5.7 Grades R and S *(1998)*

The steel is to be made by the electric-furnace or other approved process. Tubes are to be made by the seamless process and are to be either hot-finished or cold-drawn. After the completion of mechanical working, tubes are to be solution annealed at a minimum of 1040°C (1900°F) and then quenched in water or rapidly cooled by other means. Solution annealing above 1065°C (1950°F) may impair resistance to intergranular corrosion after subsequent exposure to sensitizing conditions. Subsequent to the initial high-temperature solution anneal, a stabilization or resolution anneal at 815°C to 900°C (1500°F to 1650°F) may be used to meet the requirements.

7 Marking *(1998)*

Identification markings are to be legibly stenciled on each tube 31.8 mm (1.25 in.) in outside diameter or over, provided the length is not under 900 mm (3 ft). For Grades R and S tubes, the marking fluid, ID tags and securing wire are not to contain any harmful metal or metal salt such as zinc, lead or copper, which cause corrosive attack upon heating. For tubes less than 31.8 mm (1.25 in.) in outside diameter and all tubes less than 900 mm (3 ft) in length, the required markings are to be marked on a tag securely attached to the bundle or box in which the tubes are shipped. The markings are to include: the name or brand of the manufacturer; either the ABS grade or the ASTM designation and grade for the material from which the tube is made; the hydrostatic test pressure or the letters NDET; whether electric-resistance-welded or seamless, hot-finished or cold-drawn; also the Bureau markings as furnished by the Surveyor and indicating satisfactory compliance with the Rule requirements. The markings are to be arranged as follows:

- The name or brand of the manufacturer
- The ABS grade or ASTM designation and type or grade
- The test pressure or the letters NDET
- The method of forming (i.e., seamless hot-finished or cold-drawn or electric-resistance-welded)
- The ABS markings from the Surveyor

9 Chemical Composition – Ladle Analysis

An analysis of each heat is to be made to determine the percentages of the elements specified. The chemical composition thus determined is to be reported to the Surveyor and is to conform to the requirements of 2-3-5/Table 1.

11 Check Analysis

11.1 General *(1998)*

A check analysis is required for Grades K, L, M, N, O, P, R, and S. Check analysis for other grades may also be made where required by the purchaser. The check analysis is to be in accordance with the following requirements and the chemical composition is to conform to the requirements in 2-3-5/Table 1.

11.3 Samples

Samples for check analysis are to be taken by drilling several points around each tube selected for analysis or, when taken from the billet, they are to be obtained by drilling parallel to the axis at any point midway between the outside and center of the piece, or the samples may be taken as prescribed in ASTM E59 (Method of Sampling Steel for Determination of Chemical Composition).

11.5 Grades D, F, G, and H

For these Grades, the check analysis is to be made by the supplier from one tube per heat or from one tube per lot.

Note A lot consists of 250 tubes for sizes 76.2 mm (3.0 in.) and under or 100 tubes for sizes over 76.2 mm (3.0 in.) prior to cutting length.

11.7 Grades J, K, L, M, N, O, P, R, and S *(1998)*

For these Grades, check analysis is to be made by the supplier from one tube or billet per heat.

11.9 Retests for Seamless Tubes *(1998)*

If the original test for check analysis for Grades H, J, K, L, M, N, O, P, R, or S tubes fails, retests of two additional billets or tubes are to be made. Both retests for the elements in question are to meet the requirements; otherwise, all remaining material in the heat or lot is to be rejected or, at the option of the supplier, each billet or tube may be individually tested for acceptance.

11.11 Retests for Electric-resistance-welded Tubes

If the original test for check analysis for Grades D, F, or G tubes fails, retests of two additional lengths of flat-rolled stock or tubes are to be made. Both retests, for the elements in question, are to meet the requirements; otherwise all remaining material in the heat or lot is to be rejected or, at the option of the supplier, each length of flat-rolled stock or tube may be individually tested for acceptance.

13 Mechanical Tests Required

The type and number of mechanical tests are to be in accordance with 2-3-5/Table 2. For a description and requirements of each test, see 2-3-5/17 through and including 2-3-5/33. For retests see 2-3-5/35.

15 Test Specimens

15.1 Selection of Specimens *(1998)*

Test specimens required for the flattening, flanging, flaring, tension, crushing and reverse flattening tests are to be taken from the ends of drawn tubes after any heat treatment and straightening, but prior to upsetting, swaging, expanding, or other forming operations, or being cut to length. They are to be smooth on the ends and free from burrs and defects.

15.3 Tension Test Specimens

If desirable and practicable, tension tests may be made on full sections of the tubes up to the capacity of the testing machine. For larger-size tubes, the tension test specimen is to consist of a strip cut longitudinally from the tube not flattened between gauge marks. The sides of this specimen are to be parallel between gauge marks; the width, irrespective of the thickness, is to be 25 mm (1 in.); the gauge length is to be 50 mm (2 in.).

15.5 Testing Temperature

All specimens are to be tested at room temperature.

17 Tensile Properties

The material is to conform to the requirements as to tensile properties in the grades specified in 2-3-5/Table 3.

19 Flattening Test

19.1 Seamless and Electric-resistance-welded Tubes *(1998)*

For all Grades of tubing, a section of tube, not less than 65 mm (2.5 in.) in length for seamless and not less than 100 mm (4 in.) in length for welded, is to be flattened cold between parallel plates in two steps. During the first step, which is a test for ductility, no cracks or breaks on the inside, outside or end surfaces of seamless tubes, or on the inside or outside surfaces of electric-resistance-welded tubes is to occur until the distance between the plates is less than the value 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 tube, in mm (in.)

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

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

= 0.09 for Grades D, G, H, R, and S

= 0.08 for Grades K, L, M, N, O, and P

= 0.07 for Grades F and J

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 tube 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.

19.3 Electric-resistance-welded Tubes

In the case of Grades D, F, and G tubes, the weld is to be placed 90 degrees from the line of direction of the applied force.

21 Reverse Flattening Test

For Grades D, F, and G tubes, a section 100 mm (4 in.) in length is to be taken from every 460 m (1500 ft) of finished welded tubing and it is to be split longitudinally 90 degrees on each side of the weld and the sample opened and flattened with the weld at the point of maximum bend. There is to be no evidence of cracks or lack of penetration or overlaps resulting from flash removal in the weld.

23 Flange Test

For Grades D, F, and G tubes, a section of tube is to be capable of having a flange turned over at a right angle to the body of the tube without cracking or developing defects. The width of the flange is not to be less than the following.

Outside Diameter of Tube mm (in.)	*Width of Flange*	
	D, G	F
Over 19.1 mm (0.75 in.) to 63.5 mm (2.50 in.) incl.	15% of outside diameter	75% of that required for Grades D and G
Over 63.5 mm (2.5 in.) to 95.3 mm (3.75 in.) incl.	$12^1/_2$ % of outside diameter	
Over 95.3 mm (3.75 in.)	10% of outside diameter	

25 Flaring Test *(1998)*

For Grades H, J, K, L, M, N, O, P, R, and S tubes, a section of tube approximately 100 mm (4 in.) in length is to stand being flared with a tool having a 60-degree included angle until the tube at the mouth of the flare has been expanded to the following percentages, without cracking or developing defects.

*Ratio of Inside Diameter to Outside Diameter**	*Minimum Expansion of Inside Diameter, %*	
	H, J, K, L, M, R, S	N, O, P
0.9	21	15
0.8	22	17
0.7	25	19
0.6	30	23
0.5	39	28
0.4	51	38
0.3	68	50

* In determining the ratio of inside diameter to outside diameter, the inside diameter is to be defined as the actual mean inside diameter of the material to be tested.

27 Crush Test

For Grade D tubes, when required by the Surveyor, crushing tests are to be made on sections of tube 65 mm (2.5 in.) in length which are to stand crushing longitudinally, without cracking, splitting or opening at the weld, as shown in the following table. For tubing less than 25.4 mm (1.0 in.) in outside diameter, the length of the specimen is to be $2^1/_2$ times the outside diameter of the tube. Slight surface checks are not to be cause for rejection.

Wall Thickness	*Height of Section After Crushing*
3.43 mm (0.135 in.) and under	19.1 mm (0.75 in.) or until outside folds are in contact
Over 3.43 mm (0.135 in.)	31.8 mm (1.25 in.)

29 Hardness Tests

29.1 Type of Test *(1998)*

Hardness tests are to be made on Grades G, H, J, K, L, M, N, O, P, R, and S tubes. For tubes 5.1 mm (0.2 in.) and over in wall thickness, the Brinell hardness test is to be used and on tubes having wall thicknesses from 5.1 mm (0.2 in.) to 9.5 mm (0.375 in.) exclusive, a 10 mm ball with a 1,500 kg load, or a 5 mm ball with a 750 kg load may be used, at the option of the manufacturer. For tubes less than 5.1 mm (0.2 in.) in wall thickness, the Rockwell hardness test is to be used, except that for tubes with wall thickness less than 1.65 mm (0.065 in.) no hardness tests are required. In making the Brinell and Rockwell hardness tests, reference should be made to the Standard Methods and Definitions for the Mechanical Testing of Steel Products ASTM 370.

29.3 Brinell Hardness Test

The Brinell hardness test may be made on the outside of the tube near the end or on the outside of a specimen cut from the tube, at the option of the manufacturer.

29.5 Rockwell Hardness Test

The Rockwell hardness test is to be made on the inside of a specimen cut from the tube.

29.7 Tubes with Formed Ends

For tubes furnished with upset, swaged, or otherwise formed ends, the hardness test is to be made as prescribed in 2-3-5/29.1 on the outside of the tube near the end after the forming operation and heat treatment.

29.9 Maximum Permissible Hardness *(1998)*

The tubes are to have hardness-numbers not exceeding the following values.

Tube Grade	*Brinell Hardness Number* *Tubes 5.1 mm (0.2 in.) and over in wall thickness*	*Rockwell Hardness Number* *Tubes less than 5.1 mm (0.2 in.) in wall thickness*
G	125	B 72
H	137	B 77
J	143	B 79
K	146	B 80
L	153	B 81
M	137	B 77
N, O, and P	163	B 85
R, S	192	B 90

31 Hydrostatic Test

31.1 General

Each tube is to be hydrostatically tested at the mill or be subjected to a nondestructive electrical test in accordance with 2-3-5/33. The test may be performed prior to upsetting, swaging, expanding, bending or other forming operation. The hydrostatic test pressure is to be determined by the equation given in 2-3-5/31.3, but is not to exceed the following values, except as provided in 2-3-5/31.7.2.

Outside Diam. of Tubes, mm (in.)	*Test Pressure, bar (kgf/cm^2, psi)*
Under 25.4 (1.0 in.)	69 (70.3, 1000)
25.4 (1.0 in.) to 38.1 (1.5 in.), excl.	103 (105, 1500)
38.1 (1.5 in.) to 50.8 (2.0 in.), excl.	140 (140, 2000)
50.8 (2.0 in.) to 76.2 (3.0 in.), excl.	170 (175, 2500)
76.2 (3.0 in.) to 127 (5.0 in.), excl.	240 (245, 3500)
127 (5.0 in.) and over	310 (315, 4500)

31.3 Maximum Hydrostatic Test Pressure

SI Units	*MKS Units*	*US Units*
$P = 20St/D$ $S = PD/20t$	$P = 200St/D$ $S = PD/200t$	$P = 2St/D$ $S = PD/2t$

where

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

S = allowable fiber stress of 110 N/mm^2 (11 kgf/mm^2, 16,000 psi)

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

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

31.5 Duration of Test

The test pressure is to be held for a minimum of 5 seconds.

31.7 Alternate Tests

31.7.1

When requested by the purchaser and so stated in the order, tubes are to be tested to one and one-half times the specified working pressure (when one and one-half times the specified working pressure exceeds the test pressure prescribed in 2-3-5/31.1), provided the fiber stress corresponding to those test pressures does not exceed 110 N/mm^2 (11 kgf/mm^2, 16,000 psi) as calculated in accordance with 2-3-5/31.3.

31.7.2

When requested by the purchaser and so stated in the order, or at the option of the manufacturer, tubes are to be tested at pressures calculated in accordance with 2-3-5/31.1 corresponding to a fiber stress of more than 110 N/mm^2 (11 kgf/mm^2, 16,000 psi), but not more than 165 N/mm^2 (17 kgf/mm^2, 24,000 psi).

31.9 Rejection

If any tube shows leaks during the hydrostatic test, it is to be rejected.

33 Nondestructive Electric Test (NDET) *(1998)*

33.1 General

When specified by the purchaser, each ferritic steel tube, Grades D, F, G, H, J, K, L, M, N, O, and P, is to be tested in accordance with ASTM E213, for Ultrasonic Examination of Metal Pipe and Tubing or 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. When specified by the purchaser, each austenitic stainless steel tube, Grades R and S, is to be tested in accordance with ASTM E213, for Ultrasonic Examination of Metal Pipe and Tubing or ASTM E426, for Electromagnetic (Eddy-Current) Examination of Seamless and Welded Tubular Products, Austenitic Stainless Steel and Similar Alloys, 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

33.3 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 tube or 0.1 mm (0.004 in.), whichever is greater. The width of the notch is not to exceed two times the depth.

33.5 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. For welded tubing, they are to be placed in the weld, if visible.

33.5.1 Drilled Hole

Three or more holes not larger than 0.785 mm (0.031 in.) in diameter and equally spaced about the pipe circumference and sufficiently separated longitudinally to ensure a separately distinguishable response are to be drilled radially and completely through tube wall, care being taken to avoid distortion of the tube while drilling. Alternatively, one hole may be used, provided that the calibration tube is scanned at a minimum of three locations each 120 degrees apart, or at more frequent scans with smaller angular increments, provided that the entire 360 degrees of the eddy-current coil is checked.

33.5.2 Transverse Tangential Notch

Using a round tool or file 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 tube. Said notch is to have a depth not exceeding 12.5% of the nominal wall thickness of the tube or 0.1 mm (0.004 in.), whichever is greater.

33.5.3 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 tube axis on the outside surface of the tube, to have a depth not exceeding 12.5% of the nominal wall thickness of the tube or 0.1 mm (0.004 in.), whichever is greater. The length of the notch is to be compatible with the testing method.

33.7 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 tube 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.

33.9 Rejection

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

33.11 Affidavits

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

35 Retests *(1998)*

For all grades of tubes, if the results of the mechanical tests do not conform to the requirements, retests may be made on additional tubes from the same lot, double the original number specified, each of which is to conform to the requirements. If heat-treated tubes fail to conform to the test requirements, the individual tubes, groups or lots of tubes represented, may be re-heat-treated and resubmitted for retest, as indicated. Only two reheat treatments will be permitted.

37 Finish *(2008)*

Tubes of all grades are to be examined by the Surveyor prior to fabrication or installation, and are to be reasonably straight and have smooth ends free from burrs. At a minimum, the finished tubes are to be visually inspected at the same frequency as that required for the flattening test specified in 2-3-5/Table 2 for the applicable grade. They are to be free from defects and are to have a workmanlike finish. Grade R and S tubes are to be free from scale by pickling or by the use of bright annealing. Minor defects may be removed by grinding provided the wall thicknesses are not decreased beyond the permissible variations in dimensions. Welding repair to any tube is not to be carried out without the purchaser's approval and is to be to the Surveyor's satisfaction.

39 Permissible Variations in Dimensions *(1998)*

At a minimum, the finished tubes are to be measured at the same frequency as that required for the flattening test specified in 2-3-5/Table 2 for the applicable grade.

39.1 Wall Thickness

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

39.3 Outside Diameter

Variations from the ordered outside diameter are not to exceed the amounts prescribed in 2-3-5/Table 4.

TABLE 1
Chemical Composition for Tubes *(1998)*

Maxima or Permissible Range of Chemical Composition in %
ABS Grades

	D	*F*	*G*	*H*	*J*	*K*	*L*	*M*	*N*	*O*	*P*	*R**	*S***
Carbon	0.06 to 0.18	0.35	0.06 to 0.18	0.06 to 0.18	0.27	0.10 to 0.20	0.15 to 0.25	0.14	0.05 to 0.15	0.05 to 0.15	0.05 to 0.15	0.08	0.08
Manganese	0.27 to 0.63	0.80	0.27 to 0.63	0.27 to 0.63	0.93	0.30 to 0.80	0.30 to 0.80	0.30 to 0.80	0.30 to 0.60	0.30 to 0.60	0.30 to 0.60	2.00	2.00
Phosphorus	0.035	0.035	0.05	0.035	0.035	0.025	0.025	0.025	0.025	0.025	0.025	0.040	0.040
Sulfur	0.035	0.035	0.06	0.035	0.035	0.025	0. 025	0.025	0.025	0.025	0.025	0.030	0.030
Silicon			0.25	0.25	0.10 (min.)	0.10 to 0.50	0.10 to 0.50	0.10 to 0.50	0.50 to 1.00	0.50	0.50	0.75	0.75
Chromium									1.00 to 1.50	0.80 to 1.25	1.90 to 2.60	17.0 to 20.0	17.0 to 20.0
Molybdenum						0.44 to 0.65	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		
Nickel												9.00 to 13.00	9.00 to 13.00

Note:

* Grade R is to have a titanium content of not less than five times the carbon content and not more than 0.60%.

** Grade S is to have a columbium (niobium) plus tantalum content of not less than ten times the carbon content and not more than 1.00%.

TABLE 2
Mechanical Tests *(1998)*

Grade	*Type of Test*	*Number of Tests*
D	Flattening	One test on specimens from each of two tubes from each lot (1) or fraction thereof and from each 610 m (2000 ft) or fraction thereof of safe-end material.
	Flanging	As for flattening test.
	Crushing	As for flattening test when required by the Surveyor.
	Reverse Flattening	One test per 460 m (1500 ft) of finished welded tubing.
	Hydrostatic or NDET (3)	All tubes.
F	Flattening	One test on specimens from each of two tubes from each lot (1) or fraction thereof.
	Flanging	As for flattening test.
	Reverse Flattening	One test per each 460 m (1500 ft) of finished welded tubing.
	Tension	As for flattening test.
	Hydrostatic or NDET (3)	All tubes.
G	Flattening	One test on specimens from each of two tubes from each lot (1) or fraction thereof.
	Flanging	As for flattening test.
	Reverse Flattening	One test per each 460 m (1500 ft) of finished welded tubing.
	Hardness	One Brinell or Rockwell hardness determination on 5% of the tubes when heat-treated in a batch-type furnace or 1% of the tubes when heat treated in a continuous furnace, but in no case less than 5 tubes.
	Hydrostatic or NDET (3)	All tubes.
H *(1998)*	Flattening	One test on specimens from each end of two tubes from each lot (1) or fraction thereof but not the same tube used for the flaring test.
	Flaring	As for flattening test, but not the same tube used for the flattening test.
	Hardness	One Brinell or Rockwell hardness determination on 5% of the tubes when heat-treated in a batch-type furnace or 1% of the tubes when heat-treated in a continuous furnace, but in no case less than 5 tubes.
	Hydrostatic or NDET (3)	All tubes.
J, K, L, M, N, O, P	Flattening	One test on specimens from each end of one finished tube per lot (2), but not the same tube used for the flaring test.
	Flaring	One test on specimens from each end of one finished tube per lot (2), but not the same tube used for flattening test.
	Tension	One test on one specimen from one tube from each lot (2).
	Hardness	One Brinell or Rockwell hardness determination on 5% of the tubes when heat-treated in a batch-type furnace or 1% of the tubes when heat-treated in a continuous furnace, but in no case less than 5 tubes.
	Hydrostatic or NDET (3)	All tubes.
R, S *(1998)*	Flattening	One test on specimens from each end of one finished tube per lot (2), but not the same tube used for the flaring test.
	Flaring	One test on specimens from each end of one finished tube per lot (2), but not the same tube used for flattenig test.
	Tension	One test on one specimen for each lot of 50 tubes or less. One test on one specimen from each of two tubes for lots (4) of more than 50 tubes.
	Hardness	One Brinell or Rockwell hardness determination on two tubes from each lot (4).
	Hydrostatic or NDET (3)	All tubes.

Notes

1 A lot consists of 250 tubes for sizes 76.2 mm (3.0 in.) and under and of 100 tubes for sizes over 76.2 mm (3.0 in.) prior to cutting to length.

2 *(1998)* The term lot, used here, applies to all tubes prior to cutting to length of the same nominal size and wall thickness which are provided from the same heat of steel. When final heat treatment is in a batch-type furnace, a heat-treatment lot is to include only those tubes of the same size and from the same heat which are heat-treated in the same furnace charge. When the final heat treatment is in a continuous furnace, the number of tubes of the same size and from the same heat in a lot is to be determined from the size of the tubes as prescribed below.

TABLE 2 (continued)
Mechanical Tests *(1998)*

Size of Tube	*Size of Lot*
50.8 mm (2.0 in.) and over in outside diameter and 5.1 mm (0.2 in.) and over in wall thickness	Not more than 50 tubes
Less than 50.8 mm (2.0 in.) but over 25.4 mm (1.0 in.) in outside diameter or over 25.4 mm (1.0 in.) in outside diameter and under 5.1 mm (0.2 in.) in wall thickness	Not more than 75 tubes
25.4 mm (1.0 in.) or less in outside diameter	Not more than 125 tubes

3 *(1998)* In lieu of the hydrostatic pressure test, a nondestructive electric test may be used. See 2-3-5/33.

4 *(1998)* The term lot, used here, applies to all tubes prior to cutting to length of the same nominal size and wall thickness which are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a heat-treatment lot is to include only those tubes of the same size and from the same heat which are heat-treated in the same furnace charge. When the final heat treatment is in a continuous furnace, a lot is to include all tubes of the same size and heat, heat-treated in the same furnace at the same temperature, time at heat and furnace speed.

TABLE 3
Tensile Properties of Tubes *(1998)*

Tensile Strength, min.	*F*	*G*,H**	*J*	*K*	*L*	*M*	*N,O,P*	*R,S (1998)*
N/mm^2	415	325	415	380	415	365	415	519
kgf/mm^2	42	33	42	39	42	37.5	42	53
psi	60000	47000	60000	55000	60000	53000	600	75000
Yield Strength, min.								
N/mm^2	255	180	255	205	220	195	205	205
kgf/mm^2	26	18.5	26	21	22.5	19.5	21	21
psi	37000	26000	37000	30000	32000	28000	300	30000
Elongation in 50 mm (2 in.), min. %	30	35	30	30	30	30	30	35
Deduction in elongation for each 0.8 mm (0.031 in.) decrease in wall thickness below 7.9 mm (0.313 in.) on longitudinal strip tests	1.50	—	1.50	1.50	1.50	1.50	1.50	—

* No tensile tests are required for these grades, the data is given for design purposes only.

TABLE 4
Permissible Variations in Outside Diameter for Tubes (1)

Millimeters	*Outside Diameter Variation Including Out-of-roundness*	
Outside Diameter	*Over*	*Under*
Seamless, Hot-finished Tubes:		
101.6 and under	0.4	0.8
Over 101.6 to 190.5 inclusive	0.4	1.2
Over 190.5 to 228.6 inclusive	0.4	1.6
Seamless, Cold-drawn Tubes (2) and Welded Tubes:		
Under 25.4 (3)	0.10	0.10
25.4 to 28.1 inclusive (3)	0.15	0.15
Over 38.1 to 50.8 exclusive (3)	0.20	0.20
50.8 to 63.5 exclusive	0.25	0.25
63.5 to 76.2 exclusive	0.30	0.30
76.2 to 101.6 inclusive	0.38	0.38
Over 101.6 to 190.5 inclusive	0.38	0.63
Over 190.5 to 228.6 inclusive	0.38	1.14

Inches	*Outside Diameter Variation Including Out-of-roundness*	
Outside Diameter	*Over*	*Under*
Seamless, Hot-finished Tubes:		
4 and under	$^1/_{64}$	$^1/_{32}$
Over 4 to 7.5 inclusive	$^1/_{64}$	$^3/_{64}$
Over 7.5 to 9 inclusive	$^1/_{64}$	$^1/_{16}$
Seamless, Cold-drawn Tubes (2): and Welded Tubes:		
Under 1 (3)	0.004	0.004
1 to 1.5 inclusive (3)	0.006	0.006
Over 1.5 to 2 exclusive (3)	0.008	0.008
2 to 2.5 exclusive	0.010	0.010
2.5 to 3 exclusive	0.012	0.012
3 to 4 inclusive	0.015	0.015
Over 4 to 7.5 inclusive	0.015	0.025
Over 7.5 to 9 inclusive	0.015	0.045

Notes

1 The permissible variations in outside diameters apply only to the tubes as rolled or drawn and before swaging, expanding, bending, polishing or other fabricating operations.

2 *(1998)* Thin wall tubes usually develop significant ovality during final annealing or straightening. Thin wall tubes are those with a wall of 0.5 mm (0.020 in.) or less, those with a specified outside diameter equal to or less than 50.8 mm (2 in.) and with a wall thickness of 2% of the specified outside diameter or less, and those with a specified outside diameter of greater than 50.8 mm (2 in.) and with a wall thickness of 3% of the specified outside diameter or less. The ovality allowance is 2% of the specified outside diameter for tubes over 25.4 mm (1 in.) and is 0.5 mm (0.020 in.) for tubes with the specified outside diameter equal to and less than 25.4 mm (1 in.). In all cases, the average outside diameter must comply with the permissible variation allowed by this table.

3 *(1998)* Grade R and S austenitic stainless steel tube has an ovality allowance for all sizes less than 50.8 mm (2 in.) outside diameter. The allowance provides that the maximum and minimum diameter at any cross section is not to deviate from the nominal diameter by more than ±0.25 mm (±0.010 in.). In the event of conflict between the permissible variation allowed by this note and note 2, the larger ovality tolerance will apply. In all cases, the average outside diameter must comply with the permissible variation allowed by this table.

PART

2

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

SECTION 6 Boiler Rivet and Staybolt Steel and Rivets

Note: In substantial agreement with ASTM A31 Boiler Rivet Steel and Rivets.

1 Process of Manufacture *(2008)*

The steel is to be made by one or more of the following processes: open-hearth, basic-oxygen or electric-furnace. All such bars and rivets will be examined at the mills by the Surveyor when specially requested by the purchaser. They are to be free from defects and have a workmanlike finish.

3 Marking and Retests

3.1 Manufacturer's Markings

The bars and rivets, when loaded for shipment, are to be properly separated in bundles or containers marked with the name or brand of the manufacturer, the letter indicating the grade of steel and the heat number of identification.

3.3 Bureau Markings

The Bureau markings, indicating satisfactory compliance with the Rule requirements, and as furnished by the Surveyor, are to be marked on the material or on each bundle or container near the marking specified in 2-3-6/3.1.

3.5 Retests

When the result of any of the physical tests specified for any of the material does not conform to the requirements, two additional specimens may, at the request of the manufacturer, be taken from the same lot and tested in the manner specified, but in such case, both of the specimens must conform to the requirements. In the case of tension tests, this retest is to be allowed if the percent of elongation obtained is less than required.

5 Tensile Properties

The material is to conform to the following requirements as to tensile properties.

	Grade A	*Grade B*
Tensile Strength N/mm^2 (kgf/mm^2, psi)	310–380 (31.5–39, 45000–55000)	400–470 (41–48, 58000–68000)
Yield Point, min., N/mm^2 (kgf/mm^2, psi)	155 (16, 23000)	195 (20, 29000)
Elongation in 200 mm (8 in.), min., %	27	22

7 Bending Properties

The test specimen for Grade A steel is to stand being bent cold through 180 degrees flat on itself without cracking on the outside of the bent portion. The test specimen for Grade B steel is to stand being bent cold through 180 degrees without cracking on the outside of the bent portion, as follows: for material 19.1 mm (0.75 in.) and under in diameter, around an inside diameter which is equal to one-half the diameter of the specimen; for material over 19.1 mm (0.75 in.) in diameter, around an inside diameter which is equal to the diameter of the specimen.

9 Test Specimens

Bend and tension test specimens are to be the full diameter of the bars as rolled and, in the case of rivet bars which have been cold-drawn, the test specimens shall be normalized before testing.

11 Number of Tests

Two tension and two cold-bend tests are to be made from each heat.

13 Tests of Finished Rivets

13.1 Bending Properties

The rivet shank of Grade A steel is to stand being bent cold through 180 degrees flat on itself without cracking on the outside of the bent portion. The rivet shank of Grade B steel is to stand being bent cold through 180 degrees without cracking on the outside of the bent portion, as follows: for material 19.1 mm (0.75 in.) and under in diameter, around an inside diameter which is equal to the diameter of the shank; for material over 19.1 mm (0.75 in.) in diameter, around an inside diameter which is equal to one and one-half times the diameter of the shank.

13.3 Flattening Tests

The rivet head is to stand being flattened, while hot, to a diameter two and one-half times the diameter of the shank without cracking at the edges.

13.5 Number of Tests

Three bend and three flattening tests are to be made from each size in each lot of rivets offered for inspection.

PART

2

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

SECTION 7 **Steel Machinery Forgings**

1 Carbon Steel Machinery Forgings *(2000)*

1.1 Process of Manufacture

1.1.1 General *(2005)*

The following requirements cover carbon-steel forgings intended to be used in machinery construction. Alternatively, forgings which comply with national or proprietary specifications may be accepted, provided such specifications give reasonable equivalence to these requirements.

Forgings are to be made by a manufacturer approved by the Bureau.

The steel is to be fully killed and is to be manufactured by a process approved by the Bureau. For crankshafts, where grain flow is required in the most favorable direction with regard to the mode of stressing in service, the proposed method of manufacture may require special approval. In such cases, tests may be required to demonstrate that satisfactory microstructure and grain flow are obtained. The shaping of forgings or rolled slabs and billets by thermal cutting, scarfing or arc-air gouging is to be undertaken in accordance with recognized good practice and, unless otherwise approved, is to be carried out before the final heat treatment. Preheating is to be employed when necessitated by the composition and/or thickness of the steel. For certain components, subsequent machining of all thermal cut surfaces may be required.

When two or more forgings are joined by welding to form a composite component, the proposed welding procedure specification is to be submitted for approval.

The plastic deformation is to be such as to ensure soundness, uniformity of structure and satisfactory mechanical properties after heat treatment. The reduction ratio is to be calculated with reference to the average cross-sectional area of the cast material. Where the cast material is initially upset, this reference area may be taken as the average cross-sectional area after this operation.

Unless otherwise approved, the total reduction ratio is to be at least:

- For forgings made from ingots or from forged blooms or billets, 3:1 where $L > D$ and 1.5:1 where $L \leq D$.
- For forgings made from rolled products, 4:1 where $L > D$ and 2:1 where $L \leq D$.
- For forgings made by upsetting, the length after upsetting is to be not more than one-third of the length before upsetting or, in the case of an initial forging reduction of at least 1.5:1, not more than one-half of the length before upsetting.
- For rolled bars used in lieu of forgings, 6:1.

L and D are the length and diameter, respectively, of the part of the forging under consideration.

A sufficient discard is to be made from each ingot to secure freedom from piping and undue segregation.

1.1.2 Chemical Composition *(2008)*

All forgings are to be made from killed steel. An analysis of each heat is to be made to determine the percentages of the elements specified. The chemical composition thus determined is to be reported to the Surveyor and is to conform to the requirements of 2-3-7/Table 1. The carbon content of Grades 2, 3 and 4 is not to exceed 0.23% or carbon equivalent (Ceq) of Grades 2, 3 and 4 is not to exceed 0.41%, unless specially approved, see 2-3-7/Table 1. The carbon content of Grade 4C is not to exceed 0.55%. Welding of Grade 4C is not permitted unless specially approved. Specially approved grades having more than the maximum specified carbon are to have **S** marked after the grade designation.

Forgings for rudder stocks and pintles are to be of weldable quality.

The chemical composition of each heat is to be determined by the manufacturer on a sample taken preferably during the pouring of the heat. When multiple heats are tapped into a common ladle, the ladle analysis shall apply.

1.1.3 ASTM Designations

The grades are in substantial agreement with ASTM as follows:

ABS Grade	*ASTM Designation*
2	A668, Class B
3	A668, Class D
4	A668, Class E
4C	A668, Class E

1.3 Marking, Retests and Rejection

1.3.1 Marking *(2005)*

The manufacturer is to adopt a system of identification which will enable all finished forgings to be traced to the original cast and the Surveyor is to be given full facilities for tracing the forgings when required.

In addition to appropriate identification markings of the manufacturer, Bureau markings, indicating satisfactory compliance with the Rule requirements, and as furnished by the Surveyor, are to be stamped on all forgings in such locations as to be discernable after machining and installation. In addition, Grade 2, Grade 3, Grade 4, and Grade 4C forgings are to be stamped **AB/2**, **AB/3**, **AB/4** and **AB/4C**, respectively.

1.3.2 Retests *(2005)*

Test material, sufficient for the required number of tests and for possible retest purposes, is to be provided for each forging. If the results of the mechanical tests for any forging or any lot of forgings do not conform to the requirements specified, two additional test samples representative of the forging or forging batch may be taken in accordance with 2-3-1/9. If satisfactory results are obtained from both of the additional tests, the forging or batch of forgings is acceptable. If one or both retests fail, the forging or batch of forgings is to be rejected. The manufacturer may reheat-treat forgings that have failed to meet test requirements, in accordance with 2-3-7/1.5.6. After reheat-treating, the forgings are to be submitted for all mechanical testing.

1.3.3 Rejection

Any forging having injurious discontinuities that are observed prior to or subsequent to acceptance at the manufacturer's plant is to be subject to rejection.

1.5 Heat Treatment

1.5.1 General *(2005)*

Unless a departure for the following procedures is specifically approved, Grade 2 and 3 forgings are to be annealed, normalized or normalized and tempered. Grade 4 and 4C forgings are to be normalized and tempered or double-normalized and tempered. The furnace is to be of ample proportions to bring the forgings to a uniform temperature.

A sufficient number of thermocouples are to be connected to the furnace charge to measure and record that its temperature is adequately uniform unless the temperature uniformity of the furnace can be verified at regular intervals.

Heat treatment is to be carried out in properly constructed furnaces, which are efficiently maintained with adequate means to control and record temperature. The furnace dimensions are to be such as to allow the whole furnace charge to be uniformly heated to the necessary temperature. In the case of very large forgings, alternative methods of heat treatment will be specially considered. If for any reason a forging is subsequently heated for further hot working, the forging is to be reheat-treated. If a forging is locally reheated or any straightening operation is performed after the final heat treatment, consideration is to be given to a subsequent stress relieving heat treatment. The forge is to maintain records of heat treatment, identifying the furnace used, furnace charge, date, temperature and time at temperature, together with the number and location of thermocouples. The records are to be available to the Surveyor upon request.

1.5.2 Cooling Prior to Heat Treatment

After forging and before reheating for heat treatment, the forgings are allowed to cool in a manner to prevent injury and to accomplish transformation. The cooling rate is to be approximately 55°C (100°F) per hour until temperature below 315°C (600°F) is reached.

1.5.3 Annealing

The forgings are to be reheated to and held at the proper austenitizing temperature for a sufficient time to effect the desired transformation and then be allowed to cool slowly and evenly in the furnace until the temperature has fallen to about 455°C (850°F) or lower.

1.5.4 Normalizing

The forgings are to be reheated to and held at the proper temperature above the transformation range for a sufficient time to effect the desired transformation and then withdrawn from the furnace and allowed to cool in air. Water sprays and air blasts may be specially approved for use to achieve more rapid cooling. The faster cooling rates are to be agreed to by the purchaser.

1.5.5 Tempering *(2005)*

The forgings are to be reheated to and held at the proper temperature, which will be below the transformation range, and are then to be cooled under suitable conditions to 315°C (600°F) or lower. The tempering temperature is not to be less than 550°C (1022°F).

1.5.6 Retreatment

The manufacturer may re-heat treat the forging, but not more than three additional times.

1.5.7 Surface Hardening *(2005)*

Where it is intended to surface harden forgings, full details of the proposed procedure and specification are to be submitted for approval. For the purposes of this approval, the manufacturer may be required to demonstrate by test that the proposed procedure gives a uniform surface layer of the required hardness and depth, and that it does not impair the soundness and properties of the steel.

Where induction hardening or nitriding is to be carried out, forgings are to be heat-treated at an appropriate stage to a condition suitable for this subsequent surface hardening.

Where carburizing is to be carried out, forgings are to be heat treated at an appropriate stage (generally, either by full annealing or by normalizing and tempering) to a condition suitable for subsequent machining and carburizing.

1.7 Tensile Properties

The forging tensile properties are to conform to the requirements of 2-3-7/Table 2.

1.9 Test Specimens

1.9.1 Location and Orientation of Specimens

Mechanical properties are to be determined from test specimens taken from prolongations having a sectional area not less than the body of the forging. Specimens may be taken in a direction parallel to the axis of the forging in the direction in which the metal is most drawn out or may be taken transversely. The axes of longitudinal specimens are to be located at any point midway between the center and the surface of the solid forgings and at any point midway between the inner and outer surfaces of the wall of hollow forgings. The axes of transverse specimens may be located close to the surface of the forgings. In the cases of reduction gear ring forgings, reduction gear pinions and gear forgings, and reduction gear shaft forgings, the test specimen location and orientation are specified in 2-3-7/1.11.1(d), 2-3-7/1.11.1(e) and 2-3-7/1.11.1(f), respectively. Test results from other locations may be specially approved, provided appropriate supporting information is presented, which indicates that the specified location will be in conformity with the specified tensile properties.

1.9.2 Hollow-drilled Specimens

In lieu of prolongations, the test specimens may be taken from forgings submitted for each test lot; or if satisfactory to the Surveyor, test specimens may be taken from forgings with a hollow drill.

1.9.3 Very Small Forgings

In the cases of very small forgings weighing less than 113 kg (250 lb) each, where the foregoing procedures are impractical, a special forging may be made for the purpose of obtaining test specimens, provided the Surveyor is satisfied that these test specimens are representative of the forgings submitted for test. In such cases, the special forgings should be subjected to the same amount of working and reduction as the forgings represented and should be heat-treated with those forgings.

1.9.4 Identification of Specimens

The test specimens are not to be detached from the forgings until the final heat treatment of the forgings has been completed and test specimens have been stamped by the Surveyor for identification. Where the material identification system of the manufacturer is found acceptable to the Bureau and is maintained in that condition through initial and periodical verification by the Bureau, it may be considered in lieu of stamping by the Surveyor before detachment.

1.11 Number and Location of Tests

1.11.1 Tension Test

1.11.1(a) Large Forgings. In the case of large forgings with rough machined weights of 3180 kg (7000 lb) or over, one tension test specimen is to be taken from each end of the forging. In the case of ring and hollow cylindrical forgings, the two tensile test specimens may be taken 180 degrees apart from the same end of the forging.

1.11.1(b) Intermediate-Sized Forgings. In the case of forgings with rough machined weights less than 3180 kg. (7000 lb), except as noted in the following paragraph, at least one tension test specimen is to be taken from each forging.

1.11.1(c) Small Forgings (2005). In the case of small normalized forgings with rough machined weights less than 1000 kg (2200 lb), and quenched and tempered forgings with rough machined weights less than 500 kg (1100 lb) one tension test specimen may be taken from one forging as representative of a lot, provided the forgings in the lot are of a similar size, are of one grade and kind only, are made from the same heat and are heat-treated in the same furnace charge. The maximum lot size for testing purposes is 25 forgings and the total mass of the furnace charge is not to exceed 6000 kg (13200 lb) for normalized forgings and 3000 kg (6600 lb) for quenched and tempered forgings.

1.11.1(d) Reduction Gear Ring Forgings. In the case of ring forgings for reduction gears, two tension tests are to be taken 180 degrees apart from a full-size prolongation left on one end of each individual forging or both ends of each multiple forging. Test specimens are to be in a tangential orientation at mid-wall of the ring as close as practical to the end of the rough machined surface of the forging.

1.11.1(e) Reduction Gear Pinion and Gear Forgings. In the case of pinion and gear forgings for reduction gears, the tension test is to be taken in the longitudinal or tangential orientation from a location as close as practical to the mid-radius location of the main body (toothed portion) of solid forgings or the mid-wall of bored forgings. Extending the axial length of the main body (toothed portion) of the forging for a sufficient distance would be an acceptable location for tension specimen removal.

1.11.1(f) Reduction Gear Shaft Forgings. In the case of shaft forgings for reduction gears, the tension test is to be taken in the longitudinal direction at the mid-radius location of a full size prolongation.

1.11.1(g) Carburized Forgings (2006). When forgings are to be carburized, sufficient test material is to be provided for both preliminary tests at the forge and for final tests after completion of carburizing. For this purpose, duplicate sets of test material are to be taken from positions as detailed in 2-3-7/1.9 except that, irrespective of the dimensions or mass of the forging, the tests are required from one position only and, in the case of forgings with integral journals, are to be cut in a longitudinal direction. The test material is to be machined to a diameter of *D*/4 or 60 mm, whichever is less, where *D* is the finished diameter of the toothed portion.

For preliminary tests at the forge, one set of test material is to be given a blank carburizing and heat treatment cycle simulating that which subsequently will be applied to the forging. For final acceptance tests, the second set of test material is to be blank carburized and heat treated along with the forgings which they represent.

At the discretion of the forgemaster or gear manufacturer, test samples of larger cross section may be either carburized or blank carburized, but these are to be machined to the required diameter prior to the final quenching and tempering heat treatment.

Alternative procedures for testing of forgings which are to be carburized may be specially agreed with the Bureau.

1.11.2 Hardness Tests

1.11.2(a) Large, Intermediate and Small Sized Forgings. Each forging, except those with rough machined weights of less than 113 kg (250 lbs), is to be hardness tested to meet the following requirements. The variation in hardness of any forging is not to exceed 30 Brinell Hardness numbers.

ABS Grade	*Hardness, BHN, Minimum, (10 mm dia. ball, 3000 kg load)*
2	120
3	150
4, 4C	170

1.11.2(b) Reduction Gear Forgings. In the case of ring forgings for reduction gears, Brinell hardness tests are to be taken at approximately $^{1}/_{4}$ of the radial thickness from the outside diameter and in accordance with the following frequency and locations:

Outside Diameter, cm.(in)	*Number of Hardness Tests*
To 102 (40)	1 on each end, 180 degrees apart
102 to 203 (40 to 80)	2 on each end, 180 degrees apart
203 to 305 (80 to 120)	3 on each end, 120 degrees apart
Over 305 (120)	4 on each end, 90 degrees apart

1.11.2(c) Reduction Gear Pinion and Gear Forgings. In the case of pinion and gear forgings with diameters 203 mm (8 in) and over, four Brinell hardness tests are to be made on the outside surface of that portion of the forging on which teeth will be cut, two tests being made on each helix 180 degrees apart and the tests on the two Helices are to be 90 degrees apart. On each forging under 203 mm (8 in) in diameter, two Brinell hardness tests are to be made on each helix 180 degrees apart. Hardness tests are to be taken at the quarter-face width of the toothed portion diameter.

1.11.2(d) Disc, Ring and Hollow Forgings. Each forging, except those with rough machined weights of less than 113 kg (250 lbs), is to be hardness tested to meet the requirements of 2-3-7/1.11.2(a). Forgings are to be tested at the approximate mid-radius and 180 degrees apart on each flat surface of the forging; the testing locations on opposite sides are to be offset by 90 degrees.

1.11.2(e) Very Small Forgings. In cases involving very small forgings weighing less than 113 kg (250 lb) each, where the foregoing procedures are impractical, the hardness tests may be made from broken tension test specimens, or on a special forging representing the lot; see 2-3-7/1.9.3.

1.13 Examination *(2008)*

All forgings are to be examined by the Surveyor after the final heat treatment and they are to be found free from defects. Where applicable, this is to include the examination of internal surfaces and bores.

The manufacturer is to verify that all dimensions meet the specified requirements.

When required by the relevant construction Rules, or by the approved procedure for welded composite components, appropriate nondestructive testing is also to be carried out before acceptance and the results are to be reported by the manufacturer. The extent of testing and acceptance criteria are to be agreed with the Bureau. Part 2, Appendix 7 is regarded as an example of an acceptable standard.

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

1.13.1 Surface Inspection of Tail Shaft Forgings

All tail shaft forgings are to be subjected to a nondestructive examination such as magnetic particle, dye penetrant or other nondestructive method. Discontinuities are to be removed to the satisfaction of the Surveyor. (See 4-3-2/3.7.3 of the *Rules for Building and Classing Steel Vessels* for surface inspection requirements in finished machined condition.)

1.13.2 Ultrasonic Examination of Tail Shaft Forgings

Forgings for tail shafts 455 mm (18 in.) and over in finished diameter are to be ultrasonically examined to the satisfaction of the attending Surveyor. Conformity with Appendix 7-A-12, "Guide for Ultrasonic Examination of Carbon Steel Forgings of Tail Shafts" of the ABS *Rules for Survey After Construction (Part 7)*, or equivalent, will be considered to meet this requirement.

1.15 Rectification of Defective Forgings *(2005)*

Defects may be removed by grinding or chipping and grinding, provided that the component dimensions remain acceptable. The resulting grooves are to have a bottom radius of approximately three times the groove depth and are to be blended into the surrounding surface so as to avoid any sharp contours. Complete elimination of the defective material is to be verified by magnetic particle testing or liquid penetrant testing.

Repair welding of forgings may be permitted subject to prior approval by the Bureau. In such cases, full details of the extent and location of the repair, the proposed welding procedure, heat treatment and subsequent inspection procedures are to be submitted for approval.

The forging manufacturer is to maintain records of repairs and subsequent inspections that are traceable to each forging repaired. The records are to be presented to the Surveyor on request.

1.17 Certification *(2005)*

The manufacturer is to provide the required type of inspection certificate giving the following particulars for each forging or batch of forgings which has been accepted:

i) Purchaser's name and order number

ii) Description of forgings and steel quality

iii) Identification number

iv) Steelmaking process, cast number and chemical analysis of ladle sample

v) Results of mechanical tests

vi) Results of nondestructive tests, where applicable

vii) Details of heat treatment, including temperature and holding times

viii) Specification

3 Alloy Steel Gear Assembly Forgings *(2000)*

3.1 Process of Manufacture

3.1.1 General *(2005)*

The following requirements cover gear and pinion alloy steel forgings intended to be used principally for propulsion units and auxiliary turbines. Typical components include forging rims and blanks for steel gears and pinions, used in shipboard gear assemblies. The steel is to be fully killed and is to be manufactured by a process approved by the Bureau. Alternatively, forgings which comply with national or proprietary specifications may be accepted, provided such specifications give reasonable equivalence to these requirements.

Forgings are to be made by a manufacturer approved by the Bureau.

The shaping of forgings or rolled slabs and billets by thermal cutting, scarfing or arc-air gouging is to be undertaken in accordance with recognized good practice and, unless otherwise approved, is to be carried out before the final heat treatment. Preheating is to be employed when necessitated by the composition and/or thickness of the steel. For certain components, subsequent machining of all thermal cut surfaces may be required.

When two or more forgings are joined by welding to form a composite component, the proposed welding procedure specification is to be submitted for approval.

The plastic deformation is to be such as to ensure soundness, uniformity of structure and satisfactory mechanical properties after heat treatment. The reduction ratio is to be calculated with reference to the average cross-sectional area of the cast material. Where the cast material is initially upset, this reference area may be taken as the average cross-sectional area after this operation.

Unless otherwise approved, the total reduction ratio is to be at least:

- For forgings made from ingots or from forged blooms or billets, 3:1 where $L > D$ and 1.5:1 where $L \le D$.
- For forgings made from rolled products, 4:1 where $L > D$ and 2:1 where $L \le D$.
- For forgings made by upsetting, the length after upsetting is to be not more than one-third of the length before upsetting or, in the case of an initial forging reduction of at least 1.5:1, not more than one-half of the length before upsetting.
- For rolled bars used in lieu of forgings, 6:1.

L and *D* are the length and diameter, respectively, of the part of the forging under consideration.

A sufficient discard is to be made from each ingot to secure freedom from piping and undue segregation. The forging process is to have ample power to adequately flow the metal within the maximum cross-section of the forging.

3.1.2 Chemical Composition *(2005)*

All forgings are to be made from killed steel. An analysis of each heat is to be made to determine the percentages of the elements specified. The chemical composition thus determined is to be reported to the Surveyor and is to conform to the requirements of 2-3-7/Table 3. The analysis is to be carried out with a coupon cast during the pouring of the heat.

3.1.3 ASTM Designations

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

ABS Grade	*ASTM Designation*
A1	A291 Class 2
A2	A291 Class 3
A3	A291 Class 4
A4	A291 Class 5
A5	A291 Class 6
A6	A291 Class 7

3.3 Marking, Retests and Rejection

3.3.1 Marking *(2005)*

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

In addition to appropriate identification markings of the manufacturer, Bureau markings, indicating satisfactory compliance with the Rule requirements, and as furnished by the Surveyor, are to be stamped on all forgings in such locations as to be discernable after machining and installation. In addition, Grade A1 through Grade A6 forgings are to be stamped **AB/A1**, **AB/A2**, **AB/A3**, **AB/A4**, **AB/A5**, and **AB/A6**, respectively.

3.3.2 Retests *(2005)*

Test material, sufficient for the required number of tests and for possible retest purposes, is to be provided for each forging. If the results of the mechanical tests for any forging or any lot of forgings do not conform to the requirements specified, two additional test samples representative of the forging or forging batch may be taken in accordance with 2-3-1/9 or 2-1-2/11.7. If satisfactory results are obtained from both of the additional tests, the forging or batch of forgings is acceptable. If one or both retests fail, the forging or batch of forgings is to be rejected. The manufacturer may reheat-treat forgings that have failed to meet test requirements, in accordance with 2-3-7/3.5.7. After reheat-treating, the forgings are to be submitted for all mechanical testing.

3.3.3 Rejection

Any forging having injurious discontinuities that are observed prior to or subsequent to acceptance at the manufacturer's plant is to be subject to rejection.

3.5 Heat Treatment

3.5.1 General *(2005)*

A sufficient number of thermocouples are to be connected to the furnace charge to measure and record that its temperature is adequately uniform, unless the temperature uniformity of the furnace can be verified at regular intervals.

Heat treatment is to be carried out in properly constructed furnaces, which are efficiently maintained with adequate means to control and record temperature. The furnace dimensions are to be such as to allow the whole furnace charge to be uniformly heated to the necessary temperature. In the case of very large forgings, alternative methods of heat treatment will be specially considered. If for any reason a forging is subsequently heated for further hot working, the forging is to be reheat-treated. If a forging is locally reheated or any straightening operation is performed after the final heat treatment consideration is to be given to a subsequent stress relieving heat treatment.

The forge is to maintain records of heat treatment, identifying the furnace used, furnace charge, date, temperature and time at temperature, together with the number and location of thermocouples. The records are to be available to the Surveyor upon request.

The required heat treatment for each forging grade is as follows:

<u>Required Heat Treatment and Minimum Tempering Temperature</u>

Grade	*Heat Treatment*	*Temperature, in °C (°F)*
A1	Quench + Temper	620 (1150)
A2	Quench + Temper	580 (1075)
A3	Quench + Temper	580 (1075)
A4	Quench + Temper	565 (1050)
A5	Quench + Temper	565 (1050)
A6	Quench + Temper	565 (1050)

Alternative heat treatment procedures may be specially approved with due consideration given to the section thickness and the intended function of the forged component. The furnace is to be of ample proportions to bring the forgings to a uniform temperature.

3.5.2 Cooling Prior to Heat Treatment

After forging and before reheating for heat treatment, the forgings are allowed to cool in a manner to prevent injury and to accomplish transformation. The cooling rate is to be approximately 55°C (100°F) per hour until a temperature below 315°C (600°F) is reached.

3.5.3 Annealing

The forgings are to be reheated to and held at the proper austenitizing temperature for a sufficient time to effect the desired transformation and then be allowed to cool slowly and evenly in the furnace until the temperature has fallen to about 455°C (850°F) or lower.

3.5.4 Normalizing

The forgings are to be reheated to and held at the proper temperature above the transformation range for a sufficient time to effect the desired transformation and then withdrawn from the furnace and allowed to cool in air.

3.5.5 Tempering

The forgings are to be reheated to and held at the proper temperature, which is to be below the transformation range but above the minimum temperature in 2-3-7/3.5.1, and are then to be cooled at a rate not exceeding 100°F (55°C) per hour until a temperature below 315°C (600°F) is reached.

3.5.6 Stress Relieving *(2008)*

Where heat treatment for mechanical properties is carried out before final machining, the forgings are to be stress relieved after machining at a temperature 28°C (50°F) to 55°C (100°F) below the previous tempering temperature, but in no case less than 540°C (1000°F). The cooling rate is not to exceed 55°C (100°F) per hour until temperature below 315°C (600°F) is reached.

3.5.7 Retreatment

The manufacturer may re-heat treat the forging, but not more than three additional times.

3.7 Mechanical Properties

3.7.1 Tensile Properties

The forging tensile properties are to conform to the requirements of 2-3-7/Table 4.

3.7.2 Hardness

Each forging, except those with rough machined weights of less than 113 kg (250 lbs), is to be hardness tested to meet the following requirements.

ABS Grade	*Hardness, BHN, (10 mm dia. ball, 3000 kg load)*
A1	201 to 241
A2	223 to 262
A3	248 to 293
A4	285 to 331
A5	302 to 352
A6	341 to 415

3.9 Test Specimens

3.9.1 Location and Orientation of Specimens

Mechanical properties are to be determined from tensile test specimens taken from prolongations having a sectional area not less than the body of the forging. The tensile test specimens may be taken in a direction parallel to the axis of the forging in the direction in which the metal is most drawn out or tangential to that direction, as indicated by the ductility requirements in 2-3-7/Table 4. The axes of the longitudinal specimens are to be located at any point 32 mm (1.25 in) below the surface of the forging. The axes of the tangential specimens are to be located as near to the surface of the forging as practicable. In the cases of reduction gear ring forgings, reduction gear pinions and gear forgings, and reduction gear shaft forgings, the test specimen location and orientation are specified in 2-3-7/3.9.3(d), 2-3-7/3.9.3(e) and 2-3-7/3.9.3(f), respectively.

3.9.2 Identification of Specimens

The test specimens are not to be detached from the forgings until the final heat treatment of the forgings has been completed and test specimens have been stamped by the Surveyor for identification. Where the material identification system of the manufacturer is found acceptable to the Bureau and is maintained in that condition through initial and periodical verification by the Bureau, it may be considered in lieu of stamping by the Surveyor before detachment.

3.9.3 Tension Tests

3.9.3(a) Large Forgings. In the case of large forgings with rough machined weights of 3180 kg (7000 lb) or over, one tension test is to be taken from each end of the forging. In the case of ring and hollow cylindrical forgings, the tests may be taken 180 degrees apart from the same end of the forging.

3.9.3(b) Intermediate-Sized Forgings. In the case of forgings with rough machined weights less than 3180 kg. (7000 lb), except as noted in the following paragraph, at least one tension test is to be taken from each forging.

3.9.3(c) Small Forgings (2005). In the case of small normalized forgings with rough machined weights less than 1000 kg (2200 lb) and quenched and tempered forgings with rough machined weights less than 500 kg (1100 lb), one tension test specimen may be taken from one forging as representative of a lot, provided the forgings in the lot are of a similar size, are of one grade and kind only, are made from the same heat and are heat-treated in the same furnace charge. The maximum lot size for testing purposes is 25 forgings and the total mass of the furnace charge is not to exceed 6000 kg (13200 lb) for normalized forgings and 3000 kg (6600 lb) for quenched and tempered forgings.

3.9.3(d) Reduction Gear Ring Forgings. In the case of ring forgings for reduction gears, two tension tests are to be taken 180 degrees apart from a full-size prolongation left on one end of each individual forging or both ends of each multiple forging. Test specimens are to be in a tangential orientation as close as practical to the end of the rough machined surface of the forging.

3.9.3(e) Reduction Gear Pinion and Gear Forgings. In the case of pinion and gear forgings for reduction gears, the tests are to be taken in the longitudinal or tangential orientation. Extending the axial length of the main body (toothed portion) of the forging for a sufficient distance would be an acceptable location for test specimen removal.

3.9.3(f) Reduction Gear Shaft Forgings. In the case of shaft forgings for reduction gears, the tests are to be taken in the longitudinal direction from a full size prolongation.

3.9.3(g) Carburized Forgings (2006). When forgings are to be carburized, sufficient test material is to be provided for both preliminary tests at the forge and for final tests after completion of carburizing. For this purpose, duplicate sets of test material are to be taken from positions as detailed in 2-3-7/1.9 except that, irrespective of the dimensions or mass of the forging, the tests are required from one position only and, in the case of forgings with integral journals, are to be cut in a longitudinal direction. The test material is to be machined to a diameter of $D/4$ or 60 mm, whichever is less, where D is the finished diameter of the toothed portion.

For preliminary tests at the forge, one set of test material is to be given a blank carburizing and heat treatment cycle simulating that which subsequently will be applied to the forging. For final acceptance tests, the second set of test material is to be blank carburized and heat treated along with the forgings which they represent.

At the discretion of the forgemaster or gear manufacturer, test samples of larger cross section may be either carburized or blank carburized, but these are to be machined to the required diameter prior to the final quenching and tempering heat treatment.

Alternative procedures for testing of forgings which are to be carburized may be specially agreed with the Bureau.

3.9.4 Hardness

3.9.4(a) Large, Intermediate and Small Sized Forgings. Each forging except those with rough machined weights of less than 113 kg (250 lbs) is to be hardness tested.

3.9.4(b) Reduction Gear Forgings. In the case of ring forgings for reduction gears, Brinell hardness tests are to be taken at approximately $^1/_4$ of the radial thickness from the outside diameter and in accordance with the following frequency and locations:

Outside Diameter, cm.(in)	*Number of Hardness Tests*
To 102 (40)	1 on each end, 180 degrees apart
102 to 203 (40 to 80)	2 on each end, 180 degrees apart
203 to 305 (80 to 120)	3 on each end, 120 degrees apart
Over 305 (120)	4 on each end, 90 degrees apart

3.9.4(c) Reduction Gear Pinion and Gear Forgings. In the case of pinion and gear forgings with diameters 203 mm (8 in) and over, four Brinell hardness tests are to be made on the outside surface of that portion of the forging on which teeth will be cut, two tests being made on each helix 180 degrees apart and the tests on the two helices are to be 90 degrees apart. On each forging under 203 mm (8 in) in diameter, two Brinell hardness tests are to be made on each helix 180 degrees apart. Hardness tests are to be taken at the quarter-face width of the toothed portion diameter.

3.9.4(d) Reduction Gear Shaft Forgings. In the case of shaft forgings for reduction gears, two hardness tests at each end, spaced at 180 degrees apart, are to be taken.

3.11 Examination *(2008)*

After final heat treatment, all forgings are to be examined in accordance with 2-3-7/1.13 by the Surveyor and found free from defects. The finish is to be free of cracks, seams, laps, cold shuts, laminations, shrinkage and burst indications.

3.13 Rectification of Defective Forgings *(2005)*

Rectification of defects is to be carried out in accordance with 2-3-7/1.15.

3.15 Certification *(2005)*

The manufacturer is to provide the required type of inspection certificate, in accordance with 2-3-7/1.17.

5 Alloy Steel Shaft and Stock Forgings *(2000)*

5.1 Process of Manufacture

5.1.1 General *(2005)*

The following requirements cover shaft and stock alloy steel forgings intended to be used principally for propulsion units and stock type applications. Typical components include tail shafts, intermediate shafts, thrust shafts, other torsional shafts, sleeves, couplings, propeller nuts, rudder stocks and canard stocks, used in shipboard units. The steel is to be fully killed and is to be manufactured by a process approved by the Bureau. Alternatively, forgings which comply with national or proprietary specifications may be accepted, provided such specifications give reasonable equivalence to these requirements.

Forgings are to be made by a manufacturer approved by the Bureau.

The shaping of forgings or rolled slabs and billets by thermal cutting, scarfing or arc-air gouging is to be undertaken in accordance with recognized good practice and, unless otherwise approved, is to be carried out before the final heat treatment. Preheating is to be employed when necessitated by the composition and/or thickness of the steel. For certain components, subsequent machining of all thermal cut surfaces may be required.

When two or more forgings are joined by welding to form a composite component, the proposed welding procedure specification is to be submitted for approval.

The plastic deformation is to be such as to ensure soundness, uniformity of structure and satisfactory mechanical properties after heat treatment. The reduction ratio is to be calculated with reference to the average cross-sectional area of the cast material. Where the cast material is initially upset, this reference area may be taken as the average cross-sectional area after this operation

Unless otherwise approved, the total reduction ratio is to be at least:

- For forgings made from ingots or from forged blooms or billets, 3:1 where $L > D$ and 1.5:1 where $L \leq D$.
- For forgings made from rolled products, 4:1 where $L > D$ and 2:1 where $L \leq D$.
- For forgings made by upsetting, the length after upsetting is to be not more than one-third of the length before upsetting or, in the case of an initial forging reduction of at least 1.5:1, not more than one-half of the length before upsetting.
- For rolled bars used in lieu of forgings, 6:1.

L and D are the length and diameter, respectively, of the part of the forging under consideration.

A sufficient discard is to be made from each ingot to secure freedom from piping and undue segregation.

5.1.2 Chemical Composition *(2005)*

All forgings are to be made from killed steel. An analysis of each heat is to be made to determine the percentages of the elements specified. The chemical composition thus determined is to be reported to the Surveyor and is to conform to the requirements of 2-3-7/Table 5. The analysis is to be carried out with a coupon cast during the pouring of the heat.

5.1.3 Product Analysis

The forgings are to be subjected to a product chemical analysis and meet the requirements of 2-3-7/Table 5, as modified by the product variation requirements specified in A778, General Requirements for Steel Forgings.

5.1.4 ASTM Designations

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

ABS Grade	*ASTM Designation*
A7	A470 Class 2
A8	A470 Class 4
A9	A470 Class 6
A10	A470 Class 7

5.3 Marking, Retests and Rejection

5.3.1 Marking *(2005)*

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

In addition to appropriate identification markings of the manufacturer, Bureau markings, indicating satisfactory compliance with the Rule requirements, and as furnished by the Surveyor, are to be stamped on all forgings in such locations as to be discernable after machining and installation. In addition, Grade A7 through Grade A10 forgings are to be stamped **AB/A7**, **AB/A8**, **AB/A9** and **AB/A10**, respectively.

5.3.2 Retests *(2005)*

Test material, sufficient for the required number of tests and for possible retest purposes, is to be provided for each forging. If the results of the mechanical tests for any forging or any lot of forgings do not conform to the requirements specified, two additional test samples representative of the forging or forging batch may be taken in accordance with 2-3-1/9 or 2-1-2/11.7. If satisfactory results are obtained from both of the additional tests, the forging or batch of forgings is acceptable. If one or both retests fail, the forging or batch of forgings is to be rejected. The manufacturer may reheat-treat forgings that have failed to meet test requirements, in accordance with 2-3-7/5.5.7. After reheat-treating, the forgings are to be submitted for all mechanical testing.

5.3.3 Rejection

Any forging having injurious discontinuities that are observed prior to or subsequent to acceptance at the manufacturer's plant is to be subject to rejection.

5.5 Heat Treatment

5.5.1 General *(2005)*

A sufficient number of thermocouples are to be connected to the furnace charge to measure and record that its temperature is adequately uniform, unless the temperature uniformity of the furnace can be verified at regular intervals.

Heat treatment is to be carried out in properly constructed furnaces which are efficiently maintained with adequate means to control and record temperature. The furnace dimensions are to be such as to allow the whole furnace charge to be uniformly heated to the necessary temperature. In the case of very large forgings, alternative methods of heat treatment will be specially considered. If for any reason a forging is subsequently heated for further hot working, the forging is to be reheat-treated. If a forging is locally reheated or any straightening operation is performed after the final heat treatment, consideration is to be given to a subsequent stress relieving heat treatment.

The forge is to maintain records of heat treatment, identifying the furnace used, furnace charge, date, temperature and time at temperature, together with the number and location of thermocouples. The records are to be available to the Surveyor upon request.

The required heat treatment for each forging grade is as follows:

Required Heat Treatment and Minimum Tempering Temperature

Grade	*Heat Treatment*	*Temperature, in °C (°F)*
A7	Double Normalize + Temper	580 (1075)
A8	Double Normalize + Temper	580 (1075)
A9	Normalize, Quench + Temper	580 (1075)
A10	Normalize, Quench + Temper	580 (1075)

Alternative heat treatment procedures may be specially approved with due consideration given to the section thickness and the intended function of the forged component. The furnace is to be of ample proportions to bring the forgings to a uniform temperature.

5.5.2 Cooling Prior to Heat Treatment

After forging and before reheating for heat treatment, forgings are allowed to cool in a manner to prevent injury and to accomplish transformation. The cooling rate is to be approximately 55°C (100°F) per hour until a temperature below 315°C (600°F) is reached.

5.5.3 Annealing

Forgings are to be reheated to and held at the proper austenitizing temperature for a sufficient time to effect the desired transformation and then be allowed to cool slowly and evenly in the furnace until the temperature has fallen to about 455°C (850°F) or lower.

5.5.4 Normalizing

Forgings are to be reheated to and held at the proper temperature above the transformation range for a sufficient time to effect the desired transformation and then withdrawn from the furnace and allowed to cool in air. Water sprays and air blasts may be specially approved for use with Grade A7 and A8 forgings to achieve more rapid cooling. The faster cooling rates are to be agreed to by the purchaser.

5.5.5 Tempering

Forgings are to be reheated to and held at the proper temperature, which is to be below the transformation range but above the minimum temperature in 2-3-7/5.5.1, and are then to be cooled at a rate not exceeding 100°F (55°C) per hour until a temperature below 315°C (600°F) is reached.

5.5.6 Stress Relieving

Where heat treatment for mechanical properties is carried out before final machining, the forgings are to be stress relieved at a temperature not more than 55°C (100°F) below the previous tempering temperature, but in no case less than 550°C (1025°F). The cooling rate is not to exceed 55°C (100°F) per hour until a temperature below 315°C (600°F) is reached. Stress relieving may be used to augment tempering, in order to make final adjustments to the mechanical properties. If the stress relief temperature is within 14°C (25°F) of the final tempering temperature or higher for quenched and tempered steel, mechanical tests are to be made to assure that these temperatures have not adversely affected the mechanical properties of the steel.

5.5.7 Retreatment

The manufacturer may re-heat treat the forging, but not more than three additional times.

5.7 Mechanical Properties

5.7.1 Tensile Properties

The forging tensile properties are to conform to the requirements of 2-3-7/Table 6.

5.7.2 Hardness

Each forging, except those with rough machined weights of less than 113 kg (250 lbs), is to be hardness tested to meet the following requirements. The variation in hardness of any forging is not to exceed 30 Brinell Hardness numbers.

ABS Grade	*Hardness, BHN, (10 mm dia. ball, 3000 kg load)*
A7	163 to 207
A8	223 to 262
A9	223 to 262
A10	248 to 293

5.7.3 Charpy Impact *(2005)*

Charpy V-notch impact testing is not required for applications where the service design temperature is 0°C (32°F) and above.

5.7.4 Thermal Stability Test *(2005)*

The thermal stability test is not required for applications where the service design temperature is 0°C (32°F) and above.

5.9 Test Specimens

5.9.1 Location and Orientation of Specimens

Mechanical properties are to be determined from tensile test specimens taken from prolongations having a sectional area not less than the body of the forging. The tensile test specimens may be taken in a direction parallel to the axis of the forging in the direction in which the metal is most drawn out or may be taken in a radial direction, as indicated by the ductility requirements in 2-3-7/Table 4. The axes of the specimens are to be located at any point midway between the center and the surface of the solid forgings and at any point midway between the inner and outer surfaces of the wall of hollow forgings. In the cases of sleeves, couplings and nut forgings, the test specimen location and orientation are specified in 2-3-7/5.9.3(d).

5.9.2 Identification of Specimens

The test specimens are not to be detached from the forgings until the final heat treatment of the forgings has been completed and test specimens have been stamped by the Surveyor for identification. Where the material identification system of the manufacturer is found acceptable to the Bureau and is maintained in that condition through initial and periodical verification by the Bureau, it may be considered in lieu of stamping by the Surveyor before detachment.

5.9.3 Tension Tests

5.9.3(a) Large Forgings. In the case of large forgings with rough machined weights of 3180 kg (7000 lb) or over, one tension test is to be taken from each end of the forging. In the case of ring and hollow cylindrical forgings, the tests may be taken 180 degrees apart from the same end of the forging.

5.9.3(b) Intermediate-Sized Forgings. In the case of forgings with rough machined weights less than 3180 kg. (7000 lb), except as noted in the following paragraph, at least one tension test is to be taken from each forging.

5.9.3(c) Small Forgings (2005). In the case of small normalized forgings with rough machined weights less than 1000 kg (2200 lb) and quenched and tempered forgings with rough machined weights less than 500 kg (1100 lb), one tension test specimen may be taken from one forging as representative of a lot, provided the forgings in the lot are of a similar size, are of one grade and kind only, are made from the same heat and are heat-treated in the same furnace charge. The maximum lot size for testing purposes is 25 forgings and the total mass of the furnace charge is not to exceed 6000 kg (13200 lb) for normalized forgings and 3000 kg (6600 lb) for quenched and tempered forgings.

5.9.3(d) Sleeves, Couplings and Nut Forgings. In the case of ring-type or cylinder-type forgings for use as sleeves, coupling or nuts, the tension test is to be taken from a full-size prolongation left on one end of each individual forging. Test specimens are to be in a longitudinal orientation at mid-wall of the ring or cylinder as close as practical to the end of the rough machined surface of the forging.

5.9.4 Hardness

5.9.4(a) Large, Intermediate and Small Sized Forgings. Each forging, except those with rough machined weights of less than 113 kg (250 lbs), is to be hardness tested to meet the requirements of 2-3-7/5.7.2. The forging is to be tested at locations 180 degrees apart on each end.

5.9.4(b) Sleeves, Couplings and Nut Forgings. In the case of ring-type or cylinder-type forgings for use as sleeves, coupling or nuts, Brinell hardness tests are to be taken at approximately $^{1}/_{4}$ of the radial thickness from the outside diameter and in accordance with the following frequency and locations:

Outside Diameter, cm.(in)	*Number of Hardness Tests*
To 102 (40)	1 on each end, 180 degrees apart
102 to 203 (40 to 80)	2 on each end, 180 degrees apart

5.11 Examination *(2008)*

After final heat treatment, all forgings are to be examined, in accordance with 2-3-7/1.13, by the Surveyor and found free from defects. The finish is to be free of cracks, seams, laps, cold shuts, laminations, shrinkage and burst indications.

5.11.1 Surface Inspection of Tail Shaft Forgings

All tail shaft forgings are to be subjected to a nondestructive examination such as magnetic particle, dye penetrant or other nondestructive method. Discontinuities are to be removed to the satisfaction of the Surveyor. (See 4-3-2/3.7.3 of the ABS *Rules for Building and Classing Steel Vessels* for surface inspection requirements in finished machined condition.)

5.11.2 Ultrasonic Examination of Tail Shaft Forgings

Forgings for tail shafts 455 mm (18 in) and over in finished diameter are to be ultrasonically examined to the satisfaction of the attending Surveyor. Conformity with Appendix 7-A-12, "Guide for Ultrasonic Examination of Carbon Steel Forgings of Tail Shafts" of the ABS *Rules for Survey After Construction (Part 7)*, or equivalent, will be considered to meet this requirement.

5.13 Rectification of Defective Forgings *(2005)*

Rectification of defects is to be carried out in accordance with 2-3-7/1.15.

5.15 Certification *(2005)*

The manufacturer is to provide the required type of inspection certificate, in accordance with 2-3-7/1.17.

7 General Shipboard Alloy Steel Forgings *(2000)*

7.1 Process of Manufacture

7.1.1 General *(2005)*

The following requirements cover alloy steel forgings intended to be used for general shipboard applications. The steel is to be fully killed and is to be manufactured by a process approved by the Bureau. Alternatively, forgings which comply with national or proprietary specifications may be accepted, provided such specifications give reasonable equivalence to these requirements.

Forgings are to be made by a manufacturer approved by the Bureau.

The shaping of forgings or rolled slabs and billets by flame cutting, scarfing or arc-air gouging is to be undertaken in accordance with recognized good practice and, unless otherwise approved, is to be carried out before the final heat treatment. Preheating is to be employed when necessitated by the composition and/or thickness of the steel. For certain components, subsequent machining of all flame cut surfaces may be required.

When two or more forgings are joined by welding to form a composite component, the proposed welding procedure specification is to be submitted for approval.

The plastic deformation is to be such as to ensure soundness, uniformity of structure and satisfactory mechanical properties after heat treatment. The reduction ratio is to be calculated with reference to the average cross-sectional area of the cast material. Where the cast material is initially upset, this reference area may be taken as the average cross-sectional area after this operation.

Unless otherwise approved, the total reduction ratio is to be at least:

- For forgings made from ingots or from forged blooms or billets, 3:1 where $L > D$ and 1.5:1 where $L \leq D$.
- For forgings made from rolled products, 4:1 where $L > D$ and 2:1 where $L \leq D$.
- For forgings made by upsetting, the length after upsetting is to be not more than one-third of the length before upsetting or, in the case of an initial forging reduction of at least 1.5:1, not more than one-half of the length before upsetting.
- For rolled bars used in lieu of forgings, 6:1.

L and D are the length and diameter, respectively, of the part of the forging under consideration.

A sufficient discard is to be made from each ingot to secure freedom from piping and undue segregation. The forging process is to have ample power to adequately flow the metal within the maximum cross-section of the forging.

7.1.2 Chemical Composition *(2005)*

All forgings are to be made from killed steel. An analysis of each heat is to be made to determine the percentages of the elements specified. The chemical composition thus determined is to be reported to the Surveyor and is to conform to the requirements of 2-3-7/Table 7. The analysis is to be carried out with a coupon cast during the pouring of the heat.

7.1.3 ASTM Designations

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

ABS Grade	*ASTM Designation*
A11	A668 Class J
A12	A668 Class K
A13	A668 Class L
A14	A668 Class M
A15	A668 Class N

7.3 Marking, Retests and Rejection

7.3.1 Marking *(2005)*

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

In addition to appropriate identification markings of the manufacturer, Bureau markings, indicating satisfactory compliance with the Rule requirements and as furnished by the Surveyor, are to be stamped on all forgings in such locations as to be discernable after machining and installation. In addition, Grade A11 through Grade A15 forgings are to be stamped **AB/A11**, **AB/A12**, **AB/A13**, **AB/A14** and **AB/A15**, respectively.

7.3.2 Retests *(2005)*

Test material, sufficient for the required number of tests and for possible retest purposes, is to be provided for each forging. If the results of the mechanical tests for any forging or any lot of forgings do not conform to the requirements specified, two additional test samples representative of the forging or forging batch may be taken in accordance with 2-3-1/9 or 2-1-2/11.7. If satisfactory results are obtained from both of the additional tests, the forging or batch of forgings is acceptable. If one or both retests fail, the forging or batch of forgings is to be rejected. The manufacturer may reheat-treat forgings that have failed to meet test requirements, in accordance with 2-3-7/7.5.6. After reheat-treating, the forgings are to be submitted for all mechanical testing.

7.3.3 Rejection

Any forging having injurious discontinuities that are observed prior to or subsequent to acceptance at the manufacturer's plant is to be subject to rejection.

7.5 Heat Treatment

7.5.1 General *(2005)*

A sufficient number of thermocouples are to be connected to the furnace charge to measure and record that its temperature is adequately uniform, unless the temperature uniformity of the furnace can be verified at regular intervals.

Heat treatment is to be carried out in properly constructed furnaces which are efficiently maintained with adequate means to control and record temperature. The furnace dimensions are to be such as to allow the whole furnace charge to be uniformly heated to the necessary temperature. In the case of very large forgings, alternative methods of heat treatment will be specially considered. If for any reason a forging is subsequently heated for further hot working, the forging is to be reheat-treated. If a forging is locally reheated or any straightening operation is performed after the final heat treatment, consideration is to be given to a subsequent stress relieving heat treatment.

The forge is to maintain records of heat treatment, identifying the furnace used, furnace charge, date, temperature and time at temperature, together with the number and location of thermocouples. The records are to be available to the Surveyor upon request.

Unless a departure from the following procedures is specifically approved, Grade A11 forgings are to be normalized and tempered, or normalized, quenched and tempered. Grades A12, A13, A14 and A15 forgings are to be normalized, quenched and tempered. The furnace is to be of ample proportions to bring the forgings to a uniform temperature.

7.5.2 Cooling Prior to Heat Treatment

After forging and before reheating for heat treatment, forgings are allowed to cool in a manner to prevent injury and to accomplish transformation. The cooling rate is to be approximately 55°C (100°F) per hour until a temperature below 315°C (600°F) is reached.

7.5.3 Annealing

Forgings are to be reheated to and held at the proper austenitizing temperature for a sufficient time to effect the desired transformation and then be allowed to cool slowly and evenly in the furnace until the temperature has fallen to about 455°C (850°F) or lower.

7.5.4 Normalizing

Forgings are to be reheated to and held at the proper temperature above the transformation range for a sufficient time to effect the desired transformation and then withdrawn from the furnace and allowed to cool in air. Water sprays and air blasts may be specially approved for use to achieve more rapid cooling. The faster cooling rates are to be agreed by the purchaser.

7.5.5 Tempering

Forgings are to be reheated to and held at the proper temperature, which will be below the transformation range, and are then to be cooled under suitable conditions to 315°C (600°F) or lower.

7.5.6 Retreatment

The manufacturer may re-heat-treat the forging, but not more than three additional times.

7.7 Mechanical Properties

7.7.1 Tensile Properties

The forging tensile properties are to conform to the requirements of 2-3-7/Table 8.

7.7.2 Hardness

Each forging, except those with rough machined weights of less than 113 kg (250 lbs), is to be hardness tested to meet the following requirements. The variation in hardness of Grade A11 forgings is not to exceed 40 Brinell Hardness numbers. The variation in hardness of Grades A12 forgings through A15 forgings is not to exceed 50 Brinell Hardness numbers.

ABS Grade	*Size, in mm (in.)*	*Hardness, BHN, (10 mm dia. ball, 3000 kg load)*
A11	≤ 180 (7)	197 to 255
	> 180 (7), ≤ 255 (10)	187 to 235
	> 255 (10), ≤ 510 (20)	187 to 255
A12	≤ 180 (7)	212 to 269
	> 180 (7), ≤ 510 (20)	207 to 269
A13	≤ 100 (4)	255 to 321
	> 100 (4), ≤ 180 (7)	235 to 302
	> 180 (7), ≤ 510 (20)	223 to 293
A14	≤ 100 (4)	293 to 352
	> 100 (4), ≤ 180 (7)	285 to 341
	> 180 (7), ≤ 255 (10)	269 to 331
	> 255 (10), ≤ 510 (20)	269 to 341
A15	≤ 180 (7)	331 to 401
	> 180 (7), ≤ 255 (10)	321 to 388
	> 255 (10), ≤ 510 (20)	321 to 402

7.9 Mechanical Testing

7.9.1 Location and Orientation of Specimens

Mechanical properties are to be determined from tensile test specimens taken from prolongations having a sectional area not less than the body of the forging. The length of the prolongation is to be such that the distance from the test specimen mid-gauge to the end of the prolongation is to be 89 mm (3.5 in) or one-half the forging section thickness or diameter, whichever is less. The tensile test specimens may be taken in a direction parallel to the axis of the forging in the direction in which the metal is most drawn out or tangential to that direction, as indicated by the ductility requirements in 2-3-7/Table 8. The axes of the specimens are to be located at any point midway between the center and the surface of the solid forgings and at any point midway between the inner and outer surfaces of the wall of hollow forgings.

7.9.2 Hollow-drilled Specimens

In lieu of prolongations, the test specimens may be taken from forgings submitted for each test lot; or if satisfactory to the Surveyor, test specimens may be taken from forgings with a hollow drill.

7.9.3 Very Small Forgings

In the cases of very small forgings weighing less than 113 kg (250 lb) each, where the foregoing procedures are impractical, a special forging may be made for the purpose of obtaining test specimens, provided the Surveyor is satisfied that these test specimens are representative of the forgings submitted for test. In such cases, the special forgings should be subjected to the same amount of working and reduction as the forgings represented and should be heat-treated with those forgings.

7.9.4 Identification of Specimens

The test specimens are not to be detached from the forgings until the final heat treatment of the forgings has been completed and test specimens have been stamped by the Surveyor for identification. Where the material identification system of the manufacturer is found acceptable to the Bureau and is maintained in that condition through initial and periodical verification by the Bureau, it may be considered in lieu of stamping by the Surveyor before detachment.

7.11 Number and Location of Tests

7.11.1 Tension Tests

7.11.1(a) Large Forgings. In the case of large forgings with rough machined weights of 3180 kg (7000 lb) or over, one tension test is to be taken from each end of the forging. In the case of ring and hollow cylindrical forgings, the tests may be taken 180 degrees apart from the same end of the forging.

7.11.1(b) Intermediate-Sized Forgings. In the case of forgings with rough machined weights less than 3180 kg. (7000 lb), except as noted in the following paragraph, at least one tension test is to be taken from each forging.

7.11.1(c) Small Forgings (2005). In the case of small normalized forgings with rough machined weights less than 1000 kg (2200 lb) and quenched and tempered forgings with rough machined weights less than 500 kg (1100 lb), one tension test specimen may be taken from one forging as representative of a lot, provided the forgings in the lot are of a similar size, are of one grade and kind only, are made from the same heat and are heat-treated in the same furnace charge. The maximum lot size for testing purposes is 25 forgings and the total mass of the furnace charge is not to exceed 6000 kg (13200 lb) for normalized forgings and 3000 kg (6600 lb) for quenched and tempered forgings.

7.11.1(d) Sleeves, Couplings and Nut Forgings. In the case of ring-type or cylinder-type forgings for use as sleeves, coupling or nuts, the tension test is to be taken from a full-size prolongation left on one end of each individual forging. Test specimens are to be in a longitudinal orientation at mid-wall of the ring or cylinder as close as practical to the end of the rough machined surface of the forging.

7.11.2 Hardness Tests

7.11.2(a) Large, Intermediate and Small Sized Forgings. Each forging, except those with rough machined weights of less than 113 kg (250 lbs), is to be hardness tested to meet the requirements of 2-3-7/7.7.2. Forgings are to be tested at locations 180 degrees apart on each end.

7.11.2(b) Discs, Rings and Hollow Forgings. Each forging except, those with rough machined weights of less than 113 kg (250 lbs), is to be hardness tested to meet the requirements of 2-3-7/7.7.2. Forgings are to be tested at the approximate mid-radius and 180 degrees apart on each flat surface of the forging; the testing locations on opposite sides are to be offset by 90 degrees.

7.11.2(c) Very Small Forgings. In cases involving very small forgings weighing less than 113 kg (250 lb) each, where the foregoing procedures are impractical, the hardness tests may be made from broken tension test specimens, or on a special forging representing the lot; see 2-3-7/7.9.3.

7.13 Examination *(2008)*

After final heat treatment, all forgings are to be examined, in accordance with 2-3-7/1.13, by the Surveyor and found free from defects. The finish is to be free of scale, cracks, seams, laps, fins, cold shuts, laminations, nicks, gouges, pipe, shrinkage, porosity and burst indications.

7.15 Rectification of Defective Forgings *(2005)*

Rectification of defects is to be carried out in accordance with 2-3.-/1.15.

7.17 Certification *(2005)*

The manufacturer is to provide the required type of inspection certificate, in accordance with 2-3-7/1.17.

TABLE 1
Chemical Composition Requirements for Carbon Steel Machinery Forgings (1), in percent *(2008)*

Element	*Grade 2*	*Grade 3*	*Grade 4*	*Grade 4C*
Carbon	0.23 (2)	0.23 (2)	0.23 (2)	0.36 to 0.55
Manganese	0.30–1.35	0.30–1.35	0.30–1.35	0.30–1.35
Silicon (3)	0.10–0.45	0.10–0.45	0.10–0.45	0.10–0.45
Sulfur	0.035	0.035	0.035	0.035
Phosphorus	0.035	0.035	0.035	0.035

Note:

1 Single values are maxima, unless noted.

2 The carbon content may be increased above this level, provided that the carbon equivalent (Ceq) is not more than 0.41 %, calculated using the following formula:

$$C_{eq} = \mathrm{C} + \frac{\mathrm{Mn}}{6} + \frac{\mathrm{Cr} + \mathrm{Mo} + \mathrm{V}}{5} + \frac{\mathrm{Ni} + \mathrm{Cu}}{15} \ (\%)$$

3 Silicon minimum is applicable if the steel is silicon killed.

TABLE 2
Tensile Property Requirements (1) for Carbon-steel Machinery Forgings *(2008)*

Grade	*Size, in mm (in)*	*Tensile Strength (2) in N/mm² (kgf/mm², ksi)*	*Yield Strength (3) in N/mm² (kgf/mm², ksi)*	*Longitudinal (4)*			*Tangential (4)*		
				Elongation (5), in percent		*RA, in percent*	*Elongation (5), in percent*		*RA, in percent*
				Gauge Length			*Gauge Length*		
				4d	*5d*		*4d*	*5d*	
2	≤ 300 (12)	415 (42, 60)	205 (21, 30)	25	23	38	20	18	29
	> 300 (12)	415 (42, 60)	205 (21, 30)	24	22	36			
3	≤ 200 (8)	515 (53, 75)	260 (26.5, 37.5)	24	22	40	18	16	28
	> 200 (8) ≤ 300 (12)	515 (53, 75)	260 (26.5, 37.5)	22	20	35			
	> 300 (12) ≤ 500 (20)	515 (53, 75)	260 (26.5, 37.5)	20	18	32			
	> 500 (20)	515 (53, 75)	260 (26.5, 37.5)	19	17	30			
4, 4C		570 (58.5, 83)	295 (30.5, 43)	20	18	35	17	16	27

Notes:

1 All tensile property requirements are minima, unless indicated.

2 In the case of large forgings requiring two tension tests, the range of tensile strength is not to exceed 70 N/mm² (7 kgf/mm², 10000 psi).

3 Yield strength is determined by the 0.2% offset method.

4 When tangential specimens are taken from wheels, rings, rims, discs, etc. in which the major final hot working is in the tangential direction, the tension test results are to meet the requirements for longitudinal specimens.

5 Elongation gauge length is 50 mm (2 in.); see 2-3-1/Figure 2.

RA = Reduction of Area

TABLE 3
Chemical Composition Requirements for Alloy Steel Gear Assembly Forgings (1), in percent

Element	*Grade A1*	*Grade A2*	*Grades A3, A4, A5 and A6*
Carbon	0.50	0.45	0.35 to 0.50
Manganese	0.40 to 0.90	0.40 to 0.90	0.40 to 0.90
Silicon (2)	0.35	0.35	0.35
Sulfur	0.040	0.040	0.040
Phosphorus	0.040	0.040	0.040
Nickel	Note 3	0.50	1.65 min.
Chromium	Note 3	1.25	0.60 min.
Molybdenum	Note 3	0.15 min.	0.20 to 0.60
Copper	0.35	0.35	0.35
Vanadium	0.10	0.50	0.10

Notes:

1 Single values are maxima, unless noted.

2 If the steel is vacuum-carbon deoxidized, the silicon content is to be 0.10 maximum.

3 The nickel, chromium and molybdenum contents are to be specially approved.

TABLE 4
Tensile Property Requirements for Alloy Steel Gear Assembly Forgings [1] *(2008)*

Grade	*Diameter, in mm (in)*	*Tensile Strength, in N/mm², (kgf/mm², ksi)*	*Yield Strength [2], in N/mm², (kgf/mm², ksi)*	*Longitudinal*			*Tangential*		
				Elongation [3], in percent		*RA, in percent*	*Elongation [3], in percent*		*RA, in percent*
				Gauge Length			*Gauge Length*		
				4d	*5d*		*4d*	*5d*	
A1	≤ 255 (10)	655 (67, 95)	485 (49, 70)	20	18	45	18	16	35
	> 255 (10) ≤ 510 (20)	655 (67, 95)	485 (49, 70)	20	18	45	19	16	34
	> 510 (20)	655 (67, 95)	485 (49, 70)	18	16	38	16	15	30
A2	≤ 255 (10)	725 (74, 105)	550 (56, 80)	19	17	45	17	16	34
	> 255 (10) ≤ 510 (20)	725 (74, 105)	550 (56, 80)	19	17	45	16	15	32
	> 510 (20)	725 (74, 105)	550 (56, 80)	18	16	38	14	13	30
A3	≤ 255 (10)	825 (84, 120)	655 (67, 95)	16	15	40	13	12	32
	> 255 (10) ≤ 510 (20)	825 (84, 120)	655 (67, 95)	14	13	35	12	11	30
	> 510 (20)	795 (81, 115)	620 (63, 90)	13	12	33	10	9	25
A4	≤ 255 (10)	965 (98, 140)	795 (81, 115)	16	15	40	14	13	35
	> 255 (10) ≤ 510 (20)	930 (95, 135)	760 (77, 110)	14	13	35	12	11	30
	> 510 (20)	895 (91, 130)	725 (74, 105)	12	11	30	10	9	25
A5	≤ 255 (10)	1000 (102, 145)	825 (84, 120)	15	14	40	13	12	35
	> 255 (10) ≤ 510 (20)	965 (98, 140)	795 (81, 115)	14	13	35	12	11	30
	> 510 (20)	930 (95, 135)	760 (77, 110)	12	11	30	10	9	25
A6	≤ 255 (10)	1170 (120, 170)	965 (98, 140)	14	13	35	12	11	30
	> 255 (10) ≤ 510 (20)	1140 (116, 165)	930 (95, 135)	12	11	30	10	9	25
	> 510 (20)	1105 (112, 160)	895 (91, 130)	10	9	25	10	9	25

Notes:

1 All tensile property requirements are minima, unless indicated.

2 Yield strength is determined by the 0.2% offset method.

3 Elongation gauge length is 50 mm (2 in.); see 2-3-1/Figure 2.

RA = Reduction of Area

TABLE 5
Chemical Composition Requirements for Alloy Steel Shaft and Stock Forgings (1), in percent

Element	*Grade A7*	*Grade A8*	*Grades A9 and A10*
Carbon	0.25	0.28	0.28
Manganese	0.20 to 0.60	0.20 to 0.60	0.20 to 0.60
Silicon	0.15 to 0.30 (2)	0.15 to 0.30 (2)	0.10 (3)
Sulfur	0.015	0.015	0.015
Phosphorus	0.012	0.012	0.012
Nickel	2.50 min.	2.50 min.	3.25 to 4.00
Chromium	0.75	0.75	1.25 to 2.00
Molybdenum	0.25 min.	0.25 min.	0.25 to 0.60
Vanadium	0.03 min.	0.03 min.	0.05 to 0.15
Antimony	Note (4)	Note (4)	Note (4)

Notes:

1. Single values are maxima, unless noted.
2. If the steel is vacuum-carbon deoxidized, the silicon content is to be 0.10 maximum.
3. If the steel is vacuum arc remelted, the silicon content range may be 0.15% to 0.30%.
4. The antimony content is to be reported for information.

TABLE 6
Tensile Property Requirements for Alloy Steel Shaft and Stock Forgings (1) *(2008)*

Grade	*Tensile Strength, in N/mm^2 (kgf/mm^2, ksi)*	*Yield Strength (2), in N/mm^2 (kgf/mm^2, ksi)*	*Yield Strength (3), in N/mm^2 (kgf/mm^2, ksi)*	*Longitudinal*			*Radial*		
				Elongation (4), in percent		*RA, in percent*	*Elongation (4), in percent*		*RA, in percent*
				Gauge Length			*Gauge Length*		
				4d	*5d*		*4d*	*5d*	
A7	550 (56, 80)	415 (42, 60)	380 (39, 55)	22	20	50	20	18	50
A8	725 (74, 105)	620 (63, 90)	585 (60, 85)	17	16	45	16	15	40
A9	725 (74, 105) to 860 (88, 125)	620 (63, 90)	585 (60, 85)	18	16	52	17	16	50
A10	825 (84, 120) to 930 (95, 135)	690 (70, 100)	655 (67, 95)	18	16	52	17	16	50

Notes:

1. All tensile property requirements are minima, unless indicated.
2. Yield strength is determined by the 0.2% offset method.
3. Yield strength is determined by the 0.02% offset method.
4. Elongation gauge length is 50 mm (2 in.); see 2-3-1/Figure 2.

RA = Reduction of Area

TABLE 7
Chemical Composition Requirements for General Shipboard Alloy Steel Forgings (1), in percent

Element	*Grades* *A11, A12, A13, A14 and A15*
Carbon	Note 2
Manganese	Note 2
Silicon (3)	0.10 min.
Sulfur	0.040
Phosphorus	0.040
Nickel	Note 2
Chromium	Note 2
Molybdenum	Note 2
Copper	Note 2
Vanadium	Note 2

Notes:

1 Single values are maxima, unless noted.

2 The indicate contents are to be reported.

3 Silicon minimum is applicable if the steel is silicon killed.

TABLE 8
Tensile Property Requirements for General Shipboard Alloy Steel Forgings (1) *(2008)*

Grade	*Size, in mm (in)*	*Tensile Strength, in N/mm² (kgf/mm², ksi)*	*Yield Strength (2), in N/mm² (kgf/mm², ksi)*	*Longitudinal*			*Tangential*		
				Elongation (3), in percent		*RA, in percent*	*Elongation (3), in percent*		*RA, in percent*
				Gauge Length			*Gauge Length*		
				4d	*5d*		*4d*	*5d*	
A11	≤ 180 (7)	655 (67, 95)	485 (49, 70)	20	18	50	18	16	40
	> 180 (7) ≤ 255 (10)	620 (63, 90)	450 (46, 65)	20	18	50	18	16	40
	> 255 (10) ≤ 510 (20)	620 (63, 90)	450 (46, 65)	18	16	48	16	15	40
A12	≤ 180 (7)	725 (74, 105)	550 (56, 80)	20	18	50	18	16	40
	> 180 (7) ≤ 255 (10)	690 (70, 100)	515 (53, 75)	19	17	50	17	16	40
	> 255 (10) ≤ 510 (20)	690 (70, 100)	515 (53, 75)	18	16	48	16	15	40
A13	≤ 100 (4)	860 (88, 125)	725 (74, 105)	16	15	50	14	13	40
	> 100 (4) ≤ 180 (7)	795 (81, 115)	655 (67, 95)	16	15	45	14	13	35
	> 180 (7) ≤ 255 (10)	760 (77, 110)	585 (60, 85)	16	15	45	14	13	35
	> 255 (10) ≤ 510 (20)	760 (77, 110)	585 (60, 85)	14	13	40	12	11	30
A14	≤ 100 (4)	1000 (102, 145)	825 (84, 120)	15	14	45	13	12	35
	> 100 (4) ≤ 180 (7)	965 (98, 140)	795 (81, 115)	14	13	40	12	11	30
	> 180 (7) ≤ 255 (10)	930 (95, 135)	760 (77, 110)	13	12	40	12	11	30
	> 255 (10) ≤ 510 (20)	930 (95, 135)	760 (77, 110)	12	11	38	11	10	30
A15	≤ 100 (4)	1170 (120, 170)	965 (98, 140)	13	12	40	11	10	30
	> 100 (4) ≤ 180 (7)	1140 (116, 165)	930 (95, 135)	12	11	35	11	10	30
	> 180 (7) ≤ 255 (10)	1105 (112, 160)	895 (91, 130)	11	10	35	10	9	28
	> 255 (10) ≤ 510 (20)	1105 (112, 160)	895 (91, 130)	11	10	35	10	9	28

Notes:

1 All tensile property requirements are minima, unless indicated.

2 Yield strength is determined by the 0.2% offset method.

3 Elongation gauge length is 50 mm (2 in.); see 2-3-1/Figure 2.

RA = Reduction of Area

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PART

2

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

SECTION **8** **Hot-rolled Steel Bars for Machinery**

1 Hot-rolled Steel Bars

Hot-rolled steel bars up to and including 305 mm (12 in.) diameter, presented for inspection after special approval for each specific application, are to be made by one or more of the following processes: open-hearth, basic-oxygen, electric-furnace or such other process as may be approved. Hot-rolled bars used in lieu of carbon-steel forgings (see Section 2-3-7) are to be fully killed, heat treated in accordance with 2-3-7/1.5, and the cross-sectional area of the unmachined finished bar is not to exceed one-sixth of the cross-sectional area of the ingot. In addition, hot-rolled bars used in lieu of forgings for tail shafts are to meet the nondestructive examination requirements of 2-3-7/1.13.1. The tensile properties are to meet the requirements of 2-3-7/1.7 for the proposed application.

3 Number of Tests

Four tension tests are to be taken from each lot of material exceeding 907 kg (2000 lb) in weight. When the weight of a lot is 907 kg (2000 lb) or less, two tension tests may be taken. In any case, only one tension test will be required from any one bar. A lot is to consist of bars from the same heat; if the bars are heat-treated, then a lot is to consist of bars from the same heat which have been heat-treated in the same furnace charge. If the bars in a lot differ 9.5 mm (0.375 in.) or more in diameter, the test specimens taken are to be representative of the greatest and least diameter bar.

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PART

2

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

SECTION 9 **Steel Castings for Machinery, Boilers and Pressure Vessels**

1 General

1.1 Process of Manufacture *(2005)*

The following requirements cover carbon-steel castings intended to be used in machinery, boiler and pressure-vessel construction, such as crankshafts, turbine casings and bedplates. For other applications, additional requirements may be necessary, especially when the castings are intended for service at low temperatures. Castings which comply with national or proprietary specifications may also be accepted, provided such specifications give reasonable equivalence to these requirements. None of the above preclude the use of alloy steels in accordance with the permissibility expressed in 2-3-1/1. The steel is to be manufactured by a process approved by the Bureau.

Castings are to be made by a manufacturer approved by the Bureau. The Surveyor is permitted at any time to monitor important aspects of casting production, including mold preparation and chaplet positioning; pouring times and temperatures; mold breakout; repairs; heat treatment and inspection.

Thermal cutting, scarfing or arc-air gouging to remove surplus metal is to be undertaken in accordance with recognized good practice and is to be carried out before the final heat treatment. Preheating is to be employed when necessitated by the chemical composition and/or thickness of the castings. If necessary, the affected areas are to be either machined or ground smooth.

When two or more castings are joined by welding to form a composite component, the proposed welding procedure is to be submitted for approval and welding is to be carried out to the satisfaction of the attending Surveyor.

Sulfur and phosphorous contents are to be less than 0.040% and silicon less than 0.60%.

For welded construction, the maximum carbon content is to be 0.23%.

1.3 ASTM Designations *(2005)*

The various Grades are in substantial agreement with ASTM, as follows and, in addition, the requirements of this Section apply:

ABS Grade	*ASTM Designation*
1	A27, Grade 60–30
2	A27, Grade 70–36
3	A216, Grade WCA
4	A216, Grade WCB

3 Marking and Retests

3.1 Marking *(2005)*

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

The manufacturer's name or identification mark and pattern number is to be cast on all castings, except those of such small size as to make this type of marking impracticable. The Bureau markings, indicating satisfactory compliance with the Rule requirements, and as furnished by the Surveyor is to be stamped on all castings accepted in such location as to be discernible after machining and installation. Grade 1, 2, 3 and 4 castings are to be stamped **AB/1**, **AB/2, AB/3** and **AB/4**, respectively. In addition, identification numbers of the heats used for pouring the castings are to be stamped on all castings individually weighing 227 kg (500 lb) or more.

3.3 Retests *(2005)*

If the results of the physical tests for any casting or any lot of castings do not conform to the requirements specified, the manufacturer may reheat-treat castings or lots of castings that have failed to meet test requirements. Two additional test samples representative of the casting or casting batch may be taken. If satisfactory results are obtained from both of the additional tests, the casting or batch of castings is acceptable. If one or both retests fail, the casting or batch of castings is to be rejected.

5 Heat Treatment *(2005)*

Except in cases specifically approved otherwise, all castings are to be either fully annealed, normalized or normalized and tempered in a furnace of ample proportions to bring the whole casting to uniform temperature above the transformation range on the annealing or normalizing cycle. The furnaces are to be maintained and have adequate means for control and recording temperature. Castings are to be held soaking at the proper temperature for at least a length of time equivalent to one hour per 25.5 mm (1 in.) of thickness of the heaviest member. No annealed casting is to be removed from the furnace until the temperature of the entire furnace charge has fallen to or below a temperature of 455°C (850°F). A sufficient number of thermocouples are to be connected to the furnace charge to measure and record that its temperature is adequately uniform, unless the temperature uniformity of the furnace can be verified at regular intervals. Tempering is to be carried out at a temperature of not less than 550°C (1022°F).

Local heating or cooling and bending and straightening of annealed castings are not permitted, except with the express sanction of the Surveyor.

The foundry is to maintain records of heat treatment, identifying the furnace used, furnace charge, date, temperature and time at temperature, together with the number and location of thermocouples. The records are to be available to the Surveyor upon request.

7 Tensile Properties *(2008)*

Steel castings are to conform to the following requirements as to tensile properties.

ABS Grade	*Tensile Strength, Min., N/mm^2 (kgf/mm^2, psi)*	*Yield Point/ Yield Strength, Min., N/mm^2 (kgf/mm^2, psi)*	*Elongation Min., %*		*Reduction of Area Min%*
			Gauge Length		
			4d	*5d*	
1	415 (42, 60000)	205 (21.0, 30000)	24	22	35
2	485 (49, 70000)	250 (25.5, 36000)	22	20	30
3	415 (42, 60000)	205 (21.0, 30000)	24	22	35
4	485 (49, 70000)	250 (25.5, 36000)	22	20	35

9 Application

9.1 General and High-temperature Applications

Any of the above grades may be used for miscellaneous applications. Grade 3 or Grade 4 castings are to be used for boiler mountings, valves, fittings and for pressure parts of boilers and other pressure vessels where the temperature does not exceed 427°C (800°F). See 4-6-2/3.1.2 of the ABS *Rules for Building and Classing Steel Vessels*.

9.3 Propeller and Forging Applications

Any of the above grades may be used for propellers and for castings which have been approved to take the place of forgings.

9.5 Alloy Steels or Special Carbon Steels

When alloy steels or carbon steels differing from the requirements of 2-3-9/7 are proposed for any purpose, the purchaser's specification shall be submitted for approval in connection with the approval of the design for which the material is proposed. Specifications such as ASTM A356 or A217 Grades WC1, WC6, or WC9, or other steels suitable for the intended service will be considered.

11 Test Specimens

11.1 Material Coupons *(2005)*

Test material, sufficient for the required number of tests and for possible retest purposes, is to be provided for each casting. The physical properties are to be determined from test specimens prepared from coupons which, except as specified in 2-3-9/11.3, are to be cast integral with the casting to be inspected. When this is impracticable, the coupons may be cast with and gated to the casting and are to have a thickness of not less than 30 mm (1.2 in.). In either case, these coupons are not to be detached until the heat treatment of the castings has been completed, nor until the coupons have been stamped by the Surveyor for identification. Where the material identification system of the manufacturer is found acceptable to the Bureau and is maintained in that condition through initial and periodical verification by the Bureau, it may be considered in lieu of stamping by the Surveyor before detachment.

Where the casting finished mass exceeds 10,000 kg (22,000 lb) or is of complex design, two test samples are to be provided. Where large castings are made from two or more casts which are not from the same pour, two or more test samples are to be provided, corresponding to the number of casts involved. The samples are to be integrally cast at locations as widely separated as possible.

11.3 Separately Cast Coupons

In the case of small castings having an estimated weight of less than 907 kg (2000 lb), each of the coupons may be cast separately, provided the Surveyor is furnished an affidavit by the manufacturer stating that the separately cast coupons were cast from the same heat as the castings represented and that they were heat-treated with the castings.

13 Number of Tests

13.1 Machinery Castings *(2005)*

At least one tension test is to be made from each heat in each heat-treatment charge, except where two or more samples are required as indicated in 2-3-9/11.1. If the manufacturer's quality-control procedure includes satisfactory automatic chart recording of temperature and time, then one tension test from each heat for castings subject to the same heat-treating procedure may be allowed at the discretion of the attending Surveyor.

13.3 Steel Propeller Castings

One tension test is to be made from each blade of a built-up propeller, and for solid propellers there is to be one tension test from each of two opposite blades when the propeller is over 2130 mm (7 ft) in diameter and one tension test from one of the blades when the diameter of the propeller is 2130 mm (7 ft) or smaller.

15 Inspection and Repair

15.1 General *(2008)*

All castings are to be examined by the Surveyor after final heat treatment and thorough cleaning to ensure that the castings are free from defects. Where applicable internal surfaces are to be inspected, surfaces are not to be hammered or peened or treated in any way which may obscure defects.

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

The manufacturer is to verify that all dimensions meet the specified requirements. The Surveyor is to spot check key dimensions to confirm the manufacturer's recorded dimensions.

When required by the relevant construction Rules, castings are to be pressure tested before final acceptance. The tests are to be carried out in the presence and to the satisfaction of the attending Surveyor.

15.3 Minor Defects *(2006)*

Defects are to be considered minor when the cavity prepared for welding has a depth not greater than 20% of the actual wall thickness, but in no case greater than 25 mm (1 in.), and has no lineal dimension greater than four times the wall thickness nor greater than 150 mm (6 in.). Shallow grooves or depressions resulting from the removal of defects may be accepted, provided that they will cause no appreciable reduction in the strength of the casting. The resulting grooves or depressions are to be subsequently ground smooth and complete elimination of the defective material is to be verified by MT or PT. Repairs of minor defects where welding is required are to be treated as weld repairs and repaired in accordance with an approved procedure. Minor defects in critical locations are to be treated as, and repaired in the same manner as, major defects.

15.5 Major Defects

Defects other than minor defects with dimensions greater than those given in 2-3-9/15.3 above, may, with the Surveyor's approval, be repaired by welding using an approved procedure.

15.7 Welded Repair *(2005)*

After it has been agreed that a casting can be repaired by welding, full details of the extent and location of the repair, the proposed welding procedure, heat treatment and subsequent inspection procedures are to be submitted for approval. Removal of defects and weld repair are to be carried out in accordance with a recognized standard. See Part 2, Appendix 6. The defects are to be removed to sound metal, and before welding, the excavation is to be investigated by suitable approved, nondestructive examination methods to ensure that the defect has been removed. In the case of repair of major defects, welding is not permitted on unheat-treated castings. Corrective welding is to be associated with the use of preheat.

15.9 Postweld-repair Heat Treatment *(2005)*

All welded repairs of defects are to be given a suitable postweld heat treatment, as indicated in 2-3-9/5, or subject to the prior agreement of the materials department consideration may be given to the acceptance of a local stress relieving heat treatment at a temperature of not less than 550°C (1022°F). The heat treatment employed will be dependant on the chemical composition of the casting, the casting and dimensions, and the position of the repairs.

On completion of heat treatment, the weld repairs and adjacent material are to be ground smooth and examined by magnetic particle or liquid penetrant testing. Supplementary examination by ultrasonics or radiography may also be required, depending on the dimensions and nature of the original defect. Satisfactory results are to be obtained from all forms of nondestructive testing used.

The manufacturer is to maintain full records detailing the extent and location of minor and major repairs made to each casting and details of weld procedures and heat treatments applied. These records are to be available to the Surveyor and copies provided on request.

15.11 Crankshaft Castings *(2005)*

The foregoing provisions may not apply in their entirety to the repair of crankshaft castings. In the case of repair of crankshaft castings, the applicable procedures and extent of repairs will be specially considered. All castings for crankshafts are to be suitably preheated prior to welding.

17 Castings for Ice-strengthened Propellers

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

19 Nondestructive Testing *(2005)*

When required by the relevant construction Rules or by the approved procedure for welded components, appropriate nondestructive testing is also to be carried out before acceptance and the results are to be reported by the manufacturer. The extent of testing and acceptance criteria are to be agreed with the Bureau. Part 2, Appendix 6 is regarded as an example of an acceptable standard. Additional NDE is to be considered at chaplet locations and areas of expected defects.

21 Certification *(2005)*

The manufacturer is to provide the required type of inspection certificate giving the following particulars for each casting or batch of castings which has been accepted:

i) Purchaser's name and order number

ii) Description of forgings and steel quality

iii) Identification number

iv) Steelmaking process, cast number and chemical analysis of ladle sample

v) Results of mechanical tests

vi) Results of nondestructive tests, where applicable

vii) Details of heat treatment, including temperature and holding times.

viii) Where applicable, test pressure.

ix) Specification

PART

2

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

SECTION **10 Ductile (Nodular) Iron Castings** *(2006)*

1 Scope

1.1

Important spheroidal or nodular graphite 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

These requirements are applicable only to castings where the design and acceptance tests are related to mechanical properties at ambient temperature. For other applications additional requirements may be necessary, especially when the castings are intended for service at low or elevated temperatures.

1.5

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.

1.7

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

3 Manufacture

3.1 *(2008)*

All important castings (i.e., castings that are required to be certified per 4-2-1/Table 1) 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 make 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 Casting

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 the mechanical properties specified for the castings. The chemical composition of the ladle samples is to be reported to the Bureau.

9 Heat Treatment

9.1

Except as required by 2-3-10/9.3, castings may be supplied in either the as cast or heat-treated condition.

9.3

For applications such as high temperature service or where dimensional stability is important, it may be required that castings be given a suitable tempering or stress relieving heat treatment. This is to be carried out after any refining heat treatment and before machining The materials in 2-3-10/Table 2 are to undergo a ferritizing heat treatment.

9.5

Where it is proposed to locally harden the surfaces of a casting, full details of the proposed procedure and specification are to be submitted for approval.

11 Mechanical Tests

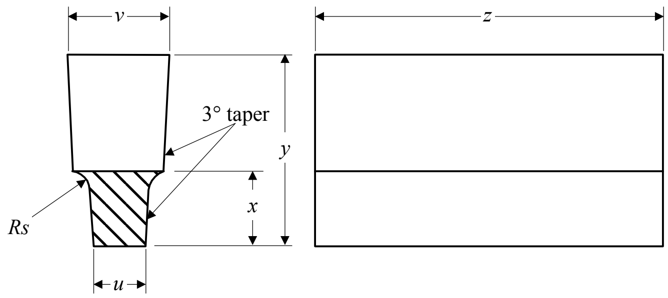
11.1

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

11.3

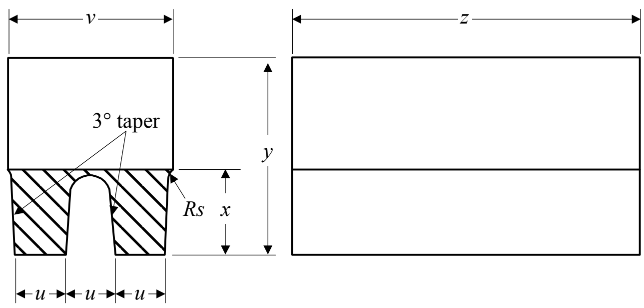
The test samples are generally to be one of the standard types detailed in 2-3-10/Figures.1, 2 and 3 with a thickness of 25 mm (1.0 in.). Test samples of other dimensions to 2-3-10/Figures 1, 2 and 3 may, however, be specially required for some components.

FIGURE 1
Type A Test Samples (U-type)



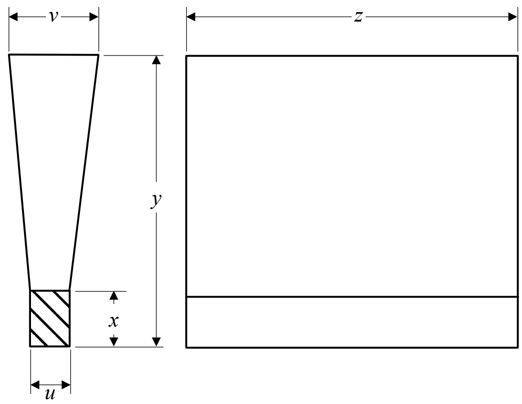
Dimensions – mm (in.)	*Standard Sample*	*Alternative Samples when Specially Required*		
u	25 (1.0)	12 (0.5)	50 (2.0)	75 (3.0)
v	55 (2.2)	40 (1.6)	90 (3.5)	125 (5.0)
x	40 (1.6)	30 (1.2)	60 (2.4)	65 (2.6)
y	100 (4.0)	80 (3.2)	150 (6.0)	165 (6.5)
z	To suit testing machine			
Rs	Approximately 5 mm (0.20 in.)			

FIGURE 2
Type B Test Samples (Double U-type)



Dimensions – mm (in.)	*Standard Sample*
u	25 (1.0)
v	90 (3.5)
x	40 (1.6)
y	100 (4.0)
z	To suit testing machine
Rs	Approximately 5 mm (0.20 in.)

FIGURE 3
Type C Test Samples (Y-type)



Dimensions – mm (in.)	*Standard Sample*	*Alternative Samples when Specially Required*		
u	25 (1.0)	12 (0.5)	50 (2.0)	75 (3.0)
v	55 (2.2)	40 (1.6)	100 (4.0)	125 (5.0)
x	40 (1.6)	25 (1.0)	50 (2.4)	65 (2.6)
y	140 (5.5)	135 (5.5)	150 (6.0)	175 (7.0)
z	To suit testing machine			
Min. thickness of mold surrounding test sample	40 (1.6)	40 (1.6)	80 (3.2)	80 (3.2)

11.5

At least one test sample is to be provided for each casting and, unless otherwise required, may be either gated to the casting or separately cast. Alternatively, test material of other suitable dimensions may be provided integral with the casting.

11.7

For large castings where more than one ladle of treated metal is used, additional test samples are to be provided so as to be representative of each ladle used.

11.9

As an alternative to 2-3-10/11.3, a batch testing procedure may be adopted for castings with a fettled mass of 1,000 kg (2,200 lb) or less. All castings in a batch are to be of similar type and dimensions, and cast from the same ladle of treated metal. One separately cast test sample is to be provided for each multiple of 2,000 kg (4,400 lb) of fettled castings in the batch.

11.11

Where separately cast test samples are used, they are to be cast in molds made from the same type of material as used for the castings and are to be taken towards the end of pouring of the castings. The samples are not to be stripped from the molds until the temperature is below 500°C (930°F).

11.13

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

11.15

Where castings are supplied in the heat treated condition, the test samples are to be heat treated together with the castings which they represent.

11.17

One tensile specimen is to be prepared from each test sample and is to be machined to the dimensions given in 2-3-1/Figure 2. Note that for nodular cast iron with an elongation less than 10%, the radius $R \geq 20$ mm (0.8 in.).

11.19

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.

11.21

Impact tests may additionally be required. In such cases a set of three specimens of an agreed type is to be prepared from each sample. Where Charpy V-notch test specimens are used, the dimensions and testing procedures are to be in accordance with 2-1-1/Figure 3.

13 Mechanical Properties

13.1

2-3-10/Tables 1 and 2 give the minimum requirement for 0.2% proof stress and elongation corresponding to different strength levels. Typical Brinell hardness values are also given in 2-3-10/Table 1 and are intended for information purposes only.

13.3

Castings may be supplied to any specified minimum tensile strength selected within the general limits detailed in 2-3-10/Table 1, and any additional requirements of the relevant construction Rules.

13.5

Unless otherwise agreed, only the tensile strength and elongation need to be determined. The results of all tensile tests are to comply with the appropriate requirements of 2-3-10/Table 1.

13.7

When the tensile test fails to meet the requirements, two further tests may be made from the same piece. If both 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.

The additional tests detailed above are to be taken preferably from material taken adjacent to the original tests, but alternatively from another test position or sample representative of the item/batch.

TABLE 1
Mechanical Properties for Spheroidal or Nodular Cast Iron

Specified minimum Tensile strength, N/mm^2 (ksi)	*0.2% proof stress, N/mm^2 (ksi)*	*Elongation on $5.65\sqrt{S_o}$ (%) min*	*Typical hardness (Brinell)*	*Typical structure of matrix*
370 (54)	230 (33)	17	120-180	Ferrite
400 (58)	250 (36)	12	140-200	Ferrite
500 (73)	320 (46)	7	170-240	Ferrite/Pearlite
600 (87)	370 (54)	3	190-270	Ferrite/Pearlite
700 (102)	420 (61)	2	230-300	Pearlite
800 (116)	480 (70)	2	250-350	Pearlite or tempered structure

TABLE 2
Mechanical Properties for Spheroidal or Nodular Cast Iron with Additional Charpy Requirements

Specified minimum Tensile strength, N/mm^2 (ksi)	*0.2% proof stress, N/mm^2 (ksi)*	*Elongation on $5.65\sqrt{S_o}$ (%) min*	*Typical hardness (Brinell)*	*Impact energy test min values (3)*		*Typical structure of matrix*
				Test temp.	*Ave Joules*	
350 (51)	220 (32)	22 (2)	110-170	+20	17 (14)	Ferrite
400 (58)	250 (36)	18 (2)	140-200	+20	14 (11)	Ferrite

Notes for tables 1 and 2:

1. Intermediate values for mechanical properties may be obtained by interpolation
2. In the case of integrally cast samples, the elongation may be 2 percentage points less.
3. The average value measured on three Charpy V-notch specimens. One result may be below the average value but not less than the minimum shown in parentheses.

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, where applicable, the examination of internal surfaces. Unless otherwise agreed, the verification of dimensions is the responsibility of the manufacturer

15.5

Supplementary examination of castings by suitable nondestructive test 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 the event of any casting proving defective during subsequent machining or testing is to be rejected notwithstanding any previous certification.

15.11

Cast crankshaft are to be subjected to a magnetic particle inspection. Crack like indications are not allowed.

17 Metallographic Examination

17.1

For crankshafts, a metallograpic examination is to be carried out.

17.3

When required, a representative sample from each ladle of treated metal is to be prepared for metallograpghic examination. These samples may be taken from the tensile test specimens but alternative arrangements for the provisions of the samples may be adopted provided that they are taken from the ladle towards the end of the casting period.

17.5

Examination of the samples is to show that at least 90% of the graphite is in a dispersed spheroidal or nodular form. Details of typical matrix structures are given in 2-3-10/Table 1 and are intended for information purposes only.

19 Rectification of Defective Castings

19.1

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

19.3

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

19.5

Repairs by welding are generally not permitted.

21 Identification of Castings

21.1

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

21.3

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:

i) Grade of cast iron

ii) Identification number or other marking enabling the full history of the casting to be traced.

iii) Manufacturer's name or trademark.

iv) Date of final inspection.

v) ABS office, initials or symbol.

vi) Personal stamp of Surveyor responsible for inspection

vii) Test pressure, if applicable

21.5

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

23 Certification

23.1

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

i) Purchaser's name and order number

ii) Description of castings and quality of cast iron

iii) Identification number

iv) Results of mechanical tests

v) Where applicable, general details of heat treatment

vi) Where specifically required, the chemical analysis of the ladle samples

vii) Where applicable, test pressure