PART

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CHAPTER 3 **Materials for Machinery, Boilers, Pressure Vessels, and Piping**

SECTION 11 **Gray-iron Castings** *(2006)*

1 Scope

1.1

Gray iron castings, as defined in the relevant construction rules, are to be manufactured and tested in accordance with the requirements of this Section.

1.3

Alternatively, castings which comply with national or proprietary specifications may be accepted, provided such specifications give reasonable equivalence to these requirements or otherwise are specially approved or required by the Bureau.

1.5

Where small castings are produced in large quantities, the manufacturer may adopt alternative procedures for testing and inspection subject to the approval of the Bureau.

3 Process of Manufacture

3.1 *(2008)*

Gray iron castings are to be made at foundries where the manufacturer has demonstrated to the satisfaction of the Bureau that the necessary manufacturing and testing facilities are available and are supervised by qualified personnel.

3.3

Suitable mechanical methods are to be employed for the removal of surplus material from castings. Thermal cutting processes are not acceptable, except as a preliminary operation to mechanical methods.

3.5

Where castings of the same type are regularly produced in quantity, the manufacturer is to carry out tests necessary to prove the quality of the prototype castings and is also to make periodical examinations to verify the continued efficiency of the manufacturing technique. The Surveyor is to be given the opportunity to witness these tests.

5 Quality of Castings

Castings are to be free from surface or internal defects, which would prove detrimental to their proper application in service. The surface finish is to be in accordance with good practice and any specific requirements of the approved design.

7 Chemical Composition

The chemical composition of the iron used is left to the discretion of the manufacturer, who is to ensure that it is suitable to obtain mechanical properties specified for the castings. The composition of ladle sample is to be reported to the Bureau.

9 Heat Treatment

9.1

Except as required for 2-3-11/9.3, castings may be supplied in either the cast or heat treated condition.

9.3

For applications such as high temperature service or when dimensional stability is important, castings may require to be given a suitable tempering or stress relieving heat treatment.

11 Mechanical Tests

11.1

Test material sufficient for the required tests and for possible re-tests is to be provided for each casting or batch of castings.

11.3

Separately cast test samples are to be used unless otherwise agreed between the manufacturer and purchaser, and are to be in the form of round bars 30 mm (1.2 in.) in diameter and of a suitable length. They are to be of cast iron from the same ladle as the castings in molds of the same type of material as the molds for the castings and are not to be stripped from the molds until the metal temperature is below 500°C (930°F). When two or more test samples are cast simultaneously in a single mold, the bars are to be at least 50 mm (2.0 in.) apart.

11.5

Integrally cast samples may be used when a casting is more than 20 mm (0.8 in.) thick and its mass exceeds 200 kg (440 lb), subject to agreement between the manufacturer and the purchaser. The type and location of the sample are to be selected to provide approximately the same cooling conditions as for the casting it represents and also subject to agreement.

11.7

With the exception of 2-3-11/11.13, at least one test sample is to be cast with each batch.

11.9

With the exception of 2-3-11/11.11, a batch consists of the castings poured from a single ladle of metal, provided that they are all of similar type and dimensions. A batch should not normally exceed 2,000 kg (4,400 lbs) of fettled castings and a single casting will constitute a batch if its mass is 2,000 kg (4,400 lbs) or more.

11.11

For large mass casting of the same grade, produced by continuous melting, the batch weight may be taken as the weight of casting produced in two hours of pouring. The pouring rate is not to be accelerated beyond the capacity of the caster.

11.13

If one grade of cast iron is melted in large quantities and production is monitored by systematic checking of the melting process, such as a chill testing, chemical analysis or thermal analysis, test samples may be taken at longer intervals, as agreed by the Surveyor.

11.15

All test samples are to be suitably marked to identify them with the castings which they represent.

11.17

Where castings are supplied in the heat-treated condition, the test samples are to be heat treated together with the castings which they represent. For cast-on-test samples, the sample shall not be removed from the casting until after the heat treatment.

11.19

One tensile test specimen is to be prepared from each test sample. 30 mm (1.2 in.) diameter samples are to be machined to the dimensions given in 2-3-1/Figure 3. Where test samples of other dimensions are specially required, the tensile test specimens are to be machined to agreed dimensions.

11.21

All tensile tests are to be carried out using test procedures in accordance with Section 2-3-1. Unless otherwise agreed, all tests are to be carried out in the presence of the Surveyor.

13 Mechanical Properties

13.1 Tensile Strength

13.1.1

The tensile strength is to be determined, and the results obtained from tests are to comply with the minimum value specified for the castings being supplied. The value selected for the specified minimum tensile strength is not to be less than 200 N/mm^2 (29.0 ksi) but subject to any additional requirements of the relevant construction Rules. The fractured surfaces of all tensile test specimens are to be granular and gray in appearance.

13.1.2

When the tensile test fails to meet the requirements, two further tests may be made from the same piece. If both of these additional tests are satisfactory, the item and/or batch (as applicable) is acceptable. If one or both of these tests fail, the item and/or batch is to be rejected.

13.1.3 Higher Strength Castings

When higher-strength cast iron is proposed for any purpose, the purchaser's specifications are to be submitted specially for approval in connection with the approval of the design for which the material is intended.

15 Inspection

15.1

All castings are to be cleaned and adequately prepared for examination. The surfaces are not to be hammered, peened or treated in any way which may obscure defects.

15.3

All castings are to be visually examined by the Surveyor including the examination of internal surfaces where applicable. Unless otherwise agreed, the verification of dimensions is the responsibility of the manufacturer.

15.5

Supplementary examination of castings by suitable nondestructive testing procedures is generally not required unless otherwise stated on the approved plan or in circumstances where there is reason to suspect the soundness of the casting.

15.7

When required by the relevant construction Rules, castings are to be pressure tested before final acceptance.

15.9

In any event of any casting proving defective during subsequent machining or testing, it is to be rejected notwithstanding any previous certification.

17 Rectification of Defective Casting

17.1

At the discretion of the Surveyor, small surface blemishes may be removed by local grinding.

17.3

Subject to approval, castings containing local porosity may be rectified by impregnation with a suitable plastic filler.

17.5

Repairs by welding are generally not permitted. In cases where welding is proposed, full details of the proposed repair are to be submitted for review prior to commencing the repair.

19 Identification of Castings

19.1

The manufacturer is to adopt a system of identification, which will enable all finished castings to be traced to the original ladle of metal. The Surveyor is to be given full facilities for tracing the castings when required.

19.3

Before acceptance, all castings which have been tested and inspected with satisfactory results are to be clearly marked by the manufacturer with the following details:

- Grade of cast iron
- Identification number or other marking enabling the full history of the casting to be traced.
- Manufacturer's name or trademark.
- Date of final inspection
- ABS office, initials or symbol
- Personal stamp of Surveyor responsible for inspection
- Test pressure, if applicable

19.5

Where small castings are manufactured in large numbers, modified arrangements for identification may be specially agreed with the Surveyor.

21 Certification

The manufacturer is to provide the Surveyor with a test certificate or shipping statement giving the following particulars for each casting or batch of castings which has been accepted:

- Purchaser's name and order number
- Description of castings and quality of cast iron
- Identification number
- Results of mechanical test
- Where applicable, general details of the heat treatment
- Where specifically required, the chemical analysis of ladle samples
- Where applicable, test pressures

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PART

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CHAPTER 3 Materials for Machinery, Boilers, Pressure Vessels, and Piping

SECTION 12 Steel Piping

1 Scope *(1998)*

The following specifications cover thirteen grades of steel pipe designated 1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13 and 14.

3 General

3.1 Grades 1, 2 and 3

Grades 1, 2 and 3 cover seamless and welded steel pipe. Pipe ordered under these grades is of a nominal (average) wall thickness suitable for welding and suitable for forming operations involving coiling, bending and flanging, subject to the following limitations: Grade 1 furnace-butt-welded pipe is not intended for flanging; when seamless or electric-resistance-welded pipe is required for close-coiling or cold-bending, Grade 2 should be specified; this provision is not intended to prohibit the cold-bending of Grade 3 pipe. When pipe is required for close-coiling, this is to be specified on the order. Electric-resistance-welded Grades 2 and 3 may be furnished either non-expanded or cold-expanded, at the option of the manufacturer. When pipe is cold expanded, the amount of expansion is not to exceed 1.5% of the outside diameter pipe size.

3.3 Grades 4 and 5

Grades 4 and 5 cover seamless carbon-steel pipe for high-temperature service. Pipe ordered to these grades is of a nominal (average) wall thickness and is to be suitable for bending, flanging and similar forming operations. Grade 4 rather than Grade 5 pipe should be used for close-coiling, cold-bending or forge-welding; this provision is not intended to prohibit the cold-bending of Grade 5 pipe.

3.5 Grade 6

Grade 6 covers seamless carbon-molybdenum alloy-steel pipe for high-temperature service. Pipe ordered to this grade is of a nominal (average) wall thickness and is to be suitable for bending, flanging (vanstoning) and similar forming operations, and for fusion-welding.

3.7 Grades 7, 11, 12, 13 and 14 *(1998)*

Grades 7, 11, 12, 13 and 14 cover seamless chromium-molybdenum alloy-steel pipe for high-temperature service. Pipe ordered to these grades is of a nominal (average) wall thickness and is to be suitable for bending, flanging (vanstoning) and similar forming operations, and for fusion-welding.

3.9 Grades 8 and 9

Grades 8 and 9 cover electric-resistance-welded steel pipe 762 mm (30 in.) and under in diameter. Pipe ordered to these grades is of a nominal (average) wall thickness and is intended for conveying liquid, gas or vapor. Only Grade 8 is adapted for flanging and bending; this provision is not intended to prohibit the cold-bending of Grade 9 pipe. The pipe may be furnished either cold-expanded or non-expanded.

3.11 ASTM Designations *(2006)*

The various grades are in substantial agreement with ASTM, as follows:

ABS Grade	*ASTM Designation*
1	A53, Grade A, Furnace-welded
2	A53, Grade A Seamless or Electric-resistance-welded
3	A53, Grade B Seamless or Electric-resistance-welded
4	A106, Grade A
5	A106, Grade B
6	A335, Grade P1
7	A335, Grade P2
8	A135, Grade A
9	A135, Grade B
11	A335, Grade P11
12	A335, Grade P12
13	A335, Grade P22
14	A335, Grade P5

5 Process of Manufacture

5.1 Grades 1, 2 and 3

The steel for welded or seamless steel pipe in these Grades is to be made by one or more of the following processes: open-hearth, basic-oxygen or electric-furnace. Special consideration may be given to other processes, subject to such supplementary requirements or limits on application as are to be specially determined in each case.

5.3 Grades 4 and 5

The steel for seamless steel pipe in these Grades is to be killed steel made by one or more of the following processes: open-hearth, basic-oxygen or electric-furnace. Pipe that is 60.3 mm in outside diameter (2 in. nominal diameter) and over is to be, unless otherwise specified, furnished hot-finished. Hot-finished pipe need not be annealed. Cold-drawn pipe is to be process-annealed after the final cold-draw pass at a temperature of 650°C (1200°F) or higher.

5.5 Grades 6 and 7

The steel for seamless steel pipe in these Grades is to be made by either or both the open-hearth or electric-furnace process or other approved process. A sufficient discard is to be made from each ingot to secure freedom from injurious piping and undue segregation. Pipe that is 60.3 mm in outside diameter (2 in. nominal size) and over is to be, unless otherwise specified, furnished hot-finished, and pipe under 60.3 mm O.D. (2 in. diameter) may be furnished either hot-finished or cold-drawn. The hot-rolled or cold-drawn pipe Grades 6 and 7 as a final heat treatment, are to be stress-relief-annealed at 650°C (1200°F) to 705°C (1300°F). The steel from which Grade 7 pipe is made is to be a coarse-grained steel having a carburized austenitic grain size of 1 to 5 as determined in accordance with the Methods for Estimating the Average Grain Size of Metals (ASTM E112) and its Plate IV, by carburizing at 925°C (1700°F) for 8 hours. The specimen is to be taken from the bloom or billet.

5.7 Grades 8 and 9

The steel for electric-resistance-welded steel pipe in these Grades is to be made by one or more of the following processes: open-hearth, basic-oxygen or electric-furnace.

5.9 Grades 11, 12, 13 and 14 *(1998)*

The steel for seamless alloy steel pipe is to be made by the electric-furnace process or other approved process, except that Grade 12 may be made by the open-hearth process. A sufficient discard is to be made from each ingot to secure freedom from injurious piping and undue segregation. Pipe that is 60.3 mm in outside diameter (2 in. nominal diameter) and over is to be, unless otherwise specified, furnished hot-finished, and pipe under 60.3 mm O.D. (2 in. nominal diameter) may be furnished either hot-finished or cold-drawn. The steel for Grade 12 pipe is to be made by coarse-grain melting practice. Grades 11, 13 and 14 pipe are to be reheated and furnished in the full-annealed, isothermal annealed or normalized and tempered condition; if furnished in the normalized and tempered condition, or if cold drawn pipe is furnished, the temperature for tempering following normalizing or cold drawing is to be 677°C (1250°F) or higher for Grades 13 and 14, and 650°C (1200°F) or higher for Grade 11. The hot-rolled or cold-drawn Grade 12 pipe, as a final heat treatment, is to be given a stress-relieving treatment at 650°C (1200°F) to 705°C (1300°F).

7 Marking *(1998)*

Identification markings are to be legibly stenciled, stamped, or rolled on each length of pipe, except that in the case of small-diameter pipe which is bundled, the required markings are to be placed on a tag securely attached to the bundle. The markings are to be arranged and are to include the following information:

- Name or brand of the manufacturer
- ABS Grade or ASTM Designation and Type or Grade. Heat number or manufacturer's number by which the heat can be identified (For Grades 6, 7, 11, 12, 13and 14 pipe only)
- Test pressure or the letters NDE
- Method of forming (i.e., butt-welded, lap-welded, electric-resistance-welded or seamless hot-finished or cold-drawn)
- "XS" for extra strong or "XXS" for double-extra strong (when applicable for Grades 1, 2 and 3 pipe only)
- ABS markings by the Surveyor

9 Chemical Composition

The material for pipe is to conform to the applicable requirements as to chemical composition shown in 2-3-12/Table 1.

11 Ladle Analysis *(1998)*

For Grades 4, 5, 6, 7, 8, 9, 11, 12, 13 and 14, the manufacturer is to submit a report showing the ladle analysis of each heat of steel from which the pipe has been made and the chemical composition is to conform to the requirements specified in 2-3-12/9. In lieu of a report of the ladle analysis, a report of check analysis as provided for in 2-3-12/13 will be acceptable.

13 Check Analysis

13.1 General

A check analysis may be made where so specified by the purchaser. The chemical composition thus determined is to conform to the requirements specified in 2-3-12/9. If check analyses are made, they are to be in accordance with the following requirements.

13.3 Samples

Samples for check analysis are to be taken by drilling several points around each pipe selected for analysis or when taken from the billet they are to be obtained by drilling parallel to the billet axis at a point midway between the outside and center or when taken from a broken tension test specimen, they are to be taken so as to represent the entire cross section of the specimen.

13.5 Grades 1, 2 and 3

For these grades, analyses of two pipes from each lot of 500 lengths or fraction thereof are to be made.

13.7 Grades 4 and 5

For these grades, analyses of two pipes from each lot of 400 lengths or fraction thereof, of each size and heat 60.3 mm O.D. (2 in. nominal diameter) up to, but not including 168.3 mm O.D. (6 in. nominal diameter), and from each lot of 200 lengths or fraction thereof of each size and heat 168.3 mm O.D. (6 in. nominal diameter) and over, are to be made.

13.9 Grades 6, 7, 11, 12, 13 and 14 *(1998)*

For these grades, analyses of two pipes from each lot and heat, as specified in 2-3-12/Table 2, are to be made.

13.11 Grades 8 and 9

For these grades, analyses of two pipes from each lot of 400 lengths or fraction thereof of each size under 168.3 mm O.D. (6 in. nominal), from each lot of 200 lengths or fraction thereof of each size 168.3 mm O.D. (6 in. nominal diameter) to 508 mm (20 in.) O.D., and from each lot of 100 lengths or fraction thereof of each size over 508 mm (20 in.) O.D. to 762 mm (30 in.) O.D. are to be made. With the Surveyor's permission, the analysis may be made of the skelp and the number is to be determined in the same manner as when taken from the finished pipe.

13.13 Retests for Grades 1, 2, 3, 4 and 5

If an analysis for these grades does not conform to the requirements specified, analyses are to be made on additional pipes of double the original number from the same lot, each of which is to conform to the requirements specified.

13.15 Retests for Grades 6, 7, 11, 12, 13 and 14 *(1998)*

If a check or ladle analysis for these grades does not conform to the requirements specified, an analysis of each billet or pipe from the same heat or lot may be made, and all billets or pipe conforming to the requirements are to be accepted.

13.17 Retests for Grades 8 and 9

For these grades, if the analysis of either length of pipe or length of skelp does not conform to the requirements, analyses of two additional lengths from the same lot are to be made, each of which is to conform to the requirements specified.

15 Mechanical Tests Required *(1998)*

The type and number of mechanical tests are to be in accordance with 2-3-12/Table 3. For a description and the requirements of each test, see 2-3-12/17 through and including 2-3-12/29. For retests, see 2-3-12/33.

17 Tension Test Specimens

17.1 Grades 1, 2 and 3

For these grades, tension test specimens are to be cut longitudinally from the end of the pipe and not flattened between gauge marks. The sides of strip specimens are to be parallel between gauge marks; the width is to be 38 mm (1.5 in.) and the gauge length 50 mm (2 in.). If desired, tension test specimens may consist of a full section of pipe. When impracticable to pull a test specimen in full thickness, the tension test specimen shown in 2-3-1/Figure 2 may be used. The transverse-weld tension test specimens from electric-resistance-welded Grade 2 and Grade 3 pipe are to be taken with the weld at the center of the specimen and are to be 38 mm (1.5 in.) wide in the gauge length.

17.3 Grades 4, 5, 6, 7, 11, 12, 13 and 14 *(1998)*

For these grades, the tension test specimens are to be cut longitudinally, but may be cut transversely for pipe 219.1 mm in outside diameter (8 in. nominal diameter) and over.

17.3.1 Longitudinal Tension Test Specimens

The longitudinal tension test may be made in full section of the pipe, up to the capacity of the testing machine. For larger sizes, tension test specimens are to consist of strips cut from the pipe; the width of these specimens is to be 38 mm (1.5 in.) and they are to have a gauge length of 50 mm (2 in.). When the pipe-wall thickness is 19.1 mm (0.75 in.) and over, the tension test specimen shown in 2-3-1/Figure 2 may be used. Longitudinal tension test specimens are not to be flattened between gauge marks. The sides of the specimens are to be parallel between gauge marks.

17.3.2 Transverse Tension Test Specimens

Transverse tension test specimens may be taken from a ring cut from the pipe or from sections resulting from the flattening tests. Test specimens are to consist of strips cut transversely from the pipe; the width of the specimens is to be 38 mm (1.5 in.) and their gauge length 50 mm (2 in.). When the pipe-wall thickness is 19.1 mm (0.75 in.) and over, the tension test specimen

shown in 2-3-1/Figure 2 may be used. Specimens cut from the ring section are to be flattened cold and are to be parallel between gauge marks. Specimens from Grades 6, 7, 11, 12, 13 and 14 pipes are to be flattened cold and heat-treated in the same manner as the pipe. Transverse tension test specimens may be machined off on either or both surfaces to secure uniform thickness.

17.5 Grades 8 and 9

For these grades, the tension test specimens are to be cut longitudinally from the end of the pipe, or by agreement between the manufacturer and the Surveyor, the specimens may be taken from the skelp, at a point approximately 90 degrees from the weld. The specimens are not to be flattened between the gauge marks. Transverse tension test specimens are to be taken across the weld and from the same end of the pipe as the longitudinal test specimens. The sides of each strip specimen are to be parallel between gauge marks; the width is to be 38 mm (1.5 in.) and the gauge length 50 mm (2 in.). When impracticable to pull a test specimen in full thickness, the tension test specimen shown 2-3-1/Figure 2 may be used.

19 Bend and Flattening Test Specimens

Test specimens for the bend and flattening tests are to consist of sections cut from a pipe and the specimens for flattening tests are to be smooth on the ends and free from burrs, except when made on crop ends.

21 Testing Temperature

All test specimens are to be tested at room temperature.

23 Tensile Properties

The material is to conform to the applicable requirements as to tensile properties shown in 2-3-12/Table 4.

25 Bend Test

25.1 General

This test is required for Grades 1, 2, 3, 4 and 5 pipe having outside diameters of 60.3 mm (2 in. nominal diameter) and under, except that double-extra-strong pipe over 42.2 mm in outside diameter (1.25 in. nominal diameter) need not be subjected to a bend test.

25.3 Details of Test

A sufficient length of pipe is to stand being bent cold around a cylindrical mandrel without developing cracks at any portion or without opening the weld. The requirements for bending angle, mandrel diameter, and pipe diameter are tabulated below.

Pipe Grade	*Bending Angle in degrees*	*Ratio of Mandrel Diameter to Nominal Pipe Diameter*
1, 2, 3, 4, 5	90	12
1, 2, 3, 4, 5 for close-coiling	180	8

27 Flattening Test

27.1 General

Flattening tests are to be made for all Grades of pipe, except Grades 1, 2 and 3 double extra strong and Grades 1, 2, 3, 4 and 5 in sizes 60.3 mm in outside diameter (2 in. nominal diameter) and under. The test is to consist of flattening cold a section of pipe between parallel plates.

27.3 Furnace-welded Pipe

For Grade 1 furnace-welded pipe, the test section is not to be less than 100 mm (4 in.) in length and the weld is to be located 45 degrees from the line of direction of the applied force. The test is to be made in three steps.

27.3.1 Test Step No. 1

During the first step, which is a test for quality of the weld, no cracks or breaks on the inside, outside or end surfaces are to occur until the distance between the plates is less than three-fourths of the original outside diameter.

27.3.2 Test Step No. 2

During the second step, which is a test for ductility exclusive of the weld, the flattening is to be continued and no cracks or breaks on the inside, outside or end surfaces are to occur until the distance between the plates is less than 60% of the original outside diameter for butt-welded pipe.

27.3.3 Test Step No. 3

During the third step, which is a test for soundness, the flattening is to be continued until the test specimen breaks or the opposite walls of the pipe meet. Evidence of laminated or unsound material or of incomplete weld that is revealed during the entire flattening test is to be cause for rejection. Superficial ruptures as a result of surface imperfections are not to be cause for rejection.

27.5 Electric-resistance-welded Pipe

For electric-resistance-welded pipe of Grades 2, 3, 8 and 9 the crop ends, at least 100 mm (4 in.) in length, cut from each end of each single length of pipe are to be flattened and the tests from each end are to be made alternately with the welds at 0 degrees and 90 degrees from the line of direction of force. When produced in multiple lengths, flattening tests are required from each end of each multiple length or coil with the weld at 90 degrees from the line of direction of force. In addition, tests are to be made on two intermediate rings cut from each multiple length or coil with the weld at 0 degrees from the line of direction of force. The test is to be made in three steps.

27.5.1 Test Step No. 1

During the first step, which is a test for ductility of the weld, no cracks or breaks on the inside or outside surfaces are to occur until the distance between the plates is less than two-thirds of the original outside diameter of the pipe.

27.5.2 Test Step No. 2

During the second step, which is a test for ductility exclusive of the weld, the flattening is to be continued and no cracks or breaks on the inside or outside surfaces, elsewhere than in the weld, are to occur until the distance between the plates is less than one-third of the original outside diameter of the pipe.

27.5.3 Test Step No. 3

During the third step, which is a test for soundness, the flattening is to be continued until the test specimen breaks or the opposite walls of the pipe meet. Evidence of laminated, burned or unsound material or of an incomplete weld that is revealed during the entire flattening test is to be cause for rejection. Superficial ruptures as a result of surface imperfections are not to be cause for rejection.

27.7 Seamless Pipe *(1998)*

For seamless pipe of Grades 2, 3, 4, 5, 6, 7, 11, 12, 13 and 14, the test section is not to be less than 63.5 mm (2.5 in.) in length. The test is to be made in two steps.

27.7.1 Test Step No. 1

During the first step, which is a test for ductility, no cracks or breaks on the inside or outside or end surfaces are to occur until the distance between the plates is less than the value of H obtained from the following equation:

$$H = (1 + e)t/(e + t/D)$$

where

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

t = specified wall thickness of pipe, in mm (in.)

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

e = deformation per unit length, constant for a given Grade as follows.

= 0.09 for Grade 2

= 0.08 for Grades 4, 6, 7, 11, 12, 13 and 14

= 0.07 for Grades 3 and 5

27.7.2 Test Step No. 2

During the second step, which is a test for soundness, the flattening is to be continued until the specimen breaks or the opposite walls of the pipe meet. Evidence of laminated, burned or unsound material that is revealed during the entire flattening test is to be cause for rejection.

29 Hydrostatic Test

29.1 General *(1998)*

Except when intended for structural use, such as stanchions, each length of pipe of all grades is to be hydrostatically tested at the mill in accordance with the following requirements, or when specified by the purchaser, seamless pipe is to be subjected to a nondestructive electrical test in accordance with 2-3-12/31. When each pipe is hydrostatically tested as a regular procedure during the process of manufacture, an affidavit covering this test may be accepted by the Surveyor.

29.3 Grades 1, 2 and 3 *(1999)*

For these grades, each pipe is to withstand an internal hydrostatic pressure as shown in 2-3-12/Table 5. This does not prohibit testing at a higher pressure, but the maximum fiber stress produced by the test is not to exceed 90% of the minimum specified yield strength of the material. Welded pipe that is 60.3 mm O.D. (2 in. nominal diameter) and larger is to be jarred near one end while under test pressure. The hydrostatic pressure is to be maintained for not less than 5 seconds for all sizes of seamless and electric-welded pipe.

29.5 Grades 4, 5, 6, 7, 11, 12, 13 and 14 *(1999)*

For these grades, each pipe is to withstand an internal hydrostatic test pressure which will produce in the pipe wall a stress of not less than 60% of the minimum specified yield point at room temperature. This pressure is to be determined by the equation given in 2-3-12/29.9. The hydrostatic test pressure determined by the equation is to be rounded to the nearest 5 bar (5 kgf/cm^2, 50 psi) for pressures below 70 bar (70 kgf/cm^2, 1000 psi) and to the nearest 10 bar (10 kgf/cm^2, 100 psi) for pressures 70 bar (70 kgf/cm^2, 1000 psi) and above. Regardless of the pipe wall stress determined by the equation in 2-3-12/29.9, the minimum hydrostatic test pressure required to satisfy this requirement need not exceed 170 bar (170 kgf/cm^2, 2500 psi) for sizes 88.9 mm O.D. (3 in. nominal diameter) and under, or 190 bar (190 kgf/cm^2, 2800 psi) for all sizes over 88.9 mm O.D. (3 in. nominal diameter). This does not prohibit testing at a higher pressure, but the maximum fiber stress produced by the test is not to exceed 90% of the minimum specified yield strength of the material. The hydrostatic pressure is to be maintained for not less than 5 seconds.

29.7 Grades 8 and 9

For these grades, each pipe is to withstand an internal hydrostatic test pressure calculated from the equation given in 2-3-12/29.9. The maximum test pressure is not to exceed 172 bar (176 kgf/cm^2, 2500 psi). For pipe with a wall thickness greater than 3.9 mm (0.154 in.), the pipe is to be jarred near both ends with a 1 kg (2 lb.) hammer or its equivalent while under the test pressure. The hydrostatic pressure is to be maintained for not less than 5 seconds.

29.9 Test Pressures *(1999)*

The test pressures for applicable grades are to be determined by the following equation.

$$P = KSt/D$$

where

K = 20 (200, 2)

P = maximum hydrostatic-test pressure, in bar (kgf/cm^2, psi)

t = specified thickness of pipe wall, in mm (in.)

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

S = permissible fiber stress

= 0.60 times the specified yield point, in N/mm^2 (kgf/mm^2 or psi), for ABS Grades 4, 5, 6, 7, 11, 12, 13 and 14

= 110 N/mm^2 (11 kgf/mm^2, 16000 psi) to 125 N/mm^2 (12.5 kgf/mm^2, 18000 psi), but in no case is the stress produced to exceed 80% of the specified yield point for ABS Grade 8

= 140 N/mm^2 (14 kgf/mm^2, 20000 psi) to 150 N/mm^2 (15.5 kgf/mm^2, 22000 psi), but in no case is the stress produced to exceed 80% of the specified yield point for ABS Grade 9

29.11 Exceptions *(1999)*

The maximum test pressure for special service pipes, such as diesel engine high pressure fuel injection piping, will be specially considered. The manufacturer is to submit the proposed maximum test pressure along with technical justification and manufacturing control process for the piping. The justification is to include pipe fiber stress analysis and substantiating prototype test results.

31 Nondestructive Electric Test (NDET) for Seamless Pipe *(1998)*

31.1 General

When specified by the purchaser, seamless pipe is to be tested in accordance with ASTM E213, for Ultrasonic Examination of Metal Pipe and Tubing, ASTM E309, for Eddy-Current Examination of Steel Tubular Products Using Magnetic Saturation, ASTM E570, for Flux Leakage Examination of Ferromagnetic Steel Tubular Products, or other approved standard. It is the intent of this test to reject tubes containing defects and the Surveyor is to be satisfied that the nondestructive testing procedures are used in a satisfactory manner

31.3 Ultrasonic Calibration Standards

Notches on the inside or outside surfaces may be used. The depth of the notch is not to exceed 12.5% of the specified wall thickness of the pipe or 0.1 mm (0.004 in.), whichever is greater. The width of the notch is not to exceed two times the depth.

31.5 Eddy-Current Calibration Standards

In order to accommodate the various types of nondestructive electrical testing equipment and techniques in use and manufacturing practices employed, any one of the following calibration standards may be used at the option of the producer to establish a minimum sensitivity level for rejection.

31.5.1 Drilled Hole

Three or four holes equally spaced about the pipe circumference and sufficiently separated longitudinally to ensure a separately distinguishable response are to be drilled radially and completely through the pipe wall, care being taken to avoid distortion of the pipe wall while drilling. The diameter of the holes is to be as follows:

Calibration Pipe Diameter in mm (inch)	*Hole Diameter in mm (inch)*
under 12.5 (0.5)	1 (0.039)
12.5 (0.5) to 31.8 (1.25), excl.	1.4 (0.055)
31.8 (1.25) to 50 (2.0), excl.	1.8 (0.071)
50 (2.0) to 125 (5.0), excl.	2.2 (0.087)
125 (5.0) and over	2.7 (0.106)

31.5.2 Transverse Tangential Notch

Using a round file or tool with a 6.35 mm (0.25 in.) diameter, a notch is to be filed or milled tangential to the surface and transverse to the longitudinal axis of the pipe. Said notch is to have a depth not exceeding 12.5% of the nominal wall thickness of the pipe or 0.1 mm (0.004 in.), whichever is greater.

31.5.3 Longitudinal Notch

A notch 0.785 mm. (0.031 in.) or less in width is to be machined in a radial plane parallel to the pipe axis on the outside surface of the tube to a depth not exceeding 12.5% of the nominal wall thickness of the pipe or 0.1 mm (0.004 in.), whichever is greater. The length of the notch is to be compatible with the testing method.

31.7 Flux Leakage Calibration Standards

The depth of longitudinal notches on the inside and outside surfaces is not to exceed 12.5% of the specified wall thickness of the pipe or 0.1 mm (0.004 in.), whichever is greater. The width of the notch is not to exceed the depth, and the length of the notch is not to exceed 25.4 mm (1.0 in.). Outside and inside surface notches are to be located sufficiently apart to allow distinct identification of the signal from each notch.

31.9 Rejection

Tubing producing a signal equal to or greater than the calibration defect is to be subject to rejection.

31.11 Affidavits

When each tube is subjected to an approved nondestructive electric test as a regular procedure during the process of manufacture, an affidavit covering this test may be accepted by the Surveyor.

33 Retests

33.1 General *(1998)*

For all grades of pipe, if the results of the mechanical tests of any lot do not conform to the requirements, retests may be made on additional pipe of double the original number from the same lot, each of which is to conform to the requirements specified.

33.3 Grades 1, 2, 3, 8 and 9

For these grades, should any section fail when flattening tests are made on the crop ends of each length of welded pipe, other pieces from the length may be cut until satisfactory tests are obtained, otherwise, the length is to be rejected.

33.5 Grades 4 and 5

For these grades, should a crop end of a finished pipe fail in the flattening test, one retest may be made from the failed end. The pipe may be normalized either before or after the first test, but the pipe is to be subjected to only two normalizing treatments.

33.7 Grades 6, 7, 11, 12, 13 and 14 *(1998)*

For these grades, should individual lengths of pipe selected to represent any lot fail to conform to the mechanical requirements, the lot may be reheat-treated and resubmitted for test, except that any individual lengths which meet the test requirements before re-treating will be accepted.

35 Pipe Testing and Inspection

35.1 Group I Piping *(2008)*

Pipes intended for use in Group I piping systems (Class I and Class II, see 4-6-1/3, *Rules for Building and Classing Steel Vessels*) are to be tested, preferably at the mill, to the satisfaction of the Surveyor. The material surfaces will be examined by the Surveyor when specially requested by the purchaser. See also 4-6-7/3.5.1 of the *Rules for Building and Classing Steel Vessels*.

35.3 Group I and II Piping *(1998)*

The pipes are to be reasonably straight, free from defects, and have a workmanlike finish. At a minimum, the finished pipe is to be visually inspected at the same frequency as that required for the tension test specified in 2-3-12/Table 3 for the applicable grade. Welding repair to the pipe is not to be carried out without the purchaser's approval and is to be the Surveyor's satisfaction.

37 Permissible Variation in Wall Thickness *(1998)*

The permissible variations in wall thickness for all pipe are based on the ordered thickness and are to conform to that given in the applicable ASTM designation for acceptance, but the minimum thickness for all pipe is not to be less than that required by the Rules for a specific application regardless of such prior acceptance. At a minimum, the finished pipe is to be measured at the same frequency as that required for the tension test specified in 2-3-12/Table 3 for the applicable grade.

39 Permissible Variations in Outside Diameter

39.1 Grades 1, 2, 3

For pipe of these grades 48.3 mm O.D. (1.5 in. nominal diameter) and under, the outside diameter at any point is not to vary more than 0.4 mm (0.016 in.) over nor more than 0.8 mm (0.131 in.) under the specified diameter. For pipe 60.3 mm O.D. (2 in. nominal diameter) and over, the outside diameter is not to vary more than plus or minus 1% from the specified diameter.

39.3 Grades 4, 5, 6, 7, 11, 12, 13 and 14 *(1998)*

For these grades, variation in outside diameter from that specified is not to exceed the amount prescribed in 2-3-12/Table 6.

39.5 Grades 8 and 9

For these grades, the outside diameter is not to vary more than plus or minus 1% from the nominal diameter specified.

39.7 Inspection *(1998)*

At a minimum, the finished pipe is to be measured at the same frequency as that required for the tension test specified in 2-3-12/Table 3 for the applicable grade.

TABLE 1
Maxima or Permissible Range of Chemical Composition in Percent for Pipe *(1998)*

	ABS Grades												
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*11*	*12*	*13*	*14*
Carbon	0.30	0.25	0.30	0.25	0.30	0.10 to 0.20	0.10 to 0.20	0.25	0.30	0.05 to 0.15	0.05 to 0.15	0.05 to 0.15	0.15
Manganese	1.20	0.95	1.20	0.27 to 0.93	0.29 to 1.06	0.30 to 0.80	0.30 to 0.61	0.95	1.20	0.30 to 0.60	0.30 to 0.61	0.30 to 0.60	0.30 to 0.60
Phosphorus	0.05	0.05	0.05	0.035	0.035	0.025	0.025	0.035	0.035	0.025	0.025	0.025	0.025
Sulfur	0.045	0.045	0.045	0.035	0.035	0.025	0.025	0.035	0.035	0.025	0.025	0.025	0.025
Silicon				0.10 (min)	0.10 (min)	0.10 to 0.50	0.10 to 0.30			0.50 to 1.00	0.50	0.50	0.50
Chromium	0.40	0.40	0.40	0.40	0.40		0.50 to 0.81			1.00 to 1.50	0.80 to 1.25	1.90 to 2.60	4.00 to 6.00
Molybdenum	0.15	0.15	0.15	0.15	0.15	0.44 to 0.65	0.44 to 0.65			0.44 to 0.65	0.44 to 0.65	0.87 to 1.13	0.45 to 0.65
Nickel	0.40	0.40	0.40	0.40	0.40								
Copper	0.40	0.40	0.40	0.40	0.40								
Vanadium	0.08	0.08	0.08	0.08	0.08								

TABLE 2
Lot Sizes for Pipe Grades 6, 7, 11, 12, 13 and 14 *(1998)*

Outside Diameter	*Lengths of Pipe in Lot*
Under 60.3 mm (2 in.)*	400 or fraction thereof
60.3 mm to 141.3 mm incl. (2 in. to 5 in. incl.)*	200 or fraction thereof
168.3 mm and over (6 in. and over)*	100 or fraction thereof

*Dimensions refer to nominal pipe diameter.

TABLE 3
Mechanical Tests for Pipe *(1998)*

Grade	*Type of Test*	*Number of Tests*
1, 2, 3	Tension (Longitudinal)	One test on one length of pipe from each lot of 500 lengths or fraction thereof of each size.
	Transverse Weld Tension [1]	As for tension test, only for electric-resistance-welded pipe 219.1 mm in outside diameter (8 in. nominal diameter) and over.
	Bend [1]	As for tension test, only for pipe 60.3 mm in outside diameter (2 in. nominal diameter) and under, except not required for double-extra- strong-pipe over 42.2 mm in outside diameter (1-1/4 in. nominal diameter).
	Flattening	As for tension test except: 1 Not required for pipe 60.3 mm in outside diameter (2 in. nominal diameter) and under. 2 Not required for double-extra strong pipe. 3 In the case of welded pipe ordered for flanging and electric-resistance-welded pipe, the crop ends cut from each length are to be subjected to this test. 4 *(1998)* When pipe is produced in multiple lengths, tests are required on the crop ends from the front and back ends of each coil and on two tests are required on the crop ends from the intermediate rings representing each coil.
	Hydrostatic [1]	All pipes.
4, 5	Tension (Longitudinal or Transverse [5])	One test on one length of pipe from each lot [2] of 400 lengths or fraction thereof of each size under 168.3 mm in outside diameter (6 in. Nominal diameter) and one test on one length of pipe from each lot of 200 lengths or fraction thereof of each size 168.3 mm in outside diameter (6 in. nominal diameter) and over.
	Bend [1]	One test on one length of pipe from each lot [2] of 400 lengths or fraction thereof of each size 60.3 mm in outside diameter (2 in. nominal diameter) and under, except not required for double-extra-strong pipe over 42.2 mm in outside diameter (1-1/4 in. nominal diameter.)
	Flattening	As for tension test, only for pipe over 60.3 mm in outside diameter (2 in. diameter).
	Hydrostatic [1]	All pipes.
6, 7, 11, 12, 13, 14 *(1998)*	Tension (Longitudinal or Transverse [5])	One test on 5% of the pipe in a lot [3]. For the pipe heat-treated in a batch-type furnace, at least one pipe from each heat-treated lot [3]. For pipe heat-treated by continuous process, at least two pipes from each heat-treated lot[3] are to be tested.
	Flattening	As for tension test.
	Hydrostatic [1]	All pipes.
8, 9	Tension (Longitudinal)	One test on one length of pipe from each of 400 lengths or fraction thereof of each size 168.3 mm in outside diameter (6 in. nominal diameter) and one test on one length of pipe from each lot of 200 lengths or fraction thereof of each size from 168.3 mm in outside diameter (6 in. nominal diameter) to and including 508 mm (20 in.) in outside diameter and one test on one length of pipe from each lot of 100 length or fraction thereof of each size over 508 mm (20 in.) in outside diameters.[4]
	Transverse [1] Weld Tension	As for tension test, only for pipe 168.3 mm in outside diameter (6 in. nominal diameter) and over.[4]
	Flattening	One test on each of both crop ends cut from each length of pipe. When pipe is produced in multiple lengths, tests are required on the crop ends from the front and back ends of each coil and on two intermediate rings representing each coil.
	Hydrostatic [1]	All pipes.

TABLE 3 (continued)
Mechanical Tests for Pipe *(1998)*

Notes

1 Pipes intended for structural use, such as stanchions, need *not* be subjected to this test.

2 A lot, in this case, consists of all pipe of the same size and wall thickness from any one heat.

3 The term “lot” used here applies to all pipe of the same nominal size and wall thickness which is produced from the same heat of steel and subjected to the same finishing heat treatment in a continuous furnace. When the final heat treatment is in a batch-type furnace, the lot is to include only that pipe which is heat-treated in the same furnace charge. When no heat treatment is performed following the forming operations, the lot is to include hot-rolled material only or cold-drawn material only.

4 When taken from the skelp, the number of tests is to be determined in the same manner as when taken from finished pipe.

5 The transverse tension test may *not* be made on pipe under 219.1 mm in outside diameter (8 inch nominal diameter).

TABLE 4
Tensile Requirements for Pipe *(1998)*

SI Units & MKS Units

	ABS Grades								
	1	*2 (c)*	*3 (c)*	*4*	*5*	*6 and 7*	*8 (b)*	*9 (b)*	*11, 12, 13, 14 (1998)*
Tensile Strength, min. N/mm^2 (kgf/mm^2)	310 (31.5)	330 (33.7)	415 (42)	330 (33.7)	415 (42)	380 (39)	330 (33.7)	415 (42)	415 (42)
Yield Strength, min. N/mm^2 (kgf/mm^2)	170 (17.5)	205 (21)	240 (24.5)	205 (21)	240 (24.5)	205 (21)	205 (21)	240 (24.5)	205 (21)
Elongation in 200 mm, min., %	20 (a)								
Elongation in 50 mm. min., percent. Basic minimum elongation for walls 7.9 mm and over, strip tests, and for all small sizes tested in full section.									
Transverse				25	16.5	20			20
Longitudinal		35	30	35	30	30	35	30	30
When standard round 50 mm gauge length test specimen is used.									
Transverse				20	12	14			14
Longitudinal	30	28	22	28	22	22			22
Deduction in elongation for each 0.8 mm decrease in wall thickness below 7.9 mm for strip test.									
Transverse				1.25	1.00	1.00			1.00
Longitudinal		1.75	1.50	1.75	1.50	1.50	1.75	1.50	1.50

Notes

a Gauge distances for measuring elongation on pipe of 26.7 mm O.D. and smaller are to be as follows:

O.D.	*Gauge Length*
26.7 mm and 21.3 mm	150 mm
17.1 mm and 13.7 mm	100 mm
103 mm	50 mm

b The test specimen taken across the weld is to show a tensile strength not less than the minimum specified for the grade pipe ordered. This test will not be required for pipe under 168.3 mm in outside diameter.

c The test specimen taken across the weld is to show a tensile strength not less than the minimum specified for the grade of pipe ordered. This test will not be required for pipe under 219.1 mm in outside diameter.

TABLE 4 (continued)
Tensile Requirements for Pipe *(1998)*

US Units

	ABS Grades								
	1	*2* [(c)]	*3* [(c)]	*4*	*5*	*6 and 7*	*8* [(b)]	*9* [(b)]	*11, 12, 13, 14 (1998)*
Tensile Strength, min., psi	45000	48000	60000	48000	60000	55000	48000	60000	60000
Yield Strength, min. psi	25000	30000	35000	30000	35000	30000	30000	35000	30000
Elongation in 8 in., min., %	20 [(a)]								
Elongation in 2 in. min., percent. Basic minimum elongation for walls $^5/_{16}$ in. and over, strip tests, and for all small sizes tested in full section.									
Transverse				25	16.5	20			20
Longitudinal		35	30	35	30	30	35	30	30
When standard round 2 in. gauge length test specimen is used.									
Transverse				20	12	14			14
Longitudinal	30	28	22	28	22	22			22
Deduction in elongation for each $^1/_{32}$ in. decrease in wall thickness below $^5/_{16}$ in. for strip test.									
Transverse				1.25	1.00	1.00			1.00
Longitudinal		1.75	1.50	1.75	1.50	1.50	1.75	1.50	1.50

Notes

a Gauge distances for measuring elongation on pipe of nominal sizes $^3/_4$ in. and smaller are to be as follows:

Nominal Size	*Gauge Length*
$^3/_4$ in. and $^1/_2$ in.	6 in.
$^3/_8$ in. and $^1/_4$ in.	4 in.
$^1/_8$ in.	2 in.

b The test specimen taken across the weld is to show a tensile strength not less than the minimum specified for the grade pipe ordered. This test will not be required for pipe under 6 in. in nominal diameter.

c The test specimen taken across the weld is to show a tensile strength not less than the minimum specified for the grade of pipe ordered. This test will not be required for pipe under 8 in. in nominal diameter.

TABLE 5
Hydrostatic-test Pressure for Welded and Seamless Plain-end Steel Pipe

SI Units

Pressure in bars

Outside Diameter, mm	*Standard Weight*			*Extra-strong*			*Double Extra-strong*		
	Grade	*Grade*	*Grade*	*Grade*	*Grade*	*Grade*	*Grade*	*Grade*	*Grade*
	1	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*
10.3 to 33.4	48	48	48	59	59	59	69	69	69
42.2 and 48.3	69	69	76	90	103	110	97	124	131
60.3	69	159	172	90	172	172	97	172	172
73.0	69	172	172	90	172	172	97	172	172
88.9	69	152	172	90	172	172		172	172
101.6	83	138	165	117	193	193			
114.3	83	131	152	117	186	193		193	193
141.3		117	131		165	193		193	193
168.3		103	124		159	186		193	193
219.1		90	110		145	165		193	193
273.1		83	97		117	138		193	193
323.9		76	83		97	110		193	193
355.6		66	76		90	103			
406.4		59	69		76	90			
457.2		52	62		69	83			
508.0		48	55		62	69			
609.6		38	45		52	62			

MKS Units

Pressure in kgf/cm^2

Outside Diameter, mm	*Standard Weight*			*Extra-strong*			*Double Extra-strong*		
	Grade	*Grade*	*Grade*	*Grade*	*Grade*	*Grade*	*Grade*	*Grade*	*Grade*
	1	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*
10.3 to 33.4	49.2	49.2	49.2	59.8	59.8	59.8	70.3	70. 3	70.3
42.2 and 48.3	70.3	70.3	77.3	91.3	103	112	98.4	124	134
60.3	70.3	162	176	91.4	176	176	98.4	176	176
73.0	70.3	176	176	91.4	176	176	98.4	176	176
88.9	70.3	155	176	91.4	176	176		176	176
101.6	84.4	141	169	120	197	197			
114.3	84.4	136	155	120	190	190		197	197
141.3		120	136		169	197		197	197
168.3		105	127		162	190		197	197
219.1		91.4	112		148	169		197	197
273.1		84.4	98.4		120	141		197	197
323.9		77.3	84.4		98.4	112		197	197
355.6		66.8	77.3		91.4	105			
406.4		59.8	70.3		77.3	91.4			
457.2		52.7	63.3		70.3	84.4			
508.0		49.2	56.2		63.3	70.3			
609.6		38.7	45.7		52.7	63.3			

TABLE 5 (continued)
Hydrostatic-test Pressure for Welded and Seamless Plain-end Steel Pipe

US Units

Pressure in psi

IPS Size, in.	*Standard Weight*			*Extra-strong*			*Double Extra-strong*		
	Grade 1	*Grade 2*	*Grade 3*	*Grade 1*	*Grade 2*	*Grade 3*	*Grade 1*	*Grade 2*	*Grade 3*
1/8 to 1	700	700	700	850	850	850	1000	1000	1000
1 1/4 and 1 1/2	1000	1000	1100	1300	1500	1600	1400	1800	1900
2	1000	2300	2500	1300	2500	2500	1400	2500	2500
2 1/2	1000	2500	2500	1300	2500	2500	1400	2500	2500
3	1000	2200	2500	1300	2500	2500		2500	2500
3 1/2	1200	2000	2400	1700	2800	2800			
4	1200	1900	2200	1700	2700	2800		2800	2800
5		1700	1900		2400	2800		2800	2800
6		1500	1800		2300	2700		2800	2800
8		1300	1600		2100	2400		2800	2800
10		1200	1400		1700	2000		2800	2800
12		1100	1200		1400	1600		2800	2800
14		950	1100		1300	1500			
16		850	1000		1100	1300			
18		750	900		1000	1200			
20		700	800		900	1000			
24		550	650		750	900			

TABLE 6
Out-of-roundness Variation *(1998)*

Millimeters

		Out-of-roundness Variation	
Pipe Outside Diameter		*Over*	*Under*
10.3 to 48.3 incl.		0.38	0.79
Over 48.3 to 114.3 incl.		0.79	0.79
Over 114.3 to 219.1 incl.		1.57	0.79
Over 219.1 to 457.2 incl.		2.36	0.79
Over 457.2 to 660.4 incl.		3.17	0.79
Over 660.4 to 863.6 incl. *(1998)*		4.0	0.8
Over 863.6 to 1219.2 incl. *(1998)*		4.8	0.8

Inches

		Out-of-roundness Variation	
Nominal Pipe Size		*Over*	*Under*
1/8 to 1 1/2 incl.		1/64 (0.015)	1/32 (0.031)
Over 1 1/2 to 4 incl.		1/32 (0.031)	1/32 (0.031)
Over 4 to 8 incl.		1/16 (0.062)	1/32 (0.031)
Over 8 to 18 incl.		3/32 (0.093)	1/32 (0.031)
Over 18 to 26 incl.		1/8 (0.125)	1/32 (0.031)
Over 26 to 34 incl. *(1998)*		5/32 (0.156)	1/32 (0.031)
Over 34 to 48 incl. *(1998)*		3/16 (0.187)	1/32 (0.031)

PART

2

CHAPTER 3 Materials for Machinery, Boilers, Pressure Vessels, and Piping

SECTION 13 Piping, Valves and Fittings for Low-temperature Service [Below -18°C (0°F)]

1 Scope

The following specifications cover six representative grades of steel for pipes, valves and fittings for use in piping systems designed for temperatures lower than -18°C (0°F). Steels differing in chemical composition, mechanical properties or heat treatment will be specially considered. The requirements for aluminum alloys or other non-ferrous materials will be specially considered.

Materials for Liquefied Gas Carrier are to comply with Section 5C-8-6.

3 Designation

The various grades are to be in substantial agreement with ASTM, as follows.

ABS Grade	*Nominal Composition*	*ASTM*
1L	Carbon Steels	A333 Grades 1 and 6; A334 Grades 1 and 6; A350 Grades LF1 and LF2; A352 Grade LCB; A420 Grade WPL6
2L	$^1/_2$ Mo	A352 Grade LC1
3L	$2^1/_2$ Ni	A333 Grades 4 and 7; A334 Grade 7; A350 Grade LF4; A352 Grade LC2
4L	$3^1/_2$ Ni	A333 Grade 3; A334 Grade 3; A350 Grade LF3; A352 Grade LC3; A420 Grade WPL3
5L	9 Ni	A333 Grade 8; A334 Grade 8; A522; A420 Grade WPL8
6L	10 Ni 20 Cr or 20 Ni 25 Cr	A351 Grades CF8C and CK20

5 Manufacture

The steel is to be made by the basic oxygen, open hearth or electric furnace process. The steel is to be killed and made with a fine-grain deoxidation practice.

7 Heat Treatment

The steel is to be furnished in the normalized condition or as required by the applicable specification.

9 Marking

The name or brand of the manufacturer is to be legibly marked on each pipe, flange and fitting. The Bureau grade and initials **AB** are to be placed on the material near the marking of the manufacturer.

11 Chemical Composition

The materials selected from 2-3-13/3 are to conform to the chemical requirements given in the ASTM designation indicated, except as modified by 2-3-13/5 or otherwise specially approved.

13 Mechanical Tests

The materials selected from 2-3-13/3 are to be tested in accordance with the requirements of the applicable ASTM designation as to tension test, hydrostatic test, flattening test, etc., unless otherwise specially approved.

15 Impact Properties

The materials selected from 2-3-13/3 are to conform to the toughness requirements of 2-3-13/23.

17 Steels for Service Temperatures Between -18°C (0°F) and -196°C (-320°F)

The following grades may be used for the minimum design service temperature indicated.

Grade	*Minimum Design Service Temperature °C (°F)*
1L	-34 (-30)
2L	-46 (-50)
3L	-73 (-100)
4L	-101 (-150)
5L & 6L	-196 (-320)

19 Steels for Service Temperatures Below -196°C (-320°F)

Steels intended for service temperatures below -196°C (-320°F) are to be austenitic stainless steels. The chemical composition, heat treatment and tensile properties of these materials are to be submitted for each application.

21 Materials for Nuts and Bolts

Ferritic-alloy nuts and bolts conforming to ASTM A194 Grade 4 and A320 L43 may be used where system service temperatures are not below -101°C (-150°F). Austenitic-alloy nuts and bolts conforming to ASTM A194 Grades 8T and 8F and A320 Grades B8T, B8F and B8M may be used where the design service temperature is not below -196°C (-320°F).

23 Toughness

Low temperature notch toughness is to be determined by impact testing using Charpy V-notch specimens. Testing is to consist of at least three longitudinally oriented specimens from each lot. Lot size is as defined in the applicable ASTM designation, except that at least one set of impact tests is to be made from each heat in each heat treatment charge. The energies absorbed by each set of impact specimens for Grades 1L and 2L is to conform to the requirements specified below.

Specimen Size	*Minimum Average*		*Minimum-One Specimen*	
mm	*J*	*(kgf-m, ft-lbf)*	*J*	*(kgf-m, ft-lbf)*
10 × 10	27.0	(2.8, 20)	18.5	(1.9, 13.5)
10 × 7.5	22.5	(2.3, 16.5)	15.0	(1.5, 11)
10 × 5.0	18.5	(1.9, 13.5)	12.0	(1.2, 9)
10 × 2.5	13.5	(1.4, 10)	9.0	(0.9, 6.5)

The Charpy impact requirements for Grades 3L, 4L and 5L are 125% of the values shown above. Charpy impact tests are not required for Grade 6L. Where material thicknesses are such that the quarter size impact specimen cannot be obtained, the requirements for toughness testing will be specially considered.

25 Impact Test Temperature

Materials selected from 2-3-13/3 are not to be used at temperatures lower than those indicated in 2-3-13/17 and are to be tested at temperatures at least 5.5°C (10°F) below the minimum design service temperature. Where the test temperature is determined to be below -196°C (-320°F), testing may be conducted at -196°C (-320°F).

27 Witnessed Tests *(2006)*

Piping intended for temperature below -18°C (0°F) is to be tested in the presence of the Surveyor. Materials intended for fabrication of valves fittings and piping are to be tested by the manufacturers and, upon request, the test results are to be submitted to the Bureau.

For vessels intended to carry Liquefied Gases in Bulk, see 5C-8-6/1.3.

29 Retests

When the material fails to meet the minimum impact requirements of 2-3-13/23 by an amount not exceeding 15%, retests are permitted in accordance with 2-1-2/11.7.

31 Welding

Weld procedure is to be approved in accordance with the requirements of 2-4-3/5.3. See also 2-4-2/9.9.

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PART

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CHAPTER 3 Materials for Machinery, Boilers, Pressure Vessels, and Piping

SECTION 14 Bronze Castings

1 For General Purposes

1.1 Tensile Properties

The castings are to be free from injurious defects. The material is to have the following tensile properties.

Type	*Tensile Strength Minimum, N/mm^2 (kgf/mm^2, psi)*	*Elongation in 50 mm (2 in.) Minimum percent*	*Stamping*
1	205 (21, 30000)	15	**AB/1**

1.3 Number of Tests

At least one tension test is to be made from each melt and the tension test specimen is to be machined to the dimensions shown in 2-3-1/Figure 2.

3 Propellers and Propeller Blades

3.1 Foundry Approval *(2006)*

3.1.1 Approval

All propellers and propeller components are to be cast by Bureau-approved foundries. For this purpose, the foundries are to demonstrate that they have available the necessary facilities and skilled personnel to enable proper manufacture of propellers which will satisfy these Rules.

3.1.2 Scope of the Approval Test

The following aspects of manufacture are to be taken into account:

- Casting types and sizes
- Material specifications
- Repair procedures
- Ladle capacities

- Manufacturing practices and procedures for melting and pouring, molding, heat treatment, welding repairs, hot and cold straightening, destructive and nondestructive testing methods and equipment, and chemical and metallographic capabilities.

Cast coupons of the propeller materials involved are to be tested in order to verify that composition and mechanical properties comply with these Rules.

3.1.3 Quality Control

In addition, information as to the company's facilities and organization, especially as they relate to quality control, is also required to be presented, including certification in accordance with national or international standards, such as ISO standards.

3.2 Castings

The castings are to be free from defects.

3.3 Chemical Composition

The chemical composition in % is to conform to an approved specification, four of which are listed in the table below as representative of bronze alloys currently used for propellers and propeller blades. See also 2-3-14/3.19. The samples for chemical analysis may be taken from test coupons or representative castings.

	Type 2 Mn Bronze	*Type 3 Ni-Mn Bronze*	*Type 4 Ni-Al Bronze*	*Type 5 Mn-Ni-Al Bronze*
Copper	55–60	53.5–57	78 min	71 min
Tin	1.00 max	1.00 max	—	—
Lead	0.40 max	0.20 max	0.03 max	0.03 max
Iron	0.4–2.0	1.0–2.5	3.0–5.0	2.0–4.0
Manganese	1.5 max	2.5–4.0	3.5 max	11.0–14.0
Aluminum	0.5–1.5	2.0 max	8.5–11.0	7.0–8.5
Nickel	0.5 max	2.5–4.0	3.0–5.5	1.5–3.0
Silicon	—	—	—	0.10 max
Zinc	Remainder	Remainder	—	—
Total Others	—	—	0.50 max	0.50 max

3.5 Zinc Equivalent

The chemical composition of Type 2 and Type 3 alloys are to be so controlled that the zinc equivalent, based on the following equation, does not exceed 45.0%.

$$\%\ \text{zinc equivalent} = 100 - \left(\frac{100 \times \%\ copper}{100 + A} \right)$$

where A is the algebraic sum of the following zinc replacement factors:

Tin = $+1.0 \times \%$ Sn

Iron = $-0.1 \times \%$ Fe

Aluminum = $+5.0 \times \%$ Al

Lead = 0.0

Manganese = $-0.5 \times \%$ Mn

Nickel = $-2.3 \times \%$ Ni

3.7 Alternative Zinc Equivalent

When the alpha content of a specimen taken from the end of the acceptance test bar is determined by microscopic measurement to be 20% or more, the foregoing ‘‘zinc equivalent’’ requirement will be waived.

3.9 Tensile Properties *(2008)*

The material represented by the test specimens machined from separately cast test coupons is to conform to the following minimum tensile properties.

Tensile Properties of Separately Cast Test Coupons (1, 2)

	Tensile Strength		*Yield Strength* (3)		*Elongation* (4) *Min. percent*	
					Gauge Length	
Type	*N/mm²*	*(kgf/mm², psi)*	*N/mm²*	*(kgf/mm², psi)*	*4d*	*5d*
2	450	(46, 65,000)	175	(18, 25,000)	20	18
3	515	(53, 75,000)	220	(22.5, 32,000)	18	16
4	590	(60, 86,000)	245	(25, 36,000)	16	15
5	630	(64, 91,000)	275	(28, 40,000)	20	18

Notes

1 These properties are generally not representative of the tensile properties of the propeller casting itself, which could be substantially lower than that of a separately cast test coupon.

2 The tensile requirements of integral-cast test coupons are to be specially approved.

3 Yield strength is to be determined in accordance with 2-3-1/13.3.

4 See 2-3-1/Figure 2.

3.11 Test Specimens *(2008)*

The test-coupon casting from which the tensile test specimen is machined is to be of an approved form. The tensile test specimen is to be machined to the dimensions shown in 2-3-1/Figure 1 (Round Specimen Alternative C). The test coupons may be separately cast or integral with the casting.

3.13 Separately Cast Coupons *(1996)*

Separately cast test coupons, as shown in 2-3-14/Figure 1 (test coupon according to the broken line may also be accepted) or in accordance with a recognized national standard, are to be poured from the same ladles of metal used to pour the castings, and into molds of the same material as used for the casting. In cases where more than one ladle of metal is required for a casting, a test coupon is to be provided for each ladle. Satisfactory evidence is to be furnished the Surveyor to identify the test coupons as representing the material to be tested.

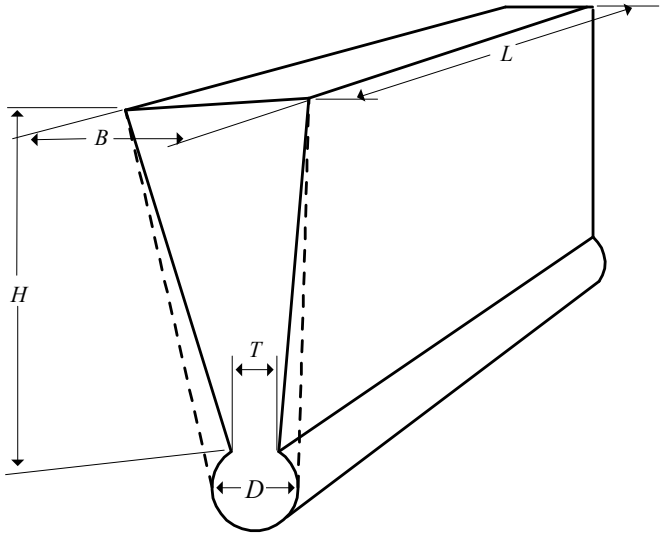
3.15 Integrally Cast Coupons

Integrally cast coupons are to be furnished as coupons cast on the surfaces of the castings.

3.17 Number of Tests

One tension test is to be made for each casting when integrally cast test coupons are provided and one tension test is to be made from each ladle when separately cast test coupons are provided. The test results are to comply with the requirements prescribed in 2-3-14/3.9.

FIGURE 1
Test Coupons *(1996)*



H = 100 mm (4 in.)
B = 50 mm (2 in.)
L > 150 mm (3 in.)
T = 15 mm (0.59 in.)
D = 25 mm (1 in.)

3.19 Special Compositions

It is recognized that other bronze alloys have been developed and proven by tests and service experience to be satisfactory. When propeller materials not meeting the chemical compositions in 2-3-14/3.3 are proposed, specifications are to be submitted for approval in connection with the approval of the design for which the material is intended.

3.21 Inspection and Repair

The entire surface of the finished propeller is to be visually examined. A liquid penetrant examination of critical areas is to be made on all propellers over 2 m (78 in.) in diameter. In addition, liquid penetrant examination is to be conducted on all suspect areas. All inspections and repairs are to be to the satisfaction of the Surveyor. Conformity with Appendix 7-A-10, "Guidance Manual for Bronze and Stainless Steel Propeller Castings" of the *Rule Requirements for Survey After Construction (Part 7)*, will be considered to meet requirements for the inspection and repair of propeller castings.

3.23 Marking

The manufacturer's name and other appropriate identification markings are to be stamped on each propeller or propeller blade in such location as to be discernible after finishing and assembly. In addition, Type 2, 3, 4and 5 castings are to be stamped **AB/2**, **AB/3**, **AB/4** or **AB/5**, respectively, to indicate satisfactory compliance with Rule requirements. Bronze alloys produced to specifications other than those covered herein in accordance with the permissibility expressed in 2-3-14/3.19 are to be stamped **AB/S** and with the applicable specification number.

5 Castings for Ice-Strengthened Propellers

Castings for ice-strengthened propellers are to meet the requirements for bronze, carbon, alloy, or stainless steel propeller alloy, as applicable, and the following additional requirements.

Ice Strengthening Class	*Additional Requirements*
All ice classes except ice class **D0**	Minimum Charpy V-Notch absorbed energy 20.5 J (2.1 kgf-m, 15 ft-lbs) at -10°C (14°F) 19% minimum elongation in 5D

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PART

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CHAPTER 3 Materials for Machinery, Boilers, Pressure Vessels, and Piping

SECTION 15 Austenitic Stainless Steel Propeller Castings

Note: In substantial agreement with ASTM A-743, Grade CF-3

1 Process of Manufacture and Foundry Approval *(2006)*

1.1 Process of Manufacture

The following requirements cover austenitic stainless steel castings intended to be used for propellers and propeller blades. The stainless steel is to be melted by the electric arc or electric induction process, or other process as may be approved.

1.3 Foundry Approval

Stainless steel propellers and propeller components, including grade CF-3 and other grades, as indicated in 7-A-10/3 of the ABS *Rules for Survey After Construction (Part 7)*, are to be cast by Bureau-approved foundries. For this purpose, foundries are to demonstrate that they have available the necessary facilities and skilled personnel to enable proper manufacture of propellers which will satisfy these Rules.

1.5 Scope of the Approval Test

The following aspects of manufacture are to be taken into account:

- Casting types and sizes
- Material specifications
- Repair procedures
- Ladle capacities
- Manufacturing practices and procedures for: Melting and pouring, molding, heat treatment, welding repairs, hot and cold straightening, destructive and nondestructive testing methods and equipment, and chemical and metallographic capabilities.

Cast coupons of the propeller materials involved are to be tested in order to verify that composition and mechanical properties comply with these Rules.

1.7 Quality Control

In addition, information as to the company's facilities and organization, especially as they relate to quality control, is required to be presented, including certification in accordance with national or international organizations standards, such as ISO standards.

3 Inspection and Repair

The entire surface of the finished propeller is to be visually examined. A liquid penetrant examination of critical areas is to be made. In addition, all suspect areas should be examined by the liquid penetrant method. The surfaces of all propellers are to be suitably protected from the corrosive effects of industrial environments until fitted on the vessel. All inspections and repairs are to be to the satisfaction of the Surveyor. Conformity with Appendix 7-A-10, "Guidance Manual for Bronze and Stainless Steel Propeller Castings" of the *Rule Requirements for Survey After Construction (Part 7)*, will be considered to meet requirements for the inspection and repair of propeller castings.

5 Chemical Composition

An analysis of each heat is to be made by the manufacturer from a test sample that is representative of the heat and that is taken during the pouring of the heat. The chemical composition in % thus determined is to conform to the requirements specified below.

Carbon max.*	0.03
Manganese max.	1.50
Silicon max.	2.00
Phosphorus max.	0.04
Sulfur max.	0.04
Chromium	17.0–21.0
Nickel	8.0–12.0

* A carbon content up to and including 0.0345% is considered to meet the 0.03 maximum requirement.

7 Tensile Properties

The metal represented by the test specimens is to conform to the following minimum tensile properties.

Grade	*Tensile Strength N/mm^2 (kgf/mm^2, psi)*	*Yield Strength N/mm^2 (kgf/mm^2, psi)*	*Elongation in 50 mm (2 in.) %*
CF-3	485 (49, 70,000)	205 (21, 30,000)	35

9 Tests and Marking

9.1 Test Specimens

The test-coupon casting from which the tension test specimen is machined is to be of an approved form. The tension test specimen is to be machined to the dimensions shown in 2-3-1/Figure 2. The test coupons may be separately or integrally cast.

9.3 Separately Cast Coupons *(2006)*

Separately cast test coupons are to be poured from the same ladles of metal used to pour the castings, and into molds of the same material as used for the casting. Test coupons are to be heat treated with the castings represented. In cases where more than one ladle of metal is required for a casting, a test coupon is to be provided for each ladle. Satisfactory evidence is to be furnished the Surveyor to identify the test coupons as representing the material to be tested.

9.5 Integral Coupons *(2006)*

Integral test coupons are to be furnished as coupons attached to the hub or on the blade. Where possible, test bars attached on blades are to be located in an area between 0.5 to 0.6R, where R is the radius of the propeller. Test bars are not to be detached from the casting until final heat treatment has been carried out. Removal is to be by non-thermal means.

9.7 Number of Tests

One tension test is to be made for each casting when integrally cast test coupons are provided, and one tension test is to be made from each ladle when separately cast test coupons are provided. The test results are to comply with the requirements prescribed in 2-3-15/7.

9.9 Special Compositions

It is recognized that other alloys have been developed and proven by tests and service experience to be satisfactory. When propeller materials not meeting the chemical compositions in 2-3-15/5 are proposed, specifications are to be submitted for approval in connection with the approval of the design for which the material is intended.

9.11 Marking

The manufacturer's name and other appropriate identification markings are to be stamped on each propeller or propeller blade in such location as to be discernible after finishing and assembly. In addition, Grade CF-3 castings are to be stamped **AB/CF–3** to indicate satisfactory compliance with Rule requirements. Alloys produced to specifications other than those covered herein in accordance with the permissibility expressed in 2-3-15/9.9 are to be stamped **AB/S**, and with the applicable specification number.

11 Castings for Ice-strengthened Propellers

Castings for ice-strengthened propellers are to comply with 2-3-14/5.

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PART

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CHAPTER 3 Materials for Machinery, Boilers, Pressure Vessels, and Piping

SECTION 16 Seamless Copper Piping *(1998)*

Note: In substantial agreement with ASTM B42.

1 Scope

The following specifications cover seven grades of seamless copper pipe designated C1, C2, C3, C4, C5, C6 and C7.

3 General

3.1 Grades C1, C2, C3, C4, C5, C6 and C7

These grades cover seamless copper pipe intended for boiler feed-water lines, plumbing, and other similar service. Pipe ordered in all standard pipe sizes, both regular and extra strong, under these grades is considered suitable for welding and brazing.

3.3 ASTM Designation

These grades are in substantial agreement with ASTM, as follows:

ABS Grade	*ASTM Designation*
C1	UNS C10100
C2	B42, UNS C10200
C3	B42, UNS C10300
C4	B42, UNS C10800
C5	B42, UNS C12000
C6	B42, UNS C12200
C7	UNS C14200

5 Process of Manufacture *(2008)*

The material is to be produced by either hot or cold working operations, or both. It is to be finished, unless otherwise specified, by such cold working and annealing or heat treatment as may be necessary to meet the properties specified. All pipe is to be normally furnished in the drawn-temper condition, (H55). Hard-drawn temper (H80) may be furnished also. When pipe is required for bending, the pipe is to be furnished with a proper bending temper, or annealed temper (061). All pipes for working pressures over 10 bar (10.5 kgf/cm^2, 150 psi) are to be tested at the mills to the satisfaction of the Surveyor. The pipes are examined by the Surveyor when requested by the purchaser. The pipe is to be commercially round and is to be free from defects that interfere with normal applications.

7 Marking

7.1 Manufacturer's Marking

The name or brand of the manufacturer, the designation B42, and the test pressure are to be legibly marked by stamping or stenciling on each length of pipe. On small-diameter pipe, which is bundled, this information may be marked on a tag securely attached to each bundle.

7.3 Bureau Markings

The Bureau markings, indicating satisfactory compliance with the Rule requirements, and as furnished by the Surveyor, are to be placed on the material near the markings specified in 2-3-16/7.1.

9 Chemical Composition

The material is to conform to the applicable requirements as to chemical composition as shown in 2-3-16/Table 1.

11 Tension Test

11.1 Tension Test Specimens

Tensile test specimens are to be a full section of the pipe. For larger sizes, tension test specimens are to consist of longitudinal strips cut from the pipe in accordance with ASTM E8.

11.3 Tensile Properties

The material is to conform to the applicable requirements as to tensile properties shown in 2-3-16/Table 2.

13 Expansion Test

Specimens selected for test, after annealing, are to withstand an expansion of 25% of the outside diameter when expanded by a tapered pin having a 60-degree included angle. The expanded tube is to show no cracking or rupture visible to the unaided eye.

15 Flattening Test

As an alternate to the expansion test for pipe over 114.3 mm outside diameter (4 in. nominal size) in the annealed condition, a section 100 mm (4 in.) in length is to be cut from the end of one of the lengths for a flattening test. This 100 mm (4 in.) specimen is to be flattened so that a gauge set at three times the wall thickness will pass over the pipe freely throughout the flattened part. The pipe so tested is to develop no cracks or defects visible to the unaided eye as a result of this test. In making the flattening test, the specimens are to be slowly flattened by one stroke of the press.

17 Hydrostatic Test

17.1 Limiting Test Pressures

Each length of the pipe is to stand, without showing weakness or defects, an internal hydrostatic pressure sufficient to subject the material to a fiber stress of 41 N/mm^2 (4.22 kgf/mm^2, 6000 psi), determined by the following equation. No pipe is to be tested beyond a hydrostatic pressure of 69 bar (70.3 kgf/cm^2, 1000 psi) unless so specified. At the option of the manufacturer, annealed pipe with wall thickness up to 2.11 mm (0.083 in.) inclusive may be tested in the hard-drawn condition prior to annealing.

$$P = KSt/(D - 0.8t)$$

where

P = pressure in bar (kgf/cm^2, psi)

S = allowable unit stress of the material, 41 N/mm^2 (4.22 kgf/mm^2, 6000 psi)

t = thickness of pipe wall, in mm (in.)

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

K = 20 (200, 2)

17.3 Affidavits of Tests

Where each pipe is hydrostatically tested as a regular procedure during the process of manufacture, an affidavit covering this test may be accepted by the Surveyor.

19 Number of Tests

The lot is to consist of pipe of the same size and temper. The lot size is to be 2270 kg (5000 lb) or a fraction thereof for pipe up to 48.3 mm O.D. (1.5 in. nominal size) incl.; 4550 kg (10,000 lb) or a fraction thereof for pipe over 48.3 mm O.D. (1.5 in. nominal size) to 114.3 mm O.D. (4 in. nominal size) incl., 18,150 kg (40,000 lb) or a fraction thereof for pipe over 114.3 mm O.D. (4 in. nominal size). Sample pieces are to be taken for test purposes from each lot as follows:

Number of Pieces in Lot	*Number of Sample Pieces to Be Taken*
1 to 50	1
51 to 200	2
201 to 1500	3
Over 1500	0.2% of total number of pieces in the lot, but not to exceed 10 sample pieces

Chemical analyses, where required, tensile tests, expansion tests, flattening tests, bend tests, where required, dimensional examinations and visual examinations are to be made on each of the sample pieces selected for test. Each length of pipe is to be subjected to the hydrostatic test specified in 2-3-16/17.

21 Retests

If the results of the test on one of the specimens, made to determine the mechanical properties, fails to meet the requirements, this test is to be repeated on each of two additional specimens taken from different pieces and the results of both of these tests is to comply with the requirements. Failure of more than one specimen to meet the requirements for a particular property is to be cause for rejection of the entire lot.

23 Permissible Variations in Dimensions

The permissible variations in wall thickness and diameter are based on the ordered thickness and are to conform to that given in the applicable ASTM designation for acceptance, but the minimum thickness for all pipe is not to be less than that required by the Rules for a specific application, regardless of such prior acceptance.

TABLE 1
Chemical Composition for Copper Pipe and Tube *(1998)*

Pipe Grade	*Tube Grade*	*Minimum Copper*, %*	*Phosphorus, %*	*Arsenic, %*	*Maximum Oxygen, ppm*
C1	CA	99.99	—	—	—
C2	CB	99.5	—	—	10
C3	CC	99.95**	0.001 to 0.005	—	—
C4	CD	99.95**	0.005 to 0.012	—	—
C5	CE	99.90	0.004 to 0.012	—	—
C6	CF	99.9	0.015 to 0.040	—	—
C7	CG	99.40	0.015 to 0.040	0.15-0.50	—

Notes:

* Including silver.

** Total of copper, silver and phosphorus.

TABLE 2
Tensile Properties for Copper Pipe and Tube *(1998)*

Temper Designation		*Tensile Strength, min*	*Yield Strength*, min.*
Standard	*Former*	*N/mm^2 (kgf/mm^2, ksi)*	*N/mm^2 (kgf/mm^2, ksi)*
061/060	annealed	205 (21,30)	62 (6,9)**
H55	light drawn	250 (25,36)	205 (21,30)
H80	hard drawn	310 (32,45)	275 (28,40)

Notes:

* At 0.5% extension under load.

** Light straightening operation is permitted.

PART

2

CHAPTER 3 Materials for Machinery, Boilers, Pressure Vessels, and Piping

SECTION 17 Seamless Red-brass Piping

Note: In substantial agreement with ASTM B43.

1 Process of Manufacture *(2008)*

The material is to be produced by either hot or cold working operations, or both. It is to be finished, unless otherwise specified, by such cold working and annealing or heat treatment as may be necessary to meet the properties specified. All pipe is normally to be furnished in the annealed condition. The degree of anneal is to be sufficient to show complete recrystallization and to enable the pipe to meet the test requirements prescribed in these specifications. The pipe may be furnished in the drawn-temper condition instead of the annealed condition if so specified by the purchaser. All pipes for working pressures over 10 bar (10.5 kgf/cm^2, 150 psi) are to be tested at the mills to the satisfaction of the Surveyor. The pipes are examined by the Surveyor when requested by the purchaser. The pipe is to be commercially round and is to be free from defects that interfere with normal applications.

3 Marking

3.1 Manufacturer's Marking

The name or brand of the manufacturer, the designation B43, and the test pressure is to be legibly marked by stamping or stenciling on each length of pipe. On small-diameter pipe, which is bundled, this information may be marked on a tag securely attached to each bundle.

3.3 Bureau Marking

The Bureau markings, indicating satisfactory compliance with the Rule requirements, and as furnished by the Surveyor, are to be marked on the material near the markings specified in 2-3-17/3.1.

5 Scope

These specifications cover seamless red-brass pipe in all standard sizes, both regular and extra strong.

7 Chemical Composition

The material is to conform to the following requirements as to chemical composition.

Copper	84.00% to 86.00%
Lead	0.06% max.
Iron	0.05% max.
Zinc	remainder
Total other elements	0.15%

Analysis is regularly to be made only for the elements specifically mentioned in this table. If, however, the presence of other elements is suspected or indicated in the course of routine analysis, further analysis is to be made to determine that the total of these other elements is not in excess of the limit specified.

9 Expansion Test

Specimens selected for test, after annealing, are to withstand an expansion of 25% of the inside diameter, without cracking, when expanded by a tapered pin having a 60-degree included angle. The expanded tube is to show no cracking or rupture visible to the unaided eye.

11 Flattening Test

As an alternate to the expansion test for pipe over 114.3 mm outside diameter (4 in. nominal size) in the annealed condition, a section 100 mm (4 in.) in length is to be cut from the end of one of the lengths for a flattening test. This 100 mm (4 in.) specimen is to be flattened so that a gauge set at three times the wall thickness will pass over the pipe freely through the flattened part. The pipe so tested is to develop no cracks or defects visible to the unaided eye as a result of this test. In making the flattening test, the elements are to be slowly flattened by one stroke of the press.

13 Mercurous Nitrate Test

A test specimen 150 mm (6 in.) in length is to be taken from each pipe selected for test and, after proper cleaning, is to withstand, without cracking, an immersion of 30 minutes in an aqueous mercurous nitrate solution containing 10 grams of mercurous nitrate and 10 milliliters of nitric acid (specific gravity 1.42) per liter of solution. Immediately after removal from the solution, the specimen is to be wiped free of excess mercury and examined for cracks.

15 Bend Test

In the case of pipe required for bending, annealed full sections of the pipe are to stand being bent cold through an angle of 180 degrees around a pin, the diameter of which is one and one-half times the inside diameter of the pipe, without cracking on the outside of the bent portion. This test is to apply only to sizes 50.8 mm (2 in.) and under in outside diameter.

17 Hydrostatic Test

17.1 Limiting Test Pressures

Each length of the pipe is to stand, without showing weakness or defects, an internal hydrostatic pressure sufficient to subject the material to a fiber stress of 48 N/mm^2 (4.92 kgf/mm^2, 7000 psi), determined by the following equation. No pipe is to be tested beyond a hydrostatic pressure of 69 bar (70.3 kgf/cm^2, 1000 psi) unless so specified.

$$P = KSt/(D - 0.8t)$$

where

P = pressure, in bar (kgf/cm^2, psi)

S = allowable unit stress of the material, 48 N/mm^2 (4.92 kgf/mm^2, 7000 psi)

t = thickness of pipe wall, in mm (in.)

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

K = 20 (200, 2)

17.3 Affidavits of Tests

Where each pipe is hydrostatically tested as a regular procedure during the process of manufacture, an affidavit covering this test may be accepted by the Surveyor.

19 Number of Tests

The lot is to consist of pipe of the same size and temper. The lot size is to be 2270 kg (5000 lb) or a fraction thereof for pipe up to 48.3 mm O.D. (1.5 in. nominal size) incl., 4540 kg (10,000 lb) or a fraction thereof for pipe over 48.3 mm O.D. (1.5 in. nominal size) to 114.3 mm O.D. incl. (4 in. nominal size), 18,150 kg (40,000 lb) or a fraction thereof for pipe over 114.3 mm O.D. (4 in. nominal size). Sample pieces are to be taken for test purposes from each lot as follows.

Number of Pieces in Lot	*Number of Sample Pieces to Be Taken*
1 to 50	1
51 to 200	2
701 to 1500	3
over 1500	0.2% of total number of pieces in the lot, but not to exceed 10 sample pieces

Expansion, flattening and bend tests, where required, are to be made on each of the sample pieces selected for test. Each length of pipe is to be subjected to the hydrostatic test specified in 2-3-17/17.1.

21 Retests

If the results of the test on one of the specimens, made to determine the physical properties, fails to meet the requirements, this test is to be repeated on each of two additional specimens taken from different pieces and the results of both of these tests are to comply with the requirements. Failure of more than one specimen to meet the requirements for a particular property is to be cause for rejection of the entire lot.

23 Permissible Variations in Dimensions

The permissible variations in wall thicknesses are based on the ordered thicknesses and is to conform to that given in the applicable ASTM designation for acceptance, but the minimum thickness for all pipe is not to be less than that required by the Rules for a specific application, regardless of such prior acceptance.

PART

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CHAPTER 3 Materials for Machinery, Boilers, Pressure Vessels, and Piping

SECTION 18 Seamless Copper Tube *(1998)*

Note: In substantial agreement with ASTM B75.

1 Scope

The following specifications cover seven grades of seamless copper tube designated CA, CB, CC, CD, CE, CF and CG.

3 General

3.1 Grades CA, CB, CC, CD, CE, CF and CG

These grades cover seamless copper tube intended for boiler feedwater lines, plumbing, and general engineering applications. Tube is to be ordered to outer diameter and wall thickness specified by the purchaser and approved for the application. Tube ordered under these grades are considered suitable for welding and brazing. Seamless round copper tube in standard pipe sizes and schedules is considered to be pipe and is covered by Section 2-3-16.

3.3 ASTM Designation

The grades are in substantial agreement with ASTM, as follows:

ABS Grade	*ASTM Designation*
CA	B75, UNS C10100
CB	B75, UNS C10200
CC	B75, UNS C10300
CD	B75, UNS C10800
CE	B75, UNS C12000
CF	B75, UNS C12200
CG	B75, UNS C14200

5 Process of Manufacture *(2008)*

The material is to be produced by either hot or cold working operations, or both. It is to be finished, unless otherwise specified, by such cold working and annealing or heat treatment as may be necessary to meet the properties specified. All tube is to be normally furnished in the drawn-temper condition, (H55). Hard-drawn temper (H80) may be furnished also. When tube is required for bending, the tube is to be furnished with a proper bending temper, or annealed temper (O60). All tubes for working pressures over 10 bar (10.5 kgf/cm^2, 150 psi) are to be tested at the mills to the satisfaction of the Surveyor. The pipes are examined by the Surveyor when requested by the purchaser. The tube is to be commercially round and is to be free from defects that interfere with normal applications.

7 Marking

7.1 Manufacturer's Marking

The name or brand of the manufacturer, the designation B75, and the test pressure are to be legibly marked by stamping or stenciled on each length of tube. On small-diameter tube, which is bundled, this information may be marked on a tag securely attached to each bundle.

7.3 Bureau Markings

The Bureau markings, indicating satisfactory compliance with the Rule requirements, and as furnished by the Surveyor, are to be placed on the material near the markings specified in 2-3-18/7.1.

9 Chemical Composition

The material is to conform to the applicable requirements as to chemical composition as shown in 2-3-16/Table 1.

11 Tension Test

11.1 Tension Test Specimens

Tensile test specimens are to be a full section of the tube. For larger sizes, tension test specimens are to consist of longitudinal strips cut from the tube in accordance with ASTM E8.

11.3 Tensile Properties

The material is to conform to the applicable requirements as to tensile properties shown in 2-3-16/Table 2.

13 Expansion Test

Note: This test is required for tubes manufactured in the annealed temper.

Specimens selected for test, after annealing, are to withstand an expansion of the outside diameter when expanded by a tapered pin having a 60-degree included angle to 30 percent for tube over 19.0 mm ($^3/_4$ in.) in outside diameter and to 40 percent for smaller sized tube. The expanded tube is to show no cracking or rupture visible to the unaided eye.

15 Flattening Test

As an alternate to the expansion test for tube over 114.3 mm outside diameter (4 in. nominal size) in the annealed condition, a section 100 mm (4 in.) in length is to be cut from the end of one of the lengths for a flattening test. This 100 mm (4 in.) specimen is to be flattened so that a gauge set at three times the wall thickness will pass over the pipe freely throughout the flattened part. The tube so tested is to develop no cracks or defects visible to the unaided eye as a result of this test. In making the flattening test, the specimens are to be slowly flattened by one stroke of the press.

17 Hydrostatic Test

17.1 Limiting Test Pressures

Each length of the tube is to stand, without showing weakness or defects, an internal hydrostatic pressure sufficient to subject the material to a fiber stress of 41 N/mm^2 (4.22 kgf/mm^2, 6000 psi), determined by the following equation. No pipe is to be tested beyond a hydrostatic pressure of 69 bar (70.3 kgf/cm^2, 1000 psi) unless so specified. At the option of the manufacturer, annealed tube with wall thickness up to 2.11 mm (0.083 in.) inclusive may be tested in the hard-drawn condition prior to annealing.

$$P = KSt/(D - 0.8t)$$

where

P = pressure, in bar (kgf/cm^2, psi)

S = allowable unit stress of the material, 41 N/mm^2 (4.22 kgf/mm^2, 6000 psi)

t = thickness of pipe wall, in mm (in.)

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

K = 20 (200, 2)

17.3 Affidavits of Tests

Where each tube is hydrostatically tested as a regular procedure during process of manufacture, an affidavit covering this test may be accepted by the Surveyor.

19 Number of Tests

The lot is to consist of tubes of the same size and temper. The lot size is to be 4540 kg (10,000 lb) or a fraction thereof. Sample pieces are to be taken for test purposes at random from each lot, as follows:

Number of Pieces in Lot	*Number of Sample Pieces to be Taken*
1 to 50	1
51 to 200	2
201 to 1500	3
over 1500	0.2% of total number of pieces in the lot, but not to exceed 10 sample pieces

Chemical analyses, where required, tensile tests, expansion tests, flattening tests, bend tests, where required, dimensional examinations and visual examinations are to be made on each of the sample pieces selected for test. Each length of pipe is to be subjected to the hydrostatic test specified in 2-3-18/19.

21 Retests

If the results of the test on one of the specimens, made to determine the mechanical properties, fails to meet the requirements, this test is to be repeated on each of two additional specimens taken from different pieces and the results of both of these tests is to comply with the requirements. Failure of more than one specimen to meet the requirements for a particular property is to be cause for rejection of the entire lot.

23 Permissible Variations in Dimensions

The permissible variations in wall thickness and diameter are based on the ordered thickness and are to conform to that given in the applicable ASTM for acceptance, but the minimum thickness for all pipe is not to be less than that required by the Rules for a specific application, regardless of any prior acceptance.

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CHAPTER 3 Materials for Machinery, Boilers, Pressure Vessels, and Piping

SECTION 19 Condenser and Heat Exchanger Tube *(1998)*

Note: In substantial agreement with ASTM B111.

1 Scope

The following specifications covers two grades of seamless copper-nickel tube designated CNA and CNB.

3 General

3.1 Grades CNA and CNB

Grades CNA, and CNB cover seamless copper-nickel tube intended for use in condensers, evaporators and heat exchanger which may use sea water as the cooling medium. Tube ordered under these grades is considered suitable for welding, and suitable for forming operations involving coiling, bending, flaring and tube rolling. Tube is to be ordered to outer diameter and wall thickness specified by the purchaser and approved for the application.

3.3 ASTM Designation

The grades are in substantial agreement with ASTM, as follows:

ABS Grade	*ASTM Designation*
CNA	B111, UNS C70600
CNB	B111, UNS C71500

5 Process of Manufacture

5.1 Grade CNA

Grade CNA tube is to be cold worked to the specified size. The tube may be supplied either in the annealed temper (O61) or in the light drawn temper (H55).

5.3 Grade CNB

Grade CNB tube is to be cold worked to the specified size. The tube may be supplied either in the annealed temper (O61) or in the drawn and stress relieved temper (HR50).

All grades of tube shall be round, straight, clean, smooth and free from harmful defects and deleterious films in the bore.

7 Marking

Identification markings are to be legibly stenciled, or suitably marked on each length of tube, except that in the case of smaller-diameter tube which is bundled, the required markings are to be placed on a tag securely attached to the bundle. The markings are to be arranged and are to include the following information:

- Name or brand of the manufacturer
- ABS Grade or ASTM Designation and Grade
- Temper number
- Tube diameter
- Wall thickness
- Test Pressure or the letters NDET
- ABS markings by the Surveyor

9 Chemical Composition

9.1 Chemical Requirements

The material is to conform to the applicable requirements as to chemical composition as shown in 2-3-19/Table 1.

9.3 Chemical Analysis Sampling

Samples may be taken at the time the metal is cast or may be taken from semi-finished product, or from finished product in accordance with sampling in 2-3-19/21.

11 Tension Test

11.1 Tension Test Specimens

Tensile test specimens are to be a full section of the tube. For larger sizes, tension test specimens are to consist of longitudinal strips cut from the tube in accordance with ASTM E8, for Tension Testing of Metallic Materials.

11.3 Tensile Properties

The material is to conform to the applicable requirements as to tensile properties shown in 2-3-19/Table 2.

13 Expansion Test

Specimens selected for testing in accordance with ASTM B153, for Expansion (Pin Test) of Copper and Copper-Alloy Pipe and Tubing, are to withstand an expansion of the outside diameter to 30 percent for annealed temper (O61) tube and to 20 percent for drawn temper (H55 or HR50) tube. The expanded tube is to show no cracking or rupture visible to the unaided eye.

15 Flattening Test

The specimen selected for testing is to be at least 450 mm (18 in.) in length, and is to be flattened so that a gauge set at three times the wall thickness will pass over the tube freely throughout the flattened part. The tube so tested is to develop no cracks or defects visible to the unaided eye as a result of this test. In making the flattening test, the specimens are to be slowly flattened by one stroke of the press. Specimens not initially in the annealed temper (O61) are to be annealed prior to flattening.

17 Nondestructive Electric Test (NDET)

All tubes are to be eddy-current tested in accordance with ASTM E243, for Electromagnetic (Eddy-Current) Examination of Copper and Copper-Alloy Tubes or, alternatively, when specified, may be hydrostatically tested in accordance with 2-3-19/19. A calibration reference standard is to be made from a length of tube of the same type, wall thickness, and outside diameter as that to be tested. The standard is to have transverse notches or drilled holes in accordance with the dimensions shown. Tubing producing a signal equal to or greater than the calibration defect is to be rejected.

Diameter of Drilled Hole

Tube OD, in mm (inch)	*Diameter, in mm (inch)*
6.0 (0.25) ≤ OD ≤ 19.0 (0.75)	0.635 (0.025)
19.0 (0.75) < OD ≤ 25.4 (1.0)	0.785 (0.031)
25.4 (1.0) < OD ≤ 31.8 (1.25)	0.915 (0.036)
31.8 (1.25) < OD ≤ 38.1 (1.5)	1.07 (0.042)
38.1 (1.5) < OD ≤ 44.4 (1.75)	1.17 (0.046)
44.4 (1.75) < OD ≤ 50.8 (2.0)	1.32 (0.052)

Notch Depth

	Tube OD, in mm (inch)		
Tube Wall Thickness, in mm (inch)	6.4 (0.25) ≤ ≤ 19.1 (0.75)	19.1 (0.75) < ≤ 31.8 (1.25)	31.8 (1.25) < ≤ 80 (3.125)
0.43 (0.17) < T < 0.8 (0.032)	0.127 (0.005)	0.152 (0.006)	0.179 (0.007)
0.80 (0.032) < T < 1.24 (0.049)	0.152 (0.006)	0.152 (0.006)	0.191 (0.0075)
1.24 (0.049) < T < 2.10 (0.083)	0.179 (0.007)	0.191 (0.0075)	0.216 (0.008)
2.10 (0.083) < T < 2.77 (0.109)	0.191 (0.0075)	0.216 (0.0085)	0.241 (0.0095)
2.77 (0.109) < T < 3.05 (0.120)	0.229 (0.009)	0.229 (0.009)	0.279 (0.011)

19 Hydrostatic Test

19.1 Limiting Test Pressures

As an alternate to the eddy-current test, hydrostatic testing may be performed. Each tube that is tested is to stand, without showing evidence of leakage, an internal hydrostatic pressure sufficient to subject the material to a fiber stress of 48 N/mm^2 (4.92 kgf/mm^2, 7000 psi), determined by the following equation for thin hollow cylinders under tension. The tube is not to be tested at a hydrostatic pressure of over 69 bar (70.3 kgf/cm^2, 1000 psi) unless so specified.

$$P = KSt/(D - 0.8t)$$

where

P = pressure in bar (kgf/cm^2, psi)

S = allowable unit stress of the material, 48 N/mm^2 (4.92 kgf/mm^2, 7000 psi)

t = thickness of pipe wall, in mm (in.)

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

K = 20 (200, 2)

19.3 Affidavits of Tests

Where each tube is hydrostatically tested as a regular procedure during the process of manufacture, an affidavit covering this test may be accepted by the Surveyor.

21 Number of Tests

The lot is to consist of tubes of the same size and temper. The lot size is to be 4540 kg (10,000 lb) or a fraction thereof. Sample pieces are to be taken for test purposes at random from each lot, as follows:

Number of Pieces in Lot	*Number of Sample Pieces to be Taken*
1 to 50	1
51 to 200	2
201 to 1500	3
over 1500	0.2% of total number of pieces in the lot, but not to exceed 10 sample pieces

Chemical analyses, where required, tensile tests, expansion tests, flattening tests, dimensional examinations and visual examinations are to be made on each of the sample pieces selected for test. Each length of pipe is to be subjected to the eddy-current test or the hydrostatic test.

23 Retests

If the results of the test on one of the specimens, made to determine the mechanical properties, fails to meet the requirements, this test is to be repeated on each of two additional specimens taken from different pieces and the results of both of these tests is to comply with the requirements. Failure of more than one specimen to meet the requirements for a particular property is to be cause for rejection of the entire lot.

25 Finish

Tubes selected for testing are to be examined for finish and workmanship. Tubes are to be free from cracks, injurious surface flaws, and similar defects to the extent determinable by visual or NDET examination. Tubes are to be clean and free of any foreign material that would render the tubes unfit for the intended use. Cut ends of tubes are to be deburred.

27 Dimensions and Tolerances

Tubes selected for testing are to be measured and examined for dimensions and tolerances.

27.1 Diameter

The tube outside diameter is to not vary from the specified values by more than the amounts shown.

Diameter Tolerances, mm (inches)

Outside Diameter, mm (inch)	*Wall Thickness, mm (inch)*				
	0.51 to (0.020) to 0.71 (0.028*)	0.81 (0.032)	0.89 (0.035)	1.07 (0.042)	1.24 and Over (0.049) and Over
Up to 12.5, incl. Up to (0.500), incl.	0.076 (0.003)	0.064 (0.0025)	0.064 (0.0025)	0.064 (0.0025)	0.064 (0.0025)
Over 12.5-19.0, incl. Over (0.500-0.740), incl.	0.102 (0.0040)	0.102 (0.004)	0.102 (0.004)	0.089 (0.0035)	0.076 (0.003)
Over 19.0-25.4, incl Over (0.740-1,000), incl.	0.152 (0.0060)	0.152 (0.006)	0.127 (0.005)	0.114 (0.0045)	0.102 (0.004)
Over 25.4-31.8, incl. Over (1.000-1.250), incl	… …	0.229 (0.009)	0.203 (0.008)	0.152 (0.006)	0.114 (0.0045)
Over 31.8-35.0, incl. Over (1.250-1.375), incl	… …	… …	… …	0.203 (0.008)	0.127 (0.005)
Over 35.0-50.8, incl. Over (1.375-2.000), incl.	… …	… …	… …	… …	0.152 (0.006)

* Tolerances in this column are applicable to light and drawn tempers only. Tolerances for annealed tempers are to be as agreed upon between the manufacturer and the purchaser.

27.3 Wall Thickness Tolerances

For tubes ordered to minimum wall, no tube wall at its thinnest point is to be less than the specified wall thickness and no tube at its thickest point is to have a plus deviation greater than twice the value shown. For tubes ordered to nominal wall thickness, the maximum plus and minus deviation in inches from the nominal wall at any point is to not exceed the values shown.

Wall Thickness Tolerances, mm (inches)

Wall Thickness, mm (inch)	*Outside Diameter, mm (inch)*		
	Over 3.2 (0.125) to Over 15.9 (0.625), incl.	Over 15.9 (0.625) to 25.4 (1.0), incl.	Over 25.4 (1.0) to 50 (2.0), incl.
0.51, incl. to 0.81 (0.020), incl. to (0.032)	0.076 (0.003)	0.076 (0.003)	
0.81, incl. to 0.89 (0.032), incl. to (0.035)	0.076 (0.003)	0.076 (0.003)	0.102 (0.004)
0.89, incl. to 1.47 0.035, incl. to 0.058	0.102 (0.004)	0.114 (0.0045)	0.114 (0.0045)
1.47, incl. to 2.11 (0.058), incl. to (0.083)	0.114 (0.0045)	0.127 (0.005)	0.127 (0.005)
2.11, incl. to 3.05 (0.083), incl. to (0.120)	0.127 (0.005)	0.165 (0.0065)	0.165 (0.0065)
3.05, incl. to 3.40 (0.120), incl. to (0.134)	0.179 (0.007)	0.179 (0.007)	0.191 (0.0075)

27.5 Length

The length of tubes is to not be less than that specified when measured at a temperature of 20°C (68°F) and may exceed the specified values by the amounts shown.

Specified Length, m (feet)	*Tolerance, All Plus, mm (inch)*
Up to 4.5 (15)	2.4 ($^3/_{32}$)
Over 4.5 (15) to 6.0 (20), incl.	3.2 ($^1/_8$)
Over 6.0 (20) to 10 (30), incl.	4.0 ($^5/_{32}$)
Over 10 (30) to 18 (60), incl.	9.5 ($^3/_8$)
Over 18 (60) to 30 (100), incl.*	13.0 ($^1/_2$)

* Length tolerances for wall thickness 0.51 mm (0.020 in.) to 0.81 mm (0.032 in.) are to be as agreed upon between the manufacturer or supplier and the purchaser.

27.7 Squareness of Cut

The departure from squareness of the end of the tube is to not exceed the following.

Specified Outside Diameter	*Tolerance*
Up to 15.9 mm ($^5/_8$ in.) incl.	0.25 mm (0.010 in.)
Over 15.9 mm ($^5/_8$ in.)	0.016 mm/mm (0.016 in./in.) of diameter

TABLE 1
Chemical Composition for Copper Nickel Pipe and Tube *(1998)*

Element	*Grade CNA* *Grade CN1* *Grade CN3*	*Grade CNB* *Grade CN2* *Grade CN4*
Copper	Remainder	Remainder
Nickel + Cobalt	9.0 to 11.0	29.0 to 33.0
Iron	1.0 to 1.8	0.40 to 1.0
Managnese	1.0	1.0
Zinc	0.50	0.50
Lead	0.02	0.02
Carbon	0.05	0.05
Sulfur	0.02	0.02
Phosphorus	0.02	0.02

Single values are maximum

TABLE 2
Tensile Properties for Seamless Copper Nickel Pipe and Tube *(1998)*

Grade	*Temper Designation*	*Tensile Strength, min. N/mm^2 (kgf/mm^2, ksi)*	*Yield Strength, min. N/mm^2 (kgf/mm^2, ksi)*	*Elongation, min. percent*
CNA	061	275 (28,40)	105 (11,15)	—
CNA	H55	310 (32,45)	240 (25,35)	—
CNB	061	360 (36,52)	125 (13,18)	—
CNB	HR50	495 (51,72)	345 (35,50)	12*; 15**

Notes:

* For wall thickness 1.21 mm (0.048 in.) and less.

** For wall thickness over 1.21 mm (0.048 in.).

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CHAPTER 3 Materials for Machinery, Boilers, Pressure Vessels, and Piping

SECTION 20 Copper-Nickel Tube and Pipe *(1998)*

Note: In substantial agreement with ASTM B466 and B467.

1 Scope

This specification covers four grades of seamless and welded copper-nickel tube and pipe designated CN1, CN2, CN3 and CN4.

3 General

3.1 Grades CN1 and CN2

Grades CN1 and CN2 cover seamless copper-nickel tube and pipe intended for use in general engineering applications requiring seawater corrosion resistance. Tube and pipe ordered under these grades are considered suitable for welding, and suitable for forming operations involving bending, flaring and flanging. Tube is to be ordered to outer diameter and wall thickness specified by the purchaser and approved for the application.

3.3 Grades CN3 and CN4

Grades CN3 and CN4 cover welded copper-nickel pipe intended for use in general engineering applications requiring seawater corrosion resistance. Pipe ordered under these grades are considered suitable for welding, and suitable for forming operations involving bending, flaring and flanging.

3.5 ASTM Designation

These grades are in substantial agreement with ASTM as follows:

ABS Grade	*ASTM Designation*
CN1	B466, UNS C70600
CN2	B466, UNS C71500
CN3	B467, UNS C70600
CN4	B467, UNS C71500

5 Process of Manufacture

The material is to be produced by either hot or cold working operations, or both. The tubing is to be finished, unless otherwise specified, by such cold working or annealing or heat treatment as may be necessary to meet the properties for either annealed or light drawn material. The light drawn properties apply only to grades CN1 and CN3.

5.1 Grades CN1 and CN2

Grade CN1 may be supplied in either annealed (O60) or light drawn (H55) tempers. Grade CN2 may be supplied in only annealed (O60) temper.

5.3 Grades CN3 and CN4

Grade CN3 may be supplied in either the welded from annealed skelp temper (WM50), or the welded and fully finished as annealed temper (WO61). Grade CN4 may be supplied in the welded and fully finished as annealed temper (WO61). The internal and external flash is to be removed by scarfing and there is to be no crevice in the weld seam visible to the unaided eye.

7 Marking

Identification markings are to be legibly stenciled, or suitably marked on each length of tubular, except that in the case of small-diameter tubular which is bundled, the required markings are to be placed on a tag securely attached to the bundle. The markings are to be arranged and are to include the following information:

- Name or brand of the manufacturer
- ABS Grade or ASTM Designation and Grade
- Temper number
- Diameter
- Wall thickness or Pipe Schedule
- Test Pressure or the letters NDET
- ABS markings by the Surveyor

9 Chemical Composition

9.1 Chemical Requirements

The material is to conform to the chemical requirements specified in 2-3-19/Table 1.

9.3 Chemical Analysis Sampling

Samples may be taken at the time the metal is cast or may be taken from semi-furnished product, or from finished product in accordance with sampling in 2-3-20/21.

11 Tension Test

11.1 Tension Test Specimens

Tensile test specimens are to be a full section of the tube. For larger sizes, tension test specimens are to consist of longitudinal strips cut from the tube in accordance with ASTM E8, for Tension Testing of Metallic Materials.

11.3 Seamless Tensile Properties

Seamless material is to conform to the applicable requirements as to tensile properties shown.

Temper Number	*Temper*	*Grade*	*Tensile Strength, min. N/mm^2 (kgf/mm^2, ksi)*	*Yield Strength, min. N/mm^2 (kgf/mm^2, ksi)*
060	Soft anneal	CN1	260 (27, 38)	90 (9, 13)
		CN2	360 (37, 52)	125 (13, 18)
H55	Light Drawn	CN1	310 (32, 45)	240 (25, 35)

11.5 Welded (WO61) Tensile Properties

Welded and fully finished pipe furnished in the annealed temper (WO61) is to conform to the applicable requirements as to the tensile properties shown.

Grade	*Outside Diameter, mm (inch)*	*Tensile Strength min. N/mm^2 (kgf/mm^2, ksi)*	*Yield Strength, min. N/mm^2 (kgf/mm^2, ksi)*	*Elongation percent*
CN3	Up to 114 (4.5), incl.	275 (28, 40)	105 (11, 15)	25.0
	over 114 (4.5)	260 (27, 38)	90 (9, 13)	25.0
CN4	Up to 114 (4.5), incl.	345 (35, 50)	140 (14, 20)	30.0
	over 114 (4.5)	310 (32, 45)	105 (11, 15)	30.0

11.7 Welded (WO50) Tensile Properties

As-welded pipe fabricated from annealed strip (WO50) is to conform to the applicable requirements as to the tensile properties shown.

Grade	*Outside Diameter, mm (inch)*	*Tensile Strength, min. N/mm^2 (kgf/mm^2, ksi)*	*Yield Strength, min. N/mm^2 (kgf/mm^2, ksi)*
CN3	up to 114 (4.5), incl.	310 (32, 45)	205 (21, 30)

13 Expansion Test

Note: This test is required for tubes manufactured in the annealed temper.

13.1 Grades CN1 and CN2

Annealed specimens selected for testing in accordance with ASTM B153, for Expansion (Pin Test) of Copper and Copper-Alloy Pipe and Tubing, are to withstand an expansion of the outside diameter to 30 percent. The expanded specimen is to show no cracking or rupture visible to the unaided eye.

13.3 Grades CN3 and CN4

Annealed specimens selected for testing in accordance with ASTM B153, for Expansion (Pin Test) of Copper and Copper-Alloy Pipe and Tubing, are to withstand an expansion of the outside diameter to 30 percent. As welded specimens are to withstand an expansion of the outside diameter to 20 percent when similarly tested. The expanded specimen is to show no cracking or rupture visible to the unaided eye.

15 Flattening Test

As an alternate to the expansion test for seamless material over 100 mm (4 in.) in diameter and in the annealed condition, a flattening test may be carried out. This specimen selected for testing is to be at least 450 mm (18 in.) in length, and is to be flattened so that a gauge set at three times the wall thickness will pass over the tube freely throughout the flattened part. The tube so tested is to develop no cracks or defects visible to the unaided eye as a result of this test. In making the flattening test, the specimens are to be slowly flattened by one stroke of the press. Specimens not initially in the annealed temper (O60) are to be annealed prior to flattening.

17 Nondestructive Examination

17.1 Nondestructive Electric Test (NDET)

All tubes are to be eddy-current tested in accordance with ASTM E243, for Electromagnetic (Eddy-Current) Examination of Copper and Copper-Alloy Tubes or, alternatively, when specified, may be hydrostatically tested in accordance with 2-3-19/19. A calibration reference standard is to be made from a length tube of the same type, wall thickness and outside diameter as that to be tested. The standard is to have transverse notches of depth that when rounded to 0.25 mm (0.001 in.) represents 22 percent of the wall thickness. The notch depth tolerance is to be 0.013 mm (0.0005 in.). Tubulars producing a signal equal to or greater than the calibration defect are to be rejected.

17.3 Radiographic Examination

When specified, the welds of Grades CN3 and CN4 are to be examined by radiography.

19 Hydrostatic Test

19.1 Limiting Test Pressures

As an alternate to the eddy-current test, hydrostatic testing may be performed. Each tube that is tested to stand, without showing evidence of leakage, an internal hydrostatic pressure sufficient to subject the material to a fiber stress of 48 N/mm^2 (4.92 kgf/mm^2, 7000 psi), determined by the following equation for thin hollow cylinders under tension. The tube is not to be tested at a hydrostatic pressure of 69 bar (70.3 kgf/cm^2, 1000 psi) unless so specified.

$$P = KSt/(D - 0.8t)$$

where

P = pressure in bar (kgf/cm^2, psi)

S = allowable unit stress of the material, 48 N/mm^2 (4.92 kgf/mm^2, 7000 psi)

t = thickness of tube wall, in mm (in.)

D = outside diameter of the tube, in mm (in.)

K = 20 (200, 2)

19.3 Affidavits of Tests

Where each tube is hydrostatically tested as a regular procedure during the process of manufacture, an affidavit covering this test may be accepted by the Surveyor.

21 Number of Tests

The lot is to consist of tubulars of the same size and temper. The lot size is to be 5000 kg (10000 lb) or a fraction thereof. For Grades CN3 and CN4 over 100 mm (4 in.) in diameter, the lot size is to be 9100 kg (20000 lb) or a fraction thereof. Sample pieces are to be taken for test purposes from each lot as follows:

Number of Pieces in Lot	*Number of Sample Pieces to Be Taken*
1 to 50	1
51 to 200	2
201 to 1500	3
over 1500	0.2% of total number of pieces in the lot, but not to exceed 10 sample pieces

Chemical analyses, where required, tensile tests, expansion tests, flattening tests, dimensional examinations and visual examinations are to be made on each of the sample pieces selected for test. Each length of pipe is to be subjected to the hydrostatic test or, when specified, a radiographic examination.

23 Retests

If the results of the test on one of the specimens, made to determine the mechanical properties, fails to meet the requirements, this test is to be repeated on each of two additional specimens taken from different pieces and the results of both of these tests is to comply with the requirements. Failure of more than one specimen to meet the requirements for a particular property is to be cause for rejection of the entire lot.

25 Finish

Tubes selected for testing are to be examined for finish and workmanship. Tubes are to be free from cracks, injurious surface flaws and similar defects to the extent determinable by visual or NDET examination. Tubes are to be clean and free of any foreign material that would render the tubes unfit for the intended use.

27 Dimensions and Tolerances

Each sample selected for testing is to be examined for dimensions and tolerances.

27.1 Diameter

The tubular outside diameter is to not vary from the specified values by more than the amounts shown. When all minus diameter tolerances or all plus diameter tolerances are specified, the tolerances shown may be doubled.

Average Diameter	
Specified Diameter mm (inch)	*Tolerance, Plus and Minus, mm (inch)*
Up to 15.9 ($^5/_8$), incl.	0.064 (0.0025)
Over 15.9 ($^5/_8$) to 25.4 (1.0), incl.	0.076 (0.003)
Over 25.4 (1.0) to 50 (2.0), incl.	0.102 (0.004)
Over 50 (2.0) to 76 (3.0), incl.	0.127 (0.005)
Over 76 (3.0) to 100 (4.0) incl.	0.152 (0.006)
Over 100 (4.0) to 125 (5.0), incl.	0.203 (0.008)
Over 125 (5.0) to 150 (6.0), incl.	0.229 (0.009)
Over 150 (6.0) to 200 (8.0), incl.	0.254 (0.010)
Over 200 (8.0) to 255 (10.0), incl.	0.330 (0.013)
Over 255 (10.0) to 305 (12.0), incl.	0.381 (0.015)
Over 305 (12.0)	0.5%

27.3 Roundness

The difference between the major diameter and the minor diameter as determined at any one cross section is not the following.

Roundness		
Grade	*t/D (2)*	*Tolerance Percent (3)*
CN1 (1) and CN2 (1)	0.01 to 0.03, incl.	1.5
	Over 0.03 to 0.05, incl.	1.0
	Over 0.05 to 0.10, incl.	0.8*
	Over 0.10	0.7*
CN3 and CN4	All ratios	3.0

1 Drawn, unannealed straight lengths, wall thickness not less than 0.41 mm (0.016 in.)

2 Ration of wall thickness to outside diameter

3 Percent of outside diameter, to nearest 0.025 mm (0.001 in.)

* Or 0.051 mm (0.002 in.) whichever is greater

27.5 Wall Thickness Tolerances

The permissible variations in wall thickness for all tubulars are based upon the ordered thickness and are to conform to that given in the applicable ASTM designation for acceptance.

27.7 Length

The length of tubulars is to not be less than that specified when measured at a temperature of 20°C (68°F) and may exceed specified values by the amounts shown. The tolerance for stock lengths and for specific lengths with ends is 25.4 mm (1.0 in.).

Length Tolerance, mm (inch)
Applicable Only to Full-Length Pieces

Specified Lengths	*Grades CN1 and CN2*			*Grades CN3 CN4*
	≤ 25 mm (1 in.)	*> 25.4 mm (1 in.) < 100 mm (4 in.)*	*> 100 mm (4 in.)*	
Up to 150 mm (6 in.), incl.	0.8 ($^1/_{32}$)	1.5 ($^1/_{16}$)	—	1.5 ($^1/_{16}$)
Over 150 to 600 mm (6 in. to 2 ft.), incl.	1.5 ($^1/_{16}$)	2.5 ($^3/_{32}$)	3.0 ($^1/_8$)	2.5 ($^3/_{32}$)
Over 600 to 2000 mm (2 to 6 ft.), incl.	2.5 ($^3/_{32}$)	3.0 ($^1/_8$)	6.0 ($^1/_4$)	3.0 ($^1/_8$)
Over 2000 to 4000 mm (6 to 14 ft.), incl.	6.0 ($^1/_4$)	6.0 ($^1/_4$)	6.0 ($^1/_4$)	6.0 ($^1/_4$)
Over 4000 mm (14 ft)	12.0 ($^1/_2$)	12.0 ($^1/_2$)	12.0 ($^1/_2$)	12.0 ($^1/_2$)

27.9 Squareness of Cut

The departure from squareness of the end of the tube is to not exceed the following:

Specified Outside Diameter	*Tolerance*
Up to 15.9 mm ($^5/_8$ in.) incl. of CN1 and CN2	0.25 mm (0.010 in.)
All diameters of CN3 and CN4.	0.016 mm/mm (0.016 in./in.) of diameter

27.11 Straightness Tolerances

For seamless tubulars of any drawn temper, 6.0 mm (0.25 in.) to 100 mm (3.5 in.) in outside diameter, inclusive, but not for redrawn, extruded or annealed tubulars, the straightness tolerances are as shown.

Maximum Curvature

Length, mm (feet)	*(Depth of Arc), mm (inch)*
Over 1000 to 2000 (3 to 6), incl.	5.0 ($^3/_{16}$)
Over 2000 to 2500 (6 to 8), incl.	8.0 ($^5/_{16}$)
Over 2500 to 3000 (8 to 10), incl.	12.0 ($^1/_2$)

For lengths greater than 3000 mm (10 ft.), the maximum curvature is to not exceed 12.5 mm ($^1/_2$ in.) in any 3000 mm (10 ft.) portion of the total length.

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PART

2

CHAPTER 3 Materials for Machinery, Boilers, Pressure Vessels, and Piping

SECTION 21 Monel Pipe and Tube *(1999)*

1 Scope

This specification covers four grades of seamless and welded nickel-copper (Monel) pipe and tube, designated M1, M2, M3, and M4.

3 General

3.1 Grades M1 and M2

Grades M1 and M2 cover cold-worked, seamless nickel-copper pipe and pipe intended for use in general engineering applications requiring superior seawater corrosion resistance. Pipe and tube ordered under these grades are considered suitable for welding, and suitable for forming operations involving bending, flaring and flanging. Pipe is to be ordered to ANSI B36.19. Tube is to be ordered to an outer diameter and a nominal or minimum wall thickness specified by the purchaser and approved for the application.

3.3 Grades M3 and M4

Grades M3 and M4 cover welded, cold-worked nickel-copper pipe and pipe intended for use in general engineering applications requiring superior seawater corrosion resistance. Pipe and tube ordered under these grades are considered suitable for welding, and suitable for forming operations involving bending, flaring and flanging. Pipe is to be ordered to ANSI B36.19. Tube is to be ordered to an outer diameter and a nominal or minimum wall thickness specified by the purchaser and approved for the application.

3.5 ASTM Designation

The grades are in substantial agreement with ASTM, as follows:

ABS Grade	*Heat Treatment*	*ASTM Designation*	*Product Form*
M1	Annealed	B165, UNS N04400	Seamless Pipe and Tube
M2	Stress Relieved	B165, UNS N04400	Seamless Pipe and Tube
M3	Annealed	B730, UNS N04400	Welded Pipe and Tube
M4	Stress Relieved	B730, UNS N04400	Welded Pipe and Tube

5 Process of Manufacture

5.1 Grades M1 and M2

These grades are to be finished by cold-working in order to assure that acceptable corrosion resistance in the weld area and base metal will be developed during heat treatment. These grades of pipe and tube are to be supplied in the annealed, Grade M1 or stress-relieved, Grade M2 condition.

5.3 Grades M3 and M4

These grades are to be made from flat-rolled material by an automatic welding process with no addition of filler metal. After welding but before heat treatment, the pipe and tube are to be cold worked in order to assure that acceptable corrosion resistance in the weld area and base metal will be developed during heat treatment. Heat treatment is to consist of annealing, as Grade M3, or stress-relieving, as Grade M4. Welded pipe and tube are to be furnished with a scale-free finish. When bright annealing is used, descaling is not necessary.

7 Marking

Identification markings are to be legibly stenciled, or marked on each length of pipe and tube. The marking fluid is not to be harmful to the pipe and tube and is not to rub off or smear in normal handling. The fluid is not to be affected by solvents used in subsequent cleaning and preservation operations, but is to be readily removed by hot alkaline solution. In the case of small-diameter tube or pipe with an outside diameter less than 19.0 mm ($^3/_4$ in.) which is bundled or boxed, the required markings are to be placed on a tag securely attached to the bundle or box, or on the box. The markings are to be arranged and are to include the following information:

- Name or brand of the manufacturer
- ABS Grade or ASTM Specification and Grade
- UNS Alloy Number
- Heat number or manufacturer's number by which the heat can be identified
- Temper designation
- Tube diameter/NPS Designation
- Wall thickness (specify minimum or nominal)/NPS schedule
- Test pressure
- NDET if so tested
- ABS markings by Surveyor