Welding Connections to Pipe

API RECOMMENDED PRACTICE 5C6
FIRST EDITION, DECEMBER 1996

American
Petroleum
Institute

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Exploration and Production Department

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SUGGESTIONS FOR ORDERING EQUIPMENT

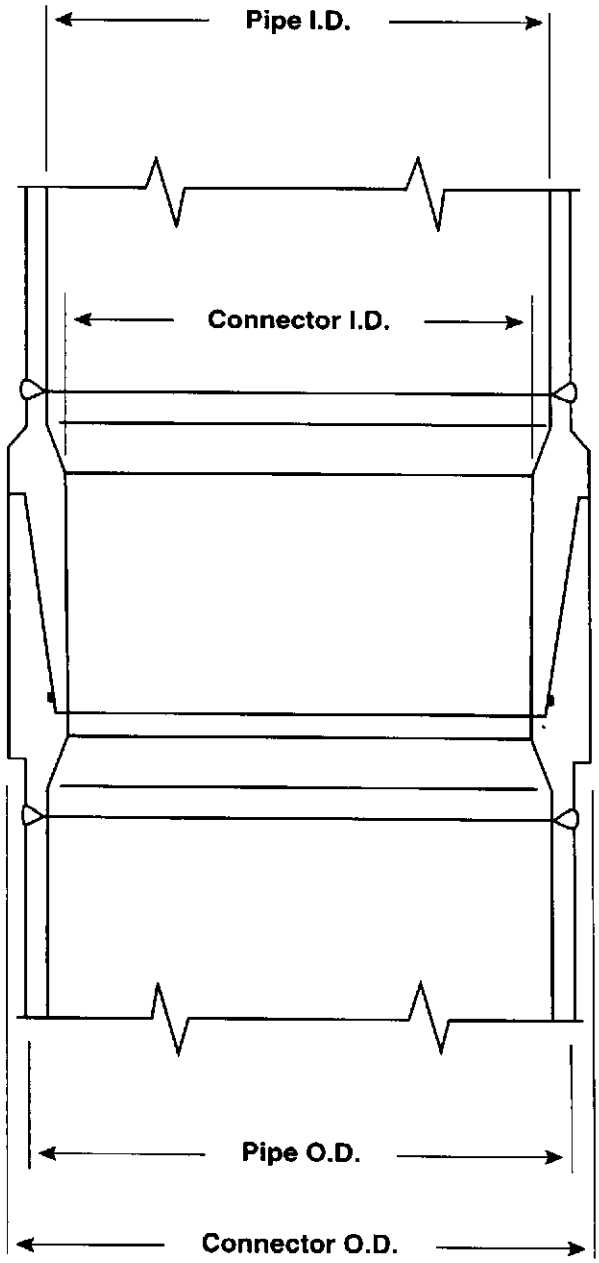
In placing orders for connectors to be welded to pipe in accordance with this recommended practice, the purchaser should specify the following in the purchase order.:

Checklist	Requirement
❑	Specification
❑	Quantity
❑	Delivery date
❑	Shipping instructions
Type of Pipe	
❑	Specification (include edition & grade)
❑	Diameter
❑	Weight per foot or wall thickness
❑	Range
Type of Connector	
❑	Manufacturer's designation
❑	Connector dimensional considerations (see Figure 1)
❑	Description of welded attachments (pad eyes, lift eyes, etc.)
❑	Radiographic examination per API Spec 1104 is standard

Supplemental requirements are listed below. As supplements, these are nonstandard but occasionally imposed and identified on the purchase order prior to production work.

SR 21	Hardness testing for the welding procedure qualification record (PQR)
SR 22 or SR 23	Impact testing for the PQR
SR 24	Radiographic examination per ASME Code, Section VIII
SR 25	Magnetic particle examination per ASME Code, Section V and VIII
SR 26	Production hardness testing
SR 27	Full length drift testing
SR 28	End drift testing
SR 29	Connector to connector alignment
SR 30	Compliance to NACE MR0175
SR 31	Ultrasonic examination

SUGGESTIONS FOR ORDERING EQUIPMENT (Continued)



When selecting connectors for an application, care should be taken to assess the geometry of the connector. The connector I.D. shall be large enough to allow passage of any hardware that will be subsequently run through the connector. The connector O.D. shall be smaller than the openings through which it will be run.

Connector type shown is threaded. The same consideration shall be given to mechanical connectors as well.

Figure 1—Connector Dimensional Considerations

Welding Connections to Pipe

1 Scope

1.1 PURPOSE

This recommended practice was created to provide a standard industry practice for the shop or field welding of connectors to pipe.

The technical content provides requirements for welding procedure qualification, welder performance qualification, materials, testing, production welding and inspection. Additionally, suggestions for ordering are included.

1.2 EQUIPMENT

This recommended practice covers the weld fabrication of connectors and handling attachments such as lift eyes and landing pads to pipe.

This document includes practices currently being implemented by a broad spectrum of the industry. This recommended practice is intended to be analogous to API 6A PSL 1 with additional requirements specific to the equipment fabrication.

1.3 SUPPLEMENTAL REQUIREMENTS

Supplements to this recommended practice shall not be considered as requirements except when specified on the purchase order.

2 Referenced Standards

Unless otherwise specified, the most recent editions or revisions of the following standards, codes, and specifications shall, to the extent herein, form a part of this standard.

API

Spec 6A	*Specification for Wellhead and Christmas Tree Equipment*
Spec 1104	*Welding of Pipelines and Related Facilities*
Spec 5L	*Specification For Line Pipe*
Spec 5CT	*Specification For Casing and Tubing*

ASME[1]

Boiler and Pressure Vessel Code, Section IX, Section V, and Section VIII, Division 1

AWS[2]

D1.1	*Structural Welding Code—Steel*

ASTM[3]

A370-92	*Standard Methods and Definitions for Mechanical Testing of Steel Products*
E10	*Brinell Hardness of Metallic Materials*
E18	*Standard Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials*
E140	*Standard Hardness Conversion Tables for Metals*

NACE[4]

MR0175	*Sulfide Stress Cracking Resistant Metallic Materials for Oilfield Equipment*

3 Definitions and Abbreviations

3.1 alignment: Refer to Section 8 of this document.

3.2 API: American Petroleum Institute.

3.3 ASME: American Society for Mechanical Engineers.

3.4 ASTM: American Society for Testing and Materials.

3.5 AWS: American Welding Society.

3.6 axial alignment: Alignment to within specified tolerances of the connector centerline, to the centerline of the connector at the opposite end of the pipe.

3.7 base metal: Metal to be welded or cut.

3.8 base metal grouping: System used to describe comparable base metal characteristics such as chemical composition, weldability, thermal processing, and mechanical properties.

3.9 calibration: Comparison and adjustment of instruments to a standard of known accuracy.

3.10 carbon equivalent: Equation where variables are defined by base metal composition. The result is used as information to help assess the base metal weldability.

3.11 casing: Steel pipe used in oil wells to seal off fluids from the bore and to prevent the walls of the hole from sloughing off or caving.

3.12 connector: Forging, machined to a geometry to function as a mechanical connection welded to pipe or casing. Other materials may be used if approved by purchaser.

[1] American Society for Mechanical Engineers, 345 East 47th Street, New York, New York 10017.
[2] American Welding Society, 550 N.W. Le Jeune Road, Miami, Florida 33135.
[3] American Society for Testing and Materials, 100 Bar Harbor Drive, West Conshohocken, Pennsylvania 19428.
[4] National Association of Corrosion Engineers, International, Inc., P.O. Box 218340, Houston, Texas 77218-8340.

3.13 connector parallelism: A measure of the connector face or plane with respect to the connector face at the opposite end of the pipe.

3.14 CVN impact test: Charpy V-notch impact testing in accordance with ASTM A370.

3.15 discontinuity: An interruption of the typical structure of a weldment such as lack of homogeneity in the mechanical, metallurgical, or physical characteristics. A discontinuity is not necessarily a defect.

3.16 drift mandrel: A precision dimensioned cylinder sized to pass through or be inserted into the ends of pipe. It is passed through or into the pipe end ID to locate obstructions or to assure compliance with appropriate specifications. Other drift configurations shall be approved by purchaser.

3.17 fabricator: The company responsible for welding.

3.18 grinding: Removing material from a pipe surface or weld by abrading, e.g., grinding wheel.

3.19 hardness test: A measure of the hardness of a metal, as determined by pressing a hard steel ball or diamond penetrant into a smooth surface under standard conditions. Results are often expressed in terms of Rockwell hardness number (HRB or HRC) or Brinell Hardness Number (BHN). Refer to the latest editions of ASTM E10 and ASTM E18 for added information.

3.20 heat affected zone (HAZ): Base metal zone adjacent to a weld that has had a metallurgical change induced by welding.

3.21 manufacturer: The company that manufactures the connector.

3.22 magnetic particle examination: A nondestructive test method utilizing magnetic flux leakage fields and suitable indicating materials to disclose surface and near-surface discontinuity indications.

3.23 NACE: National Association of Corrosion Engineers, previously NACE, now NACE International, Inc.

3.24 nondestructive exam (NDE): Inspection to detect internal, surface, and concealed defects or flaws in materials using techniques that do not damage or destroy the items being tested.

3.25 pipe: In this document, refers to plain end pipe to which connectors are to be welded.

3.26 postweld heat treat (PWHT): Thermal heat treatment applied at the completion of a weld as specified on the welding procedure specification.

3.27 radiographic examination: The use of x-rays or nuclear radiation, or both, to detect discontinuities in material and to present their images on a recording medium.

3.28 squareness: A measurement of the connector with respect to the pipe axis adjacent to the pipe end.

3.29 weld: A localized coalescence of metals produced either by heating the materials to the welding temperature, with or without the application of pressure and with or without the use of filler metal.

3.30 weld reinforcement: Weld metal in excess of the quantity required to fill a joint. Sometimes referred to as the weld cap on the O.D. and weld protrusion on the I.D.

3.31 welded attachments: Attachments are equipment such as lift eyes and handling pads described on the purchase order to supplement standard design of connector to pipe.

3.32 welding consumables: Materials added to the coalescence of base metal (weld) that directly affect the weld metal's properties.

3.33 welding procedure qualification record (PQR): A record of the welding data used to weld a test coupon. The PQR is a record of variables recorded during the welding of the test coupons.

3.34 welding procedure specification (WPS): A written qualified welding procedure prepared to provide direction for making production welds.

3.35 visual examination: The primary evaluation of the fabrication weld joint. Visual aids and gauges are sometimes used. Inspection of welds usually includes quantitative as well as qualitative assessment of the joint.

3.36 welder performance qualification (WPQ): The qualification of a welder or welding operator. The qualification requires the welder or welding operator to weld a test coupon in accordance with the WPS. The test coupon is then tested in accordance with the applicable welding code. The qualification limitations are provided in the requirements of the applicable welding code.

4 Materials Information Requirements

4.1 DOCUMENTATION

When materials (pipe or connectors) are furnished by the purchaser, they should be accompanied by traceable material test reports or data sheets stating chemical analysis, heat treatment condition and mechanical properties to allow for selection of welding procedure specifications by the fabricator.

4.2 PIPE

4.2.1 Pipe may be supplied by the fabricator or the purchaser, as specified in the purchase order.

4.2.2 Pipe may be any of the following as specified in the purchase order:

a. Pipe manufactured in accordance with API Specification 5L.
b. Pipe manufactured in accordance with API Specification 5CT.
c. Pipe manufactured in accordance with other industry, national, or international standards (e.g. ASTM, BS, ISO) or with modifications to specifications or standards, as specified in the purchase order.

4.2.3 For API Specification 5L grades with specified minimum yield strength of 60 ksi and higher, the following additional information regarding pipe manufacturing shall be provided:

a. Process of manufacture (e.g. controlled rolling).
b. Specific processing temperature ranges, if applicable.
c. Specific heat treatment temperatures, if applicable.

4.3 CONNECTORS

4.3.1 Connectors may be supplied by the fabricator or the purchaser, as specified in the purchase order.

4.3.2 Forgings for connectors may be carbon steel, low alloy steel, microalloyed steel, or other types of weldable materials based on the design requirements for strength, toughness, and other considerations Materials other than forgings may be used with purchaser approval.

5 Welding Procedure Qualification

5.1 WRITTEN PROCEDURE

5.1.1 Welding procedure specifications (WPS) shall be written and qualified in accordance with Article II of the ASME Code, Section IX, and as described in this recommended practice.

5.1.2 The WPS shall identify all essential, nonessential, and (when required) supplementary essential variables specified by the ASME Code, Section IX for each welding process and materials to be welded.

5.1.3 The welding procedure qualification records (PQR) shall record all essential and (when required) supplementary essential variables associated with the qualification tests.

5.1.4 Both WPS and PQR documents shall be maintained a minimum of 5 years.

5.2 BASE METAL GROUPINGS

5.2.1 ASME Code, Section IX lists base metal groupings. However, as a minimum, base metal groupings shall be based on material strength to ensure that weld joint strength meets the design requirements.

5.2.2 Additionally, the base metal groupings shall be based on one or more of the following technical considerations:

a. Carbon equivalency formula, where:

$$CE = C + \frac{Mn + Si}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$$

or

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

b. Composition parameter Pcm, where:

$$Pcm = C + \frac{Si}{30} + \frac{Mn}{20} + \frac{Cu}{20} + \frac{Ni}{60} + \frac{Cr}{20} + \frac{Mo}{15} + \frac{V}{10} + 5B$$

c. Material heat treatment condition.

5.3 WELDING CONSUMABLES

5.3.1 The WPS shall identify the filler metal AWS classifications that can be used with the procedure.

5.3.2 If no AWS classification applies to the consumable, the commercial designation or brand name of the consumable shall be documented as part of the PQR used to qualify the procedure.

5.3.3 Consumables not within the AWS classification system shall be specified on the WPS and become an essential variable for that procedure.

5.4 HARDNESS TESTING

When compliance of the welding procedure to NACE MR0175 is specified by a supplementary requirement, the fabricator shall perform hardness testing and record as part of the PQR in order to determine the maximum hardness of the weldment.

Testing shall be performed in accordance with ASTM E18 for the Rockwell method and shall include, as a minimum, surveys of the weld metal and the base material heat affected zones (HAZ).

When other hardness methods have been performed, results may be converted to Rockwell, as applicable, in accordance with ASTM E140. Brinell hardness survey is not acceptable for testing weld metal heat affected zone in a PQR test.

5.5 CHARPY IMPACT TESTING

When impact testing is specified by a supplementary requirement, it shall be performed in accordance with ASTM A370 using the Charpy V-Notch specimen.

A minimum of one set of three test specimens shall be removed at the ¼ thickness location of the test weldment for the weld metal, connector HAZ, and pipe HAZ, unless otherwise specified.

The root of the notch shall be oriented normal to the surface of the test weldment. The weld metal specimens shall have the notched portion composed of 100 percent weld

metal. The base material HAZ specimens shall have the notched portion sampling as much HAZ material as possible.

Results of testing shall comply to the applicable specified supplementary requirement. Refer to Supplements SR 22 and SR 23.

5.6 POSTWELD HEAT TREATMENT (PWHT)

5.6.1 If PWHT is specified by the WPS, all PQR testing shall be done with the test weldment in the postweld heat treatment condition. PWHT shall be performed in accordance with the fabricator's WPS or the written procedure. Both furnace and local resistance type PWHT methods shall be considered acceptable. Heating by direct flame impingement shall not be permitted.

5.6.2 The PWHT procedure or WPS shall specify the applicable PWHT temperature range and time at temperature.

5.6.3 When SR 30 is specified on the purchase order, PWHT shall be in compliance with NACE MR0175.

6 Welder and Welding Operator Qualification

6.1 TESTING REQUIREMENTS

Welders and welding operators shall be qualified in accordance with Article III of the ASME Code, Section IX.

6.2 RECORDS

Records of welding performance qualification (WPQ) shall include all essential welding variables and qualified ranges, as specified in ASME Code, Section IX.

7 Production Welding Controls

7.1 QUALIFICATIONS

Welding shall be in accordance with qualified WPS and should be performed by qualified welders or welding operators.

7.2 USE OF WPS

Welders and welding operators shall have access to and should comply with the welding parameters specified in the WPS.

7.3 PREHEATING

Preheating, when required, shall be performed in accordance with the WPS or other written procedures or specifications.

7.4 FIT-UP

The weld joint fit-up shall take into account squareness. The fabricator shall develop a procedure for fit-up methods. SR 29 of this document provides an optional alignment procedure suitable to meet the intent of this recommended practice.

7.5 POSTWELD HEAT TREATMENT

When required, PWHT shall be in accordance with the applicable qualified WPS or written procedure.

7.6 WELDING CONTROLS

7.6.1 The fabricator's welding control system shall include procedures for monitoring, updating, and controlling the qualification of welders or welding operators and the use of WPS.

7.6.2 Instruments to verify temperature, voltage, and amperage shall be serviced and calibrated in accordance with written procedures or specifications. Temperature indicating crayons may be used to monitor preheat and interpass temperature.

8 Inspection

8.1 CALIBRATION OF MEASURING AND TEST EQUIPMENT

Equipment used to inspect, test or examine material or other equipment shall be identified, controlled, calibrated, and adjusted at specified intervals in accordance with documented manufacturer instructions, and consistent with referenced industry standards, to maintain the accuracy required by this specification.

8.2 CONNECTOR SQUARENESS AND ALIGNMENT VERIFICATION

Squareness of each connector welded to pipe shall be inspected to verify conformance with the following requirements.

8.2.1 Squareness Verification

Squareness is a measurement of the connector with respect to the pipe axis and shall be inspected to assure compliance with the requirements set forth in this recommended practice.

a. The maximum allowable deviation from square shall be 1/16 inch per 12 inches.
b. All squareness measurements utilizing the pipe O.D. as a reference surface shall be taken at a distance of no less than 2 inches away from the weld.

c. Squareness verification measurements shall be taken at 2 locations as a minimum at 90 degrees apart.

8.2.2 Alignment Verification

When alignment verification is specified as a supplementary requirement (SR 29), the fabricator shall perform alignment verification as specified below.

Connector to pipe alignment verification is a measurement of one connector face relative to the connector face on the opposite end of the pipe. The measurement includes axial alignment and connector parallelism.

8.2.3 Equipment

Typical alignment verification equipment consists of a set of two fixtures including a target and a telescope (or other sighting or image projection device). These fixtures are positioned on opposite ends of the joint being verified such that they are both parallel with the connector or pipe face and centered with the axial centerline of the connector or pipe end. The target typically consists of a well defined center area (bull's-eye) with concentric target circles of a known diameter. The sighting device should be of sufficient magnification to observe sight placement within the prescribed target circle for the length of joint being fabricated (usually 40 feet).

8.2.4 Alignment method

With alignment fixtures made up to the connectors (or pipe end), the connectors should be manipulated and tack welded to satisfy the alignment acceptance criteria specified in SR 29.

8.3 NONDESTRUCTIVE EXAMINATION OF WELDMENTS

Conduct visual examination in accordance with API Standard 1104 with the following additional requirements.

8.3.1 Weld Reinforcement

Visual inspection shall be conducted to verify compliance with the following restrictions to both the internal and external weld reinforcements. At no point shall the crown of the weld be below the surface of the pipe nor shall it be raised above the parent metal by more than 1/16 inch. Those welds where the raised height of the weld reinforcement exceeds the limits set forth may be brought to within tolerance by grinding.

Weld reinforcement may exceed 1/16 inch when welding reduced bore connectors, girth weld on end opposite the elevator lift end, and other special cases. The fabricator and purchaser may need to consider drift and handling equipment requirements to ensure compatibility.

8.3.2 Radiographic Examination

Radiographic examinations shall be conducted in accordance with the procedures set forth in API Standard 1104, Sections 8.1.1 through 8.1.13. All discontinuities located by radiographic examination shall be subject to the acceptance standards presented in Section 6 of API Standard 1104.

8.3.3 Production Weld Test Frequency

Nondestructive testing consisting of radiographic and visual inspection shall be conducted on 100 percent of all production welds.

APPENDIX A—SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements are applicable only when specified on the purchase order.

A.1 SR 21—HARDNESS TESTING

For the purpose of welding procedure qualification testing, hardness tests across the weld and base material heat affected zone (HAZ) cross section shall be performed and recorded as part of the PQR. Hardness testing locations and frequency shall be by the Rockwell method or the Vickers 10Kg method.

A.1.1 Rockwell Method

Rockwell testing location shall be as shown in Figure A-1. Additionally,

a. For a weld cross section thickness less than ½ inch, four hardness tests each shall be made in the base materials, the weld, and the HAZ.
b. For a weld cross section thickness equal to or greater than ½ inch, six hardness tests each shall be made in the base materials, the weld, and the HAZ.
c. For all thicknesses, HAZ hardness tests shall be performed in the base material with 1/16 inch of the weld interface and at least one each within ⅛ inch from top and bottom of the weld.

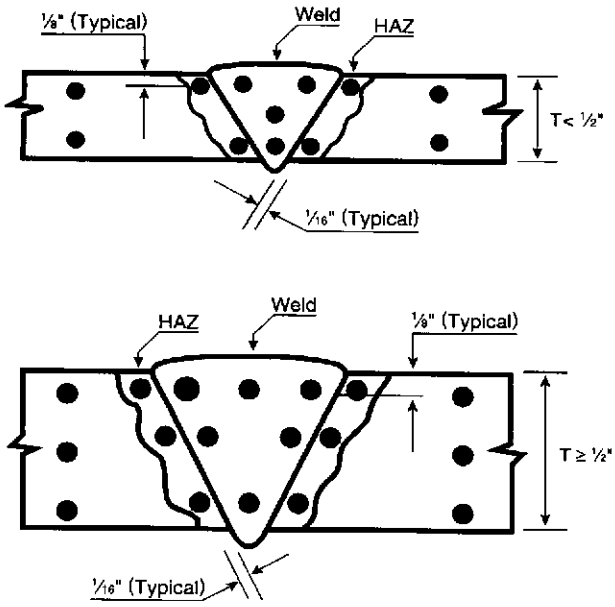


Figure A-1—Rockwell Method

A.1.2 Vickers Method

Vickers testing locations shall be as shown in Figure A-2. Additionally,

a. For a weld cross section thickness less than ½ inch, four hardness tests each shall be made in the base materials and the weld.
b. For a weld cross section thickness equal to or greater than ½ inch, six hardness tests each shall be made in the base materials and the weld.

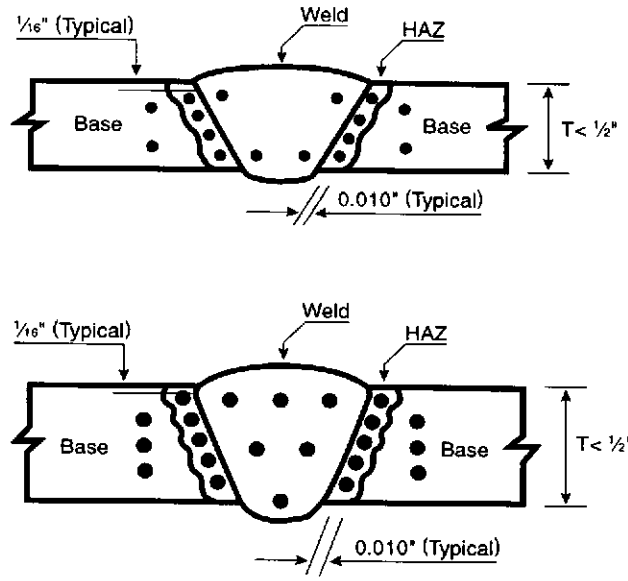


Figure A-2—Vickers Method

A.2 SR 22—IMPACT TESTING

Impact testing shall be performed in accordance with Section 4.5 of this recommended practice using Charpy V-notch specimens. Results of testing in the weld and base material HAZ shall meet 15/10 ft-lbs (avg ÷ min) at 0°F.

A.3 SR 23—IMPACT TESTING

Impact testing shall be performed in accordance with Section 4.5 of this recommended practice using the Charpy V-notch technique. Results of testing in the weld and base material HAZ shall meet 15/10 ft-lbs (avg ÷ min) at –20°F.

A.4 SR 24—RADIOGRAPHIC EXAMINATION

Radiographic examination shall be performed in accordance with ASME Code, Section VIII, Division 1 UW-51.

A.5 SR 25—MAGNETIC PARTICLE EXAMINATION (MPI)

MPI shall be performed in accordance with ASME Code, Section V, Article 7. Acceptance criteria per ASME Code, Section VIII, Appendix 9, Article 9-1, Paragraph 9-130. Welds subject to MPI shall be identified on the purchase order.

A.6 SR 26—PRODUCTION HARDNESS TESTING

The hardness testing method and acceptance criteria shall be agreed between the fabricator and purchaser. In the event the purchaser has not specified hardness testing method and acceptance criteria on the purchase order, the fabricator's standard method may be used.

The hardness test shall be performed once on each weldment at the following locations:

a. Connector HAZ.
b. Weld metal.
c. Pipe HAZ.

A.7 SR 27—FULL LENGTH DRIFT

Each welded joint shall be drift tested throughout the entire length. All drift testing shall be performed with a drift mandrel that is a minimum of 12 inches long. The connector manufacturer shall establish drift diameter and tolerances unless otherwise stated on purchase order.

A.8 SR 28—END DRIFT

Each welded joint shall be drift tested, passing the drift beyond the connector weld yet not the full length of the pipe. All drift testing shall be performed with a drift mandrel that is a minimum of 12 inches long. The connector manufacturer shall establish the drift diameter and tolerances unless otherwise stated on the purchase order.

A.9 SR 29—CONNECTOR ALIGNMENT

Connectors on each welded joint shall be aligned and verified per Section 7.2.2 of this recommended practice. The acceptance criteria for connector alignment shall be agreed upon by fabricator and purchaser. Acceptance criteria should, as a minimum, consider connector manufacturer recommendations, connector make-up features and service application.

A.10 SR 30—NACE

Welding shall comply with the requirements of MR0175.

A.11 SR 31—ULTRASONIC EXAMINATION

Ultrasonic examination shall be performed in accordance with the requirements specified on the purchase order.

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