# Specification for CRA Clad or Lined Steel Pipe

API SPECIFICATION 5LD
SECOND EDITION, JULY 1998

EFFECTIVE DATE: DECEMBER 31, 1998

American Petroleum Institute

**Helping You Get The Job Done Right.**SM

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# FOREWORD

This is the second edition of Spec 5LD as approved by letter ballot through December, 1996. Spec 5LD covers seamless, centrifugal cast, and welded clad steel line pipe, and lined steel pipe with improved corrosion-resistant properties. The clad and lined steel line pipe specified in this document shall be composed of a base metal outside and CRA layer inside the pipe. The base material shall conform to API Spec 5L, *Specification for Line Pipe*, except as modified in the 5LC document. Spec 5LD provides standards for pipe with improved corrosion-resistance suitable for use in conveying gas, water, and oil in both the oil and natural gas industries.

The bar notations identify parts of this standard that have been changed from the previous API edition.

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Suggested revisions are invited and should be submitted to the director of the Exploration and Production Department, American Petroleum Institute, 1220 L Street, N.W., Washington, D.C. 20005.

## SUGGESTIONS FOR ORDERING API CRA CLAD OR LINED PIPE

In placing orders for CRA Clad or Lined Pipe in accordance with API Spec 5LD, the purchaser should specify the following on the purchase order:

- Specification ..... 5LD
- Quantity
- Grade of Base Material ..... Par. 1.1
- Grade of CRA Layer ..... Table 1
- Type of CRA Layer ..... Par. 4.1.a
- Size
  - Nominal Diameter of Base Material ..... Par. 1.1
  - Wall Thickness of Base Material ..... Par. 1.1
  - Minimum Thickness of CRA Layer ..... Table 3
- Nominal Length ..... Par. 9.5
- End Finish ..... Par. 9.8

The purchaser should also state on the purchase order his requirements concerning the following stipulations which are optional with the purchaser:

- Chemical Analysis Reports ..... Par. 5.1, 5.3
- Defect Repair Procedures ..... Par. 11.6, 11.7, 11.8

Attention is called to the following stipulations which are subject to agreement between the purchaser and the manufacturer:

- Chemical Requirements for the CRA Layer ..... Table 1
- Hardness Test Frequency (Centrifugally-Cast) ..... Par. 6.18.c
- Mechanical Properties of CRA Layer ..... Par. 6.1
- CRA Layer Bonding Test ..... Par. 7.3
- OD Tolerance applied to ID ..... Table 3
- Maximum Thickness of CRA layer ..... Table 3
- Supplementary Hydrostatic Test ..... Par. 8.4
- Intermediate Diameters and Walls ..... Par. 9.2, 9.3
- Jointers ..... Par. 9.7
- NDT of Welded Clad Pipe ..... Par. 10.1
- NDT of Seamless and Centrifugally-Cast Clad Pipe ..... Par. 10.2
- NDT of Lined Pipe ..... Par. 10.3
- Continuity of CRA Layer ..... Par. 11.2.g
- Repair of Defects in CRA Layer ..... Par. 11.5.b
- Marking on Inside Surface ..... Par. 12.2.b, A.2
- Supplementary Requirements ..... Appendix B: SR 1, SR 2

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# Specification for CRA Clad or Lined Steel Pipe

## 1 Scope

### 1.1 COVERAGE

This specification covers seamless, centrifugal cast, and welded clad steel line pipe and lined steel pipe with improved corrosion resistant properties. The clad and lined steel line pipe specified herein shall be composed of a base metal outside and a corrosion-resistant alloy (CRA) layer inside the pipe. The base material shall conform to API Spec 5L except as modified herein.

The primary product has square ends, but other special end preparation may be furnished by agreement between the purchaser and manufacturer. Included are NPS: 1 in. through 42 in.

Grades of base metal covered by this specification are X42, X46, X52, X56, X60, X65, X70 and X80 and grades intermediate to these. Grades of the CRA layer are LC 1812, 2205, 2506, 2242, and 2262 and other grades which are subject to agreement between the purchaser and the manufacturer.

### 1.2 GENERAL

a. This specification is under the jurisdiction of the Committee on Standardization of Tubular Goods.

b. The purpose of this specification is to provide standards for pipe with improved corrosion resistance suitable for use in conveying gas, water, and oil in both the oil and natural gas industries.

c. Although the plain-end line pipe meeting this specification is primarily intended for field makeup by circumferential welding, the manufacturer will not assume responsibility for field welding.

d. The size designations are nominal pipe sizes. In the text paragraphs herein, where pipe size limits (or size ranges) are given, these are outside-diameter sizes except where stated to be nominal. These outside-diameter size limits and ranges apply also to the corresponding nominal sizes.

### 1.3 METRIC UNITS

Metric units in this specification are shown in parentheses in the text and in many tables. Outside diameters and wall thicknesses are converted from inch dimensions. The converted diameters are rounded to the nearest 0.1 mm for diameters less than 18 in., and to the nearest 1.0 mm for diameters 18 in. and larger. Wall thicknesses are rounded to the nearest 0.1 mm.

Metric plain-end weights are calculated from the metric outside diameters and wall thicknesses using the formula in 9.1 and rounded to the nearest 0.01 kg/m.

Metric hydrostatic pressures are calculated from metric outside diameters and wall thicknesses and metric fiber stresses shown in Sec. 8.

The factors used where conversions are appropriate are as follows:

| | |
|---|---|
| 1 inch (in.) | = 25.4 millimeters (mm) exactly. |
| 1 square inch | = 645.16 square millimeters ($mm^2$) exactly. |
| 1 foot (ft.) | = 0.3048 meters (m) exactly. |
| 1 pound (lb.) | = 0.45359 kilograms (kg). |
| 1 pound per foot (lb/ft) | = 1.4882 kilograms per meter (kg/m). |
| 1 pound per square inch (psi) | = 6.895 kilopascals (kPa) for pressure. |
| | = .006895 megapascals (MPa) for stress. |
| 1 foot-pound (ft-lb) | = 1.3558 Joules (J) for impact energy. |

The following formula was used to convert degrees Fahrenheit (°F) to degrees Celsius (°C):

$$°C = {}^{5}/_{9} (°F–32)$$

## 2 Referenced Standards

### 2.1 GENERAL

This specification includes by reference, either in total or in part, other API, industry, and government standards listed in 2.4, below.

### 2.2 REQUIREMENTS

Requirements of other standards included by reference in this specification are essential to the safety and interchangeability of the equipment produced.

### 2.3 EQUIVALENT STANDARDS

Other nationally or internationally recognized standards shall be submitted to and approved by API for inclusion in this specification prior to their use as equivalent standards.

### 2.4 NORMATIVE STANDARDS

The most recent editions of the following standards contain provisions that, through reference in this text, form a part of this standard.

API

| | |
|---|---|
| Spec 5L | *Specification for Line Pipe* |
| Spec 5LC | *Specification for CRA Line Pipe* |
| Std 1104 | *Standard for Welding Pipelines and Related Facilities* |

ASME[1]

*Boiler and Pressure Vessel Code, Section IX*

ASTM[2]

A264 *Specification for Stainless Chromium-Nickel Steel Clad Plate, Sheet and Strip*

A262 *Recommended Practice for Detecting Susceptibility of Intergranular Attack in Austenitic Stainless Steels*

A370 *Mechanical Testing of Steel Products Annex II Steel Tubular Products*

A751 *Methods, Practices and Definitions for Chemical Analysis of Steel Products*

E10 *Standard Method of Test for Brinnell Hardness of Metallic Materials*

E18 *Standard Methods of Test for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials*

JISC[3]

G3602 *Nickel and Nickel Alloy Clad Steels*

## 3 Definitions

For the purposes of this specification the following definitions apply:

**3.1 clad:** Refers to a metallurgically-bonded CRA layer.

**3.2 CRA layer:** A general term referring to any internal corrosion resistant alloy layer.

**3.3 lined:** Refers to a mechanically-bonded CRA layer.

**3.4 manufacturer:** As used throughout this specification refers to the firm, company, or corporation responsible for marking the product to warrant that the product conforms to the specification. The manufacturer may be either a pipe mill or a processor, as applicable. This manufacturer is responsible for compliance with all of the applicable provisions of the specification.

**3.5 may:** May is used to indicate that a provision is optional.

**3.6 pipe mill:** A firm, company, or corporation that operates pipe-making facilities.

**3.7 processor:** A firm, company, or corporation that operates facilities capable of heat-treating pipe made by a pipe mill.

**3.8 shall:** Shall is used to indicate that a provision is mandatory.

**3.9 should:** Should is used to indicate that a provision is not mandatory, but recommended as good practice.

## 4 Process of Manufacture and Material

### 4.1 PROCESS OF MANUFACTURE

Clad or lined steel pipe furnished to this specification shall be seamless, welded, or centrifugally-cast steel pipe, clad or lined, as defined below.

a. CRA Layer

1. Clad. Clad steel pipe is a bimetallic pipe composed of an internal CRA layer metallurgically bonded to the base metal.

2. Lined. Lined pipe is pipe in which a CRA layer is affixed inside the carbon steel pipe full length by expanding the liner and/or shrinking the pipe, or by other applicable processes. The CRA layer and the carbon steel pipe shall be manufactured in accordance with Spec 5LC and Spec 5L, respectively, except as may be otherwise specified, herein.

b. Base Material for Clad Pipe

1. Seamless. Seamless clad pipe is produced by the seamless process defined in Spec 5L, 2.1 or 5LC, 5.1 from composite material prepared by methods such as casting, explosion, pipe nesting, hot extrusion, powder metallurgy or other applicable processes.

2. Centrifugally-Cast. Centrifugally-cast clad pipe is produced by the centrifugal casting process defined in Spec 5LC, 5.1.a.2. The entire inner surface of centrifugally-cast clad pipe shall be machined. The outer surface may be machined as well, when agreed upon between the purchaser and the manufacturer.

3. Welded. Welded clad pipe is produced from clad plate or skelp. The longitudinal seam of the tubular shape is welded by one of the welding processes as defined in Spec 5LC, 5.1.b, or their combination, except electric-weld, which is applicable only to the base metal of the carbon steel. For welded-with-filler metal, at least one pass shall be on the inside and one pass on the outside. Tack welds, if applied, shall be removed by machining or remelted by subsequent arc welding. Tack welds are not subject to the subsequent weld requirements of this specification.

c. Base Material for Lined Pipe. The base material for lined pipe shall be produced in accordance with Spec 5L.

### 4.2 COLD EXPANSION

Cold expansion of the clad or lined pipe, up to 1.5%, shall be permitted if agreed upon between the purchaser and the manufacturer.

[1]ASME International, 345 East 47th Street, New York, New York 10017.
[2]American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428.
[3]Japanese Industrial Standards Committee, c/o Standards Department, Agency of Industrial Science and Technology, Ministry of International Trade and Industry, 1-3-1, Kasumigaseki, Chiyoda-ku, Tokyo 100

### 4.3 HEAT TREATMENT

Pipe furnished to this specification may be as-rolled, solution-annealed[4], or quench-and-tempered. For lined pipe, heat treatment may be applied to the outer pipe and the inner pipe, individually, before lining. Other appropriate heat treatment may be agreed upon between purchaser and manufacturer.

## 5 Chemical Properties and Tests

### 5.1 COMPOSITION

The composition of the CRA layer furnished to this specification, as determined by heat analyses, shall conform to the chemical requirements specified in Table 1.

### 5.2 HEAT ANALYSES OF THE CRA LAYER

When requested by the purchaser, the manufacturer shall furnish a report giving the heat analysis of each heat of material used in the manufacture of the CRA layer for pipe furnished on the purchase order. The analysis so determined shall conform to the requirements specified in 5.1.

If alloys other than those specified in Table 1 for a particular grade of CRA layer are added for other than deoxidation purposes, the heat analyses, including the alloy additions, shall be reported for each heat applied to the purchaser's order.

### 5.3 PRODUCT ANALYSES OF THE CRA LAYER

One test from each of two lengths of pipe or plate or skelp from each lot size as indicated below shall be analyzed for product analyses of the CRA layer by the manufacturer. The results of the analyses shall be available to the purchaser on request.

| Size, in. | Lot Size (All Grades) |
|---|---|
| 1 through $12^3/_4$ | 200 lengths or less |
| 14 and over | 100 lengths or less |

For multiple length seamless pipe, a length shall be considered as all of the sections cut from a particular multiple length. The samples shall be taken as follows:

a. Seamless Clad or Lined Pipe. At the option of the manufacturer, samples used for product analyses of the CRA layer shall be taken either from tensile test specimens or from the finished pipe.

b. Welded Clad or Lined Pipe. At the option of the manufacturer, samples used for product analyses of the CRA layer shall be taken from either finished pipe, plate, skelp, tensile test specimens, or flattening test specimens. The location of the samples shall be a minimum of 90° from the weld of longitudinally-welded pipe.

The product analyses of the CRA layer may be made by the supplier of the plate or skelp providing the analyses are made in accordance with the frequency requirement stated above.

Note: While the corrosion-resistance and other properties of the weld seam and adjacent areas in the welded CRA layer may differ from those of the layer itself, it is the intent of this document that the weld metal shall have corrosion-resistance equal to or exceeding that of the CRA layer.

The composition so determined shall conform to the chemical requirements shown in Table 1, within the permissible variations for product analyses as shown in Table 3 of Spec 5LC.

### 5.4 RECHECK ANALYSES

If the product analyses of the CRA layer of both lengths of pipe representing the lot fail to conform to the specified requirements, at the manufacturer's option, either the lot shall stand rejected, or all the remaining lengths in the lot shall be tested individually for conformance to the specified requirements. If only one of the two samples fails, at the manufacturer's option, either the lot shall stand rejected, or two recheck analyses shall be made on two additional lengths from the same lot. If both recheck analyses conform to the requirements, the lot shall be accepted except for the length represented by the initial analyses which failed. If one or both of the recheck analyses fail, at the manufacturer's option, the entire lot shall be rejected or each of the remaining lengths shall be tested individually. In the individual testing of the remaining lengths in any lot, analyses for only the rejecting element or elements need be determined. Samples for recheck analyses shall be taken in the same location as specified for product analysis samples.

### 5.5 CONTROL ANALYSES

A product analysis shall be made by the manufacturer, as a control, of each heat used for the production of pipe under this specification. A record of such analyses shall be available to the purchaser.

### 5.6 CHEMICAL ANALYSES PROCEDURES

Methods and practices relating to chemical analysis shall be performed in accordance with ASTM A751, *Standard Methods, Practices and Definitions for Chemical Analysis of Steel Products*. Calibrations performed shall be traceable to established standards.

### 5.7 BASE MATERIAL

The chemical properties of the base material, including the composition, chemical analysis, recheck analysis and test reports shall conform to Section 3 of Spec 5L.

[4]Solution-annealing involves treating at an appropriate temperature and cooling at an appropriate rate to minimize the precipitation of harmful carbides, as well as to secure softness and ductility. The rate of cooling determines the amount of carbides remaining in solution.

Table 1—Chemical Requirements for Heat Analysis of CRA Layer, Percent

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | | 8 | | 9 | | 10 | | 11 | | 12 | | 13 | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Grades[a] | C | Mn | P | S | Si | Ni | | Cr | | Mo | | N | | Cu | | Others | | UNS[b] Numbers | |
| | Max | Max | Max | Max | Max | Min | Max | Min | Max | Min | Max | Min | Max | Min | Max | Min | Max | | |
| LC 1812 | 0.030 | 2.00 | 0.040 | 0.030 | 0.75 | 10.0 | 15.0 | 16.0 | 18.0 | 2.0 | 3.0 | — | 0.16 | — | — | — | — | S31603 or S31653 | Austenitic Steels |
| LC 2205 | 0.030 | 2.00 | 0.030 | 0.020 | 1.00 | 4.5 | 6.5 | 21.0 | 23.0 | 2.5 | 3.5 | 0.08 | 0.20 | — | — | — W | — | S31803 | Duplex Stainless |
| LC 2506 | 0.030 | 1.00 | 0.030 | 0.030 | 0.75 | 5.5 | 7.5 | 24.0 | 26.0 | 2.5 | 3.5 | 0.10 | 0.30 | — | 0.8 | — | 0.50 | S31260 | Duplex Stainless |
| LC 2242 | 0.050 | 1.00 | 0.030 | 0.030 | 0.50 | 38.0 | 46.0 | 19.5 | 23.5 | 2.5 | 3.5 | — | — | 1.5 | 3.0 | Ti 0.6 | 1.20 | N08825 | Ni Base Alloy |
| LC 2262 | 0.10 | 0.50 | 0.015 | 0.015 | 0.50 | 58.0 | — | 20.0 | 23.0 | 8.0 | 10.0 | — | — | — | — | Cb+Ta 3.15<br>Co —<br>Fe —<br>Al —<br>Ti — | 4.15<br>1.0<br>5.0<br>0.40<br>0.40 | N06625 | Ni Base Alloy |

Notes:

[a]If necessary, all grades may be modified or other grades may be specified by agreement between purchaser and manufacturer. In this case, the composition of the grade shall be designated with Cr and Ni content of the CRA layer as follows:

LC (Cr% Ni%)

[b]UNS Numbers do not show exactly the same chemical compositions depicted in this table.

# 6 Mechanical Properties and Tests

## 6.1 MECHANICAL PROPERTIES

All grades of base metal shall conform to the tensile requirements of Sec. 4 of Spec 5L, as applicable. For Grades X42 and higher, other grades intermediate to the listed grades shall conform to the tensile requirements agreed upon between the purchaser and manufacturer, which shall be consistent with those specified in Table 4.1, Spec 5L. The yield strength shall be the tensile stress required, for base metal, to produce a total elongation of 0.5% of the gage length, as determined by an extensometer. When elongation is recorded or reported, the record or report shall show the nominal width of base metal of the test specimen when strip specimens are used, or state when full specimens are used.

Although compliance with the mechanical properties of this specification is determined by the properties of the base material alone, the mechanical properties of the CRA layer may be specified by agreement between the purchaser and the manufacturer.

## 6.2 TENSILE TESTS—GENERAL

Tensile test orientation shall be as shown in Fig. 4.1, of Spec 5L. At the option of the manufacturer, the specimen may be either full section, strip specimen, or round-bar specimens per 6.4, 6.5, and Fig. 4.2, of Spec 5L. The CRA layer shall be removed from all specimens. The type, size, orientation of the specimens, and removal of the CRA layer shall be reported. Strip specimens shall be approximately $1^1/_2$ in. (38.1 mm) wide in the gage length if suitable curved-face testing grips are used or if the ends of the specimens are machined to reduce the curvatures in the grip area. Otherwise, they shall be approximately 1 in. (25.4 mm) wide for pipe 4 in. through $6^5/_8$ in. and approximately $1^1/_2$ in. (38.1 mm) wide for pipe $8^5/_8$ in. and larger. The full-section specimen may be applied to pipe $3^1/_2$ in. and smaller. Alternately, when grips with curved faces are not available, the ends of the specimens may be flattened without heating. All tensile tests shall be made in the delivery condition. The tensile and yield stress shall be calculated using the actual thickness of the base metal specimen.

## 6.3 TESTING FREQUENCY

Tensile tests shall be made at the frequency shown in Table 4.2, Spec 5L.

## 6.4 LONGITUDINAL TENSILE TESTS

At the option of the manufacturer, longitudinal tests may utilize a full-section specimen, a strip specimen, or for base metal pipe with thickness greater than 0.750 in., a 0.500 in.

diameter round bar specimen, which are all shown in Fig 4.2, Spec 5L. The strip specimen shall be tested without flattening.

### 6.5 TRANSVERSE TENSILE TESTS

The transverse tensile properties shall be determined, at the option of the manufacturer, by one of the following methods:

a. The yield strength, ultimate strength, and elongation values shall be determined on either a flattened rectangular specimen or 0.500 in. or 0.350 in. on a round bar specimen.
b. The yield strength shall be determined by the ring expansion method using the pipe ring specimen, without the CRA layer, with the ultimate strength and elongation values determined from a flattened rectangular specimen or round bar.

The same method for testing shall be employed, as specified in Spec 5L, for all lots on an order item.

### 6.6 WELD TENSILE TESTS

Weld tensile test specimens as specified in Spec 5L shall be taken 90° to the weld, with the weld at the center. The clad layer shall be removed flush with the surface of the base metal. All base metal reinforcement shall be removed. Weld tensile tests need not include determination of yield strength and elongation.

### 6.7 CONTROL TENSILE TESTS

One tensile test shall be made as a control for each heat of material used by the manufacturer for the production of pipe. A record of such tests shall be available to the purchaser. For welded pipe, these tensile tests shall be made on either the skelp or the finished pipe at the option of the manufacturer.

### 6.8 RETESTS

Retests shall be performed as required in Spec 5L.

### 6.9 FLATTENING TESTS—ELECTRIC WELD BASE MATERIAL

Flattening tests shall be performed for electric weld pipe. The test sample shall retain the CRA layer. Frequency of testing, sample location, and test orientation are shown in Fig. 4.3, Spec 5L. When a weld-stop condition occurs during the production of a multiple length, flattening tests, with the weld at 90°, shall be made from the crop ends resulting from each side of the weld-stop, and may be substituted for intermediate flattening tests.

### 6.10 ACCEPTANCE CRITERIA

Acceptable criteria for flattening tests shall be as follows:

a. Flatten to $^2/_3$ original OD without the weld opening.
b. Continue flattening to $^1/_3$ original OD without cracks or breaks other than the weld.
c. Continue flattening until opposite walls of the pipe meet.
d. No evidence of lamination or burnt metal may develop during the entire test.

### 6.11 RETESTS

Flattening retest provisions shall be performed as shown in Table 5, Spec 5LC.

### 6.12 FLATTENING TESTS—SEAMLESS, CENTRIFUGALLY-CAST, WELDED WITHOUT-FILLER METAL CLAD, AND LINED PIPE

Seamless, centrifugally-cast, and welded without-filler metal clad and lined pipe shall be tested by flattening; except that welded without-filler metal pipe may be tested by the guided bend test, in lieu of flattening, at the option of the manufacturer. A section of pipe not less than $2^1/_2$ in. (63.5 mm) in length shall be flattened cold between parallel plates in two steps. The CRA layer shall be retained on the test specimen. During the first step, which is a test for ductility, no cracks or breaks on the inside, outside, or end surfaces shall occur until the distance between the plates is less than the value of $H$, which is calculated as follows:

$$H = 1.09t / (.09 + t/D)$$

where

$H$ = distance between flattening plates, in. (mm),

$t$ = specified full-wall thickness, in. (mm),

$D$ = specified or calculated (from the specified inside diameter and wall thickness) outside diameter, in. (mm).

During the second step, which is a test for soundness, the flattening shall be continued until either the specimen breaks or the opposite walls of the pipe meet.

During the first step of the flattening test, no disbonding between the CRA layer and the base material, except for lined pipe, shall occur.

a. Frequency of Test. One end of each pipe shall be tested for centrifugally-cast clad pipe. For all other applicable pipe, two tests are required per lot of 50 lengths or less.
b. Retest. Manufacturer may elect to retest any failed end until the requirements are met, providing that the finished pipe is not less than 80% of its length after initial cropping.

### 6.13 GUIDED BEND TESTS

Welds with-filler metal and, at the option of the manufacturer, welds without-filler metal shall be tested by the guided bend test.

The specimens shall be taken from each weld in a length of pipe from each lot of 50 lengths or less of each size. The

specimens shall not contain any repair welding made by the manual metallic-arc procedure.

### 6.14 GUIDED BEND TEST—CLAD PIPE ONLY

A guided bend test shall be performed for the welded pipe with filler metal to conform to the requirements of Spec 5L for the welded seam of the base metal. The clad layer shall be removed from the test seam. One face bend and one root bend specimen shall be bent approximately 180° in a jig, substantially as specified in Spec. 5L.

### 6.15 GUIDED BEND TEST—RETESTS

Retests shall be performed as specified in Spec 5L.

### 6.16 WELD DUCTILITY TEST FOR ELECTRIC-WELDED PIPE

The weld ductility shall be determined by tests on full section specimens, including CRA layer, of 2 in. (50.8 mm) minimum length. The specimens shall be flattened cold between parallel plates. The weld shall be placed 90° from the direction of applied force (point of maximum bending). No cracks or breaks exceeding $^1/_8$ in. (3.18 mm) in any direction in the weld or parent metal shall occur on the outside surface until the distance between the plates is less than the value of "*S*", calculated by the formulas (a) and (b) below:

(a) Grades less than 52 ksi Yield Strength:

$$S = \frac{3.07t}{.07 + 3t/D}$$

(b) Grades 52 ksi Yield Strength and Higher:

$$S = \frac{3.05t}{.05 + 3t/D}$$

where

$S$ = distance between flattening plates, in. (mm),

$t$ = specified full-wall thickness of the base material, in. (mm),

$D$ = specified outside diameter of the pipe, in. (mm).

Cracks which originate at the edge of the specimen and which are less than $^1/_4$ in. (6.35 mm) long shall not be cause for rejection. One test shall be made on a length of pipe from each lot size as indicated below.

For multiple length pipe, a length shall be considered as each section cut from a particular multiple length. The weld ductility test may also serve as one of the flattening tests in 6.10 by compliance with the appropriate amounts of flattening.

| Outside Diameter, in. | Lot Size No. of Lengths |
|---|---|
| through $12^3/_4$ | 200 or less |
| 14 and over | 100 or less |

### 6.17 RETESTS

Retests shall be performed as specified in Spec 5L.

### 6.18 CENTRIFUGALLY-CAST HOMOGENEITY TEST[5]

Centrifugally-cast pipe furnished to this specification shall be tested for hardness on sections of both base metal and CRA layer, as follows:

a. Definitions:

1. Impression. One HRC indentation (see Fig. 1). Although impressions below HRC 20 may not be precise they may be used for the calculation of readings. Care should be exercised when evaluating those hardness values below HRC 20.

2. Reading. The average of three impressions in an arc parallel to the circumference of the pipe CRA layer or base metal (see Fig. 1).

b. Hardness Requirements. Hardness tests shall be made in accordance with the latest edition of ASTM E18: *Standard Methods of Tests for Rockwell Hardness and Rockwell Superficial Hardness for Metallic Materials*.

Hardness readings are not taken into account. Only the difference between readings is to be measured. The difference in hardness readings in a quadrant on any test ring shall not exceed that specified below:

| Wall Thickness of CRA Layer or Base Metal, in. | Allowable Hardness Gradation, HRC |
|---|---|
| 0.500 or less | 3.0 |
| 0.501 to 0.749 | 4.0 |
| 0.750 to 0.999 | 5.0 |
| 1.000 and greater | 6.0 |

c. Test Frequency. A test ring shall be cut from one end of each pipe. Approximately 50% of these test rings shall be cut from the front ends and approximately 50% from the back ends of the pipe. HRC impressions shall be made in one quadrant of each ring as shown in Fig. 1.

By agreement between the purchaser and the manufacturer, hardness test frequencies other than those required above may be specified.

[5]The homogeneity of the CRA layer and the base material are to be evaluated separately.

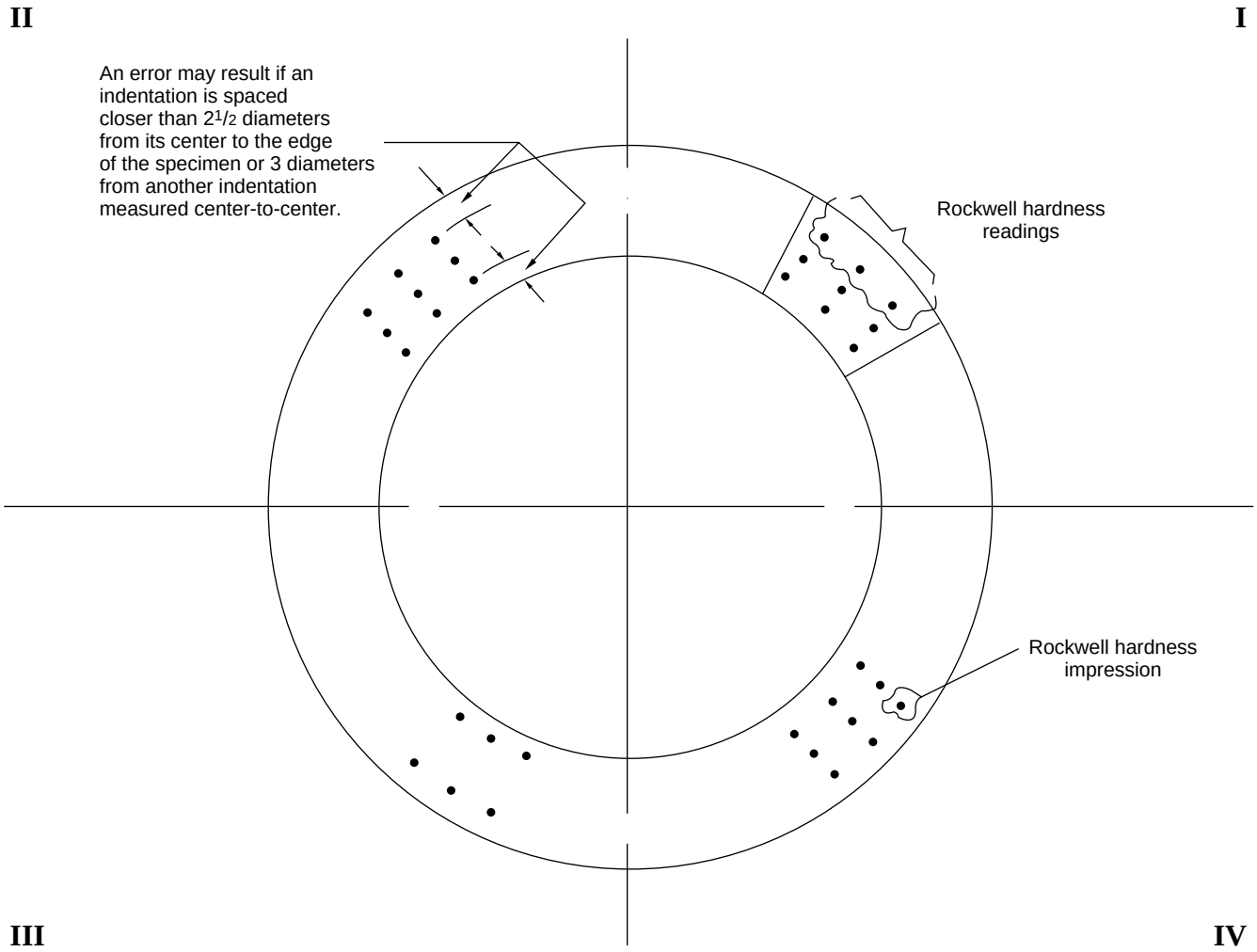



Figure 1—Base Metal and CRA Layer Hardness Test Locations

## 7 Special Tests

### 7.1 FERRITE/AUSTENITE RATIO FOR DUPLEX STAINLESS STEEL

When the CRA layer is composed of duplex stainless steel the ferrite/austenite ratio shall be measured. Ferrite/austenite ratio for duplex stainless steel shall be within 0.35 to 0.65. This ratio shall be determined by using commercially available methods such as Ferrite Indicator, microscopic point-count method, computerized structure-analysis method, etc. In case of dispute, microscopic point-count method shall be used as the standard method.

One test for each heat or heat-treatment lot shall be performed as described in the footnote to Table 7 of Spec 5LC. Each test specimen shall be tested to determine the ferrite/austenite ratio and shall comply with the requirement described above. For the ferrite/austenite ratio determination on the weld, a test specimen shall be taken adjacent to weld tensile test specimen as specified in 6.6. The ratio measured on this test specimen shall comply with the requirements described above.

The determination of ferrite/austenite ratio shall be conducted at three points of the CRA layer. The average of the three readings shall be within specified values.

### 7.2 INTERGRANULAR CORROSION TEST (STRAUSS TEST)

Intergranular corrosion test shall be performed for the CRA layers of austenitic steel and Ni-base alloy as described below. The purpose of this test is to assure proper manufacturing procedures for austenitic steel (LC3O-1812) and Ni-base alloy (LC3O-2242). It is not a test to determine susceptibility for use with a particular environment.

a. Summary of Test Procedure. A suitable sample embedded in copper shot or grindings is exposed to boiling acidified copper sulfate solution for 24 hours. After exposure in the boiling solution, the specimen is bent. The testing procedure

shall conform to the requirement of the latest edition of ASTM A262, Practice E.

b. Specimen Sampling. One specimen shall be taken from the CRA layer. For welded pipe, another specimen containing the weld shall also be taken from the seam-welded portion. The specimen axis may be either transverse or longitudinal to the pipe axis.

One test for each heat or each heat-treatment lot shall be performed as described in the footnote to Table 7 of Spec 5LC.

c. Specimen Preparation. The specimen shall be made of CRA layer and be approximately 3 in. (76.2 mm) long and 1 in. (25.4 mm) wide. Detailed sampling condition may be specified in the agreement between the purchaser and the manufacturer. Sawing is preferred to shearing; but if sheared, the sheared edge of the specimen shall be machined or ground-off. The specimen shall be tested in the as-received condition except that it may be flattened, if desired. Any scale on the specimen shall be removed mechanically with 120 grit iron-free aluminum oxide abrasive. Alternatively, chemical removal of scale is permissible. Each specimen shall be degreased using acetone, alcohol, or a vapor degreaser prior to testing.

d. Test Condition. Test solution is made dissolving 100g of copper sulfate ($CuSO_4 \cdot 5H_20$) in 700 ml of distilled water, adding 100 ml of sulfuric acid ($H_2SO_4$) and diluting to 1000 ml with distilled water. The volume of test solution shall be sufficient to completely immerse the specimens.

The test specimen shall be immersed in an ambient temperature test solution which is then brought to a boil and maintained at boiling for 24 hours. After 24-hour immersion, the test specimen shall be removed from the test solution. If adherent copper remains, it may be removed by a brief immersion in nitric acid at room temperature prior to bending.

e. Bend Test. For acceptance, the tested specimen shall be bent through 180° over a diameter equal to twice the thickness of the specimen. Bending axis shall be perpendicular to the direction of the test specimen. Unless otherwise specified, the bend test system shall be a root bend; i.e., the inside surface of the pipe shall be strained in tension. The wall thickness need not be greater than $^3/_8$ in. (9.52 mm).

In case of material having low ductility, the maximum angle of bend without causing cracks in the material shall be determined by bending an untested specimen of the same configuration as the specimen to be tested.

For welded specimens, the fusion line shall be located approximately at the centerline of the bend.

f. Minimum Acceptance Criteria. The bent test specimen shall first be examined at low magnification. If the evaluation is questionable, the specimen shall then be examined at a magnification of 100 ×. No cracking is permitted. An investigation to determine cause of failure is required and agreement by the purchaser is required prior to any retest procedure.

Table 2—Young's Modulus and Poisson's Ratio at 77°F (25°C)

| Alloy | Young's Modulus (103 ksi) | Poisson's Ratio |
|---|---|---|
| LC 1812 | 28 | 0.30 |
| LC 2205 | 28 | 0.29 |
| LC 2505 | 30 | 0.29 |
| LC 2242 | 28 | 0.31 |
| LC 2262 | 30 | 0.31 |

### 7.3 TEST FOR BONDING

a. Clad Steel Pipe

Special bond shear strength tests shall be performed. Typical tests for bond shear strength include those found in ASTM A264 and JISC Standard G3602. Minimum acceptable bond shear strength, test method, and frequency of test shall be by agreement between purchaser and manufacturer.

As an alternate to the bond shear strength test, a flattening test may be conducted. Acceptance limit of clad separation or crack length shall be specified by agreement between purchaser and manufacturer.

b. Lined Steel Pipe

Gripping force shall be measured. The method of measurement shall be by agreement between purchaser and manufacturer.

An example of such a test method is the residual compressive stress test, conducted as follows:

2 to 4 biaxial strain gages are placed on the inside surface of the CRA layer of a short ring cut from the lined pipe. The CRA layer is taken out of the base metal restriction by saw-cutting the base metal pipe. The change in hoop strains and axial strains before and after take-out of the CRA layer are measured. Bonding force is calculated as the average value.

Note: Bonding force in the circumferential direction is:

$$\sigma = E/(1-v^2) \times (\Sigma\varepsilon_y/n + v_{\Sigma\varepsilon\chi}/n)$$

where

$E$ = Young's Modulus of CRA layer,

$V$ = Poisson's Ratio of CRA layer,

$n$ = number of strain gages.

Another example of gripping force measurement is the application of a modified bond shear test as referenced in 7.3.a.

## 8 Hydrostatic Tests

### 8.1 INSPECTION HYDROSTATIC TEST

All pipe shall be tested after cladding or lining and heat treatment. Each length of pipe shall withstand, without leakage, an inspection hydrostatic test to at least the pressure specified in 8.3. Test pressures for all sizes of seamless pipe

and for welded pipe in sizes 15 in. and smaller shall be held for not less than 5 sec. Test pressures for welded pipe in sizes 20 in. and larger shall be held for not less than 10 sec. The water used for hydrostatic testing shall contain less than 50 ppm chlorides.

### 8.2 VERIFICATION OF TEST

In order to ensure that every length of pipe is tested to the required test pressure, each tester shall be equipped with a recording device that will record the test pressure and duration of time applied to each length of pipe, or equipped with some positive and automatic or interlocking device to prevent pipe from being classified as "tested" until the test requirements (pressure and time) have been complied with. Such records or charts shall be available for examination at the manufacturer's facility by the purchaser's inspectors when the purchaser is so represented at the manufacturer's facility.

### 8.3 TEST PRESSURES

The minimum test pressure shall be computed on the nominal wall thickness of the base metal by the formula given below. When computed pressures are not an exact multiple of 10 psi (100 kPa), they shall be rounded to the nearest 10 psi (100 kPa). Alternately, the test pressure may be calculated using the nominal wall thickness of the bimetallic pipe, by agreement between manufacturer and purchaser.

Note: The hydrostatic test pressure requirements given herein are manufacturer-inspection test pressures, are not intended as a basis for design, and do not necessarily have any direct relationship to working pressures.

| US Customary Formula | Metric Formula |
|---|---|
| $P = \frac{2St}{D}$ | $P = \frac{2000St}{D}$ |

where

$P$ = hydrostatic test pressure in pounds per square inch (kPa),

$S$ = fiber stress in pounds per sq. in. (MPa), equal to a percentage of the specified minimum yield strength of base metal for the various sizes as shown below,

$t$ = specified wall thickness of base metal, in. (mm),

$D$ = specified outside diameter, in. (mm).

Notes:

1. Test pressures shall be limited to 3000 psi (20,700 kPa) to accommodate hydrostatic tester limitations.
2. When hydrostatic testing in excess of 90% of specified minimum yield strength, using the above formula, the applied forces for end-sealing produce a compressive longitudinal stress which should be considered. Recognizing this phenomenon, the manufacturer should submit appropriate calculations for determining the test pressure.

| Grade | Size | Percent of Specified Minimum Yield Strength<br>Standard Test Pressure |
|---|---|---|
| All Grades | 1 to $8^5/_8$ | 75 |
| All Grades | $10^3/_4$ to 18 incl | 85 |
| All Grades | 20 and larger | 90 |

### 8.4 SUPPLEMENTARY HYDROSTATIC TESTS

By agreement between the purchaser and the manufacturer, the manufacturer shall make additional internal pressure tests, which may involve one or more of the following methods. In all supplementary hydrostatic tests, the formula shown in 8.3 shall be used for stress calculations. The conditions of the test shall be as agreed upon.

a. Hydrostatic destructive tests in which the minimum length of the specimen is ten times the outside diameter of the pipe, but need not exceed 40 ft. (12.19 m).

b. Full-length destructive tests made by the "hydrostatic pressure water column" method.

c. Hydrostatic transverse yield strength tests using accurate strain gages.

## 9 Dimensions, Weights, and Lengths

### 9.1 DIMENSION AND WEIGHTS

Line pipe shall be furnished in the base metal sizes and wall thicknesses provided in Table 6.2 of API 5L and 9.2 and 9.3, below, as specified on the purchase order.

Note: The plain-end weight, $w_{pe}$, shall be calculated using the following formula:

US Customary Formula

$$w_{pe} = 10.68\,(D - T) \times T + 10.68\,(D - 2T - t) \times t \times F$$

Metric Formula

$$w_{pe} = 0.02466\,(D - T) \times T + 0.02466\,(D - 2T - t) \times t \times F$$

where

$w_{pe}$ = plain-end weight, rounded to the nearest 0.01 lb/ft (0.01 kg/m),

$D$ = outside diameter, rounded to the nearest 0.001 in. (0.1 mm for sizes less than 457 mm, and 1 mm for sizes 457 mm and larger),

$T$ = specified wall thickness of base metal, rounded to the nearest 0.001 in. (0.1 mm),

$t$ = specified wall thickness of CRA layer, rounded to the nearest 0.001 in. (0.1 mm),

$F$ = correction factor for CRA materials.

| Material | *F* |
|---|---|
| 1812 | 1.017 |
| 2205 | 0.995 |
| 2506 | 0.995 |
| 2242 | 1.038 |
| 2262 | 1.075 |

Note: The correction factor for grades not listed in Table 3 shall be subject to agreement between the purchaser and manufacturer.

## 9.2 DIAMETER

The outside diameter shall be within the tolerances specified in Table 3. (Inside diameters are governed by the outside diameter, wall, and CRA layer tolerances.) Pipe with outside diameters intermediate to those listed in Table 6.2 of API 5L is available by agreement between the purchaser and the manufacturer. Such pipe shall be consistent with all requirements of this specification and shall be marked in accordance with Sec. 12.

As an alternate, when agreed upon between the purchaser and the manufacturer, pipe sizes may be furnished based upon an inside diameter.

## 9.3 WALL THICKNESS

Each length of finished pipe shall be measured for conformance to wall thickness and CRA layer requirements. The wall thickness at any place shall conform to the tolerances specified in Table 3. Wall thickness measurements shall be made with a mechanical caliper or with a properly calibrated nondestructive inspection device of appropriate accuracy. Pipe with wall thicknesses intermediate to those listed in Table 6.2 of API 5L is available by agreement between the purchaser and manufacturer. Such pipe shall be consistent with all requirements of this specification and shall be marked in accordance with Section 12.

## 9.4 WEIGHT

Each length of pipe $5\,^{9}/_{16}$ in. and larger shall be weighed separately, and the carload weights determined. Lengths of pipe $4^{1}/_{2}$ in. and smaller shall be weighed either individually or in convenient lots, at the option of the manufacturer, and the carload weights determined. A carload is considered to be a minimum of 40,000 lb. (18144 kg).

The weights determined as described above shall conform to the specified weights or calculated weights for plain-end pipe.

Table 3—Tolerances on Dimensions and Weights

**Outside Diameter D**

**Pipe Body**

| | |
|---|---|
| 1.900 in. and smaller | +0.016 in. (0.41 mm)<br>–0.031 in. (0.79 mm) |
| $2^{3}/_{8}$ in. through 18 in. | ±0.75% |
| 20 in. and larger | ±1.00% |

For pipe $4^{1}/_{2}$-in. OD and larger, the outside diameter measurements on the body of the pipe shall be made at the mill with a diameter tape on a random basis, but no less than three measurements per 8 hour working turn.

**Pipe Ends**

Pipe $10\,^{3}/_{4}$ in. and smaller shall not be more than $^{1}/_{64}$ in. (0.40 mm) smaller than the specified outside diameter for a distance of 4 in. (101.6 mm) from the end of the pipe and shall permit the passage over the ends, for a distance of 4 in. (101.6 mm) of a ring gage which has a bore $^{1}/_{16}$ in. (1.59 mm) larger than the specified outside diameter of the pipe. Pipe $12\,^{3}/_{4}$ in. to 20 in., inclusive, shall not be more than $^{1}/_{32}$ in. (0.79 mm) smaller than the specified outside diameter for a distance of 4 in. (101.6 mm) from the end of the pipe and shall permit passage over the ends, for a distance of 4 in. (101.6 mm) of a ring gage which has a bore $^{3}/_{32}$ in. (2.38 mm) larger than the specified outside diameter of the pipe. For SAW line pipe, it is permissible to notch or slot the ring gage to permit passage of the gage over the weld bead. At the option of the manufacturer, the minimum outside diameter of pipe in sizes 20 in. and smaller may be measured with a diameter tape. Pipe larger than 20 in. shall not be more than $^{1}/_{32}$ in. (0.79 mm) smaller, nor more than $^{3}/_{32}$ in. (2.38 mm) larger than the specified outside diameter for a distance of 4 in. (101.6 mm) from the end of the pipe, as measured with a diameter tape.

By agreement between the purchaser and the manufacturer, the tolerance on outside diameter at the ends may be applied, instead, to the inside diameter at the ends.

**Out-of-Roundness**

For pipe larger than 20-in. OD, and for a distance of 4 in. (101.6 mm) from the ends of the pipe, the maximum outside diameter shall not be more than 1% larger than specified, and the minimum outside diameter shall not be more than 1% smaller than specified, measured with a bar gage, caliper, or other device capable of measuring the actual minimum and maximum diameters.

**Wall Thickness Tolerance For**

| Size (OD in.) and Process | Base Material Tolerance Percent |
|---|---|
| Less than 20 | –12.5 |
| 20 and larger welded | –8.0 |
| 20 and larger seamless and cc | –10.0 |

Notes:
1. A minimum ID tolerance may be established by agreement between the purchaser and the manufacturer.
2. The minimum thickness of the base material shall be as specified above.
3. The CRA layer shall be not less than $^{1}/_{32}$ in. (0.79 mm) under specified thickness. Maximum thickness of the CRA layer is not specified but may be established by agreement between the purchaser and the manufacturer. The CRA layer thickness shall be measured by mechanical or nondestructive methods.

**Weight**

| | |
|---|---|
| Single lengths | +15.0%,<br>–3.5% |
| Carload lots | –1.75% |

A carload is considered to be a minimum of 40,000 lb. (18,144 kg).

Weight tolerances apply to calculated weights.

Note: Calculated weights shall be determined in accordance with the following formula:

$$WL = w_{pe} \times L$$

where

$WL$ = calculated weight of a piece of pipe of length L lb (kg),

$w_{pe}$ = plain-end weight, lb/ft (kg/m),

$L$ = length of pipe, including end finish, as defined in section 9.5, ft (m).

### 9.5 LENGTH

Unless otherwise agreed upon between the purchaser and the manufacturer, pipe shall be furnished in the lengths shown in Table 6.4 of Spec 5L as specified on the purchase order. The accuracy of length measuring devices for lengths of pipe less than 100 ft. (30 m) shall be ±0.1 ft. (0.03 m).

### 9.6 STRAIGHTNESS

Pipe shall be reasonably straight. All pipe shall be randomly checked for straightness, and deviation from a straight line shall not exceed 0.2% of the length. Measurements may be made using a taut string or wire from end-to-end along the side of the pipe, measuring the greatest deviation.

### 9.7 JOINTERS

When specified on the purchase order, jointers (two or more pieces of pipe coupled or welded together to make a standard length) may be furnished. Details of procedures and tests required for furnishing such jointers shall be by agreement between the purchaser and the manufacturer.

### 9.8 PIPE ENDS

Unless otherwise ordered, plain-end pipe (other than double-extra-strong pipe) in sizes $2^3/_8$ in. and larger shall be furnished with ends beveled to an angle of 30°, +5°, –0°, measured from a line drawn perpendicular to the axis of the pipe, and with a root face of $^1/_{16}$ in. $\pm^1/_{32}$ in. (1.59 ±0.79 mm). For seamless pipe where internal machining is required to maintain the root face tolerance, the angle of the internal taper, measured from the longitudinal axis, shall be no larger than that listed below.

| Specified Wall Thickness (in.) | Maximum Angle of Taper (Deg.) |
|---|---|
| Less than 0.418 (10.6 mm) | 7 |
| 0.418 through 0.555 (10.6 through 14.1 mm) | $9^1/_2$ |
| 0.556 through 0.666 (14.1 through 16.9 mm) | 11 |
| Over 0.666 (16.9 mm) | 14 |

For the removal of an internal burr on welded pipe larger than $4^1/_2$-in. OD, the internal taper, measured from the longitudinal axis, shall be no larger than 7°.

Double-extra-strong plain-end pipe in sizes $2^3/_8$ in. and larger shall be furnished with square-cut ends, unless beveled ends (as above) are specified on the purchase order. For pipe sizes $10^3/_4$ in. and larger, the ends shall be cut square within $^1/_{16}$ in. (1.59 mm), and measured not less than three times per 8 hour working shift. The end-finish for pipe in sizes smaller than $2^3/_8$ in. shall be as specified on the purchase order. Both ends of submerged-arc and gas metal-arc welded pipe shall have the inside weld reinforcement removed for a distance of approximately 4 in. (101.6 mm) from the end of the pipe.

## 10 Nondestructive Inspection

### 10.1 INSPECTION METHODS FOR WELDED CLAD PIPE

The weld seam of welded, clad pipe shall be inspected full-length (100%) by radiological methods in accordance with 10.4, or by an appropriate nondestructive method and acceptable criteria, as agreed upon by the purchaser and the manufacturer. The ERW seam of base material shall be inspected in accordance with Spec 5L prior to the application of the weld in the CRA layer.

### 10.2 INSPECTION METHODS FOR SEAMLESS AND CENTRIFUGALLY-CAST CLAD PIPE

Centrifugally-cast pipe shall be inspected full-length for defects by such nondestructive methods as are appropriate to the CRA layer and to the base material. The acceptance criteria are subject to agreement between the purchaser and the manufacturer. The location of the equipment shall be at the discretion of the manufacturer; however, the nondestructive inspection shall take place after all heat-treating and expansion operations, if performed, but may take place before cropping, beveling, and end-sizing.

### 10.3 INSPECTION METHODS FOR LINED PIPE

Both the base metal and the CRA layer of the lined pipe shall be inspected. The inspection may be before or after lining, by agreement between the purchaser and the manufacturer. This inspection shall be capable of discovering defects in the full volume of the base metal and the CRA layer.

The ERW seam of base material for lined pipe shall be inspected in accordance with the provisions of Spec 5L.

### 10.4 RADIOLOGICAL INSPECTION—EQUIPMENT

The homogeneity of weld seams examined by radiological methods shall be determined by means of X-rays directed through the weld onto a suitable radiographic film or fluores-

cent screen. A television screen may be used provided adequate sensitivity can be obtained.

### 10.5 FLUOROSCOPIC OPERATOR QUALIFICATION

Operators of fluoroscopic equipment shall be trained, tested and certified by the manufacturer.

Details of such training, testing, and certification programs shall be available to the purchaser. Included in this program shall be:

a. Classroom instructions in the fundamentals of radiological inspection techniques.
b. On-the-job training designed to familiarize the operator with specific installations including the appearance and interpretation of weld imperfections and defects. The length of time for such training shall be sufficient to assure adequate assimilation of the knowledge required for conducting the inspection.
c. Knowledge of appropriate requirements of this specification.
d. An eye examination at least once per year to determine the Operator's optical capability to perform the required inspection.
e. Upon completion of items a, b, and c, above, an examination shall be given by the manufacturer to determine if the Operator is qualified to properly perform fluoroscopic examinations.

### 10.6 OPERATOR CERTIFICATION

Certified Operators whose work has not included fluoroscopic inspection for a period of one year or more shall be recertified by successfully completing the examination of item e, above, and also passing the eye examination, item d, above. Substantial changes in procedure or equipment shall require recertification of the Operators.

### 10.7 REFERENCE STANDARDS

Unless otherwise specified, the reference standard shall be the ISO Wire Penetrameter described in 10.9. By agreement between purchaser and manufacturer, other standard penetrameters may be used.

### 10.8 ISO WIRE PENETRAMETER

The ISO Wire Penetrameter shall be 2% of wall thickness and either Fe 6/12 or Fe 10/16 in accordance with Table 4 for the appropriate wall thickness.

### 10.9 FREQUENCY

The penetrameter shall be used to check the sensitivity and adequacy of the radiological technique on each length of pipe, when the fluoroscopic method is used full length, and on each film when film is used. Using the penetrameter, each length of pipe shall be held in a stationary position during the adjustment of the radiological technique. Proper definition and sensitivity is attained when individual wires of the ISO penetrameter are clearly discernible.

### 10.10 PROCEDURE FOR EVALUATING IN-MOTION OPERATION OF THE FLUOROSCOPE

To evaluate the definition of defects at operational speeds, a pipe section having a minimum wall of 0.375 in. (9.5 mm) shall be used. Series of $^1/_{32}$ in. (0.79 mm) holes, as shown in Example 6, Fig. 3, shall be drilled into the center of the weld to a depth of 30% of the total thickness. At least four such series shall be used, spaced one foot apart. As an alternate to the use of the pipe section described above, a penetrameter as described in 10.8 may be used at the option of the manufacturer. The speed of operation shall be adjusted so that the holes in the pipe section, or at least the wire in the ISO penetrameter requested for the nominal wall thickness, are clearly visible to the Operator.

### 10.11 ACCEPTANCE LIMITS

Radiological examination shall be capable of detecting weld imperfections and defects as described in 10.12 and 10.13.

### 10.12 IMPERFECTIONS

The maximum acceptable size and distribution of slag inclusion and/or gas pocket discontinuities are shown in Tables 5 and 6, and Figs. 2 and 3.

Note: Unless the discontinuities are elongated, it cannot be determined with assurance whether the radiological indications represent slag inclusions or gas pockets. Therefore, the same limits apply to all circular-type discontinuities.

The important factors to be considered in determining rejection or acceptance limits are size and spacing of discontinuities and the sum of the diameters in an established distance. For simplicity, the distance is established as any 6 in. (152.4 mm) length. Discontinuities of this type usually occur in an aligned pattern, but no distinction is made between aligned or scattered patterns. Also, the distribution pattern may be of assorted sizes.

### 10.13 DEFECTS

Cracks, lack of complete penetration, or lack of complete fusion, and discontinuities greater in size and/or distribution than shown in Tables 5 and 6, and Figs. 2 and 3, as indicated by radiological examination, shall be considered defects.

### 10.14 WELD REPAIR

Any weld rejected as a result of radiological examination may be repaired at the option of the manufacturer and, if repaired by welding, shall be done in accordance with Sec. 11, and shall be reexamined radiologically.

Table 4—ISO Wire Penetrameter (Sensitivity 2%)

| 1 | 2 | 3 | 4 | |
|---|---|---|---|---|
| | Wire Diameter | | Wall Thickness | |
| Wire No. | mm | in. | in. | mm |
| | | Fe 6/12 | | |
| 6 | (1.00) | 0.040 | 2.000 | (50.8) |
| 7 | (0.80) | 0.032 | 1.600 | (40.6) |
| 8 | (0.63) | 0.025 | 1.250 | (31.8) |
| 9 | (0.50) | 0.020 | 1.000 | (25.4) |
| 10 | (0.40) | 0.016 | 0.800 | (20.3) |
| 11 | (0.32) | 0.013 | 0.650 | (15.9) |
| 12 | (0.25) | 0.010 | 0.500 | (12.7) |
| | | Fe 10/16 | | |
| 10 | (0.40) | 0.016 | 0.800 | (20.3) |
| 11 | (0.32) | 0.013 | 0.650 | (15.9) |
| 12 | (0.25) | 0.010 | 0.500 | (12.7) |
| 13 | (0.20) | 0.008 | 0.400 | (10.2) |
| 14 | (0.16) | 0.006 | 0.325 | (8.3) |
| 15 | (0.13) | 0.005 | 0.250 | (6.4) |
| 16 | (0.10) | 0.004 | 0.200 | (5.1) |

Note: Always use penetrameter with wall-equivalent wire near center.

Table 5—Elongated Slag-Inclusion-Type Discontinuities[a] (See Fig. 3)

| 1 | | 2 | | 3 |
|---|---|---|---|---|
| Maximum Dimensions | | Minimum Separation | | Maximum Number in any 6 in. (152.4 mm) |
| in. | mm. | in. | mm. | |
| $1/16 \times 1/2$ | (1.6 × 12.7) | 6 | (152.4) | 1 |
| $1/16 \times 1/4$ | (1.6 × 6.4) | 3 | (76.2) | 2 |
| $1/16 \times 1/8$ | (1.6 × 3.2) | 2 | (50.8) | 3 |

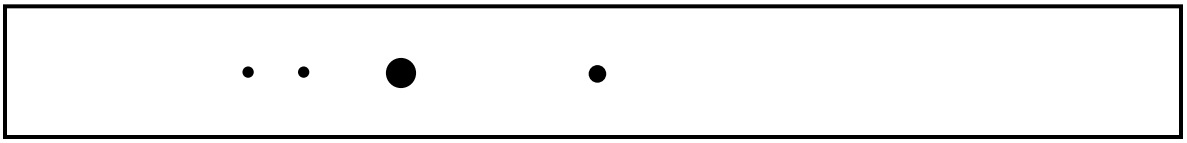
[a] Maximum accumulated length of discontinuities in any 6 in. (152.4 mm) shall not exceed $1/2$ in. (12.7 mm).

Table 6—Circular Slag-Inclusion and Gas-Pocket-Type Discontinuities[a] (See Fig. 2)

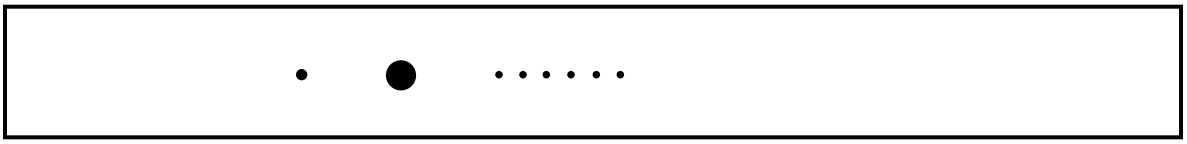
| 1 | | 2 | | 3 | | 4 |
|---|---|---|---|---|---|---|
| Size | | Adjacent Size | | Minimum Separation | | Maximum Number in any 6 in.(152.4 mm) |
| in. | mm | in. | mm | in. | mm | |
| $1/8$[b] | (3.2) | $1/8$[b] | (3.2) | 2 | (50.8) | 2 |
| $1/8$[b] | (3.2) | $1/16$ | (1.6) | 1 | (25.4) | Varies |
| $1/8$[b] | (3.2) | $1/32$ | (0.8) | $1/2$ | (12.7) | Varies |
| $1/8$[b] | (3.2) | $1/64$ | (0.4) | $3/8$ | (9.5) | Varies |
| $1/16$ | (1.6) | $1/16$ | (1.6) | $1/2$ | (12.7) | 4 |
| $1/16$ | (1.6) | $1/32$ | (0.8) | $3/8$ | (9.5) | Varies |
| $1/16$ | (1.6) | $1/64$ | (0.4) | $1/4$ | (6.4) | Varies |
| $1/32$ | (0.8) | $1/32$ | (0.8) | $1/4$[c] | (6.4) | 8 |
| $1/32$ | (0.8) | $1/64$ | (0.4) | $3/16$ | (4.8) | Varies |
| $1/64$ | (0.4) | $1/64$ | (0.4) | $1/8$ | (3.2) | 16 |

[a]The sum of the diameters of all discontinuities in any 6 in. (152.4 mm) not to exceed $1/4$ in. (6.4 mm).
[b]Maximum size discontinuity for 0.250 in. (6.4 mm) wall and lighter shall be $3/32$ in. (2.4 mm).
[c]Two discontinuities, $1/32$ in. (0.8 mm) or smaller, may be as close as one diameter apart provided they are separated from any other discontinuity by at least $1/2$ in. (12.7 mm).

Example 1: Two 1/8" (3.2 mm) discontinuities

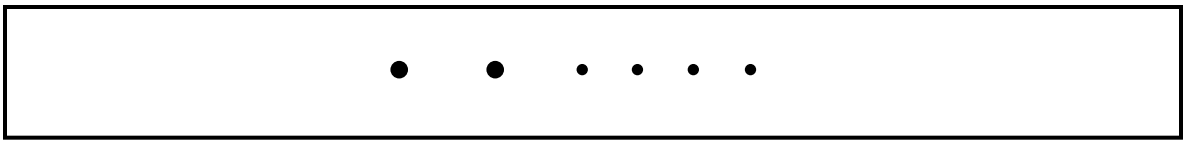


Example 2: One 1/8" (3.2 mm), one 1/16" (1.6 mm), two 1/32" (0.8 mm) discontinuities

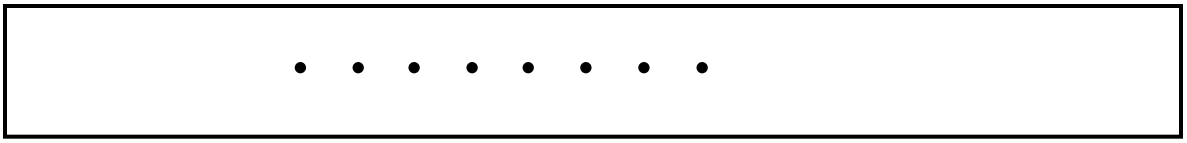


Example 3: One 1/8" (3.2 mm), one 1/32" (0.8 mm), six 1/64" (0.4 mm) discontinuities

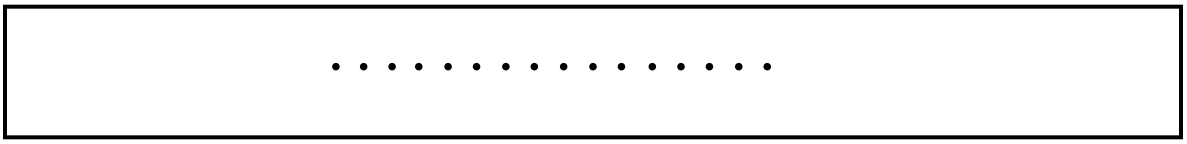
Example 4: Four 1/16" (1.6 mm) discontinuities



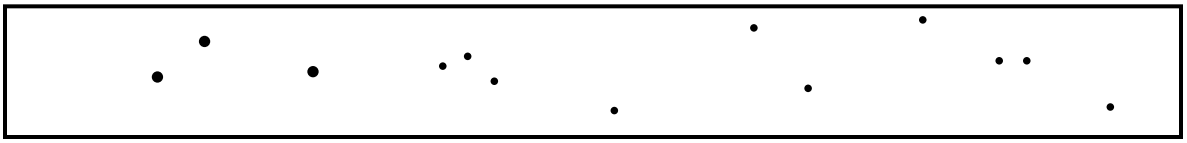
Example 5: Two 1/16" (1.6 mm), four 1/32" (0.8 mm) discontinuities



Example 6: Eight 1/32" (0.8 mm) discontinuities



Example 7: Sixteen 1/64" (0.4 mm) discontinuities



Example 8: Scattered, three 1/32" (0.8 mm), ten 1/64" (0.4 mm) discontinuities

Figure 2—Examples of Maximum Distribution Patterns of Indicated Circular Slag-Inclusion and Gas-Pocket-Type Discontinuities

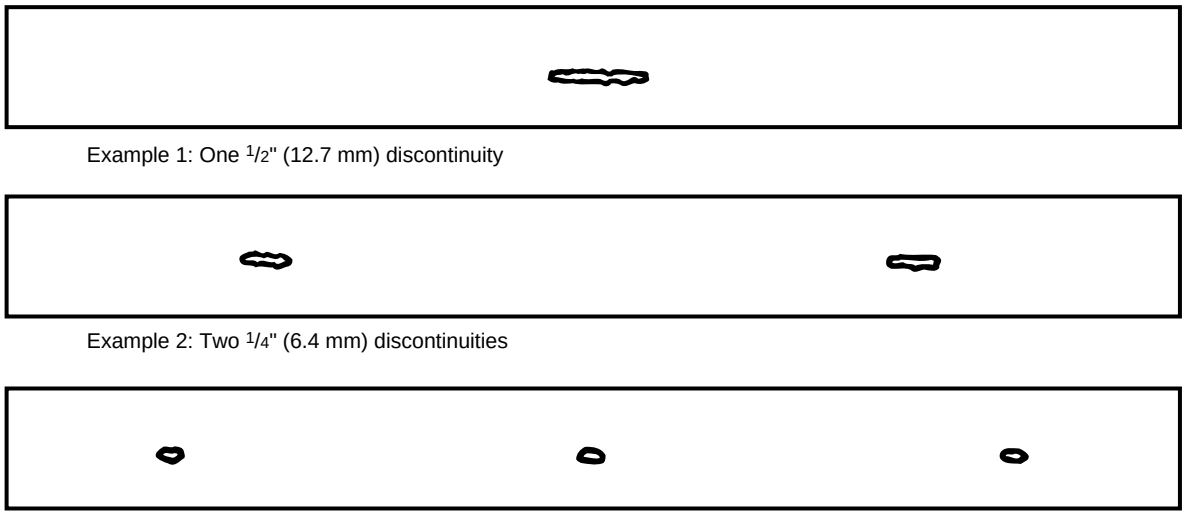



Figure 3—Examples of Maximum Distribution Patterns of Indicated Elongated Slag-Inclusion-Type Discontinuities

## 11 Workmanship, Visual Inspection, and Repair of Defects

### 11.1 PURCHASER INSPECTION

Unless otherwise provided, the provisions of Appendix C shall apply.

### 11.2 WORKMANSHIP

Defects of the following types shall be considered poor workmanship. Pipe containing such defects shall be rejected. The manufacturer shall take all reasonable precautions to minimize reincurring damage to the pipe.

a. Dents. The pipe shall contain no dents greater than $^1/_4$ in. (6.35 mm), measured as the gap between the lowest point of the dent and a prolongation of the original contour of the pipe. The length of the dent in any direction shall not exceed one-half the pipe diameter. All cold-formed dents deeper than $^1/_8$ in. (3.18 mm) with a sharp bottom gouge shall be considered a defect. The gouge may be removed by grinding.

b. Offset of Plate Edges. For submerged-arc and gas metal-arc welded pipe with wall thicknesses 0.500 in. (12.7 mm) and less, the radial offset (misalignment) of plate edges in the weld seams shall not be greater than $^1/_{16}$ in. (1.59 mm). For submerged-arc and gas metal-arc welded pipe with wall thicknesses over 0.500 in. (12.7 mm) the radial offset shall not be greater than 0.125*t* or $^1/_8$ in. (3.18 mm), whichever is smaller. For electric-welded pipe, the radial offset of plate edges plus flash trim shall be no greater than 0.060 in. (1.52 mm).

c. Out-of-Line Weld Bead in Submerged-Arc and Gas Metal-Arc Welded Pipe. Out-of-line weld bead (off-seam weld) shall not be cause for rejection, provided that complete penetration and complete fusion have been achieved as indicated by nondestructive examination. When the electric-resistance welding process is used for tack-welding, the subsequent submerged-arc or gas metal-arc weld must eliminate all evidence of the tack weld.

d. Height of Outside and Inside Weld Beads. The weld bead shall not extend above the prolongation of the original surface of the pipe more than the amount listed below:

| Wall thickness | Maximum Height of Weld Bead |
|---|---|
| $^1/_2$ in. (12.70 mm) and under | $^1/_8$ in. (3.18) |
| Over $^1/_2$ in. (12.70 mm) | $^3/_{16}$ in. (4.76) |

Weld beads higher than permitted by the requirements of this paragraph may be ground to acceptable limits at the option of the manufacturer.

The height of the weld bead shall in no case come below a prolongation of the surface of the pipe (outside or inside the weld bead), except that contouring by grinding, otherwise covered in this specification, shall be permitted.

e. Flash of Electric-Welded Pipe (Base Metal). The inside and outside flash of electric-welded pipe shall be trimmed to an essentially flush condition.

f. Grinding. Cosmetic grinding on both base metal and CRA layer is permissible at the discretion of the manufacturer. When grinding is performed it shall be done in a workmanlike manner.

g. CRA Layer. The CRA layer shall be inspected for continuity. Any discontinuity which completely penetrates the CRA layer shall be considered a defect. The method for such inspection shall be by agreement between purchaser and manufacturer.

### 11.3 VISUAL INSPECTION

All finished pipe shall be visually examined and shall be free of defects as defined in 11.4. See 11.5 through 11.8 for repair of defects.

### 11.4 DEFECTS

The following conditions in both base metal and CRA layer are defined as defects.

a. Cracks and Leaks. All cracks, sweats, and leaks shall be considered defects.

b. Lamination and Inclusions. Any lamination or inclusion extending into the face or bevel of the pipe and having a transverse dimension exceeding $^1/_4$ in. (6.35 mm) is considered a defect. Pipe containing such defects shall be cut back until no lamination or inclusion on the face of the bevel is greater than $^1/_4$ in. (6.35 mm).

c. Arc Burns. Arc burns, defined as localized points of surface melting caused by arcing between electrode or ground and the pipe surface, shall be considered defects.

Note: Contact marks, defined as intermittent marks adjacent to the weld line resulting from the electrical contact between the electrodes supplying the welding current and the pipe surface, are not defects.

Pipe containing arc burns shall be given one of the following dispositions:

1. Arc burns may be removed by grinding, chipping, or machining. The resulting cavity shall be thoroughly cleaned and checked for complete removal of damaged material by etching with an appropriate reagent.

The cavity may be merged smoothly into the original contour of the pipe by grinding, provided that the remaining wall thickness is within the specified limits.

2. The section of pipe containing the arc burn may be cut off within the limits of the requirements on length.
3. Rejected.

d. Undercuts. Undercutting on submerged-arc or gas metal-arc welded pipe is the reduction in thickness of the pipe wall adjacent to the weld where it is fused to the surface of the pipe. Undercutting can best be located and measured visually. Minor undercutting on either the inside or the outside of the pipe is permissible without repair or grinding. Minor undercutting is defined as follows:

1. Maximum depth of $^1/_{32}$ in. (0.79 mm) with a maximum length of one-half the wall thickness and not more than two such undercuts in any 1 ft. (0.30 m) of the weld length.
2. Maximum depth of $^1/_{64}$ in. (0.40 mm), any length.

Undercuts longer than one-half the wall thickness and $^1/_{64}$ to $^1/_{32}$ in. (0.40 to 0.79 mm) in depth, but not exceeding $12^1/_2$% of the specified wall thickness, shall be removed by grinding. Undercuts greater in depth than $^1/_{32}$ in. (0.79 mm) shall be considered defects.

e. Disbonding. Disbonding is defined as lack of bond between base metal and CRA layer, except in the case of lined pipe, shall be considered a defect when the size of the disbonding is larger than agreed upon between purchaser and manufacturer.

f. Other Defects. Any imperfection in the base material having a depth greater than $12^1/_2$% of the specified wall thickness, measured from the surface of the pipe shall be considered a defect. For the CRA layer the depth shall not exceed $^1/_{32}$ in. (0.79 mm).

g. Disposition. Pipe containing a defect must be given one of the following dispositions:

1. The defect may be removed by grinding, provided that the remaining wall thickness is within specified limits.
2. Repaired in accordance with 11.5 through 11.8.
3. The section of pipe containing the defect may be cut off within the limits of the requirements on length.
4. Rejected.

### 11.5 REPAIR OF DEFECTS

a. Base Metal. The repair of base metal is permissible in accordance with Spec 5L, Par. 10.8.

b. CRA Layer. Defects in the CRA layer and disbonded areas considered as defects may be repaired by agreement between the purchaser and the manufacturer.

c. Weld Seam. The weld seam may be repaired at the discretion of the manufacturer, in accordance with 11.6, 11.7, and 11.8.

### 11.6 PROCEDURE FOR REPAIR OF WELD SEAMS OF SUBMERGED-ARC WELDED PIPE

The repair of defects in the weld seam of submerged-arc welded pipe shall conform to the following requirements. Conformance is subject to approval of the purchaser's inspector.

a. The defect shall be completely removed and the cavity thoroughly cleaned.

b. The minimum length of a repair weld shall be 2 in. (50.8 mm). The repair weld shall be made either semi-automatic or automatic submerged-arc welding, by manual or semi-automatic or automatic gas metal-arc (TIG or MIG) welding, or manual shielded metal-arc welding using suitable electrodes. The welding procedures and personnel performance shall be qualified in accordance with Appendix A of Spec 5LC. Shielding gas, containing hydrogen, shall not be used for duplex alloys.

c. Each length of repaired pipe shall be hydrostatically-tested in accordance with Sec. 8.

### 11.7 PROCEDURE FOR REPAIR OF WELD SEAMS OF ELECTRIC-WELDED AND INDUCTION-WELDED PIPE

Repair welding of the weld seam of electric-resistance welded pipe and induction-welded pipe shall conform to the

following requirements and shall include the weld zone which is defined for the purposes of repair as $^1/_2$ in. (12.7 mm) on either side of the fusion line. Conformance to the repair procedure is subject to approval of the purchaser's inspector.

a. The weld zone defect shall be removed completely by chipping and/or grinding and the resultant cavity shall be thoroughly cleaned.

b. The minimum length of repair weld shall be 2 in. (50.8 mm), and individual weld repairs must be separated by at least 10 ft. (3 m).

c. The repair weld shall be made either by manual or semi-automatic submerged-arc welding, gas metal-arc welding, or manual shielded metal-arc welding using suitable electrodes. The metal temperature in the area to be repaired shall be a minimum of 50°F (10°C). The welding procedure and personnel performance shall be qualified in accordance with Appendix A of Spec 5LC.

d. When a repair weld is made through the full wall thickness, it shall include weld passes made from both the ID and the OD of the pipe. Starts and stops of the ID and OD repair welds shall not coincide.

e. The repair shall be ground to merge smoothly into the original contour of the pipe and shall have a maximum crown of 0.06 in. (1.52 mm).

f. Repair welds shall be inspected by either ultrasonic methods in accordance with 9.14 through 9.16 of Spec 5L, except that the equipment need not be capable of continuous and uninterrupted operation, or by radiological methods in accordance with 10.4 through 10.14. The choice of these nondestructive testing methods shall be at the option of the manufacturer.

g. Repaired pipe shall be hydrostatically-tested after repaired in accordance with Sec. 8.

### 11.8 PROCEDURE FOR REPAIR OF WELD SEAM OF GAS METAL-ARC WELDED PIPE

The repair of defects in the weld seam of gas metal-arc welded pipe shall conform to the following requirements. Conformance is subject to the approval of the purchaser's inspector:

a. The defects shall be completely removed and the cavity thoroughly cleaned. The size of the cavity shall be sufficiently large (at least 2 in. [50.8 mm] in length) so as to permit multiple pass repairs wherein starts and stops of individual passes do not coincide.

b. The repair weld shall be made by suitable coated electrodes, semi-automatic, or automatic gas metal-arc welding. The welding procedure and personnel performance shall be qualified in accordance with Appendix A of Spec 5LC.

c. Each length of repaired pipe shall be hydrostatically tested in accordance with Sec. 8.

## 12 Marking and Surface Treatment

### 12.1 MARKING—GENERAL

Pipe manufactured in conformance with this specification shall be marked by the manufacturer as specified hereinafter.

a. The required marking on pipe shall be as stipulated in 12.3.

b. Size, weight per foot, length, and hydrostatic test pressure markings shall be in English units except that for pipe intended for use in countries utilizing the metric system; these markings shall be in metric units or both English and metric units, if so specified on the purchase order. If not so specified, for pipe made and intended for use in countries utilizing the metric system, these markings may be given in metric units only, at the option of the manufacturer.

### 12.2 LOCATION OF MARKINGS

The location and sequence of identification markings shall be as follows:

a. 1.900-in. OD and smaller—Die stamped on a metal tag fixed to the bundle, or may be printed on the straps or banding clips used to tie the bundle.

b. Larger than 1.900-in. OD and less than 16-in. OD—Paint stencil on the outside surface starting at a paint between 18 and 30 inches from the end of the pipe, and in the sequence shown below, except when agreed between the purchaser and the manufacturer that some or all of the markings may be placed on the inside surface in a sequence convenient to the manufacturer. Compatible Standards Product in compliance with multiple compatible standards may be stenciled with the name of each standard.

c. Pipe 16-in. OD and larger—Paint stencil on the inside surface starting at a point no less than 6 in. from the end of the pipe in a sequence convenient to the manufacturer, unless otherwise specified by the purchaser.

### 12.3 SEQUENCE OF MARKINGS

a. Manufacturer's name or mark.

b. Spec 5LD[6]. "Spec 5LD" shall be paint-stenciled when the product is in complete compliance with this specification. Compatible Standard Products in compliance with multiple compatible standards may be stenciled with the name of each standard.

c. Sizes. The outside diameter in inches followed by the nominal wall thickness of base metal and CRA layer, in inches.

[6]Users of this specification should note that there is no longer a requirement for marking a product with the API monogram. The American Petroleum Institute continues to license use of the monogram on products covered by this specification but it is administered by the staff of the Institution separately from the specification. The policy describing licensing and use of the monogram is contained in Appendix A herein. No other use of the monogram is permitted.)

d. Weight per Foot. For sizes $4^1/_2$ in. and larger, the calculated weight using the formula in 9.1, in pounds per foot for plain-end pipe shall be paint-stenciled.
e. Grade. The symbols to be used are as follows:

X (Yield Strength of Base Metal)/LC (Cr5, Ni5 of CRA layer)

f. Process of Manufacture (Base Material and CRA Layer). The symbols to be used are as follows:

| | |
|---|---|
| Seamless | S |
| Welded | E |
| Centrifugal | C |
| Lined | L |

g. Heat Treatment. The symbols to be used are as follows:

| | |
|---|---|
| Normalized | N |
| As-rolled | AR |
| Quench and Tempered | HQ |
| Solution Anneal | H |

h. Test Pressure. When the specified hydrostatic test pressure is higher than the pressure in 8.3, the test pressure in pounds per square inch, preceded by the word TESTED, shall be paint-stenciled.
i. Supplementary Requirements. See Appendix B.
Example:
14-inch OD 0.375 inch base metal wall thickness, 0.120 inch CRA layer wall thickness, Grade X70 seamless base metal, L-C 30-1812 CRA lined, solution annealed, seamless should be stenciled as follows:

ABCO Spec 5LD 14 × .375/.120 71.68
X70S/LC 1812 SLH

Note: The weight per foot (71.68) is computed by the formula in 9.1.

### 12.4 LENGTH

In addition to the identification markings stipulated in 12.1 and 12.2, the length shall be marked as follows:

a. For pipe in sizes larger than 1.900-in. OD, the length in feet and tenths of a foot, unless otherwise specified on the purchase order, as measured on the finished pipe shall be paint- stenciled on the outside surface at a place convenient to the manufacturer, except by agreement between the purchaser and the manufacturer. The length marking may be placed inside the pipe at a convenient location.
b. For sizes 1.900-in. OD and smaller, the total length of pipe in the bundle in feet and tenths of a foot (or equivalent metric units), unless otherwise specified on the purchase order, shall be marked on the tag, band, or clip.

### 12.5 DIE STAMPING

Cold die stamping of all grades plate or pipe not subsequently heat-treated, and all pipe with wall thickness of 0.156 in. and less is prohibited, except that by agreement between the purchaser and the manufacturer and when so specified on the purchase order, pipe or plate may be cold die stamped. The manufacturer at his option may hot die stamp (2000°F [930°C] or higher) plate or pipe, cold die stamp plate or pipe if it is subsequently heat-treated. Cold die stamping shall be done with rounded or blunt dies. All die stamping shall be at least 1 in. (25 mm) from the weld for all grades. Etching or marking with a vibrograph are permitted in lieu of die stamping.

### 12.6 SURFACE TREATMENT

The corrosion-resistant behavior of the CRA layer is adversely affected by poor surface condition. Therefore, scale spatter and annealing surface residues of the CRA layer shall be removed by blasting, pickling, brushing, or a combination of these methods.

### 12.7 PIPE PROCESSOR MARKINGS

Pipe heat-treated by a processor other than the manufacturer shall be marked as stipulated in 12.2, 12.3, 12.4 and 12.5. The processor shall remove any identity which is not indicative of the new product as a result of heat-treating (i.e. prior grade identity, original pipe manufacturer's name or logo).

## 13 Documents

### 13.1 CERTIFICATION

The manufacturer shall, upon request by the purchaser, furnish to the purchaser a certificate of compliance stating that the material has been manufactured, sampled, tested, and inspected in accordance with this specification and has been found to meet the requirements.

### 13.2 ELECTRONIC CERTIFICATE OF COMPLIANCE

A Material Test Report, Certificate of Compliance, or similar document printed or used in electronic form from an electronic data interchange (EDI) transmission shall be regarded as having the same validity as a counterpart printed in the certifier's facility. The content of the EDI transmitted document must meet the requirements of this specification and conform to any existing EDI agreement between the purchaser and the supplier.

# APPENDIX A—MARKING INSTRUCTIONS FOR API LICENSEES

## A.1 Marking—General

The following marking requirements apply to licensed manufacturers using the API monogram on products covered by this specification.

Pipe and pipe couplings manufactured in conformance with this specification may be marked by the licensee as specified hereinafter, or as specified in Section 12. Products to which the monogram is applied shall be marked as specified in Appendix A.

a. The required marking on pipe shall be as stipulated in A.3.

b. Size, weight per foot, length, and hydrostatic test pressure markings shall be in US Customary units except that for pipe intended for use in countries utilizing the metric system. These markings shall be in metric units, or both US Customary and metric units, if so specified on the purchase order. If not so specified, for pipe made and intended for use in countries utilizing the metric system, these markings may be given in metric units only, at the option of the manufacturer.

The location and sequence of identification markings shall be as follows:

## A.2 Location of Markings

1.900-in. OD and smaller—Die stamped on a metal tag fixed to the bundle, or may be printed on the straps or banding clips used to tie the bundle.

Seamless pipe in all other sizes and welded up to 16-in. OD—Paint stencil on the outside surface starting at a point between 18 and 30 inches from the end of the pipe, and in the sequence shown below, except when agreed between the purchaser and the manufacturer that some or all of the markings may be placed on the inside surface in a sequence convenient to the manufacturer.

Welded pipe 16-in. OD and larger—Paint stencil on the inside surface starting at a point no less than 6 in. from the end of the pipe in a sequence convenient to the manufacturer, unless otherwise specified by the purchaser.

## A.3 Sequence of Markings

The sequence of identification markings shall be as follows:

a. Manufacturer's API License Number. (The manufacturer's name or mark is optional.) The manufacturer's API license number shall be die stamped or paint-stenciled, at the option of the manufacturer.

b. API Monogram (  ) and Date.

The API monogram () immediately followed by the date of manufacture (defined as the month and year in which the monogram is applied), shall be applied only to products complying with the requirements of the specification and only by authorized manufacturers.

c. Sizes. The outside diameter in inches followed by the nominal wall thickness of base metal and CRA layer, in inches.

d. Weight per Foot. For sizes $4^1/_2$ in. and larger, the calculated weight using the formula in 9.1, in pounds per foot for plain-end pipe, shall be paint-stenciled.

e. Grade. The symbols to be used are as follows:

X (Yield Strength of Base Metal) /LC (Cr5, Ni5 of CRA Layer)

f. Process of Manufacture (Base Material and CRA layer). The symbols to be used are as follows:

| | |
|---|---|
| Seamless | S |
| Welded | E |
| Centrifugal Cast | C |
| Lined | L |

g. Heat Treatment. The symbols to be used are as follows:

| | |
|---|---|
| Normalized | N |
| As-rolled | AR |
| Quench and Tempered | HQ |
| Solution Anneal | H |

h. Test Pressure. When the specified hydrostatic test pressure is higher than the pressure in 8.3, the test pressure in pounds per square inch, preceded by the word TESTED, shall be paint-stenciled.

i. Supplementary Requirements. See Appendix B.

Example:

14-inch NPS 0.375 base metal wall thickness, 0.120 inch CRA layer wall thickness, Grade X70 seamless base metal, LC 30-1812 CRA lined, solution annealed, seamless should be stenciled as follows:

5LD XXXX.X  (MO-YR) 14

× .375/.120 71.68 X70S/LC 1812 SLH

Note: The weight per foot (71.68) is computed by the formula in 9.1.

## A.4 Length

In addition to the identification markings stipulated in 12.1 and 12.2, the length shall be marked as follows:

a. For pipe in sizes larger than 1.900-in. OD, the length in feet and tenths of a foot, unless otherwise specified on the purchase order, as measured on the finished pipe shall be paint-stenciled on the outside surface at a place convenient to the manufacturer, except by agreement between the purchaser

and the manufacturer that the length marking may be placed inside the pipe at a convenient location.

b. For sizes 1.900-in. OD and smaller, the total length of pipe in the bundle in feet and tenths of a foot, unless otherwise specified on the purchase order, shall be marked on the tag, band, or clip.

## A.5 Die Stamping

Cold die stamping of all grades of plate or pipe not subsequently heat-treated, and all pipe with a wall thickness of 0.156 in. and less, is prohibited, except that by agreement between the purchaser and the manufacturer, and when so specified on the purchase order, pipe or plate may be cold die stamped. The manufacturer at his option may hot die stamp (200°F [93°C] or higher) plate or pipe, cold die stamp plate, or pipe, if it is subsequently heat-treated. Cold die stamping shall be done with rounded or blunt dies. All die stamping shall be at least 1 in. (25 mm) from the weld for all grades. Either etching or marking with a vibrograph are permitted in lieu of cold die stamping.

## A.6 Pipe Processor Markings

Pipe heat-treated by a processor other than the original pipe manufacturer shall be marked as stipulated in 12.1, 12.2, 12.3, and 12.4. The processor shall remove any identity which is not indicative of the new condition of the product as a result of heat-treating (i.e., prior grade identity, original pipe manufacturer's name or logo).

# APPENDIX B—SUPPLEMENTARY REQUIREMENTS

By agreement between the purchaser and manufacturer and when specified on the purchase order the following supplementary requirements shall apply.

## B.1 Supplementary Requirement 1 (SR 1) Nondestructive Testing of Metallurgically-Bonded Clad Pipe

### SR 1 Inspection

Each full length of pipe shall be inspected by the ultrasonic method for the soundness of the bonding between the CRA layer and the base material. In the case of welded clad pipe, this inspection may be conducted on clad pipe or skelp used for the welded clad pipe, at the option of the manufacturer. The inspection procedure and the acceptance criteria shall be agreed upon between the purchaser and the manufacturer.

## B.2 Supplementary Requirement 2 (SR 2) Nondestructive Inspection of Mechanically-Bonded Lined Pipe

### SR 2 Inspection

Each full length of the pipe shall be inspected by appropriate nondestructive methods for tightness between the base material and the CRA layer. The inspection procedure and acceptance criteria shall be agreed upon between the purchaser and the manufacturer.

# APPENDIX C—PURCHASER INSPECTION

## C.1 Inspection Notice

Where the inspector representing the purchaser desires to inspect pipe or witness tests, reasonable notice shall be given of the time at which the run is to be made.

## C.2 Plant Access

The inspector representing the purchaser shall have unrestricted access at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that will concern the manufacture of the pipe ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy the inspector that the pipe is being manufactured in accordance with this specification. All inspections should be made at the place of manufacture prior to shipment unless otherwise specified on the purchase order, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

## C.3 Compliance

The manufacturer is responsible for complying with all of the provisions of this specification. The purchaser may make any investigation necessary to assure compliance by the manufacturer and may reject any material that does not comply with this specification.

## C.4 Rejection

Unless otherwise provided, material that shows defects on inspection or subsequent to acceptance at the manufacturer's works, or material that proves defective when properly applied in service, may be rejected and the manufacturer so notified. If tests that require the destruction of material are made, any product proven not to have met the requirements of the specification shall be rejected. Disposition of rejected product shall be a matter of agreement between the manufacturer and the purchaser.

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