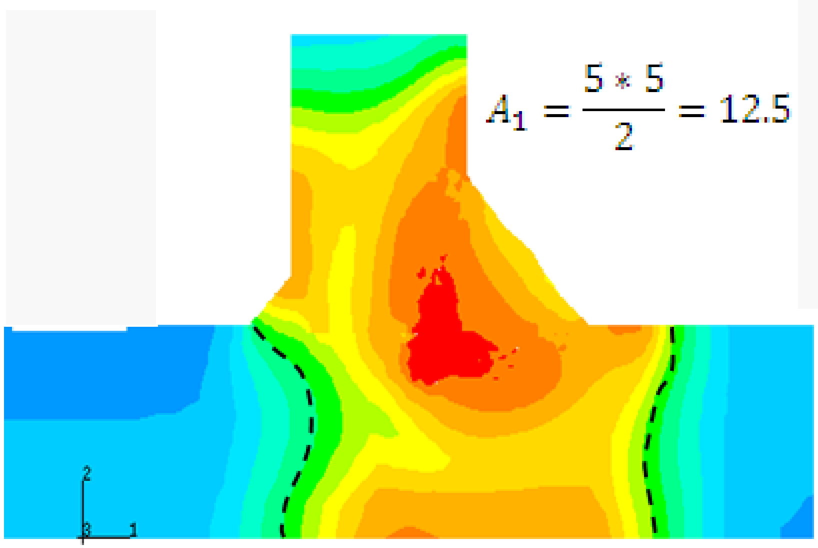
Stiffeners fit "top-down" and resulted in significantly more distortion than "center-out" method



Comparison of Plastic Zone

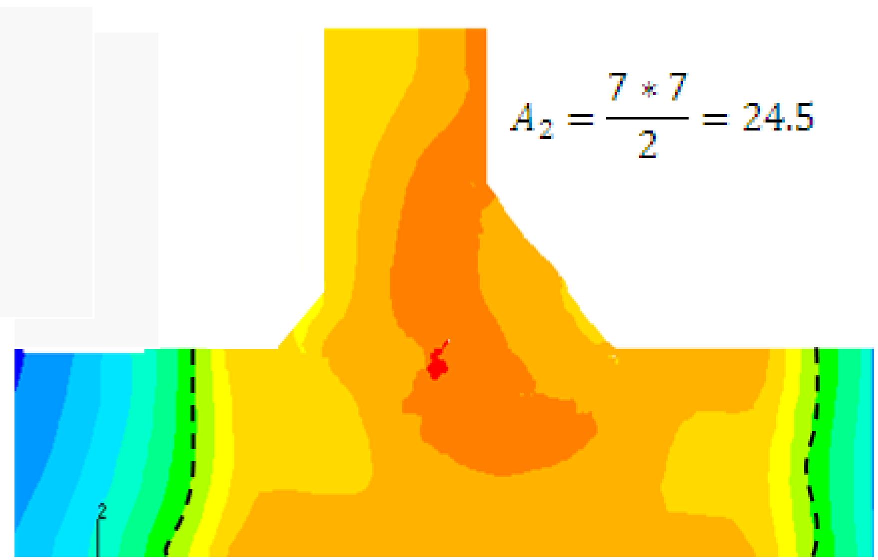
Weld Sizing Effect: 5mm versus 7mm Fillet Weld

Leg: 5mm



Plastic zone size

Leg: 7mm

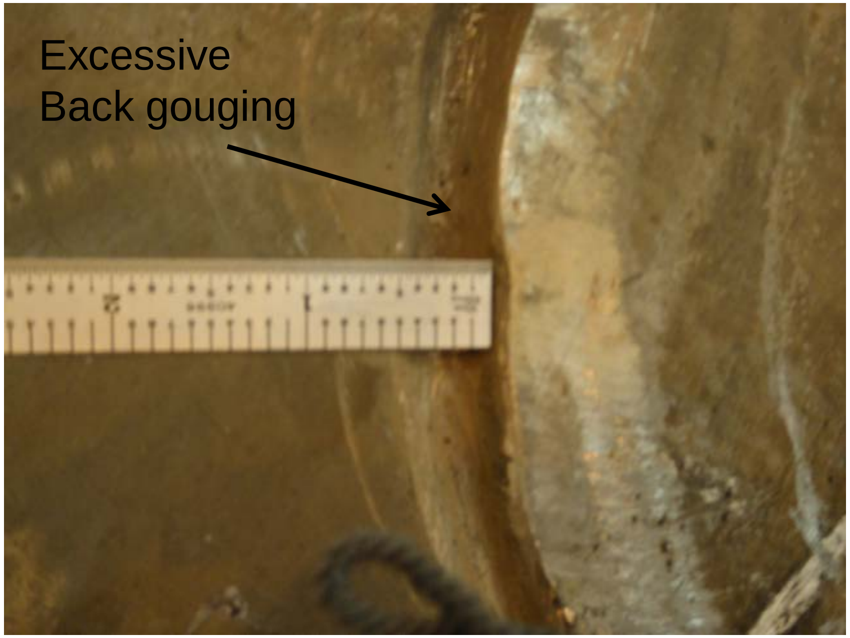


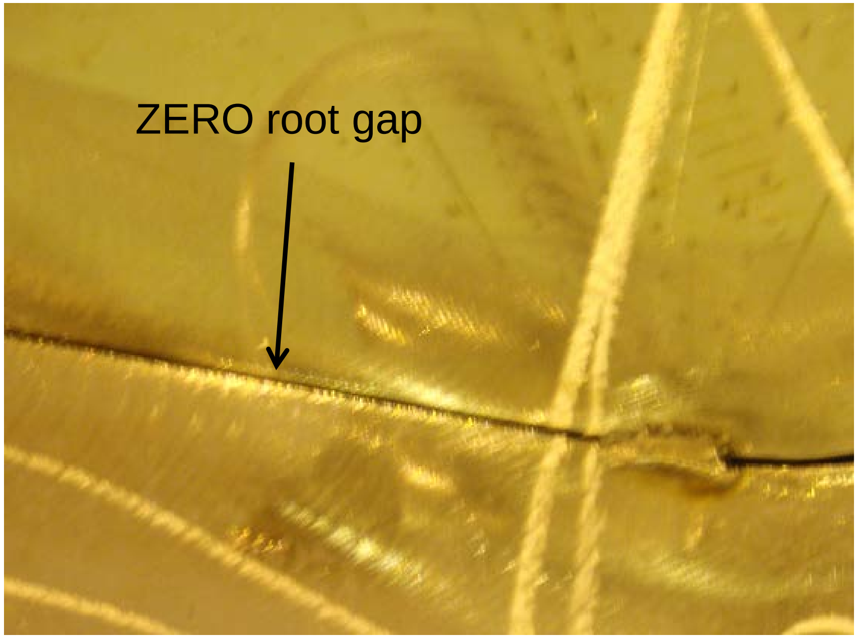
Plastic zone size

2mm increase in weld size causes DOUBLE the heat input and distortion

Optimal Construction Techniques

Improve Fit-Up / Reduce Root Gap





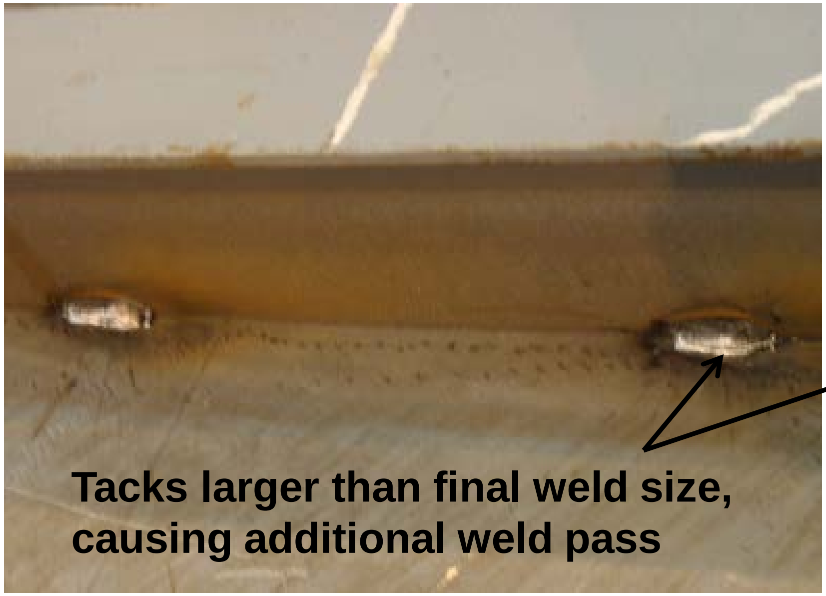
Welders should be challenged to be conscious of the effect enlarged back-gouging and fit-up have on weld size

- Optimal root gap is 1-2mm to achieve proper weld sizing on thin plate, the example above shows a back gouge of 12 mm.

- Reducing heat input by limiting root gap (without force fitting inserts), back gouge size, etc. are key to reducing the negative effects that inserts cause on distortion.

Optimal Construction Techniques

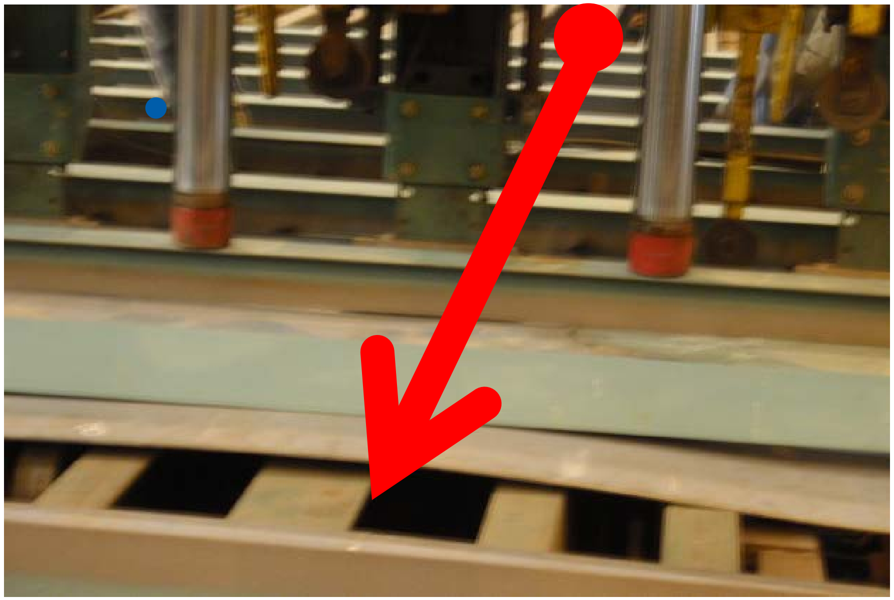
Minimize Tack Size



Tack size often drives an increase in weld size to cover tacks

- Fitters/Welders should limit tack size to at least 1/16” less than design weld size
- When tacks are too large, welders should grind them down in order to avoid overwelding and inducing unnecessary heat
- Using a smaller weld wire (3/32”) is another affective way to further reduce tack size.

Optimal Construction Techniques
Optimize Fit/Weld Sequence



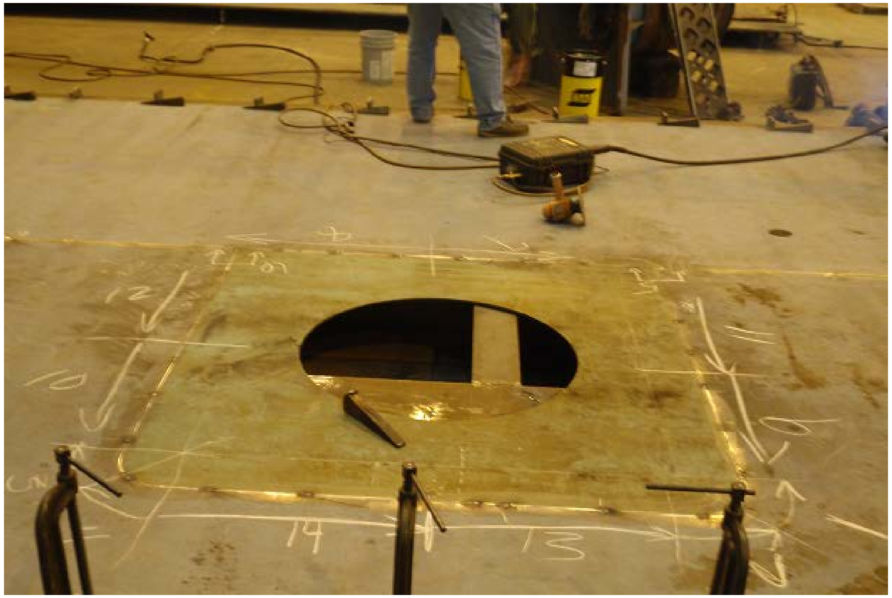
Optimizing stiffener fit and weld sequence is a key ship construction process

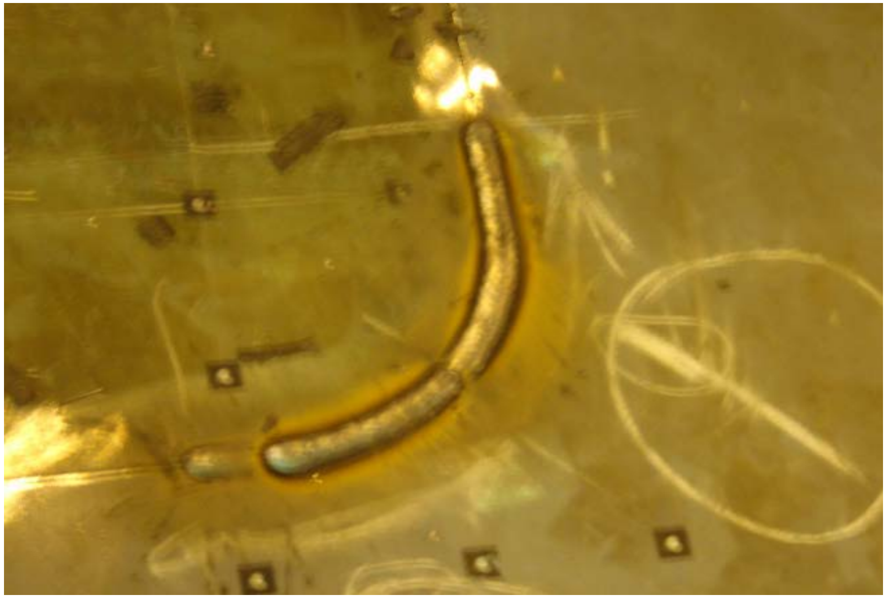
Fit/Weld from center out – Eliminates locking distortion into panel

Proper sequencing counteracts distortion caused from inserts, weld size, etc.

Optimal Construction Techniques

Use Back-Step Weld Sequence





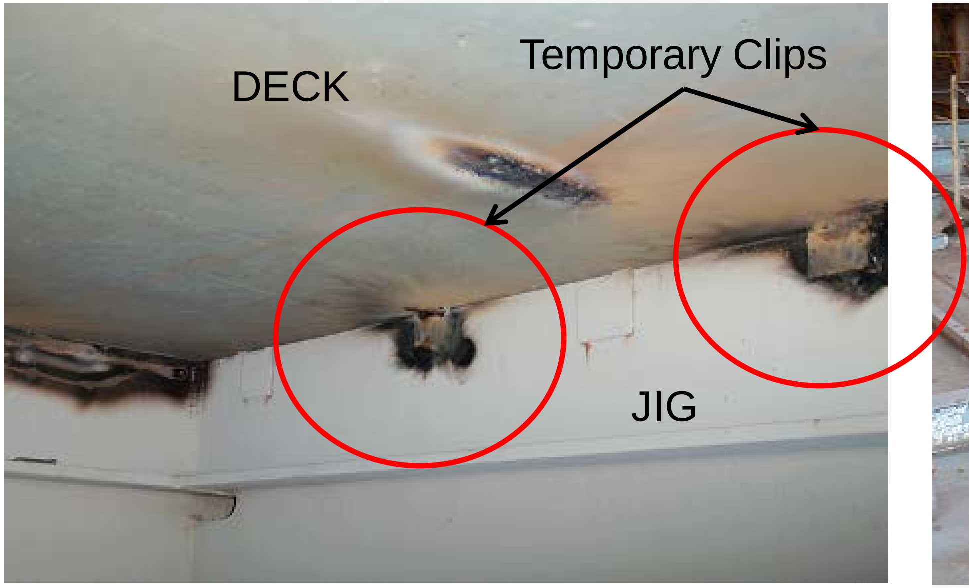
Using Back-Step Weld Sequence – Reduces Rotational Distortion

Reduces Out-of-Plane Distortion Caused by Inserts

Radius Should be left Unwelded until Properly Reinforced with Structurals

Optimal Construction Techniques

Tooling/Fixtures



Units should be tacked flat to the jig in order to hold the deck plate flat while transverse members are welded

Tacking large plates flat to jig keeps units flat while welding transverse stiffeners and bulkheads, less spring-back & distortion when turned shipshape

Optimal Construction Techniques

Use Weights w/ Large Footprint

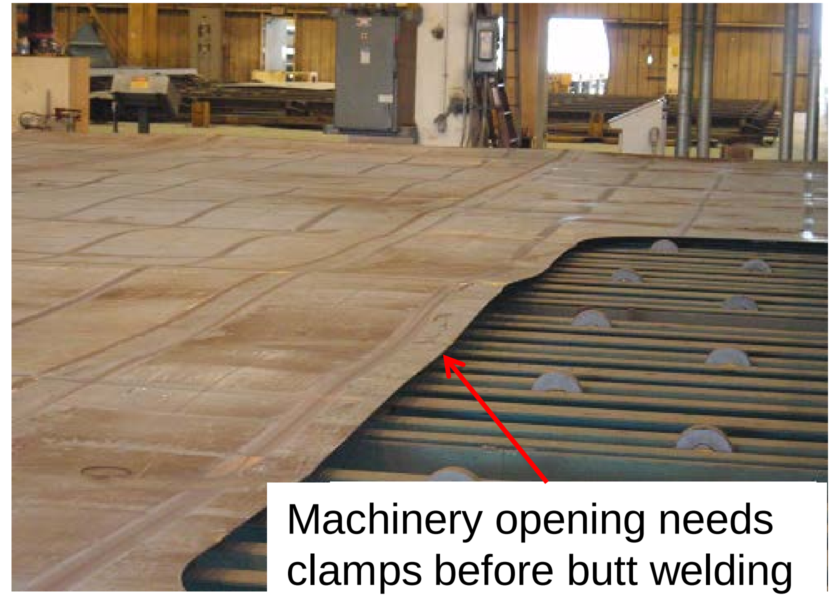
Beams replace keel blocks as weight restraints for thin plate butt welding

- Keel blocks concentrate too much weight on a small surface area preventing out of plane distortion and natural plate shrinkage in the area it contacts only

- Beams spread out weight over larger surface area and allow for consistent shrinkage while still restraining plate from buckling distortion

Optimal Construction Techniques

Clamp Plate (Edges & Cutouts)



Single Most Important Procedure to Resist Buckling Distortion

Clamping Plate Edges Significantly Reduces Buckling Distortion

Thin Panels Need to Have Edges & Cutouts Clamped Prior to ANY Welding

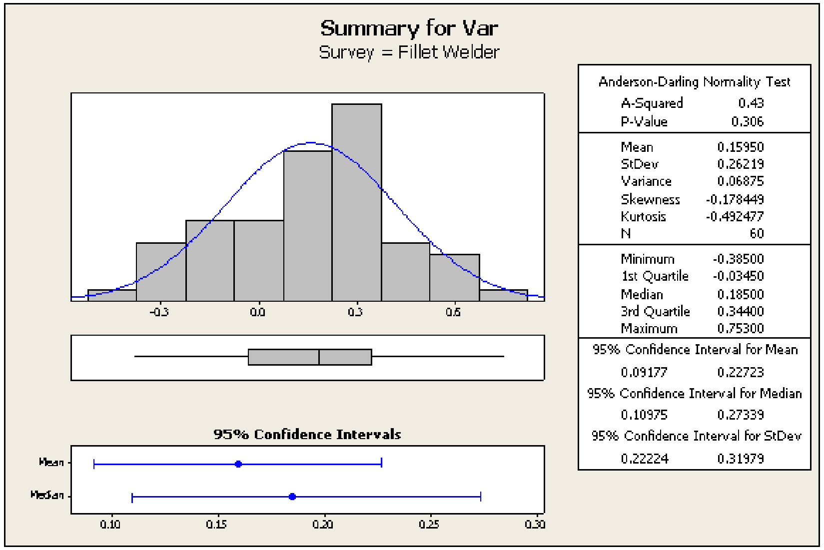
Cutouts should be left tabbed while seams and stiffeners are welded

- Tabs should be spaced every 12-18” depending on cutout size/type

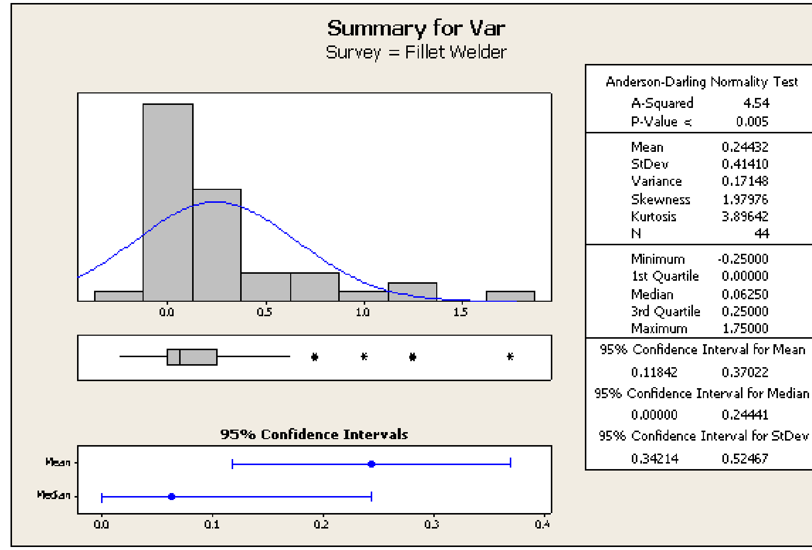
Fillet Weld Panel Comparison (3/16" base plate)

Restraint Comparison on Unstable Distortion

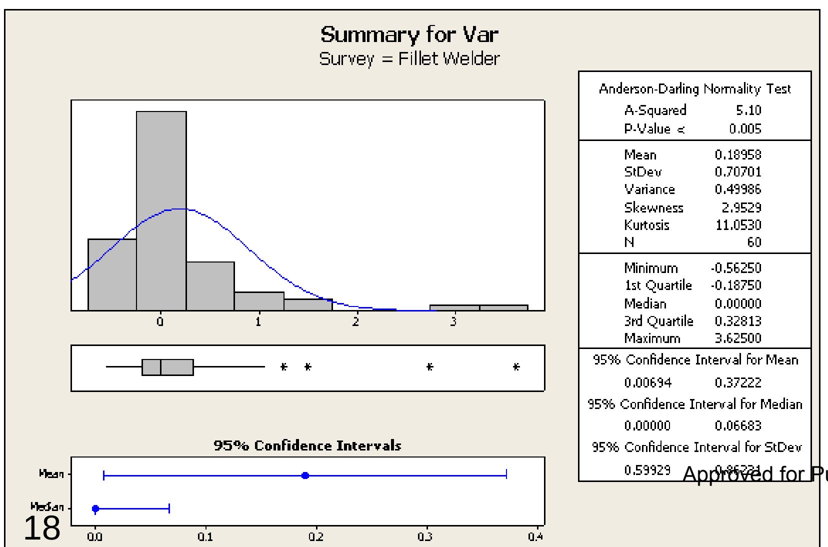
P1: Clamps/Weights During Butts & Fillets **(Var = 0.069)**



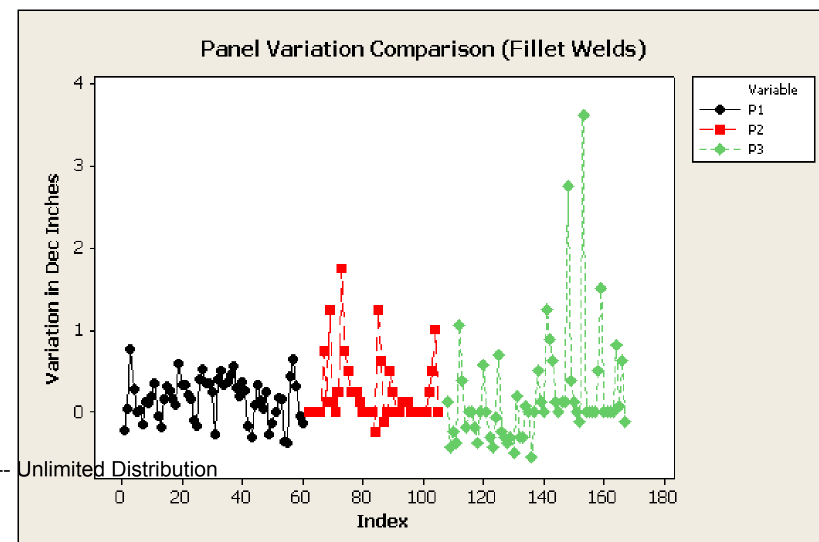
P2: Weights for Butts, Nothing for Fillets **(Var = 0.171)**



P3: Unrestrained During Butts and Fillets **(Var = 0.500)**



P1 vs. **P2** vs. **P3**



Distortion from Insufficient Support

Panel Line

- When space is limited, thin panels MUST take optimal storage priority
- Extra effort to reduce distortion in manufacturing practices nullified when panels are not staged properly
- Unlike thicker panels, stiffener and panel weight cause a bending moment that permanently distorts thinner panels

Grinding and Jig Construction Issues

Excessive Grinding, Proper Jig Use

- Shell plate not welded prior to turning for paint
- Noticeable panel distortion between tacked sections on jig
- Excessive paint grinding for weld prep

Construction Difficulties – Material Handling

Improper Handling of Stiffeners

Improper handling puts bending moment on beam

Permanent plastic deformation in beam

Deck pulled up to curvature of stiffener and locks in distortion

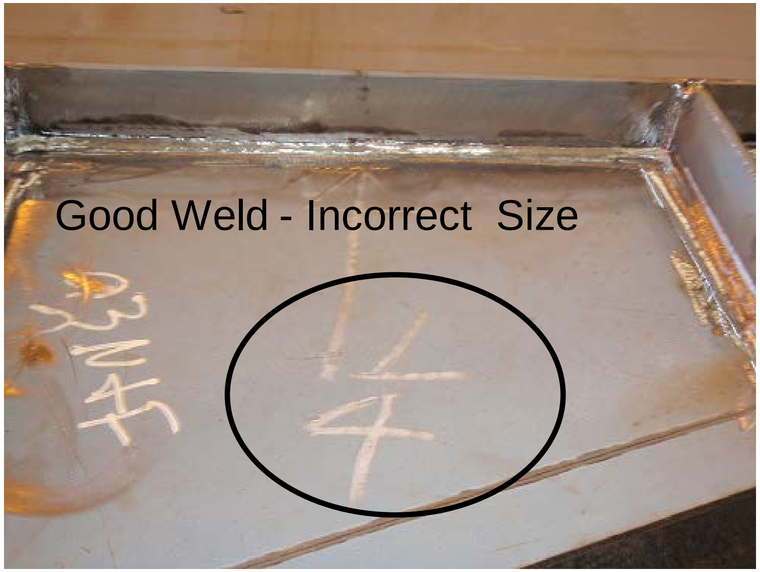
Material Handling Damage

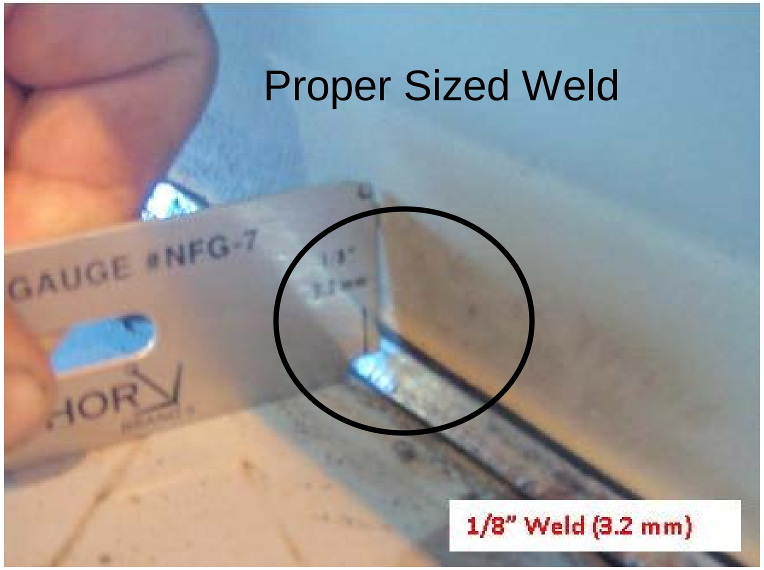
Fabrication Shop

- Longer panels are often staged overlapping shorter panels. When forklifts and other machinery run over these panels significant permanent distortion is noticed.
- Simple fix that eliminates adding additional distortion in panels before welding heat is even introduced

Achieving Design Specified Weld Size

Shipyard Wide Culture Change





- Small welds obtainable with proper tooling (smaller weld wire, utilizing bug-o whenever possible, increased weld speed)
- Our engineering group has made great efforts to address the overwelding issues that presently exist in our shipyard
  - Welders have a tendency to “overweld” to cover QA inspections
  - Proper weld tooling and training is critical to achieving weld design size

Reduce Damage from Flame Straightening

- Thin material is often over-corrected due to excessive heat during flame straightening
- Over-heating thin material can cause severe disruption to compartment completion schedule
  - Tripped members
  - Shrinking unit out of dimensional tolerances
  - Burning up paint and creating extensive rework

Setting Flame Straightening Guidelines

- Parameters were established for material ¼” and below and are as follows:
  - 1-1.25” spot pattern
  - 900-1000 degree heat spots
  - Staggered pattern along stiffener with spots every 2”

Summary

- The trend of thin steel in today's ship designs
- The issues thin steel designs bring to production
- Key design factors that affect thin steel producibility
- Key construction techniques used to mitigate distortion
- Preferred manufacturing processes and administration of correction methods to avoid creating additional production problems in order to reduce construction costs

Thank You

Questions?