ASME B16.49-2023
(Revision of ASME B16.49-2017)

Factory-Made, Wrought Steel, Buttwelding Induction Bends for Transportation and Distribution Systems

AN AMERICAN NATIONAL STANDARD

The American Society of Mechanical Engineers

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The American Society of Mechanical Engineers
Two Park Avenue • New York, NY • 10016 USA

Date of Issuance: November 10, 2023

The next edition of this Standard is scheduled for publication in 2028.

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FOREWORD

In 1993, members of the ASME B31.8 Code for Pressure Piping, Gas Transmission and Distribution Piping Systems Committee approached the B16 Committee to develop a standard that covers pipeline bends produced by the induction bending process.

Subcommittee F reviewed the request and identified that no current specification covered this product to the satisfaction of the users. It was also determined that this Standard would need to be more performance-based than most other B16 standards, which are normally product standards with set dimensional requirements.

At the 1994 meeting of Subcommittee F, the project to develop a standard was accepted. Through the cooperation of producers and users familiar with the process, and with approval by the Standards Committee and ASME, ASME B16.49-2000 received approval as an American National Standard on April 25, 2000.

In 2005, the Committee undertook a general review of this document. Based on the usage of this Standard over the last 5 years, a number of revisions, clarifications, and additions were determined to be needed to make the document more user friendly. Some requirements were dropped, revised, and clarified to reflect the desires of the users and manufacturers. The reference data were updated and the interpretation section was removed from the Standard. These revisions were incorporated into the B16.49-2007 edition.

In 2012, the Committee reviewed this document and made revisions to requirements in hardness testing and updated the references found in Mandatory Appendix I. ASME B16.49-2012 was approved by the American National Standards Institute (ANSI) on October 22, 2012.

In the 2017 edition, provisions were made to update verbiage and readings. Following the approval by the ASME B16 Standards Committee, approval as an American National Standard was given by ANSI on September 7, 2017, with the new designation ASME B16.49-2017.

In ASME B16.49-2023, the tables and figures have been redesignated. Cross-references have been updated accordingly. Also, the references in Mandatory Appendix I have been updated. Revisions were made to address quality systems, specimen sizes, and starting materials. Revisions were also made to sections referring to heat treatment, tensile testing, the applicability of NDE, and section 14 on certification. Table 10.1-1 (formerly Table 3) was revised by adding bending temperature. Para. SR15.5 has been revised, and paras. SR15.9 and SR15.10 have been added. Following approval by the ASME B16 Standards Committee, ASME B16.49-2023 was approved by ANSI on September 25, 2023.

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Standardization of Valves, Flanges, Fittings, and Gaskets

(The following is the roster of the Committee at the time of approval of this Standard.)

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This Standard is always open for comment, and the committee welcomes proposals for revisions. Such proposals should be as specific as possible, citing the paragraph number, the proposed wording, and a detailed description of the reasons for the proposal, including any pertinent background information and supporting documentation.

Cases

(a) The most common applications for cases are

(1) to permit early implementation of a revision based on an urgent need

(2) to provide alternative requirements

(3) to allow users to gain experience with alternative or potential additional requirements prior to incorporation directly into the Standard

(4) to permit the use of a new material or process

(b) Users are cautioned that not all jurisdictions or owners automatically accept cases. Cases are not to be considered as approving, recommending, certifying, or endorsing any proprietary or specific design, or as limiting in any way the freedom of manufacturers, constructors, or owners to choose any method of design or any form of construction that conforms to the Standard.

(c) A proposed case shall be written as a question and reply in the same format as existing cases. The proposal shall also include the following information:

(1) a statement of need and background information

(2) the urgency of the case (e.g., the case concerns a project that is underway or imminent)

(3) the Standard and the paragraph, figure, or table number

(4) the edition of the Standard to which the proposed case applies

(d) A case is effective for use when the public review process has been completed and it is approved by the cognizant supervisory board. Approved cases are posted on the committee web page.

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ASME does not act as a consultant for specific engineering problems or for the general application or understanding of the Standard requirements. If, based on the information submitted, it is the opinion of the committee that the inquirer should seek assistance, the request will be returned with the recommendation that such assistance be obtained. Inquirers can track the status of their requests at https://go.asme.org/Interpretations.

ASME procedures provide for reconsideration of any interpretation when or if additional information that might affect an interpretation is available. Further, persons aggrieved by an interpretation may appeal to the cognizant ASME committee or subcommittee. ASME does not "approve," "certify," "rate," or "endorse" any item, construction, proprietary device, or activity.

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ASME B16.49-2023
SUMMARY OF CHANGES

Following approval by the ASME B16 Standards Committee and ASME, and after public review, ASME B16.49-2023 was approved by the American National Standards Institute on September 25, 2023.

In ASME B16.49-2023, the tables and figures have been redesignated. Cross-references have been updated accordingly. In addition, ASME B16.49-2023 includes the following changes identified by a margin note, **(23)**. The Record Numbers listed below are explained in more detail in the "List of Changes in Record Number Order" following this Summary of Changes.

Page	*Location*	*Change (Record Number)*
1	1.9	Revised *(18-2466)*
4	5.1	Revised *(18-2466)*
5	8.2	Revised *(18-2466)*
6	9.2	Added and subsequent paragraphs redesignated *(18-2466)*
7	9.3	Former para. 9.2 redesignated and revised *(18-2466)*
8	Table 10.1-1	Formerly Table 3; entry for "Bending Temperature" added *(18-2466)*
8	11.1.1	Revised *(18-2466)*
11	13.2	Revised *(18-2466)*
11	14	Revised *(18-2466)*
11	SR15.5	Revised *(18-2466)*
12	SR15.9	Added *(18-2466)*
12	SR15.10	Added *(18-2466)*
13	Mandatory Appendix I	Updated *(18-2466, 21-2646)*

LIST OF CHANGES IN RECORD NUMBER ORDER

Record Number	Change
18-2466	Revised para. 1.9 on quality systems, para. 5.1 on starting materials, para. 8.2 on specimen sizes, para. 9.2 on heat treatment, para. 11.1.1 on tensile testing, para. 13.2 on applicability of NDE, and section 14 on certification. Added SR15.9 and SR15.10 and revised SR15.5. Added ASTM A991/A991M to Mandatory Appendix I. Revised Table 10.1-1 by adding bending temperature.
21-2646	Updated references in Mandatory Appendix I.

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FACTORY-MADE, WROUGHT STEEL, BUTTWELDING INDUCTION BENDS FOR TRANSPORTATION AND DISTRIBUTION SYSTEMS

1 SCOPE AND DEFINITIONS

1.1 General

This Standard covers design, material, manufacturing, testing, marking, and inspection requirements for factory-made pipeline bends of carbon steel materials having controlled chemistry and mechanical properties, produced by the induction bending process, with or without tangents. This Standard covers induction bends for transportation and distribution piping applications (e.g., ASME B31.4 and ASME B31.8). Process and power piping have differing requirements and materials that may not be appropriate for the restrictions and examinations described herein and, therefore, are not included in this Standard.

1.2 Manufacturing Process

This process uses induction heating to heat a narrow band 360 deg around a pipe or cylinder at the point of bending as the pipe or cylinder is being pushed through the inductor coil at a constant velocity. After the material passes through the coil, it may be cooled by forced air or water spray, or it may be allowed to cool in still air. Bends in any producible wall thickness and diameter are covered. Induction bends covered by this Standard may be produced from seamless pipe, welded pipe, or cylinders.

1.3 Fabricated Bends

Larger angle bends obtained by girth welding two or more smaller angle bends together are considered pipe fabrications and as such, are not within the scope of this Standard.

1.4 Standard Units

This Standard states values in both SI (metric) and U.S. Customary units. These systems of units are to be regarded separately as standard. Within the text, the U.S. Customary units are shown in parentheses. The values stated in each system are not exact equivalents; therefore, it is required that each system of units be used independently of the other. Combining values from the two systems constitutes nonconformance with the Standard.

1.5 References

Standards and specifications adopted by reference in this Standard are shown in Mandatory Appendix I. It is not practical to identify the specific edition of each standard and specification in the individual references. Instead, the specific edition reference is identified in Mandatory Appendix I. A product made in conformance with a prior edition of reference standards and in all other respects conforming to this Standard will be considered to be in compliance.

1.6 Codes and Regulations

A bend used under the jurisdiction of a referencing code or governmental regulation is subject to any limitation of that code or regulation. This includes any maximum temperature limitation or rule governing the use of a material at low temperature.

1.7 Service Conditions

Criteria for selection of bend material for a particular fluid service are not within the scope of this Standard.

1.8 Convention

For determining conformance with this Standard, the convention for fixing significant digits where limits (maximum and minimum values) are specified shall be as defined in ASTM E29. This requires that an observed or calculated value be rounded off to the nearest unit in the last right-hand digit used for expressing the limit. Decimal values and tolerances do not imply a particular method of measurement.

1.9 Quality Systems (23)

Requirements relating to the manufacturers' quality system programs are described in Nonmandatory Appendix A. The Quality System shall specify controls for the manufacturing process, heat treatment process, testing, inspection, material traceability from starting material to final bend, and documentation requirements necessary to ensure compliance with this Standard. The

manufacturer shall establish and follow documented procedures for maintaining the heat and lot identity throughout the entire supply chain. Traceability procedures shall provide means for tracing any bend to the proper heat and lot and the chemical and mechanical test results.

1.10 Glossary

bend qualification procedure: a document that specifies the properties of the starting pipe; the equipment to be used; the bending parameters; the qualification bend test results; and the postbend, heat-treat equipment, and cycle used for the manufacture of the bends. If nondestructive testing of the bend is required, procedures that have not been approved previously shall be submitted.

cylinder: a joint of pipe produced by a rolling and welding plate, as opposed to a joint of pipe produced in accordance with a recognized specification.

extrados: the outside arc of the bend.

intrados: the inside arc of the bend.

minimum (design) wall thickness: the wall thickness specified or computed in accordance with the piping code as the minimum acceptable for the temperature and pressure application.

nominal (design) wall thickness: the wall thickness specified on the order or marked on the bend.

ovality, %: [(O.D. max. − O.D. min.)/(O.D. nom)] × 100, where O.D. is a linear measurement of the maximum, minimum, or nominal outside diameter.

qualification bend: a bend segment that is produced and tested, and is used to qualify the bending procedure.

transition zone: the area, at the tangent points of a bend, that covers the change (transition) from unheated to heated material.

NOTE: The terms *bender* and *manufacturer* are used interchangeably in this Standard.

1.11 Ordering Information

The purchaser shall be responsible to specify all the ordering information necessary to purchase the needed bends. Examples of such information include, but are not limited to, the following:

(a) quantity
(b) description of bend and nominal dimensions (i.e., size, bend radius, wall thickness, bend angle, tangent lengths, etc.)
(c) steel composition by grade
(d) seamless or welded
(e) specification number (including year)
(f) supplementary requirements from section SR15
(g) additional requirements

Nonmandatory Appendix B is provided as one possible guideline for providing the required information.

2 PRESSURE RATINGS

2.1 Basis of Ratings

The allowable internal pressure rating for bends designed in accordance with this Standard shall not be less than that which is calculated for straight seamless pipe (or for pipe welded with a joint efficiency factor of 1.0) of equivalent material (as shown by comparison of composition and mechanical properties in the respective material specifications) in accordance with the rules established in the applicable sections of the referencing code for pressure piping. For these calculations, applicable data for the nominal size, nominal wall thickness, and material equivalent to that of the bend material shall be used. Nominal size, nominal wall thickness, and material identity markings on the bend may be used in lieu of pressure-rating markings.

2.2 Design of Bends

The required internal pressure design thickness at the intrados (inside radius) of the bend shall be determined in accordance with eq. (1). The thickness at the neutral axis (see Figure 2.2-1) and on the extrados (outer radius) of the bend shall be no less than the mating pipe design thickness or the customer-specified minimum wall thickness.

$$T_I \geq \left[\frac{4(R/D_o) - 1}{4(R/D_o) - 2}\right] t \qquad (1)$$

where

D_o = nominal outside diameter
R = bend centerline radius
t = nominal design wall thickness (see para. 2.1)
T_I = minimum required thickness at the intrados

3 SIZE

The diameter of bends shall be identified by the nominal pipe size (NPS) as defined in ASME B36.10 (e.g., NPS 24). Alternatively or in addition, the marking may include the nominal size as defined in ISO 6708, which consists of the letters “DN” followed by a dimensionless whole number, which is indirectly related to the physical size, in millimeters, of the outside diameter of pipe to which the bend is intended to be welded (e.g., DN 600).

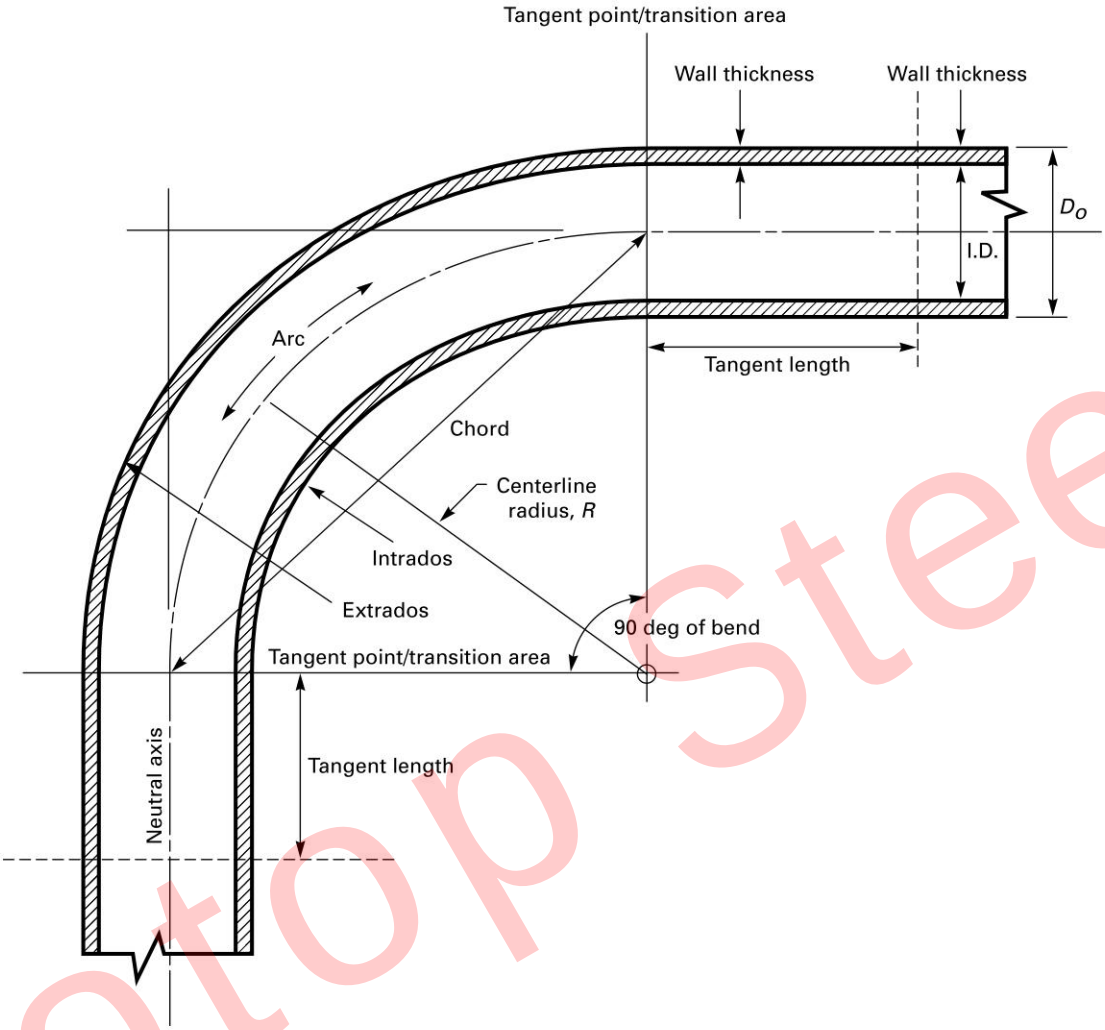
4 MARKING

4.1 Standard Marking

Each bend shall be marked on the outside surface within 300 mm (12 in.) of one end to show the following:

(a) manufacturer's name or trademark

Figure 2.2-1
Bend Dimensional Terms



(b) heat number or manufacturer's heat identification
(c) material grade symbol (see para. 11.3 and Table 4.1-1)
(d) B16.49
(e) nominal pipe size (NPS)
(f) nominal wall thickness
(g) bend radius
(h) bend angle
(i) postbending, heat-treatment condition (see para. 9.4)
(j) supplementary requirements (if applicable) (see section SR15)

Marking may be in any consistent units (metric or customary) but care shall be taken to avoid confusion. Use "X" and grade in lieu of "P" and grade for material designation for the customary stamping option.

When specified by the purchaser, each bend shall be paint-stenciled with the same information in 25-mm (1-in.) or larger letters on the inside surface within 150 mm (6 in.) of each end, except for NPS 12 (DN 300) or smaller, which only requires outside surface marking. Marking materials shall not adversely affect the bend or coating.

4.2 Depth of Stamping

Where steel stamps are used, care shall be taken so that the stamping is not so deep or so sharp as to cause cracking, or to reduce the wall thickness of the bend below the minimum allowed.

Table 4.1-1
Tensile Properties

Grade (Symbol)	Minimum Tensile Properties			Maximum Hardness	
	Yield Strength, MPa (ksi)	Tensile Strength, MPa (ksi)	Elongation, %	HBW [Note (1)]	HRC [Note (2)]
P241 (X241)	241 (35)	414 (60)	20	238	22
P290 (X290)	290 (42)	414 (60)	20	238	22
P317 (X317)	317 (46)	434 (63)	20	238	22
P359 (X359)	359 (52)	455 (66)	20	238	22
P386 (X386)	386 (56)	490 (71)	20	238	22
P414 (X414)	414 (60)	517 (75)	20	238	22
P448 (X448)	448 (65)	531 (77)	18	238	22
P483 (X483)	483 (70)	565 (82)	16	247	24
P552 (X552)	552 (80)	621 (90)	16	247	24

GENERAL NOTE: Intermediate grades may be purchased subject to agreement between the purchaser and manufacturer.

NOTES:
(1) HBW (Hardness Brinell) is the primary number.
(2) HRC (Hardness Rockwell C) is an approximation based on ASTM E140 hardness conversion.

4.3 Compliance

Marking B16.49 on the bend designates that the bend was manufactured in conformance with ASME B16.49. Adding the prefix "ASME" is optional.

Table 5.1-1
Maximum Limits of Chemical Elements That May Be Used

Element	Symbol	Maximum, %
Carbon	C	0.30
Manganese	Mn	1.60 [Note (1)]
Phosphorus	P	0.025
Sulfur	S	0.015
Silicon	Si	0.50
Chromium	Cr	0.30
Molybdenum	Mo	0.25
Vanadium	V	0.10
Copper	Cu	0.50
Nickel	Ni	1.00
Niobium	Nb (Cb)	0.10

GENERAL NOTE: The chemical requirements of this table are not intended to represent the composition of any heat of steel, but to record the maximum permissible amounts of individual elements.

NOTE: (1) For Grades P483 (X483) and higher, for each reduction of 0.01% below the specified maximum carbon content, an increase of 0.05% above the maximum manganese content is permissible, up to a maximum of 2.00%.

5 MATERIAL

5.1 Starting Materials (23)

Bends covered by this Standard shall be produced from carbon steel pipe or cylinders having a chemistry in conformance with Table 5.1-1. Pipe may be furnished by the purchaser or supplied by the manufacturer. Starting pipe shall be seamless, submerged arc welded (SAW), or high frequency electric resistance welded (ERW). Helically welded pipe is allowed, provided the more stringent testing requirements of para. 11.1.3(b) are met. Starting material shall be free from low-melting-temperature metals, cracks, nicks, gouges, waves, buckles, or other such surface contamination defects that may inhibit successful completion of a bend. Pipe or cylinders formed from thermomechanical controlled process (TMCP) may be used with caution. Since TMCP material results in loss of strength when heated over 260°C (500°F), this type of material is seldom used for induction bends. Acceptable forming methods and heat treatment shall be as agreed between the purchaser and manufacturer.

5.1.1 Contamination. Contamination of pipe surfaces before or during bending by low-melting-temperature metals (i.e., copper, brass, zinc/galvanized, aluminum) can have serious effects on the bending process and the finished bend properties. Contact with such metals shall not be allowed.

5.1.2 Surface Condition. Prior to bending, material Grades P359 (X359) and higher shall be grit-blasted to a commercial finish (SSPC-SP 6) as a minimum on those sections to be bent.

6 MATERIAL FOR BENDS CONTAINING WELDS

6.1 Longitudinal Weld Seams

6.1.1 Seam welds in pipe made to an API, ASTM, or CSA specification must meet welding and nondestructive examination (NDE) requirements of that specification.

6.1.2 Other pipe or cylinders not manufactured to the above specifications shall be made by welders, welding operators, and welding procedures qualified under the provisions of the ASME Boiler and Pressure Vessel Code (BPVC), Section IX. Before bending, 100% of each weld seam shall be radiographed in accordance with ASME BPVC, Section VIII, Division 1, UW-51 and shall meet the acceptance criteria specified therein.

In place of radiographic examination, welds may be ultrasonically examined in accordance with ASME BPVC, Section VIII, Division 1, Mandatory Appendix 12.

6.1.3 The longitudinal weld seam should be located on the neutral axis (ϕ = 0 deg or 180 deg in Figure 2.2-1). When this is not possible, the weld seam shall be located not more than 15 deg from the neutral axis. Helically welded pipe is an exception to this weld location requirement.

6.2 Girth Welds

Bending through a girth weld shall not be allowed unless agreed upon between the purchaser and manufacturer.

7 CHEMICAL COMPOSITION

The chemical composition of each heat[1] of material furnished to this Standard, as determined by a product analysis, shall be in accordance with Table 5.1-1. Each element specified in Table 5.1-1 shall be tested for and reported on the material test report required in section 14. The carbon equivalent (CE) shall not exceed 0.45% as computed by eq. (2):

$$CE = C + \frac{Mn}{6} + \frac{(Cr + Mo + V)}{5} + \frac{(Cu + Ni)}{15} \quad (2)$$

8 MATERIAL PROPERTIES

The properties of the bend, as determined for each lot,[2] shall be in accordance with the ordered grade listed in Table 4.1-1.

8.1 Tensile Properties

The tensile properties shall be determined for the qualification bend in accordance with ASTM A370. The yield-to-tensile ratio shall not exceed 0.90, except for Grade P483 (X483) and higher, for which the ratio shall not exceed 0.93. When the strength of the bend does not meet the ordered strength, the manufacturer may provide, with purchaser approval, bends of comparable strength to the design pipe. The thickness of the bend shall be at least equal to the specified design pipe thickness multiplied by the ratio of the specified minimum yield strength of the pipe and the minimum tested yield strength of the bend. For bends from welded pipe of NPS 8 (DN 200) or larger, a transverse weld tensile test in the final heat-treat condition shall be conducted to determine the ultimate tensile strength. See para. 11.1.1 for number, location, and orientation of test samples required.

8.2 Fracture Toughness Properties (23)

Notch toughness properties of the bend material in the final heat-treated condition shall be determined on the qualification bend in all locations specified in Figure 8.2-1 or Figure 8.2-2 by a set of three transverse, full-size, Charpy V-notch specimens, with or without tapering[3] the ends, in accordance with ASTM A370. When the material wall thickness does not permit machining full-size (10 mm × 10 mm) specimens, the largest size possible of ¾ size, ⅔ size, or ½ size shall be substituted. All dimensions other than thickness are the same for full-size specimens. Specimens shall be taken with the axis transverse to the longitudinal axis of the bend. If material wall thickness does not allow at least a ½-size Charpy specimen, no impact testing is required. Specimens shall be tested at −10°C (+14°F) or lower, unless otherwise specified by the purchaser (see para. SR15.4), and shall achieve an average shear area for all specimens of at least 50%, with no one specimen less than 40%. In addition, all specimens shall exhibit a minimum absorbed energy value of 27 J (20 ft-lbf) for Grade P386 (X386) and lower, and a minimum of 54 J (40 ft-lbf) for grades higher than P386 (X386). Weld metal shall meet an absorbed energy value of 27 J (20 ft-lbf) minimum for all grades. If using reduced specimens, the impact values may be reduced in accordance with the correction ratios in ASTM A370. See para. 11.1.2 for location of testing samples required.

8.3 Hardness Testing

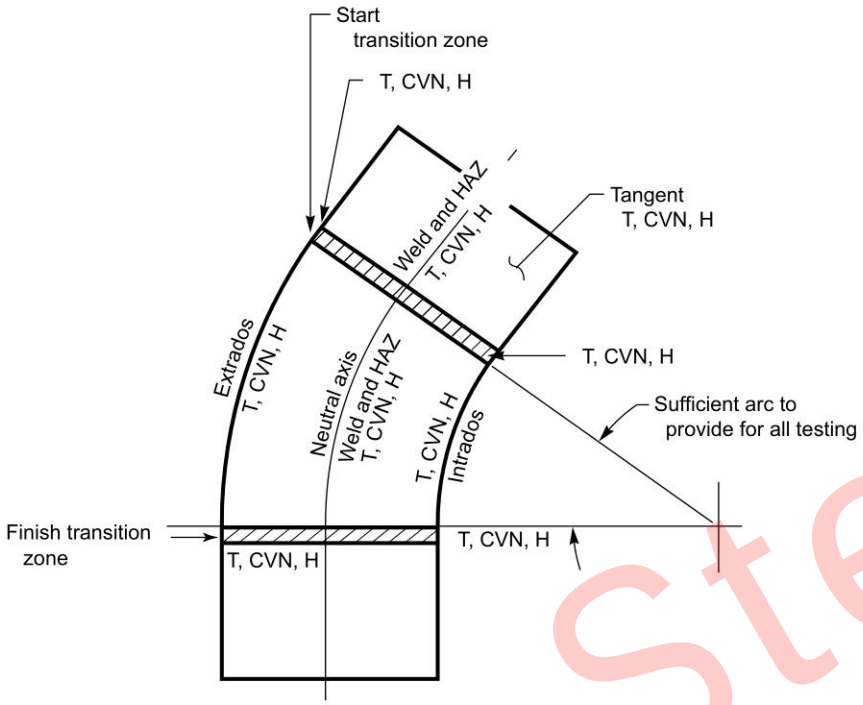
Hardness tests shall be performed in accordance with ASTM A370 on the bend as required in para. 11.1.4. To verify uniformity in the bending process, all production

[1] A heat of material shall consist of all pipe or cylinders from the same manufacturer and produced from a single cycle of a batch melting process.

[2] A lot shall consist of all bends from the same heat of material given the same heat treatment in a controlled furnace within a range of ±15°C (±25°F).

[3] When tapered-end specimens are used, the tapering shall not reduce the specimen length on one side below 28 mm (1.1 in.) or the end thickness below one-half the nominal specimen thickness.

Figure 8.2-1
Test Specimen Locations and Orientations — Longitudinal Seam



Legend:
CVN = transverse Charpy V-notch specimen, set of three
H = hardness reading
T = transverse or longitudinal tensile specimen, size dependent

bends shall be tested for hardness in the same locations as the qualification bend. The corresponding areas shall have average hardness readings not varying by more than 30 Brinell hardness, or equivalent, from the average value measured in the same location of the qualification bend, with no average equating to a tensile strength less than that required in Table 4.1-1 for the material grade marked on the bend. Use an average of at least three readings for each location tested. The type of portable hardness tester used on production bends shall be the same as used on the qualification bend. All testing shall be conducted in the final heat-treated condition. No hardness measurement shall exceed the maximum specified in Table 4.1-1.

9 HEAT TREATMENT

9.1 Type

Unless otherwise specified by the purchaser, each bend shall be heat-treated after bending (except as permitted in para. SR15.1) by one or more of the following methods:

(a) Stress Relieve or Temper. Uniformly, heat between 480°C (900°F) and 675°C (1,250°F) and hold at temperature for at least 30 min per 25 mm (1 in.) of thickness at temperature, but not less than 30 min.

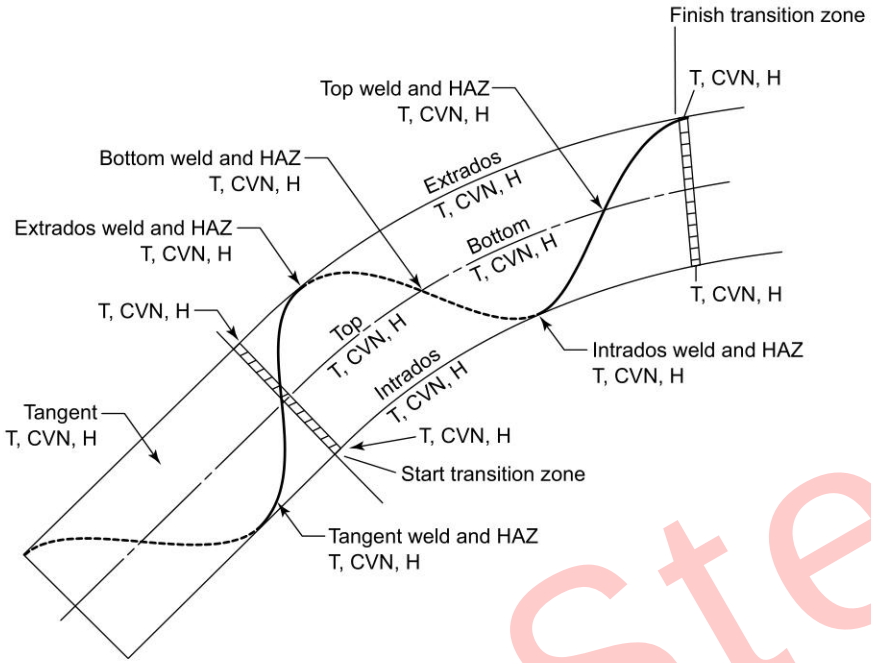
(b) Normalize. Heat above the transformation temperature range and hold at temperature for a minimum of 20 min per 25 mm (1 in.) of thickness, but not less than 20 min, and allow to cool in still air.

(c) Quench and Temper. Heat above the transformation temperature range and hold at temperature for a minimum of 20 min per 25 mm (1 in.) of thickness and direct quench in water, oil, or a synthetic quenchant. Reheat to temper as defined above. Quench facilities shall be of sufficient size and shall be equipped to ensure proper and uniform cooling.

9.2 Heat-Treatment Procedures (23)

Heat-treatment procedures shall be available for review at the facility and shall include requirements for furnace temperatures and soak times at temperature. For quench treatments, cooling medium temperature before and after quench shall be controlled along with time from the furnace to the quench tank. Cooling medium temperature

Figure 8.2-2
Test Specimen Locations and Orientations — Helical Seam



Legend:
CVN = transverse Charpy V-notch specimen, set of three
H = hardness reading
T = transverse or longitudinal tensile specimen, size dependent

and agitation should be considered to ensure proper cooling rate based on maximum mass being heat treated. The performance of furnaces shall be monitored frequently for scale build-up, burner malfunction, loss of refractory material, or hot spots on the shell of the furnace that can affect their functioning properly.

(23) **9.3 Equipment**

All furnace heat-treatment equipment shall have a recording device that is calibrated at least quarterly. Heat-treat furnaces shall be surveyed annually, or at a shorter interval, as necessary to maintain uniformity of heat treatment, or thermocouples shall be attached to each furnace load. Thermocouples shall be calibrated at least quarterly. Records shall be kept of furnace surveys, thermocouple calibrations, and, if used, thermocouple readings for each furnace load. The furnace shall be controlled within a range of ±15°C (±25°F). The adequacy of the furnace working zone to achieve and to maintain temperature uniformity of ±15°C (±25°F) shall be established by annual survey in accordance with a recognized standard (e.g., ASTM A991/A991M) and records shall be retained.

9.4 Heat-Treat Designators

Each bend and the material test report (see section 14) shall be identified with one of the following designators indicating final heat-treat condition:

N = normalize
NT = normalize and temper
QT = quench and temper
SR = stress relieve

10 QUALIFICATION BEND

10.1 Essential Variables

Prior to production bending, a qualification bend shall be made and tested from each heat of material to demonstrate the suitability of the bending procedure to provide a product meeting the required dimensions and material properties. This bend and tangent section shall be of adequate length to obtain all the required test coupons. All bends (i.e., qualification and production) shall be completed in a continuous heating cycle without stops or starts, unless such areas are included in the bend procedure qualification testing and found acceptable. Postbend heating for production bend dimensional corrections is not allowed unless covered in the

(23) **Table 10.1-1**
Limits on Essential Variables

Essential Variable	Limits of Variation
Pipe wall thickness	±3 mm (±0.12 in.)
Bend-radius-to-diameter ratio (R/D_o)	$+1R - 0$
Forming velocity	±2.5 mm (±0.1 in.) per min
Forming temperature	±25°C (±50°F) from the qualification temperature
Coil design	No change allowed
Coolant type	No change allowed
Cooling water temperature	±15°C (±25°F)
Flow rate/pressure of coolant	±10% change in flow rate (or equivalent rate in pressure)
Weld seam	15 deg from the neutral axis
Heat treatment	±15°C (±25°F) in holding temperature or any change in procedure
Induction heating frequency	±20%
Soaking time	0 min to 15 min
Bending temperature recorded by pyrometers located 180 deg from each other on the intrados and extrados	±20°C (±36°F)

qualification bend procedure. The procedure qualification shall account for the essential variables required to make a bend. When any of these essential variables change, a new qualification bend must be made. The manufacturer's quality assurance program shall include procedures that ensure that the essential variables are properly controlled. This includes equipment calibration frequency as necessary for control but in no case less than annually. Essential variables are shown in Table 10.1-1.

10.2 Records

10.2.1 Bend Qualification Procedure. Each manufacturer shall prepare a written procedure that demonstrates that bends having suitable properties such as strength, ductility, and hardness can be formed by that procedure. These records shall be available for the purchaser's review. Changes in the essential variables beyond the limits of variation shown in Table 10.1-1 shall require a new qualification bend test and procedure.

10.2.2 Testing Results. All applicable testing results shall be part of the records.

11 TEST REQUIREMENTS

The testing requirements differ between the qualification bend and the production bends. The following requirements apply in the locations specified. The qualification bend testing shall be conducted on a bend representative of the final heat-treat condition. The production bend tests shall be conducted on each bend in the same final heat-treat condition as that which produced the qualification bend.

11.1 Qualification Bend Requirements

11.1.1 Tensile Testing. Transverse tensile samples for (23)
NPS 8 (DN 200) or larger shall be taken from the tangent, the transition zone, and the bend segment at both the intrados and extrados for each lot of material as shown in Figure 8.2-1 or Figure 8.2-2. For sizes smaller than NPS 8 (DN 200), either transverse or longitudinal test specimens shall be used. If the tangents and/or transition zones are not left integral to the bend, no tensile tests are required except on the bend. See Figure 8.2-1 or Figure 8.2-2. Bends manufactured where the entire length of the finished bend, including the tangents, is subjected to the same continuous heating, cooling, and speed parameters are not considered to have transition zones requiring testing. Testing samples are preferred to be from unflattened specimens. However, cold-flattened transverse specimens may be used, provided consideration is given to the amount of cold-working and the effects that cold-working might have on the test results being representative of the final finished bend.

11.1.2 Fracture Toughness Testing. A set of three transverse Charpy V-notch impact specimens shall be taken from the tangent, the transition zones, and the bend at both the intrados and extrados for each lot of material. See Figure 8.2-1 or Figure 8.2-2 for locations. If the tangents and/or transition zones are not left integral to the bend, no impact tests are required except on the bend. See Figure 8.2-1 or Figure 8.2-2.

11.1.3 Weld Testing

(a) Longitudinal Seams. The tensile, impact, and hardness tests shall be performed on the pipe or cylinder longitudinal seam weld at the locations shown in Figure 8.2-1. Acceptance criteria shall be as specified in paras. 8.1 through 8.3 and 11.1.4.

(b) Helical Seam. The tensile, impact, and hardness tests shall be performed on the pipe or cylinder helical seam at the locations shown in Figure 8.2-2. Acceptance criteria shall be as specified in paras. 8.1, 8.2, 8.3, and 11.1.4.

11.1.4 Hardness Testing. The bend shall be tested for average hardness in all the same locations as the tensile tests are taken as well as each transition zone. In addition, an average hardness reading shall be taken from a minimum of two locations in the bend at the extrados and intrados. The allowable difference between the minimum and maximum hardness readings for a quadrant around the circumference is 30 Brinell hardness number,

or equivalent, if another testing method is used. See Figure 8.2-1 or Figure 8.2-2.

11.2 Production Bend Requirements

To demonstrate uniformity between the qualification and production bends, each production bend shall be hardness tested in all the same locations as the qualification bend. In addition, hardness readings shall be taken for each additional 30 deg of arc beyond the qualification bend angle. All values within like quadrants around the circumference shall be within the same range as determined in para. 11.1.4. No readings shall exceed the maximum specified in Table 4.1-1, and no average shall equate to a tensile strength less than the minimum required in Table 4.1-1 for the specified grade.

11.3 Testing Results

The bend shall be marked with the appropriate grade symbol of Table 4.1-1 based on the test results for all locations meeting the minimum values specified for that grade. If the bend strength is different from the mating pipe, and the substitution of wall thickness for yield strength is used in accordance with para. 8.1, both the bend grade and the intended mating pipe grade shall be marked on the bend (i.e., P414/X483).

12 DIMENSIONAL REQUIREMENTS

The dimensional requirements in section 12 shall be met on each bend.

12.1 Ovality

Ovality shall be measured throughout the bend and tangents. The difference between the maximum and minimum outside diameter shall not exceed 3% of the nominal mating pipe outside diameter within the bend and 1% at the welding end. The purchaser and manufacturer may agree to a different ovality tolerance (see para. SR15.3).

12.2 Outside Diameter

The outside diameter of each welding end shall be within 1% of the nominal mating pipe outside diameter. The diameter throughout the bend and the remainder of the tangents need only meet the ovality tolerance, unless the purchaser and manufacturer agree to other tolerances.

12.3 Wall Thickness

The wall thickness shall be checked in sufficient locations throughout the bend to ensure that the minimum wall does not fall below 90% of the nominal mating wall thickness marked on the bend (or below the purchaser-specified minimum wall thickness). This below-tolerance allowance does not apply to those areas determined to need reinforcement as a result of design requirements of para. 2.2. Inspection shall be done using compression wave ultrasonic examination by calibrated equipment that meets a procedure developed by the manufacturer to ensure accurate readings.

12.4 Inside Diameter

12.4.1 Welding Ends. For NPS 36 (DN 900) and smaller, the inside diameter tolerance at the bevel face shall be ±2.5 mm (±0.10 in.). For larger sizes, the inside diameter tolerance shall be ±3 mm (±0.12 in.).

12.4.2 Body. Unless otherwise agreed to by the purchaser, the average internal diameter at any location in the bend shall not be less than 97% of the minimum specified mating pipe internal diameter. Proof of conformance to this requirement shall be demonstrated by passing a sphere or other suitable gaging device through the bend without assistance of power equipment.

12.5 End Preparation

Welding ends shall be beveled using ASME B16.25, Figure 3.1-1, illustration (a) or Figure 3.1-2, illustration (a) end preparations unless otherwise specified by the purchaser.

12.6 Bend Dimensional Tolerances

The bend angle, center-to-end dimensions, bend radius, chord lengths, squareness, and bend plane shall be measured and recorded for each bend. The tolerances on the ordered dimensions shall be as follows:

Dimension	Tolerance
Bend angle	±½ deg
Bend radius	±1%
Bend plane	±1 deg
End squareness	
NPS 36 (DN 900) and smaller	±2.4 mm (±0.09 in.)
Greater than NPS 36 (DN 900)	±3 mm (±0.12 in.)
Linear dimensions	
NPS 24 (DN 600) and smaller	±5 mm (±0.19 in.)
Greater than NPS 24 (DN 600)	±6 mm (±0.25 in.)

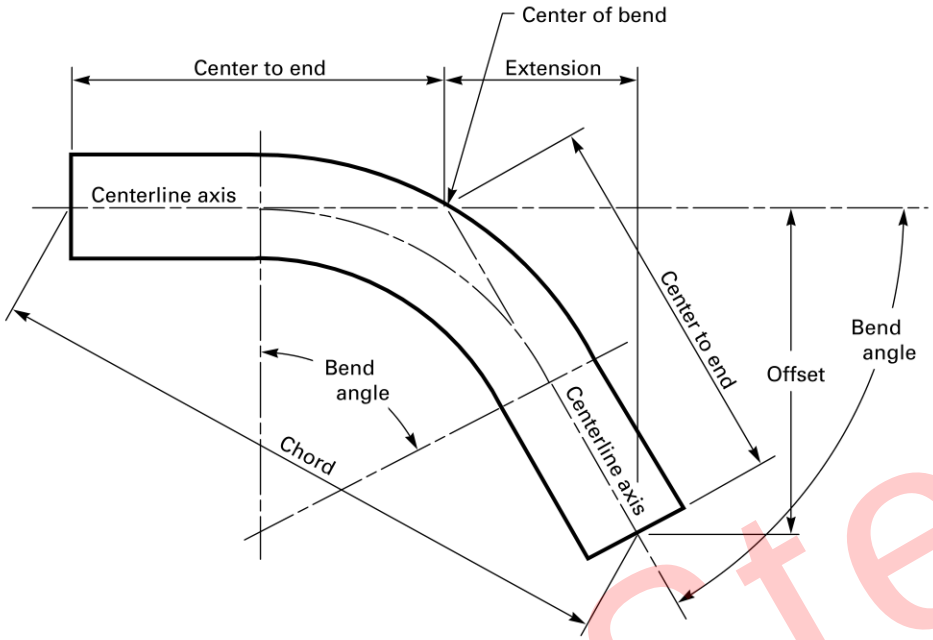
See Figure 12.6-1, illustrations (a) and (b).

13 INSPECTION OF PRODUCTION BENDS

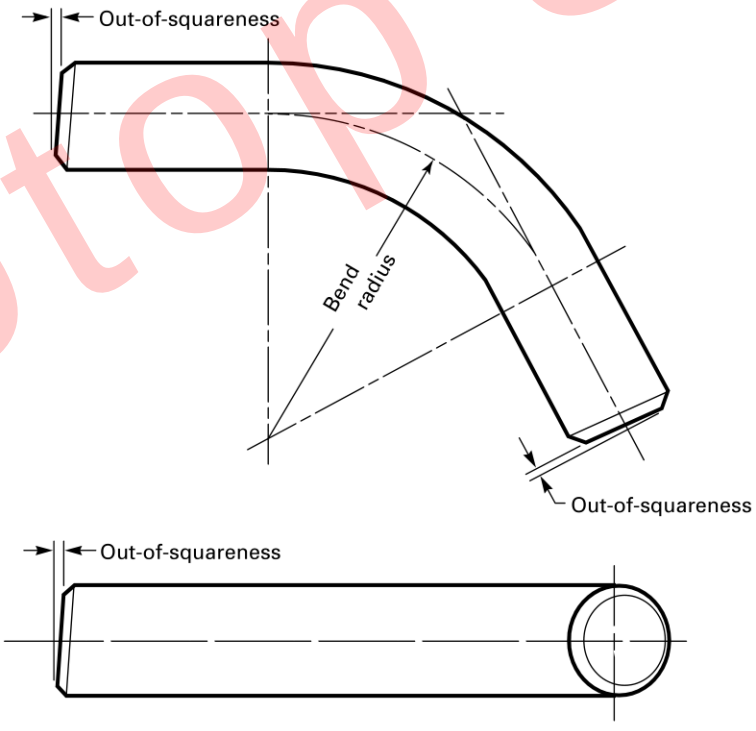
13.1 Workmanship and Finish

If required for inspection, all bends shall be grit-blasted or shot-blasted clean to a bright metal finish in accordance with SSPC-SP 6. All bends shall be visually examined on all accessible surfaces for laminations, cracks, notches, gouges, arc burns, wrinkles, or other defects. Surface imperfections shall be removed by grinding or machining, provided they are not deeper than allowed in para. 12.3. Repair by welding of base metal or weld metal is not

Figure 12.6-1
Measurement of Bend Angle and Out-of-Squareness



(a) Measurement of Bend Angle by Measurement and Calculation



(b) Measurement of Out-of-Squareness

permitted without purchaser approval. It is characteristic of the induction process that an upset occurs at each tangent point (transition) of a bend. These are of a cosmetic nature and are not classified as injurious defects, provided these upsets have a dimension measured from peak to valley not exceeding 2% of the pipe outside diameter.

(23) **13.2 Nondestructive Examination**

The entire extrados of each bend Grade P359 and higher, from neutral axis to neutral axis including the weld seam, shall be a magnetic particle or liquid penetrant examined for injurious defects. The area shall be free of cracks, laps, or laminations. All rounded indications greater than 3 mm (0.12 in.) in any direction shall be classified as imperfections and shall be removed as required in para. 13.1.

13.3 Outside Inspection

An inspector representing the purchaser shall be authorized access to areas of the manufacturer's facility that involve the manufacture of the ordered bends. All testing records, welding records, etc., shall be available for inspection prior to shipment.

(23) **14 CERTIFICATION**

A Certified Material Test Report (CMTR) and bend report shall be furnished listing at a minimum the following information:

(a) statement that the product was manufactured, sampled, tested, and inspected as specified in this Standard and the purchaser order, and was found to have met such requirements

(b) name and location of bend manufacturer

(c) results of chemical composition product analysis (including CE); see section 7 and Table 5.1-1

(d) tensile properties of the qualification bend, test specimen size, and tensile strength of weld (if applicable); see para. 8.1

(e) impact properties of the qualification bend to include size, orientation, temperature, and actual results for each specimen; see para. 8.2

(f) hardness results of the qualification bend and each production bend; see para. 8.3

(g) heat treatment method used including temperatures and hold times; see para. 9.1

(h) bend qualification procedure; see para. 10.2

(i) seamless or welded including type of weld

(j) nondestructive examination results; see para. 13.2

(k) dimensional report including wall thickness

(l) applicable supplementary requirements (see paras. SR15.1 through SR15.8)

SR15 SUPPLEMENTARY REQUIREMENTS

The supplementary requirements (see paras. SR15.1 through SR15.8) are not applicable to the product furnished to this Standard except when specified on the purchase order or otherwise agreed upon. When specified or agreed upon, supplementary requirements shall have the same force as requirements of mandatory sections 1 through 14. Each bend shall be marked with the applicable supplementary requirement (e.g., SR15.1) after the normal marking required in para. 4.1.

SR15.1 Heat Treatment

Bends can be furnished in an "as-bent" condition. The properties of section 8 must be met for that heat of material offered. Each bend shall be identified with "AB SR15.1" as the heat-treat designator.

SR15.2 Nondestructive Examination

Magnetic particle or liquid penetrant examination shall be performed on the bend area including the intrados, extrados, and weld seam. No cracks are permitted. All other indications will be addressed by an agreement between the purchaser and manufacturer. All inspections shall be done by personnel and procedures approved by the purchaser.

SR15.3 Segmentable Bends

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

SR15.4 Fracture Toughness

Notch toughness requirements other than those specified shall be by agreement between the purchaser and manufacturer. This can include lower test temperatures, greater absorbed-energy requirements, or different shear area requirements.

SR15.5 Sour Gas Applications (23)

Bends required for sour gas applications shall be furnished to meet ANSI/NACE MR0175/ISO 15156 including maximum hardness and nickel content. Bends of higher Grade than P483 are prohibited.

SR15.6 Weld Seam Examination: UT

SR15.6.1 In lieu of radiography, each weld seam in a pipe or starting cylinder may be ultrasonically tested. Acceptance criteria shall be by agreement between the purchaser and manufacturer.

SR15.6.2 Each bend shall be ultrasonically examined for the full length of weld from bevel end to bevel end after forming and final heat treatment. Testing procedure and

acceptance standards shall be as agreed upon between the purchaser and manufacturer.

SR15.7 Weld Seam Examination: RT

Each bend shall have the weld seam 100% radiographed for the full length from bevel end to bevel end after forming and final heat treatment. Testing procedure and acceptance standards shall be as agreed upon between the purchaser and manufacturer.

SR15.8 Chemistries

SR15.8.1 Alternative chemical requirements and/or lower carbon equivalent shall be as agreed upon between the purchaser and manufacturer.

SR15.8.2 Acceptance of previous bend qualification procedures based on similar material chemistries shall be as agreed upon between the purchaser and manufacturer. This can include variations to other essential variable requirements if agreed upon.

SR15.9 Manufacturing Procedure Specification (MPS) (23)

Induction bends shall be manufactured in accordance with a documented manufacturing procedure specification. If specified by the purchaser, manufacturing shall not proceed until the MPS has been approved by the purchaser. The MPS shall specify the following:

(a) starting pipe or cylinder information including grade, type, and dimensions

(b) testing and inspection requirements for both qualification and production bends

(c) bending process

(d) details of postbend heat treating

(e) additional requirements (e.g., end preparation, marking)

SR15.10 Inspection Test Plan (ITP) (23)

The inspection and testing to be performed during the qualification and production shall be summarized. Production shall not start until the ITP is approved by the purchaser. Hold points shall be identified.

MANDATORY APPENDIX I
REFERENCES

(23)

The following is a list of publications referenced in this Standard. Unless otherwise specified, the latest edition of ASME publications shall apply.

ANSI/NACE MR0175/ISO 15156:2015. Petroleum and natural gas industries — Materials for use in H_2S-containing environments in oil and gas production. The Association for Materials Protection and Performance [formerly the National Association of Corrosion Engineers (NACE) and the Society for Protective Coatings (SSPC)].

ASME Boiler and Pressure Vessel Code, Section VIII. Rules for Construction of Pressure Vessels — Division 1. The American Society of Mechanical Engineers.

ASME Boiler and Pressure Vessel Code, Section IX. Welding, Brazing, and Fusing Qualifications. The American Society of Mechanical Engineers.

ASME B16.25. Buttwelding Ends. The American Society of Mechanical Engineers.

ASME B31 Code for Pressure Piping. The American Society of Mechanical Engineers.

ASME B36.10. Welded and Seamless Wrought Steel Pipe. The American Society of Mechanical Engineers.

ASTM A370-21. Standard Test Methods and Definitions for Mechanical Testing of Steel Products. ASTM International.

ASTM A991/A991M-17. Standard Test Method for Conducting Temperature Uniformity Surveys of Furnaces Used to Heat Treat Steel Products. ASTM International.

ASTM E29-13(2019). Standard Practice for Using Significant Digits in Test Data to Determine Conformance With Specifications. ASTM International.

ASTM E140-12b(2019)e1. Hardness Conversion Table for Metals Relationship Among Brinell Hardness, Vickers Hardness, Rockwell Hardness, Superficial Hardness, Knoop Hardness, Scleroscope Hardness, and Leeb Hardness. ASTM International.

ISO 6708:1995. Pipework components — Definition and selection of DN (nominal size).[1] International Organization for Standardization.

ISO 9000:2015. Quality management systems — Fundamentals and vocabulary.[1] International Organization for Standardization.

ISO 9001:2015. Quality management systems — Fundamentals and vocabulary.[1] International Organization for Standardization.

ISO 9004:2018. Quality management — Quality of an organization — Guidance to achieve sustained success.[1] International Organization for Standardization.

SSPC-SP 6/NACE No. 3, Commercial Blast Cleaning. The Association for Materials Protection and Performance [formerly the National Association of Corrosion Engineers (NACE) and the Society for Protective Coatings (SSPC)].

[1] This publication may be obtained from American National Standards Institute (ANSI): www.ansi.org.

NONMANDATORY APPENDIX A
QUALITY SYSTEM PROGRAM

The products manufactured in accordance with this Standard shall be produced under a quality system program following the principles of an appropriate standard from the ISO 9000 series.[1] A determination of the need for registration and/or certification of the product manufacturer's quality system program by an independent organization shall be the responsibility of the manufacturer. Detailed documentation demonstrating program compliance shall be available to the purchaser at the manufacturer's facility. A written summary description of the program used by the product manufacturer shall be available to the purchaser upon request. The product manufacturer is defined as the entity whose name or trademark appears on the product in accordance with the marking or identification requirements of this Standard.

[1] The series is also available from the American National Standards Institute (ANSI) and the American Society for Quality (ASQ) as American National Standards that are identified by the prefix "Q," replacing the prefix "ISO." Each standard of the series is listed under References in Mandatory Appendix I.

NONMANDATORY APPENDIX B
INDUCTION BEND DATA SHEET

Induction Bend Data Sheet

SO#:_____ Quote Order #:_____ Project Ref: _____

Bend Specification: ASME B16.49 latest edition
Pipe Specification: API 5L latest edition as minimum

Bend Procedure Qualification Test Is Required for Each Representative Heat of Pipe.

Design Conditions

Bend to Weld to:
Size: _____ Wall: _____ Grade: _____

Bend Radius: _____ DN (nominal diameter)

Bend Angle: _____ Tangent Length: _____
One End ☐ Both ☐

Minimum CL Length Required Between Bends (S bend only): _____

Field Segmentable Bend: ☐ Yes ☐ No

Coating Required: ☐ Yes ☐ No

*Min. I.D. at Ends and in Body: _____

*NOTE: Vendor to supply pipe to meet the above design conditions and be sized at the ends to meet the following:
(a) The ends of each bend are to be beveled to match the pipe to which it is to be welded (see ASME B31.8, Appendix I, Figure I-5) for bevel detail for unequal wall thickness).
(b) The allowable welding mismatch tolerance is 0.047 in. (1.193 mm) for walls up to 0.250 in. (6.35 mm) and 0.094 in. (2.387 mm) for walls 0.251 in. (6.375 mm) and greater.

Notch Toughness Properties Acceptance Criteria: _____

Temperature of Charpy Testing: _____

B16 AMERICAN NATIONAL STANDARDS FOR PIPING, PIPE FLANGES, FITTINGS, AND VALVES

B16.1-2020	Gray Iron Pipe Flanges and Flanged Fittings: Classes 25, 125, and 250
B16.3-2021	Malleable Iron Threaded Fittings: Classes 150 and 300
B16.4-2021	Gray Iron Threaded Fittings: Classes 125 and 250
B16.5-2020	Pipe Flanges and Flanged Fittings: NPS ½ Through NPS 24 Metric/Inch Standard
B16.9-2018	Factory-Made Wrought Buttwelding Fittings
B16.10-2022	Face-to-Face and End-to-End Dimensions of Valves
B16.11-2016	Forged Fittings, Socket-Welding and Threaded
B16.12-2019	Cast Iron Threaded Drainage Fittings
B16.14-2018	Ferrous Pipe Plugs, Bushings, and Locknuts With Pipe Threads
B16.15-2018	Cast Copper Alloy Threaded Fittings
B16.18-2021	Cast Copper Alloy Solder Joint Pressure Fittings
B16.20-2023	Metallic Gaskets for Pipe Flanges
B16.21-2021	Nonmetallic Flat Gaskets for Pipe Flanges
B16.22-2021	Wrought Copper and Copper Alloy Solder-Joint Pressure Fittings
B16.23-2021	Cast Copper Alloy Solder Joint Drainage Fittings: DWV
B16.24-2021	Cast Copper Alloy Pipe Flanges, Flanged Fittings, and Valves: Classes 150, 300, 600, 900, 1500, and 2500
B16.25-2022	Buttwelding Ends
B16.26-2018	Cast Copper Alloy Fittings for Flared Copper Tubes
B16.29-2022	Wrought Copper and Wrought Copper Alloy Solder-Joint Drainage Fittings — DWV
B16.33-2012 (R2017)	Manually Operated Metallic Gas Valves for Use in Gas Piping Systems Up to 175 psi (Sizes NPS ½ Through NPS 2)
B16.34-2020	Valves — Flanged, Threaded, and Welding End
B16.36-2020	Orifice Flanges
B16.38-2012 (R2017)	Large Metallic Valves for Gas Distribution: Manually Operated, NPS 2½ (DN 65) to NPS 12 (DN 300), 125 psig (8.6 bar) Maximum
B16.39-2019	Malleable Iron Threaded Pipe Unions: Classes 150, 250, and 300
B16.40-2019	Manually Operated Thermoplastic Gas Shutoffs and Valves in Gas Distribution Systems
B16.42-2021	Ductile Iron Pipe Flanges and Flanged Fittings: Classes 150 and 300
B16.44-2023	Manually Operated Metallic Gas Valves for Use in Aboveground Piping Systems Up to 5 psi
B16.47-2020	Large Diameter Steel Flanges: NPS 26 Through NPS 60 Metric/Inch Standard
B16.48-2020	Line Blanks
B16.49-2023	Factory-Made, Wrought Steel, Buttwelding Induction Bends for Transportation and Distribution Systems
B16.50-2021	Wrought Copper and Copper Alloy Braze-Joint Pressure Fittings
B16.51-2021	Copper and Copper Alloy Press-Connect Pressure Fittings
B16.52-2018	Forged Nonferrous Fittings, Socket-Welding and Threaded (Titanium, Titanium Alloys, Aluminum, and Aluminum Alloys)

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ASME B16.49-2023

ISBN 978-0-7918-7610-7