PART

2

Rules for Testing and Certification of Materials

CHAPTER 2 Equipment

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CHAPTER 2 Equipment

SECTION 1 Anchors

1 General Requirements *(2007)*

1.1 Scope

These requirements apply to the materials, manufacture, testing and certification of anchors, shanks and anchor shackles produced from cast or forged steel, or fabricated by welded rolled steel plate and bars.

These manufacturing requirements are applicable to ordinary anchors and superior holding power (SHP) anchors.

1.3 Types of Anchor

1.3.1 Ordinary Anchors (Also see 3-5-1/7)

Ordinary stockless anchors are to be of an approved design. Any changes or alterations from the approved design are to be approved prior to manufacture.

The mass of the heads of stockless anchors including pins and fittings are not to be less than 60% of the total mass of the anchor.

1.3.2 Superior Holding Power (SHP) Anchors (Also see 3-5-1/7)

SHP anchors are to be of an approved design and subject to special approval. Any changes or alterations to the approved design made during manufacture are to have prior approval.

SHP anchors are to be suitable for ship use and are not to require prior adjustment or special placement on the seabed.

SHP anchors are to have at least twice the holding power of ordinary stockless anchors of the same weight.

The mass of each bower anchor can be reduced by up to 25% of the mass specified in 2-2-1/Table 6.

Approved manufacturers of SHP anchors are included in a specific directory maintained by the Bureau.

1.3.3 SHP Anchors for Restricted Service and to a Maximum Weight of 1500 kg (3306 lbs)

Special approval can be given to superior holding power anchors with holding powers of at least 4 times the holding power of ordinary anchors. The mass of each bower anchor can be reduced by up to 50% of the mass specified in 2-2-1/Table 6.

3 Materials for Anchors *(2010)*

All anchors are to be manufactured from materials meeting the requirements of the ABS *Rules for Materials and Welding (Part 2)*.

Cast steel anchor flukes, shanks, swivels and shackles are to be manufactured and tested in accordance with the requirements of Section 2-1-5 and comply with the requirements for castings for welded construction. The steel is to be fine grain treated with aluminum.

Two test programs “A” and “B” are permitted in accordance with 2-2-1/7.3.1. Charpy V notch (CVN) impact testing of cast material is required. Special consideration is to be given to the use of other grades of steels for the manufacture of swivels.

Forged steel anchor pins, shanks, swivels and shackles are to be manufactured and tested in accordance with the requirements of Section 2-1-6. Shanks, swivels and shackles are to comply with the requirements for carbon and carbon-manganese steels for welded construction. Special consideration is to be given to the use of other grades of steels for the manufacture of swivels.

Rolled plates and bars for fabricated steel anchors are to be manufactured and tested in accordance with the requirements of Section 2-1-1.

Rolled bars intended for pins, swivels and shackles are to be manufactured and tested in accordance with the requirements of Section 2-1-1 or Section 2-3-8.

3.1 Superior Holding Power (SHP) Anchors for Restricted Service and to a Maximum Weight of 1500 kg (3306 lbs)

In addition to the above requirements, steel is to be selected in accordance with 3-1-2/Table 1 Class II. The welding consumables are to meet the toughness for the base steel grades. Toughness of the anchor shackles is to meet that for Grade 3 anchor chain. The toughness of steel castings is to be not less than a Charpy V-notch energy average of 27 J at 0°C (2.8 kgf-m at 0°C, 20 ft-lbs at 32°F).

5 Manufacture of Anchors *(2007)*

5.1 Tolerance

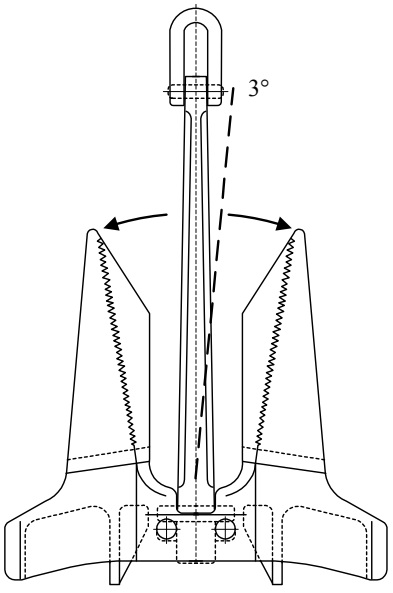
If not otherwise specified in standards or on drawings demonstrated to be appropriate, the following assembly and fitting tolerances are to be applied.

The clearance either side of the shank within the shackle jaws is to be no more than 3 mm (0.12 inch) for small anchors up to 3 tonnes (3.3 tons) weight, 4 mm (0.16 inch) for anchors up to 5 tonnes (5.5 tons) weight, 6 mm (0.24 inch) for anchors up to 7 tonnes (7.7 tons) weight and is not to exceed 12 mm (0.47 inch) for larger anchors. The shackle pin is to be a push fit in the eyes of the shackle, which are to be chamfered on the outside to ensure a good tightness when the pin is clenched over on fitting. The shackle pin to hole tolerance is to be no more than 0.5 mm (0.02 inch) for pins up to 57 mm (2.24 inch) and 1.0 mm (0.04 inch) for pins of larger diameter.

The trunnion pin is to be a snug fit within the chamber and be long enough to prevent horizontal movement. The gap is to be no more than 1% of the chamber length.

The lateral movement of the shank is not to exceed 3 degrees, see 2-2-1/Figure 1.

FIGURE 1
Allowable Lateral Movement of Shank *(2007)*



5.3 Welding of Anchors

Welded construction of fabricated anchors is to be in accordance with approved procedures in accordance with Section 2-4-1 and Section 2-4-3. NDE is to be carried in accordance with the requirements of 2-2-1/Table 3 or 2-2-1/Table 4 or 2-2-1/Table 5 product tests.

5.5 Heat Treatment

Components for cast or forged anchors are to be properly heat treated; fully annealed; normalized or normalized and tempered in accordance with 2-1-5/5 or 2-1-6/5. Fabricated anchors may require stress relief after welding depending upon weld thickness. Stress relief is to be carried out as indicated in the approved welding procedure. Stress relief temperatures are not to exceed the tempering temperature of the base material.

5.7 Surface Cleanliness

All parts are to have a clean surface consistent with the method of manufacture and intended method of inspection.

5.9 Repairs *(2010)*

Any necessary repairs to forged and cast anchors are to be agreed to by the Surveyor and carried out in accordance with the repair criteria indicated in 2-1-5/13 and 2-1-6/11.9. The restrictions of 2-2-1/7.3.7 - Repair Criteria, also apply.

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

Repairs to fabricated anchors are to be agreed to by the Surveyor and carried out in accordance with qualified weld procedures, by qualified welders, following the parameters of the welding procedures used in construction.

5.11 Anchor Assembly

Assembly and fitting are to be done in accordance with the design details. Securing of the anchor pin, shackle pin or swivel nut, by welding, is to be in accordance with an approved procedure.

7 Testing and Certification *(2007)*

All anchors are to be inspected and tested in the presence of the Surveyor, the proof testing is to be done in a machine recognized for such purposes. The Surveyor is to be satisfied that all testing machines, including material testing machines, are maintained in a satisfactory condition, and is to keep a record of the dates and by whom the machines were rechecked and calibrated.

7.1 Proof Load Testing of Anchors

Proof load testing for ordinary and SHP anchors is to be carried out by an approved testing facility.

7.1.1 Proof Load Testing of Ordinary Anchors *(2009)*

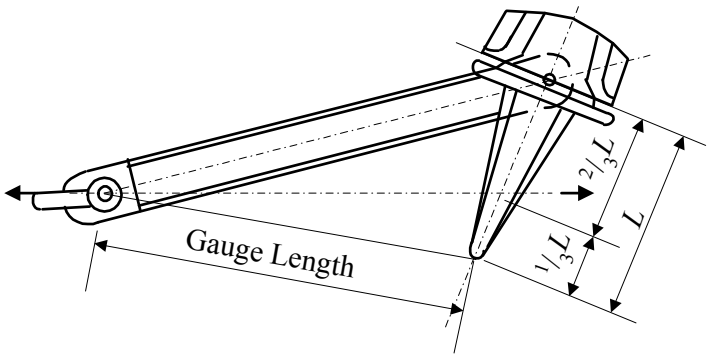
Before application of proof test load, the anchors are to be visually examined, and all defects are to be removed, and if necessary repaired by welding, prior to testing. Proof tests are to be carried out on all anchors after being temporarily assembled. The proof tests are to be in accordance with the values given in 2-2-1/Table 6. The proof load in accordance with 2-2-1/Table 6 is to be applied on the fluke at a location one third of the distance from the tip of the fluke to the center of the crown as shown in 2-2-1/Figure 2.
In the case of stockless anchors, both arms are to be tested at the same time, first on one side of the shank, then reversed and tested on the other.

After proof load testing the anchors are to be examined for cracks and other defects, and for excessive deformation due to seating.

Upon completion of the proof load tests, anchors made in more than one piece are to be examined for free rotation of their heads over the complete angle.

The gauge lengths (see 2-2-1/Figure 2) under a load equal to one-tenth of the proof test load are to be determined before and after the application of full proof load on each side. The gauge length after the application of full proof load is to be not more than 1% in excess of the corresponding gauge length before the application of full proof load.

FIGURE 2
Proof Load Application



7.1.2 Proof Load Testing of SHP Anchors

SHP anchors are to be proof tested with loads required by 2-2-1/Table 6 for an anchor mass equal to 1.33 times the actual mass of the SHP anchor. The proof loading procedure and examination procedure for SHP anchors are to comply with those for ordinary anchors, described in 2-2-1/7.1.

7.1.3 Testing of SHP Anchors for Restricted Service with 4 Times Holding Power of Ordinary Anchors

These anchors are to be proof tested with the load required by 2-2-1/Table 6 for an anchor mass equal to 2 times the actual mass of the SHP anchor. The proof loading procedure and examination procedure for SHP anchors are to comply with those for ordinary anchors, described in 2-2-1/7.1.

7.1.4 SHP Full Scale Anchor Holding Power Tests at Sea

In addition to proof tests SHP anchors are to undergo anchor holding power sea tests on various types of sea bottom, using anchors representative of the full range of anchor size proposed.

7.3 Product Tests

7.3.1 Product Test Programs

There are two test programs, which apply to anchor manufacture.

- Program A, or
- Program B.

TABLE 1
Applicable Test Programs for Each Product Form *(2010)*

Product Test	*Product Form*		
	Cast Components	*Forged Components*	*Fabricated/Welded Components*
Program A	Applicable (1)	Not Applicable	Not Applicable
Program B	Applicable (1)	Applicable	Applicable

Notes:

1 CVN impact tests are to be carried out to demonstrate at least 27 J average at 0°C (2.8 kgf-m at 0°C, 20 ft-lbs at 32°F).

TABLE 2
Product Test Requirements for Program A and B *(2010)*

Program A	*Program B*
Drop test	Drop test
Hammering test	---
Visual inspection	Visual inspection
General NDE	General NDE
---	Extended NDE

7.3.2 Drop Test

Each anchor fluke and shank is to be individually raised to a height of 4 m (13.1 ft) and dropped on to a steel slab without fracturing. The steel slab is to be suitable to resist the impact of the dropped component.

7.3.3 Hammering Test

After the drop test, hammering tests are to be carried out on each anchor fluke and shank, which is slung clear of the ground, using a non-metallic sling, and hammered to check the soundness of the component. A hammer of at least 3 kg (6.6 lbs) mass is to be used.

7.3.4 Visual Inspection

After proof loading visual inspection of all accessible surfaces is to be carried out.

7.3.5 General Nondestructive Examination

After proof loading, general NDE is to be carried out as indicated in 2-2-1/Table 3 and 2-2-1/Table 4.

TABLE 3
General NDE for Ordinary and SHP Anchors

Location	*Method of NDE*
In way of feeders of castings	PT or MT
In way of risers of castings	PT or MT
In way of weld repairs	PT or MT
Forged components	Not required
Fabrication welds	PT or MT

Part 2, Appendix 6, "Guidelines for Nondestructive Examination of Marine Steel Castings" is regarded as an example of an acceptable standard for surface and volumetric examination.

TABLE 4
General NDE for SHP Anchors for Restricted Service with 4 Times Holding Power of Ordinary Anchors

Location	*Method of NDE*
In way of feeders of castings	PT or MT and UT
In way of risers of castings	PT or MT and UT
In way of weld repairs	PT or MT
Forged components	Not required
Fabrication welds	PT or MT

Part 2, Appendix 6, "Guidelines for Nondestructive Examination of Marine Steel Castings" is regarded as an example of an acceptable standard for surface and volumetric examination.

7.3.6 Extended Nondestructive Examination

After proof loading extended NDE is to be carried out as indicated in 2-2-1/Table 5.

TABLE 5
Extended NDE for Ordinary and all SHP Anchors

Location	*Method of NDE*
In way of feeders of castings	PT or MT and UT
In way of risers of castings	PT or MT and UT
All surfaces of castings	PT or MT
Random areas of castings	UT
In way of weld repairs	PT or MT
Forged components	Not required
Fabrication welds	PT or MT

Part 2, Appendix 6, "Guidelines for Nondestructive Examination of Marine Steel Castings" is regarded as an example of an acceptable standard for surface and volumetric examination.

7.3.7 Repair Criteria

If defects are detected by NDE, repairs are to be carried out in accordance with 2-2-1/5.9. For fracture and unsoundness detected in a drop test or hammering test, repairs are not permitted and the component is to be rejected.

7.5 Mass and Dimensional Inspection

Unless otherwise agreed, the verification of mass and dimensions is the responsibility of the manufacturer. The Surveyor is only required to monitor this inspection. The mass of the anchor is to exclude the mass of the swivel, unless the swivel is an integral component.

7.7 Retests

Mechanical retest is permitted in accordance with the requirements of 2-1-5/3.3 and 2-1-6/3.3.

9 Marking for Anchors

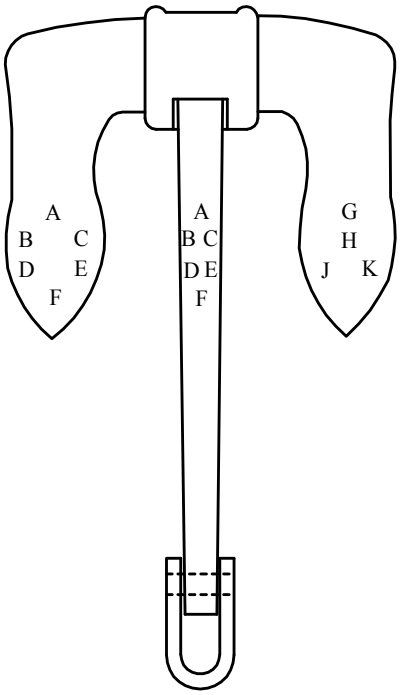
9.1 Markings

When anchors have satisfactorily passed the above test requirements, they are to be clearly stamped by the manufacturer, as shown in 2-2-1/Figure 3.

9.3 Provisions for Marks *(2005)*

One side of the anchor is to be reserved solely for the above marks and the other side used for the maker's name or other trademarks that may be desired. If the design of the anchor does not permit the above marks being placed or grouped as indicated, a suitable boss is to be cast on each arm on which the marks are to be stamped. The Maltese Cross, ✠ is to be stamped at positions "B" & "J" along with the witnessing Surveyor's initials per 2-2-1/Figure 3.

FIGURE 3
Stockless Anchor *(2008)*



A	The number of Certificate. (Furnished by the Surveyor)	00-PA123
B	*(2005)* The Maltese Cross Stamp and the Initials of the Surveyor who witnesses the Proof Test	✠ X.Y.X.
C	Month and Year of Test	1-00
D	Proof Test applied	34680
E	Signifying that the Testing Machine is recognized by the Committee of the American Bureau of Shipping	AB
F	The Weight of Anchor	1906
G	*(2008)* Signifying that Anchor Head has been verified by a Surveyor to the American Bureau of Shipping	AB
H	The Weight of Anchor Head	1140
J	*(2005)* The Maltese Cross Stamp and the Initials of the Surveyor who witnesses the Drop Test	✠ X.Y.X.
K	Month and Year of Drop Test	6-00

11 Certification *(2007)*

Anchors which meet the requirements of this section are to be certified by the Bureau. The following items that are to be included in the certificate:

- Manufacturer's name
- Type
- Mass
- Fluke and Shank identification numbers

- Grade of materials
- Proof test loads
- Heat treatment
- Markings applied to anchor

13 Painting *(2007)*

All types of anchor are to remain unpainted until all tests and inspections have been completed.

TABLE 6
Proof Tests for Anchors

Note *See also 3-5-1/7*

SI Units

Mass of Anchor kg	*Proof Test* kN	*Mass of Anchor* kg	*Proof Test* kN	*Mass of Anchor* kg	*Proof Test* kN	*Mass of Anchor* kg	*Proof Test* kN	*Mass of Anchor* kg	*Proof Test* kN	*Mass of Anchor* kg	*Proof Test* kN	*Mass of Anchor* kg	*Proof Test* kN
50	23	500	116	2000	349	4500	622	7000	804	15000	1260	38000	2330
55	25	550	125	2100	362	4600	631	7200	818	15500	1270	40000	2410
60	27	600	132	2200	376	4700	638	7400	832	16000	1300	42000	2490
65	29	650	140	2300	388	4800	645	7600	845	16500	1330	44000	2570
70	31	700	149	2400	401	4900	653	7800	861	17000	1360	46000	2650
75	32	750	158	2500	414	5000	661	8000	877	17500	1390	48000	2730
80	34	800	166	2600	427	5100	669	8200	892	18000	1410		
90	36	850	175	2700	438	5200	677	8400	908	18500	1440		
100	39	900	182	2800	450	5300	685	8600	922	19000	1470		
120	44	950	191	2900	462	5400	691	8800	936	19500	1490		
140	49	1000	199	3000	474	5500	699	9000	949	20000	1520		
160	53	1050	208	3100	484	5600	706	9200	961	21000	1570		
180	57	1100	216	3200	495	5700	713	9400	975	22000	1620		
200	61	1150	224	3300	506	5800	721	9600	987	23000	1670		
225	66	1200	231	3400	517	5900	728	9800	998	24000	1720		
250	70	1250	239	3500	528	6000	735	10000	1010	25000	1770		
275	75	1300	247	3600	537	6100	740	10500	1040	26000	1800		
300	80	1350	255	3700	547	6200	747	11000	1070	27000	1850		
325	84	1400	262	3800	557	6300	754	11500	1090	28000	1900		
350	89	1450	270	3900	567	6400	760	12000	1110	29000	1940		
375	93	1500	278	4000	577	6500	767	12500	1130	30000	1990		
400	98	1600	292	4100	586	6600	773	13000	1160	31000	2030		
425	103	1700	307	4200	595	6700	779	13500	1180	32000	2070		
450	107	1800	321	4300	604	6800	786	14000	1210	34000	2160		
475	112	1900	335	4400	613	6900	794	14500	1230	36000	2250		

TABLE 6 (continued)
Proof Tests for Anchors

Note *See also 3-5-1/7*

Metric Units

Mass of Anchor *kg*	*Proof Test* *kgf*	*Mass of Anchor* *kg*	*Proof Test* *kgf*	*Mass of Anchor* *kg*	*Proof Test* *kgf*	*Mass of Anchor* *kg*	*Proof Test* *kgf*	*Mass of Anchor* *kg*	*Proof Test* *kgf*	*Mass of Anchor* *kg*	*Proof Test* *kgf*	*Mass of Anchor* *kg*	*Proof Test* *kgf*
50	2370	500	11800	2000	35600	4500	63400	7000	82000	15000	128000	38000	238000
55	2570	550	12700	2100	36900	4600	64300	7200	83400	15500	130000	40000	246000
60	2760	600	13500	2200	38300	4700	65100	7400	84800	16000	133000	42000	254000
65	2950	650	14300	2300	39600	4800	65800	7600	86200	16500	136000	44000	262000
70	3130	700	15200	2400	40900	4900	66600	7800	87800	17000	139000	46000	270000
75	3300	750	16100	2500	42200	5000	67400	8000	89400	17500	142000	48000	278000
80	3460	800	16900	2600	43500	5100	68200	8200	91000	18000	144000		
90	3700	850	17800	2700	44700	5200	69000	8400	92600	18500	147000		
100	3990	900	18600	2800	45900	5300	69800	8600	94000	19000	150000		
120	4520	950	19500	2900	47100	5400	70500	8800	95400	19500	152000		
140	5000	1000	20300	3000	48300	5500	71300	9000	96800	20000	155000		
160	5430	1050	21200	3100	49400	5600	72000	9200	98000	21000	160000		
180	5850	1100	22000	3200	50500	5700	72700	9400	99400	22000	165000		
200	6250	1150	22800	3300	51600	5800	73500	9600	100600	23000	170000		
225	6710	1200	23600	3400	52700	5900	74200	9800	101800	24000	175000		
250	7180	1250	24400	3500	53800	6000	74900	10000	103000	25000	180000		
275	7640	1300	25200	3600	54800	6100	75500	10500	106000	26000	184000		
300	8110	1350	26000	3700	55800	6200	76200	11000	109000	27000	189000		
325	8580	1400	26700	3800	56800	6300	76900	11500	111000	28000	194000		
350	9050	1450	27500	3900	57800	6400	77500	12000	113000	29000	198000		
375	9520	1500	28300	4000	58800	6500	78200	12500	115000	30000	203000		
400	9980	1600	29800	4100	59800	6600	78800	13000	118000	31000	207000		
425	10500	1700	31300	4200	60700	6700	79400	13500	120000	32000	211000		
450	10900	1800	32700	4300	61600	6800	80200	14000	123000	34000	220000		
475	11400	1900	34200	4400	62500	6900	81000	14500	125000	36000	229000		

TABLE 6 (continued)
Proof Tests for Anchors

Note *See also 3-5-1/7*

US Units

Mass of Anchor	*Proof Test*	*Mass of Anchor*	*Proof Test*	*Mass of Anchor*	*Proof Test*	*Mass of Anchor*	*Proof Test*	*Mass of Anchor*	*Proof Test*	*Mass of Anchor*	*Proof Test*	*Mass of Anchor*	*Proof Test*	*Mass of Anchor*	*Proof Test*
lb	*lbf*	*lb*	*lbf*	*lb*	*lbf*	*lb*	*lbf*	*lb*	*lbf*	*lb*	*lbf*	*lb*	*lbf*	*lb*	*lbf*
100	5000	1000	24100	3000	57700	5000	86500	7000	110500	9000	131500	28000	256000	56000	400000
125	5900	1100	25900	3100	59200	5100	87800	7100	112000	9500	136000	29000	262000	58000	410000
150	6800	1200	27700	3200	60700	5200	89100	7200	113000	10000	140500	30000	266000	60000	419000
175	7600	1300	29500	3300	62200	5300	90400	7300	114000	11000	148500	31000	272000	62000	428000
200	8300	1400	31200	3400	63700	5400	91700	7400	115000	12000	156000	32000	275000	64000	437000
250	9700	1500	32900	3500	65200	5500	93000	7500	116000	13000	163500	33000	281000	66000	446000
300	10900	1600	34600	3600	66700	5600	94300	7600	117000	14000	170500	34000	287000	68000	455000
350	12000	1700	36300	3700	68200	5700	95500	7700	118000	15000	177000	35000	292000	70000	464000
400	13000	1800	38000	3800	69700	5800	96700	7800	120000	16000	185000	36000	298000	75000	486000
450	14000	1900	39700	3900	71200	5900	97900	7900	120500	17000	192000	37000	303000	80000	507000
500	15000	2000	41400	4000	72600	6000	99100	8000	121500	18000	200000	38000	309000	85000	528000
550	16000	2100	43100	4100	74100	6100	100500	8100	122500	19000	208000	39000	314000	90000	549000
600	16900	2200	44700	4200	75500	6200	101500	8200	123500	20000	214000	40000	320000	95000	569000
650	17800	2300	46400	4300	76900	6300	102500	8300	124500	21000	221000	42000	330000	100000	590000
700	18700	2400	48000	4400	78300	6400	104000	8400	125500	22000	227000	44000	341000	105000	610000
750	19600	2500	49700	4500	79700	6500	105000	8500	126500	23000	232000	46000	351000	110000	630000
800	20500	2600	51300	4600	81100	6600	106500	8600	127500	24000	239000	48000	361000		
850	21400	2700	52900	4700	82500	6700	107500	8700	128500	25000	243000	50000	371000		
900	22300	2800	54500	4800	83800	6800	108500	8800	129500	26000	247000	52000	381000		
950	23200	2900	56100	4900	85200	6900	109500	8900	130500	27000	251000	54000	390000		

PART
2

CHAPTER 2 Equipment

SECTION 2 Anchor Chain

1 Scope

Three grades of stud-link anchor chain are covered, and are described as follows:

Strength Level	*Grade*	*Method of Manufacture*
Normal Strength	1	Flash Butt-welded
High Strength	2a	Flash Butt-welded or Drop-forged
	2b	Cast Steel
Extra-high Strength	3a	Flash Butt-welded or Drop-forged
	3b	Cast Steel

3 General

All chain is to have a workmanlike finish and be free from injurious defects. There is to be an odd number of links in each shot of anchor chain cable to insure shackles leading over the windlass are in the same position.

5 Specially Approved Chain

Steel chain made by processes or to requirements differing from those shown in 2-2-2/Table 1 and certain types of drop-forged chain will be subject to special consideration.

7 Qualification of Manufacturers

7.1 General *(2005)*

Manufacturers of Grades 2 and 3 chain and chain accessories are to be approved by the Bureau and are to submit their manufacturing process and material specifications for review. Data in support of mechanical properties, weld soundness (when applicable) and compliance with the Rules in all respects are also to be submitted for review and approval.

7.3 Locking Pins in Accessories

Locking pins in detachable connecting links are to have taper contact at both top and bottom in the link halves. Lead or other acceptable material is to be used for plugging the locking pin hole which is to contain an appropriate undercut recess or equivalent arrangement to secure the plug.

7.5 Stud Attachment *(2005)*

Studs are to be securely fastened by press fitting or welding with an approved procedure. When the stud is welded in place, the weld is to be opposite the flash butt weld in the chain. The welding is to be carried out in the horizontal position at least on both faces of the link for a length sufficient to hold the stud securely in place. Any welding of chain subsequent to the approved manufacturing process is to be approved by the attending Surveyor.

Welding of studs is to be in accordance with an approved procedure subject to the following conditions:

i) The studs must be of weldable steel.

ii) The studs are to be welded at one end only, i.e., opposite to the weldment of the link. The stud ends must fit the inside of the link without appreciable gap.

iii) The welds, preferably in the horizontal position, shall be executed by qualified welders using suitable welding consumables.

iv) All welds must be carried out before the final heat treatment of the chain cable.

v) The welds must be free from defects liable to impair the proper use of the chain. Under-cuts, end craters and similar defects are to be ground off, where necessary.

The Bureau reserves the right to call for a procedure test for the welding of chain studs.

9 Chain Dimensions and Tolerances

9.1 Shape

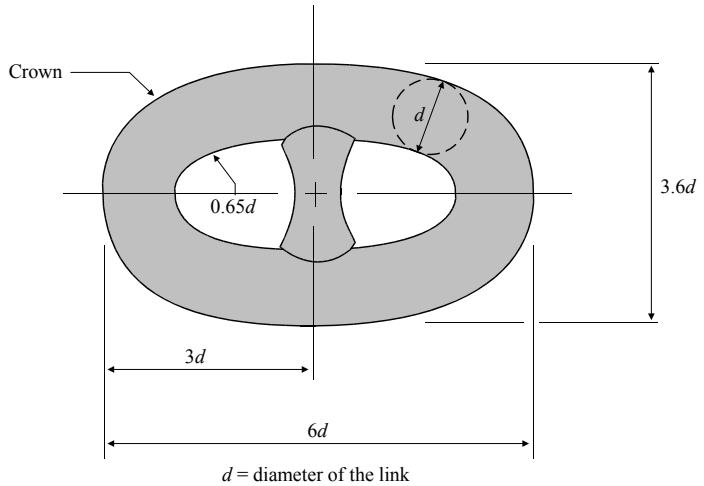
Each link is to be uniform and symmetrical, and is to have smooth internal radii that are to be at least 0.65 times the chain diameter.

9.3 Dimensions *(2005)*

The dimensions, shape and proportions of links and accessories must conform to an approved recognized standard, such as ISO 1704, or the designs are to be specially approved

After proof testing, measurements are to be taken on at least one link per each 27.5 m (15 fathoms) of chain tested and are to conform to the dimensions shown below.

Common Link



d = diameter of the link

9.5 Tolerances *(1999)*

The minus tolerances on the diameter in the plane of the link at the crown are permitted to the extent shown below, provided the cross-sectional area of the link at that point is at least the theoretical area of the nominal diameter:

Chain Diameter in mm (in.)		*Crown Minus Tolerance*
Over	*Up to*	*in mm (in.)*
—	40 ($1^{9}/_{16}$)	1 ($^{1}/_{32}$)
40 ($1^{9}/_{16}$)	84 ($3^{5}/_{16}$)	2 ($^{1}/_{16}$)
84 ($3^{5}/_{16}$)	122 ($4^{3}/_{4}$)	3 ($^{1}/_{8}$)
122 ($4^{3}/_{4}$)	162 ($6^{3}/_{8}$)	4 ($^{5}/_{32}$)

No minus tolerance on the diameter is allowed at locations other than the crown.

The plus tolerance on the diameter is not to exceed 5% of the nominal diameter. The manufacturer's specification for plus tolerance in way of weld is to be submitted for approval.

Subject to 2-2-2/9.7, the tolerances on other dimensions in 2-2-2/9.3 are not to exceed ±2.5%.

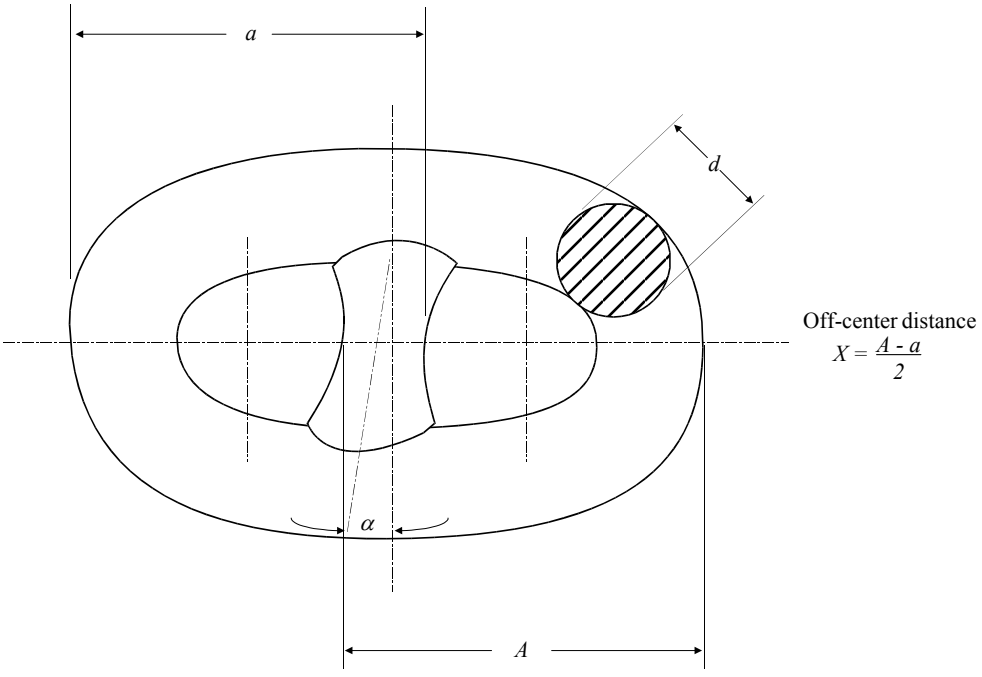
Studs are to be located in the links centrally and at right angles to the sides of the link, except that the studs for the final link at each end of any length may be located off-center to facilitate the insertion of the joining shackle. The following tolerances are acceptable, provided that the stud fits snugly and its ends lie practically flush against the inside of the link.

Maximum off-center distance "X": 10% of the nominal diameter, *d*

Maximum deviation angle "α" from the 90° position: 4°

The tolerances are to be measured, as follows:

Final Link



9.7 Length Over Five Links

After completion of the proof testing, the length over five links is to be measured while applying a tension of approximately 10% of the applied proof load. The Surveyor is to verify the length over a five link measurement from at least three locations per each 27.5 m (15 fathoms) of chain tested. The allowable tolerance for the length over any five common links is 0.0% of the chain diameter below, and 55% of the chain diameter above the length given in 2-2-2/Table 2.

11 Material for Chain

11.1 General

11.1.1 Process of Steel Manufacture and Deoxidation *(1996)*

The steel used for the manufacture of chain is to be made by the open-hearth, basic-oxygen, electric-furnace or such other process as may be specially approved.

Rimmed steel is not acceptable for any grade of chain.

11.1.2 Chemical Composition *(1996)*

The chemical composition of the material for chain manufacture is to be determined by the steelmaker on samples taken from each ladle of each heat and is to comply with the approved specification of the chain manufacturer.

13 Material Testing

13.1 Heat Treatment of Test Specimens

Test specimens are to be taken from material heat-treated in the same manner as intended for the finished chain, except that in the case of Grades 1 and 2a flash butt-welded chain, test specimens may be taken from material in either the as-rolled or heat-treated condition.

13.3 Number of Tests

One set of tests consisting of one tension, and one bend or three impact test specimens, as required in 2-2-2/Table 1, are to be taken from the largest casting or drop forging from each lot of 50 tons or fraction thereof from each heat.

13.5 Tension Test Specimens *(1996)*

For cast or drop-forged links, machined type specimens are to be used. They are to be cut and notched as shown in 2-2-2/Figure 1. The tension-test results for stud-link anchor chain materials are to meet the applicable requirements shown in 2-2-2/Table 1.

The required minimum percentage elongation values in 2-2-2/Table 1 are based on specimens having gauge lengths equal to 5 times the diameter. For specimens having other gauge lengths, the equivalent elongation value is to be calculated by the following equation:

$$n = 2E(\sqrt{A}\,/L)^{0.4}$$

where

n = equivalent minimum elongation

A = actual cross-sectional area of the specimen

L = actual gauge length

E = specified minimum percentage elongation for specimens having a gauge length of 5 times the diameter

The above equation is not applicable to quenched and tempered steel, for which the specimen is to have a gauge length of 5 times the specimen diameters.

13.7 Bend Test Specimens

For cast or drop-forged links, machined type specimens are to be used. Each specimen is to withstand, without fracture, cold bending around a mandril diameter and through the angle specified in 2-2-2/Table 1.

13.9 Impact Test Specimens

Impact test specimens are to be in accordance with 2-1-1/11.11. They are to be cut and notched as shown in 2-2-2/Figure 1. The average value of 3 specimens is to comply with the requirements of 2-2-2/Table 1.

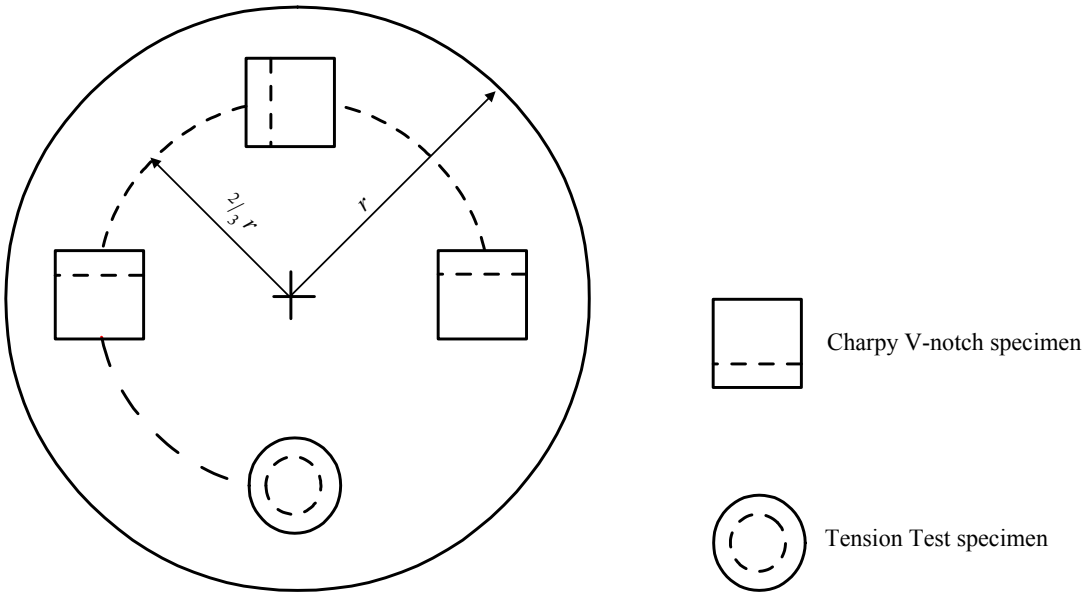
13.11 Additional Tests before Rejection *(1996)*

When a specimen fails to meet the requirements of 2-2-2/Table 1, retest in accordance with 2-1-2/9.11, 2-1-2/9.13, 2-1-2/11.7 and 2-1-2/11.9 may be permitted, as applicable.

13.13 Manufacturer's Option

At the option of the chain manufacturer, the above material tests (normally conducted prior to chain fabrication) may be waived, provided the required test specimens representative of each heat are taken from finished links after final heat treatment, if any, and in the same proportion of number of tests to tonnage, as outlined in 2-2-2/13.3.

FIGURE 1
Location and Orientation of Test Specimens



15 Heat Treatment of Chain Lengths

15.1 Flash Butt-welded Chain

Grades 1 and 2a flash butt-welded chain may be supplied in either the as-welded or normalized condition.

15.3 Drop-forged, Cast-steel and Extra-high-strength Chain

Grade 2a drop-forged chain, Grade 2b cast-steel chain and Grades 3a and 3b extra-high-strength chain are to be normalized, normalized and tempered or quenched and tempered in accordance with the manufacturer's approved specification.

15.5 Sequence of Heat Treatment

Heat treatment is to be completed prior to the proof and breaking tests.

17 Testing and Inspection of Chain Lengths

17.1 General *(1996)*

All anchor chain is to be subjected to breaking and proof tests in the presence of a Surveyor. The Surveyor is to satisfy himself that the testing machines are maintained in a satisfactory and accurate condition and is to keep a record of the dates and by whom the machines were rechecked or calibrated. Prior to test and inspection, the chain is to be free from paint or other coating which would tend to conceal defects. After proof testing, links are to be carefully examined for workmanship, concentricity, distortion, stud attachment, test grip damage, surface appearance and alignment of butt welds.

Provided their depth is not greater than 5% of the link diameter, surface discontinuities may be removed by grinding and blending to a smooth contour. The cross sectional area in way of the grinding is to be not less than the theoretical area of nominal chain diameter. Links repaired by grinding are to be subjected to magnetic particle or dye penetrant inspection.

17.3 Chain Identification

Each shot is to be stamped with a distinctive mark in order to identify it through the several processes of gauging, testing, measuring, examining, repairing and weighing, and in the event of the Surveyor being in attendance at the works while forged chains are being fabricated, which will ultimately be submitted for testing, the break test specimens will be selected as far as possible during the process of fabrication.

17.5 Testing Precautions

Care is to be taken that arrangements are made for each link to be tested at least once. The gripping arrangements are to be such that they do not put any stress on the end links of the portion under test, except such stress as is equally applied to every link tested.

17.7 Weighing of Tested Chain

When chains have satisfactorily passed the requirements, they are to be weighed, together with the shackles forming the outfit, and this actual weight will be given on the certificate of test.

17.9 Testing of Used Chain

When a chain, which has been in use, is submitted for testing or retesting, the size for testing purposes is to be the original chain diameter. The certificate issued for such chain will include for descriptive purposes the original chain diameter as well as the mean diameter of the part most worn, and will be marked, “This chain is not new, and has been previously used’’.

19 Details of Tests on Chain Lengths

19.1 Breaking Test *(2005)*

A break-test specimen consisting of at least three links is to be taken from the chain or produced at the same time and the same way as the chain. Where produced separately, the specimen is to be securely attached to the chain during any heat treatment. One specimen is to be taken from each four 27.5 m (15 fathoms) lengths or less of flash butt-welded or drop-forged chain and one from each heat treatment batch with a minimum of one from each four 27.5 m (15 fathoms) lengths or less of cast-steel chain. Each specimen is to be subjected to the applicable breaking load given in 2-2-2/Table 2 (stud-link chain). The breaking load test is to be carried out in the presence of the Surveyor and is to be maintained for a minimum of 30 seconds. A specimen will be considered to have successfully passed the test if there is no sign of fracture after application of the required load. Special attention is to be given to the visual inspection of the flash butt weld. Where the first test is not satisfactory, one more specimen may be cut out and subjected to the breaking load. If this test fails, the shot is to be rejected, and additional specimens are to be cut from each of the three remaining shots of 27.5 m (15 fathoms) or less and subjected to the breaking load. In such cases, each shot from which the satisfactory break specimens have been taken is to be rejoined and may be accepted, provided it passes the required proof test. All breaking test specimens are to be subsequently discarded.

Alternative test procedures to the required breaking test of chain of Grades 2a, 2b, 3a, and 3b may be accepted. This alternative procedure consists of additional mechanical tests and the preparation of macro sections on a two or three link sample of chain taken from every four lengths of 27.5 m (15 fathoms) or less of completed chain. In the case of Grade 3a or 3b chain, the two or three link sample is not to be taken from the same length of chain as that length from which the link to be mechanically tested, according to 2-2-2/19.5, is taken.

19.3 Proof Test

Each shot of chain of 27.5 m (15 fathoms) length or less and the entire length of chain when produced in lengths longer than 27.5 m (15 fathoms) is to withstand the applicable proof load indicated in 2-2-2/Table 2 (stud-link chain). Upon special request and when approved by the Bureau, detachable links may be subjected to a greater proof load than required for the chain. After the proof test, the length of chain is to be ascertained and the chain carefully examined. Any link showing surface defects or excessive deformation is to be taken out and the chain repaired, after which the proof test is again to be applied and the chain re-examined. If one link breaks under the proof test, a joining link is to be inserted and the proof test again applied; if a second link breaks, the shot or length under test is to be rejected. For chain produced in long continuous lengths, if more than one link breaks under proof test, the entire length is to be rejected unless approved otherwise.

19.5 Mechanical Tests on Completed Chain *(2005)*

One link from every four lengths of 27.5 m (15 fathoms) or less of

Grade 2a flash butt welded chain delivered in as welded condition, and

Grades 3a or 3b chain

is to be subjected to a set of mechanical tests consisting of one tension and three impact tests. The mechanical tests are to be carried out in the presence of the Surveyor.

In the case of a welded chain, the above mentioned test specimens are to be taken from the base metal of the link opposite to the weldment and, additionally, three impact specimens are to be taken with notches at the weld center. The results of the tests are to comply with the requirements given in 2-2-2/Table 1. When the results of the original tests fail to meet the requirements, retests in accordance with 2-1-2/9.11 and 2-1-2/11.7 may be permitted, as applicable.

19.7 Mechanical and Breaking Tests on Chain Produced in Long Continuous Lengths

When chain is produced in lengths longer than 27.5 m (15 fathoms), the test frequency for the mechanical and breaking tests required in 2-2-2/19.1 and 2-2-2/19.5 are to be based on tests at regular intervals according to the following table:

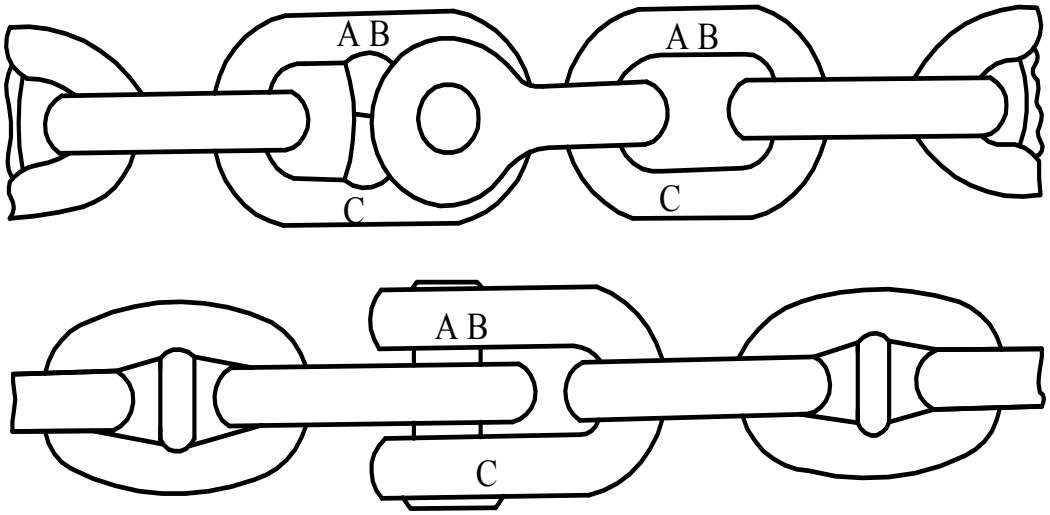
Nominal Chain Size		*Maximum Specified Length to Obtain Samples*	
mm	*in.*	*m*	*ft*
Min to 48	Min to $1\frac{7}{8}$	91	300
50 to 60	2 to $2\frac{3}{8}$	110	360
64 to 73	$2\frac{1}{2}$ to $2\frac{7}{8}$	131	430
76 to 85	3 to $3\frac{3}{8}$	152	500
87 to 98	$3\frac{1}{2}$ to $3\frac{7}{8}$	175	575
102 to 111	4 to $4\frac{3}{8}$	198	650

If an order or a fraction of an order is less than the specified length, that length is to be subject to all tests required for a full length.

21 Marking for Chain *(2001)*

The shackles and the end links of each length and one link in every 27.5 m (15 fathoms) of stud-link chain, made in a continuous length without joining shackles, are to be clearly stamped by the manufacturer as shown in 2-2-2/Figure 2 in location A, B and C. When Kenter shackles are used, the marking is to be clearly stamped on the Kenter shackle and on both adjoining common links. Any accessory tested to a break load for a lower grade chain, as permitted in 2-2-2/23.13, is to be marked with the grade of the chain to which it is tested.

FIGURE 2
Marking for Chain



A	The Number of the Certificate (Furnished by the Surveyor)	78 PT1234
B	Signifying that the Chain has been satisfactorily tested to the Bureau Requirements and the Grade as Applicable	AB/1, AB/2 or AB/3
C	Nominal Chain Diameter in mm or in. (When chain manufacturers emboss the chain diameter in a permanent manner by some suitable means such as forging or casting, marking of the chain diameter in location C may be omitted.)	

23 Anchor Chain Accessories

23.1 Dimensions and Dimensional Tolerances *(1996)*

The dimensions of anchor chain accessories are to be in accordance with a recognized standard such as ISO 1704. The following tolerances are applicable to anchor chain accessories.

Nominal diameter: +5%, -0%

Other dimensions: ±2.5%

23.3 Material Testing

Test specimens are to be taken either from finished accessories or from special test bars indicated in 2-2-2/23.5 and 2-2-2/23.7. In all cases, the specimens are to be taken from pieces representing the largest diameter accessory in the lot. A lot is defined as the accessories of the same grade, made from the same heat of steel and heat-treated in the same furnace charge where the diameter does not differ by more than 25 mm (1 in.). Test results are to comply with 2-2-2/Table 1 or such other specification as may be specially approved. When the results of original tests fail to meet the requirements, retests in accordance with 2-1-2/9.11 and 2-1-2/11.7 may be permitted, as applicable.

23.5 Cast Accessories

Test specimens may be taken from integrally or separately cast test blocks, heat-treated together with the accessories represented.

23.7 Forged Accessories

Test specimens may be taken from a special forging, representative of the accessories in the lot. In such cases, the special forging is to be subjected to approximately the same amount of working and reduction as the forging represented, and is to be heat-treated with the forgings represented.

23.9 Inspection

All accessories are to be inspected by magnetic particle or other suitable method to assure freedom from injurious surface defects. Special attention is to be given to welds.

23.11 Hardness Test

All accessories are to be subjected to a Brinell hardness test to meet the following:

Grade	*Brinell Hardness Number Minimum 10 mm ball, 3000 kg load*
1	120
2	145
3	207

23.13 Break Test *(2001)*

Break tests are to be made on 1 out of 25 accessories (or 1 out of 50 in the case of Kenter shackles), representative of the same type, grade and heat treatment procedure, but not necessarily representative of each heat of steel, heat treatment charge or individual purchase order. When the range of Brinell hardness readings of these accessories in the batch exceed 30 Brinell hardness numbers, the accessories represented by the lowest and highest Brinell hardness readings are to be tested. This requirement may be waived when the range of properties represented by the Brinell hardness numbers is established to the satisfaction of the Surveyor. For accessories from the same lot (see 2-2-2/23.3), the Surveyor may reduce the number of break tests to a minimum of two per lot. All parts of the accessory subjected to a break test required by this subparagraph are to be subsequently discarded, except where further use is permitted by 2-2-2/23.13.1 below.

23.13.1 Use of Break Tested Parts *(2001)*

Where it is demonstrated by either one of the following methods that the accessories can withstand at least 140% of the breaking test load prescribed in 2-2-2/Table 2 for the chain in which they are intended, such accessories may be used in service provided:

23.13.1(a) the material of the accessories is of higher grade than the chain (e.g., grade 3 accessories of grade 2 size in grade 2 chain), or

23.13.1(b) where an accessory of increased dimension is specially approved for the particular application and a procedure test is completed at 140% of the 2-2-2/Table 2 break test load. All parts of the accessories used in this procedure test are to be subsequently discarded.

In either case, each accessory requiring a break test is to be tested to 100% of the 2-2-2/Table 2 break load for the chain in which it is intended to be used.

23.15 Proof Tests

Each accessory is to be subjected to a proof test in accordance with 2-2-2/19.3.

23.17 Markings

The certificate number, **AB/Chain Grade**, and nominal chain diameter are to be steel die stamped on each accessory. The stamping of the nominal chain diameter may be omitted, provided the nominal chain diameter is cast or forged into the accessory. Markings are to be located in such a manner as to be readily visible when completely assembled together with the chain.

25 Unstudded Short-link Chain

25.1 General

Unstudded short-link chain is to meet the requirements specified in 2-2-2/3 and 2-2-2/11. Material is to be in accordance with the manufacturer's specification which is to be the equivalent of normal strength Grade 1 requirements of 2-2-2/Table 1.

25.3 Testing

Breaking and proof testing are to be in accordance with 2-2-2/19 and subjected to the applicable testing loads as given in 2-2-2/Table 3.

25.5 Marking

One link, including the end link in every 4.5 m (2.5 fathoms), is to be steel die stamped by the manufacturer as prescribed in locations A, B and C as shown in 2-2-2/Figure 1. In special cases, shots of comparatively small size may be marked or stenciled in lieu of die stamping or the markings may be shown on a metal tag attached at every 4.5 m (2.5 fathoms).

TABLE 1
Chain Materials – Mechanical Properties *(1999)*

Chain Grade	*Grade 1*	*Grade 2*	*Grade 3*
Yield Point N/mm^2 *(kgf/mm², ksi)*	-	295 (30, 42.8)	410 (42, 60)
Tensile Range N/mm^2 *(kgf/mm², ksi)*	370-490 (38-51, 53.7-71.1)	490-690 (50-70, 71.1-99.6)	690 min. (70, 99.6) min.
Elongation (5D), min %	25	22	17
Reduction of Area, min %	-	-	40
Average Impact Value @ 0°C (32°F), J (kgf-m, ft-lbf)			
base metal	-	27 [1] (2.8, 20)	60 (6, 43)
at weld center	-	27 [1] (2.8, 20)	50 (5, 36)
Bend Test			
mandrel dia.[2]	2T	3T	
Angle (degree)	180	180	

Notes:

1 Impact test for Grade 2 chain material is required for flash butt welded chain to be delivered in as-welded condition.

2 T = diameter or thickness of test specimen.

TABLE 2
Stud-link Anchor-chain Proof and Break Tests

SI Units

		Normal Strength Grade 1		High Strength Grade 2		Extra-high Strength Grade 3		
Chain Diameter	*Length of Five Links*	*Proof Load*	*Breaking Load*	*Proof Load*	*Breaking Load*	*Proof Load*	*Breaking Load*	*Mass kilograms per 27.5 meters*
mm	*mm*	*kN*	*kN*	*kN*	*kN*	*kN*	*kN*	*kg*
12.5	275	46.1	65.7	65.7	92.2	92.2	132.4	110
14	308	57.9	82.4	82.4	115.7	115.7	164.8	130
16	352	75.5	106.9	106.9	150.0	150.0	215.7	170
17.5	385	89.3	127.5	127.5	179.5	179.5	260.8	180
19	418	104.9	150.0	150.9	210.8	210.8	301.1	220
20.5	451	122.6	174.6	174.6	244.2	244.2	349.1	260
22	484	140.2	200.1	200.1	280.5	280.5	401.1	300
24	528	166.7	237.3	237.3	332.4	332.4	475.6	340
26	572	194.2	277.5	277.5	389.3	389.3	556.0	420
28	616	224.6	320.7	320.7	449.1	449.1	642.3	480
30	660	256.9	367.7	367.7	513.9	513.9	734.5	550
32	704	291.3	416.8	416.8	582.5	582.5	832.6	610
34	748	327.5	467.8	467.8	655.1	655.1	936.5	700
36	792	365.8	522.7	522.7	731.6	731.6	1049.3	790
38	836	406.0	580.6	580.6	812.0	812.0	1157.2	880
40	880	448.2	640.4	640.4	896.3	896.3	1284.7	970
42	924	492.3	703.1	703.1	980.7	980.7	1402.3	1070
44	968	538.4	768.8	768.8	1078.7	1078.7	1539.6	1170
46	1012	585.5	836.5	836.5	1167.0	1167.0	1676.9	1270
48	1056	635.5	908.1	908.1	1274.9	1274.9	1814.2	1380
50	1100	686.5	980.7	980.7	1372.9	1372.9	1961.3	1480
52	1144	739.4	1059.1	1059.1	1480.8	1480.8	2108.4	1600
54	1188	794.3	1137.6	1137.6	1588.7	1588.7	2265.3	1720
56	1232	851.2	1216.0	1216.0	1706.4	1706.4	2432.0	1850
58	1276	909.1	1294.5	1294.5	1814.2	1814.2	2598.8	1990
60	1320	968.9	1382.7	1382.7	1941.7	1941.7	2765.5	2120
62	1364	1029.7	1471.0	1471.0	2059.4	2059.4	2942.0	2250
64	1408	1098.3	1559.3	1559.3	2186.9	2186.9	3128.3	2440
66	1452	1157.2	1657.3	1657.3	2314.4	2314.4	3304.8	2590
68	1496	1225.8	1745.6	1745.6	2451.7	2451.7	3501.0	2750
70	1540	1294.5	1843.7	1843.7	2579.1	2579.1	3687.3	2910
73	1606	1392.5	1990.7	1990.7	2794.9	2794.9	3991.3	3180
76	1672	1500.4	2147.6	2147.6	3010.6	3010.6	4295.3	3470
78	1716	1578.9	2255.5	2255.5	3157.7	3157.7	4501.3	3650
81	1782	1686.7	2412.4	2412.4	3383.3	3383.3	4824.9	3930
84	1848	1804.4	2579.1	2579.1	3608.8	3608.8	5158.3	4250
87	1914	1922.1	2745.9	2745.9	3854.0	3854.0	5501.5	4560
90	1980	2049.6	2922.4	2922.4	4089.4	4089.4	5844.8	4860
92	2024	2128.0	3040.1	3040.1	4256.1	4256.1	6080.1	5100
95	2090	2255.5	3226.4	3226.4	4511.0	4511.0	6443.0	5400
97	2134	2343.8	3344.1	3344.1	4677.8	4677.8	6688.1	5670
98	2156	2383.0	3402.9	3402.9	4766.0	4766.0	6815.6	5750
100	2200	2471.3	3530.4	3530.4	4942.6	4942.6	7060.8	6010
102	2244	2559.5	3657.9	3657.9	5119.1	5119.1	7315.8	6250
105	2310	2696.8	3854.0	3854.0	5393.7	5393.7	7698.2	6600
107	2354	2785.1	3981.5	3981.5	5570.2	5570.2	7963.0	6820
108	2376	2834.1	4040.3	4040.3	5658.4	5658.4	8090.4	6950
111	2442	2971.4	4246.3	4246.3	5942.8	5942.8	8482.8	7290
114	2508	3108.7	4442.4	4442.4	6227.2	6227.2	8894.6	7640
117	2574	3255.8	4648.4	4648.4	6511.6	6511.6	9296.7	7980
120	2640	3492.9	4854.3	4854.3	6805.8	6805.8	9718.4	8310
122	2684	3501.0	5001.4	5001.4	7001.9	7001.9	9993.0	8620
124	2728	3599.0	5138.7	5138.7	7198.1	7198.1	10277.4	8920
127	2794	3746.1	5354.4	5354.4	7492.3	7492.3	10708.9	9380
130	2860	3903.0	5570.2	5570.2	7796.3	7796.3	11140.4	9840
132	2904	4001.1	5717.3	5717.3	8002.2	8002.2	11424.7	10140
137	3014	4256.1	6080.1	6080.1	8512.2	8512.2	12160.2	10910
142	3124	4520.9	6452.8	6452.8	9031.9	9031.9	12905.6	11670
147	3234	4785.6	6835.2	6835.2	9561.5	9561.5	13660.7	12440
152	3344	5050.4	7217.7	7217.7	10100.8	10100.8	14425.6	13200
157	3454	5325.0	7600.2	7600.2	10640.2	10640.2	15200.3	14000
162	3564	5599.6	8002.2	8002.2	11199.2	11199.2	15994.6	14700

Note: The weight of chain is not to be more than $2^1/_2$% under the weight specified.

TABLE 2 (continued)
Stud-link Anchor-chain Proof and Break Tests

MKS Units

		Normal Strength Grade 1		*High Strength Grade 2*		*Extra-high Strength Grade 3*		
Chain Diameter	*Length of Five Links*	*Proof Load*	*Breaking Load*	*Proof Load*	*Breaking Load*	*Proof Load*	*Breaking Load*	*Mass kilograms per 27.5 meters*
mm	*mm*	*kgf*	*kgf*	*kgf*	*kgf*	*kgf*	*kgf*	*kg*
12.5	275	4700	6700	6700	9400	9400	13500	110
14	308	5900	8400	8400	11800	11800	16800	130
16	352	7700	10900	10900	15300	15300	22000	170
17.5	385	9100	13000	13000	18300	18300	26100	180
19	418	10700	15300	15300	21500	21500	30700	220
20.5	451	12500	17800	17800	24900	24900	35600	260
22	484	14300	20400	20400	28600	28600	40900	300
24	528	17000	24200	24200	33900	33900	48500	340
26	572	19800	28300	28300	39700	39700	56700	420
28	6126	22900	32700	32700	45800	45800	65500	480
30	660	26200	37500	37500	52400	52400	74900	550
32	704	29700	42500	42500	59400	59400	84900	610
34	748	33400	47700	47700	66800	66800	95500	700
36	792	37300	53300	53300	74600	74600	107000	790
38	836	41400	59200	59200	82800	82800	118000	880
40	880	45700	65300	65300	91400	91400	131000	970
42	924	50200	71700	71700	100000	100000	143000	1070
44	968	54900	78400	78400	110000	110000	157000	1170
46	1012	59700	85300	85300	119000	119000	171000	1270
48	1056	64800	92600	92600	130000	130000	185000	1380
50	1100	70000	100000	100000	140000	140000	200000	1480
52	1144	75400	108000	108000	151000	151000	215000	1600
54	1188	81000	116000	116000	162000	162000	231000	1720
56	1232	86800	124000	124000	174000	174000	248000	1850
58	1276	92700	132000	132000	185000	185000	265000	1990
60	1320	98800	141000	141000	198000	198000	282000	2120
62	1364	105000	150000	150000	210000	210000	300000	2250
64	1408	112000	159000	159000	223000	223000	319000	2440
66	1452	118000	169000	169000	236000	236000	337000	2590
68	1496	125000	178000	178000	250000	250000	357000	2750

		Normal Strength Grade 1		*High Strength Grade 2*		*Extra-high Strength Grade 3*		
Chain Diameter	*Length of Five Links*	*Proof Load*	*Breaking Load*	*Proof Load*	*Breaking Load*	*Proof Load*	*Breaking Load*	*Mass kilograms per 27.5 meters*
mm	*mm*	*kgf*	*kgf*	*kgf*	*kgf*	*kgf*	*kgf*	*kg*
70	1540	132000	188000	188000	263000	263000	376000	2910
73	1606	142000	203000	203000	285000	285000	407000	3180
76	1672	153000	219000	219000	307000	307000	438000	3470
78	1716	161000	230000	230000	322000	322000	459000	3650
81	1782	172000	246000	246000	345000	345000	492000	3930
84	1848	184000	263000	263000	368000	368000	526000	4250
87	1914	196000	280000	280000	393000	393000	561000	4560
90	1980	209000	298000	298000	417000	417000	596000	4860
92	2024	217000	310000	310000	434000	434000	620000	5100
95	2090	230000	329000	329000	460000	460000	657000	5400
97	2134	239000	341000	341000	477000	477000	682000	5670
98	2156	243000	347000	347000	486000	486000	695000	5750
100	2200	252000	360000	360000	504000	504000	720000	6010
102	2244	261000	373000	373000	522000	522000	746000	6250
105	2310	275000	393000	393000	550000	550000	785000	6600
107	2354	284000	406000	406000	568000	568000	812000	6820
108	2376	289000	412000	412000	577000	577000	825000	6950
111	2442	303000	433000	433000	606000	606000	865000	7290
114	2508	317000	453000	453000	635000	635000	907000	7640
117	2574	332000	474000	474000	664000	664000	948000	7980
120	2640	347000	495000	495000	694000	604000	991000	8310
122	2684	357000	510000	510000	714000	714000	1019000	8620
124	2728	367000	524000	524000	734000	734000	1048000	8920
127	2794	382000	546000	546000	764000	764000	1092000	9380
130	2860	398000	568000	568000	795000	795000	1136000	9840
132	2904	408000	583000	583000	816000	816000	1165000	10140
137	3014	434000	620000	620000	868000	868000	1240000	10910
142	3124	461000	658000	658000	921000	921000	1316000	11670
147	3234	488000	697000	697000	975000	975000	1393000	12440
152	3344	515000	736000	736000	1030000	1030000	1471000	13200
157	3454	543000	775000	775000	1085000	1085000	1550000	14000
162	3564	571000	816000	816000	1142000	1142000	1631000	14700

Note: The weight of chain is not to be more than $2^1/_2$% under the weight specified.

TABLE 2 (continued)
Stud-link Anchor-chain Proof and Break Tests

US Units

Chain Diameter	Length of Five Links		Normal Strength Grade 1		High Strength Grade 2		Extra-high Strength Grade 3		
			Proof Load	Breaking Load	Proof Load	Breaking Load	Proof Load	Breaking Load	Mass pounds per 15 fathoms
in.	ft	In	lbf	lbf	lbf	lbf	lbf	lbf	lb
1/2	-	11	10700	15300	15300	21400	21400	30600	230
9/16	1	0 3/8	13500	19300	19300	27000	27000	38600	290
5/8	1	1 3/4	16600	23700	23700	33200	33200	47500	370
11/16	1	3 1/8	20100	28600	28600	40100	40100	57300	410
3/4	1	4 1/2	23800	34000	34000	47600	47600	68000	480
13/16	1	5 7/8	27800	39800	39800	55700	55700	79500	570
7/8	1	7 1/4	32200	46000	46000	64400	64400	91800	660
15/16	1	8 5/8	36800	52600	52600	73700	73700	1050000	760
1	1	10	41800	59700	59700	86300	83600	119500	860
1 1/16	1	11 3/8	47000	67200	67200	94100	94100	135000	970
1 1/8	2	0 3/4	52600	75000	75000	105000	105000	150000	1080
1 3/16	2	2 1/8	58400	83400	83400	116500	116500	167000	1220
1 1/4	2	3 1/2	64500	92200	92200	129000	129000	184000	1350
1 5/16	2	4 7/8	70900	101500	101500	142000	142000	203000	1490
1 3/8	2	6 1/4	77500	111000	111000	155000	155000	222000	1630
1 7/16	2	7 5/8	84500	120500	120500	169000	169000	241000	1780
1 1/2	2	9	91700	131000	131000	183500	183500	262000	1940
1 9/16	2	10 3/8	99200	142000	142000	198500	198500	284000	2090
1 5/8	2	11 3/4	108000	153000	153000	214000	214000	306000	2240
1 11/16	3	1 1/8	115000	166500	166500	229000	229000	327000	2410
1 3/4	3	2 1/2	123500	176000	176000	247000	247000	352000	2590
1 13/16	3	3 7/8	132000	188500	188500	264000	264000	377000	2790
1 7/8	3	5 1/4	140500	201000	201000	281000	281000	402000	2980
1 15/16	3	6 5/8	149500	214000	214000	299000	299000	427000	3180
2	3	8	159000	227000	227000	318000	318000	454000	3360
2 1/16	3	9 3/8	168500	241000	241000	337000	337000	482000	3570
2 1/8	3	10 3/4	178500	255000	255000	357000	357000	510000	3790
2 3/16	4	0 1/8	188500	269000	269000	377000	377000	538000	4020
2 1/4	4	1 1/2	198500	284000	284000	396000	396000	570000	4250
2 5/16	4	2 7/8	209000	299000	299000	418000	418000	598000	4490
2 3/8	4	4 1/4	212000	314000	314000	440000	440000	628000	4730
2 7/16	4	5 5/8	231000	330000	330000	462000	462000	660000	4960
2 1/2	4	7	242000	346000	346000	484000	484000	692000	5270
2 9/16	4	8 3/8	254000	363000	363000	507000	507000	726000	5540
2 5/8	4	9 3/4	265000	379000	379000	530000	530000	758000	5820
2 11/16	4	11 1/8	277000	396000	396000	554000	554000	792000	6110
2 3/4	5	0 1/2	289000	413000	413000	578000	578000	826000	6410
2 13/16	5	1 7/8	301000	431000	431000	603000	603000	861000	6710
2 7/8	5	3 1/4	314000	449000	449000	628000	628000	897000	7020
2 15/16	5	4 5/8	327000	467000	467000	654000	654000	934000	7330
3	5	6	340000	485000	485000	679000	679000	970000	7650
3 1/16	5	7 3/8	353000	504000	504000	705000	705000	1008000	7980
3 1/8	5	8 3/4	366000	523000	523000	732000	732000	1046000	8320
3 3/16	5	10 1/8	380000	542000	542000	759000	759000	1084000	8660
3 1/4	5	11 1/2	393000	562000	562000	787000	787000	1124000	9010
3 5/16	6	0 7/8	407000	582000	582000	814000	814000	1163000	9360
3 3/8	6	2 1/4	421000	602000	602000	843000	843000	1204000	9730
3 7/16	6	3 5/8	435000	622000	622000	871000	871000	1244000	10100
3 1/2	6	5	450000	643000	643000	900000	900000	1285000	10500
3 9/16	6	6 3/8	465000	664000	664000	929000	929000	1327000	10900
3 5/8	6	7 3/4	479000	685000	685000	958000	958000	1369000	11300
3 3/4	6	10 1/2	509000	728000	728000	1019000	1019000	1455000	12000
3 7/8	7	1 1/4	540000	772000	772000	1080000	1080000	1543000	12900
3 15/16	7	2 5/8	556000	794000	794000	1111000	1111000	1587000	13300
4	7	4	571000	816000	816000	1143000	1143000	1632000	13700
4 1/8	7	6 3/4	603000	862000	862000	1207000	1207000	1724000	14600
4 1/4	7	9 1/2	636000	908000	908000	1272000	1272000	1817000	15400
4 3/8	8	0 1/4	669000	956000	956000	1338000	1338000	1911000	16200
4 1/2	8	3	703000	1004000	1004000	1405000	1405000	2008000	17100
4 5/8	8	5 3/4	737000	1053000	1053000	1474000	1474000	2105000	18000
4 3/4	8	8 1/2	772000	1102000	1102000	1543000	1543000	2204000	18900
4 7/8	8	11 1/4	807000	1153000	1153000	1613000	1613000	2305000	19900
5	9	2	842000	1203000	1203000	1685000	1685000	2407000	20900
5 1/8	9	4 3/4	878000	1255000	1255000	1757000	1757000	2509000	22000
5 3/8	9	10 1/4	951000	1359000	1359000	1903000	1903000	2718000	24000
5 5/8	10	3 3/4	1026000	1466000	1466000	2052000	2052000	2932000	26100
5 3/4	10	6 1/2	1064000	1520000	1520000	2128000	2128000	3039000	27000
6	11	0	1140000	1629000	1629000	2280000	2280000	3257000	29100
6 1/8	11	2 3/4	1179000	1684000	1684000	2357000	2357000	3367000	30200
6 3/8	11	8 1/4	1256000	1795000	1795000	2512000	2512000	3589000	32400

Note: See also 2-2-2/9

The weight of chain is not to be more than $2^1/_2$% under the weight specified.

TABLE 3
Unstudded Short-link Chain

SI Units (MKS Units)				
Diameter of Common Links	*Breaking Test*		*Proof Test*	
mm	*kN*	*kgf*	*kN*	*kgf*
6	11.6	1180	5.8	590
8	22.6	2300	11.3	1150
10	35.9	3660	17.9	1830
12	52.8	5380	26.4	2690
14	71.5	7290	35.8	3650
16	93.6	9540	46.8	4770
18	119.2	12150	59.9	6110
20	147.7	15060	74.4	7590
22	178.6	18210	89.7	9150
24	212.5	21670	106.5	10860
26	249.9	25480	125.0	12750
28	288.9	29460	144.5	14730
30	332.6	33920	166.8	16960
32	379.6	38710	189.5	19320
34	427.5	43590	213.6	21780
36	477.2	48660	239.3	24400
38	534.1	54460	267.1	27240

US Units		
Diameter of Common Links	*Breaking Test*	*Proof Test*
in.	*lbf*	*lbf*
5/16	5040	2520
3/8	7280	3640
7/16	10080	5040
1/2	13440	6720
9/16	16800	8400
5/8	20720	10360
11/16	25200	12600
3/4	30240	15120
13/16	35392	17696
7/8	40880	20440
15/16	47040	23520
1	53760	26880
1 1/16	60480	30240
1 1/8	67760	33880
1 3/16	75712	37856
1 1/4	84000	42000
1 5/16	92400	46200
1 3/8	101360	50680
1 7/16	110880	55440
1 1/2	120960	60480

PART
2

CHAPTER 2 Equipment

SECTION 3 Rolled Steel Bars for Chain, Cast and Forged Materials for Accessories and Materials for Studs

1 General *(2005)*

Rolled steel bars Grades U1, U2 or U3 for Grade 1, 2 or 3 chains, cast and forged materials for accessories and materials for studs are to be in accordance with this section. Bars for offshore mooring chains are to be in accordance with the ABS *Guide for the Certification of Offshore Mooring Chain*.

These Rules are not intended to replace or modify any part of a chain manufacturer's specification approved by the Bureau.

1.1 Process of Manufacture *(2005)*

The manufacturers of materials for anchor chain and accessories are to be approved. Approval is not required for Grade 1 bars. The bar manufacturers are to submit the manufacturing specifications and the details of the manufacturing procedure.

The steel is to be made by the open-hearth, basic oxygen, vacuum-arc remelt, electro-slag remelt electric-furnace or such other process as may be specially approved.

Unless otherwise stipulated, the steel bars are to be supplied in the as rolled condition.

1.3 Deoxidation Practice

Bars are to be fully killed and, in addition, Grade U2 or U3 bars are to be produced to a fine grain practice.

1.5 Chemical Composition and Heat Treatment *(1999)*

The chemical composition and heat treatment are to be in accordance with the manufacturer's specification that is to be approved by the Bureau. In general, they are to conform to 2-2-3/Table 1.

1.7 Mechanical Properties *(1999)*

Mechanical tests are to be carried out in accordance with 2-2-3/3 and the results are to meet the requirements in 2-2-2/Table 1.

1.9 Dimensional properties *(1999)*

Unless otherwise approved, the tolerances on diameter and roundness ($d_{max} - d_{min}$) are to be within the limits listed in 2-2-3/Table 2, where d_{max} and d_{min} are the maximum and minimum diameter measured at the section under consideration.

3 Material Testing

3.1 Heat Treatment of Test Specimens

Test specimens are to be taken from material heat-treated in the same manner as intended for the finished chain.

3.3 Number of Tests

One tensile and three impact test specimens are to be taken from two different bars of steel from each heat unless the material from a heat is less than 50 metric tons (49.21 long tons), in which case, tests from one bar will be sufficient. If, however, the material from one heat differs 9.5 mm (0.375 in.) or more in diameter, one set of tests is to be taken from the thinnest and thickest material rolled.

3.5 Tension Test Specimens *(1996)*

Tension test specimens for bar material are to be taken at $^2/_3r$, as shown in 2-2-2/Figure 1 or as close thereto as possible and machined to 2-1-1/Figure 1 or an appropriate national standard specimen.

The required minimum percentage of elongation values in 2-2-2/Table 1 are based on specimens having gauge lengths equal to five (5) times the diameter. For specimens having other gauge lengths, the equivalent elongation value is to be calculated by the following equation:

$$n = 2E(\sqrt{A}\,/L)^{0.4}$$

where

n = equivalent minimum elongation

A = actual cross-sectional area of the specimen

L = actual gauge length

E = specified minimum percentage elongation for specimens having a gauge length of five (5) times the diameter

The above equation is not applicable to quenched and tempered steel, for which the specimen is to have a gauge length of five (5) times the specimen diameter.

3.7 Bend Test Specimens

Bend test specimens may be either the full section of the bar or may be machined at the option of the manufacturer to a 25 mm (1 in.) diameter or to a rectangular cross section of 25 mm × 12.5 mm (1 in. × 0.5 in.), but not less than 12.5 mm × 12.5 mm (0.5 in. × 0.5 in.). Each specimen is to withstand, without fracture, cold bending around a mandrel diameter and through the angle specified in 2-2-2/Table 1.

3.9 Impact Test Specimens

Impact test specimens are to be in accordance with 2-1-1/11.11. They are to be cut and notched as shown in 2-2-2/Figure 1. The average value of three (3) specimens is to comply with the requirements of 2-2-2/Table 1.

3.11 Additional Tests before Rejection *(1996)*

When a specimen fails to meet the requirements of 2-2-2/Table 1, retests in accordance with 2-1-2/9.11, 2-1-2/9.13, 2-1-2/11.7 and 2-1-2/11.9 may be permitted, as applicable.

3.13 Manufacturer's Option

At the option of the chain manufacturer, the above material tests (normally conducted prior to chain fabrication) may be waived, provided the required test specimens representative of each heat are taken from finished links after final heat treatment, if any, and in the same proportion of number of tests to tonnage as outlined in 2-2-2/13.3.

3.15 Freedom from Defects *(2005)*

The materials are to be free from internal and surface defects that might impair proper workability and use. Surface defects may be repaired by grinding, provided the admissible tolerance is not exceeded.

3.17 Identification of Material *(2005)*

Manufacturers are to effectively operate an identification system ensuring traceability of the material to the original cast.

3.19 Marking *(2005)*

The minimum markings required for the steel bars are the manufacturer's brandmark, the steel grade and an abbreviated symbol of the heat. Steel bars having diameters up to and including 40 mm (1.6 in.) and combined into bundles may be marked on permanently affixed labels.

3.21 Material Certification *(2005)*

Bar material for Grade 2 or Grade 3 is to be certified by the Bureau. For each consignment, manufacturers shall forward to the Surveyor a certificate containing at least the following data:

- Manufacturer's name and/or purchaser's order No.
- Number and dimensions of bars and weight of consignment
- Steel specification and chain grade
- Heat number
- Manufacturing procedure
- Chemical composition
- Details of heat treatment of the test sample (where applicable)
- Results of mechanical tests (where applicable)
- Number of test specimens (where applicable)

3.23 Forged Steels for Chain Cables and Accessories *(2005)*

Forged steels used for the manufacture of chain cables and accessories are to be in compliance with Section 2-1-6 "Hull Steel Forgings", unless otherwise specified in the following paragraphs.

The chemical composition is to comply with the specification approved by the Bureau. The steel manufacturer must determine and certify the chemical composition of every heat of material.

The stock material may be supplied in the as-rolled condition. Finished forgings are to be properly heat treated, i.e., normalized, normalized and tempered or quenched and tempered, whichever is specified for the relevant grade of chain.

3.25 Cast Steels for Chain Cables and Accessories *(2005)*

Cast steels used for the manufacture of chain cables and accessories are to be in compliance with Section 2-1-5 "Hull Steel Castings", unless otherwise specified in the following paragraphs.

The chemical composition is to comply with the specification approved by the Bureau. The foundry is to determine and certify the chemical composition of every heat.

All castings must be properly heat treated (i.e., normalized, normalized and tempered or quenched and tempered), whichever is specified for the relevant grade of chain.

3.27 Materials for Studs *(2005)*

The studs are to be made of steel corresponding to that of the chain cable or from rolled, cast or forged mild steels. The use of other materials (e.g., gray or nodular cast iron) is not permitted.

TABLE 1
Rolled Bars for Chain – Chemical Composition and Intended Chain Condition *(2008)*

Bar Stock Grade	*U1*	*U2*	*U3*
Intended Chain Grade	*Grade 1*	*Grade 2*	*Grade 3*
Deoxidation	fully killed	fully killed, fine grain	fully killed, fine grain
Intended Chain Condition	as rolled	as rolled or normalized [4]	normalized, normalized and tempered or quenched and tempered
Chemical Composition [1], (Ladle Analysis) - % max unless specified otherwise			
C	0.20	0.24	0.36
Si	0.15 - 0.35	0.15 - 0.55	0.15 - 0.55
Mn	0.40 min.	1.00 - 1.60	1.00 - 1.90
P	0.040	0.035	0.035
S	0.040	0.035	0.035
Al [2] (total) min.	-	0.020	0.020
Bar Stock Marking	AB/U1	AB/U2 [3], [4]	AB/U3

Notes:

1 Other intentionally added elements are to be reported on the mill sheet.

2 Specified aluminum contents may be partly replaced by other grain refining elements. See 2-1-3/5.

3 Bars impact tested in accordance with Note 1 to 2-2-2/Table 1 to be marked AB/U2AW.

4 Normalized bars for Grade 2 chains are to be marked AB/U2N.

TABLE 2
Rolled Bar for Chain – Dimensional Tolerances *(1999)*

Specified Bar Diameter, mm (in.)		*Tolerance on Diameter,*	*Tolerance on ($d_{max} - d_{min}$)*
over	*up to*	*mm (in.)*	*mm (in.)*
less than 25 (1.0)		- 0, + 1.0 (0.04)	0.6 (0.02)
25 (1.0) or above	35 (1.37)	- 0, + 1.2 (0.05)	0.8 (0.03)
35 (1.37)	50 (2.0)	- 0, + 1.6 (0.06)	1.1 (0.04)
50 (2.0)	80 (3.12)	- 0, + 2.0 (0.08)	1.50 (0.06)
80 (3.12)	100 (4.0)	- 0, + 2.6 (0.10)	1.95 (0.08)
100 (4.0)	120 (4.75)	- 0, + 3.0 (0.12)	2.25 (0.09)
120 (4.75)	160 (6.25)	- 0, + 4.0 (0.16)	3.00 (0.12)

PART

2

Rules for Testing and Certification of Materials

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

CONTENTS

PART
2

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

SECTION 1 General Requirements

1 Testing and Inspection

1.1 General *(2007)*

All materials subject to test and inspection, intended for use in boilers, pressure vessels, piping and machinery of vessels classed or proposed for classification, are to be verified by the Surveyor in accordance with the following requirements or their equivalent. Materials, test specimens, and testing procedures having characteristics differing from those prescribed herein require special approval for each application of such materials and the physical tests may be modified to suit conditions as approved in connection with the design.

1.3 Test and Test Data

1.3.1 Witnessed Tests

The designation (W) indicates that the Surveyor is to witness the testing unless the plant and product is approved under the Bureau's Quality Assurance Program.

1.3.2 Manufacturer's Data

The designation (M) indicated that test data is to be provided by the manufacturer without verification by a Surveyor of the procedures used or the results obtained.

1.3.3 Other Tests

The designation (A) indicates those tests for which test data is to be provided by the supplier and audited by the Surveyor to verify that the procedures used and random tests witnessed are in compliance with Rule requirements.

See Part 2, Appendix 1 for the complete listing of indicated designations for the various tests called out by Part 2, Chapter 3.

1.5 Rejection of Previously Accepted Material

In the event of any material proving unsatisfactory in the process of being worked, it is to be rejected, notwithstanding any previous certificate of satisfactory testing.

1.7 Calibrated Testing Machines *(2005)*

The Surveyor is to be satisfied that the testing machines are maintained in a satisfactory and accurate condition and is to keep a record of the dates and by whom the machines were rechecked or calibrated. All tests are to be carried out to a recognized national or international Standard by competent personnel.

1.9 ASTM References

For identification of ASTM references, see 2-1-1/1.13.

3 Defects

All materials are to be free from cracks, injurious surface flaws, injurious laminations and similar defects. Except as indicated for specific materials, welding or dressing for the purpose of remedying defects is not permitted unless and until sanctioned by the Surveyor. In such cases, where sanction is required for materials to be so treated, the Surveyor may prescribe further probing and necessary heat treatment; then, if found satisfactory, the part treated is to be stamped with the Surveyor's identification mark and surrounded by a ring of paint.

5 Identification of Materials

The manufacturer is to adopt a system of marking ingots, slabs, finished plates, shapes, castings and forgings which will enable the material to be traced to its original heat; and the Surveyor is to be given every facility for so tracing material.

7 Manufacturer's Certificates

7.1 Form of Certificate

Unless requested otherwise, four copies of the certified mill test reports and shipping information (may be separate or combined documents) of all accepted material indicating the grade of steel, heat identification numbers, test results and weight shipped are to be furnished to the Surveyor. One copy of the mill test report is to be endorsed by the Surveyor and forwarded to the Purchaser, and three are to be retained for the use of the Bureau. Before the certified mill test reports and shipping information are distributed to the local Bureau office, the manufacturer is to furnish the Surveyor with a certificate stating that the material has been made by an approved process and that it has satisfactorily withstood the prescribed tests. The following form of certificate will be accepted if printed on each certified mill test report with the name of the firm and initialed by the authorized representative of the manufacturer:

"We hereby certify that the material described herein has been made to the applicable specification by the _____ process (state process) and tested in accordance with the requirements of _____ (the American Bureau of Shipping Rules or state other specification) with satisfactory results."

At the request of manufacturers, consideration may be given to modifications in the form of the certificate, provided it correspondingly indicates compliance with the requirements of the Rules to no less degree than indicated in the foregoing statement.

7.3 Other Certificates

Where steel is not produced in the works at which it is rolled or forged, a certificate is to be supplied to the Surveyor stating the process by which it was manufactured, the name of the manufacturer who supplied it and the number of the heat from which it was made. The number of the heat is to be marked on each plate or bar for the purpose of identification.

9 Marking and Retests

9.1 Identification of Test Specimens

Where test specimens are required to be selected by the Surveyor, they are not to be detached until stamped with his identification mark; but in no case, except as otherwise specified, are they to be detached until the material has received its final treatment. Satisfactory Bureau-tested material is to be stamped **AB**, or as specified for a particular material, to indicate compliance with the requirements.

9.3 Defects in Specimens

If any test specimen shows defective machining or develops defects, it may be discarded and another specimen substituted, except that for forgings, a retest is not allowed if a defect develops during testing which is caused by rupture, cracks, or flakes in the steel.

9.5 Retests *(2005)*

The elongation value is, in principle, valid only if the distance between the fracture and the nearest gauge mark is not less than one-third of the original gauge length. However, the result is valid irrespective of the location of the fracture if the percentage elongation after fracture is equal to or greater than the required value.

Generally, elongation, A_5, is determined on a proportional gauge length, $5.65\sqrt{S_0} = 5d$, but may also be given for other specified gauge lengths.

If the material is a ferritic steel of low or medium strength and not cold worked, and the elongation is measured on a non-proportional gauge length, the required elongation, A_0, on that gauge length, L_0, may after agreement be calculated from the following formula:

$$A_0 = 2A_5\left(\frac{\sqrt{S_0}}{L_0}\right)^{0.40}$$

9.7 Rejected Material

In the event that any set of test specimens fails to meet the requirements, the material from which such specimens have been taken are to be rejected and the required markings withheld or obliterated.

11 Standard Test Specimens

11.1 General

Test specimens are to be taken longitudinally and of the full thickness or section of material as rolled, except as otherwise specified.

11.3 Test Specimens *(2005)*

Test specimens are to receive no other preparation than that prescribed and are to similarly and simultaneously receive all of the treatment given the material from which they are cut, except as otherwise specified. Straightening of specimens distorted by shearing is to be carried out while the piece is cold. The accuracy of the tensile test machines is to be within ±1% of the load.

11.5 Tension Test Specimens for Plates and Shapes

Tension test specimens for rolled plates, shapes and flats are to be cut from the finished material and machined to the form and dimensions shown in 2-3-1/Figure 1, or they may be prepared with both edges parallel throughout their length. Alternatives to the foregoing are indicated under specific materials.

11.7 Tension Test Specimens for Castings (Other than Gray Cast Iron) and Forgings *(2006)*

Tension test specimens for castings (other than gray cast iron) and forgings are to be machined to the form and dimensions shown for the round specimen alternative C in 2-3-1/Figure 1 or in accordance with 2-3-1/Figure 2.

11.9 Tension Test Specimens (for Gray Cast Iron) *(2006)*

Tension test specimens for gray cast iron are, unless otherwise approved, to be machined to the form and dimensions shown in 2-3-1/Figure 3 from test bars cast separately from the casting represented. Such test bars are to be poured from ladles of iron used to pour the castings and under the same sand conditions, and they are to receive the same thermal treatment as the castings they represent.

11.11 Transverse or Flexure Test Specimens for Gray Cast Iron *(2006)*

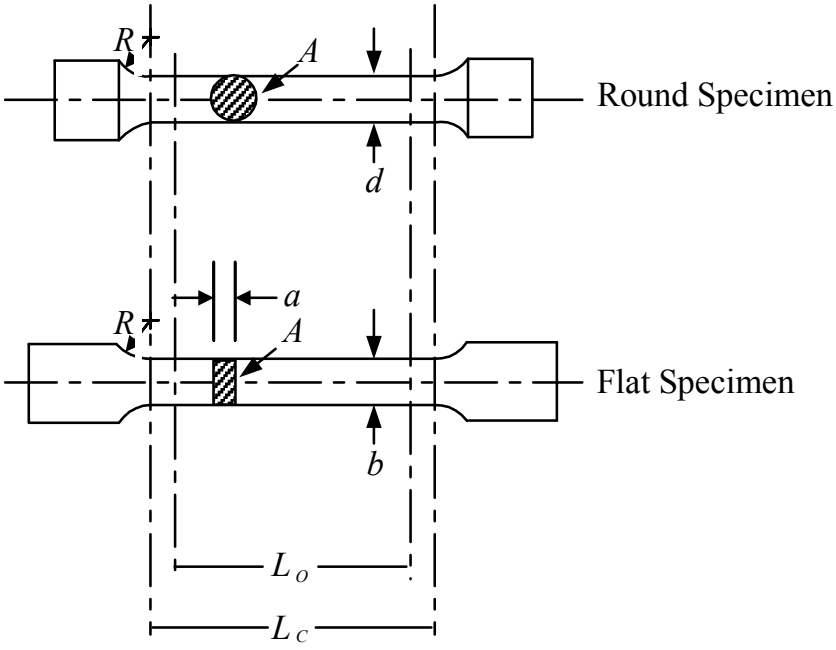
Transverse or flexure test specimens for gray cast iron are, unless otherwise approved, to be a test bar as cast with a 50 mm (2 in.) diameter and 700 mm (27 in.) length. Such test bars are to be cast under the same conditions as described in 2-3-1/11.9.

11.13 Bend Test Specimens for Steel Castings and Forgings *(2005)*

When required, bend test specimens for steel castings and forgings may be machined to 25 mm × 20 mm (1 in. × 0.790 in.) in section. The length is unimportant, provided that it is enough to perform the bending operation.

The edges on the tensile side of the bend test specimens may have the corners rounded to a radius of 1–2 mm (0.040–0.080 in.).

FIGURE 1
Standard Tension Test Specimen (1) *(2006)*



d = diameter in mm
a = thickness in mm
b = width in mm
L_o = original gauge length in mm
L_c = parallel length in mm
A = original cross sectional area in mm^2
R = transition radius in mm

	d	a	b	L_o	L_c	R
Flat specimen Alternative A	–	t (2)	25	$5.65\sqrt{A}$	$L_o + 2\sqrt{A}$	25
Flat specimen Alternative B	–	t (2)	25	200	225	25
Round specimen Alternative C	14	–	–	70	85	10

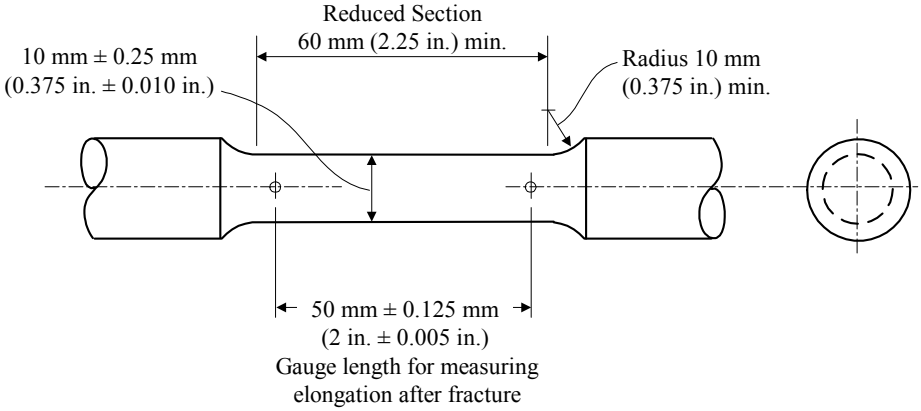
Notes:

1 Standard specimen in accordance with ASTM E8/E8M or A370 will also be acceptable in conjunction with the corresponding elongation requirements in 2-1-2/Table 2 or 2-1-3/Table 2.

2 t is the full thickness of the material as produced. If the capacity of the testing machine does not allow full thickness specimens to be broken, the thickness may be reduced by machining one surface only.

3 L_o, the proportional gauge length, is to be greater than 20 mm.

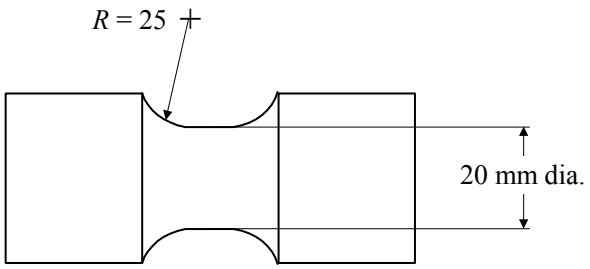
FIGURE 2
Standard Round Tension Test Specimen with 50 mm (2 in.) Gauge Length *(2008)*



Note:

(2008) The gauge length and fillets are to be as shown, but the ends may be of any shape to fit the holders of the testing machine in such a way that the load is to be axial. The reduced section may have a gradual taper from the ends towards the center, with the ends not more than 0.13 mm (0.005 in.) larger in diameter than the center.

FIGURE 3
Tension Test Specimen Machined from Transverse or Flexure Test Bars for Gray Cast Iron *(2006)*



13 Definition and Determination of Yield Point and Yield Strength

13.1 Yield Point *(2005)*

The yield point is the first stress in a material, less than the maximum obtainable stress, at which an increase in strain occurs without an increase in stress. The value of stress is measured at the commencement of plastic deformation at yield, or the value of stress measured at the first peak obtained during yielding even when that peak is equal to or less than any subsequent peaks observed during plastic deformation at yield. Yield point may be determined by the halt of the pointer or autographic diagram. The 0.5% total extension under load method will also be considered acceptable.

The test is to be carried out with an elastic stress within the following limits:

Modulus of Elasticity of the Material (E), N/mm^2	*Rate of Stressing, N/mm^2-s^{-1}*	
	Min.	*Max.*
< 150,000	2	20
≥ 150,000	6	60

13.3 Yield Strength *(2005)*

The yield strength is the stress at which a material exhibits a specified limiting deviation from the proportionality of stress to strain. When no well-defined yield phenomenon exists, yield strength is to be determined by the 0.2% (*Rp 0.2*) offset method. Alternatively, for material whose stress-strain characteristics are well known from previous tests in which stress-strain diagrams were plotted, the 0.5% extension under load method may be used. When agreed upon between the supplier and purchaser for austenitic and duplex stainless steel products, the 1% proof stress (*Rp 1*) may be determined in addition to *Rp 0.2*.

The rate of loading is to be as stated in the limits above:

13.5 Tensile Strength *(2005)*

After reaching the yield or proof load, for ductile material, the machine speed during the tensile test is not to exceed that corresponding to a strain rate of 0.008 s^{-1}. For brittle materials, such as gray cast iron, the elastic stress rate is not to exceed 10 N/mm^2 per second.

15 Permissible Variations in Dimensions *(1994)*

15.1 Scope

The under tolerance specified below represents the minimum material certification requirements and is to be considered as the lower limit of usual range of variations (plus/minus) from the specified dimension.

The responsibility for meeting the specified tolerances rests with the manufacturer who is to maintain a procedure acceptable to the Surveyor.

15.3 Plates *(1996)*

The maximum permissible under thickness tolerance for plates and wide flats for construction of machinery, excluding boilers, pressure vessels and independent tanks for liquefied gases and chemicals (see 2-3-2/1.15), is to be in accordance with the following:

Nominal Thickness, t, in mm (in.)	*Under Thickness Tolerance in mm. (in.)*
$5 \le t < 8$ mm ($0.20 \le t < 0.32$ in.)	0.4 mm (0.016 in.)
$8 \le t < 15$ mm ($0.32 \le t < 0.59$ in.)	0.5 mm (0.02 in.)
$15 \le t < 25$ mm ($0.59 \le t < 0.98$ in.)	0.6 mm (0.024 in.)
$25 \le t < 40$ mm ($0.98 \le t < 1.57$ in.)	0.8 mm (0.032 in.)
$t \ge 40$ mm ($t \ge 1.57$ in.)	1.0 mm (0.04 in.)

The thickness is to be measured at a distance of 10 mm (0.375 in.) or more from the edge.

The under thickness tolerance for plates and wide flats less than 5 mm (0.20 in.) in thickness will be specially considered.

PART
2

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

SECTION 2 **Steel Plates for Machinery, Boilers and Pressure Vessels**

1 General Requirements for All Grades of Steel Plates for Machinery, Boilers, and Pressure Vessels

1.1 General

1.1.1 Examination at Mills *(2008)*

The grades of steel covered in 2-3-2/3, 2-3-2/5 and 2-3-2/7 are rolled plates intended for use in machinery, boilers and other pressure vessels. All tests are to be conducted in the presence of the Surveyor at the place of manufacture prior to shipping, unless the plant is approved under the Bureau's Quality Assurance Program for Rolled Products. The material surfaces will be examined by the Surveyor when specially requested by the purchaser. Plates are to be free from defects and have a workmanlike finish, subject to the conditions given under 2-3-2/1.17.

1.1.2 Alloy Steels or Special Carbon Steels

When alloy steels or carbon steels differing from those indicated herein are proposed for any purpose, the purchaser's specification is to be submitted for approval in connection with the approval of the design for which the material is proposed. Specifications such as ASTM A387 (Grade C or Grade D) or other steels suitable for the intended service will be considered.

1.3 Marking

1.3.1 Plates and Test Specimens

The name or brand of the manufacturer, the letter indicating the grade of steel, the manufacturer's identification numbers and the letters **PV** to indicate pressure-vessel quality are to be legibly stamped (except as specified in 2-3-2/1.3.4) on each finished plate in two places, not less than 300 mm (12 in.) from the edges. Plates, the maximum lengthwise and crosswise dimensions of which do not exceed 1800 mm (72 in.), are to have the marking stamped in one place approximately midway between the center and an edge. The manufacturer's test identification number is to be legibly stamped on each test specimen. All test specimens are to be ring-stamped, match-marked or otherwise suitably identified to the satisfaction of the attending Surveyor before being detached.

1.3.2 Heat-treatment Marking

When the heat treatment is to be carried out by the fabricator as covered in 2-3-2/5.5 and 2-3-2/7.5, the letter **G** is to also be stamped on each plate by the steel producer to indicate that the material is in the unheat-treated (green) condition. After heat treatment at the fabricator's plant, the letter **T** is to be stamped following the letter **G**.

1.3.3 Bureau Markings

The Bureau markings **AB**, indicating satisfactory compliance with the Rule requirements and other markings as furnished by the Surveyor, are to be stamped on all plates near the marking specified in 2-3-2/1.3.1 to signify that the material has satisfactorily complied with the test prescribed, and that certificates for the material will be furnished to the Surveyor in accordance with 2-3-1/7. For coiled steel which is certified for chemical analysis only, the marking **AB** without grade designation is to be marked on the outer wrap of each coil shipped.

1.3.4 Thin Plates

Plates under 6.4 mm (0.25 in.) in thickness are to be legibly stenciled with the markings specified in 2-3-2/1.3.1 and 2-3-2/1.3.2 instead of stamped.

1.3.5 Special Impact Testing

When steel is impact tested in accordance with 2-3-2/9, the grade marking is to be followed by the test temperature in degrees Celsius. A prefix "0" to the test temperature is to indicate a temperature colder than zero degrees Celsius.

1.5 Process of Manufacture

The steel is to be made by one or more of the following processes: open-hearth, basic-oxygen or electric-furnace. The steel may be cast in ingots or may be strand (continuous) cast. The ratio of reduction of thickness from strand (continuous) cast slab to finished plate is to be a minimum of 3 to 1 unless specially approved.

1.5.1 Plates Produced from Coils

For coiled plate, the manufacturer or processor is to submit supporting data for review and approval to indicate that the manufacturing, processing and testing will provide material which is in compliance with the Rules.

1.7 Chemical Composition

1.7.1 Ladle Analysis

An analysis of each heat of steel is to be made by the manufacturer to determine the percentage of the elements specified. This analysis is to be made from a test sample taken during pouring of the heat. The chemical composition thus determined is to be reported to the Surveyor and is to conform to the requirements as specified for each grade in 2-3-2/3.5, 2-3-2/5.7 or 2-3-2/7.7.

1.7.2 Check Analysis

The chemical composition determined by check analysis is to conform to the requirements as specified for each Grade in 2-3-2/3.5, 2-3-2/5.7, and 2-3-2/7.7.

1.9 Test Specimens

1.9.1 Selection of Specimens

One tension test specimen is to be taken from each plate as rolled in such manner that the longitudinal axis of the specimen is transverse to the final direction of rolling of the plate. The tension test specimen is to be taken from a corner of the plate. If the final rolling direction of the plate is parallel to the original longitudinal ingot axis, the tension test specimen is to be taken from the "bottom" end of the plate. If the final direction of rolling of the plate is transverse to the original longitudinal ingot axis, or if the relationship of final rolling direction and original ingot axis is unknown, the tension test specimen may be taken from either end. For plates produced from coils, two tension test specimens are to be made from each coil. One tension test specimen is to be obtained from a location immediately prior to the first plate produced and a second test specimen obtained from the approximate center lap. When required, impact tests are to be obtained adjacent to both tension test coupons and a third coupon is to be obtained immediately after the last plate produced to the qualifying grade or specification.

1.9.2 Specimens from Plates 19 mm (0.75 in.) and Under in Thickness

For plates 19 mm (0.75 in.) and under in thickness, tension test specimens are to be the full thickness of the material and are to be machined to the form and dimensions shown in 2-3-1/Figure 1 or with both edges parallel.

1.9.3 Specimens from Plates Over 19 mm (0.75 in.) Thickness

For plates over 19 mm (0.75 in.) in thickness, tension test specimens may be machined to the form and dimensions shown in 2-3-1/Figure 2, and the axis of each such specimen is to be located as nearly as practicable midway between the center and the surface of the plate, or for plates up to 101.6 mm (4 in.) inclusive in thickness, they may be the full thickness of the material and of the form shown in 2-3-1/Figure 1 when adequate testing-machine capacity is available.

1.9.4 Stress Relieving

When required, test specimens are to be stress-relieved by gradually and uniformly heating them to 590–650°C (1100–1200°F), holding at temperature for at least 1 hour per 25 mm (1 in.) thickness and cooling in still atmosphere to a temperature not exceeding 315°C (600°F). If applicable, in the case of plates which are to be heat-treated and subsequently stress-relieved, the test specimens for such plates are to, before testing, be stress-relieved following the heat treatment.

1.11 Tensile Properties

1.11.1 Tensile Requirements

The material is to conform to the tensile requirements as specified for each grade in 2-3-2/3.9, 2-3-2/5.11 or 2-3-2/7.11.

1.11.2 Elongation Deduction for Material Under 7.9 mm (0.313 in.) Thick

For material under 7.9 mm (0.313 in.) in thickness, a deduction from the specified percentage of elongation in 200 mm (8 in.) of 1.25% is to be made for each decrease of 0.8 mm (0.031 in.) of the specified thickness below 7.9 mm (0.313 in.).

1.11.3 Elongation Deduction for Material Over 88.9 mm (3.50 in.) Thick

For material over 88.9 mm (3.50 in.) in thickness, a deduction from the specified percentage of elongation in 50 mm (2 in.) of 0.50% is to be made for each increase of 12.7 mm (0.50 in.) of the specified thickness above 88.9 mm (3.50 in.). This deduction is not to exceed 3%.

1.13 Retests

1.13.1 For All Thicknesses

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 plate and tested in the manner specified, but in such case, both of the specimens are to conform to the requirements (see 2-3-1/9.5).

1.13.2 For Heat-treated Material *(2008)*

If any heat-treated material fails to meet the mechanical requirements, the material may be reheat-treated, and all physical tests are to be repeated. Where plates are specially ordered requiring surface inspection, the Surveyor is to reexamine the plate surfaces following any additional heat treatment.

1.15 Thickness Variation

No plate is to vary more than 0.25 mm (0.01 in.) or 6% under the thickness specified, whichever is the lesser (See 4-4-1A1/1.7).

1.17 Finish

Except when ordered for riveted construction, plates may be conditioned by the manufacturer, for the removal of surface defects on either surface by grinding, provided the ground area is well faired and grinding does not reduce the thickness of the plate below the permissible minimum thickness.

1.19 Weldability

All of the grades covered in 2-3-2/3, 2-3-2/5 and 2-3-2/7 are intended for fusion welding, but welding technique is of fundamental importance and the welding procedure is to be in accordance with approved methods. See Part 2, Chapter 4.

3 Steel Plates for Intermediate-temperature Service

3.1 Scope

Three grades of low and intermediate-tensile-strength carbon-steel plates designated MA, MB, and MC are covered.

3.3 General

The various grades are in substantial agreement with ASTM designations as follows.

ASTM – A285 Grades A, B, C

ABS – Grades MA, MB, MC

The maximum thickness of these grades is to be 50.8 mm (2.0 in.).

3.5 Chemical Composition

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

	Grade MA	*Grade MB*	*Grade MC*
Carbon, max., %	0.17	0.22	0.28
Manganese, max., %	0.90	0.90	0.90
Phosphorus, max., %	0.035	0.035	0.035
Sulfur, max., %	0.045	0.045	0.045
Copper*, when Copper Steel is specified			
Ladle Analysis	0.20/0.35	0.20/0.35	0.20/0.35
Check Analysis	0.18/0.37	0.18/0.37	0.18/0.37

Note: See 2-3-2/1.7.

* When specified, the maximum incidental copper content is to be 0.25%.

3.7 Specimen Preparation

Test specimens are to be prepared for testing from material in its rolled condition.

3.9 Tensile Properties

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

	Grade MA	*Grade MB*	*Grade MC*
Tensile Strength N/mm^2 (kgf/mm^2) (psi)	310–450 (31.5–46) (45000–65000)	345–485 (35–49) (50000–70000)	380–515 (39–53) (55000–75000)
Yield Strength, min., N/mm^2 (kgf/mm^2, psi)	165 (17, 24000)	185 (19, 27000)	205 (21, 30000)
Elongation in 200 mm (8 in.) min., %*	27	25	23
Elongation in 50 mm (2 in.) min., %	30	28	27

* See 2-3-2/1.11.2 and 2-3-2/1.11.3.

5 Steel Plates for Intermediate- and Higher-temperature Service

5.1 Scope

Seven grades of steel plates designated MD, ME, MF, MG, H, I and J are covered. Grades MD, ME, MF and MG cover intermediate and higher-tensile-strength ranges in carbon-silicon steel plates; Grades H, I and J cover three high-tensile-strength ranges in carbon-molybdenum steel plates.

5.3 General

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

ASTM – A515 Grades 55, 60, 65, 70	ABS – Grades MD, ME, MF, MG
ASTM – A204 Grades A, B, C	ABS – Grades H, I, J

Plates are limited in thickness as follows: Grade MD to 304.8 mm (12.0 in.); Grades ME, MF and MG to 203.2 mm (8.0 in.); Grades H and I to 152.4 mm (6.0 in.) and Grade J to 101.6 mm (4 in.).

5.5 Heat Treatment

5.5.1 Treatment

Plates of Grades MD, ME, MF and MG over 50.8 mm (2.0 in.) and Grades H, I and J over 38.1 mm (1.5 in.) in thickness are to be treated either by normalizing or heating uniformly for hot forming. If the required treatment is to be obtained in conjunction with the hot-forming operation, the temperature to which the plates are heated for hot forming is to be equivalent to and is not to significantly exceed the normalizing temperature. If this treatment is not done at the rolling mill, the testing is to be carried out in accordance with 2-3-2/5.5.3.

5.5.2 Heat-treatment Instructions on Orders

Orders to the plate manufacturer or the fabricator are to specify when plates are to be heat-treated and any special requirement that the test specimens be stress-relieved, so that proper provision may be made for the heat treatment of the test specimens. The purchaser is to also indicate in the orders to the mill whether the rolling mill or the fabricator is to perform the required heat treatment of the plates.

5.5.3 Responsibility for Heat Treatment

When a fabricator is equipped and elects to perform the required normalizing or fabricates by hot forming as provided in 2-3-2/5.5.1, the plates are to be accepted on the basis of tests made at the plate manufacturer's plant on specimens heat-treated in accordance with the purchaser's order requirements. If the heat-treatment temperatures are not indicated on the purchase order, the plate manufacturer is to heat-treat the specimens under conditions considered appropriate to meet the test requirements. The plate manufacturer is to inform the fabricator of the procedure followed in treating the specimens at the mill for guidance in treating the plates. When the plates are to be normalized at the plate manufacturer's plant, the mechanical properties are to be determined on specimens simultaneously treated with the plates.

5.7 Chemical Composition

The steel is to conform to the requirements of 2-3-2/Table 1 as to chemical composition.

5.9 Test Specimens

5.9.1 Plates Not Requiring Heat Treatment

For plates not requiring heat treatment (see 2-3-2/5.5.1), the test specimens are to be prepared for testing from the material in its rolled condition. When Grades H, I and J plates are to be used in a boiler or pressure vessel which is to be stress-relieved, the test specimens for Grades H, I and J are to be stress-relieved. See 2-3-2/1.9.

5.9.2 Plates Requiring Heat Treatment

For plates requiring heat treatment (see 2-3-2/5.5.1), the test specimens are to be prepared from the material in its heat-treated condition, or from full-thickness samples similarly and simultaneously treated. When Grades H, I and J plates are to be used in a boiler or pressure vessel which is to be stress-relieved, the test specimens for Grades H, I and J are to be stress-relieved following the heat treatment. See 2-3-2/1.9 and 2-3-2/5.5.

5.11 Tensile Properties

The material is to conform to the requirements of 2-3-2/Table 2 as to tensile properties.

7 Steel Plates for Intermediate- and Lower-temperature Service

7.1 Scope

Four grades of carbon-manganese-silicon steel plates made to fine-grain practice in four tensile-strength ranges designated K, L, M, N are covered.

7.3 General

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

ASTM – A516 Grades 55, 60, 65, 70

ABS – Grades K, L, M, N

Plates are limited in thickness, as follows: Grade K to 304.8 mm (12.0 in.); Grades L, M and N to 203.2 mm (8.0 in.).

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

7.5 Heat Treatment

7.5.1 Grain Refinement

Plates over 38.1 mm (1.5 in.) are to be heat-treated to produce grain refinement either by normalizing or heating uniformly for hot forming. If the required treatment is to be obtained in conjunction with hot forming, the temperature to which the plates are heated for hot forming is to be equivalent to and is not to exceed significantly the normalizing temperature. If this treatment is not done at the rolling mill, the testing is to be carried out in accordance with 2-3-2/7.5.3. When improved notch toughness is required for plates 38 mm (1.5 in.) and under in thickness, heat treatment is to be specified as above.

7.5.2 Heat-treatment Instructions on Orders

Orders to the plate manufacturer or the fabricator are to specify when plates are to be heat-treated for grain refinement, and any special requirements that the test specimens be stress-relieved, so that proper provision may be made for the heat treatment of the test specimens. The purchaser is also to indicate in the orders to the mill whether the rolling mill or the fabricator is to perform the required heat treatment of the plates.

7.5.3 Responsibility for Heat Treatment

When a fabricator is equipped and elects to perform the required normalizing or fabricates by hot forming as provided in 2-3-2/7.5.1, the plates are to be accepted on the basis of tests made at the plate manufacturer's plant on specimens heat-treated in accordance with the purchaser's order requirements. If the heat-treatment temperatures are not indicated on the purchase order, the plate manufacturer is to heat-treat the specimens under conditions considered appropriate for grain refinement, and to meet the test requirements. The plate manufacturer is to inform the fabricator of the procedure followed in treating the specimens at the mill for guidance in treating the plates. When the plates are to be normalized at the plate manufacturer's plant, the mechanical properties are to be determined on specimens simultaneously treated with the plates.

7.7 Chemical Composition

The steel is to conform to the requirements of 2-3-2/Table 3 as to chemical composition.

7.9 Test Specimens

7.9.1 Plates 38.1 mm (1.5 in.) and Under in Thickness

For plates 38.1 mm (1.5 in.) and under in thickness, not requiring heat treatment, the test specimens are to be prepared for testing from the material in its rolled condition.

7.9.2 Plates Requiring Heat Treatment

For plates 38.1 mm (1.5 in.) and under in thickness, requiring heat treatment (see 2-3-2/7.5.1), or for plates over 38.1 mm (1.5 in.) in thickness, the test specimens are to be prepared from the material in its heat-treated condition, or from full-thickness samples similarly and simultaneously treated.

7.11 Tensile Properties

The material is to conform to the requirements of 2-3-2/Table 4 as to tensile properties.

9 Materials for Low Temperature Service [Below -18°C (0°F)]

Materials intended for service temperatures of below -18°C (0°F) may be provided in accordance with those requirements listed in 2-1-4/9. Other special low temperature materials, when the Charpy V-notch impact tests are conducted at 5°C (10°F) below minimum design temperature in accordance with 2-1-4/5.1 and meet the applicable requirements of 2-1-2/11 and 5C-8-6/Table 2 (ABS) may also be accepted. Such tests are not required for austenitic stainless steels or aluminum alloys such as type 5083.

TABLE 1
Chemical Composition for Plate Grades MD, ME, MF, MG, H, I, J

Note *See also 2-3-2/1.7*

	MD	*ME*	*MF*	*MG*	*H*	*I*	*J*
Carbon, max., %:							
For plates 25.4 mm (1.0 in.) and under in thickness	0.20	0.24	0.28	0.31	0.18	0.20	0.23
For plates over 25.4 mm (1.0 in.) to 50.8 mm (2.0 in.) incl., in thickness	0.22	0.27	0.31	0.33	0.21	0.23	0.26
For plates over 50.8 mm (2.0 in.) to 101.6 mm (4.0 in.) incl., in thickness	0.24	0.29	0.33	0.35	0.23	0.25	0.28
For plates over 101.6 mm (4.0 in.) to 203.2 mm (8.0 in.) incl., in thickness	0.26	0.31	0.33	0.35	0.25	0.27	
For plates over 203.2 mm (8.0 in.) to 304.8 mm (12.0 in.) incl., in thickness	0.28						
Manganese, max., %	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Phosphorous max., %	0.035	0.035	0.035	0.035	0.035	0.035	0.035
Sulphur, max., %	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Silicon, %:							
Ladle analysis	0.15-0.30	0.15-0.30	0.15-0.30	0.15-0.30	0.15-0.30	0.15-0.30	0.15-0.30
Check analysis	0.13-0.33	0.13-0.33	0.13-0.33	0.13-0.33	0.13-0.32	0.13-0.32	0.13-0.32
Molybdenum, %:							
Ladle analysis					0.45-0.60	0.45-0.60	0.45-0.60
Check analysis					0.41-0.64	0.41-0.64	0.41-0.64

TABLE 2
Tensile Properties for Plate Grades MD, ME, MF, MG, H, I, J

A characteristic of certain types of alloy steels is a local, disproportionate increase in the degree of necking down or contraction of the specimens under tension tests, resulting in a decrease in the percentage of elongation as the gauge length is increased. The effect is not so pronounced in the thicker plates.

	MD	***ME***	***MF***	***MG***	***H***	***I***	***J***
Tensile Strength,							
N/mm^2	380-515	415-550	450-585	485-620	450-585	485-620	515-655
kgf/mm^2	39-53	42-56	46-60	49-63	46-60	49-63	53-67
psi	55000-75000	60000-80000	65000-85000	70000-90000	65000-85000	70000-90000	75000-95000
Yield Strength, min.,							
N/mm^2	205	220	240	260	255	275	295
kgf/mm^2	21	22.5	24.5	27	26	28	30.5
psi	30000	32000	35000	38000	37000	40000	43000
Elongation in 200 mm, (8 in.), min., %	23 [a]	21 [a]	19 [a]	17 [a]	19 [a,d]	17 [a,d]	16 [a,d]
Elongation in 50 mm, (2 in.) min., % [c]	27 [b]	25 [b]	23 [b]	21 [b]	23 [b]	21 [b]	20 [b]

Notes

a See 2-3-2/1.11.2

b See 2-3-2/1.11.3

c When specimen shown in 2-3-1/Figure 2 is used.

d For plates over 6.4 mm (0.25 in.) to 19.1 mm (0.75 in.) inclusive, in thickness, if the percentage of elongation of a 200 mm (8 in.) gauge-length test specimen falls not more than 3% below the amount specified, the elongation is to be considered satisfactory, provided the percentage of elongation in 50 mm (2 in.) across the break is not less than 25%.

TABLE 3
Chemical Composition for Plate Grades K, L, M, N

Note *See also 2-3-2/1.7*

	K	*L*	*M*	*N*
Carbon, max., %:				
For plates 12.7 mm (0.50 in.) and under in thickness	0.18	0.21	0.24	0.27
Over 12.7 mm (0.50 in.) to 50.8 mm (2.0 in.) incl.	0.20	0.23	0.26	0.28
Over 50.8 mm (2.0 in.) to 101.6 mm (4.0 in.) incl.	0.22	0.25	0.28	0.30
Over 101.6 mm (4.0 in.) to 203.2 mm (8.0 in.) incl.	0.24	0.27	0.29	0.31
Over 203.2 mm (8.0 in.) to 304.8 mm (12.0 in.) incl.	0.26			
Manganese, %:				
For plates 12.7 mm (0.50 in.) and under in thickness				
Ladle	0.60/0.90	0.60/0.90	0.85/1.20	0.85/1.20
Check	0.56/0.94	0.56/0.94	0.80/1.25	0.80/1.25
Over 12.7 mm (0.50 in.) to 304.8 mm (12.0 in.) incl				
Ladle	0.60/1.20	0.85/1.20	0.85/1.20	0.85/1.20
Check	0.56/1.25	0.80/1.25	0.80/1.25	0.80/1.25
Phosphorus, max., %	0.035	0.035	0.035	0.035
Sulphur, max., %	0.04	0.04	0.04	0.04
Silicon, %:				
Ladle	0.15/0.30	0.15/0.30	0.15/0.30	0.15/0.30
Check	0.13/0.33	0.13/0.33	0.13/0.33	0.13/0.33

TABLE 4
Tensile Properties for Plate Grades K, L, M, N

	K	*L*	*M*	*N*
Tensile Strength,				
N/mm^2	380-515	415-550	450-585	485-620
kgf/mm^2	39 to 53	42 to 56	46 to 60	49 to 63
psi	55000-75000	60000-80000	65000-85000	70000-90000
Yield Strength, min.,				
N/mm^2	205	220	240	260
kgf/mm^2	21	22.5	24.5	27
psi	30000	32000	35000	38000
Elongation in 200 mm, (8 in.), min., %	23 (a)	21 (a)	19 (a)	17 (a)
Elongation in 50 mm, (2 in.), min., % (c)	27 (b)	25 (b)	23 (b)	21 (b)

Notes:

a See 2-3-2/1.11.2

b See 2-3-2/1.11.3

c When specimen shown in 2-3-1/Figure 2 is used.

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

SECTION 3 Seamless Forged-steel Drums

Note: In substantial agreement with ASTM A266 as to physical properties for Classes 1 and 3.

1 Tests and Inspections

In the event that any seamless forged-steel drums are presented for survey after special approval for each specific application, they are to be tested and surveyed in general accordance with the applicable procedures given for steel forgings. One tension test is to be taken from each end of the forging midway between the inner and outer surfaces of the wall in a tangential direction, the two specimens being taken from opposite sides of the drum. Grade A material is to have the following minimum properties, tensile strength 415 N/mm^2 (42 kgf/mm^2, 60,000 psi), yield strength 205 N/mm^2 (21 kgf/mm^2, 30,000 psi), elongation 23% in a 50 mm (2 in.) gauge length; Grade B material is to have the following minimum properties, tensile strength 515 N/mm^2 (53 kgf/mm^2, 75,000 psi), yield strength 260 N/mm^2 (26.5 kgf/mm^2, 37,500 psi), elongation 19% in a 50 mm (2 in.) gauge length.

3 Heat Treatment

Except as specified herein, tests for acceptance are to be made after final treatment of the forgings. When the ends of drums are closed in by reforging after machining, the drums may be treated and tested prior to reforging. After reforging, the whole of the forging is to be simultaneously re-treated. If the original treatment was annealing, the re-anneal is to be above the transformation range, but not above the temperature of the first anneal. If the original treatment was normalizing and tempering, the re-treatment is to be identical with the original.

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

SECTION 4 **Seamless-steel Pressure Vessels**

1 General

The material for the manufacture of and the finished seamless pressure vessels are to be free from seams, cracks or other defects. Test specimens are to be cut from each cylinder before the necking-down process, stamped with the identification mark of the Surveyor and is to receive all heat treatments simultaneously with the cylinders.

3 Tension Test

A standard test specimen cut either longitudinally or circumferentially from each cylinder is to show the material to have a minimum tensile strength of 415 N/mm^2 (42 kgf/mm^2, 60,000 psi), maximum yield point of 70% of the tensile strength and a minimum elongation of 10% in 200 mm (8 in.).

5 Flattening Test

A ring 200 mm (8 in.) long is to be cut from each cylinder and is to stand being flattened without signs of fracture until the outside distance over the parallel sides is not greater than six times the thickness of the material.

7 Hydrostatic Test

Each cylinder is to be subjected to a hydrostatic pressure of not less than one and one-half times the working pressure while submerged in a water jacket for a period of at least thirty seconds. The permanent volumetric expansion is not to exceed 5% of the total volumetric expansion at the prescribed test pressure. This test is to be made without previously subjecting the cylinder to any pressure in excess of one-third of the working pressure.

9 Inspection

All cylinders are to be properly annealed and be free from dirt and scale. Before necking-down, the Surveyor is to examine the cylinders carefully for defects and gauge the cylinder walls to ascertain that the thickness of the material is in accordance with the approved plan.

11 Marking

Upon satisfactory compliance with the above requirements, the cylinders will be stamped **AB** with the identification mark of the Surveyor, the serial number, hydrostatic pressure and the date of acceptance.

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

SECTION **5 Boiler and Superheater Tubes**

1 Scope *(1998)*

The following specifications cover thirteen grades of boiler and superheater tubes designated D, F, G, H, J, K, L, M, N, O, P, R, and S.

3 General

3.1 Grades D and F

Grades D and F cover electric-resistance-welded tubes made of carbon steel and intended for boiler tubes, boiler flues, superheater flues and safe ends. Grade F tubes are not suitable for safe-ending by forge-welding.

3.3 Grade G

Grade G covers electric-resistance-welded, steel boiler and superheater tubes intended for high-pressure service.

3.5 Grade H

Grade H covers seamless carbon-steel boiler tubes and superheater tubes intended for high-pressure service.

3.7 Grade J

Grade J covers seamless medium carbon-steel boiler tubes and superheater tubes, boiler flues, including safe ends, arch and stay tubes. Grade J tubes are not suitable for safe-ending by forge-welding.

3.9 Grades K, L and M

Grades K, L and M cover seamless carbon-molybdenum alloy-steel boiler and superheater tubes.

3.11 Grades N, O and P

Grades N, O and P cover seamless chromium-molybdenum alloy-steel boiler and superheater tubes.

3.13 Grades R and S *(1998)*

Grades R and S cover seamless austenitic stainless steel superheater tubes.

3.15 ASTM Designation *(1998)*

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

ABS Grade	*ASTM Designation*
D	A178, Grade A
F	A178, Grade C
G	A226
H	A192
J	A210, Grade A-1
K	A209, Grade T1
L	A209, Grade T1a
M	A209, Grade T1b
N	A213, Grade T11
O	A213, Grade T12
P	A213, Grade T22
R	A213, Grade TP321
S	A213, Grade TP347

5 Process of Manufacture

5.1 Grades D, F, and G

The steel is to be made by one or more of the following processes: open-hearth, basic-oxygen or electric-furnace. Special consideration may be given to other processes, subject to such supplementary requirements or limits on application as will be specially determined in each case. Grade G is to be killed steel. All tubes of Grade D, F, and G are to be made by electric-resistance welding and are to be normalized at a temperature above the upper critical temperature.

5.3 Grades H, J, K, L, and M *(1998)*

The steel is to be killed steel made by one or more of the following processes: open hearth, electric furnace, or basic oxygen furnace. Tubes are to be made by the seamless process and are to be either hot-finished or cold-drawn. Cold-drawn tubes are to be heat-treated by isothermal annealing or by full annealing at a temperature of 650°C (1200°F) or higher. Cold-drawn tubes of Grades H, and J may also be heat-treated by normalizing. Cold-drawn tubes of Grades K, L, and M may also be heat-treated by normalizing and tempering at 650°C (1200°F) or higher. Hot-finished Grades H and J tubes need not be heat-treated. Hot-finished Grades K, L, and M tubes are to be heat-treated at a temperature of 650°C (1200°F) or higher.

5.5 Grades N, O, and P *(1998)*

The steel is to be made by the electric-furnace process or other approved process, except that Grade N may be made by the basic oxygen process and Grade O by basic oxygen or open hearth process. Tubes are to be made by the seamless process and are to be either hot-finished or cold-drawn. All material is to be furnished in the heat-treated condition. The heat treatment for Grades N and P is to consist of full annealing, isothermal annealing, or normalizing and tempering, as necessary to meet the requirements. The tempering temperature following normalizing is to be 650°C (1200°F) or higher for Grade N and 680°C (1250°F) or higher for Grade P. The hot-rolled or cold-drawn tubes Grade O, as a final heat treatment, are to be process annealed at 650°C (1200°F) to 730°C (1350°F).

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 *(2010)*

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.

Before undertaking the repair welding of forgings, the manufacturer is to prove to the satisfaction of the Surveyor that the welders or welding operators are duly qualified for the work intended.

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 *(2009)*

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

ABS Grade	*ASTM Designation*
A1	A291 Grade2
A2	A291 Grade 3
A3	A291 Grade 4
A4	A291 Grade 5
A5	A291 Grade 6
A6	A291 Grade 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:

Required Heat Treatment and Minimum Tempering Temperature

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 $L \le D$.
- 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.

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 $L \le D$.
- 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.

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/mm² (kgf/mm², ksi)*	*Yield Strength (2), in N/mm² (kgf/mm², ksi)*	*Yield Strength (3), in N/mm² (kgf/mm², 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

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.

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 *(2010)*

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.

Before undertaking the repair welding of castings, the manufacturer is to prove to the satisfaction of the Surveyor that the welders or welding operators are duly qualified for the work intended.

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

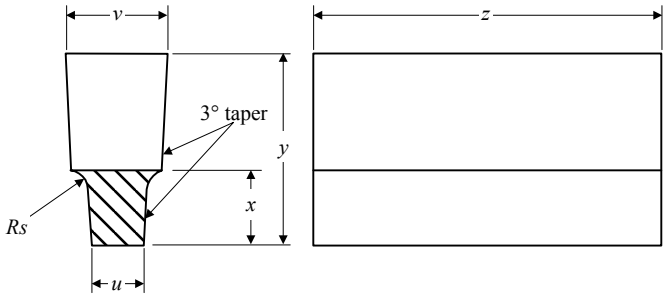
11.1

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

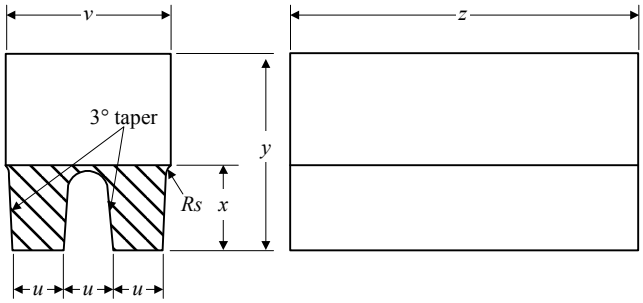
The test samples are generally to be one of the standard types detailed in 2-3-10/Figures 1, 2 and 3 with a thickness of 25 mm (1.0 in.). Test samples of other dimensions to 2-3-10/Figures 1, 2 and 3 may, however, be specially required for some components.

FIGURE 1
Type A Test Samples (U-type)



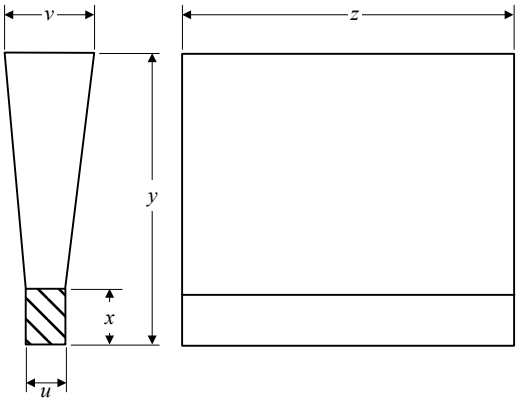
Dimensions – mm (in.)	*Standard Sample*	*Alternative Samples when Specially Required*		
u	25 (1.0)	12 (0.5)	50 (2.0)	75 (3.0)
v	55 (2.2)	40 (1.6)	90 (3.5)	125 (5.0)
x	40 (1.6)	30 (1.2)	60 (2.4)	65 (2.6)
y	100 (4.0)	80 (3.2)	150 (6.0)	165 (6.5)
z	To suit testing machine			
Rs	Approximately 5 mm (0.20 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/mm² (ksi)	*0.2% proof stress, N/mm² (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/mm² (ksi)	*0.2% proof stress, N/mm² (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 crankshafts 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

PART
2

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

SECTION 11 Gray-iron Castings *(2006)*

1 Scope

1.1

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

1.3

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

1.5

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

3 Process of Manufacture

3.1 *(2008)*

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

3.3

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

3.5

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

5 Quality of Castings

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

7 Chemical Composition

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

9 Heat Treatment

9.1

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

9.3

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

11 Mechanical Tests

11.1

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

11.3

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

11.5

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

11.7

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

11.9

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

11.11

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

11.13

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

11.15

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

11.17

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

11.19

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

11.21

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

13 Mechanical Properties

13.1 Tensile Strength

13.1.1

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

13.1.2

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

13.1.3 Higher Strength Castings

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

15 Inspection

15.1

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

15.3

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

15.5

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

15.7

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

15.9

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

17 Rectification of Defective Casting

17.1

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

17.3

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

17.5

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

19 Identification of Castings

19.1

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

19.3

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

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

19.5

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

21 Certification

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

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

PART
2

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

SECTION 12 **Steel Piping**

1 Scope *(1998)*

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

3 General

3.1 Grades 1, 2 and 3

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

3.3 Grades 4 and 5

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

3.5 Grade 6

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

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

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

3.9 Grades 8 and 9

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

3.11 ASTM Designations *(2006)*

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

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

5 Process of Manufacture

5.1 Grades 1, 2 and 3

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

5.3 Grades 4 and 5

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

5.5 Grades 6 and 7

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

5.7 Grades 8 and 9

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

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

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

7 Marking *(1998)*

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

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

9 Chemical Composition

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

11 Ladle Analysis *(1998)*

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

13 Check Analysis

13.1 General

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

13.3 Samples

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

13.5 Grades 1, 2 and 3

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

13.7 Grades 4 and 5

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

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

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

13.11 Grades 8 and 9

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

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

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

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

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

13.17 Retests for Grades 8 and 9

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

15 Mechanical Tests Required *(1998)*

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

17 Tension Test Specimens

17.1 Grades 1, 2 and 3

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

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

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

17.3.1 Longitudinal Tension Test Specimens

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

17.3.2 Transverse Tension Test Specimens

Transverse tension test specimens may be taken from a ring cut from the pipe or from sections resulting from the flattening tests. Test specimens are to consist of strips cut transversely from the pipe; the width of the specimens is to be 38 mm (1.5 in.) and their gauge length 50 mm (2 in.). When the pipe-wall thickness is 19.1 mm (0.75 in.) and over, the tension test specimen shown in 2-3-1/Figure 2 may be used. Specimens cut from the ring section are to be flattened cold and are to be parallel between gauge marks. Specimens from Grades 6, 7, 11, 12, 13 and 14 pipes are to be flattened cold and heat-treated in the same manner as the pipe. Transverse tension test specimens may be machined off on either or both surfaces to secure uniform thickness.

17.5 Grades 8 and 9

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

19 Bend and Flattening Test Specimens

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

21 Testing Temperature

All test specimens are to be tested at room temperature.

23 Tensile Properties

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

25 Bend Test

25.1 General

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

25.3 Details of Test

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

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

27 Flattening Test

27.1 General

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

27.3 Furnace-welded Pipe

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

27.3.1 Test Step No. 1

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

27.3.2 Test Step No. 2

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

27.3.3 Test Step No. 3

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

27.5 Electric-resistance-welded Pipe

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

27.5.1 Test Step No. 1

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

27.5.2 Test Step No. 2

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

27.5.3 Test Step No. 3

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

27.7 Seamless Pipe *(1998)*

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

27.7.1 Test Step No. 1

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

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

where

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

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

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

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

= 0.09 for Grade 2

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

= 0.07 for Grades 3 and 5

27.7.2 Test Step No. 2

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

29 Hydrostatic Test

29.1 General *(1998)*

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

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

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

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

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

29.7 Grades 8 and 9

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

29.9 Test Pressures *(1999)*

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

$$P = KSt/D$$

where

K = 20 (200, 2)

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

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

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

S = permissible fiber stress

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

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

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

29.11 Exceptions *(1999)*

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

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

31.1 General

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

31.3 Ultrasonic Calibration Standards

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

31.5 Eddy-Current Calibration Standards

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

31.5.1 Drilled Hole

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

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

31.5.2 Transverse Tangential Notch

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

31.5.3 Longitudinal Notch

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

31.7 Flux Leakage Calibration Standards

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

31.9 Rejection

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

31.11 Affidavits

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

33 Retests

33.1 General *(1998)*

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

33.3 Grades 1, 2, 3, 8 and 9

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

33.5 Grades 4 and 5

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

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

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

35 Pipe Testing and Inspection

35.1 Group I Piping *(2008)*

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

35.3 Group I and II Piping *(1998)*

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

37 Permissible Variation in Wall Thickness *(1998)*

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

39 Permissible Variations in Outside Diameter

39.1 Grades 1, 2, 3

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

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

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

39.5 Grades 8 and 9

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

39.7 Inspection *(1998)*

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

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

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

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

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

* Dimensions refer to nominal pipe diameter.

TABLE 3
Mechanical Tests for Pipe *(1998)*

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

Notes

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

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

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

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

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

TABLE 4
Tensile Requirements for Pipe *(1998)*

SI Units & MKS Units

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

Notes

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

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

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

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

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

US Units

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

Notes

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

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

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

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

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

SI Units

Pressure in bars

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

MKS Units

Pressure in kgf/cm^2

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

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

US Units

Pressure in psi

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

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

Millimeters

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

Inches

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