Phase 1 – Bend and Elbow Standards, Manufacturing Capabilities, and Proposed Specifications

INGAA Foundation Workshop on Welding of Field Segmented Induction Bends and Elbows for Pipeline Construction

Bill Amend, Det Norske Veritas (USA), Inc.
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Scope of Work

- Phase 1 – Guidance for Specification and Purchase
  - Review Current Industry Codes and Standards
    - Manufacturing
    - Field Welding
  - Dimensional Control Capabilities of Various Manufacturers
    - Induction Bend Manufacturers
    - Forged Elbows
  - Proposed Specification Requirements for Purchasing
- Phase 2 – Guidance for field construction practices
- Phase 3 – Guidance for existing pipelines
### Manufacturing

<table>
<thead>
<tr>
<th>Standard</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASME B16.49 – 2007</td>
<td>Factory-Made, Wrought Steel, Buttwelding Induction Bends for Transportation and Distribution Systems</td>
</tr>
<tr>
<td>ASME B16.9 – 2007</td>
<td>Factory-Made Wrought Buttwelding Fittings</td>
</tr>
<tr>
<td>ASME B31.11 – 2002</td>
<td>Slurry Transportation Piping Systems</td>
</tr>
<tr>
<td>CSA Z245.11 – 2009</td>
<td>Petroleum and Natural Gas Industry Systems</td>
</tr>
<tr>
<td>ISO 15590-1 – 2009</td>
<td>Petroleum and natural gas industries -- Induction bends, fittings and flanges for pipeline transportation systems -- Part 1: Induction bends</td>
</tr>
<tr>
<td>MSS SP-75-2008</td>
<td>Specification for High-Test, Wrought, Butt-Welding Fittings</td>
</tr>
<tr>
<td>Offshore standard</td>
<td>Recommended Standards for Induction Bending of Pipe and Tube, Tube and Pipe Association International, 1998</td>
</tr>
<tr>
<td>DNV-OS-F101</td>
<td>Submarine Pipeline Systems, October 2002</td>
</tr>
<tr>
<td>NORSOK std M-630</td>
<td>“Material Data Sheets and Element Data Sheets for Piping”</td>
</tr>
<tr>
<td></td>
<td>EDS NBE2</td>
</tr>
<tr>
<td></td>
<td>MDS C11</td>
</tr>
<tr>
<td></td>
<td>MDS C01</td>
</tr>
<tr>
<td></td>
<td>MDS C23</td>
</tr>
</tbody>
</table>

Company specifications from the nine participating companies and DNV were also reviewed for useful content.
### Field Welding

<table>
<thead>
<tr>
<th>Standard</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>API 1104 – 2005</td>
<td>Welding of Pipelines and Related Facilities</td>
</tr>
<tr>
<td>ASME B31.4 – 2009</td>
<td>Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids</td>
</tr>
<tr>
<td>ASME B31.8 – 2007</td>
<td>Gas Transmission and Distribution Piping Systems</td>
</tr>
<tr>
<td>CSA Z662 – 2007</td>
<td>Oil and Gas Pipeline Systems</td>
</tr>
</tbody>
</table>

Company specifications from the nine participating companies were also reviewed for useful content.
Background

How the Information was Developed

- Industry survey of manufacturers (4 benders, 3 elbow manufacturers)
- Visits to 5 manufacturers (4 benders, 1 elbow mfg)
Background (cont.)

- **What We Learned**
  - Many standards and manufacturers consider “segmentable” to include out of roundness of 1% maximum throughout the length of the bend.
  - Some manufacturers stipulate the additional requirement for constant ID.
  - Ovality in bends influenced by D/t, bending temperature, bending speed.
  - Spiral weld pipe not recommended.
  - Some manufacturers (all those visited) require some type of heat treatment after bending to enhance dimensional stability.
  - Elbows may be Q&T or N&T, then re-rounded (effect of re-rounding on residual stress?)
  - Average diameter shrinkage for bends: ½% (no shrinkage for elbows) *What effect on hi-low at root?*
  - “Bump” typically formed at transition from tangent to bend related to induction coil start/stop.
Background (continued)

- **What We Learned (continued)**

  - Field segmentation is a slow, time consuming process when done correctly. Factory-marked cut lines for various angles (i.e., 5 degree increments) could speed the process of field segmentation.
### Dealing with ID Shrinkage

- Compensation possible by using special order “Large ID” pipe.
- How severe is ½% shrinkage?

<table>
<thead>
<tr>
<th>Diameter and wall</th>
<th>Perfectly Round Pipe and Bend</th>
<th>Shrinkage +1% Ovality</th>
</tr>
</thead>
<tbody>
<tr>
<td>36 x 0.625 inch</td>
<td>0.087” (&lt;3/32”)</td>
<td>0.174”</td>
</tr>
<tr>
<td>36 x 0.375 inch</td>
<td>0.088” (&lt;3/32”)</td>
<td>0.176”</td>
</tr>
<tr>
<td>30 x 0.344 inch</td>
<td>0.073” (&gt;1/16”)</td>
<td>0.147”</td>
</tr>
<tr>
<td>20 x 0.250 inch</td>
<td>0.049” (~3/64”)</td>
<td>0.098”</td>
</tr>
<tr>
<td>16 x 0.250 inch</td>
<td>0.039” (&lt;3/64”)</td>
<td>0.078”</td>
</tr>
</tbody>
</table>

![Diagram showing acceptable design](image)
Remedy for the Bump

- **Eliminate by:** Push tangent ends through the induction coil
  - Not all equipment can do this

- **Minimize by:** Alter the bending parameters
## Capabilities of Individual Manufacturers

<table>
<thead>
<tr>
<th>Bend Manufacturer</th>
<th>IBM1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Definition of Segmentable</strong></td>
<td>Same ID as adjoining straight pipe throughout tangent and bend, Maximum ovality of 1% Has received a tempering heat treatment</td>
</tr>
<tr>
<td><strong>Dimensional Control</strong></td>
<td>Start with heavier pipe to accommodate thinning on extrados Pass tangent ends through induction coil Entire bend is heat treated Can weld pups to ends Because ID matches pipe, no taper boring is required</td>
</tr>
<tr>
<td><strong>Other</strong></td>
<td>Can make and segment bends on short notice</td>
</tr>
</tbody>
</table>
# Bend Manufacturer

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>IBM2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Definition of Segmentable</strong></td>
<td>Unsure of ability to pass tangent ends through induction coil</td>
</tr>
<tr>
<td></td>
<td>Maximum ovality of 1% for D/t up to 20 for 3D, and D/t up to 25 for 5D</td>
</tr>
<tr>
<td><strong>Other</strong></td>
<td>Makes few segmentable bends</td>
</tr>
<tr>
<td></td>
<td>Prefers that actual wall thickness design requirement be specified when ordering</td>
</tr>
<tr>
<td></td>
<td>Higher strength pipe requires higher bending temperature which reduces ovality but increases shrinkage</td>
</tr>
</tbody>
</table>
# Bend Manufacturer

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>IBM3</th>
</tr>
</thead>
</table>

**Definition of Segmentable**

Clam shells used to reround after bending

7D bends result in less ovality and less thinning

Slower bending can reduce ovality, but may adversely affect YS of high strength pipe

Ovality increases from the start to the end of the bend

**Other**

Does not make segmentable bends
## Elbow Manufacturer Information

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>EM1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Definition</strong></td>
<td>Maximum 1% ovality</td>
</tr>
</tbody>
</table>
| **Dimensional control** | 1% ovality is the best achievable  
Ovality is measured at 5 locations along the elbow |
| **Other** | Manufactured by either mandrel or by forged+welded (preferred)  
Segmenting can be performed in the factory on short notice  
Ovality, radius, bend angle, wall thickness, circumference, etc. measured but not recorded unless requested |
Purchase Specifications

- One for bends, one for elbows
- Each one has a version specific to segmentability and a version that is more general that includes reference to segmentability
- The specifications include the “best” content from a variety of sources; they tend to be conservative and comprehensive
- Intended purpose is to serve as a “copy and paste” resource for further development of existing Company specifications
- Significant features:
  - Enhanced toughness requirements comparable to approaches for line pipe
  - Detailed testing requirements (intrados, extrados, seam, tangents)
- Review and comment by Manufacturers was solicited. Very few comments received
- Sources of quantitative values (including dimensions) and other content (when known) are annotated in the margins
Example of Annotations

Chemical analysis of the starting material shall meet the requirements of ASME B16.49 Section 7 except that:

- The maximum allowable carbon equivalent (CE IIW) shall be \( 0.42 \).
- The maximum allowable nickel content shall be 0.5%.
- The sum of copper, nickel, chromium, and molybdenum shall not exceed 1%.

**Comment [BA9]**: This is at the discretion of the purchasing company. The ASME spec allows up to 0.45.

**Comment [BA10]**: From MSS SP-75.
Induction Bending Process
Sometime later……
Welding Pups on the Ends (Optional)
Induction Bend Purchase Specification

- **Scope**: 4 inch and larger, grade B and stronger
- **SAWH pipe** is excluded from use
- **The purchaser** supplies the following information:

  **Adjoining pipe:**
  - grade, manufacturing process,
  - nominal OD wall thickness

  **Bend data:**
  - Tangent length, (each end) Minimum acceptable inside diameter
  - Bend radius, bend angle, Post bend heat treatment
  - Coating Maximum and minimum acceptable wall thickness

  **Service conditions:**
  - Minimum and maximum design temperatures,
  - Design pressure,
  - Service fluid
Bending Parameters

To Be Recorded and Kept Constant for All Bend Within a Heat

- Bending Temperature
- Pipe Feed Rate
- Power to Coil
- Quench Ring Water Pressure
- Orientation of pipe weld, if applicable
- Means of cooling to various temperature stages
- Terminal temperature of each cooling stage

Post bending heat treatment procedure (if required)
- Soak temperature(s) (minimum 1100 °F)
- Soak time at post bend heat treatment temperature(s)
- Cooling rate
- Cooling medium
Bends – Heat Treatment

- All segmentable bends shall be heat treated:
  - Thermocouples must be attached to bends in initial batch, then rely on furnace thermocouples after comparison to bend thermocouples,
  - Furnace records must be traceable to an individual bend
  - Recheck furnace calibration every 30 days or when modifications are made to the furnace
**Bends – Dimensional Limits; Ovality**

- **Nonsegmentable Bend Ovality:**
  - 1% in tangents
  - 2.5% in body (from MSS SP-75; B16.49 allows 3%),

- **Segmentable Bend Ovality:**
  - 1% throughout
  - Circumferential shrinkage limited to 0.5%
  - Minimum ID shall be as specified
  - Shrinkage and ovality measured within 6 inches of each end of the bend, the middle point of the bend arc and at \( \sim 10-20^\circ \) increments in between
Ovality

\[ \text{%ovality} = 100 \times \frac{\text{Maximum OD} - \text{Minimum OD}}{\text{Nominal OD}} \]

Example: Max OD = 30.15, Min OD = 29.85, Nominal = 30

\[ 100 \times \frac{(30.15-29.85)}{30} = 1.0\% \]
Bends – Dimensional Limits

- Bend radius: as specified +/- 0.5%
- Bend angle: as specified +/- 0.5°
- Beveled ends per B31.8 Figure I5
- End squareness: per ASME B16.49 (basically the same as MSS SP-75)
- OD at any point within 4 inches of the end shall not be less than nominal minus 2.5%
- ID evaluated by passing a gauging device with diameter equal to minimum allowable ID or 95% of the nominal ID of the unbent starting material
Bends – Dimensional Limits (cont.)

- Wall thickness limits: up to 0.01 in less than nominal but isolated spots with no less than 93.5% of t are OK (per MSS SP-75; ASME B16.49 allows 10% less than nominal)

- Sharp defect depth: up to 6-1/2% of t to be removed by grinding (per MSS SP75)

- Dent length or width limit: 2.5% of pipe OD; no dents in seam or with gouges

- Upsets at the tangent points are acceptable. No wrinkles are acceptable (no deviations from surface contour greater than 1/16”)

- Finished bends may not be mechanically sized without approval (not addressed in MSS SP-75 or in ASME B16.49)
Bends – Inspection and Testing

- Production testing in accordance with ASME B16.49 plus additional requirements
- Remnants at least 8 inches long to be saved for welding procedure testing
- No abrasive blasting required for inspection unless required to accomplish the inspection
- Inspection area lit to 50 ft-candles (500 lux) (5L requires 28 FC / 300 lux)
- Visual inspection criteria per ASME B16.49
- Residual magnetism may not exceed 26 gauss average, 35 gauss maximum
- Requires access to the following at time of inspection
  - Certified Material Test Reports (MTRs)
  - Chemical Analysis Reports
  - NDE Inspection Reports
  - Heat Treatment Schedules

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Bends – Testing

- Chemical composition per ASME B16.49 except:
  - Ni shall not exceed 0.5% (MSS SP-75)
  - Sum of Cu, Ni, Cr, Mo shall not exceed 1% (MSS SP-75)
  - A reduction of maximum allowable CE from 0.45 to ~0.42 is recommended

- Maximum acceptable YS is specified by purchaser (to address weld strength matching)

- Charpy impact toughness:
  - Average shear value: for each set of samples must be at least 75%
  - Absorbed energy: in accordance with API 5L Annex G section G.7 or G.8 or Table G1 (30-71 ft-lbs)
  - Test temperature adjustment required for subsize samples

- Hardness testing via Vickers, Rockwell or Brinell (others only with approval)
### Analytical Procedure

**Tensile test per ASTM E8 (Transverse Strip, 3/4" width)**

<table>
<thead>
<tr>
<th>Sample Location</th>
<th>Tensile Strength (PSI)</th>
<th>Yield Strength PSI @ 0.5% EUL</th>
<th>Elongation Percent @ 2.0&quot; Gage</th>
<th>Reduction of Area Percent</th>
<th>Fracture Type/Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mid Bend Extrados</td>
<td>92,500</td>
<td>65,500</td>
<td>27.8</td>
<td>64</td>
<td>Ductile Base</td>
</tr>
<tr>
<td>Mid Bend Intrados</td>
<td>98,000</td>
<td>78,000</td>
<td>29.8</td>
<td>70</td>
<td>Ductile Base</td>
</tr>
<tr>
<td>Mid Bend Bottom</td>
<td>97,000</td>
<td>72,000</td>
<td>29.4</td>
<td>64</td>
<td>Ductile Base</td>
</tr>
</tbody>
</table>

### Analytical Procedure

**Impact Test per ASTM E23 (Transverse)**

<table>
<thead>
<tr>
<th>Sample Location</th>
<th>Spec ID</th>
<th>Individual Size</th>
<th>Test Temp (F)</th>
<th>Energy (Ft-Lb)</th>
<th>Shear Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tangent</td>
<td>U1</td>
<td>10 mm x 10 mm</td>
<td>+ 32</td>
<td>182</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>U2</td>
<td>10 mm x 10 mm</td>
<td>+ 32</td>
<td>186</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>U3</td>
<td>10 mm x 10 mm</td>
<td>+ 32</td>
<td>210</td>
<td>100</td>
</tr>
<tr>
<td>Mid Bend Extrados</td>
<td>E1</td>
<td>10 mm x 10 mm</td>
<td>+ 32</td>
<td>190</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>E2</td>
<td>10 mm x 10 mm</td>
<td>+ 32</td>
<td>200</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>E3</td>
<td>10 mm x 10 mm</td>
<td>+ 32</td>
<td>172</td>
<td>100</td>
</tr>
<tr>
<td>Mid Bend Intrados</td>
<td>I1</td>
<td>10 mm x 10 mm</td>
<td>+ 32</td>
<td>162</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td>I2</td>
<td>10 mm x 10 mm</td>
<td>+ 32</td>
<td>180</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td>I3</td>
<td>10 mm x 10 mm</td>
<td>+ 32</td>
<td>164</td>
<td>90</td>
</tr>
<tr>
<td>Mid Bend Bottom</td>
<td>B1</td>
<td>10 mm x 10 mm</td>
<td>+ 32</td>
<td>172</td>
<td>75</td>
</tr>
<tr>
<td></td>
<td>B2</td>
<td>10 mm x 10 mm</td>
<td>+ 32</td>
<td>172</td>
<td>85</td>
</tr>
<tr>
<td></td>
<td>B3</td>
<td>10 mm x 10 mm</td>
<td>+ 32</td>
<td>196</td>
<td>75</td>
</tr>
</tbody>
</table>
Bends – NDT

- Wall thickness measured by UT:
  - at 12:00, 3:00, 6:00, and 9:00,
  - at beginning, end, and at least every 10° along the bend,
  - PLUS 6 to 8 inches axially on either side of the thinnest measurement if the measurement is less than the specified nominal wall plus 2%. (Intended to ensure that the thinnest area is measured)
  - Example: If specified nominal is 0.500 in, additional thickness measurements are required if the minimum measurement is less than 0.510 inch

- Weld seams shall be inspected with UT or radiography; Acceptance standards per API 5L

- Weld bevels to be visually and PT or MT inspected for evidence of laminations ≥0.25 inch long
Bends – NDT (cont.)

- PT or MT per ASME B16.9 and of
  - all ground surfaces,
  - accessible areas of the ID on the extrados side, and
  - seam welds in the bend area (tangents excluded unless they have been heat treated)
Bends and Elbows – Markings

- XYZ PIPELINE COMPANY order and item number
- Individual bend identification number
- “DO NOT CUT” if not segmentable
- Point of tangency
- Other bend manufacturing data when required by XYZ Pipeline Company
- If stress relieved: add “SR-XXXX”, If Q&T add “QT-YYYY/ZZZZ” where
  - XXXX is the stress relief temperature,
  - YYYY is the quench temperature, and
  - ZZZZ is the tempering temperature
- A unique identification number shall be assigned to each bend, for example identifying the PO number, the item number in the PO and the sequence or serial number if the item number includes more than 1 bend
- 12 inch and larger: Mark ID and OD both ends (B16.49 allows marking on one end only)
- Smaller bends: Mark OD only
Bends – Certification

- Manufacturer shall have a quality system in accordance with ISO 9001 for the products being produced.

- Certified test report shall be in accordance with API 5L PSL2, MSS-SP-75, or ASME B16.49 and include:
  - Company purchase order and item numbers
  - Manufacturer's shop order number
  - Individual identification number
  - Pipe manufacturer's mill test report including pipe heat number
  - Bend procedure qualification test results
  - Heat treatment method and schedule
  - Size, wall thickness and grade of pipe bend (lot)
Bends – Certification (cont.)

- Confirmation that the bend meets all dimensional tolerances of the specification
- Centerline radius and angle of pipe bend
- Notch toughness report stating both absorbed energy and shear area
- Hardness range found during testing
- Tensile testing report
- Full description of bend including ASME B16.49 grade symbol
- Records of all non-destructive tests, including ultrasonic, radiographic, and dye penetrant or magnetic particle inspection reports, showing acceptance or rejection of items tested.
- Records of all qualification bends and results of associated testing.
Bends – Other Information

- Manufacturer to notify purchaser at least 3 days in advance of
  - Bending procedure qualification
  - Start of bending
  - Heat treatment
  - Mechanical testing
  - Final inspection/release
  - Coating

- Some purchasers include a requirement for no failure during hydrotesting to as high as 103% SMYS.

- No welding (including repair welding) except for temporary attachment of extensions for pushing
Elbow Manufacturing

1. Purchase Material
2. Incoming Inspection
3. Develop Shop Orders, Drawings
4. Material Cutting
5. Form Halves, Cold or Hot
6. NDE
7. Welding
8. Machining
9. Cleaning
10. NDE and Final Inspection, Marking
11. Test Coupons
12. Shipping
13. Packaging
14. Certification
Forming Elbow Halves
Elbows – Applicable Specifications

- ASTM A234 grade WPB supplemental requirement ASTM A 960 S3
- ASTM A420 WPL6 supplemental requirements ASTM A 960 S51, S53, S59, S69
- ASTM A860 WPHY52, supplemental requirements A960 S53, S69
- All WPB (grade B) fittings shall comply with ANSI B16.9.

High yield strength fittings shall conform to supplementary requirements of MSS SP-75 (latest edition), including:

- SR-5: Upper limits on yield strength (for quenched and tempered fittings only). The maximum acceptable yield strength for other fittings shall be as shown in section 3.4
- SR-6, 7: Supplemental notch toughness requirements
- SR-10 Supplemental chemical composition requirements
- SR-14 NDE of weld ends using dye penetrant or magnetic particle inspection
Elbows - Heat Treatment

- Q&T only OK for SMYS ≥ 52 KSI;
- Minimum tempering temperature is 1100°F
- Stress relief temperature is 1100-1250°F for 1 hr minimum (1 hr/inch thickness). ASME Section VIII Div. 1 Table UCS 56.1 can be used to select hold time for reduced temperatures.
- No welding after heat treatment
Elbows - Dimensions

- The minimum inside diameter at any location in an elbow shall be at least 93.0% of the nominal inside diameter specified.

- For piggable lines, the minimum bore shall be no smaller than the greater of the nominal bore diameter minus ¼ inch, or 93% of the nominal bore diameter specified.

  - Note: B16.9 has no requirements for ovality or bore size away from the weld ends; “Bore diameters away from the ends are not specified”. For segmentable bends, “…diameter tolerance shall be furnished throughout the fitting by agreement between the manufacturer and purchaser.”

- Diameter at the inside root face of the weld bevel shall not be more than 3/32 inch smaller nor more than 3/32 inch larger than the nominal inside diameter of the fitting specified on the purchase order.
Elbow Composition

- The maximum chemical composition in Table 1 of SP-75 shall apply to product analysis and shall be modified for the following elements:

<table>
<thead>
<tr>
<th>Element</th>
<th>SP 75 Max. %</th>
<th>Proposed Maximum %</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>0.30</td>
<td>0.20%</td>
</tr>
<tr>
<td>Si</td>
<td>0.50</td>
<td>0.45%</td>
</tr>
<tr>
<td>Cu</td>
<td>0.50</td>
<td>0.40%</td>
</tr>
<tr>
<td>S</td>
<td>0.035</td>
<td>0.020% (grades Y60 and stronger)</td>
</tr>
<tr>
<td></td>
<td>0.035</td>
<td>0.025% (other grades)</td>
</tr>
<tr>
<td>P</td>
<td>0.035</td>
<td>0.025% (grades Y60 and stronger)</td>
</tr>
<tr>
<td></td>
<td>0.035</td>
<td>0.030% (other grades)</td>
</tr>
<tr>
<td>Cr</td>
<td>0.25</td>
<td>0.15%</td>
</tr>
<tr>
<td>V+Nb+Ti</td>
<td>-</td>
<td>0.10 %</td>
</tr>
</tbody>
</table>

- The carbon equivalent of SP-75 section 7.3 shall not exceed 0.43
Elbow Qualification

- Proof tests performed on prototype fittings are sufficient to qualify fittings of similar design from 1/2 to 1-1/2 times the diameter of the prototype, provided the actual tensile strength is greater than the specified min. tensile strength.

- Qualification shall be necessary if:
  - the Mfg has not supplied fittings from the plant facility used to make the fittings during the last three (3) years; or
  - when determined by the Purchaser.

- Requalification may be necessary if any of the following changes occurs:
  - source of starting materials;
  - specification for starting materials;
  - the plant facility used to make the fittings; or
  - the manufacturing procedure qualification.

- The procedure qualification requirements consist of two parts:
  - manufacturing procedure qualification information; and
  - the procedure qualification tests.
Elbow Material Testing

- Wall thickness may not be substituted for strength without permission

**Base Metal**

- YS - maximum allowable YS for fittings = 67,000 psi SMYS < 46 ksi. For higher strength materials, the actual yield strength shall not be higher than the values shown in Table 2 of MSS SP-75

- UTS

- %Elongation

- Charpy at -50°F

**Weld**

- Toughness testing per ASME Section VIII Div. 1, UG-84

- Tensile testing with reinforcement removed. Acceptance per MSS SP-75

**General** - Hardness shall not exceed HRC 30 anywhere on the fitting
Elbow NDT

- Radiography per ASME Section V, where practical, otherwise shear wave UT per ASTM E-164
- Wall thickness UT per MSS SP-75 SR-8
- Weld ends inspected per MSS SP-75 SR-14, acceptance per API 5L section K.2.1
  - Weld bevel faces shall be inspected for laminations after final machining using wet magnetic particle, dye penetrant or ultrasonic procedures.
  - Any indication with a dimension in excess of 1/4 inch or an accumulation of 1/4 inch in any 2 inch sector shall be cut out as a cylinder.
Elbow Repair

- No repairs to previous repairs, seams, or weld bevels allowed
- Jacking, hammering, re-expansion or any process causing local deformation is not permitted after heat treatment
- No dents allowed in the seam
- No dents with stress concentrators allowed
- Maximum allowable dent depth is 3/16 inch
- Body imperfections can be removed by grinding so that at least 93.5% of the nominal wall thickness remains after grinding
- Weld surface defects can be removed by grinding if the ground surface does not extend below the surface of the fitting
- Arc burns can be removed by grinding as long as remaining thickness is at least 93.5% of the nominal wall thickness remains after grinding and ammonium persulfate etch confirms removal
Elbow Repair (cont.)

- No weld repair on the body of the fitting
- Weld repair of the seam is allowed. Subsequent inspection is by the same method that found the original flaw
Segmentable Elbows:

- The out of roundness for segmentable elbows shall be no greater than 1% throughout the body of the elbow.

- Out of roundness shall be measured in the elbow within 6 inches of the start, center and within 6 inches of the end of the arc, and at approximate 20° increments in between.

- No measured points may exceed 1%.

- These measurements shall be recorded and provided with each completed elbow.

- The minimum inside circumference of segmentable elbows shall be no less than \( \pi \times (\text{nominal ID} - 3/16 \text{ inch}) \)
Out of Round for Elbows

- MSS SP-75: \[ \text{ovality} = 100 \times \frac{\text{Maximum OD} - \text{Minimum OD}}{\text{Nominal OD}} \]

- ASME B16.9: Out of round is the sum of the absolute values of plus and minus tolerance
Summary for Phase 1

- Phase 1 of this project involved development of guidance for specification and purchase of segmentable induction bends and elbows

- A review of current industry codes and company specifications for induction bends and elbows was carried out, along with a review of current manufacturing practices

- Dimensional control capabilities of various manufacturers were established for segmentable induction bends and elbows during a series of manufacturer visits and interviews

- Based on the results of these activities, generic specification requirements for purchasing segmentable induction bends and elbows were developed
Safeguarding life, property and the environment

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