Det Norske Veritas

Phase 1 Final Report

Guidance for Specification and Purchase of Segmentable Induction Bends and Elbows

for

Joint Industry Project

on

Welding of Field Segmented Induction Bends and Elbows for Pipeline Construction

to

A Group of Participants

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<tr><td colspan="4">Summary: This report describes Phase 1 of a three-phase project related to specification, manufacture, and installation of segmentable pipeline induction bends and elbows. Generic purchase specifications for segmentable induction bends and elbows are included. Manufacturing processes and capabilities are described.</td></tr>
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EXECUTIVE SUMMARY

The overall goal of this project was to develop practical guidelines for using segmented induction bends and long-radius elbows for pipeline construction and to identify practices which should be avoided. The scope of this project was limited to large diameter pipelines (e.g., 30 inch diameter and above), as the challenges to achieving proper fit-up and ultimately acceptable weld quality are complicated by such factors as ovality.

The need to use segmented induction bends and elbows can arise for a variety of reasons during construction of new pipelines or during pipeline repair and maintenance activities. Bends having a tighter radius than can be accomplished by cold field bending may be required to accommodate abrupt directional changes. While some tight-radius directional changes can be accommodated by ordering induction bends with specific bend angles, the specific bend angles required are not always known prior to construction. Therefore, the use of segmentable induction bends and elbows may also be required during pipeline repair activities.

This report describes the first of three phases of work, with each phase addressing a specific objective developed by the nine project participants. The first objective was to develop guidance regarding the specification and purchase of segmentable induction bends and elbows. The second objective was to develop guidance for field construction practices. The third objective was to evaluate the use of in-line caliper and deformation tool data to identify areas of concern in existing pipelines. This report pertains to the first objective only.

In this first phase of this work, the manufacturing methods, capabilities, and limitations of induction bend and elbow manufacturers were evaluated during visits to manufacturing facilities. Pertinent industry standards and related pipeline company specifications were reviewed. The information has been summarized and used to develop examples of generic purchasing specifications for both segmentable induction bends and manufactured elbows. Annotations in the specifications describe the source of key content and highlight content specifically related to segmentability.

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1. INTRODUCTION

The use of cold field bends is not practical for some pipeline construction applications, particularly for large diameter pipelines built with restricted work space. This may include work sites with rough terrain and insufficient room to store ditch spoil, replacement of smaller diameter lines with large diameter lines when existing profiles require shorter radius points of inflection, pipeline construction in streets where field bends are insufficient to provide clearance from other utilities, etc. For many reasons, segmenting long-radius (3D) elbows[1] and induction bends becomes necessary as part of normal construction practice.

There is currently inadequate guidance regarding the use of segmented induction bends and elbows for pipeline construction, and in particular 30-inch diameter pipe and larger. This includes a lack of consistency regarding the purchase of "segmentable" elbows and bends, the dimensional characteristics of segmentable fittings, field cutting/beveling/transitioning practices for these fittings, and verification methods to insure adequate girth weld fit-up. When fit-up (internal alignment) is not within specified limits, improved guidance is needed with respect to pipe wall transitioning and backwelding.

Recognizing the need to develop guidelines for the use of field segmented induction bends and elbows for pipeline construction, Spectra Energy organized a joint industry project (JIP) that was conducted by Det Norske Veritas (U.S.A.), Inc. (DNV). Participation in this project included:

Alliance Pipeline	CenterPoint Energy	El Paso
Kinder Morgan	NiSource	Panhandle Energy
Spectra Energy	TransCanada	Williams

The project had three main objectives. The first objective was to develop guidance regarding the specification and purchase of segmentable induction bends and elbows. The second objective was to develop guidance for field construction practices. The third objective was to evaluate the use of in-line caliper and deformation tool data to identify areas of concern in existing pipelines. This report pertains to the first objective only.

2. BACKGROUND

The need to use segmented induction bends and elbows can arise for a variety of reasons during construction of new pipelines or during pipeline repair and maintenance activities. There are often instances where bends with a tighter radius than can be accomplished by cold field bending are required to accommodate abrupt directional changes; either points of inflection, changes in topography, or both (Figure 1). Some tight-radius points of inflection or changes in topography can be accommodated by ordering induction bends or elbows with specific bend angles. This is generally true for points of inflection which can be surveyed in detail prior to construction. However, the specific bend angles required are not always known prior to construction,

[1] Radius of curvature equal to 3 times the pipe diameter.

particularly for changes in topography during pipeline construction in challenging and hilly terrain. The use of segmentable induction bends and elbows may also be required during pipeline repair activities. Often times the pipeline has to be taken out of service during these activities, and due to time constraints, purchasing a precise bend angle from a supplier would be logistically impossible. While some bend angles can be accommodated using a combination of standard (pre-manufactured) bend angle fittings and field bends, it is often useful to order segmentable induction bends and/or elbows that can be cut to the required bend angle in the field.

2.1 Field Bends

The radius of curvature for cold field bends is generally limited to 40 times the pipe diameter (1.5 degrees per pipe diameter of length) to minimize damage to fusion bonded epoxy (FBE) coatings, although cold field bends with a radius of curvature as small as 15 to 8D may be achievable in some pipe diameter and wall thickness combinations. Beyond this, wrinkling along the intrados tends to occur as well as excessive strains and wall thinning along the extrados. The practice of field bending is also heavily reliant on equipment availability and operator knowledge and experience. While field bends should be used where practical, they are not always an option.

2.2 Induction Bends

Induction bends are formed in a factory by passing a length of straight pipe through an induction bending machine (Figure 2). This machine uses an induction coil to heat a narrow band of the pipe material (Figure 3). The leading end of the pipe is clamped to a pivot arm. As the pipe is pushed through the machine, a bend with the desired radius of curvature is produced. The heated material just beyond the induction coil is quenched with a water spray on the outside surface of the pipe. Thermal expansion of the narrow heated section of pipe is restrained due to the unheated pipe on either side, which causes diameter shrinkage upon cooling. The induction bending process also causes wall thickening on the intrados and thinning on the extrados. The severity of thickening/thinning is dependant on the bending temperature, the speed at which the pipe is pushed through the induction coil, the placement of the induction coil relative to the pipe (closer to the intrados or extrados), and other factors.

Most induction bends are manufactured with tangent ends (straight sections) that are not affected by the induction bending process. Field welds are made or pipe pup sections are attached to the unaffected tangent ends (Figure 4), allowing for fitup similar to that found when welding straight sections of pipe together.

Induction bends come in standard bend angles (e.g. 45°, 90°, etc.) or can be custom made to specific bend angles. Compound bends (out-of-plane) bends in a single joint of pipe can also be produced. The bend radius is specified as a function of the diameter. For example, common bend radii for induction bends are 3D, 5D and 7D, where D is the nominal pipe diameter.

2.3 Elbows

Elbows are formed in a factory using one of several manufacturing methods. The first method involves the use of plate material that is heated and forged into two halves (clam shells) using a press and a die that will produced the desired radius and diameter (Figure 5). The edges of each half are trimmed (Figure 6) and the two halves are then assembled and welded together (Figures 7 and 8) using two submerged-arc welds (one along the intrados and the other along the extrados). The weld reinforcement is ground flush for the entire length of the elbow or for only a few inches at each end (Figure 9). Following radiographic inspection of the seam welds (Figure 10), the ends of the elbow are trimmed and prepared for field welding. Dimensional checks are then performed on the end preparations (Figure 11) and throughout the length of the elbow for diameter and out-of-roundness (Figure 12).

Elbows can also be manufactured using the "bend over mandrel" process (Figure 13). Pipe material is heated and bent while a mandrel is drawn through. The mandrel prevents ovalization and maintains a constant inside diameter throughout the length of the elbow.

Elbows also come in standard bend angles (e.g. 45°, 90°, etc.). Elbows can be custom made (i.e., cut in the factory) to specific bend angles. The bend radius is specified as a function of the diameter. For the purposes of this project, "long radius" when used to describe an elbow refers to a radius of curvature equal to three times the pipe diameter (i.e., a 3D elbow).

3. SCOPE OF WORK

The overall goal of this project was to develop practical guidelines for using segmented induction bends and long-radius elbows for pipeline construction and to identify practices which should be avoided. The scope of this project was limited to large diameter pipelines (e.g., 30 inch diameter and above), as the challenges to achieving proper fit-up and ultimately acceptable weld quality are complicated by such factors as ovality.

The scope of work for this project was divided into phases to address the three main objectives. The scope of work for Phase 1, to which this report pertains, was to address the first objective (develop guidance regarding the specification and purchase of segmentable induction bends and elbows). The work scope included the following activities:

- Review current industry codes and company specifications
- Review current manufacturing practices including procedure qualifications and testing, heat treatment, and quality assurance/documentation
- Establish dimensional control capabilities of various manufacturers with regard to supply of segmentable induction bends and long-radius elbows. Verify these dimensional control capabilities through dimensional measurements and review of quality control records. Evaluate actions taken by each manufacturer to achieve segmentable dimensional capability.

- Develop proposed specification requirements for purchasing segmentable induction bends and long-radius elbows

The scope of work for Phase 2, to which a subsequent report will pertain, will address the second objective (develop guidance for field construction practices), and will address the following issues:

- Optimal methods for mapping, cutting, beveling and transitioning
- Limits for high-low misalignment during field fit-up, alternative joint designs for unequal wall thickness
- Methods for measuring high-low in the field and methods for addressing excessive misalignment
- Backwelding methods and practices
- Radiographic issues for welds with internal transitions
- Guidance for revision of construction specifications

The scope of work for Phase 3, to which an additional subsequent report will pertain, will address the third objective (evaluate the use of caliper and deformation tool data), and will include the following:

- Evaluate the use of caliper and deformation tool data to identify areas of concern in existing pipelines

4. RESULTS FOR PHASE 1

The results for Phase 1 of this project (development of guidance regarding the specification and purchase of segmentable induction bends and elbows) are provided in the following sections.

4.1 Review Current Industry Codes and Standards

A comprehensive review of industry codes and standards was performed for both the manufacture of induction bends and elbows and for field construction practices.

4.1.1 Manufacturing

Industry codes and standards for manufacturing that were reviewed included the following:

- ASME B16.49 – 2007, Factory-Made, Wrought Steel, Buttwelding Induction Bends for Transportation and Distribution Systems
- ASME B16.9 – 2007, Factory-Made Wrought Buttwelding Fittings
- ASME B31.11 – 2002, Slurry Transportation Piping Systems
- CSA Z245.11 – 09, Steel Fittings
- ISO 15590-1 – 2009, Petroleum and natural gas industries -- Induction bends, fittings and flanges for pipeline transportation systems -- Part 1: Induction bends

- MSS SP-75-2008, Specification for High-Test, Wrought, Butt-Welding Fittings
- Recommended Standards for Induction Bending of Pipe and Tube, Tube and Pipe Association International, 1998
- Offshore standard DNV-OS-F101 Submarine Pipeline Systems, October 2002
- NORSOK standard M-630 “Material Data Sheets and Element Data Sheets for Piping”
    - EDS NBE2
    - MDS C01
    - MDS C11
    - MDS C23

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

4.1.2 Field Welding

Industry codes and standards for field welding that were reviewed included the following:

- API 1104 – 2005, Welding of Pipelines and Related Facilities
- ASME B31.4 – 2009, Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids
- ASME B31.8 – 2007, Gas Transmission and Distribution Piping Systems
- CSA Z662 – 07, Oil and Gas Pipeline Systems

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

4.2 Dimensional Control Capabilities of Various Manufacturers

An industry survey was conducted to determine current capabilities of various manufacturers of inductions and elbows with respect to segmentability. Several visits to selected manufacturers were also made. No universal definition could be found for what constitutes a segmentable induction bend and elbow. However, many manufactures that were surveyed or visited, and several industry standards that were reviewed (e.g., MSS SP-75 and ASME B16.49), consider “segmentable” to include an out-of-roundness of 1% or less throughout the bend arc. For example, ASME B16.49 requires the following:

- “Bends required to be suitable for segmentation shall be provided with an ovality through the bend and tangents of 1% maximum”

However, some of the manufacturers that were visited, in addition to the 1% ovality requirement, also stipulated that a segmentable bend should have the same inside diameter (ID) throughout the bend arc as the pipe to which it will be welded. This seems to make sense since an out-of-roundness requirement alone does not take diameter into account. Ovality in induction bends is most affected by the ratio of the pipe outside diameter to the wall thickness (D/t), bending temperature and bending speed.

It should also be noted that the manufacturers who did produce segmentable induction bends did not use and did not recommend using spiral welded pipe to produce segmentable induction bends. One reason for this is that, with spiral welded pipe, it is impossible to locate seam weld at neutral axis.

Some manufacturers have heat treat requirements for segmentable induction bends. All the manufacturers visited recommended that induction bends undergo some sort of heat treatment. The reason typically cited for requiring heat treatment for a segmentable bend is to relieve residual stresses introduced during the manufacturing process. These residual stresses may result in changes in roundness upon cutting in the field. The magnitude of the dimensional changes is a function of the bend type and heat treatment condition. This phenomenon however has not been quantified and there is currently no consensus as to whether heat treatment helps control the dimensional stability of an induction bend after it has been segmented. Intuitively, it would stand to reason that relieving residual stress in the bend would reduce any sort of dimensional changes that may be experienced after segmenting. One induction bend manufacturer places wood timbers inside induction bends during heat treatment to maintain dimensional stability. They also heat treat induction bends they plan to segment in-house.

It is standard practice to heat treat elbows using either a normalize and temper treatment or a quench and temper treatment. Often, elbows are mechanically rerounded at ambient temperature after tempering (Figure 14). However, this process would introduce (or reintroduce) residual stress into the elbow. The elbow cannot be tempered after rerounding, as this would introduce out-of-roundness again.

The transition from the bend arc to either tangent can also present challenges for segmentability. This area generally has an irregularity or bump caused when the induction heating coil is started and stopped. This can be problematic in the field when trying to determine exactly where the end of the tangent length is located. The severity of this bump varies from bend to bend and manufacturer to manufacturer. The start/stop effect can be minimized by altering the bending parameters or eliminated all together by pushing the tangent ends through the coil as well. In other words, the heating coil is turned on before the bend is pushed through and not turned off until the entire bend and tangent has passed through. However, this technique can be difficult to perform with standard machinery and not every manufacturer has this capability.

Diameter shrinkage is another side effect from induction bending that can be problematic for segmenting induction bends. Several induction bend manufacturers reported average diameter shrinkage of approximately 1/2%. Elbows do not experience diameter shrinkage due to the nature of the manufacturing process.

Specific information from visits to three induction bend manufacturers and one elbow manufacturer is contained in the sections below. In addition to these visits, contact was also made with two additional elbow manufacturers.

4.2.1 Induction Bend Manufacturers

Induction Bend Manufacturer No. 1 (IBM1)

IBM1 only produces induction bends. This manufacturer provided a very useful document pertaining to manufacture of segmentable induction bends and segmenting in the field. IBM1 defines a segmentable bend as a bend that has:

- the same ID throughout the bend arc and both tangents as the straight line pipe to which it will be joined,
- a maximum ovality of 1%, and
- has received a tempering treatment.

For dimensional control, IBM1 starts with heavier wall pipe which accounts for wall thinning along the extrados. They also prefer to start with oversized pipe which accounts for diameter shrinkage during induction bending process. Both tangent ends can be passed through the induction coil to eliminate bumps caused by starting and stopping the induction heating. This will also help to achieve a consistent diameter throughout the bend. The entire bend is heat treated to relieve residual stresses. Pup sections can be welded to pre-engineered bends (i.e., bends with specific bend angles that will not be segmented in the field). Internal welding is accomplished using vertical turntable with opening through to back side.

Segmenting guidance provided by IBM1 includes layout for rough cutting, square cutting by hand, and beveling using a beveling machine with "out of round" attachment. Because the ID of the bend is closely aligned to the ID of pipe, no taper boring is required. Taper boring is required for transitions to thinner-wall pipe. IBM1 indicated that they can make segmentable bends and segment them in the factory on very short notice once required bend angles are known. (Segmenting in the factory takes advantage of the carefully controlled and monitored factory environment and equipment for segmenting and welding, and some ability to correct out-of-roundness in factory environment).

Induction Bend Manufacturer No. 2 (IBM2)

IBM2 makes very few segmentable bends. IBM2 can provide bends with 1% maximum ovality for D/t ratios of up to 20 for 3D bends and D/t ratios of up to 25 for 5D bends. They generally expect 1/2% reduction in diameter, which was a common magnitude of shrinkage quoted by induction bend manufacturers. Higher yield strength pipe requires higher bending temperature, which causes higher diameter shrinkage but less ovality. IBM2 would prefer that the actual wall thickness design requirements were specified when ordering a bend. This would allow the manufacturer to start with the correct wall thickness to account for thinning on the extrados.

When asked about their ability to put the tangent ends of the bend through the induction coil, they were unsure as to if that would be possible.

Induction Bend Manufacturer No. 3 (IBM3)

IBM3 does not make segmentable bends, but would be willing to work with customers. They can use clam shells to re-round pipe after bending, but this cold works the pipe to some degree. They recommended the use of larger bend radius (7D) bends to achieve less ovality and less wall thinning. They also indicated ovality is likely to increase along the length of the bend from start to finish point. Slower bend speed can reduce ovality, but this may be impossible on high yield strength pipe due to the effect of extended exposure to heat on the yield strength. The idea of starting with higher yield strength pipe than required, to allow for reduction in strength during bending, was discussed.

4.2.2 Forged Elbows

Elbow Manufacturer No. 1 (EM1)

Elbow types manufactured by EM1 include forged and welded (two seam), forged from pipe (one seam or seamless), and mandrel formed (from a partner supplier and finished by EM1). EM1 defines segmentable as an elbow that has 1% ovality maximum. EM1 reported that 1% out-of-roundness is generally the best that they can do. EM1 indicated that for the purpose of making a segmentable elbow, they would choose to use a forged and welded (two seam) elbow. This allows the OD to be controlled by controlling circumference during seam preparation, tacking, and welding.

A custom cutting machine is used to trim each half before welding to ensure dimensional tolerance is met. Factory ends are taper bored to account for any extra thickness at ID. Mandrel formed elbows have a constant ID from the mandrel forming process. EM1 verifies the ovality at five locations on the elbow during the quality control process. EM1 suggested that a data sheet could be provided for each segmentable elbow ordered detailing dimensional measurements such as ovality, radius, bend angle, wall thickness, circumference, etc. These measurements are currently taken but are not documented.

EM1 indicated that they can, on very short notice, make segmented elbows in the factory once required bend angles are known.

4.3 Proposed Specification Requirements for Purchasing

Based on the work described above, two examples of generic purchase specifications were developed; one pertains to induction bends (Appendix A) and the other pertains to forged elbows (Appendix B). Both specifications include content specific to segmentability. In each specification, the content that pertains specifically to segmentability is clearly identified (highlighted in yellow) so that it can be easily extracted and used as a supplement to existing company specifications. Conversely, if induction bends and elbows that are not segmentable are required, the content related to segmentability can easily be deleted from the generic specifications.

Both generic specifications were developed following review of existing industry standards and examples of company specifications provided by participating companies. A list of the industry standards that had significant content specific to bends and elbows and that were included in the review was previously described in Section 4.1.1.

Where the origins are known, values, dimensions, and other content are annotated in the margins of each generic specification to describe the source from which the information was taken. Where appropriate, alternative values found in other source documents are also shown for comparison so that the range of approaches used within the industry for addressing specific issues could be better illustrated. As a result, the user is better able to select content options that best fit their particular company circumstances, while still being consistent with industry practices and/or at least one industry standard.

Because of the way in which they were developed, the generic specifications are clearly more exhaustive than most typical company specifications. These are not necessarily intended for use in their entirety as is, but for critical review of an existing company specification or as a guide for the development of a new company specification.

One significant departure from typical fitting specifications relates to the specification of toughness requirements in the generic specifications. Toughness requirements in the generic purchase specifications are more aligned with the requirements of API 5L. The requirements for fittings are usually less stringent than those for line pipe. However, by adopting a line pipe toughness approach, the fittings are more likely to have the toughness properties commensurate with the service conditions to which they are exposed. The resulting resistance of the fittings to brittle fracture initiation and to fracture propagation along the length of the induction bend, or elbow, is more likely to be comparable to that of the pipe, instead of representing a potential “weak link” in the chain of pipe and piping components.

5. SUMMARY FOR PHASE 1

Phase 1 of this project involved a review of current industry codes and company specifications for induction bends and elbows, and 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.

6. REFERENCES

1. API 1104 – 2005, Welding of Pipelines and Related Facilities
2. ASME B31.4 -– 2009, Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids
3. ASME B31.8 -– 2007, Gas Transmission and Distribution Piping Systems
4. ASME B16.49 – 2007, Factory-Made, Wrought Steel, Buttwelding Induction Bends for Transportation and Distribution Systems
5. ASME B16.9 – 2007, Factory-Made Wrought Buttwelding Fittings
6. ASME B31.11 – 2002, Slurry Transportation Piping Systems
7. CSA Z245.11 – 09, Steel Fittings
8. CSA Z662 – 07, Oil and Gas Pipeline Systems
9. DNV-OS-F101 Offshore standard for Submarine Pipeline Systems, October 2002
10. ISO 15590-1 – 2009, Petroleum and natural gas industries -- Induction bends, fittings and flanges for pipeline transportation systems -- Part 1: Induction bends
11. MSS SP-75-2008, Specification for High-Test, Wrought, Butt-Welding Fittings
12. NORSOK standard M-630 “Material Data Sheets and Element Data Sheets for Piping”
13. Recommended Standards for Induction Bending of Pipe and Tube, Tube and Pipe Association International, 1998

Figure 1. INDUCTION BEND BEING USED DURING CONSTRUCTION OF A CROSS-COUNTRY PIPELINE

Figure 2. INDUCTION BENDING MACHINE

Figure 3. HEATED PORTION OF PIPE MATERIAL DURING INDUCTION BENDING PROCESS

Figure 4. PIPE PUP SECTION BEING ATTACHED TO FACTORY-SEGMENTED INDUCTION BEND

Figure 5. HOT FORMING OF ELBOW HALVES

Figure 6. TRIMMING OF ELBOW HALVES

Figure 7. ASSEMBLY OF ELBOW HALVES

Figure 8. SEAM WELDING USING SUBMERGED ARC WELDING

Figure 9. GRINDING OF LONGITUDINAL SEAM WELDS

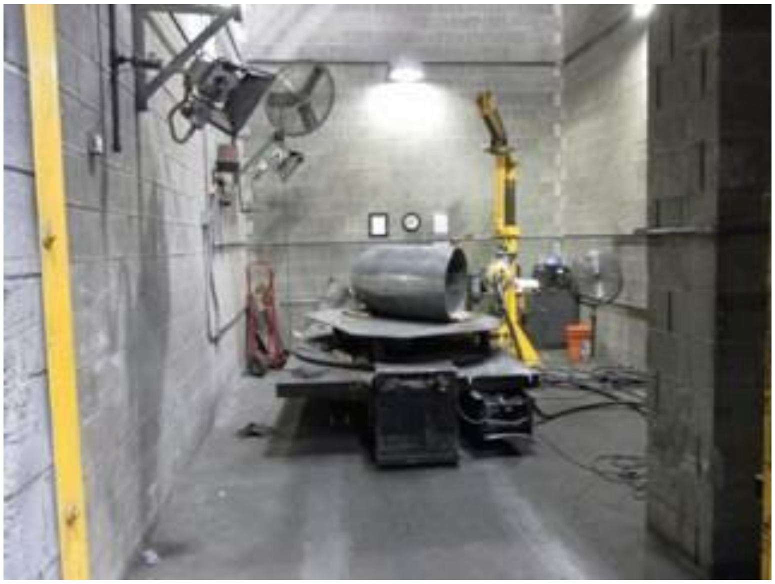

Figure 10. RADIOGRAPHY

Figure 11. DIMENSIONAL CHECK OF END PREPARATIONS

Figure 12. DIMENSIONAL CHECK OF DIAMETER AND OUT-OF-ROUNDNESS

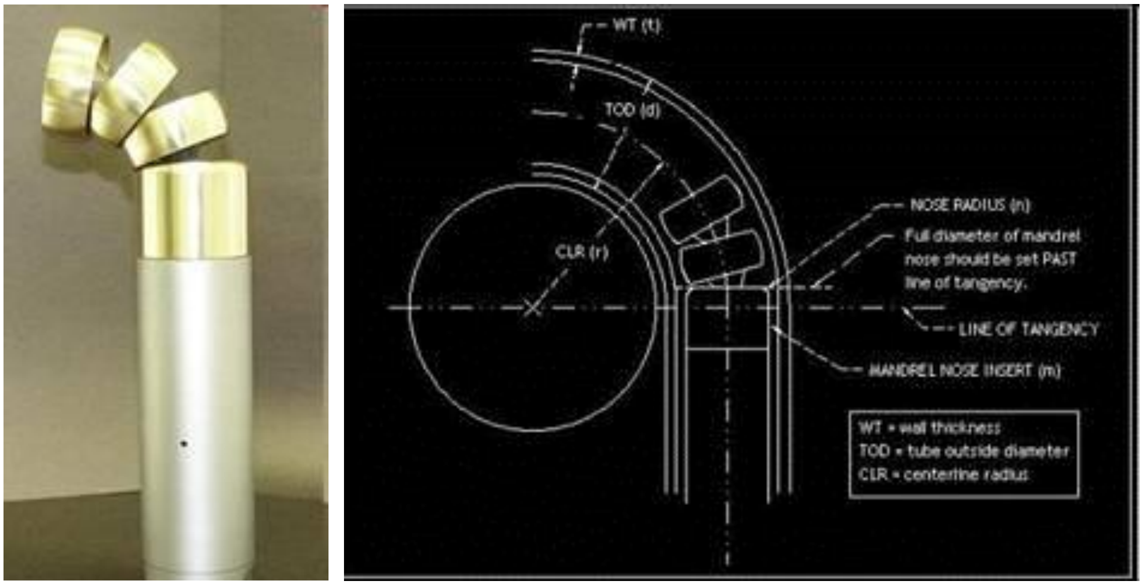

Figure 13. ILLUSTRATION OF DRAWN-OVER-MANDREL PROCESS

Figure 14. LOAD FRAME USED FOR RE-ROUNDING ELBOWS

Appendix A

Generic Specification for Purchasing Segmentable Induction Bends

Induction Bend Purchase Specification[1,2,3]

1. Scope

This specification covers the minimum requirements for the design, fabrication, testing and inspection of high strength carbon steel pipe bends and segmentable pipe bends manufactured using the induction heating and bending process. This shall apply to seamless, EW, SAWL, and SAWH pipe with a 4 inch nominal diameter or larger and API 5L PSL 2 grade B (245 MPa SMYS) or higher. SAWH pipe is not acceptable for use in segmentable bends.

It is the responsibility of the Manufacturer to comply with the requirements of the Code of Federal Regulations, Title 49, Part 192. In case of a conflict with these specifications or Manufacturers' recommendations the more stringent shall apply. Deviations from this specification are only allowable with prior written consent from XYZ PIPELINE COMPANY. Non-conformance to this specification may result in rejection of the pipe bend. This determination shall be at the sole discretion of XYZ PIPELINE COMPANY.

2. Definitions and Acronyms

The following definitions shall be considered in addition to those listed in ASME B16.49.

Dent:

> For induction bends larger than NPS 12, plain dents are considered to be 0.5% of the nominal pipe diameter or deeper.

Double Submerged Arc Welded (DSAW):

> Previously used term for SAW pipe made with welds deposited from both the inside and outside surfaces.

Electric Resistance Welded (ERW):

> Previously used term for electric resistance welded pipe, now referred to as "EW". This includes pipe made using either the high frequency (HFW) or low frequency (LFW) variants of the EW process.

Electric Welded (EW):

> Process of forming a seam by electric-resistance welding, wherein the edges to be welded are mechanically pressed together and the heat for welding is generated by the resistance to flow of electric current applied by induction or conduction. Previously known as ERW.

[1] Content highlighted in yellow pertains specifically to segmentability.
[2] Annotations provided in the margins are intended to indicate the source of values, dimensions, and other content, where known.
3 Underlined values are company-specific values that can be changed at the discretion of the purchaser

Hold Point:

Manufacturing operation or activity, such as NDE inspection or measurement of a critical parameter, shall not be performed without the notification and/or presence of XYZ PIPELINE COMPANY or an authorized representative.

Induction Bend:

The bend or bends, which the Manufacturer or Vendor will provide to XYZ PIPELINE COMPANY. For the purposes of this specification, an induction bend is a smooth contour pipe bend made using the induction heating and bending process. This process uses an induction heating coil to heat a narrow circumferential band around the pipe. When the appropriate temperature has been reached, the pipe is moved through the coil at a predetermined speed while a bending moment is applied to the heated area of the pipe. After the material has been bent, it may be cooled by forced air or quenched using water spray.

Lot:

In accordance with XYZ PIPELINE COMPANY's specifications, different heats having very similar compositions may be combined into the same Lot as allowed by B16.49 paragraph SR15.8.2.

Manufacturer:

Induction bending manufacturer, including their manufacturing facilities and sub-vendors, who supplies or proposes to supply bends to XYZ PIPELINE COMPANY in accordance with this specification.

Ovality:

The difference between the maximum and minimum outside diameters measured on any radial cross section of the bend zone. Ovality may also be evaluated using the inside diameters.

SAWH:

Submerged arc welded pipe having a helical seam

SAWL:

Submerged arc welded pipe having a straight longitudinal seam

Segmentable Induction Bend:

In accordance with B16.49 Paragraph SR15.3, 'Bends required to be suitable for segmentation shall be provided with an ovality through the bend and tangents of 1% maximum.' In addition, segmentable bend specifications include tighter tolerances for inside diameter to ensure acceptable fit up after being segmented. Segmentable bends are required to be post-bend heat treated to impart dimensional stability..

Technical Agreement:

A document signed by XYZ PIPELINE COMPANY, Manufacturer and/or Vendor which defines a mutual agreement concerning technical matter and may or may not include information about pricing and delivery schedule.

Vendor:

Individual(s) or establishment contracting with the Manufacturer and XYZ PIPELINE COMPANY to provide induction bends and/or services related to the induction bends.

Wrinkles:

A deviation from the surface contour greater than 1/16 inch measured perpendicular to the surface. Upsets due to stop and starts are acceptable provided they are limited to the tangent points. It is characteristic of the induction process that an upset occurs at each tangent point. These are of a cosmetic nature and are not detrimental to the bend.

12:00 Position:

The 12:00 position shall be defined as the orientation of the top neutral axis of the bend, laying flat such that the bend extends outward and to the right from the point of view.

3. References

The following documents were referenced in this induction bend purchase specification. It is the responsibility of the Manufacturer to comply with the requirements of this standard and with the current edition of the applicable regulatory standard or code. All materials shall be designed, manufactured, inspected and tested in accordance with those requirements. In the case of a conflict with these specifications and/or manufacturers' recommendations, the more stringent shall apply.

American Petroleum Institute (API)

- 5L, "Specification for Line Pipe", Latest Edition
- Q1 Specification for Quality Program

American Society of Mechanical Engineers (ASME)

- B16.9 Factory-Made Wrought Buttwelding Fittings
- B16.49 Factory-Made, Wrought Steel, Buttwelding Induction Bends for Transportation and Distribution Systems
- B31.4 Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids
- B31.8 Gas Transmission and Distribution Piping Systems

- B31.11 2002 Slurry Transportation Piping Systems
- Boiler and Pressure Vessel Code Section V, "Nondestructive Examination"

American Society of Nondestructive Testing (ASNT)

- ASNT SNT-TC-1A Recommended Practices for Nondestructive Testing

American Society for Testing and Materials (ASTM)

- A 370, "Standard Test Methods and Definitions for Mechanical Testing of Steel Products"
- E 92, Standard Test Method for Vickers Hardness of Metallic Materials
- E164, Standard Practice for Ultrasonic Contact Examination of Weldments.
- E273, Standard Practice for Ultrasonic Examination of Longitudinal Welded Pipe and Tubing.

Canadian Standards Association (CSA)

- CSA Z662 Oil and Gas Pipeline Systems
- CSA Z245.11 Steel Fittings

Code of Federal Regulations: Department of Transportation (CFR: DOT)

- Title 49 CFR Part 192, "Transportation of Natural and Other Gas by Pipeline: Minimum Federal Safety Standard"
- Title 49 CFR Part 195, "Transportation of Hazardous Liquids by Pipeline"

Company Specifications

- (Add in applicable company specifications)

International Pipe Association (IPA)

- Voluntary Standards for Induction Bending of Pipe, Section 2 - Standard practice for qualification of procedures

International Standards Organization (ISO)

- ISO 9001 Quality Management Systems - Requirements

Manufacturers Standardization Society of the Valve and Fittings Industry, Inc. (MSS)

- SP-75, "Specification for High Test Wrought Butt Welding Fittings"

National Association of Corrosion Engineers (NACE)

- MR 0175 Metals for Sulfide Stress Cracking and Stress Corrosion Cracking Resistant in Sour Oil Field Environments

Society for Protective Coatings (SSPC)

- SSPC SP-1 Solvent Cleaning
- SSPC - SP10 Blast Cleaning to Near-White Metal

Tube and Pipe Association International

- IBS 98 Recommended Standards for Induction Bending of Pipe and Tube

4. Design Information

4.1 Specifications

Pipe Specification: __API 5L Latest edition as minimum. Low frequency EW pipe shall not be used.__
Bend Specification: __ASME B16.49 Latest Edition, (with supplemental requirements as described herein) .__

4.2 Matching Pipe Data

Material Grade: ________(per API 5L)
Manufacturing Process: ________(seamless or type of seamed pipe)
Nominal Outside Diameter: ________(inches)
Wall Thickness: ________(inches)

4.3 Beveling

All pipe ends shall be machine-beveled to meet the requirements of ASME B31.8, Figure I5 or ASME B31.4, Figure 434.8.6(a). Exterior and interior weld reinforcement on seam welds shall be ground flush with the base metal for a length of __6 inches__ from the weld bevel.

4.4 Bend Data

Tangent Length 1: ________(feet) (note 1)
Tangent Length 2: ________(feet) (note 1)
Bend Radius: ________(feet)
Bends Angle: ________(degrees)
Wall Thickness, minimum: ________(inches) (note 2)
Wall Thickness, maximum: ________(inches) (note 2)[BA1]
Inside Diameter, minimum: ________(inches) (note 3[BA2])
Post Bend Heat Treatment: ________(schedule)
Finish: ________(coating)

Notes for bend data:

1) A tangent length shall be the greater of 24-inches or 1 pipe diameter unless otherwise specified

2) Starting material shall be selected so that the anticipated wall thickness thinning of extrados shall result in wall thickness meeting the requirements of Section 5.1.

3) Starting material shall be selected so that the anticipated contraction of the pipe diameter during bending shall result in a minimum inside diameter meeting the specified dimension. The tangent ends, including a distance of at least 4 inches from each weld bevel, shall meet the diameter requirements of Section 5.2 and 5.3.

4) For bends from longitudinally welded pipe, the longitudinal weld seam shall be located as close as possible to the neutral axis of deformation in the bend. Bends shall contain no girth welds.

A sample induction bend data sheet may be found as Appendix B in ASME B16.49.

4.5 Service Conditions

Service Medium: ________ (natural gas, crude, etc)
Service Conditions:________ (sweet or sour)
Design Pressure: ________ (psig)
Minimum Design Temperature: ________ (°F)
Maximum Design Temperature: ________ (°F)

5. Dimensional Requirements and Tolerances

5.1 Wall Thickness

The minimum wall thickness shall meet the requirements of MSS SP-75[BA3], Paragraph 13.2 "Wall Thickness", (The minimum wall thickness may be 0.01 inch under the nominal thickness, except that isolated non-continuous reductions are permitted, provided the remaining wall thickness is not diminished to less than 93.5% of the specified nominal). A fitting shall be derated if the wall thinning is greater than that allowed for new pipe according to API 5L, Specification for Line Pipe.

5.2 Outside Diameter

The outside diameter of the pipe bend shall not be reduced in any circumferential plane by more than 2.5% of the nominal pipe diameter and shall meet the requirements of API 5L for a distance of _4 inches_ [WEA4]from each end.

5.3 Inside Diameter

The minimum allowable inside diameter shall be as specified in the design information. This dimension shall be evaluated by passing a cylindrical gauging device through the bend with or without the assistance of power equipment. The gauging device shall have a diameter equal to the specified minimum allowable inside diameter. Any bend that does not allow unrestricted passage of the device shall be rejected.

5.4 Bend Radius and Angle

The measurement of the bend radius shall be as specified by the Design Information _± 0.5%_ of the specified radius.

The measurement of the bend angle shall be as specified by the Design Information _± 0.5°_ degrees of the specified angle.

5.5 Beveled Ends

Beveled ends shall be machine-beveled to meet the tolerances required in ASME B31.8, Figure I5. The squareness of both ends shall be measured for conformance with ASME B16.49[BA5].

5.6 Ovality

The ovality of the bend zone shall be a maximum of __2.5%[z6]__. The ovality of the tangents shall be a maximum of ___1%___. For bends which shall be considered segmentable, the ovality within the bend shall not exceed 1% per B16.49 Paragraph 15.3.

6. Segmentable Induction Bends

Helical seam line pipe shall not be used to produce a segmentable bend

The bends shall be manufactured to maintain a maximum ovality of 1% through the arc section.

Ovality % = 100 x (Maximum OD – Minimum OD) ÷ Nominal OD

Ovality shall be measured in the bend within 2 inches of each bevel end, within 6 inches of the start of the bend, 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 bend.

Circumferential shrinkage throughout the bend shall be limited to 0.5%. This shall be measured along the bend within 6 inches of the start of the bend, center of the bend and within 6 inches of the end of the arc, and at approximate 20° increments in between. No measured points may exceed the limits of inside diameter specified in Section 4.4. These measurements shall be recorded and provided with each completed bend.

7. Markings

7.1 Marking Method

All markings shall be applied after cleaning. Markings shall be paint stenciled on the bends, and a clear lacquer finish applied over the stenciled area. Limited use of hand lettering is acceptable at the discretion of XYZ PIPELINE COMPANY. All marks shall be legible and permanent. Marking materials used on the outside surfaces shall not adversely affect coating applications. Any marking on the pipe joint shall only be done using markers free of lead, sulfur, phosphorus or other detrimental ingredients. Cold die steel stamping of bends is prohibited.

7.2 Information Contained in Marking

In addition to the information listed in ASME B16.49, the following information shall be marked on the bend:

- XYZ PIPELINE COMPANY order and item number
- Individual bend identification number
- "Segmentable" if the bend is segmentable[WEA7]

- Point of tangency
- Other bend manufacturing data when required by XYZ PIPELINE COMPANY.

When a stress relief procedure is used, the marking shall read SR-XXXX, where XXXX is the stress relief temperature in °F. Where a quench and temper procedure is used, the marking shall read QT-YYYY/ZZZZ, where YYYY is the quench temperature and ZZZZ is the tempering temperature, both in °F.

Prior to shipment, a unique individual identification number shall be created and assigned to each induction bend. All manufacturing operations applied to the induction bend may then be traceable to that individual identification number.

An example of a unique component identification number is: "1234/56/7", where:

1234	Purchase Order #
56	Item # (obtained from the Purchase Order)
7	Sequence # applied by the Manufacturer (e.g., the seventh bend manufactured to fill the total number of bends required for Item #56 on the Purchase Order). All bend-specific certification information and inspection data is directly traceable to this sequence number

7.3 Location of Marking

All bends 12 inches nominal outside diameter and larger shall have the markings paint stenciled on both the inside and outside surfaces of both ends[BA8] of each bend within 6 inches of the end bevel or as close as practical[BA9]. Bends having a nominal outside diameter smaller than_12 inches shall have the markings stenciled only on the outside surface. Each bend shall have the starting point of the tangent paint stenciled at both ends on the exterior only.

8. Materials

Starting materials may consist of seamless, EW, SAWL or SAWH pipe. SAWH pipe is not acceptable for use as segmentable bends.

For pipe not supplied by XYZ PIPELINE COMPANY the Manufacturer shall supply a mill test report (MTR) for review and approval by XYZ PIPELINE COMPANY.

For pipe supplied by XYZ PIPELINE COMPANY the manufacturer shall review the related MTR and be responsible for determining the suitability of the pipe as a starting material that will be capable of meeting the required mechanical property and dimensional specifications for the finished bend

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[BA10].
- The maximum allowable nickel content shall be 0.5%
- The sum of copper, nickel, chromium, and molybdenum shall not exceed 1% [BA11]

9. Bending Procedure, Procedure Documentation, and Qualification

9.1 General

9.1.1 Manufacturing Procedure Qualification Information

Manufacturer shall provide for Company approval a bend procedure for each heat of pipe provided for the fabrication of the production bends. Each procedure shall outline as a minimum, the following:

1) Orientation of pipe weld, if applicable
2) Pipe feed rate
3) Final induction temperature
4) Means of cooling to various temperature stages
5) Terminal temperature of each cooling stage
6) Post bending heat treatment procedure (if required)
    a) Soak temperature(s) (minimum 1100 °F unless approved by XYZ PIPELINE COMPANY)
    b) Soak time at post bend heat treatment temperature(s)
    c) Cooling rate
    d) Cooling medium

9.1.2 Heat Treatment

Post-bend heat treatment, when used, shall meet the requirements of ASME B16.49 Section 9 “Heat treatment”. The post bend heat treatment shall encompass the full length of the bend at one time. All segmentable bends shall be post-bend heat treated. Post-bend heat treatment of nonsegmentable bends is not required unless needed to meet mechanical property requirements.

9.1.2.1 Tempering

Only well designed and maintained batch or continuous type furnaces shall be used for tempering bends. Each furnace shall be equipped with thermocouples, automatic temperature controllers and recorders. The furnaces shall be designed and calibrated to maintain ± 25 ºF of the selected tempering temperature within the predetermined heating zone. The furnace shall also have been calibrated using a furnace temperature curve as described in Section 9.1.2.2 below.

The furnace shall be preheated to the selected tempering temperature. The bends, by heat lot, shall be charged into the furnace one high. Stacking is permitted only if temperatures of the bends are individually monitored. The bends shall be uniformly heated to the selected temperature ± 25 ºF at a heating rate not exceeding 350 ºF per hour and held at that temperature for a predetermined time to assure thorough section heating.

The furnace controller and/or chart recorder shall be identified with the furnace number, heat lot number, date, product identification and material identification, and filed for future reference.

After the bends have been properly tempered and allowed to uniformly cool to room temperature, they shall be legibly marked.

9.1.2.2 Use of a Furnace Temperature Curve

In cases where several heat treating runs can be made using essentially the same number, size, and wall thickness of bends and the same heat treating time and temperature, an initial heat shall be run with thermocouples attached to selected bends. These thermocouples, attached to the bends at locations recording the hottest and coldest areas in the furnace, shall accurately reflect the internal temperature ranges and shall be used to control the heat treating cycle.

For a continuous furnace, one bend shall be used for calibration. For a batch furnace two bends, one in the hottest area and one in the coldest area, shall be used for calibration.

The temperature of bends shall be charted and, at the same time, a furnace recorder shall chart the furnace heating curve required to achieve proper part temperature. On subsequent heat treating batches, where the conditions remain the same, and no changes were made to the furnace, the furnace temperature curve shall be used to control the heat treating cycle.

For long production runs, a re-demonstration or check of the original heat treating cycle shall be made approximately every 30 days, or when a significant change has been made to the furnace, such as an overhaul or change of burners

9.1.2.3 Heat treatment records

Heat treatment procedures shall be documented. Heat treating cycles shall be continuously recorded and available for review. The furnace records shall be traceable to the unique component identification numbers

9.1.3 Manufacturing Procedure Qualification Tests

Qualification testing, including the number and types of tests and the applicable essential variables applicable to the pipe and the bending procedure shall be in accordance with ASME B16.49 Sections 11 and Section 11.3.6 of this specification. With the exception of the additional acceptance criteria below, the acceptance criteria for test results shall be as described in section 11.3.6 of this specification and in ASME B16.49 section 8 unless otherwise specified in the RFQ.

9.1.3.1 Yield Strength

The maximum acceptable yield strength shall be as follows[BA12]:

- Grade X52 and below: AA ksi
- Grade X60: BB ksi
- Grade X65: CC ksi
- Grade X70: DD ksi

9.1.3.2 Charpy Impact Toughness

The Charpy impact test result acceptance criteria shall include:

- For each set of three impact test samples the average fracture surface shear area shall be no less than 75%. No single sample shall have a shear value less than 60%
- The absorbed energy of Charpy impact test specimens shall meet the greater of the requirements of API 5L Annex G, section G.7 or G.8. For design factors less than 0.625 the requirements of Table G.1 shall apply.[BA13] When a design factor is not specified in the RFQ a design factor of 0.72 shall be used.

If using reduced specimens, the required impact energy values may be reduced in proportion to the tested size / full size impact test sample dimensions. The Charpy test temperature shall be the minimum design temperature minus a correction factor to account for the difference between the actual pipe wall thickness and the tested Charpy sample size. The Charpy impact test temperature (Tc) shall be:

$$TC = TP - 59.57 \times (t_w^{\,0.55} / t_c^{\,0.7}) + 55.56$$

Where:

TC = Charpy test temperature (°C)

TP = Pipe minimum design temperature (°C) (assume 20 °F or 6.7 °C unless otherwise indicated on the RFQ)

t_w = thickness of pipe (mm)

t_c = thickness of Charpy sample (mm)

9.1.3.3 Hardness Testing

Hardness measurements shall be made using the Brinell test method, the Rockwell test method (B or C scale) or the Vickers hardness test method. Other methods, including the UCI and Leeb (ball rebound) methods shall not be used without the review and approval by XYZ PIPELINE COMPANY of documentation describing the test method procedure qualification and test technician qualification. Test procedures must describe details of surface preparation, compensation for surface decarburization, and correction factors for use on thin wall piping (where applicable). No surface hardness measurement shall exceed HRC 22 or equivalent without review and approval by XYZ PIPELINE COMPANY.[WEA14]

9.1.4 Remnants for Welding Procedure Development

Any bend segments of a minimum of 8 inches in length which are left after mechanical testing, or as a result of cutting bends to required dimensions, shall be reserved for use by XYZ PIPELINE COMPANY for subsequent welding procedure qualification tests. The segment shall be marked with a unique identifying designator that indicates the source bend and "WPQ only"

9.1.5 Bending Procedure

The induction hot bends shall be made by induction heating 360^o around the point of bending. The pipe shall be pushed through the inductor coil at a constant speed followed by a water quench. The pipe shall not contact copper-based material or other low melting temperature materials.

All bending parameters within a given lot of steel shall be kept constant within the tolerances of the Manufacturer's bending procedure for that heat. Records shall be kept for the following parameters during the bending process for both production bends and prototype bends and provided to the Company for review. A statement certifying these parameters were followed shall be provided.

- 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 [WEA15]unless approved by XYZ PIPELINE COMPANY)
    - Soak time at post bend heat treatment temperature(s)
    - Cooling rate
    - Cooling medium

If seamless pipe is used, and circumferential variations in pipe thickness are detected, the thickest part of the pipe shall be oriented at the extrados of the bend

Unless specified otherwise in the Project Design Information, the unbent tangents shall be at least two feet (0.6 m) in length, with a tolerance of +/- 2 inches (50 mm).

No welding is permitted on any part of the bend except that necessary for temporary attachment of extensions required for pushing through the heating coil. The extension, plus at least ¼ inch of the adjacent bend tangent shall be removed prior to final heat treatment. The bevel shall be remachined prior to shipment

A finished bend that is out-of-round may be mechanically sized [BA16]through the use of internal and external dies without approval by XYZ PIPELINE COMPANY only if the maximum change in diameter in any plane is 0.015 or less. Larger deformations require the prior approval of XYZ PIPELINE COMPANY.

The diameter change shall be calculated as the absolute difference between the original and final diameter, divided by the original diameter in the same plane.

10. Production Bend Testing Requirements

Production testing, including the number and types of tests and the applicable essential variables applicable to the pipe and the bending procedure shall be in accordance with ASME B16.49 section 11.2 and Section 11 of this specification.

Hardness measurements shall be made using the same method as used for the bend qualification testing.

11. Inspection Requirements

11.1 General

The Manufacturer shall provide XYZ PIPELINE COMPANY with reasonable access to the induction bends, inspection instruments and any other machinery pertinent to the work covered by this specification. Inspection notices shall be sent to XYZ PIPELINE COMPANY'S Director of Project Services at least 10 days prior to the start of both test and production bending. If a post-bending heat treatment was performed, the final inspection shall follow that procedure. Unless otherwise specified by XYZ PIPELINE COMPANY, XYZ PIPELINE COMPANY shall witness the measurement of bend dimensions before shipment. Inspection of the bends, by XYZ PIPELINE COMPANY, shall not relieve the Manufacturer of responsibility for meeting the requirements of this standard.

Each bend shall be free of all loose mill scale, grease, oil, paint or any other foreign matter which could inhibit surface examination. Bends need not be grit blasted prior to inspection unless, in the opinion of XYZ PIPELINE COMPANY'S inspector, blasting is needed to facilitate the inspection. If necessary, the bend shall be blasted to a commercial blast surface of SSPC SP-6 to prepare the bend for inspection.

The bend shall be inspected in a reasonably clean, dry area with high intensity lighting of at least 50 foot-candles (500 Lux[BA17]). An internal crawler shall be provided, at the request of XYZ PIPELINE COMPANY'S inspector and the Manufacturer shall provide suitable office space with access to telephones, faxes, internet, etc.

11.2 Visual Inspection

A full visual inspection shall be performed on the entire interior and exterior surfaces of the bend to search for evidence of defects. Experienced and competent inspection personnel, furnished by the Manufacturer, shall conduct this examination. XYZ PIPELINE COMPANY may request records or documentation supporting the Inspector's past experience and current capabilities. Inspection shall be conducted to ensure induction bends comply with this specification and with ASME B16.49-2007. The following documents shall be available to XYZ PIPELINE COMPANY at the time of final inspection:

- Certified Material Test Reports (MTRs).
- Chemical Analysis Reports.
- NDE Inspection Reports.
- Heat Treatment Schedules.

11.2.1 Defect Definition

In addition to the defect types described in API 5L, Section 9.10 Surface Conditions, Imperfections and Defects", any surface imperfection which could affect coating application and the ultimate use of the finished bend shall also be considered a defect. These imperfections include but are not limited to scabs, seams, laps, pits, blisters, heavy rust or mill scales, gouges, scratches, and rolled in foreign material. Sharp defects such as notches, scratches, scabs, seams, laps, tears, or slivers not deeper than 6- 1/2% of nominal wall thickness shall be removed by grinding[BA18].

11.2.2 Allowable Depths

Any imperfection, with depth resulting in a wall thickness less than that specified in MSS SP-75, Paragraph 13.2 - "Wall Thickness", shall be considered a defect and removed from the bend.

11.2.3 Dents

Dents of any depth that intersect the weld zone or with sharp bottom gouges are unacceptable and shall be completely removed as a cylindrical segment. The length of a dent in any direction shall not exceed 2.5% of the specified bend diameter.

11.2.4 Hard Spots

Irregularities in the curvature of the bend surface that are not the result of mechanical damage shall be considered as hard spots. The hardness of the questionable area(s) shall be evaluated as per section 11.3.6 of this document.

11.2.5 End Bevels

Unless otherwise specified in the Project Design Information, all pipe ends shall be machine-beveled to meet the requirements of ASME B31.8, Figure I5. Exterior and interior weld reinforcement on seam welds shall be ground flush with the base metal for a length of 4 inches from the weld bevel.

11.2.6 Bend Contour

Upsets due to stops and starts are acceptable provided they are limited to the tangent points. It is characteristic of the induction process that an upset occurs at each tangent point. These are of a cosmetic nature and are not detrimental to the bend. The finished bend shall be smooth and free of visible wrinkles. Wrinkles are defined as deviations from the surface contour greater than 1/16 inch measured perpendicular to the surface. No bends containing wrinkles shall be accepted.

11.2.7 Ovality

Ovality shall meet the tolerances specified in the Project Design Information. Ovality measurements shall be using minimum and maximum outside diameter measurements at the beginning and ending of the bend. For segmentable bends measurements shall also be made at intervals not to exceed 20^{o} between the two ends.

11.2.8 Pipe Imperfections

Each bend shall be inspected for the following imperfections. Those not meeting the specified minimum requirements shall be repaired, if possible, or else rejected.

- Weld Seam Misalignment: Misalignment of the longitudinal weld seam shall not exceed 8.0% of the specified wall thickness.
- Internal Weld Trim: The internal weld bead shall not extend more than 1/32 inch above a prolongation of the internal bend surface. The maximum depth of weld bead trim below a prolongation of either the outside or inside surface shall not exceed 5% of the specified wall thickness. Tangents shall not contain inside or outside weld reinforcement for an axial distance of at least 4 inches from the ends of the bend.
- Offset of Plate Edge: Shall meet the requirements of API 5L, Paragraph 9.13.1.
- Out of Line Weld Bead for Pipe with Filler Metal Welds: Shall meet the requirements of API 5L Paragraph 9.13.13
- Height of Outside and Inside Weld Beads – Submerged-Arc Weld: Shall meet the requirements of API 5L, Paragraph 9.13.2.2.

11.2.9 Excessive Mill Damage

Finished bends with excessive mill damage, as determined by XYZ PIPELINE COMPANY (e.g., scratches, dents, deep or rough grinding, gouges, etc.), even though the individual damaged areas may be acceptable according to this Specification, shall be cause for permanent rejection of the bend. Shipping damage due to improper loading shall be considered mill-related damage.

11.3 Non-Destructive Testing

All nondestructive testing personnel involved in administering the tests shall be certified to at least an ASNT or CGSB Level I status, in the method being used. The testing supervisor shall be certified to at least an ASNT or CGSB Level II status, in the method being used. The testing supervisor shall ensure that all testing is completed in accordance with ASNT SNT-TC-1A. All relevant information gathered during the testing process shall be recorded for XYZ PIPELINE COMPANY and signed by the testing supervisor that witnessed the testing.

11.3.1 Ultrasonic Inspection

Each bend shall be inspected with an ultrasonic thickness gauge to ensure that the wall thickness, on the extrados of the bend, shall have a minimum undertolerance of __10% of the specified wall thickness. Wall thickness measurements shall be taken circumferentially at the __12:00, 3:00, 6:00 and 9:00__ o'clock positions of the pipe, plus at approximately 6-8 inches (axially) on either side of the smallest wall thickness measurement if the thinnest measurement is less than the specified nominal thickness + 2%[BA19]. Wall thickness measurements shall be taken at the beginning and end and at least every __10 degrees__ axially along the bend.

All welds shall be completely inspected on the OD and ID surfaces with an ultrasonic procedure to ensure complete fusion and the absence of cracking. In lieu of ultrasonic inspection, welds may be radiographically inspected. See 11.3.3

Weld bevels shall be visually inspected for laminations around the full circumference of the finished beveled ends. Any single lamination or non-metallic inclusion extending into the face of the bevel having a circumferential length of 0.25 inches or greater shall be considered an unacceptable defect.

For laminations having a circumferential length less than 0.25 inches, the following criteria shall be used to determine the maximum number of acceptable of laminations.

OD of Bend	Maximum number of laminations/inclusion measuring less than ¼ inch allowed per end	Required sound metal separating laminations/inclusion s
20 inch and larger	6	6 inches
Less than 20 inch	3	4 inches

Laminations and/or inclusions exceeding the maximum allowable may be removed by trimming the length of the bend and re-machining the bevel. Repair welding shall not be permitted on bevels.

Inspection equipment, reference standards and acceptance criteria shall be in accordance with API 5L 44th edition. For each bend inspected, a record of the equipment used and the readings taken shall be created and made available to XYZ PIPELINE COMPANY. Upon completion of the inspection, each bend shall be cleaned of all inspection products and inspection markings.

11.3.2 Wet Magnetic Particle and/or Liquid Penetrant Inspection

The inspection requirements of ASME B16.49 Section 13.2 apply. In addition, the inspection shall be performed on accessible areas of the ID of the bend on the extrados side and all ground surfaces and weld bevel faces shall be inspected. With the exception of linear indications detected on the weld bevel, the presence of any detectable surface imperfection is cause for rejection of the bend unless the imperfection can be removed by grinding and the remaining wall thickness meets the requirements of section 5.1 of this specification. The maximum allowable dimension and number of linear indications on the weld bevel is as described in Section 11.3.1. The seam weld inspections apply to the bend area only. No inspection is required for the seam welds in the tangents unless the tangents have been heat treated.

Upon completion of the inspection, each bend shall be cleaned of all inspection products and inspection markings. The results of the inspection shall be recorded and furnished to XYZ PIPELINE COMPANY.

11.3.3 Radiographic Inspection

All longitudinal and circumferential welds located in the arc of the bend shall be completely radiographed. The Manufacturer shall provide an adequate film viewer for XYZ PIPELINE COMPANY to use during the inspection process. No weld repairs shall be permitted. All radiographs and the results of the inspection shall be recorded and furnished to XYZ PIPELINE COMPANY. In lieu of radiographic inspection, welds may be inspected with an ultrasonic inspection technique capable of detecting cracks and other injurious defects. See 11.3.1

11.3.4 Pigging Inspection

All bends shall be pigged with a sizing pig containing at least two metallic discs separated by a minimum of 6 inches. The diameter of the metallic discs shall be at least 95% of the nominal inside diameter of the un-bent starting material. The nominal inside diameter is considered to be the nominal O.D. minus two (2) times the nominal wall thickness.

If the bend does not permit passage of the specified sizing pig, it may be re-worked and then re-pigged until the pigging test is completed successfully. No bend shall be accepted if the pig fails to pass completely through the bend. The results of the inspection shall be recorded and furnished to XYZ PIPELINE COMPANY.

11.3.5 Inspection for Residual Magnetism

The Manufacturer shall ensure that each finished bend does not contain residual magnetism which exceeds an average flux density of 25 gauss or any individual areas with a flux density exceeding 35 gauss measured with a calibrated gage acceptable to XYZ PIPELINE COMPANY. Prior to shipment, the Manufacturer shall perform all necessary demagnetization procedures.

11.3.6 Hardness Testing

Each production bend shall be surface hardness tested. Measurements shall be made at unbent tangents, the beginning and end of the bend and at intervals not greater than 25% of the length between tangent points. Hardness measurements shall be taken circumferentially at the 12:00, 3:00, 6:00 and 9:00 and the weld seam (if not located at

12:00) o'clock positions of the pipe. In addition, the bend shall be visually examined to detect irregularities in the bend curvature that may indicate hard spots or other detrimental conditions at the intrados and extrados of the bend and any stop-start areas. Any such areas shall be noted and surface hardness tested. Written records of these tests shall be produced and furnished to XYZ PIPELINE COMPANY. No surface hardness measurement shall exceed HRC 22 or equivalent without review and approval by XYZ PIPELINE COMPANY.[WEA20]

11.4 Defect Repair

Each bend, after final processing, shall be inspected for any harmful defects, which might impair its serviceability. The definition and allowable repair of harmful defects, as approved by XYZ PIPELINE COMPANY, shall be in accordance with API 5L. Repairs to the seam weld, beveled ends, or repair of a repair shall not be permitted. All repaired areas shall be inspected using a liquid penetrant or wet magnetic particle inspection technique, and shall contain no surface cracks.

11.4.1 Repair by Grinding

All surface imperfections, including scabs and slivers, shall be completely removed by grinding. The ground area shall be evenly blended into the surrounding metal. The remaining wall thickness shall have a smooth contour and be checked with an ultrasonic thickness gauge to ensure that it still exceeds the minimum required wall thickness specified in the design information.

The entire ground area shall be inspected using a wet magnetic particle or liquid penetrant inspection method to verify complete removal of the defect and the absence of cracking.

11.4.2 Repair by Welding

Repairing surface defects or end bevels by welding shall not be permitted.

11.4.3 Repair of Dents and Wrinkles

No stop/starts in the bending process shall be visible except between the bend area and tangent ends. In those areas, a small cosmetic bump may be visible, which should be similar in appearance to those on the qualification bend. Bends unexpectedly interrupted during the bending process must be reviewed by XYZ PIPELINE COMPANY and approved for acceptance.

Jacking, hammering, re-expansion, or any process causing localized deformation of the bend shall not be permitted after the heat-treating process.

Dents containing stress concentrators such as scratches, gouges, and grooves shall not be permitted.

Dents in the seam weld shall not be permitted.

Grinding to alleviate dents shall not be permitted.

12 Cleaning, Priming, and Coating

12.1 Blasting and/or Solvent Cleaning

The inside and outside surfaces of all induction bends shall be cleaned per SSPC-SP-1 to remove all dirt, grease, paint, mill scale, rust, and other foreign substances.

When a grit blasting procedure is used to prep the bend, the Manufacturer shall blast only the exterior surface to achieve a NACE #3 commercial blast finish. When specified by the Project Design Information, the interior surface shall also be abrasive blasted to the same condition as the exterior surface. Any solvents used for cleaning shall not leave a coating, residue, or any deposit that may prevent subsequent coatings from adhering to the material surface.

12.2 Priming

Immediately following the cleaning procedure, a standard shop primer shall be applied to the exterior surface of the bend only. The coating material and number of coats shall be approved by XYZ PIPELINE COMPANY and applied in accordance with the Manufacturer's recommendations. An even coat of primer shall cover the entire exterior surface with the exception of a 1.5 to 3 inch band at each end of the bend.

12.3 Coating

If specified by the Project Design Information, the bend shall be provided with an external corrosion resistant coating conforming to Company specification XXX, unless the manufacturer's coating specification has been approved in writing by the XYZ PIPELINE COMPANY The coating shall cover the entire exterior surface with the exception of a 1.5 to 3 inch band at each end of the bend.

13 Preparation for Shipping

During the quoting process, the Manufacturer shall provide XYZ PIPELINE COMPANY with drawings of the proposed method of securing inductions bends during shipping and handling. As part of those drawings, the Manufacturer shall also submit the proposed end protection to prevent damage to the beveled ends while in transit.

Before shipping, the Manufacturer shall prepare all bends in a manner which provides sufficient protection during their transportation and handling. The protection should prevent any abrasions or impacts which may cause damage to the bends, the bend coatings, or the beveled ends.

Plastic or metal end caps shall be properly secured on both ends of the bend to protect the beveled edges. Tack welding shall not be allowed for attachment of metal end caps, stays, braces, or any other protective device. Taping or force fitting is acceptable. Nonmetallic straps or adequately padded equipment shall be used for securing the loads and multiple bend shipments shall be protected from metal to metal contact. Boxes and shrink-wrapped pallets will be acceptable for smaller bends.

14 Documentation and Certification

14.1 Documentation

The Manufacturer or Vendor shall provide all required certifications and test reports to before the time of shipment. The Manufacturer shall certify in writing, that the induction bends were manufactured in accordance with the applicable qualified and approved procedures and meet all applicable specifications. Each document shall clearly show the unique identification number of the item to which it pertains to. Induction bends shall not be released for shipment prior to documentation review and acceptance by XYZ PIPELINE COMPANY.

14.2 Certification

The material manufacturer shall have a quality system certified in accordance with ISO 9001 and the system shall have undergone a specific assessment for the relevant materials

A Certified Mill Test Report (CMTR) shall be provided to XYZ PIPELINE COMPANY with each bend, heat or lot of bends. The CMTR shall be in accordance with either API 5L PSL2, MSS-SP-75, or ASME B16.49 section 14[BA21] and summarize or include the following:

- 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)
- 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.

15 Plant Access and Visitation

15.1 Notification

To facilitate inspection, the Manufacturer shall give XYZ PIPELINE COMPANY or XYZ PIPELINE COMPANY’S authorized representatives an advanced notice of at least (10_ U.S. business days prior to starting production of the induction bends.

Manufacturer shall give XYZ PIPELINE COMPANY or XYZ PIPELINE COMPANY’S authorized representatives an advanced notice of at least 10 U.S. business days prior each of the following Hold Points:

Bending procedure qualification
Start of bending
Heat treatment
Mechanical testing
Final inspection/release
Coating

15.2 Inspection of the Manufacturing Process

XYZ PIPELINE COMPANY or XYZ PIPELINE COMPANY’S authorized representatives shall have the right to inspect all raw material, induction bends, tests, instrumentation, and machinery pertinent to the induction bend manufacturing process. XYZ PIPELINE COMPANY shall have free entry at all times to the Manufacturer’s facilities during the induction bending procedure qualification and the production bending process.

Appendix B

Generic Specification for Purchasing Segmentable Elbows

Elbow Purchase Specification[1,2,3]

1. Scope

This specification covers the minimum requirements for the design, fabrication, testing and inspection of high strength, carbon steel, butt weld, elbow fittings greater than 2.375 inch diameter.

It is the responsibility of the Manufacturer to comply with the requirements of the Code of Federal Regulations, Title 49, Part 192. In case of a conflict with these specifications or Manufacturers' recommendations the more stringent shall apply. Deviations from this specification are only allowable with prior written consent from the Purchaser. Non-conformance to this specification may result in rejection of the fitting. This determination shall be at the sole discretion of the Purchaser.

2. Definitions

Design Thickness: Design thickness is the largest of specified design or prototype dimension normal to any surface on the component. .

Field Segmentable Elbows: An Elbow that can be cut to obtain a desired degree of bend and beveled to fit the adjoining pipe. Special dimensional tolerances apply to the body of the fitting.

Manufacturer: Fitting manufacturer, including their manufacturing facilities and sub-vendors, who supplies or proposes to supply elbows to the Purchaser in accordance with this specification.

Nominal Bore Diameter: Nominal outside diameter minus twice the specified nominal wall thickness.

Nominal Wall Thickness: Nominal wall thickness is the specified bevel thickness of the run diameter of the fitting.

Out of Roundness: Out of roundness shall be the difference between the maximum and minimum diameters measured on any radial cross-section.

Ovality: Out of roundness

3. Referenced Standards and Supplementary Requirements

ASTM A234 grade WPB supplemental requirement ASTM A 960 S3[A1]

ASTM A420 WPL6 supplemental requirements ASTM A 960 S51, S53, S59, S69[A2]

[1] Content highlighted in yellow pertains specifically to segmentability.
[2] Annotations provided in the margins are intended to indicate the source of values, dimensions, and other content, where known.
3 Underlined values are company-specific values that can be changed at the discretion of the purchaser

ASTM A860 WPHY52, supplemental requirements A960 S53, S69[A3]

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

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Alternative or Supplemental Specification Content

All products: Tensile Elongation, A > 20%.

Fittings to A 420: ASTM A 960 supplementary requirement S51 shall apply.

Impact testing shall be carried out to the same extent as tensile testing

MR 0175 Metals for Sulfide Stress Cracking and Stress Corrosion Cracking Resistance in Sour Oil Field Environments

SSPC SP-1 Solvent Cleaning

SSPC - SP10 Blast Cleaning to Near-White Metal

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4. Design Information

4.1 Specifications

Elbow Specification: ___MSS SP-75 Latest Edition and ASME B16.9 Latest Edition, (with supplemental requirements as described herein)__.

4.2 Matching Pipe Data

Material Grade: ________(per API 5L)
Manufacturing Process: ________.
Nominal Outside Diameter: ________(inches)
Wall Thickness: ________(inches)

4.3 Beveling

All fitting ends shall be machine-beveled to meet the requirements of ASME B31.8, Figure I5 or ASME B31.4, Figure 434.8.6(a). Exterior and interior weld reinforcement on seam welds shall be ground flush with the base metal for a length of _4 inches__ from the weld bevel.

4.4 Elbow Data

Elbow Radius: ________(feet)
Elbow Angle: ________(degrees)
Wall Thickness, minimum: ________(inches)
Wall Thickness, maximum: ________(inches)
Inside Diameter, minimum: ________(inches)
Heat Treatment: ________(schedule)
Finish: ________(coating)

4.5 Service Conditions

Service Medium: ________ (natural gas, crude, etc)
Service Conditions: Sweet or Sour?
Design Pressure: ________ (psig)
Minimum Design Temperature: ________ (°F)
Maximum Design Temperature: ________ (°F)

5. Dimensional Requirements and Tolerances

5.1 Inside Diameter

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

5.2 Inside Diameter at Ends

Circumference measurement or averages of I.D. dimensions shall determine the inside diameter at the end. This measurement shall be taken at the inside root face of the weld bevel. Diameter 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.

NOTE: Nominal fitting inside diameter equals nominal fitting outside diameter minus two times the nominal *wall thickness.*

5.3 Out of Roundness

For fittings with $D \geq 219.1$ mm (8.625 in), the out-of-roundness tolerance may be determined using the calculated inside diameter (the specified outside diameter minus two times the specified wall thickness) or measured inside diameter rather than the specified outside diameter.

Percent out of roundness = 100 x (Maximum OD – Minimum OD) ÷ Nominal OD

5.4 Elbow Radius and Angle

The measurement of the fitting radius shall be as specified by the Design Information __± 0.5%__ of the specified radius.

The measurement of the fitting angle shall be as specified by the Design Information __± 0.5°__ degrees of the specified angle.

5.5 Beveled Ends

Beveled ends shall be machine-beveled to meet the tolerances required in ASME B31.8, Figure I5. The squareness of both ends shall be measured for conformance with MSS SP-75 or the applicable standard.

6. Segmentable Elbows

These will be cut in the field to obtain the desired degree of the elbow and beveled to fit the adjoining pipe. Special dimensional tolerances apply to the body of the fitting. 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 x (nominal ID -3/16 inch)

Alternative Specification Content for Dimensional Tolerances

When an elbow is ordered as segmentable, the difference between maximum and minimum diameters at any cross-section throughout the elbow shall be limited to +0.5% of the outside diameter.

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7. Markings

7.1 Marking Method

All markings shall be applied after cleaning. Markings shall be paint stenciled on the fitting, and a clear lacquer finish applied over the stenciled area. Limited use of hand lettering is acceptable at the discretion of the Purchaser. All marks shall be legible and permanent. Marking materials used on the outside surfaces shall not adversely affect coating applications. Any marking on the fitting joint shall only be done using markers free of lead, sulfur, phosphorus or other detrimental ingredients. Cold die steel stamping of elbows is prohibited.

7.2 Information Contained in Marking

The following information shall be marked on the elbow:

- The Purchaser’s Company Name or Logo, order number, and item number
- Individual fitting identification number
- “Segmentable” if segmentable

- Other fitting manufacturing data when required by the Purchaser or the applicable standard.

When a stress relief procedure is used, the marking shall read SR-XXXX, where XXXX is the stress relief temperature in °F. Where a quench and temper procedure is used, the marking shall read QT-YYYY/ZZZZ, where YYYY is the quench temperature and ZZZZ is the tempering temperature, both in °F. When a normalizing heat treatment is used, the marking shall include the designation "N". When a normalize and temper heat treatment is used the designation shall include NT-ZZZZ where ZZZZ is the tempering temperature in °F.

Prior to shipment, a unique individual identification number shall be created and assigned to each fitting. All manufacturing operations applied to the elbow may then be traceable to that individual identification number.

An example of a unique component identification number is: "1234/56/7", where:

1234	Purchase Order #
56	Item # (obtained from the Purchase Order)
7	Sequence # applied by the Manufacturer (e.g., the seventh elbow manufactured to fill the total number of elbows required for Item #56 on the Purchase Order). All elbow-specific certification information and inspection data is directly traceable to this sequence number

7.3 Location of Marking

All fittings 12 inches nominal outside diameter and larger shall have the markings paint stenciled on both the inside and outside surfaces of both ends of each elbow within 6 inches of the end bevel or as close as practical. Elbows having a nominal outside diameter smaller than_12 inches shall have the markings stenciled only on the outside surface. Each elbow shall have the starting point of the tangent paint stenciled at both ends on the exterior only.

Alternative or Supplemental Specification Content for Marking

All fittings shall be clearly identified by marking with inverted dot or low-stress die stamps with a minimum radius of 1/32 inch (0.8 mm). The maximum depth of impression shall be 0.015 inch (0.4 mm). Welders' identification stamps shall not be used. Any welder identification stamp markings shall be removed by grinding.

The location of the die stamp markings shall be on the outside diameter, a minimum of 2 inches (50mm) from any weld bevel or weld seam.

The location of die stamped marking shall be identified using a paint marker or a similar method.

Marking shall be done by stamping. In addition, the manufacturer may paint some or all of the required marking on the fitting.

Heat treatment load number shall be permanently marked on the component when testing is required per heat treatment load

The component shall be marked to ensure full traceability to melt and heat treatment lot.

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8. Manufacture

Fittings shall be wrought, not a welded combination of tubular products. Sand packed furnace fittings are not permitted .

When indicated on the RFQ (i.e., when fittings are intended for use in pipelines subject to in-line inspection pigs) the minimum bore diameter for ells and tees shall be no smaller than the greater of the nominal bore diameter minus ¼ inch, or 93% of the nominal bore diameter.

9. Materials and Mill Test Reports

For Grade WPB Fittings, blanket certification is acceptable.

The maximum allowable yield strength for fittings shall be as shown in Section 14.

Chemical Composition

The required chemical compositions shall be in accordance with MSS-SP-75, SR-10.

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

C	0.20% Max
Si	0.45% Max
Cu	0.40% Max
S	0.020% Max (grades Y60 and stronger)
	0.025% Max (other grades)
P	0.025% Max (grades Y60 and stronger)
	0.030% Max (other grades)
Cr	0.20% Max
V+Nb+Ti	0.10 % Max

The carbon equivalent of SP-75 Section 7.3 shall not exceed 0.43

Alternative Specification Content

The chemical composition of high yield fittings shall be verified by a chemical analysis performed on each heat of material used. Phosphorus and sulfur levels shall not exceed 0.03%.

The maximum carbon equivalent for fittings shall be 0.45% and the maximum carbon content shall be 0.32%, unless otherwise approved. All fittings with a carbon equivalent in excess of 0.42% shall be marked with fluorescent red paint. The carbon equivalent shall be defined by one of the following equations, as specified in the Project Design Information:

$$\%C_E = \%C + \frac{\%Mn}{6} + \frac{(\%Cr + \%Mo + \%V)}{5} + \frac{(\%Ni + \%Cu)}{15} \qquad \text{(IIW)}$$

$$\%C_E = \%C + F\left(\frac{\%Mn}{6} + \frac{\%Si}{24} + \frac{\%Cu}{15} + \frac{\%Ni}{20} + \frac{\%Cr + \%Mo + \%V + \%Nb}{5} + 5\%B\right) \qquad \text{(CSA)}$$

Where, F is a compliance factor dependent upon carbon content as is defined as follows:

Carbon Content, %	F	Carbon Content, %	F	Carbon Content, %	F
<0.06	0.53	0.11	0.70	0.17	0.94
0.06	0.54	0.12	0.75	0.18	0.96
0.07	0.56	0.13	0.80	0.19	0.97
0.08	0.58	0.14	0.85	0.20	0.98
0.09	0.62	0.15	0.88	0.21	0.99
0.10	0.66	0.16	0.92	>0.21	1.00

10. Fabrication

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 minimum tensile strength.

Manufacturers shall submit, or have previously submitted, information outlined below under "Manufacturing procedure qualification information". New procedures and revisions to existing procedures require written approval by the Purchaser prior to use.

Qualification shall be necessary if:

(a) the Manufacturer has not supplied fittings from the plant facility used to make the fittings during the last three (3) years; or
(b) when determined by the Purchaser.

Requalification may be necessary if any of the following changes occurs:

(a) source of starting materials;
(b) specification for starting materials;

(c) the plant facility used to make the fittings; or
(d) the manufacturing procedure qualification.

The procedure qualification requirements consist of two parts:

(a) manufacturing procedure qualification information; and
(b) the procedure qualification tests.

Manufacturing procedure qualification information

Design

The Manufacturer shall submit details of the design of the fitting(s) including how the design wall thickness is calculated and other geometric details dictated by the shape of the part.

Steelmaking

The Manufacturer shall state the specified chemical analysis of the steel. The type of melting practice shall be provided, including the methods used for alloying and deoxidation.

Ordering and inventory practice

The Manufacturer shall submit details of material ordering practices and the systems employed for material identification, control, traceability, and utilization from inventory.

Forming

The Manufacturer shall submit details of the forming procedures.

Quality assurance

The Manufacturer shall provide an uncontrolled copy of the applicable quality assurance manual. All system procedures shall be available for review by the Purchaser at the Manufacturer's plant. A copy of the registration certificate for the documented quality program shall also be submitted.

Heat treatment procedures

The Manufacturer shall submit details of all heat treatment procedures including temperatures, times, and quenching methods.

Welding procedures

The Manufacturer shall submit details of all welding procedures used in accordance with ASME Section IX including joint design, welding consumables, and welding parameters.

Repair procedures

The Manufacturer shall submit details of all repair procedures, by welding or otherwise. These procedures shall include details of the nondestructive examination methods utilized to confirm the adequacy of the repair.

Nondestructive examination

The Manufacturer shall submit details of the procedures used in the nondestructive examination of the fitting.

Procedure qualification tests

Where required for the fitting proposed, the Manufacturer shall submit the results of a design proof test as described in Section 4.

Mechanical test requirements

Body material tests

The Manufacturer shall submit the results of tension tests; showing the yield strength, tensile strength, and elongation for each starting material standard or specification . The Manufacturer shall also submit the results of Charpy V-notch impact tests performed. The proposed grade or grades for each such starting material standard or specification shall be listed.

Weld & heat affected zone material tests

The Manufacturer shall submit the results of Charpy V-notch impact tests from both the weld metal and the heat affected zone from each combination of material and welding procedure. Tension test results transverse to the weld showing the ultimate tensile strength, for each such combination shall also be supplied.

Alternative Specification Requirement for Manufacturing

The MPS should specify the following items, as applicable:
a) For the starting material

- delivery condition
- chemical composition, and
- NDT procedures for examination of starting materials.

b) For fitting manufacture

- NDT procedures
- hydrostatic test procedures
- dimensional control procedures
- coating and protection procedures

- handling, loading and shipping procedures, and at-site installation recommendations.

Elbows 20 inch in diameter and smaller shall be seamless.

No ERW material is permitted.

No girth welds shall be used on any fittings.

Sand packed or furnace table fittings are not acceptable.

Weld seams shall be ground flush (-0, +1/32 inch) on both the inside and outside surfaces for a distance of 4 inches from the welding end of the fitting

(alternate definition of “flush ground”: Flush = (-0.0, +0.02 inch)

All fittings that are not already painted shall be primed with an approved primer on the exterior.

Beveled ends shall be suitably protected from damage during shipment

Primer paint or other required coatings shall not be applied until after the Company’s inspection has been carried out, if Company inspection is required

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11. Welding Fabrication

The specified minimum ultimate tensile strength of the weld filler metal shall exceed the specified minimum ultimate tensile strength of the fitting. The welding procedure qualification tests for all welds shall include Charpy V-notch impact tests of both the weld metal and the heat-affected zone in accordance with the requirements of Section 15. Specimen location and orientation shall be as specified in Paragraph UG 84 of the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1. The absorbed energy value shall be as specified in Section 15. Testing shall be done as described in Section 15.

For pressure containing welds:

- The weld procedure transverse tensile tests, as required by ASME Boiler and Pressure Vessel Code, Section IX, shall be performed on specimens with the weld reinforcement removed.
- The cross weld tensile test shall meet the ultimate tensile strength requirements specified in Table 2 of MSS SP-75.

Automatic welding shall be done with submerged arc process only, except that other electric arc processes may be used for the root bead.

The purchaser reserves the right to review welding procedure qualifications, including repair procedures, upon request.

12. Heat Treatment

No welding on a fitting after heat treatment is allowed .

Quenching and tempering is only acceptable for buttwelding fittings to have a Specified Minimum Yield Strength (SMYS) of 52,000 psi (Gr. 359) or more. Quenching shall be provided with adequate agitation and a minimum tempering temperature of 1100°F (593°C) shall be used unless otherwise approved by the purchaser.

Stress relieving temperatures shall be 1100°F (593°C) minimum and 1250°F (677°C) maximum unless otherwise approved by the purchaser. Stress relieving temperature shall be held for one hour per inch (25 mm) of thickness of the fitting or one hour, whichever is greater.

Reduced stress relief temperatures must be accompanied by longer time at stress relief temperature, in accordance with ASME BPVC Section 8 Div. 1 Table UCS 56.1.

Fittings and forgings: During heat treatment components shall be placed in such a way as to ensure free circulation around each component during the heat treatment process including possible quenching operation.

The heat treating cycles shall be continuously recorded. Where requested, the Purchaser shall receive a copy of the recording. The furnace records shall be traceable to the unique component identification number(s) .

Alternative Specification Requirements for Heat Treatment

For products delivered in quenched and tempered condition, the minimum tempering temperature shall be 620ºC (1148ºF) unless otherwise approved by the purchaser.

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13. Tensile Testing

For fittings containing welds, a tensile test on a sample across a weld shall be made from each lot of fittings to determine tensile strength, in accordance with MSS-SP-75, SR-3.

The maximum acceptable base metal (not cross weld) yield strength for fittings not receiving a quenched and tempered heat treatment follows:

Grade	Maximum Yield Strength (ksi)
B	67
Y42	67
Y46	72
Y52	77

Y56	79
Y60	82
Y65	87
Y70	92

Substitution of wall thickness for yield strength is prohibited without the written approval of the Company If the substitution of wall thickness for yield strength is permitted then a fitting may have thickness or yield strength or both unequal to the pipe with which it is intended to be used, provided the welding-end preparation at the joint assures the wall thickness of the fitting is at least equal to the specified pipe-wall thickness times the ratio of the specified minimum yield strength of the pipe and the specified minimum yield strength of the fitting

Fittings containing welds shall have one across the weld tension test made with the axis transverse to the weld seam for each heat of filler metal, or for each heat of filler metal and batch of flux for submerged arc welds, and for a given heat treatment for each lot of fittings. The yield strength, tensile strength, and elongation shall be determined and the requirements of Table 2 of MSS SP-75 shall be met. Transverse weld tensile tests shall be performed on specimens with the weld reinforcement removed.

The tensile properties for the body of the fittings shall be determined using a sample that is transverse to the axis of the fitting.

The yield strength shall be determined by the 0.5% extension under load method.

Where the same lot is heat treated in more than one furnace charge, either:

- test specimens shall be taken from each charge, or
- furnace charts showing identical heat treatment cycles for each charge (including that containing the test specimen) shall be made available to the Purchaser.

It shall not be permissible to warm or hot flatten test specimens.

14. Impact Toughness Testing

The impact test specimens shall be taken from mid-thickness position

Impact test temperature shall be based upon a minimum design temperature of +20°F unless otherwise specified on the RFQ.   The test temperature shall be adjusted as shown in equation XX to compensate for the tendency for shear area fraction to increase as sample size decreases relative to the fitting wall thickness.

Eq. xx $TC = TP - 59.57 \times (t_w^{0.55} / t_c^{0.7}) + 55.56$

Where:

TC = Charpy test temperature (°C)

TP = Pipe minimum design temperature (°C) (assume 20 °F or 6.7 °C unless otherwise indicated on the RFQ)

t_w = thickness of pipe (mm)

t_c = thickness of Charpy sample (mm)

The absorbed energy of Charpy impact test specimens shall meet the greater of the requirements of API 5L Annex G, Section G.7 or G.8 For design factors less than 0.625 the requirements of Table G.1 shall apply. When a design factor is not specified in the RFQ a design factor of 0.72 shall be used.

The average shear percent for samples from each lot shall be not less than 60%

Charpy V-notch specimens shall also be taken from the weld and heat affected zone. Weld specimen location and orientation shall be in accordance with the requirements of Paragraph UG-84 of ASME Boiler and Pressure Vessel Code, Section VIII, Division 1.

____

Alternative Specification Content for Toughness Testing

Option 1:

Percent shear shall be reported for informational purposes only.

The following Charpy absorbed energy values shall be obtained in the parent metal, the weld, and the heat affected zone.

Nominal Size (NPS)	Required Absorbed Energy at -50°F (Equivalent Full-Size Specimens)
> NPS 20	27 ft-lb
NPS 14 to NPS 18	20 ft-lb

In accordance with the requirements of ASTM A 370, Section 26.1.1, the value for one specimen may be less than the applicable value specified in the above table; provided that it is not less than 2/3 of such value.

Option 2:

Notch toughness requirements are based on Level.

Level I Fittings with requirements for proven fitting body notch toughness properties shall be in accordance with MSS SP-75, Section 11.1 and 11.2.

Level II Fittings with requirements for proven notch toughness properties in the form of energy absorption meeting the requirements of the following Table. Fracture appearance should be provided for information only.

Notch Toughness Requirements – Level II Fittings

Nominal Size (NPS)	Required Absorbed Energy at –50°F (-45°C) (Equivalent Full-Size Specimens)
> 44	30 ft-lb (40 J)
38 - 42	25 ft-lb (34 J)
16 - 36	20 ft-lb (27 J)
≤ 14 ≥ X52 (Gr. 359)	20 ft-lb (27 J)
≤ 14 ≤ X52 (Gr. 359)	13 ft-lb (18 J)

The fitting Level will be shown on the Project Design Information and the purchase order.

The test temperature for all Level II fittings shall be -49°F (–45°C).

Charpy V-notch specimens from the parent metal shall be transverse to the axis of the fitting.

Charpy V-notch specimens shall also be taken from the weld. Weld specimen location and orientation shall be in accordance with the requirements of Paragraph UG-84 of ASME Boiler and Pressure Vessel Code, Section VIII, Division 1

15. Hardness Testing

Hardness test shall be made for each test lot.

The hardness in any part of the fitting shall not exceed 30 HRC as determined in accordance with the requirements of ASTM Standard E18, or as converted from another scale as described in ASTM Standard A370.

Alternative Specification Content for Hardness testing

The maximum allowable surface hardness for all fittings shall be HRC 22, or equivalent.

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16. Non-Destructive Examination

In all cases, the mill scale shall be removed from the areas to be inspected after heat treatment and prior to inspection.

All weld repairs shall be inspected by radiographic methods, if practical, in accordance with ASME BPVC Section V. Where radiographic examination is not possible, shear wave ultrasonic examination methods in accordance with ASTM E-164 shall be used.

Magnetic Particle or Liquid Penetrant inspection conducted in accordance with the requirements of this specification shall meet the requirements of the applicable appendix of the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1 shown below:

- Magnetic particle inspection: Appendix 6
- Liquid penetrant inspection: Appendix 8

Any residual magnetism within 4 inches (100 mm) of a field welding end shall not exceed 50 gauss (5 mT).

All personnel interpreting NDT results shall be certified to minimum Level II ASNT in the relevant discipline.

The body of the fitting shall be ultrasonically examined for wall thickness in accordance with MSS-SP-75, SR-8.

The weld ends shall be inspected in accordance with MSS-SP-75, SR-14. The acceptance criteria shall be those of API 5L 44th edition Section K.2.1

Weld bevel faces shall be inspected for lamination 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. Repair welding of bevels is not permitted

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Alternative Specification Content for Nondestructive Inspection

When specified in the Project Design Information, all bevels shall be inspected by magnetic particle test methods in accordance with the requirements of ASTM E-709. Such inspection shall be performed subsequent to final machining. Any lamination in excess of ¼ inch (6.4 mm) shall be removed by machining.

Fittings to A 420: Ultrasonic testing is not acceptable as replacement of radiographic testing.

ASTM A 960 supplementary requirement, S53 and S69, magnetic particle testing, shall apply to 10% of all fittings (same test lot as defined for mechanical testing) for nominal thickness < 12.7 mm and 100 % of all fittings for nominal thickness ≥□12.7 mm. The testing shall be carried out after calibration. The acceptance criteria shall be to ASME VIII, Div. 1, Appendix 6. Supplementary requirement S53 and S69, magnetic particle testing, shall apply to 10% of all fittings (same test lot as defined for mechanical testing) for nominal thickness < 12.7 mm and 100% of all fittings for nominal thickness ≥12.7 mm. The testing shall be carried out after calibration of dimensions.

17. Defect Repair

Each elbow, after final processing, shall be inspected for any harmful defects, which might impair its serviceability. The definition and allowable repair of harmful defects, as approved by the Purchaser, shall be in accordance with API 5L. Repairs to the seam welds, beveled ends, or repair of a repair shall not be permitted. All repaired areas shall be inspected using a liquid penetrant or wet magnetic particle inspection technique, and shall contain no surface cracks.

Jacking, hammering, re-expansion, or any process causing localized deformation of the fitting shall not be permitted after the heat-treating process.

Dents containing stress concentrators such as scratches, gouges, and grooves shall not be permitted.

Dents in the seam weld shall not be permitted.

Grinding to alleviate dents shall not be permitted.

18.1 Repair by Grinding

All repairs by grinding shall be completed using a fine grit abrasive without blueing the surface. The complete removal of defects shall be verified by magnetic particle or liquid penetrant inspection.

Body defects on the inside or outside surface, such as scabs, slivers, blisters, etc. and mechanical damage in the form of scratches, gouges, etc., shall be removed by grinding provided that a minimum of 93.5% of the nominal wall thickness remains after complete removal of the defect(s).

Cracks and crack-like indications shall be removed by grinding to a maximum depth of 6.5% of the nominal specified wall thickness. Fittings containing deeper cracks or crack-like indications shall be rejected.

Weld defects such as slag inclusions, gas pockets or voids, shall be removed by grinding provided they do not extend below the projected contour of the surface of the parent fitting.

Arc burns may be removed by grinding provided that a minimum of 93.5% of the nominal wall thickness remains and it is confirmed that all traces of the arc burn have been removed by using an ammonium persulfate etchant. Weld repair of arc burns is prohibited.

18.2 Repair by Welding

Weld repair to the body of a fitting, including buttering to build up wall thickness, is strictly prohibited.

Weld repair of base material is not acceptable.

Backwelding will be permitted provided the weld area is preheated to a minimum temperature of 250^{o}F (121^{o}C) prior to backwelding. As an alternative, backwelding shall be permitted between the root pass and second pass of primary welding.

For weld defects affecting between 6.5% and 33.3% of the nominal wall thickness, where welded repairs are required, the fitting shall be preheated to a minimum temperature of 250^{o}F (121^{o}C) and a low-hydrogen welding procedure shall be used. All weld repairs shall be inspected by the same method under which the defect was originally detected.

19. Workmanship and Finish

Fittings with weld defects repaired after heat treatment will be entirely re-heat-treated.

No crack or crack-like indication shall be unrepaired.

No dent greater than 3/16 inch depth shall be permitted.

After final heat treatment, no dents are to be removed by jacking or hammering. After final heat treatment, dents that contain stress concentrators such as gouges, grooves, or scratches shall be cause for rejection.

No dent in the seam weld shall be permitted.

No grinding to alleviate a dent condition shall be permitted.

20. Cleaning, Priming, and Coating

20.1 Blasting and/or Solvent Cleaning

The inside and outside surfaces of all induction elbow shall be cleaned per SSPC-SP-1 to remove all dirt, grease, paint, mill scale, rust, and other foreign substances.

When a grit blasting procedure is used to prep the fitting, the Manufacturer shall blast only the exterior surface to achieve a NACE #3 commercial blast finish. When specified by the Project Design Information, the interior surface shall also be abrasive blasted to the same condition as the exterior surface. Any solvents used for cleaning shall not leave a coating, residue, or any deposit that may prevent subsequent coatings from adhering to the material surface.

20.2 Priming

Immediately following the cleaning procedure, a standard shop primer shall be applied to the exterior surface of the fitting only. The number of coats and the coating material shall be approved by the Purchaser and applied in accordance with the Manufacturer's recommendations. An even coat of primer shall cover the entire exterior surface with the exception of a 1.5 to 3 inch band at each end of the elbow.

20.3 Coating

If specified by the Project Design Information, the fitting shall be provided with an external corrosion resistant coating conforming to Company specification XXX, unless the manufacturer's coating specification has been approved in writing by the the purchaser". The coating shall cover the entire exterior surface with the exception of a 1.5 to 3 inch band at each end of the elbow.

21. Preparation for Shipping

During the quoting process, the Manufacturer shall provide the Purchaser with drawings of the proposed method of securing fittings during shipping and handling. As part of those drawings, the Manufacturer shall also submit the proposed end protection to prevent damage to the beveled ends while in transit.

Before shipping, the Manufacturer shall prepare all fittings in a manner which provides sufficient protection during their transportation and handling. The protection should prevent any abrasions or impacts which may cause damage to the fitting, the fitting coating, or the beveled ends.

Plastic or metal end caps shall be properly secured on both ends of the elbow to protect the beveled edges. Tack welding shall not be allowed for attachment of metal end caps, stays, braces, or any other protective device. Taping or force fitting is acceptable. Nonmetallic straps or adequately padded equipment shall be used for securing the loads and multiple fitting shipments shall be protected from metal to metal contact. Boxes and shrink-wrapped pallets will be acceptable for smaller fittings.

22. Documentation and Certification

22.1 Documentation

The Manufacturer or Vendor shall provide all required certifications and test reports to the purchaser before the time of shipment. The Manufacturer shall certify in writing, that the fittings were manufactured in accordance with the applicable qualified and approved procedures and meet all applicable specifications. Each document shall clearly show the unique identification number of the item to which it pertains to. Fittings shall not be released for shipment prior to documentation review and acceptance by the Purchaser.

22.2 Certification

The material manufacturer shall have a quality system certified in accordance with ISO 9001 and the system shall have undergone a specific assessment for the relevant materials.

The material certificate shall be issued in accordance with EN 10204 Type 3.1, and shall include the following information:

- Heat treatment condition (For QT condition, austenitizing and tempering temperature and quenching medium shall be stated.)

The manufacturer shall furnish a report of the heat analysis for each heat of steel supplied.

The manufacturer shall furnish a report of the product analysis and the carbon equivalent for each heat of steel supplied.

The manufacturer shall furnish a report of the results of the mechanical tests required by Sections 14, 15, and 16.

A written record of all nondestructive inspection results required by Section 17 shall be prepared and certified by the manufacturer for submission to the company. These records shall identify the procedure number and revision level used for the inspection.

The manufacturer shall include a copy of the drawing that was prepared by the Manufacturer and accepted by the Purchaser in the documentation package.

The reports and test certificates shall contain the following additional information:

(a) Method of heat treatment.
(b) Time and temperature for each heat treating operation.
(c) Where requested by the Purchaser, heat treatment charts (see Section 13).
(d) Identification of the weld procedures (WPS and applicable PQR) and revision numbers used, including those used for repair welds.
(e) Nominal starter stock thickness of the starting material.
(f) Confirmation that the fittings were manufactured in accordance with the requirements of this specification.

The manufacturer shall supply to the company, prior to shipping the fitting, reports and test certificates correlated to the unique component identification number.

The following documents shall be available to the Purchaser at the time of final inspection:

(a) Chemical Analysis.

(b) Certified material test reports (MTRs).
(c) NDE inspection reports.
(d) Heat treatment records.

These documents shall clearly list the unique component identification number of each item to which the documentation applies. Fittings shall not be released for shipment prior to documentation review by the Purchaser.

The Manufacturer shall furnish two (2) copies of a certified analysis (mill test report) showing chemical and physical properties, the radiographic report (if applicable), the method of heat treatment and the hydrostatic test reports (if applicable) of the fitting with the invoice. These reports and test certificates shall correlate with the traceability number if applicable. One copy shall be provided to the purchaser for review and approval before the fittings are shipped. The second copy shall accompany the fittings when shipped.

The Manufacturer shall certify in writing the fittings are in accordance with this specification, MSS SP-75 and the Department of Transportation Minimum Safety Standards Title 49 Part 192.

23. Plant Access and Visitation

23.1 Notification

To facilitate inspection, the Manufacturer shall give the Purchaser or the Purchaser's authorized representatives an advanced notice of at least _10_U.S. business days prior to starting production of the elbows.

23.2 Inspection of the Manufacturing Process

The Purchaser or the Purchaser's authorized representatives shall have the right to inspect all raw material, fabrication process, tests, instrumentation, and machinery pertinent to the manufacturing process. The Purchaser shall have free entry at all times to the Manufacturer's facilities during the manufacturing procedure qualification and the production process.

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