

# CRA Line Pipe

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## Foreword

This edition of API Specification 5LC supersedes the Third Edition and includes items approved by letter ballot through January 2014. Portions of this publication have been changed from the previous edition. Substantive changes are indicated with **gray shading and blue font**, but API makes no warranty as to the accuracy of such notations. Nonsubstantive changes will not be indicated with shading and colored font.

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Suggested revisions are invited and should be submitted to the Standards Department, API, 200 Massachusetts Avenue, NW, Suite 1100, Washington, DC 20001, [standards@api.org](mailto:standards@api.org).

## Suggestions for Ordering API CRA Line Pipe

In placing orders for line pipe to be manufactured in accordance with API Specification 5LC, the purchaser should specify the following on the purchase order:

|                                          |                |
|------------------------------------------|----------------|
| Specification .....                      | API Spec 5LC   |
| Quantity .....                           |                |
| Grade .....                              | Tables 4 and 7 |
| Type of Pipe .....                       | Section 4.1 c) |
| Size .....                               |                |
| Nominal Diameter:                        |                |
| Standard-weight Plain-end Pipe .....     | Table 12       |
| Extra-strong Plain-end Pipe .....        | Table 12       |
| Double-extra-strong Plain-end Pipe ..... | Table 12       |
| Outside Diameter:                        |                |
| Regular-weight Plain-end Pipe .....      | Table 12       |
| Special Plain-end Pipe .....             | Table 12       |
| Weight per Foot or Wall Thickness .....  | Table 12       |
| Nominal Length .....                     | Section 10.5   |
| End Finish .....                         | Section 10     |
| Delivery Date and Shipping Instructions  |                |

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

|                                                          |                           |
|----------------------------------------------------------|---------------------------|
| Certificate of Compliance .....                          | Section 1.5               |
| Chemical Analysis Test Reports .....                     | Section 6.5               |
| Acceptance and Maximum Allowable Percent of Joints ..... | Section 10.7              |
| Alternative Bevel, Plain-end Pipe in Sizes               |                           |
| 2 <sup>3</sup> / <sub>8</sub> in. OD and larger .....    | Section 10.8              |
| Defect Repair Procedures .....                           | Sections 12.7, 12.8, 12.9 |
| Markings in Metric Units .....                           | Section 13.1 b)           |
| Purchaser Inspection .....                               | Annex G                   |
| Monogram Marking * .....                                 | Annex A, Section A.4      |

\* 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 Institute separately from the specification. The policy describing licensing and use of the monogram is contained in Annex A. No other use of the monogram is permitted. Nonlicensees may mark products in conformance with Section 13 and licensees may mark products in conformance with Annex A or Section 13.

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

|                                                |                           |
|------------------------------------------------|---------------------------|
| Chemical Composition .....                     | Section 6.1               |
| Intermediate Grades .....                      | Section 7.1, Table D.1    |
| Flattening Test Orientation .....              | Section 7.9               |
| Intermediate Diameters .....                   | Section 10.2              |
| Intermediate Wall Thickness .....              | Section 10.3              |
| Supplementary Requirements .....               | Annex B                   |
| Supplementary Hydrostatic Test .....           | Section 9.4               |
| Hydrostatic Test Pressure .....                | Section 9.3               |
| Lengths Applied to Carloads .....              | Table 16                  |
| Nonstandard Length and Length Tolerances ..... | Section 10.5              |
| Repair of Welds of Electric-welded Pipe .....  | Section 12.7 b)           |
| Marking Requirements .....                     | Sections 13.1, 13.4, 13.5 |

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# CRA Line Pipe

## 1 Scope

### 1.1 Coverage

This specification covers seamless, centrifugal cast, and welded alloy line pipe with improved corrosion resistant properties. 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.

The size designations are nominal pipe sizes (NPS). 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. The primary product is beveled pipe. If plain-end square cut or other special end preparation is desired, this shall be subject to agreement between the purchaser and manufacturer. Included are NPS 1 in. through 42 in. Grades covered by this specification are LC30-1812, LC52-1200, LC65-2205, LC65-2506, LC30-2242, and [LC80-2507<sup>1</sup>](#).

### 1.2 Application of the API Monogram

If product is manufactured at a facility licensed by API and it is intended to be supplied bearing the API Monogram, the requirements of Annex A apply.

## 2 Normative References

For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies. For a list of other documents and articles associated with this standard, please see the Bibliography. The following referenced documents, either referenced in full or in part, are indispensable for the application of this document.

API Specification 5L, *Specification for Line Pipe*

API Specification Q1, *Specification for Quality Management System Requirements for Manufacturing Organizations for the Petroleum and Natural Gas Industry*

[ANSI<sup>2</sup>/NACE<sup>3</sup> MR0175, Petroleum and natural gas industries—Material for use in H<sub>2</sub>S-containing environments in oil and gas production—Part 3: Cracking-resistant CRAs \(corrosion-resistant alloys\) and other alloys](#)

ASTM A262<sup>4</sup>, *Standard Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels, Practice E*

ASTM A370, *Methods and Definitions for Mechanical Testing of Steel Products, Annex II—Steel Tubular Products*

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

ASTM E4, *Practices for Load Verification of Testing Products*

ASTM E10, *Standard Method of Test for Brinell Hardness of Metallic Materials*

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<sup>1</sup> [Seamless only.](#)

<sup>2</sup> American National Standards Institute, 1899 L Street, NW, 11th Floor, Washington, DC 20036, [www.ansi.org](http://www.ansi.org).

<sup>3</sup> NACE International, 1440 South Creek Drive, Houston, Texas 77084, [www.nace.org](http://www.nace.org).

<sup>4</sup> ASTM International, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428, [www.astm.org](http://www.astm.org).

ASTM E18, *Standard Methods of Tests for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials*

ASTM E83, *Method of Verification and Classification of Extensometers*

ASTM E562, *Practice for Determining Volume Fraction by Systematic Manual Point Count*

ISO/TR 9769<sup>5</sup>, *Steel and iron—Review of available methods of analysis*

ISO 15156-3, *Petroleum and natural gas industries-Material for use in H<sub>2</sub>S-containing environments in oil and gas production—Part 3: Cracking-resistant CRAs (corrosion-resistant alloys) and other alloys*

### 3 Terms, Definitions, and Abbreviations

#### 3.1 Terms and Definitions

For the purposes of this specification the following definitions apply.

##### 3.1.1

##### **heat**

The metal produced by a single cycle of a batch melting process.

##### 3.1.2

##### **heat analysis**

The chemical analysis representative of a heat as reported by the producer.

##### 3.1.3

##### **inspection**

The process of measuring, examining, testing, gaging, or otherwise comparing the unit of product with the applicable requirements.

##### 3.1.4

##### **lot**

A definite quantity of product manufactured under conditions that are considered uniform, for the attribute to be inspected.

##### 3.1.5

##### **lot size**

The number of units of product in a lot.

##### 3.1.6

##### **manufacturer**

Refers to the firm, company, or corporation responsible for marking the product to warrant that the product conforms to the specification.

NOTE 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.

##### 3.1.7

##### **pipe mill**

A firm, company, or corporation that operates pipe-making facilities.

<sup>5</sup> International Organization for Standardization, 1, ch. de la Voie-Creuse, CH-1211 Geneva 20, Switzerland, [www.iso.org](http://www.iso.org).

**3.1.8****processor**

A firm, company, or corporation that operates facilities capable of heat treating pipe made by a pipe mill.

**3.2 Abbreviations**

For the purposes of this specification the following abbreviations apply.

|      |                                  |
|------|----------------------------------|
| EDI  | electronic data interchange      |
| ERW  | electric resistance welding      |
| HAZ  | heat-affected zone               |
| HRC  | Rockwell hardness C scale        |
| NPS  | nominal pipe size                |
| SMYS | specified minimum yield strength |
| UNS  | unified numbering system         |

**4 General Information****4.1 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 inside diameters are calculated from the metric outside diameters and wall thicknesses and rounded to the nearest 0.1 mm.

Metric plain-end weights are included from the metric outside diameters and wall thicknesses using the equations in 10.1 and rounded to the nearest 0.01 kg/m (0.01 lb/ft).

Metric hydrostatic pressures are calculated from metric outside diameters and wall thicknesses and metric fiber stresses shown in Section 9.

The factors used where conversions are appropriate are as follows:

|                                   |   |                                                      |
|-----------------------------------|---|------------------------------------------------------|
| 1 inch (in.)                      | = | 25.4 millimeters (mm) exactly                        |
| 1 square inch (in. <sup>2</sup> ) | = | 645.16 square millimeters (mm <sup>2</sup> ) 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                 |
|                                   | = | 0.006895 megapascals (MPa) for stress                |
| 1 foot-pound (ft-lb)              | = | 1.3558 Joules (J) for impact energy                  |

Equation (1) below was used to convert degrees Fahrenheit (°F) to degrees Celsius (°C):

$$^{\circ}\text{C} = \frac{5}{9} (^{\circ}\text{F} - 32) \quad (1)$$

## 4.2 Measuring Devices

If test or measuring equipment, whose calibration or verification is required under the provisions of the specification, is subjected to unusual or questionable conditions, recalibration or reverification shall be performed before further use of the equipment.

## 4.3 Special Processes

Special processes are the final operations that are performed during pipe manufacturing that affect attribute compliance required in this specification (except chemistry and dimensions). The applicable special processes are provided in Table 1.

**Table 1—Special Processes for Manufacturing Conditions**

| Manufacturing Condition     | Special Processes                                                                                                             |
|-----------------------------|-------------------------------------------------------------------------------------------------------------------------------|
| Seamless                    |                                                                                                                               |
| As-rolled (nonexpanded)     | Final reheating and hot sizing or stretch reduction. Cold finishing if applied and repair welding. Nondestructive inspection. |
| As-rolled (expanded)        | Expansion, repair welding. Nondestructive inspection.                                                                         |
| Heat treated                | Heat treatment, repair welding. Nondestructive inspection.                                                                    |
| Centrifugally cast          |                                                                                                                               |
| As-cast (nonexpanded)       | Final reheating and hot sizing or stretch reduction. Cold finishing if applied and repair welding. Nondestructive inspection. |
| As-cast (expanded)          | Expansion, repair welding. Nondestructive inspection.                                                                         |
| Heat treated                | Heat treatment, repair welding. Nondestructive inspection.                                                                    |
| Welded without filler metal |                                                                                                                               |
| As-rolled (nonexpanded)     | Seam welding and sizing, if applicable, seam heat treatment, repair welding. Nondestructive inspection.                       |
| As-rolled (expanded)        | Expansion and seam welding. If applicable, seam heat treatment, repair welding. Nondestructive inspection.                    |
| Heat treated                | Seam welding and full-body heat treatment. If applicable, repair welding. Nondestructive inspection.                          |
| Welded with filler metal    |                                                                                                                               |
| As-rolled (nonexpanded)     | Pipe forming, seam welding, and repair welding. Nondestructive inspection.                                                    |
| As-rolled (expanded)        | Expansion and seam welding and repair welding. Nondestructive inspection.                                                     |
| Heat treated                | Seam welding, repair welding, and full-body heat treatment. Nondestructive inspection.                                        |
| As-rolled                   | Seam welding and sizing. Nondestructive inspection.                                                                           |

## 4.4 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.

Where additional information is required, including the results of mechanical testing, SR15 (Annex B) shall be specified on the purchase order.

A material test report, certificate of compliance or similar document printed from 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 shall meet the requirements of this specification and conform to any existing EDI agreement between the purchaser and the supplier.

## 4.5 Retention of Records

Tests and inspections requiring retention of records in this specification are shown in Table 2. Such records shall be retained by the manufacturer and shall be made available to the purchaser upon request for a period of at least three years after the date of purchase from the manufacturer.

**Table 2—Retention of Records**

| Test/Inspection                      | Section          |
|--------------------------------------|------------------|
| Chemical properties                  |                  |
| Heat analysis                        | 6.2              |
| Product analysis                     | 6.2              |
| Mechanical tests                     |                  |
| Tensile tests                        | 7.1 to 7.4       |
| Weld tensile tests                   | 7.5              |
| Mill control tests                   | 7.6              |
| Guided-bend tests                    | 7.14             |
| Hydrostatic tests                    |                  |
| Tester recorder charts (where used)  | 9.2              |
| Supplementary hydrostatic tests      | 9.4              |
| Nondestructive testing               |                  |
| Film (where used) fluoroscopic       | 11.4             |
| Operator qualifications              | 11.5             |
| Repair welding procedure             |                  |
| Transverse tensile test              | C.2.3.2          |
| Longitudinal tensile-elongation test | C.2.3.3          |
| Transverse guided-bend test          | C.2.3.4          |
| Nick-break test                      | C.2.3.5          |
| Procedure specification              | C.1              |
| Procedure qualification              | C.2              |
| Personnel performance qualification  | C.3              |
| Calibration tests                    | Various sections |

## 5 Process of Manufacture and Material

### 5.1 Process of Manufacture

Welded pipe may be furnished in any combination of the listed welding processes, as agreed upon between the purchaser and manufacturer. Pipe furnished to this specification shall be seamless, welded, or centrifugally cast as defined below.

- a) *Seamless and Centrifugally Cast.*

- 1) *Seamless* is defined as wrought tubular product made without a welded seam. It is manufactured by hot working steel or, if necessary, by subsequently cold finishing the hot worked product.
- 2) *Centrifugally cast* is defined as a casting technique in which the mold is rotated during solidification of the casting.

b) *Welded Processes.*

- 1) *Without Filler Metal.* Electric weld (applicable to LC30-1512 and full-body heat-treated duplex alloys only). A process of forming a seam by electric-resistance welding, or induction welding wherein the edges to be welded are mechanically pressed together and the heat for welding is generated by the resistance-to-flow of electric current.
- 2) *With Filler Metal.*
  - i) *Submerged Arc Welding.* A welding process that produces coalescence of metals by heating them with an arc or arcs between a bare metal electrode or electrodes and the work. The arc and molten metal are shielded by a blanket of granular, fusible material on the work. Pressure is not used, and the filler metal is obtained from the electrode.
  - ii) *Gas Metal Arc Welding.* A welding process that produces coalescence of metals by heating them with an arc or arcs between a continuous filler metal electrode and the work. Shielding is obtained entirely from an externally supplied gas. Pressure is not used and filler metal is obtained from the electrode.
- 3) *With or Without Filler Metal.*
  - i) *Plasma Arc Welding.* An arc welding process that produces coalescence of metals by, heating them with a constricted arc between the electrode and the workpiece (transferred arc) or the electrode and the constricting nozzle (nontransferred arc). Shielding is obtained from the hot, ionizing gas issuing from the torch, which may be supplemented by an auxiliary source of shielding gas. Shielding gas may be an inert gas or a mixture of gases. Pressure may or may not be used and filler metal may or may not be supplied.
  - ii) *Gas Tungsten Arc Welding.* An arc welding process that produces coalescence of metals by heating them with an arc between a tungsten electrode (nonconsumable) and the work pieces. Shielding is obtained from a gas. Pressure may or may not be used and filler metal may or may not be used.

c) *Pipe-making Processes (See Table 3).*

- 1) *Seamless.* Seamless pipe is produced by the seamless process defined above in 5.1.
- 2) *Centrifugally Cast.* Centrifugally cast pipe is produced by the centrifugal casting process defined above in 5.1 a) 2). The entire inner surface of centrifugally cast pipe shall be machined. The outer surface may be machined as well, when agreed upon between the purchaser and the manufacturer.
- 3) *Electric Weld.* Electric-welded pipe is defined as having one longitudinal seam produced by the electric welding process as defined in 5.1 b) 1).
- 4) *Submerged Arc.* Submerged arc welded pipe is defined as having one longitudinal seam produced by the automatic submerged arc welding process as defined in 5.1 b) 2) i). At least one pass shall be on the inside and one pass on the outside. All end welding of submerged arc welded pipe, if not done by automatic submerged arc welding, shall be done by a procedure and a welder qualified in accordance with Annex C of this specification.

**Table 3—Pipe Manufacturing Processes**

| Manufacturing Process                 | No Seam | One Longitudinal Seam | Double Seam |
|---------------------------------------|---------|-----------------------|-------------|
| 1) Without welds                      |         |                       |             |
| a) Seamless                           | X       |                       |             |
| b) Centrifugally cast                 | X       |                       |             |
| 2) Welding processes                  |         |                       |             |
| a) Without filler metal electric weld |         | X                     |             |
| b) With filler metal                  |         |                       |             |
| i) Submerged arc                      |         | X                     | X           |
| ii) Gas metal arc                     |         | X                     | X           |
| c) With or without filler metal       |         |                       |             |
| i) Plasma arc                         |         | X                     | X           |
| ii) Gas tungsten arc                  |         | X                     | X           |
| iii) Combination welding              |         | X                     | X           |

5) *Gas Metal Arc*. Gas metal arc welded pipe is defined as having one longitudinal seam produced by the continuous gas metal arc welding process as defined in 5.1 b) 2) ii). At least one pass shall be on the inside and one pass on the outside.

6) *Combination Welding*. Combination welded pipe is defined as pipe having one longitudinal or double seam produced by a combination of welding processes defined in 5.1 b) 2) and 5.1 b) 3).

7) *Double Seam*. Double seam pipe is defined as pipe having two longitudinal seams formed by welding. The location of the seams shall be approximately 180° apart. All requirements specified for the welding process used shall be applicable to double seam pipe. All weld tests shall be performed after forming and welding.

d) *Tack Welding*. A tack weld is defined as a weld made to hold parts of a weldment in proper alignment until the final welds are made. Tack welds may be by any of the processes described in 5.1 b). They shall be removed by machining or remelted by subsequent arc welding. They are not subject to the subsequent weld requirements of this specification.

e) *Jointer Weld*. A jointer weld is a circumferential seam weld that joins two pieces of pipe together.

## 5.2 Cold Expansion

Cold expansion up to 1.5 % for sizing shall be permitted if agreed upon between the purchaser and the manufacturer.

### 5.3 Heat Treatment

Pipe furnished to this specification may be as-rolled, solution annealed<sup>6</sup>, except LC52-1200, which shall be quenched and tempered. Other appropriate heat treatment may be agreed upon between purchaser and manufacturer.

### 5.4 Traceability

The manufacturer shall establish and follow procedures for maintaining heat and/or lot identity until all required heat and/or lot tests are performed and conformance with specification requirements has been shown.

### 5.5 Hydrogen Sulfide Environments

For any grade, if the intended application is for use in an environment that contains hydrogen sulfide then this should be clearly stated in the purchase agreement.

Where use in an environment containing hydrogen sulfide is stated in the purchase agreement, all requirements of ANSI/NACE MR0175 and ISO 15156-3 shall be satisfied.

In such cases, sour service designation marking according to ANSI/NACE MR0175 and ISO15156-3, Annex C shall be applied.

## 6 Chemical Properties and Tests

### 6.1 Composition

The composition of pipe furnished to this specification, as determined by heat analyses, shall conform to the chemical requirements specified in Table 4.

If necessary, all grades listed in Table 4, column 1 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 after the ksi value of yield strength using Equation (2) as follows:

$$LC(YS \text{ ksi}) - (Cr \%)(Ni \%) \quad (2)$$

### 6.2 Heat Analyses

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 pipe furnished on the purchaser order. The analysis so determined shall conform to the requirements specified in 6.1.

If elements other than those specified in Table 4 for a particular grade are added for other than deoxidation purposes, the heat analyses, including the element additions, shall be reported for each heat applied to the purchaser's order.

<sup>6</sup> 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 4—Chemical Requirements for Heat Analyses, Percent (%)

| 1                   | 2     | 3    | 4     | 5     | 6    | 7    | 8    | 9    | 10   | 11  | 12  | 13   | 14   |      |      |        |      |                             |                            |
|---------------------|-------|------|-------|-------|------|------|------|------|------|-----|-----|------|------|------|------|--------|------|-----------------------------|----------------------------|
| Grades <sup>a</sup> | C     | Mn   | P     | S     | Si   | Ni   |      | Cr   |      | Mo  |     | N    |      | Cu   |      | Others |      | UNS <sup>b</sup><br>Numbers | Material<br>Classification |
|                     | Max   | Max  | Max   | Max   | Max  | Min  | Max  | Min  | Max  | Min | Max | Min  | Max  | Min  | Max  | Min    | Max  |                             |                            |
| LC30-1812           | 0.030 | 2.00 | 0.040 | 0.030 | 0.75 | 10.0 | 15.0 | 16.0 | 18.0 | 2.0 | 3.0 | —    | —    | —    | —    | —      | —    | S31603 or S31653            | Austenitic<br>Stainless    |
|                     |       |      |       |       |      |      |      |      |      |     |     |      |      |      |      |        |      |                             |                            |
| LC52-1200           | 0.08  | 1.00 | 0.040 | 0.030 | 0.75 | —    | 0.5  | 11.5 | 13.5 | —   | —   | —    | —    | —    | —    | —      | —    | S41008                      | Martensitic Stainless      |
|                     |       |      |       |       |      |      |      |      |      |     |     |      |      |      |      |        |      |                             |                            |
| LC65-2205           | 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 | —    | —    | —      | —    | S31803                      | Duplex<br>Stainless        |
|                     |       |      |       |       |      |      |      |      |      |     |     |      |      |      |      | W      |      |                             |                            |
| LC65-2506           | 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 | —    | 1.5  | —      | 0.50 | S31260                      | Duplex<br>Stainless        |
|                     |       |      |       |       |      |      |      |      |      |     |     |      |      |      |      |        | W    |                             |                            |
| LC80-2507           | 0.030 | 1.00 | 0.030 | 0.020 | 0.80 | 6.0  | 8.0  | 24.0 | 26.0 | 2.5 | 3.5 | 0.24 | 0.32 | 0.20 | 0.80 | 1.5    | 2.5  | S39274                      | Duplex<br>Stainless        |
|                     | 0.030 | 1.00 | 0.030 | 0.010 | 1.00 | 6.0  | 8.0  | 24.0 | 26.0 | 3.0 | 4.0 | 0.20 | 0.30 | 0.50 | 1.00 | 0.5    | 1.0  | S32760                      |                            |
|                     | 0.030 | 1.20 | 0.035 | 0.020 | 0.80 | 6.0  | 8.0  | 24.0 | 26.0 | 3.0 | 5.0 | 0.24 | 0.32 | —    | —    | —      | —    | S32750                      |                            |
|                     |       |      |       |       |      |      |      |      |      |     |     |      |      |      |      | Ti     |      |                             |                            |
| LC30-2242           | 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  | 0.6    | 1.20 | N08825                      | Ni Base Alloy              |

<sup>a</sup> For editorial purposes, the first four (4) alphanumerices of the grade designation are used to describe the grades in this document.

<sup>b</sup> Unified numbering system (UNS) numbers do not show exactly the same chemical compositions depicted in this table.

<sup>a</sup> For editorial purposes, the first four (4) alphanumeric of the grade designation are used to describe the grades in this document.<sup>b</sup> Unified numbering system (UNS) numbers do not show exactly the same chemical compositions depicted in this table.

### 6.3 Product Analyses

One test from each of two lengths of pipe or plate or skelp from each lot size as indicated in Table 5 below shall be analyzed for product analyses by the manufacturer. The results of the analyses shall be available to the purchaser on request.

**Table 5—Purchaser Provided Analysis**

| Grade      | Size<br>(in.)                            | Lot Size<br>(no. of lengths) |
|------------|------------------------------------------|------------------------------|
| All Grades | 1 through 12 <sup>3</sup> / <sub>4</sub> | 200 or less                  |
|            | 14 and over                              | 100 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.

- Seamless Pipe.* At the option of the manufacturer, samples used for product analyses shall be taken either from tensile test specimens or from the finished pipe.
- Welded Pipe.* At the option of the manufacturer, samples used for product analyses 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.

For pipe manufactured from plate or skelp, the product analyses may be made by the supplier of the plate or skelp, providing the analyses are made in accordance with the frequency requirement stated above.

The composition so determined shall conform to the chemical requirements shown in Table 4 within the permissible variations for product analyses shown in Table 6, where the permissible variations shall be applied to under-minimum or over-maximum of specified limit of element.

### 6.4 Recheck Analyses

If the product analyses 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 that 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.

### 6.5 Control Analyses

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

### 6.6 Chemical Analyses Procedures

Methods of analysis methods and practices relating to chemical analysis shall be performed in accordance with ASTM A751 or [ISO/TR 9769](#). Calibrations performed shall be traceable to established standards.

**Table 6—Permissible Variation for Product Analyses of CRA Line Pipe**

| Element    | Specified Limit of Element | Permissible Variation |
|------------|----------------------------|-----------------------|
| Carbon     |                            | 0.01                  |
| Manganese  |                            | 0.04                  |
| Phosphorus |                            | 0.005                 |
| Sulfur     |                            | 0.005                 |
| Silicon    |                            | 0.05                  |
| Nickel     | over 1.00 to 5.00, incl    | 0.07                  |
|            | over 5.00 to 10.00, incl   | 0.10                  |
|            | over 10.00 to 20.00, incl  | 0.15                  |
|            | over 20.00 to 25.00, incl  | 0.20                  |
|            | over 25.00 to 30.00, incl  | 0.25                  |
|            | over 30.00 to 40.00, incl  | 0.30                  |
|            | over 40.00 to 60.00, incl  | 0.35                  |
| Chromium   | over 10.00 to 15.00, incl  | 0.15                  |
|            | over 15.00 to 20.00, incl  | 0.20                  |
|            | over 20.00 to 25.00, incl  | 0.25                  |
|            | over 25.00 to 30.00, incl  | 0.30                  |
| Molybdenum | over 1.00 to 3.00, incl    | 0.05                  |
|            | over 3.00 to 5.00, incl    | 0.10                  |
|            | over 5.00 to 20.00, incl   | 0.15                  |
| Nitrogen   | over 0.02 to 0.20, incl    | 0.01                  |
|            | over 0.20 to 0.25, incl    | 0.02                  |
|            | over 0.25 to 0.30, incl    | 0.03                  |
| Copper     |                            | 0.05                  |
| Tungsten   |                            | 0.04                  |
| Titanium   |                            | 0.05                  |

## 7 Mechanical Properties and Tests

### 7.1 Tensile Tests—General

All grades listed in this specification shall conform to the tensile requirements specified in Table 7. 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 7. The yield strength shall be the tensile stress required to produce a total elongation of 0.5 % of the gauge length as determined by an extensometer. When elongation is recorded or reported, the record or report shall show the nominal width of the test specimen when strip specimens are used, or state when full specimens are used.

Table 7—Tensile Requirements

| 1                                                                                                                                                                                                                                                                                | 2                                |       | 3                              |       | 4                                 | 5                          | 6               |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------|-------|--------------------------------|-------|-----------------------------------|----------------------------|-----------------|
| Grade                                                                                                                                                                                                                                                                            | Yield Strength min. <sup>a</sup> |       | Ultimate Tensile Strength min. |       | Elongation, min. percent in 2 in. | UNS Numbers <sup>b</sup>   | Max Hardness Rc |
|                                                                                                                                                                                                                                                                                  | psi                              | MPa   | psi                            | MPa   |                                   |                            |                 |
| LC30-1812                                                                                                                                                                                                                                                                        | 30,000                           | (207) | 70,000                         | (482) | 25                                | S31603<br>S31653           | —               |
| LC52-1200                                                                                                                                                                                                                                                                        | 52,000                           | (358) | 66,000                         | (455) | 20                                | S41008                     | 22              |
| LC65-2205                                                                                                                                                                                                                                                                        | 65,000                           | (448) | 90,000                         | (621) | 25                                | S31803                     | —               |
| LC65-2506                                                                                                                                                                                                                                                                        | 65,000                           | (448) | 95,000                         | (656) | 25                                | S31260                     | —               |
| LC80-2507                                                                                                                                                                                                                                                                        | 80,000                           | (552) | 110,000                        | (758) | 20                                | S39274<br>S32760<br>S32750 | —               |
| LC30-2242                                                                                                                                                                                                                                                                        | 30,000                           | (207) | 80,000                         | (551) | 30                                | N08825                     | —               |
| <sup>a</sup> When yield strength is changed by the modification of chemical composition or heat treatment, a grade designation shall be changed with ksi value of yield strength.<br><sup>b</sup> UNS numbers do not show the exact tensile requirements depicted in this table. |                                  |       |                                |       |                                   |                            |                 |

The basic elongation shoe, listed in Table 7, column 4, is for wall thicknesses 0.500 in. and greater for 1.5 in. wide specimens. Equation (3) below is for thinner wall thicknesses:

$$e = C \times A^{0.2} \quad (3)$$

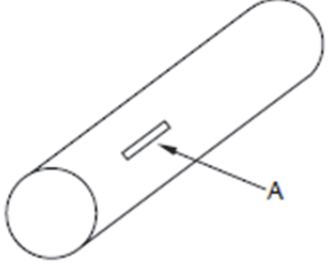
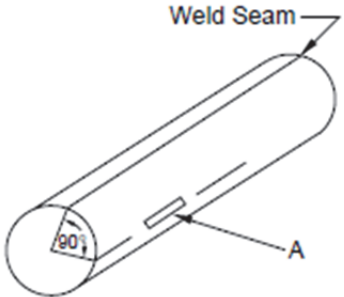
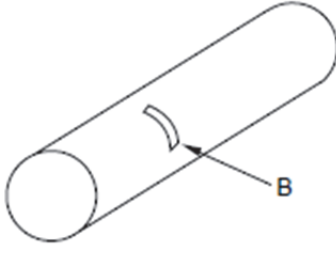
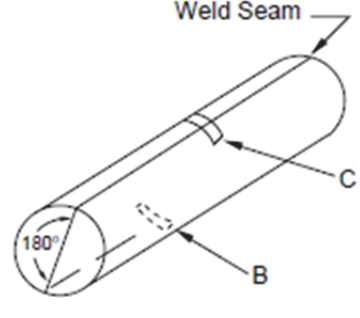
where,

- $A$  is the diameter of the guided blend test former;
- $e$  is the minimum elongation in 2 in. (to the nearest 0.5 %);
- $C$  is the constant, as shown below:
  - 26.5 for LC30-1812, LC65-2205, and LC65-2506;
  - To be developed for LC52-1200;
  - 31.8 for LC30-2242;
  - 21.2 for LC80-2507.

NOTE See Annex D for minimum elongation values calculated from this equation.

Tensile test orientation shall be as shown in Figure 1. At the option of the manufacturer, longitudinal specimens may be taken from the skelp parallel to the rolling direction and approximately midway between edge and center. Testing procedure shall conform to the requirements of the latest edition of ASTM 370. All tensile tests, except transverse weld and ring tests, shall include yield strength, ultimate tensile strength, and elongation determinations. Transverse weld tests shall include ultimate tensile strength, and ring tests shall include yield strength. All tensile tests shall be performed with the specimens at room temperature. The strain rate shall be in accordance with the requirements of the latest edition of ASTM A370. At the option of the manufacturer, the specimen may be either full section, strip specimen, or round-bar specimens according to

7.3, 7.4, and Figure 2. The type, size, and orientation of the specimens shall be reported. Strip specimens shall be approximately  $1\frac{1}{2}$  in. (38.1 mm) wide in the gauge 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  $\frac{3}{4}$  in. (19.0 mm) wide for pipe  $3\frac{1}{2}$  in. and smaller, approximately 1 in. (25.4 mm) wide for pipe 4 in. through  $6\frac{5}{8}$  in., and approximately  $1\frac{1}{2}$  in. (38.1 mm) wide for pipe  $8\frac{5}{8}$  in. and larger. 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.

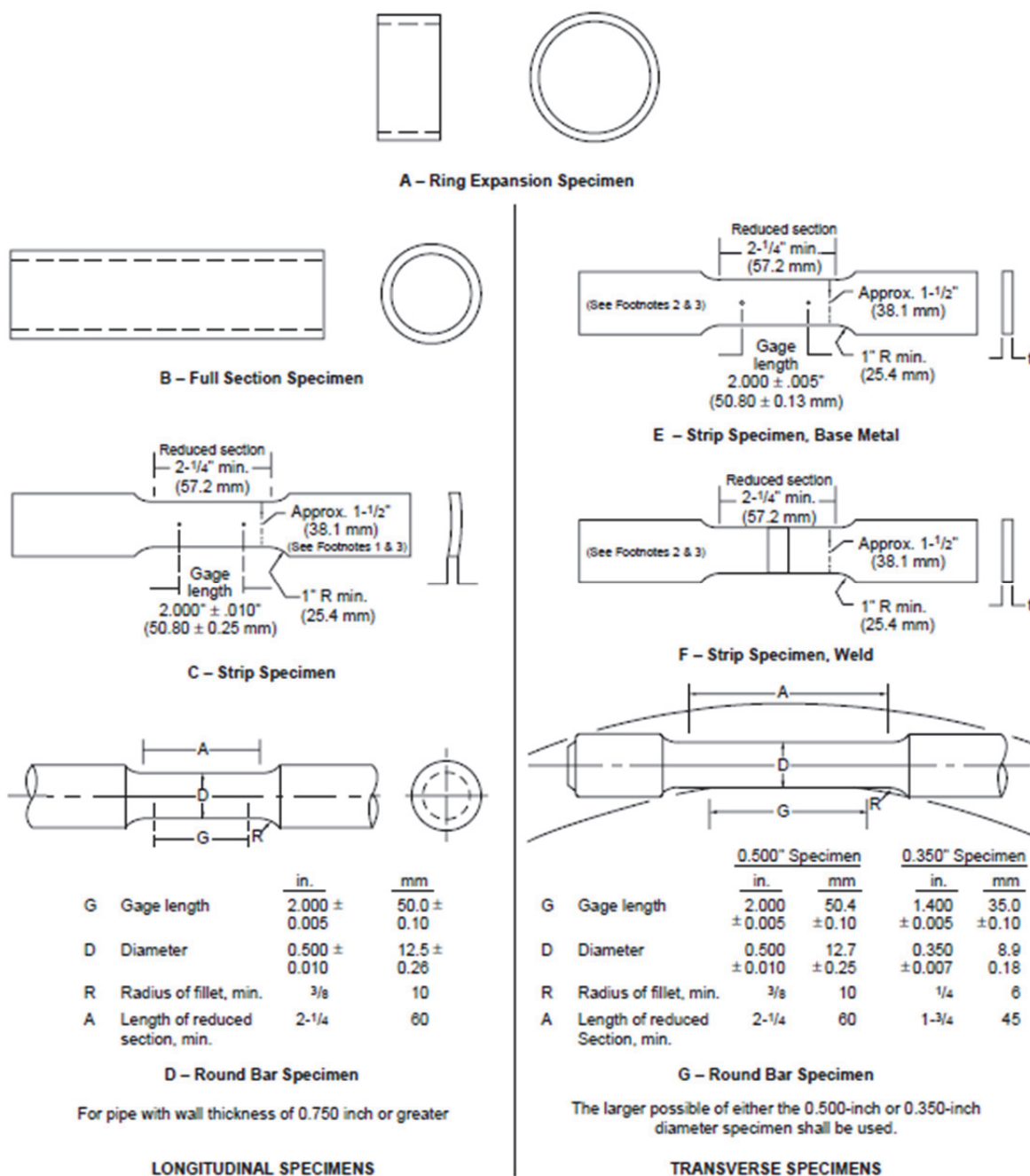
| O.D.                | Seamless Pipe,<br>Hot Rolled <sup>a</sup><br>and<br>Cold Worked                     | Welded Pipe                                                                          |
|---------------------|-------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
|                     |                                                                                     | Straight Seam                                                                        |
| $\leq 6\frac{5}{8}$ |    |    |
| $\geq 8\frac{5}{8}$ |  |  |

#### Key

- A strip specimen (any circumferential location for seamless)
- B transverse specimen (any circumferential location for seamless). For two-seam pipe, the specimen shall be taken from a location midway between the welds.
- C transverse weld specimen

<sup>a</sup> For hot-rolled seamless pipe, all tensile tests shall be obtained in the longitudinal direction, except when agreed upon between purchaser and manufacturer transverse tests may be specified for  $8\frac{5}{8}$  in. and larger.

**Figure 1—Orientation of Tensile Test Specimens**



NOTE 1 See 7.1 for gauge width if testing is not done with properly curved grips.

NOTE 2 Flattening of transverse and weld specimens shall be performed at room temperature.

NOTE 3 Hot flattening, artificial aging, or heat treatment of tensile specimens is not permitted.

**Figure 2—Tensile Test Specimens**

## 7.2 Tensile Testing

The following are requirements for all tensile testing.

- a) *Frequency.* Tensile tests shall be made at the frequency shown in Table 8.

**Table 8—Frequency of Tensile Testing**

| 1                                                                                                                                                                                     | 2                                                        | 3                                                        | 4                     |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------|----------------------------------------------------------|-----------------------|
| Size (in.)                                                                                                                                                                            | Tensile Tests                                            | Weld Tensile Tests                                       | Control Tensile Tests |
| Less than or equal to $5\frac{9}{16}$ OD                                                                                                                                              | 1 per 400 lengths                                        |                                                          |                       |
| $6\frac{5}{8}$ OD thru $12\frac{3}{4}$ OD                                                                                                                                             | 1 per 200 lengths                                        |                                                          | One per heat on       |
| $>12\frac{3}{4}$ OD                                                                                                                                                                   | 1 per 100 lengths per cold expansion amount <sup>a</sup> |                                                          | All sizes             |
| $8\frac{5}{8}$ OD thru $12\frac{3}{4}$ OD                                                                                                                                             |                                                          | 1 per 200 lengths                                        |                       |
| $>12\frac{3}{4}$ OD                                                                                                                                                                   |                                                          | 1 per 100 lengths per cold expansion amount <sup>b</sup> |                       |
| <sup>a</sup> Pipe manufactured with the same amount of cold expansion, $\pm 0.2$ %, shall be considered to have the same cold expansion.<br><sup>b</sup> Each weld for two-seam pipe. |                                                          |                                                          |                       |

For heat-treated pipe, the sample frequency shown for each size shall apply to all pipe of the same heat and thickness heat-treated in one furnace charge. For pipe heat treated in a continuous furnace, the sample frequency shown shall apply for all pipe of the same heat and thickness.

The size of the lot shown in Table 8 is maximum. For smaller lots than those shown, the frequency shall be as listed.

- b) *Equipment.* Tensile test machines shall have been calibrated within 15 months preceding any test in accordance with the procedures of ASTM E4. Extensometers shall be calibrated within 15 months preceding any test in accordance with the procedures of ASTM E83. Records retention shall be according to Section 4.

## 7.3 Longitudinal Tensile Tests

At the option of the manufacturer, longitudinal tests may utilize a full section specimen (Figure 2B), a strip specimen (Figure 2C), or for pipe with wall thickness greater than 0.750 in., a 0.500 in. diameter round-bar specimen (Figure 2.D). The trip specimen shall be tested without flattening.

## 7.4 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 (Figure 2E), or a 0.500 in. or 0.350 in. specimen (Figure 2G).
- b) The yield strength shall be determined by the ring expansion method (Figure 2A) with the ultimate strength and elongation values determined from a flattened rectangular specimen or round bar.

The same method for testing shall be employed for all lots on an order item. All transverse specimens shall be as shown in Figure 2. All specimens shall represent the full wall thickness of the pipe from which the specimen was cut, except round-bar tensile specimens. Transverse round-bar specimens shall be secured from nonflattened pipe sections, and the largest possible diameter round bar shall be used; 0.500 in. diameter round-bar specimens shall be used when the pipe size allows, and the 0.350 in. diameter round-bar specimen shall be used for other sizes. For pipe sizes too small to allow a 0.350 in. specimen, round-bar tensile specimens may not be used.

## 7.5 Weld Tensile Tests

Weld tensile test specimens as specified in Table 8 shall be taken 90° to the weld with the weld at the center as shown in Figure 1 and Figure 2 and shall represent the full wall thickness of the pipe from which the specimen was cut. Weld reinforcement may be removed at the manufacturer's option. Weld tensile tests need not include determination of yield and elongation.

## 7.6 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.

## 7.7 Retests—Tensile Tests

If the tensile test specimen representing a lot of pipe failed to conform to the specified requirements, the manufacturer may elect to make retests on two additional lengths from the same lot. If both retest specimens conform to the requirements, all the lengths in the lot shall be accepted, except for the length from which the initial specimen was taken. If one or both of the retest specimens fail to conform to the specified requirements, the manufacturer may elect to test individually the remaining lengths in the lot. In this case, determinations are required only for the particular requirements with which the specimens failed to comply in the preceding tests. Specimens for retest shall be taken in the same manner as the specimen which failed to meet the minimum requirements.

## 7.8 Defective Specimens—Tensile Tests

If any tensile test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted. When the elongation is less than that specified, and if any part of the fracture is outside the middle third of the gauge length as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

## 7.9 Flattening Tests—Electric Weld

Flattening tests shall be performed for electric-weld pipe. Frequency of testing, sample location, and test orientation are shown in Figure 3. 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.

NOTE Flattening tests with the weld at the 0° orientation may be conducted at 180° and the 90° orientation at 270° upon agreement between the purchaser and manufacturer.

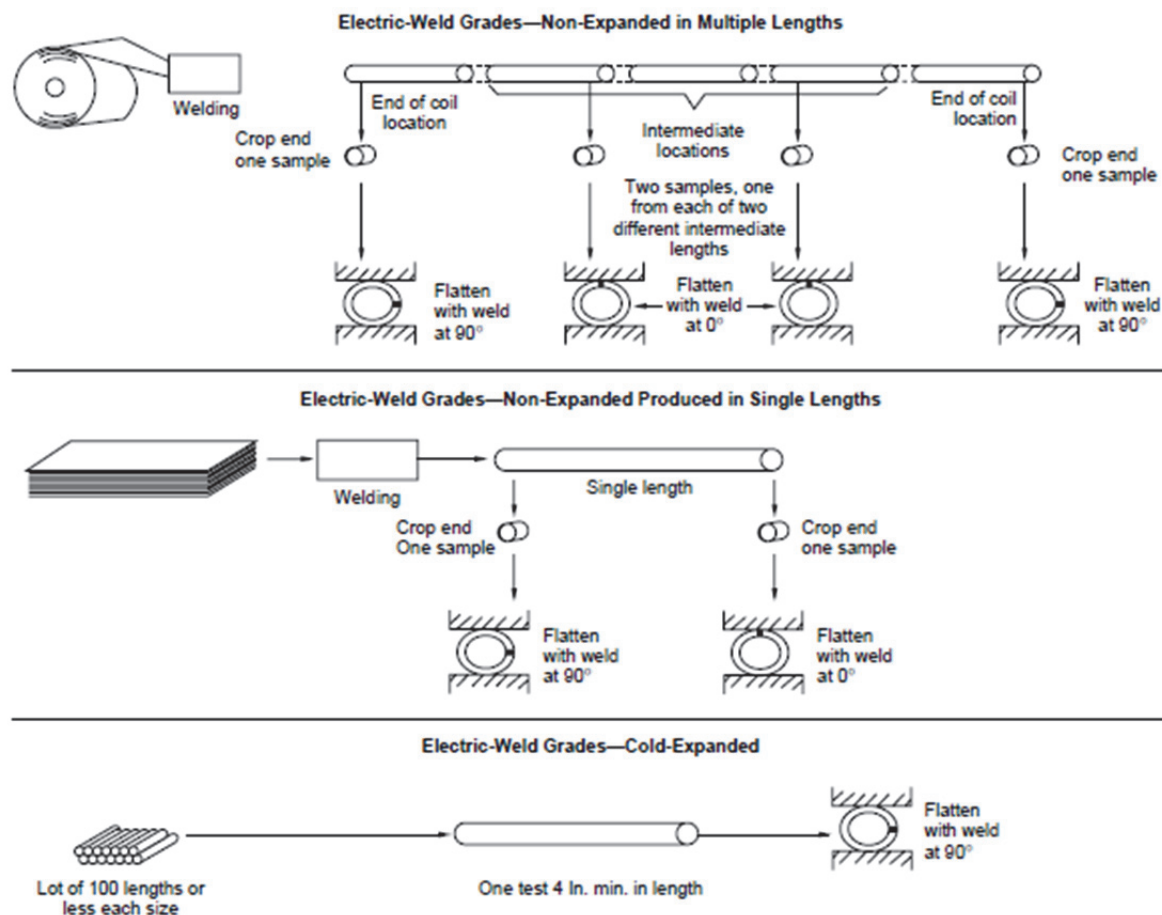


**Figure 3—Flattening Tests**

### 7.10 Acceptance Criteria—Flattening Tests

Acceptance criteria for flattening tests shall be as follows.

- Flatten to  $\frac{2}{3}$  original OD without the weld opening.
- Continue flattening to  $\frac{1}{3}$  original OD without cracks or breaks other than the weld.
- Continue flattening until opposite walls of the pipe meet.
- No evidence of lamination or burnt metal may develop during the entire test.

### 7.11 Retests—Flattening Tests

Flattening retest provisions shall be performed as shown in Table 9.

**Table 9—Flattening Retests**

| Pipe                                                                                                                                                                                                                                                                                                                                                                             | Retests                                                                                                                                                                                                                                                                                                                                                                     |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Nonexpanded electric weld produced in single lengths                                                                                                                                                                                                                                                                                                                             | Manufacturer may elect to retest any failed end until the requirements are met providing the finished pipe is not less than 80 % of its length after initial cropping.                                                                                                                                                                                                      |
| Nonexpanded electric weld produced in multiple lengths                                                                                                                                                                                                                                                                                                                           | Manufacturer may elect to retest each end of each individual length if any test fails. The retests for each end of each individual length shall be made with the weld alternately at 0° and 90°.                                                                                                                                                                            |
| Cold-expanded electric weld                                                                                                                                                                                                                                                                                                                                                      | Manufacturer may elect to retest one end from each of two additional lengths of the same lot. If both retests are acceptable, all lengths in the lot shall be accepted, except the original failed length. If one or both retests fail, the manufacturer may elect to repeat the test on specimens cut from one end of each of the remaining individual lengths in the lot. |
| <p>NOTE For the purpose of mechanical testing the weld of electric-welded pipe of 2 in. nominal and larger, "the weld" extends to a distance of <math>\frac{1}{2}</math> in. (12.7 mm) on either side of the fusion line. For pipe smaller than 2 in. nominal, "the weld" extends to a distance of <math>\frac{1}{4}</math> in. (6.35 mm) on either side of the fusion line.</p> |                                                                                                                                                                                                                                                                                                                                                                             |

## 7.12 Flattening Tests—Seamless, Centrifugally Cast, and Welded Without Filler Metal

Seamless, centrifugally cast, and welded without filler metal pipe shall be tested by flattening, except that welded without filler metal pipe, with the exception of electric resistance welding (ERW), 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  $2\frac{1}{2}$  in. (63.5 mm) in length shall be flattened cold between parallel plates in two steps. 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  $H$ , calculated using Equation (4) as follows:

$$H = \frac{1.09t}{\left(0.09 + \frac{t}{D}\right)} \quad (4)$$

where

$H$  is the distance between flattening plates, in. (mm);

$t$  specified 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 the specimen breaks or the opposite walls of the pipe meet.

- Frequency of Test.** One end of each pipe shall be tested for centrifugally cast. For seamless and welded pipe without filler metal, except ERW, two tests per lot of 50 maximum.
- 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.

### 7.13 Weld With Filler Metal Manipulation 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.

### 7.14 Guided-Bend Test

One face bend and one root bend specimen, both conforming to Figure 4 shall be bent approximately 180° in a jig, substantially in accordance with Figure 5. For any combination of diameter, wall thickness, and grade, the maximum value for jig Dimension “A” may be calculated by the formula illustrated in Figure 5. The manufacturer shall use a jig based on this dimension, or a smaller dimension at their option. However, to minimize the number of jigs required, standard values for Dimension “A” have been selected for pipe sizes 12<sup>1</sup>/<sub>4</sub> in. and larger. These values are listed for each diameter, wall thickness, and grade in Annex B.

For intermediate grades or wall thicknesses, the next smaller standard value for Dimension “A” is greater than 9 in., the length of the specimen required to contact the male die need not exceed 9 in. For pipe with wall thickness over 0.750 in., a reduced wall specimen as shown in Figure 4 may be used at the option of the manufacturer. Reduced wall specimens shall be tested in a jig with the “A” dimension calculated for 0.750 in. (19.1 mm) wall pipe of the appropriate size and grade.

The specimens shall comply with the following requirements:

- a) not fracture completely,
- b) not reveal any cracks or ruptures in the weld metal greater than <sup>1</sup>/<sub>8</sub> in. (3.18 mm) in length regardless of depth, and
- c) not reveal any cracks or ruptures in the parent metal, the heat-affected zone (HAZ), or the fusion line longer than <sup>1</sup>/<sub>8</sub> in. (3.18 mm) and deeper than 12<sup>1</sup>/<sub>2</sub> % of the specified wall thickness.

However, cracks that occur at the edges of the specimen and that are less than <sup>1</sup>/<sub>4</sub> in. (6.35 mm) long shall not be cause for rejection in Item b) or Item c) regardless of depth. If the fracture or crack in the specimen is caused by a defect or flaw, that specimen may be discarded and a new specimen substituted.

### 7.15 Retests—Guided-bend Test

If one or both of the guided-bend test specimens fail to conform to the specified requirements, the manufacturer may elect to repeat the tests on specimens cut from two additional lengths of pipe from the same lot. If such specimens conform to the specified requirements, all lengths in the lot shall be accepted, except the length initially selected for the test. If any of the retest specimens fail to pass the specified requirements, the manufacturer may elect to test specimens cut from the individual lengths remaining in the lot. The manufacturer may also elect to retest any length that has failed to pass the test by cropping back and cutting two additional specimens from the same end. If the requirements of the original test are set by both of these additional tests, that length shall be acceptable. No further cropping and retesting is permitted. Specimens for retests shall be taken in the same manner as specified in 7.14 and 7.15.

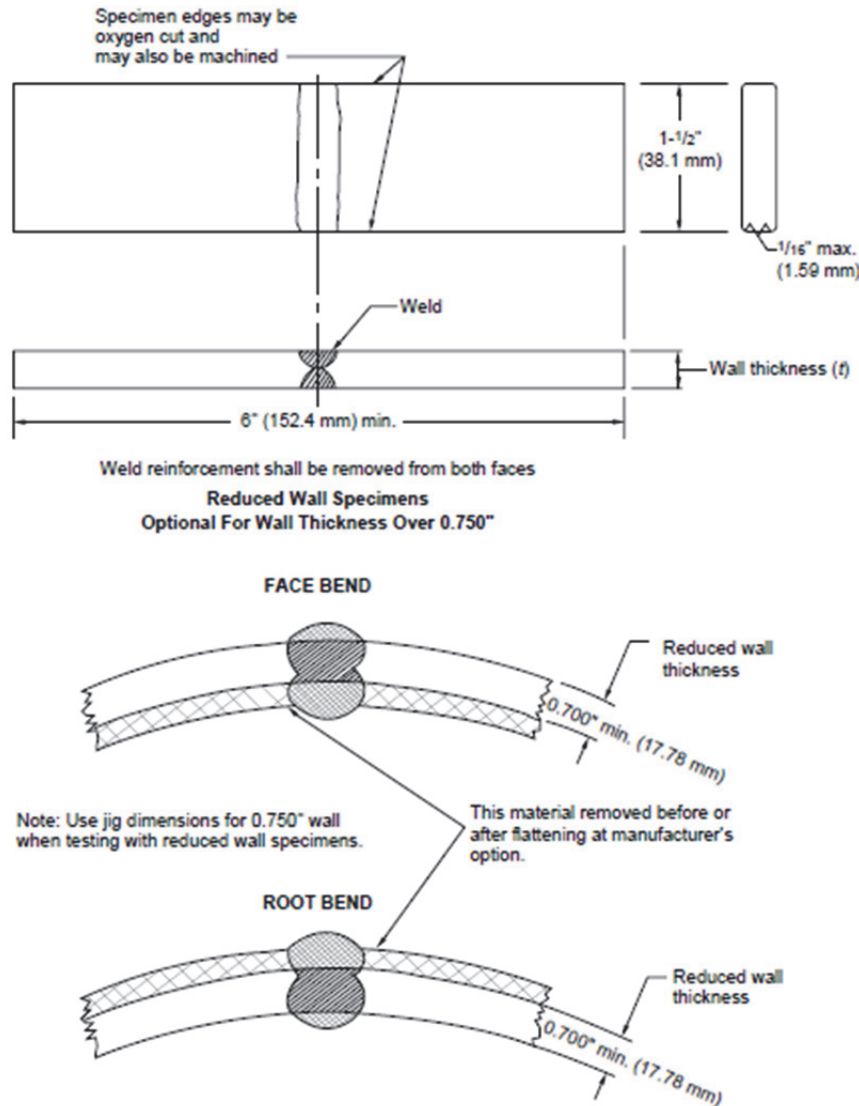


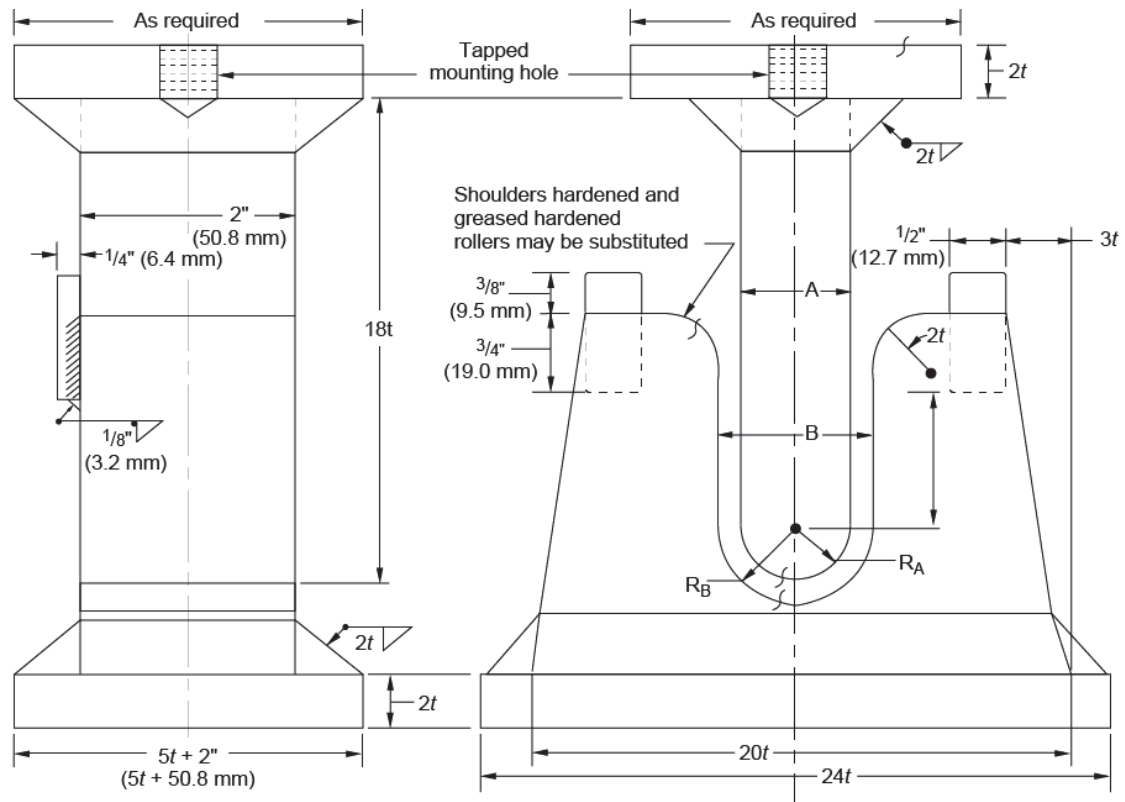
Figure 4—Guided-bend Test Specimen

## 7.16 Weld Ductility Test for Electric-welded Pipe

The weld ductility shall be determined by tests on full section specimens 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  $\frac{1}{8}$  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 Equations (5) and (6) below.

a) Grades Less than 52 ksi Yield Strength

$$S = \frac{3.07t}{\left(0.07 + \frac{3t}{D}\right)} \quad (5)$$



$t$  = Specified wall thickness of pipe

$$A = \frac{1.15 (D - 2t)}{\left(e \frac{D}{t} - 2e - 1\right)} t$$

where

1.15 = peaking factor,  
 $D$  = specified OD, in. (mm),  
 $t$  = specified wall thickness, in. (mm),  
 $e$  = strain.

|           | in./in. | mm/m  |
|-----------|---------|-------|
| LC30-1812 | 0.1175  | 117.5 |
| LC52-1200 | 0.0900  | 90.0  |
| LC65-2205 | 0.1025  | 102.5 |
| LC65-2506 | 0.1025  | 102.5 |
| LC30-2242 | 0.1175  | 117.5 |

$$B = A + 2t + \frac{1}{8} \text{ in.} \\ (A + 2t + 3.2 \text{ mm})$$

$$R_A = \frac{1}{2} A$$

$$R_B = \frac{1}{2} B$$

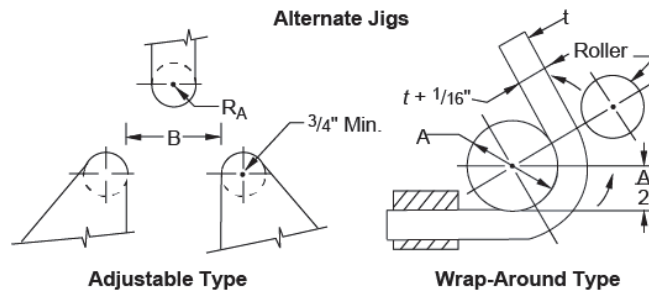


Figure 5—Jig for Guided-bend Test

b) Grades 52 ksi Yield Strength and Higher

$$S = \frac{3.05t}{\left(0.05 + \frac{3t}{D}\right)} \quad (6)$$

where

$S$  is the distance between flattening plates. in. (mm);

$t$  is the specified wall thickness of the pipe, in. (mm);

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

Cracks which originate at the edge of the specimen and which are less than  $\frac{1}{4}$  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 in Table 10.

**Table 10—Specimen Lot Test Lengths**

| Outside Diameter<br>(in.) | Lot Size<br>(no. of lengths) |
|---------------------------|------------------------------|
| Through 12 $\frac{3}{4}$  | 200 or less                  |
| 14 and over               | 100 or less                  |

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 7.9 by compliance with the appropriate amounts of flattening.

### 7.17 Retests—Weld Ductility Test

If the weld ductility test specimen representing a lot of pipe fails to conform to any of the requirements of 7.16, the manufacturer may elect to make retests on two additional lengths from the same lot.

If both retest specimens conform to the requirements, all the lengths in the lot shall be accepted, except for the length from which the initial specimen was taken. If one or both of the retest specimens fail to conform to the specified requirements, the manufacturer may elect to test specimens cut from one end of the individual lengths remaining in the lot. Precautions shall be taken so that the specimens can be identified with respect to the length of pipe from which they were cut. The manufacturer may also elect to retest any length which has failed to pass the above test procedure by cropping back and cutting two additional specimens from the same end. If the weld ductility test requirements are met by both of these additional tests, that length shall be acceptable. No further cropping and retesting is permitted.

### 7.18 Centrifugally Cast Homogeneity Test

Centrifugally cast pipe furnished to this specification shall be tested for hardness as follows.

#### a) *Definitions.*

- 1) *Impression.* One Rockwell hardness C scale (HRC) indentation (see Figure 6). 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 (see Figure 6).

#### b) *Hardness Requirements.* Hardness tests shall be made in accordance with the latest edition of ASTM E18.

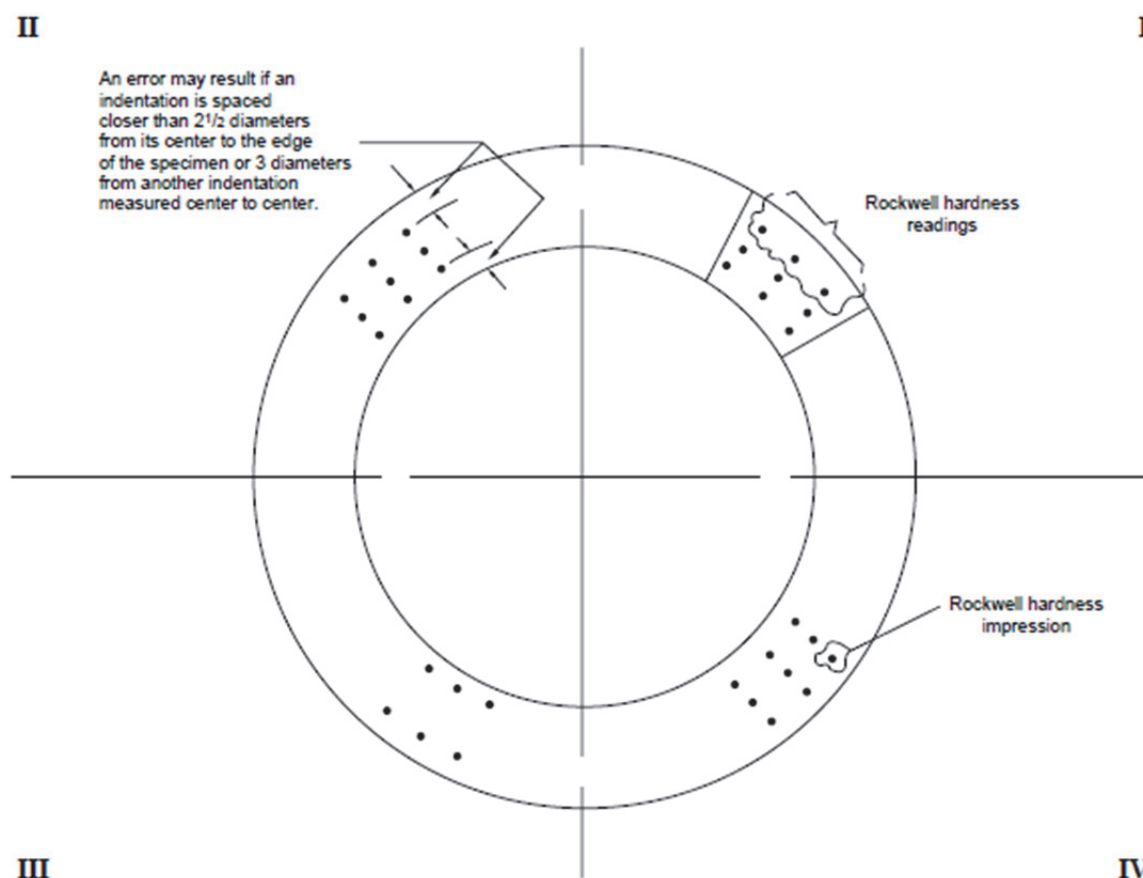
Hardness readings are not taken into account. Only the difference between readings is to be measured. The difference in hardness readings in a quadrant on any test ring shall not exceed that specified below in Table 11.

**Table 11—Quadrant Hardness Readings**

| Nominal Wall Thickness<br>(in.) | Allowable Hardness Gradation<br>(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 Figure 6.

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

**Figure 6—Through-wall Hardness Test Locations**

## 7.19 Hardness Tests (LC52-1200)

Hardness readings (three impressions) shall be made in accordance with the latest editions of ASTM E18 and ASTM E10, as appropriate.

Conversions shall be made in accordance with the latest edition of ASTM A370. The use of the HRC scale is permissible at hardness levels of less than HRC 20. 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 levels below HRC 20.

Each tensile specimen required for Grade LC52-1200 in accordance with 7.2 shall be tested for hardness and shall comply with the requirements given in Table 7. For hardness readings of weld areas, a test specimen shall be taken adjacent to the Weld Tensile Test specimen specified in 7.5. This hardness test shall include both weld metal and HAZ, and comply with the maximum reading shown in Table 7. By agreement between purchaser and manufacturer, additional hardness tests may be specified.

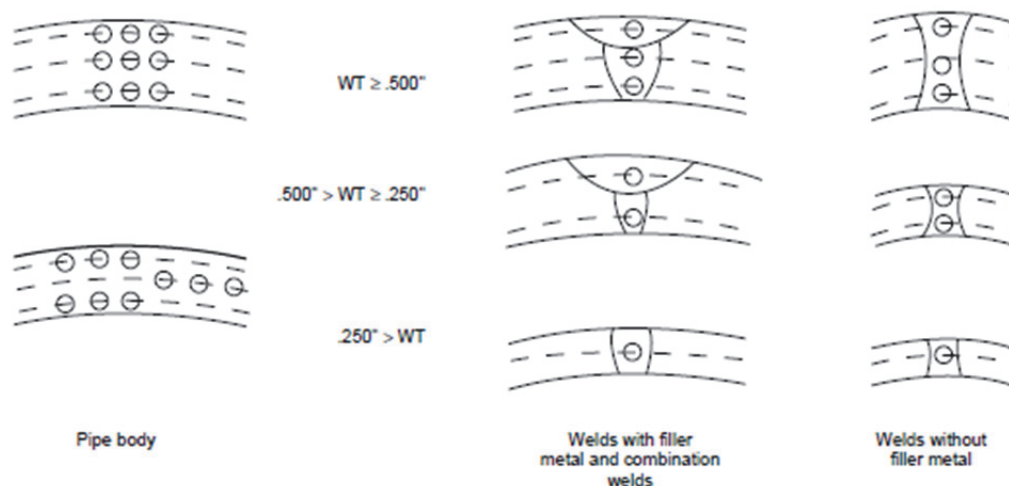
## 8 Special Tests

### 8.1 Ferrite/Austenite Ratio for Duplex Stainless Steel

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 (reference ASTM E562).

Each tensile 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 7.5. The ratio measured on this test specimen shall comply with the requirements described above.

The determination of ferrite/austenite ratio shall be conducted at nine points for pipe body specimen and at one-to-three points, depending upon thickness, for the weld specimen as shown in Figure 7. The average of three readings of the OD, centerline, and ID of the pipe body shall be within specified values. For the weld, each reading shall be within the specified values.



NOTE OD and ID readings shall be as close as practical to the OD or ID surface.

**Figure 7—Location for Determination of Through-wall Ferrite/Austenite Ratio**

## 8.2 Intergranular Corrosion Test (Strauss Test)

The purpose of this test is to assure proper manufacturing procedures for austenitic steel (LC30-1812) and Ni-base alloy (LC30-2242). It is not a test to determine susceptibility for use with a particular environment. Listed below is information regarding intergranular corrosion testing (Strauss test) that is in accordance with this specification.

- 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 of the base metal shall be taken from the pipe body. 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 8.

- c) *Specimen Preparation.* The size of specimen shall 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 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 100 g of copper sulfate ( $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ ) in 700 ml of distilled water, adding 100 ml of sulfuric acid ( $\text{H}_2\text{SO}_4$ ) 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  $180^\circ$  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  $\frac{3}{8}$  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  $100\times$ . 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.

## 9 Hydrostatic Tests

### 9.1 Inspection Hydrostatic Test

Each length of pipe shall withstand, without leakage, an inspection hydrostatic test to at least the pressure specified in 9.3. 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 seconds. Test pressures for welded pipe in sizes 20 in. and larger shall be held for not less than 10 seconds. The water used for hydrostatic testing shall contain less than 50 ppm chlorides.

### 9.2 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. The test pressure measuring device shall be calibrated by means of a deadweight tester, or equivalent, within four months prior to each use. Calibration records retention shall be in accordance with Section 4.

### 9.3 Test Pressures

The minimum test pressure shall be the standard test pressure as listed in Table 12, or an intermediate or higher pressure at the discretion of the manufacturer unless specifically limited by the purchaser, or a higher pressure as agreed upon between the purchaser and manufacturer. The minimum test pressures for grades, diameters, and wall thicknesses not listed shall be computed by the formula given below. For all grades in all sizes smaller than  $2\frac{3}{8}$  in., the test pressure has been arbitrarily assigned. Where the unlisted wall is intermediate to walls whose test pressure has been arbitrarily assigned, the test pressure for the intermediate wall shall be equal to the next heaviest wall. When computed pressures are not an exact multiple of 10 psi (100 kPa), they shall be rounded to the nearest 10 psi (100 kPa).

NOTE 1 The hydrostatic test pressures 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.

The test pressures in Table 12 were computed from Equations (7) and (8) below and rounded to the nearest 10 psi (100 kPa).

In U.S. Customary (USC) units:

$$P = \frac{2St}{D} \quad (7)$$

In metric units:

$$P = \frac{2000St}{D} \quad (8)$$

where

$P$  is the hydrostatic test pressure in psi (kPa);

$S$  is the fiber stress in psi (MPa), equal to a percentage of the specified minimum yield strength (SMYS) for the various sizes as shown in Table 13;

$t$  is the specified wall thickness in inches (mm);

$D$  is the specified outside diameter in inches (mm).

NOTE 2 When hydrostatic testing in excess of 90 % of SMYS 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.

**Table 12—Plain-end Line Pipe Dimensions <sup>a</sup>, Weights <sup>b</sup>, and Test Pressures  
(See Annex F for Metric Tables)**

| 1                                                                                                                                                                                                                                                                                                              |                      |                                     | 2                                              | 3                                 | 4                                  | 5                             | 6    | 7    | 8    |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------|-------------------------------------|------------------------------------------------|-----------------------------------|------------------------------------|-------------------------------|------|------|------|
|                                                                                                                                                                                                                                                                                                                |                      |                                     |                                                |                                   |                                    | Test Pressures<br>(psi, min.) |      |      |      |
| Nom.<br>(in.)                                                                                                                                                                                                                                                                                                  | Size:<br>Designation | Outside<br>Diameter<br>(in.)<br>$D$ | Plain-end<br>Weight<br>(lb per ft)<br>$w_{pe}$ | Wall<br>Thickness<br>(in.)<br>$t$ | Inside<br>Diameter<br>(in.)<br>$d$ | LC30                          | LC52 | LC65 | LC80 |
| 1                                                                                                                                                                                                                                                                                                              | Std                  | 1.315                               | 1.68                                           | 0.133                             | 1.049                              | 700                           | —    | 1520 | —    |
| 1                                                                                                                                                                                                                                                                                                              | XS                   | 1.315                               | 2.17                                           | 0.179                             | 0.957                              | 850                           | —    | 1840 | —    |
| 1                                                                                                                                                                                                                                                                                                              | XXS                  | 1.315                               | 3.66                                           | 0.358                             | 0.599                              | 1000                          | —    | 2170 | —    |
|                                                                                                                                                                                                                                                                                                                |                      |                                     |                                                |                                   |                                    |                               |      |      |      |
| 1 <sup>1/4</sup>                                                                                                                                                                                                                                                                                               | Std                  | 1.660                               | 2.27                                           | 0.140                             | 1.380                              | 1200                          | —    | 2600 | —    |
| 1 <sup>1/4</sup>                                                                                                                                                                                                                                                                                               | XS                   | 1.660                               | 3.00                                           | 0.191                             | 1.278                              | 1800                          | —    | 3000 | —    |
| 1 <sup>1/4</sup>                                                                                                                                                                                                                                                                                               | XXS                  | 1.660                               | 5.21                                           | 0.382                             | 0.896                              | 2200                          | —    | 3000 | —    |
|                                                                                                                                                                                                                                                                                                                |                      |                                     |                                                |                                   |                                    |                               |      |      |      |
| 1 <sup>1/2</sup>                                                                                                                                                                                                                                                                                               | Std                  | 1.900                               | 2.72                                           | 0.145                             | 1.610                              | 1200                          | —    | 2600 | —    |
| 1 <sup>1/2</sup>                                                                                                                                                                                                                                                                                               | XS                   | 1.900                               | 3.63                                           | 0.200                             | 1.500                              | 1800                          | —    | 3000 | —    |
| 1 <sup>1/2</sup>                                                                                                                                                                                                                                                                                               | XXS                  | 1.900                               | 6.41                                           | 0.400                             | 1.100                              | 2200                          | —    | 3000 | —    |
| <sup>a</sup> Outside diameter and wall thickness dimensions shown are subject to tolerances. Inside diameters are nominal and are given here for information.<br><sup>b</sup> Weights shown are for carbon steel. To obtain the weight for the alloy ordered, use the appropriate correction factor from 10.1. |                      |                                     |                                                |                                   |                                    |                               |      |      |      |

**Table 12—Plain-end Line Pipe Dimensions <sup>a</sup>, Weights <sup>b</sup>, and Test Pressures (Continued)**  
(See Annex F for Metric Tables)

| Size:<br>Outside<br>Dia.<br>(in.)<br><i>D</i> | Weight<br>(lb/ft)<br><i>w<sub>pe</sub></i> | Wall<br>Thick<br>(in.)<br><i>t</i> | Inside<br>Dia.<br>(in.)<br><i>d</i> | Test Pressures<br>(psi, min.) |      |      |      | Size:<br>Outside<br>Dia.<br>(in.)<br><i>D</i> | Weight<br>(lb/ft)<br><i>w<sub>pe</sub></i> | Wall<br>Thick<br>(in.)<br><i>t</i> | Inside<br>Dia.<br>(in.)<br><i>d</i> | Test Pressures<br>(psi, min.) |      |      |      |
|-----------------------------------------------|--------------------------------------------|------------------------------------|-------------------------------------|-------------------------------|------|------|------|-----------------------------------------------|--------------------------------------------|------------------------------------|-------------------------------------|-------------------------------|------|------|------|
|                                               |                                            |                                    |                                     | LC30                          | LC52 | LC65 | LC80 |                                               |                                            |                                    |                                     | LC30                          | LC52 | LC65 | LC80 |
| 2.375                                         | 2.03                                       | 0.083                              | 2.209                               | 1570                          | 2730 | 3000 | 3000 | 3.5                                           | 3.03                                       | 0.083                              | 3.334                               | 1070                          | 1850 | 2310 | 2850 |
| 2.375                                         | 2.64                                       | 0.109                              | 2.157                               | 2070                          | 3000 | 3000 | 3000 | 3.5                                           | 3.95                                       | 0.109                              | 3.282                               | 1400                          | 2430 | 3000 | 3000 |
| 2.375                                         | 3.00                                       | 0.125                              | 2.125                               | 2370                          | 3000 | 3000 | 3000 | 3.5                                           | 4.51                                       | 0.125                              | 3.250                               | 1610                          | 2790 | 3000 | 3000 |
| 2.375                                         | 3.36                                       | 0.141                              | 2.093                               | 2670                          | 3000 | 3000 | 3000 | 3.5                                           | 5.06                                       | 0.141                              | 3.218                               | 1810                          | 3000 | 3000 | 3000 |
| 2.375                                         | 3.65                                       | 0.154                              | 2.067                               | 2920                          | 3000 | 3000 | 3000 | 3.5                                           | 5.57                                       | 0.156                              | 3.188                               | 2010                          | 3000 | 3000 | 3000 |
| 2.375                                         | 4.05                                       | 0.172                              | 2.031                               | 3000                          | 3000 | 3000 | 3000 | 3.5                                           | 6.11                                       | 0.172                              | 3.156                               | 2210                          | 3000 | 3000 | 3000 |
| 2.375                                         | 4.39                                       | 0.188                              | 1.999                               | 3000                          | 3000 | 3000 | 3000 | 3.5                                           | 6.65                                       | 0.188                              | 3.124                               | 2420                          | 3000 | 3000 | 3000 |
| 2.375                                         | 5.02                                       | 0.218                              | 1.939                               | 3000                          | 3000 | 3000 | 3000 | 3.5                                           | 7.58                                       | 0.216                              | 3.068                               | 2780                          | 3000 | 3000 | 3000 |
| 2.375                                         | 5.67                                       | 0.250                              | 1.875                               | 3000                          | 3000 | 3000 | 3000 | 3.5                                           | 8.68                                       | 0.250                              | 3.000                               | 3000                          | 3000 | 3000 | 3000 |
| 2.375                                         | 6.28                                       | 0.281                              | 1.813                               | 3000                          | 3000 | 3000 | 3000 | 3.5                                           | 9.66                                       | 0.281                              | 2.938                               | 3000                          | 3000 | 3000 | 3000 |
| 2.375                                         | 9.03                                       | 0.436                              | 1.503                               | 3000                          | 3000 | 3000 | 3000 | 3.5                                           | 10.25                                      | 0.300                              | 2.900                               | 3000                          | 3000 | 3000 | 3000 |
|                                               |                                            |                                    |                                     |                               |      |      |      | 3.5                                           | 18.58                                      | 0.600                              | 2.300                               | 3000                          | 3000 | 3000 | 3000 |
| 2.875                                         | 2.47                                       | 0.083                              | 2.709                               | 1300                          | 2250 | 2810 | 3000 |                                               |                                            |                                    |                                     |                               |      |      |      |
| 2.875                                         | 3.22                                       | 0.109                              | 2.657                               | 1710                          | 2960 | 3000 | 3000 | 4                                             | 3.47                                       | 0.083                              | 3.834                               | 930                           | 1620 | 2020 | 2490 |
| 2.875                                         | 3.67                                       | 0.125                              | 2.625                               | 1960                          | 3000 | 3000 | 3000 | 4                                             | 4.53                                       | 0.109                              | 3.782                               | 1230                          | 2130 | 2660 | 3000 |
| 2.875                                         | 4.12                                       | 0.141                              | 2.593                               | 2210                          | 3000 | 3000 | 3000 | 4                                             | 5.17                                       | 0.125                              | 3.750                               | 1410                          | 2440 | 3000 | 3000 |
| 2.875                                         | 4.53                                       | 0.156                              | 2.563                               | 2440                          | 3000 | 3000 | 3000 | 4                                             | 5.81                                       | 0.141                              | 3.718                               | 1590                          | 2750 | 3000 | 3000 |
| 2.875                                         | 4.97                                       | 0.172                              | 2.531                               | 2690                          | 3000 | 3000 | 3000 | 4                                             | 6.40                                       | 0.156                              | 3.688                               | 1760                          | 3000 | 3000 | 3000 |
| 2.875                                         | 5.40                                       | 0.188                              | 2.499                               | 2940                          | 3000 | 3000 | 3000 | 4                                             | 7.03                                       | 0.172                              | 3.656                               | 1940                          | 3000 | 3000 | 3000 |
| 2.875                                         | 5.79                                       | 0.203                              | 2.469                               | 3000                          | 3000 | 3000 | 3000 | 4                                             | 7.65                                       | 0.188                              | 3.624                               | 2120                          | 3000 | 3000 | 3000 |
| 2.875                                         | 6.13                                       | 0.216                              | 2.443                               | 3000                          | 3000 | 3000 | 3000 | 4                                             | 9.11                                       | 0.226                              | 3.548                               | 2540                          | 3000 | 3000 | 3000 |
| 2.875                                         | 7.01                                       | 0.250                              | 2.375                               | 3000                          | 3000 | 3000 | 3000 | 4                                             | 10.01                                      | 0.250                              | 3.500                               | 2810                          | 3000 | 3000 | 3000 |
| 2.875                                         | 7.66                                       | 0.276                              | 2.323                               | 3000                          | 3000 | 3000 | 3000 | 4                                             | 11.16                                      | 0.281                              | 3.438                               | 3000                          | 3000 | 3000 | 3000 |
| 2.875                                         | 13.69                                      | 0.552                              | 1.771                               | 3000                          | 3000 | 3000 | 3000 | 4                                             | 12.50                                      | 0.318                              | 3.364                               | 3000                          | 3000 | 3000 | 3000 |

<sup>a</sup> Outside diameter and wall thickness dimensions shown are subject to tolerances. Inside diameters are nominal and are given here for information.

<sup>b</sup> Weights shown are for carbon steel. To obtain the weight for the alloy ordered, use the appropriate correction factor from 10.1.