Steel Pipes and Tubes

■ *Section 1*
General requirements

1.1 Scope

1.1.1 This Section gives the general requirements for boiler tubes, superheater tubes and pipes intended for use in the construction of boilers, pressure vessels and pressure piping systems.

1.1.2 In addition to specifying mechanical properties for the purpose of acceptance testing, these requirements give details of appropriate mechanical properties at elevated temperatures to be used for design purposes.

1.1.3 Except for pipes for Class III pressure systems (as defined in the relevant Rules), all pipes and tubes are to be manufactured and tested in accordance with the requirements of *Ch 1 General Requirements* and *Ch 2 Testing Procedures for Metallic Materials*, the general requirements of this Section and the appropriate specific requirements given in *Ch 6, 2 Seamless pressure pipes*, *Ch 6, 3 Welded pressure pipes*, *Ch 6, 4 Ferritic steel pressure pipes for low temperature service*, *Ch 6, 5 Stainless steel pressure pipes* and *Ch 6, 6 Boiler and superheater tubes*.

1.1.4 Steels intended for the piping systems for liquefied gases where the design temperature is less than 0°C are to comply with the specific requirements of *Ch 6, 4 Ferritic steel pressure pipes for low temperature service* or *Ch 6, 5 Stainless steel pressure pipes*.

1.1.5 As an alternative to *Ch 6, 1.1 Scope 1.1.3* and *Ch 6, 1.1 Scope 1.1.4*, pipes or tubes which comply with National or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of this Chapter or alternatively are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of *Ch 1 General Requirements*.

1.1.6 At the discretion of the Surveyor, a modified testing procedure may be adopted for small quantities of materials. In such cases, these may be accepted on the manufacturer's declared chemical composition and hardness tests or other evidence of satisfactory properties.

1.1.7 Pipes for Class III pressure systems are to be manufactured and tested in accordance with the requirements of an acceptable National specification. The manufacturer's test certificate will be acceptable and is to be provided for each consignment of material. Forge butt welded pipes are not acceptable for fuel oil systems, heating coils in oil tanks, primary refrigerant systems and other applications where the pressure exceeds 0,4 MPa.

1.2 Manufacture

1.2.1 Pipes for Class I and II pressure systems, boiler and superheater tubes are to be manufactured at works approved by Lloyd's Register (hereinafter referred as 'LR'). The steel used is to be manufactured and cast in ingot moulds or by an approved continuous casting process as detailed in *Ch 3, 1.4 Manufacture*.

1.2.2 Unless a particular method is requested by the purchaser, pipes and tubes may be manufactured by any of the following methods:

- Hot finished seamless.
- Cold finished seamless.
- Electric resistance or induction welded.

- Cold finished electric resistance or induction welded.
- Electric fusion welded.

1.2.3 Care is to be taken during manufacture that the pipe or tube surfaces coming in contact with any non-ferrous metals or their compounds are not contaminated to such an extent as could prove harmful during subsequent fabrication and operation.

1.3 Quality

1.3.1 All pipes and tubes are to have a workmanlike finish and are to be clean and free from such surface and internal defects as can be established by the specified tests.

1.3.2 All pipes and tubes are to be reasonably straight. The ends are to be cut nominally square with the axis of the pipe or tube, and are to be free from excessive burrs.

1.4 Dimensional tolerances

1.4.1 The tolerances on the wall thickness and diameter of pipes and tubes are to be in accordance with an acceptable National specification.

1.5 Chemical composition

1.5.1 The requirements for the chemical composition of ladle samples and acceptable methods of deoxidation are detailed in subsequent Sections in this Chapter.

1.6 Heat treatment

1.6.1 All pipes and tubes are to be supplied in the condition detailed in the relevant specific requirements.

1.7 Test material

1.7.1 Pipes and tubes are to be presented for test in batches. The size of a batch and the number of tests to be performed are dependent on the application.

1.7.2 Where heat treatment has been carried out, a batch is to consist of pipes or tubes of the same size, manufactured from the same types of steel and subjected to the same finishing treatment in a continuous furnace, or heat treated together in the same batch type furnace.

1.7.3 Where no heat treatment has been carried out, a batch is to consist of pipes or tubes of the same size manufactured by the same method from material of the same type of steel.

1.7.4 For pipes for Class I pressure systems and boiler and superheater tubes, at least two per cent of the number of lengths in each batch is to be selected at random for the preparation of tests at ambient temperature.

1.7.5 For pipes for Class II pressure systems, each batch is to contain not more than the number of lengths given in *Table 6.1.1 Batch sizes for pipes for Class II pressure systems*. Tests are to be carried out on at least one pipe selected at random from each batch or part thereof.

Table 6.1.1 Batch sizes for pipes for Class II pressure systems

Outside diameter mm	Number in batch
≤323,9	200 pipes as made
>323,9	100 pipes as made

1.8 Dimensions of test specimens and test procedures

1.8.1 The procedures for mechanical tests and the dimensions of the test specimens are to be in accordance with *Ch 2 Testing Procedures for Metallic Materials*.

1.9 Visual and non-destructive testing

1.9.1 All pipes for Class I and II pressure systems, boiler and superheater tubes, are to be presented for visual examination and verification of dimensions. The manufacturer is to provide adequate lighting conditions to enable an internal and external examination of the pipes and tubes to be carried out.

1.9.2 For welded pipes and tubes, the manufacturer is to employ suitable non-destructive methods for the quality control of the welds. It is preferred that this examination is carried out on a continuous basis.

1.10 Hydraulic test

1.10.1 Each pipe and tube is to be subjected to a hydraulic test at the manufacturer's works.

1.10.2 The hydraulic test pressure is to be determined from the following formula, except that the maximum test pressure need not exceed 14 MPa:

$$P = \frac{2st}{D}$$

where

P = test pressure, in MPa

D = nominal outside diameter, in mm

t = nominal wall thickness, in mm

s = 80 per cent of the specified minimum yield stress, in N/mm^2, for ferritic steels and 70 per cent of the specified minimum, 1,0 per cent proof stress, in N/mm^2, for austenitic steels. These relate to the values specified for acceptance testing at ambient temperature.

1.10.3 The test pressure is to be maintained for sufficient time to permit proof and inspection. Unless otherwise agreed, the manufacturer's certificate of satisfactory hydraulic test will be accepted. Where it is proposed to adopt a test pressure other than that determined as in *Ch 6, 1.10 Hydraulic test 1.10.2*, the proposal will be subject to special consideration.

1.10.4 Subject to special approval, either an ultrasonic or eddy current test can be accepted in lieu of the hydraulic test.

1.11 Rectification of defects

1.11.1 Surface imperfections may be removed by grinding provided that the thickness of the pipe or tube after dressing is not less than the required minimum thickness. The dressed area is to be blended into the contour of the tube.

1.11.2 By agreement with the Surveyor, the repair of minor defects by welding can be accepted, subject to welding procedure tests which demonstrate acceptable properties appropriate for the grade of pipe to be repaired. Weld procedure tests are to be subjected to the same heat treatment as will be applied to the actual pipes after weld repair.

1.11.3 The repaired area is to be tested by magnetic particle examination, or, for austenitic steels, by liquid penetrant examination on completion of welding, heat treatment and surface grinding.

1.12 Identification

1.12.1 Pipes and tubes are to be clearly marked by the manufacturer in accordance with the requirements of *Ch 1 General Requirements*. The following details are to be shown on all materials which have been accepted:

(a) LR or Lloyd's Register.
(b) Manufacturer's name or trade mark.
(c) Identification mark for the specification or grade of steel.
(d) Identification number and/or initials which will enable the full history of the item to be traced.

1.12.2 It is recommended that hard stamping be restricted to the end face, but it may be accepted in other positions in accordance with National Standards and practices.

1.13 Certification of materials

1.13.1 Unless a LR certificate is specified in other parts of the Rules, a manufacturer’s certificate validated by LR is to be issued, *see Ch 1, 3.1 General*.

1.13.2 The manufacturer is to provide LR with the following information:

(a) Purchaser's name and order number.
(b) If known, the contract number for which the material is intended.
(c) Address to which material is despatched.
(d) Specification or the grade of material.
(e) Description and dimensions.
(f) Identification number and/or initials.
(g) Cast number and chemical composition of ladle samples.

(h) Mechanical test results, and results of the intercrystalline corrosion tests where applicable.

(i) Condition of supply.

1.13.3 As a minimum, the chemical composition stated on the certificate is to include the content of all the elements detailed in the specific requirements. Where rimming steel is supplied, this is to be stated on the certificate.

1.13.4 When steel is not produced at the pipe or tube mill, a certificate is to be supplied by the steelmaker stating the process of manufacture, the cast number and the ladle analysis.

1.13.5 The steel manufacturer's works is to be approved by LR.

■ *Section 2*
Seamless pressure pipes

2.1 Scope

2.1.1 Provision is made in this Section for seamless pressure pipes in carbon, carbon-manganese and low alloy steels.

2.1.2 Where pipes are used for the manufacture of pressure vessel shells and headers, the requirements for forgings in *Ch 5, 7 Forgings for boilers, pressure vessels and piping systems* are applicable where the wall thickness exceeds 40 mm.

2.2 Manufacture and chemical composition

2.2.1 Pipes are to be manufactured by a seamless process and may be hot or cold finished.

2.2.2 The method of deoxidation and the chemical composition of ladle samples are to comply with the appropriate requirements given in *Table 6.2.1 Chemical composition of seamless pressure pipes*.

Table 6.2.1 Chemical composition of seamless pressure pipes

Type of steel	Grade	Method of deoxidation	Chemical composition of ladle samples %												
			C	Si	Mn	S max.	P max.	Residual elements							
Carbon and carbon-manganese	320	Semi-killed or killed	≤0,16	—	0,40—0,70	0,050	0,050	Ni 0,30 max. Cr 0,25 max. Mo 0,10 max. Cu 0,30 max. Total 0,70 max.							
	360		≤0,17	≤0,35	0,40—0,80	0,045	0,045								
	410	Killed	≤0,21	≤0,35	0,40—1,20	0,045	0,045								
	460		≤0,22	≤0,35	0,80—1,40	0,045	0,045								
	490		≤0,23	≤0,35	0,80—1,50	0,045	0,045								
$1Cr^{1}/_{2}Mo$	440	Killed	0,10 – 0,18	0,10 – 0,35	0,40—0,70	0,040	0,040	Ni	Cr	Mo	Cu	Sn	V	Al	
								0,30 max.	0,70 – 1,10	0,45 – 0,65	0,25 max.	0,03 max.	—	≤0,020	

$2^1/_4$Cr1Mo	410 490	Killed	0,08 – 0,15	0,10 – 0,50	0,40 — 0,70	0,040	0,040	0,30 max.	2,0— 2,5	0,90— 1,20	0,25 max.	0,03 max.	—	≤0,020
$^1/_2$Cr$^1/_2$Mo$^1/_4$V	460	Killed	0,10 – 0,18	0,10 – 0,35	0,40 — 0,70	0,040	0,040	0,30	0,30— 0,60	0,50— 0,70	0,25 max.	0,03 max.	0,22— 0,32	≤0,020

2.3 Heat treatment

2.3.1 Pipes are to be supplied in the condition given in *Table 6.2.2 Heat treatment*.

2.4 Mechanical tests

2.4.1 All pipes are to be presented in batches as defined in *Ch 6, 1 General requirements*.

2.4.2 Each pressure pipe selected for test is to be subjected to tensile and flattening or bend tests.

2.4.3 The results of all mechanical tests are to comply with the appropriate requirements given in *Table 6.2.3 Mechanical properties for acceptance purposes: seamless pressure pipes (maximum wall thickness 40 mm), see 2.1.2* .

2.5 Mechanical properties for design

2.5.1 Values for nominal minimum lower yield or 0,2 per cent proof stress at temperatures of 50°C and higher are given in *Table 6.2.4 Mechanical properties for design purposes: seamless pressure pipes* and are intended for design purposes only. Verification of these values is not required, except for materials complying with National or proprietary specification where the elevated temperature properties used for design are higher than those given in *Table 6.2.4 Mechanical properties for design purposes: seamless pressure pipes*.

2.5.2 In such cases, at least one tensile test at the proposed design or other agreed temperature is to be made on each cast. The test specimen is to be taken from material adjacent to that used for tests at ambient temperature and tested in accordance with the procedures given in *Ch 2 Testing Procedures for Metallic Materials*. If tubes or pipes of more than one thickness are supplied from one cast, the test is to be made on the thickest tube or pipe.

Table 6.2.2 Heat treatment

Type of steel		Condition of supply
Carbon and carbon-manganese		
Hot finished		Hot finished (*see* Note 1) Normalised (*see* Note 2)
Cold finished		Normalised (*see* Note 2)
Alloy steel		
1Cr$^1/_2$Mo		Normalised and tempered
$2^1/_4$Cr1Mo	Grade 410	Fully annealed
	Grade 490	Normalised and tempered 650—780°C
	Grade 490	Normalised and tempered 650—750°C
$^1/_2$Cr$^1/_2$Mo$^1/_4$V		Normalised and tempered
Note 1. Provided that the finishing temperature is sufficiently high to soften the material.		
Note 2. Normalised and tempered at the option of the manufacturer.		

2.5.3 As an alternative to *Ch 6, 2.5 Mechanical properties for design 2.5.2*, a manufacturer may carry out an agreed comprehensive test program for a stated grade of steel to demonstrate that the specified minimum mechanical properties at elevated temperatures can be consistently obtained. This test program is to be carried out under the supervision of the Surveyors, and the results submitted for assessment and approval. When a manufacturer is approved on this basis, tensile tests at elevated

temperatures are not required for acceptance purposes, but at the discretion of the Surveyors occasional check tests of this type may be requested.

2.5.4 Values for the estimated average stress to rupture in 100 000 hours are given in *Table 6.2.5 Mechanical properties for design purposes: seamless pressure pipes - Estimated values for stress to rupture in 100,000 hours (units N/mm^2)* and may be used for design purposes.

Table 6.2.3 Mechanical properties for acceptance purposes: seamless pressure pipes (maximum wall thickness 40 mm), *see* 2.1.2

Type of steel	Grade	Yield stress N/mm^2	Tensile strength N/mm^2	Elongation on 5,65 $\sqrt{S_o}$ % minimum	Flattening test constant *C*	Bend test diameter of former (*t* = thickness)
Carbon and carbon-manganese	320	195	320—440	25	0,10	4*t*
	360	215	360—480	24	0,10	
	410	235	410—530	22	0,08	
	460	265	460—580	21	0,07	
	490	285	490—610	21	0,07	
1Cr$^1/_2$Mo	440	275	440—590	22	0,07	4*t*
2$^1/_4$Cr1Mo	410 (see Note 1)	135	410—560	20	0,07	4*t*
	490 (see Note 2)	275	490—640	16		
$^1/_2$Cr$^1/_2$Mo$^1/_4$V	460	275	460—610	15	0,07	4*t*

Note 1. Annealed condition.

Note 2. Normalised and tempered condition.

Table 6.2.4 Mechanical properties for design purposes: seamless pressure pipes

Type of steel	Grade	Nominal minimum lower yield or 0,2% proof stress N/mm^2											
		Temperature °C											
		50	100	150	200	250	300	350	400	450	500	550	600
Carbon and carbon-manganese	320	172	168	158	147	125	100	91	88	87	—	—	—
	360	192	187	176	165	145	122	111	109	107	—	—	—
	410	217	210	199	188	170	149	137	134	132	—	—	—
	460	241	234	223	212	195	177	162	159	156	—	—	—
	490	256	249	237	226	210	193	177	174	171	—	—	—
1Cr$^1/_2$Mo	440	254	240	230	220	210	183	169	164	161	156	151	—
2$^1/_2$Cr1Mo	410 (see Note 1)	121	108	99	92	85	80	76	72	69	66	64	62
	490 (see Note 2)	268	261	253	245	236	230	224	218	205	189	167	145

$^1/_2Cr^1/_2Mo^1/_4V$	460	266	259	248	235	218	192	184	177	168	155	148	—

Note 1. Annealed condition.

Note 2. Normalised and tempered condition.

Table 6.2.5 Mechanical properties for design purposes: seamless pressure pipes - Estimated values for stress to rupture in 100,000 hours (units N/mm^2)

Temperature °C	Carbon and carbon-manganese		$1Cr^1/_2Mo$	$2^1/_4Cr1Mo$		$^1/_2Cr^1/_2Mo^1/_4V$
	Grade 320	Grade 460	Grade 440	Grade 410	Grade 490	Grade 460
	Grade 360	Grade 490		Annealed	Normalised and tempered (*see* Note)	
	Grade 410					
380	171	227	—	—	—	—
390	155	203	—	—	—	—
400	141	179	—	—	—	—
410	127	157	—	—	—	—
420	114	136	—	—	—	—
430	102	117	—	—	—	—
440	90	100	—	—	—	—
450	78	85	—	196	221	—
460	67	73	—	182	204	—
470	57	63	—	168	186	—
480	47	55	210	154	170	218
490	36	47	177	141	153	191
500	—	41	146	127	137	170
510	—	—	121	115	122	150
520	—	—	99	102	107	131
530	—	—	81	90	93	116
540	—	—	67	78	79	100
550	—	—	54	69	69	85
560	—	—	43	59	59	72
570	—	—	35	51	51	59
580	—	—	—	44	44	46

Note When the tempering temperature exceeds 750°C, the values for Grade 410 are to be used.

Section 3
Welded pressure pipes

3.1 Scope

3.1.1 Provision is made in this Section for welded pressure pipes in carbon, carbon-manganese and low alloy steels.

3.2 Manufacture and chemical composition

3.2.1 Pipes are to be manufactured by the electric resistance or induction welding process and, if required, may be subsequently hot reduced or cold finished.

3.2.2 Where it is proposed to use other welding processes, details of the welding processes and procedures are to be submitted for review.

3.2.3 In all cases, welding procedure tests are required. Test samples are to be subjected to the same heat treatment as the pipe.

3.2.4 The method of deoxidation and the chemical composition of ladle samples are to comply with the appropriate requirements given in *Table 6.3.1 Chemical composition of welded pressure pipes*.

3.3 Heat treatment

3.3.1 Pipes are to be supplied in the heat treated condition given in *Table 6.3.3 Heat treatment: welded pressure pipes*.

3.4 Mechanical tests

3.4.1 All pipes are to be presented in batches as defined in *Ch 6, 1 General requirements*.

3.4.2 Each pressure pipe selected for test is to be subjected to tensile and flattening or bend tests.

3.4.3 The results of all mechanical tests are to comply with the appropriate requirements given in *Table 6.3.2 Mechanical properties for acceptance purposes: welded pressure pipes*.

3.5 Mechanical properties for design

3.5.1 The mechanical properties at elevated temperature for carbon and carbon-manganese steels in Grades 320 to 460 and 1Cr½Mo steel can be taken from the appropriate Tables in *Ch 6, 2 Seamless pressure pipes*.

Table 6.3.1 Chemical composition of welded pressure pipes

Type of steel	Grade	Method of deoxidation	Chemical composition of ladle samples %					
			C	Si	Mn	S max.	P max.	Residual elements
Carbon and carbon-manganese	320	Any method (*see* Note)	≤0,16	–	0,30–0,70	0,050	0,050	Ni 0,30 max. Cr 0,25 max. Mo 0,10 max. Cu 0,30 max. Total 0,70 max.
	360		≤0,17	≤0,35	0,40–1,00	0,045	0,045	
	410	Killed	≤0,21	≤0,35	0,40–1,20	0,045	0,045	
	460		≤0,22	≤0,35	0,80–1,40	0,045	0,045	

1Cr$^1/_2$Mo	440	Killed	0,10 – 0,18	0,10 – 0,35	0,40– 0,70	0,040	0,040	Ni	Cr	Mo	Cu	Sn	Al
								0,30 max.	0,70– 1,10	0,45– 0,65	0,25 max.	0,03 max.	≤0,020
Note For rimming steels, the carbon content may be increased to 0,19% max.													

Table 6.3.2 Mechanical properties for acceptance purposes: welded pressure pipes

Type of steel	Grade	Yield stress N/mm^2	Tensile strength N/mm^2	Elongation on 5,65 $\sqrt{S_o}$ % minimum	Flattening test constant *C*
Carbon and carbon-manganese	320	195	320 – 440	25	0,10
	360	215	360 – 480	24	0,10
	410	235	410 – 530	22	0,08
	460	265	460 – 580	21	0,07
1Cr$^1/_2$Mo	440	275	440 – 590	22	0,07

Table 6.3.3 Heat treatment: welded pressure pipes

Type of steel	Condition of supply
Carbon and carbon-manganese, *see* Note	Normalised (Normalised and tempered at the option of the manufacturer)
1Cr$^1/_2$Mo	Normalised and tempered
Note Subject to special approval, electric resistance welded (ERW) pipes and tubes in grades 320 and 360 may be supplied without heat treatment for the following applications: Note (a) Class 2 piping systems, except for liquefied gases or other low temperature applications. Note (b) Class 3 piping systems.	

■ *Section 4*
Ferritic steel pressure pipes for low temperature service

4.1 Scope

4.1.1 Provision is made in this Section for carbon, carbon-manganese and nickel pipes intended for use in the piping arrangements for liquefied gases where the design temperature is less than 0°C. These requirements are also applicable for other types of pressure piping systems where the use of steels with guaranteed impact properties at low temperatures is required.

4.2 Manufacture and chemical composition

4.2.1 Carbon and carbon-manganese steel pipes are to be manufactured by a seamless, electric resistance or induction welding process.

4.2.2 Nickel steel pipes are to be manufactured by a seamless process.

4.2.3 Seamless pipes may be hot finished or cold finished. Welded pipes may be as-welded, hot finished or cold finished. The terms `hot finished', `cold finished' and `as-welded' apply to the condition of the pipes before final heat treatment.

4.2.4 The method of deoxidation and the chemical composition of ladle samples are to comply with the appropriate requirements given in *Table 6.4.1 Chemical composition*.

4.3 Heat treatment

4.3.1 Pipes are to be supplied in the condition given in *Table 6.4.3 Heat treatment*.

4.4 Mechanical tests

4.4.1 All pipes are to be presented for test in batches as defined in *Ch 6, 1 General requirements* for Class 1 pressure piping systems, but in addition the material in each batch is to be from the same cast.

4.4.2 At least two per cent of the number of lengths in each batch is to be selected at random for the preparation of tests.

4.4.3 Each pressure pipe selected for test is to be subjected to tensile, flattening or bend test at room temperature and, where the wall thickness is 6 mm or greater, an impact test at the test temperature specified in *Table 6.4.2 Mechanical properties for acceptance purposes*.

4.4.4 The impact tests are to consist of a set of three Charpy V-notch test specimens cut in the longitudinal direction with the notch perpendicular to the original surface of the pipe. The dimensions of the test specimens are to be in accordance with the requirements of *Ch 2 Testing Procedures for Metallic Materials*.

4.4.5 The results of all tensile, impact (when applicable), flattening and bend tests are to comply with the appropriate values in *Table 6.4.2 Mechanical properties for acceptance purposes*. *See Ch 2, 1.4 Re-testing procedures* for re-testing procedures.

Table 6.4.1 Chemical composition

Type of steel	Grade	Method of deoxidation	Chemical composition of ladle sample %								
			C max.	Si	Mn	P max.	S max.	Ni	Al_{sol} *see* Note	Residual elements	
Carbon	360	Fully killed	0,17	0,10—0,35	0,40—1,00	0,030	0,025	—	0,015 min.	Cr Cu Mo Ni	0,25 0,30 0,10 0,30
Carbon-manganese	410 and 460		0,20	0,10—0,35	0,60—1,40	0,030	0,025	—	0,015 min.	Total	0,70
3 $\frac{1}{2}$ Ni	440		0,15	0,15—0,35	0,30—0,90	0,025	0,020	3,25—3,75	—	Cr Cu Mo	0,25 0,30 0,10
9Ni	690		0,13	0,15—0,30	0,30—0,90	0,025	0,020	8,50—9,50	—	Total	0,60

Note Where a minimum Al_{sol} of 0,015% is specified, the determination of the total aluminium is acceptable provided that the result is not less than 0,020%.

Table 6.4.2 Mechanical properties for acceptance purposes

Type of steel	Grade	Yield stress N/mm^2	Tensile strength N/mm^2	Elongation on 5,65 $\sqrt{S_o}$ % minimum	Flattening test constant *C*	Bend test diameter of former (*t* = thickness)	Charpy V-notch impact tests	
							Test temperature °C	Average energy J minimum
Carbon	360	210	360—480	24	0,10	4*t*	–40	27

Carbon-manganese	410	235	410—530	22	0,08	4*t*	–50	27
	460	260	460—580	21	0,07			
3½Ni	440	245	440—590	16	0,08	4*t*	–95	34
9Ni	690	510	690—840	15	0,08	4*t*	–196	41

Note For standard subsidiary impact test specimens, the minimum energy values are to be as follows:

Required average energy value for standard 10 mm x 10 mm	Subsidiary 10 mm x 7,5 mm	Subsidiary 10 mm x 5 mm
	Average energy	Average energy
27 J	22 J	18 J
34 J	28 J	23 J
41 J	34 J	27 J

Table 6.4.3 Heat treatment

Type of steel	Condition of supply
Carbon and carbon-manganese	Hot finished
	Normalised
	Normalised and tempered
$3^1/_2$Ni	Normalised
	Normalised and tempered
9Ni	Double normalised and tempered
	Quenched and tempered

■ *Section 5*
Stainless steel pressure pipes

5.1 Scope

5.1.1 Provision is made in this Section for austenitic and duplex stainless steel pipes suitable for use in the construction of the piping systems for chemicals and for liquefied gases where the design temperature is not less than minus 165°C and for bulk chemical tankers.

5.1.2 Austenitic stainless steels may be suitable for service at elevated temperatures. Where such applications are proposed, details of the chemical composition, heat treatment and mechanical properties are to be submitted for consideration and approval.

5.1.3 Where it is intended to supply seamless pipes in the direct quenched condition, a programme of tests for approval is to be carried out under the supervision of the Surveyors, and the results are to be to the satisfaction of LR, *see Ch 1, 2.2 LR Approval – General*.

5.2 Manufacture and chemical composition

5.2.1 Pipes are to be manufactured by a seamless or a continuous automatic electric fusion welding process.

5.2.2 Welding is to be in a longitudinal direction, with or without the addition of filler metal.

5.2.3 The chemical composition of the ladle samples is to comply with the appropriate requirements of *Table 6.5.1 Chemical composition*.

5.3 Heat treatment

5.3.1 Pipes are generally to be supplied by the manufacturer in the solution treated condition over their full length.

5.3.2 Alternatively, seamless pipes may be direct quenched immediately after hot forming, while the temperature of the pipes is not less than the specified minimum solution treatment temperature.

5.4 Mechanical tests

5.4.1 All pipes are to be presented in batches as defined in *Ch 6, 1 General requirements* for Class I and II piping systems.

5.4.2 Each pipe selected for test is to be subjected to tensile and flattening or bend tests.

5.4.3 The results of all mechanical tests are to comply with the appropriate requirements given in *Table 6.5.2 Mechanical properties for acceptance purposes*.

Table 6.5.1 Chemical composition

Type of steel	Grade	Chemical composition %								
		C max.	Si	Mn	P max.	S max.	Cr	Mo	Ni	Others
Austenitic										
304L	490	0,030	≤1,00	≤2,00	0,045	0,030	18,0 – 20,0	–	8,0–12,0	N≤0,11
316L	490	0,030	≤1,00	≤2,00	0,045	0,030	16,0 – 18,5	2,0–3,0	10,0 – 14,0	–
317	490	0,08	≤1,00	≤2,00	0,045	0,030	18,0-20,0	3,0-4,0	11,0-15,0	–
321	510	0,08	≤1,00	≤2,00	0,045	0,030	17,0 – 19,0	—	9,0 – 12,0	Ti >5 x C ≤0,70
347	510	0,08	≤1,00	≤2,00	0,045	0,030	17,0 – 19,0	—	9,0 – 12,0	Nb >10 x C ≤1,10
Duplex										
UNS S31803	–	0,030	≤1,00	≤2,00	0,035	0,020	21,0–23,0	2,5–3,5	4,5–6,5	N 0,08-0,22
UNS S32750	–	0,030	≤0,80	≤1,20	0,035	0,020	24,0-26,0	3,0–5,0	6,0-8,0	N 0,24-0,32 Cu≤0,50

Table 6.5.2 Mechanical properties for acceptance purposes

Type of steel	Grade	0,2% proof stress N/mm^2 (see Note)	1,0% proof stress N/mm^2	Tensile strength N/mm^2	Elongation on $5{,}65\sqrt{S_o}$ % minimum	Flattening test constant C	Bend test diameter of former (t = thickness)
Austenitic							
304L	490	175	205	490 – 690	30	0,09	3*t*
316L	490	185	215	490 – 690	30	0,09	3*t*
317		185	205	490–690	30	0,09	3t
321	510	195	235	510 – 710	30	0,09	3*t*
347	510	205	245	510 – 710	30	0,09	3*t*
Duplex							

UNS S31803	-	450	–	620 minimum	25	0,09	3t
UNS S32750	-	550	–	800 minimum	15	0,09	3t
Note Except for the duplex stainless steel grades, the 0,2% proof stress values are given for information purposes and unless otherwise agreed are not required to be verified by test.							

5.5 Corrosion tests

5.5.1 For materials used for piping systems for chemicals, corrosion tests are to be carried out on one per cent of the number of pipes in each batch, with a minimum of one pipe. For austenitic stainless steels this should be an intercrystalline corrosion test (*see Ch 2, 9.1 Intergranular corrosion test*) and for duplex stainless steels this should be a pitting corrosion test (*see Ch 2, 9.2 Pitting corrosion test*). For the latter, the test temperatures shall be 20°C for S31803 and 30°C for S32750.

5.5.2 For pipes with an outside diameter not exceeding 40 mm, the test specimens are to consist of a full cross-section. For larger pipes, the test specimens are to be cut as circumferential strips of full wall thickness and having a width of not less than 12,5 mm. In both cases, the total surface area is to be between 15 and 35 cm^2.

5.5.3 Unless otherwise agreed or required for a particular chemical cargo, the testing procedure is to be in accordance with *Ch 2, 9 Corrosion tests* for austenitic stainless steels and *Ch 12, 3.3 Duplex stainless steels 3.3.3.(c)* for duplex stainless steels.

5.5.4 After immersion, the full cross-section test specimens are to be subjected to a flattening test in accordance with the requirements of *Ch 2 Testing Procedures for Metallic Materials*. The strip test specimens are to be subjected to a bend test through 90° over a mandrel of diameter equal to twice the thickness of the test specimen.

5.6 Fabricated pipework

5.6.1 Fabricated pipework is to be produced from material manufactured in accordance with *Ch 6, 5.2 Manufacture and chemical composition*, *Ch 6, 5.3 Heat treatment*, *Ch 6, 5.4 Mechanical tests* and *Ch 6, 5.5 Corrosion tests*.

5.6.2 Welding is to be carried out in accordance with an approved and qualified procedure by suitably qualified welders.

5.6.3 Fabricated pipework may be supplied in the as-welded condition without subsequent solution treatment provided that welding procedure tests have demonstrated satisfactory material properties including resistance to intercrystalline corrosion (austenitic stainless steel) or pitting corrosion (duplex stainless steel).

5.6.4 In addition, butt welds are to be subjected to 5 per cent radiographic examination for Class I, and 2 per cent for Class II pipes.

5.6.5 Fabricated pipework in the as-welded condition and intended for systems located on deck is to be protected by a suitable corrosion control coating.

5.7 Certification of materials

5.7.1 Each test certificate is to be of the type and give the information detailed in *Ch 1, 3.1 General* together with general details of heat treatment and, where applicable, the results obtained from the appropriate corrosion tests. As a minimum, the chemical composition is to include the content of all the elements detailed in *Table 6.5.1 Chemical composition*.

■ *Section 6*
Boiler and superheater tubes

6.1 Scope

6.1.1 Provision is made in this Section for boiler and superheater tubes in carbon, carbon-manganese and low alloy steels.

6.1.2 Austenitic stainless steels may also be used for this type of service. Where such applications are proposed, details of the chemical composition, heat treatment and mechanical properties are to be submitted for consideration and approval.

6.2 Manufacture and chemical composition

6.2.1 Tubes are to be seamless or welded and are to be manufactured in accordance with the requirements of *Ch 6, 2 Seamless pressure pipes* and *Ch 6, 3 Welded pressure pipes*, respectively.

6.2.2 The method of deoxidation and the chemical composition of ladle samples are to comply with the requirements given in *Table 6.2.1 Chemical composition of seamless pressure pipes* or *Table 6.3.1 Chemical composition of welded pressure pipes*, as appropriate.

6.3 Heat treatment

6.3.1 All tubes are to be supplied in accordance with the requirements given in *Table 6.2.2 Heat treatment* or *Table 6.3.3 Heat treatment: welded pressure pipes* as appropriate, except that 1Cr½Mo steel may be supplied in the normalised only condition when the carbon content does not exceed 0,15 per cent.

6.4 Mechanical tests

6.4.1 Tubes are to be presented for test in batches as defined in *Ch 6, 1 General requirements*.

6.4.2 Each boiler and superheater tube selected for test is to be subjected to at least the following:

(a) Tensile test.
(b) Flattening or bending test.
(c) Expanding or flanging test.

6.4.3 The results of all mechanical tests are to comply with the appropriate requirements given in *Table 6.6.1 Mechanical properties for acceptance purposes: boiler and superheater tubes*.

6.5 Mechanical properties for design

6.5.1 The mechanical properties at elevated temperature for carbon and carbon-manganese steels in Grades 320 to 460, 1Cr½Mo and 2¼Cr1Mo steels can be taken from the appropriate Tables in *Ch 6, 2 Seamless pressure pipes*.

6.5.2 Where rimming steel is used, the design temperature is limited to 400°C.

Table 6.6.1 Mechanical properties for acceptance purposes: boiler and superheater tubes

Type of steel	Grade	Yield stress N/mm^2	Tensile strength N/mm^2	Elongation on 5,65 $\sqrt{S_o}$ % minimum	Flattening test constant *C*	Bend test diameter of former (*t* = thickness)	Drift expanding and flanging test minimum % increase in outside diameter		
							Ratio $\frac{Inside diameter}{Outside diameter}$		
							≤0,6	>0,6≤0,8	>0,8
Carbon and carbon-manganese	320	195	320–440	25	0,10	4*t*	12	15	19
	360	215	360–480	24	0,10		12	15	19
	410	235	410–530	22	0,08		10	12	17
	460	265	460–580	21	0,07		8	10	15
1Cr^1 /$_2$Mo	440	275	440–590	22	0,07	4*t*	8	10	15
2^1 /$_2$Cr1Mo	410 (*see* Note 1)	135	410–560	20	0,07	4*t*	8	10	15
	490 (*see* Note 2)	275	490–640	16					

Note 1. Annealed condition.

Note 2. Normalised and tempered condition.