

JIS

JAPANESE INDUSTRIAL STANDARD

Pressure vessels (General standard)

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JAPANESE INDUSTRIAL STANDARD

J I S

Pressure vessels (General standard)

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1. Scope

1.1 Applicable pressure vessels This Japanese Industrial Standard applies to the construction, attachments and accessories⁽¹⁾ of the stationary type pressure vessels (hereafter referred to as "pressure vessels") which are the vessels retaining the pressure exceeding atmospheric pressure, vessels containing fluid which generates pressure, or the vessels subjected to the external pressure. However, the following pressure vessels are not included.

- (1) Those which are covered in the scopes of other Japanese Industrial Standards⁽²⁾
- (2) Those which are made of non-metallic materials
- (3) Those which are related to nuclear energy
- (4) Those which are of riveted construction and of brazed construction
- (5) Those which are subjected to direct fire
- (6) Those which are of special construction⁽³⁾ or of special uses⁽⁴⁾

Notes (1) The prescriptions related to the materials of this Standard are not applicable to the accessories.

(2) Examples are as given in the following:

Example 1. JIS B 8201 Construction of steel boilers for land use⁽⁵⁾

Example 2. JIS B 8233 Refillable welded steel gas cylinders for liquefied petroleum gas

Example 3. JIS B 8240 Construction of pressure vessels for refrigeration

Example 4. JIS B 8241 Seamless steel gas cylinders

Example 5. JIS B 8248 Construction of layered pressure vessels

Example 6. JIS B 8501 Welded steel tanks for oil storage

(3) Those of complicated shapes, the storage tanks of low temperature, flat bottom, cylindrical shape, the storage tanks of membrane construction and the like.

(4) Rotary machines or pressure parts of reciprocating machine of oil-hydraulic machines, hydraulic machines, pumps, compressors, turbines, internal combustion engines, and hydraulic or pneumatic cylinders.

(5) The waste heat boilers are within the scope of JIS B 8201, and are outside the scope of this Standard.

Remarks 1. The standards cited in this Standard are given in Attached Table 1.0.

2. The units and numerical values given in { } in this Standard are based on the traditional units, and are appended for informative reference.

1.2 Application of individual standards related to pressure vessels This Standard shall be the general standard relating to the construction of the pressure vessels, and shall specify the methods of application of individual standards thereof, citing the Japanese Industrial Standards given in the following which constitute the individual standards relating to the pressure vessels:

JIS B 8271	JIS B 8276	JIS B 8281
JIS B 8272	JIS B 8277	JIS B 8282
JIS B 8273	JIS B 8278	JIS B 8283
JIS B 8274	JIS B 8279	JIS B 8284
JIS B 8275	JIS B 8280	JIS B 8285

1.3 Range to be pressure vessels

1.3.1 The range to be the pressure vessels shall be the pressure vessel body (shell, heads and nozzles directly connected to these) and the parts given in the (1) to (3) of the following:

- (1) At the connecting parts with the external pipings
 - (a) For the welded joints, up to the first peripheral joint (excluding the welded joint).
 - (b) For the threaded joints, up to the first threaded joint.
 - (c) For the bolt fastened flange joint, up to the first flange face.
- (2) When the attachment is directly welded to the pressure part, up to the welded joint parts.
- (3) Including cover plates of manhole, hand hole and the like which are subjected to pressure, welded joints, bolts and nuts, and gaskets.

1.3.2 Even though the attachments being attached directly to the pressure part and accessories of safety valve and the like are not included in the range of the pressure vessel, these shall satisfy the corresponding requirements.

2. Definitions For the main terms used in this Standard, the definitions in JIS B 0190 apply, and the rest of the terms are as follows:

quenched and tempered high tensile strength steel Among the steel materials bestowed with properties as the high tensile strength steels by processing the quenching and tempering specified in 3510 of JIS G 0203, it means that of which minimum value of the standardized tensile strength is of not less than 620 N/mm² {63 kgf/mm²}.

Remarks: The JIS standardized materials corresponding to this quenched and tempered high tensile strength steel are as given in the following:

SPV 490 Q {SPV 50 Q} of JIS G 3115

SQV 1 B, SQV 2 B and SQV 3 B of JIS G 3120

SL 9 N 520 (SL 9 N 53) and SL 9 N 590 (SL 9 N 60) of JIS G 3127

SHY 685 (SHY 70), SHY 685 N (SHY 70 N) and SHY 685 NS (SHY 70 NS) of JIS G 3128

SFVQ 1 B, SFVQ 2 B and SFVQ 3 of JIS G 3204

STPL 690 (STPL 70) of JIS G 3460

STBL 690 (STBL 70) of JIS G 3464

3. Classification of grades of pressure vessels The pressure vessels shall be classified into three grades of the 1st-class vessels, 2nd-class vessels and 3rd-class vessels, according to the materials, designs, welding designs, machining in general, welding processes, heat treatments, test and inspection, and the contents of accessories.

(1) Scope of pressure vessels for respective grades The scope of the 1st-class vessels, 2nd-class vessels and 3rd-class vessels shall be in accordance with the following:

- (1.1) The 1st-class vessels may be applicable to the pressure vessels of which design temperature is less than creep region of material and of which design pressure is less than 100 MPa {1000 kgf/cm²}. However, these may be applicable to those of 100 MPa {1000 kgf/cm²} or over by taking technical considerations particularly to the material used, finish (roughness) on inside and outside surfaces of pressure vessel, accuracy of screw threads, non-destructive test, etc.
- (1.2) The 2nd-class vessels may be applicable to the pressure vessels of which design pressure is less than 30 MPa {300 kgf/cm²}.
- (1.3) The 3rd-class vessels may be applicable to the pressure vessels of 0°C or over in design temperature, under 1 MPa {10 kgf/cm²} in design pressure, and not subjected to the radiographic test of welds. However, the pressure vessels given in (a) to (d) of the following shall not be manufactured as the 3rd-class vessels:
 - (a) The pressure vessels containing lethal substances
 - (b) The pressure vessels containing liquefied gas
 - (c) The pressure vessels containing compressed acetylene gas
 - (d) The pressure vessels subjected to pressure test by gas

(2) Summary of classification of grades for pressure vessels The summary of the "range of design pressure", "range of design temperature", "materials", "establishment standards of fundamental permissible stresses of materials for pressure vessels to be used in designing", "necessity of stress analysis and fatigue analysis", "types of welded joints to be used in longitudinal joints and peripheral joints of shells and heads and non-destructive tests thereof", "mechanical tests of butt welds", "necessity of qualification test of welding procedures", and "test pressure" for the pressure vessels of respective grades are given in Table 3.1. As to the details, refer to the corresponding items of this Standard.

Table 3.1 Summary of classification of grades for pressure vessels

	1st-class pressure vessels		2nd-class pressure vessels	3rd-class pressure vessels
Range of design pressure	Less than 100 MPa {1000 kgf/cm ² }		Less than 30 MPa {300 kgf/cm ² }	Less than 1 MPa {10 kgf/cm ² }
Range of design temperature	Ranges given in the fundamental permissible stress tables of materials as below (less than creep region).		Ranges given in the fundamental permissible stress tables of materials as below.	Ranges given in the fundamental permissible stress tables of materials as below. Limited at 0°C or over.
Materials (pressure parts) See 5.2 to 5.6.	Specific iron and steel materials given in Attached Table 1.1, and general iron and steel materials and nonferrous metal materials given in Attached Tables 1.2 and 1.3.		Iron and steel materials and nonferrous metal materials given in Attached Tables 2.1 and 2.2. However, there are restrictions on types and thicknesses of materials according to the design pressures, design temperatures, contents, degrees of radiographic test (RT or 20 %RT), etc.	Iron and steel materials and nonferrous metal materials given in Attached Tables 2.1 and 2.2. However, these are limited to materials to which no radiographic test is required or to which welded joint quality factor without radiographic test is allowed to employ.
Establishment standards of fundamental permissible stresses of materials to be used in design See Annex 1.	Specific iron and steel materials	General iron and steel materials and nonferrous metal materials	$\frac{1}{4}$ the tensile strength of material at ordinary temperature and design temperature, or the minimum value or under among the yield point or $\frac{1}{1.5}$ the 0.2 % proof stress. However, that of not larger than this may also exist according to the types of material. In addition, the permissible stress establishment standards of creep region are specified.	
	$\frac{1}{2.4}$ the tensile strength of material at ordinary temperature and design temperature, or the minimum value or under among the yield point or $\frac{1}{1.5}$ the 0.2 % proof stress.	$\frac{1}{3}$ the tensile strength of material at ordinary temperature and design temperature, or the minimum value or under among the yield point or $\frac{1}{1.5}$ the 0.2 % proof stress.	The same as in the left.	
Necessity of stress analysis and fatigue analysis	To be performed. However, exemptive conditions are presented. See 6.4.3 and 6.4.4.		Not be performed. However, these may also be performed, if necessary.	Not be performed.

Table 3.1 (Continued)

	1st-class pressure vessels		2nd-class pressure vessels	3rd-class pressure vessels
	Specific iron and steel materials	General iron and steel materials and nonferrous metal materials		
Types of welded joints to be used for longitudinal joints and peripheral joints of shells and heads and non-destructive tests thereof See Tables 9.4, 9.5 and 9.6.	Longitudinal joints and peripheral joints of shells and heads are all to be butted both side welded joints of full penetration. There are conditions where RT is performed, and added with MT or PT.	Longitudinal joints and peripheral joints of shells and heads are all to be butted both side welded joints of full penetration. There are conditions where RT is performed, and added with MT or PT. However, the butted one side welded joint using backing metals on the peripheral joints may be approved conditionally.	The longitudinal joints and peripheral joints of shells and heads are to be the butted both side welded joints of full penetration or butted one side welded joints using backing metals. However, there are conditions where the butted one side welding using backing metal can not be employed. There are conditions where all are subjected to RT or 20 %RT, and added with MT or PT. Welded joint quality factors are applied according to the degrees of radiographic test and types of welded joints. See 7.2.	The longitudinal joints and peripheral joints of the shell and heads are, other than the butt welding, the both side full depth fillet welding and one side full depth fillet welding which plug welding is performed or not. It's subjected to visual inspection. Welded joint quality factors are applied according to the types of welded joints. See 7.2.
Mechanical tests of butt welded joints See 11.2.	Tension, bending and impact. However, the impact test is limited, when it is required.		The same as in the left.	Generally, not necessary.
Necessity of qualification test of welding procedures See 9.1.2.	To be performed. The portions to which specific iron and steel materials are used are subjected to full welded metal tension test.		To be performed.	To be performed.
Test pressure See 11.6.	In the case of hydraulic pressure test by multiplying the ratio of the hydraulic pressure (or pneumatic pressure) test temperature to the fundamental permissible stress of material at design temperature, 1.25 times the design pressure, and in the case of pneumatic pressure or combined gas and liquid test, 1.15 times the design pressure. However, there are conditions to limit the upper limit of pressure test.		In the case of the hydraulic test by multiplying the ratio given in the left, 1.5 times the design pressure, and in the case of pneumatic pressure test or combined gas and liquid test, 1.25 times the design pressure.	The same as in the left. However, pneumatic pressure test, and combined gas and liquid test are not permitted. For grey cast iron and malleable cast iron products, 2 times and 2.5 times the design pressure respectively, in the case of hydraulic pressure test, are used.
Remarks 1. Explanation of symbols	RT : Total lines radiographic test 20 %RT : 20 % partial radiographic test MT : Magnetic particle test PT : Liquid penetrant test		2. The specific iron and steel materials given in Attached Table 1.1 are the materials to which high temperature strength has been specified. For example, JIS G 3124 and Annex 3 (High-strength steel forgings for medium and ordinary temperature pressure vessels).	

- (3) Combination of respective types of pressure vessels which have been classified by grades By combining the pressure chambers which have been designed and manufactured, from the 1st-class vessels to the 3rd-class vessels, in accordance with respective requirements, the composite vessels may be composed by joining together. In this case, the joint part which joins the both pressure chambers shall be in accordance with the requirements of the pressure chamber of the severer side in grade of the requirements of this Standard. As regards the composite vessels, refer to 6.1.7.

4. Clarification of applicable conditions to this Standard and quality guarantee
When this Standard is applied, the user of the pressure vessel shall prepare the order specifications, including the quality control requirements, in accordance with the following requirements of 4.1 to 4.4, for the purposes of clarifying the grade of the pressure vessels to be applied and guaranteeing the qualities of the products, considering the object of use, environment and design conditions of the pressure vessels, and also, the manufacturer of the pressure vessels shall carry out the inside quality control, including the preparation of design documents, and the quality guarantee for the outside.

4.1 Order specifications and quality control requirements of user of pressure vessels The user (including the proxy deputed by the user) of the pressure vessel shall prepare the order specifications of user at his responsibility for clarifying the applicable conditions of this Standard, and shall present it to the manufacturer of the pressure vessel.

In this order specifications, the following items shall be included:

- (1) For 1st-class pressure vessels
- (a) The grade or the combination of grades of the pressure vessels
 - (b) Planned running conditions⁽¹⁾ or design conditions⁽¹⁾ constituting appropriate basic data for the selection of material, design, workings and tests inspections.
 - (c) The presence of corrodibility and erodibility, and the value of corrosion allowance
 - (d) The designation of whether the lethal substances are handled
 - (e) The fundamental shape, fundamental dimensions, etc. of pressure vessels⁽²⁾
 - (f) The necessity of fatigue analysis (dimensions or empirical data for judgement)
 - (g) Working environmental conditions
 - (h) Other matters to be referred to such as data from running experiences and the like

Notes ⁽¹⁾ Condition to determine 6.1.1, heat transfer conditions, contents and properties of matters thereof are included.

⁽²⁾ Dimensions of diameter, length and the like, manhole, nozzle, mounting positions and supporting methods of measuring instruments and apparatus, and fundamental shapes and dimensions other than these are included.

(2) For 2nd-class vessels or 3rd-class vessels

- (a) Matters specified in (1) (a) to (e) and (g)
- (b) Matters specified in (1) (f) and (h), as required

(3) Quality control requirements The users of the pressure vessels shall select the conformable quality guarantee model to the ordering features among JIS Z 9901 to JIS Z 9903 using JIS Z 9900 in the Japanese Industrial Standards related to the quality guarantee, referring to 4. of Informative reference 1 (quality control requirements of users of pressure vessels), and shall prepare the quality control requirements to include in the ordering specifications.4.2 Design documents of manufacturer of pressure vessels The design documents of the manufacturer of the pressure vessels shall be in accordance with the following:

- (1) The manufacturer of the pressure vessel shall confirm that the ordering specifications of the user satisfy the requirements of 4.1, shall establish the design conditions on the basis of the ordering specifications of the user at his responsibility, and shall acquire the approval of the user, preparing the design documents in accordance with this Standard.

Remarks: In the design documents, the specifications, drawings and design calculation sheets shall be included.

- (2) In the design calculation sheets of the 1st-class vessels, the evaluation by the stress analysis and fatigue analysis shall be included. However, when exempted by the prescriptions of 6.4.3 or 6.4.4, it shall be omitted.
- (3) In the 2nd-class vessels or 3rd-class vessels, when the maximum permissible pressure is obtained by the licensed hydraulic test specified in 11.8, instead of the calculation of the portion where the calculation of wall thickness in accordance with the calculation formula specified in this Standard is difficult, its executional instruction sheets on test shall be included.
- (4) As to that of the 2nd-class vessel which is difficult in the calculation of thickness in accordance with the prescription of the 2nd-class vessels due to a part or whole parts of the construction is complicated, or the portion subjected to repeated load due to high frequency of start and stop of running, it may be designed in accordance with the corresponding prescription of JIS B 8281. In this case, the design stress strength (S_m) at the design temperature of material shall be evaluated of the stress of each part by translating the fundamental permissible stress presented in Attached Table 2.1 or Attached Table 2.2 into the design stress strength.

4.3 Inside quality control of manufacturer of pressure vessels The manufacturer of the pressure vessel shall establish the quality system aimed at the quality control of the inside referring to JIS Z 9904 and 5.1 of Informative reference 1 [application of the quality system standard aimed at the inside quality control] and put into operation. This quality system, including the portions and parts of the pressure vessels entrusted to the manufacture of others and the operations of forming, nondestructive tests, heat treatments and others, shall be that of capable of proving that the pressure vessels have been manufactured in accordance with the prescriptions of this Standard.

4.4 Quality guarantee and manufacturing report of manufacturer of pressure vessels The manufacturer of pressure vessels shall carry out the quality guarantee satisfying the quality control requirements of the user of pressure vessels specified in 4.1 (3) in accordance with the inside quality control of 4.3. After completion of the pressure vessels, the manufacturer shall prepare the manufacturing report which certifies that the pressure vessels have been manufactured in accordance with the prescriptions of this Standard, including the quality records, and shall submit it to the user of the pressure vessels. See 5.2 (Quality guarantee required from the outside) of Informative reference 1.

5. Materials The materials shall be in accordance with the following:

5.1 Materials in general The materials to be used for the pressure parts of the pressure vessels based on this Standard shall be in accordance with the following:

- (1) **Standardized materials** The standardized materials defined in this Standard shall be the JIS standardized materials presented in Attached Tables 1.1, 1.2, 1.3, 2.1, 2.2, 3.1 and 3.2 according to the grades of the pressure vessels.

Remarks: In the 3rd-class vessels, the materials without standard verification, which have been confirmed that these materials are capable of sufficiently tolerable to use by material tests on each plate or pipe, may also be used for the pressure vessels of less than 0.2 MPa (2 kgf/cm²) in design pressure. In this case, the mechanical properties and chemical composition of the materials concerned shall be equivalent degree to the standardized materials.

- (2) **Equivalent materials** When compared with the standardized materials given in Attached Tables 1.2, 1.3, 2.1, 2.2, 3.1 and 3.2, those which are in compliance with one of the following items may be considered to be the equivalent materials to the standardized material.

- (a) That is the same in chemical composition and mechanical properties as the standardized material, and differs slightly in the range of plate thickness.
- (b) That is the same in chemical composition and mechanical properties as the standardized material, and differs in manufacturing method or shapes.
- (c) That is extremely resembling in chemical composition, mechanical properties, test methods, and sampling method to the standardized material, and is extremely similar to the standardized material in properties of material.

- (3) **Specially approved materials** Being not approved as a standard in JIS, the material which has been approved specially as appropriate to be used as the material for pressure vessel of its grade as agreed between the parties concerned, carrying out the test on the item specified in Annex 2 (Property and performance qualification test of material) according to the grades of pressure vessels, and also the materials in accordance with the standard other than JIS specified in (1) such as ISO standard, the material of which has been confirmed that having the properties equal to or superior to the standard defined in (1) according to the grades of pressure vessels, upon agreement between the parties concerned, and has been approved specially, may be used for the pressure parts of the pressure vessels.

- (4) Dimensional tolerances of materials The dimensions tolerances of materials shall be in accordance with the following:
- (a) As to the plate materials, those of the design thickness or over shall be ordered. When the difference between the actual thickness and the design thickness is the smaller value or under of 0.25 mm or 6 % the design thickness, this may be used.
 - (b) When the pipe materials are used for the pressure parts, the tolerances of the negative side of the thickness defined in the JIS standardized material shall be taken in the calculation.
- (5) Working temperature range of materials As to the standardized materials given in Attached Tables 1.1 to 1.3, 2.1, 2.2, 3.1 and 3.2, these shall not be used exceeding the temperature ranges corresponding to the fundamental permissible stresses indicated in the Tables thereof. However, the low temperature working limits of iron and steel materials shall be in accordance with the prescriptions of 5.3.5.
- (6) Fatigue characteristics of material In the design of the 1st-class pressure vessels, the fatigue characteristics of material shall be taken into consideration. When the exemptional prescriptions of fatigue analysis defined in 6.4.4 are not applicable, the materials of which design fatigue curves are presented in JIS B 8281 may be used exclusively. However, when it is possible to prepare the fatigue curves due to sufficient data, this shall be exempt from application.
- (7) Additional inspection for JIS material standard According to the JIS material standards, non-destructive inspections and special quality requirements by the designation of purchaser have been specified. The manufacturer of pressure vessels shall order the materials by designating the additional inspection, in accordance with the requirements of 5.3.4, 5.3.5 and 5.4.3 of this Standard.

In addition, in the material certificate being published by the manufacturer of materials, it shall be allowed to certificate that these are conforming to the prescriptions including the requirements of applicable material standards and the additional inspections. This material certificate shall include the certification related to the numerical values of overall necessary test results.

- (8) Restriction on use of materials for contents The materials to be used for the pressure vessels preserving the corrosive substances, due consideration shall be paid on the resistivity against the contents in advance.

5.2 Materials to be used for pressure vessels of respective grades The materials to be used for pressure vessels of respective grades shall be in accordance with the following:

5.2.1 Materials to be used for 1st-class vessels The materials to be used for the 1st-class vessels shall be in accordance with the following:

- (1) In the classification according to the positions of the welded joints specified in 7.1.1, if the standard materials given in Attached Table 1.1 [Fundamental permissible stresses (for 1st-class vessels) of specific iron and steel materials], materials equal to these specified in 5.1 (2), or specially approved materials specified in 5.1 (3) and specially approved materials as the specific iron and

steel materials are used as the materials of shells and formed heads (including manhole shell, shells and heads of dome and sump) related to the welds of classification A and classification B, the following shall be referred to.

- (1.1) In the classification according to the positions of welded joints specified in 7.1.1, the materials of pipes, nozzles, flanges, flat heads, bolted flat cover plate, tube sheets, etc. related to the welds of classification B, when the pipes of standardized materials are used for classification C, classification D and nozzle necks, shall be the iron and steel materials given in the following:
 - (a) The materials specified in Annex 3 (High strength steel forgings for medium and ordinary temperature pressure vessels), materials equivalent to those specified in 5.1 (2), or specially approved materials specified in 5.1 (3) and which have been specially approved steel forgings as the specific iron and steel materials.
 - (b) The standardized materials given in Attached Table 1.2 (Fundamental permissible stress of general iron and steel materials), materials of equivalent to those specified in 5.1 (2) or the specially approved materials specified in 5.1 (3), and the materials which have been approved specially as the general iron and steel materials for 1st-class vessels.
- (1.2) The materials of pressure vessels to be manufactured by solid forging shall be the materials specified in Annex 3, the materials equivalent to those specified in 5.1 (2), or the specially approved materials specified in 5.1 (3) and specially approved steel forgings as the specific iron and steel materials.
- (1.3) As to the members to be welded to the pressure vessel body such as the jackets, supporting structures and attachments to be mounted on the pressure parts by welding, the standardized material given in Attached Tables 1.1, 1.2 and 2.1 [Fundamental permissible stresses of iron and steel materials (for the 2nd-class vessels and 3rd-class vessels)], equivalent materials to these or specially approved materials may be used, however, the weld metal shall be of having compatibility with the specific iron and steel materials, and the welded joints shall satisfy the requirements of the 1st-class vessels.
- (2) Excluding those specified in (1), materials related to classifications A, B, C and D in the classifications according to positions of welded joints specified in 7.1.1, shall be the materials given in the following:
 - (a) Among the iron and steel materials, the standardized materials given in Attached Table 1.2 or equivalent materials to these specified in 5.1 (2). However, the restriction on use of the iron and steel materials shall be in accordance with 5.3.1 (1).
 - (b) Among the nonferrous metal materials, the standardized materials given in Attached Table 1.3 [Fundamental permissible stresses of nonferrous metal materials (for 1st-class vessels)], or equivalent materials to these specified in 5.1 (2).
 - (c) The specially approved materials specified in 5.1 (3) which have been approved specially as the materials for the 1st-class vessels.

- (d) As to the members to be welded to the pressure vessel body such as the jackets, supporting structures and attachments to be mounted on the pressure parts by welding, the standardized materials given in Attached Tables 1.2, 1.3, 2.1 and 2.2 [Fundamental permissible stresses of nonferrous metal materials (for 2nd-class vessels and 3rd-class vessels)], equivalent materials to these or specially approved materials specified in 5.1 (3) may be used, however, the weld metal shall be of having compatibility with the materials of the pressure parts of the 1st-class vessel body, and the welded joints shall satisfy the requirements of the 1st-class vessels.
 - (e) The materials of pressure vessels to be manufactured by the solid forging shall be the standardized steel forgings and standardized nonferrous forgings given in Attached Tables 1.2 and 1.3, equivalent materials to these specified in 5.1 (2), or the specially approved materials specified in 5.1 (3) and which are the steel forgings and nonferrous forgings specially approved as the materials for the 1st-class vessels.
 - (f) The materials of pressure vessels to be manufactured by the solid casting shall be the standardized steel castings given in Attached Table 1.2, equivalent materials to these specified in 5.1 (2), or the specially approved materials specified in 5.1 (3), and which are the steel castings specially approved as the materials for the 1st-class vessels.
- (3) The steel bolt materials when flanges, bolted cover plates and tube sheets are designed by the stress analysis shall be the standardized materials given in Attached Table 3.1 [Fundamental permissible stresses of bolt materials (applicable to the vessels to be subjected to design by stress analysis)], and the steel bolt materials when the bolted flanges are designed in accordance with JIS B 8273, and bolted cover plates with JIS B 8275 shall be the standardized materials given in Attached Table 3.2 [Fundamental permissible stresses of bolt materials (applicable to the vessels not to be subjected to design by stress analysis)], or shall be the equivalent materials to these specified in 5.1 (2) for either cases.

5.2.2 Materials to be used for the 2nd-class vessels The materials of the pressure parts of the 2nd-class vessels, the jackets, supporting structures, attachments to be mounted on the pressure parts by welding, and the bolts shall be in accordance with the following:

- (1) As to the iron and steel materials, the standardized materials given in Attached Tables 2.1 and 3.2, the ductile iron castings and malleable iron castings defined in Annex 5, or equivalent material to these specified in 5.1 (2). However, the restrictions on use of iron and steel materials shall be in accordance with 5.3.1.
- (2) As to the nonferrous metal materials, the standardized materials given in Attached Tables 2.2 and 3.2, or equivalent materials to these specified in 5.1 (2).
- (3) The specially approved materials specified in 5.1 (3) which have been approved specially as the materials for the 2nd-class vessels.

5.2.3 Materials to be used for the 3rd-class vessels The materials of the pressure parts of the 3rd-class vessels, the jackets, supporting structures, attachments to be mounted on the pressure parts by welding, and the bolts shall be in accordance with the following:

- (1) **Iron and steel materials** The iron and steel materials shall be limited to those of the following, among the standardized materials given in Attached Tables 2.1 and 3.2 or equivalent materials to these specified in 5.1 (2):
 - (a) Those of the group numbers 1 and 2 of P number 1 and 31.8 mm or under in nominal thickness, those of the group numbers 1 and 2 of P number 3 and 19 mm or under in nominal thickness, and those of P number 8 and of 25 mm or under in nominal thickness in the divisions of base metals. However, the quenched and tempered high tensile strength steel shall be excluded.
 - (b) JIS G 5501, JIS G 5502, JIS G 5702 and JIS G 5704
 - (c) Ductile iron castings and malleable iron castings defined in Annex 5.
- (2) **Nonferrous metal materials** The nonferrous metal materials, among the standardized materials given in Attached Tables 2.2 and 3.2 or equivalent materials to these specified in 5.1 (2), shall be limited to those of the following:
 - (a) For the welding structure, those of P numbers 21, 22, 23, 25, 31, 34 and 35 in the divisions of base metal, and those of which nominal thickness of the base metal of welds are 10 mm or under.
 - (b) JIS H 5111 and JIS H 5202

5.3 Iron and steel materials The iron and steel materials, other than those in accordance with 5.1, shall be in accordance with the following:

5.3.1 Restriction on use of iron and steel materials

- (1) **Restriction on use in general** The restriction on use in general shall be in accordance with the following:
 - (a) Those carbon steel materials or low alloy steel materials of which carbon content exceeds 0.35 % (ladle analysis) shall not be used for the welding structure. When a JIS standardized material of which carbon content has not been specified is to be used, an order shall be placed by designating that the carbon content is to be allowed to 0.35 % or under as the special requirement to that standard, and the carbon content shall have been stated in the material certificate.
 - (b) The forgings of which carbon content exceeds 0.35 % (ladle analysis) shall not be used for welding structures. However, in the case where fit welding of the non-pressure resistant attachments of small articles in accordance with 2. (2) Note (1) of Annex 6 (Attachments and supporting structures), seal weldings of threaded joints or the weldings of repair welding only are to be carried out, the carbon content may be of 0.5 % or under. That of exceeding 0.5 % in carbon content shall not be welded [see 2. (2) of Annex 7 (Special provisions relating to forged pressure vessels)].
 - (c) The material to be used for the 1st-class vessels shall be the killed steel.

- (2) Restriction on use of iron and steel materials given in Attached Table 2.1
The restriction on use of iron and steel materials given in Attached Table 2.1 shall be in accordance with the following:
- (2.1) Those which are in accordance with JIS G 3106 (excluding SM 400 A (SM 41 A), SM 490 A (SM 50 A) and SM 490 YA (SM 50 YA)) shall not be used for the shells, heads and other parts similar to these of the pressure vessels of 3 MPa (30 kgf/cm²) or over in design pressure.
- (2.2) Those which are in accordance with JIS G 3101, SM 400 A (SM 41 A), SM 490 A (SM 50 A) and SM 490 YA (SM 50 YA) of JIS G 3106 and JIS G 3457 shall not be used for the parts of pressure vessels given in the following:
- (a) The shells, heads and other parts similar to these of the pressure vessels exceeding 1.6 MPa (16 kgf/cm²) in design pressure.
 - (b) The pressure vessels of 1 MPa (10 kgf/cm²) or over in design pressure, and to which longitudinal joints of shell are welded and of which heads are provided with weld joints.
 - (c) The shells, heads and other parts similar to these of pressure vessels, and of which thicknesses of base metals of welds are exceeding 16 mm.
 - (d) The shells, heads and other parts similar to these of pressure vessels of which purposes are to contain lethal substances.
- (2.3) Those which are in accordance with JIS G 3452 shall not be used for the parts of pressure vessels given in the following:
- (a) Those which are 1 MPa (10 kgf/cm²) or over in design pressure.
 - (b) Those which are under 0°C or over 100°C in design temperature. However, in the case where compressed air, steam or water is contained, these may be used up to 200°C, and for the fluid of under 0.2 MPa (2 kgf/cm²) in design pressure, these may be used up to 350°C.
 - (c) Those of which purposes are to contain the lethal substances or the liquefied gas of 0.2 MPa (2 kgf/cm²) or over in design pressure.
- (2.4) JIS G 5501, JIS G 5502, JIS G 5702, JIS G 5704 and B. of Annex 5 (Malleable iron castings) shall not be used for the parts of pressure vessels given in the following:
- (a) Those of which purposes are to handle the lethal substances or combustible fluids (excluding the gaseous substance of under 0.2 MPa (2 kgf/cm²) in design pressure.).
 - (b) Those which handle the gaseous substance (vapour) other than lethal or combustible exceeding 1.1 MPa (11 kgf/cm²) in design pressure.
 - (c) Those of which design temperatures are under 0°C or over 250°C.
 - (d) When the liquid is handled either at the smaller one of boiling point or 49°C under the design pressure, those of which design pressures are exceeding 1.8 MPa (18 kgf/cm²).
 - (e) As to the plugged and bolted cover plates being installed at the opening parts not constituting the principal parts of the pressure vessels, those of which design pressures are exceeding 2.1 MPa (21 kgf/cm²).

(2.5) The ductile iron castings defined in Annex 5 shall not be used for those given in the following:

- (a) Those of which purposes are to handle the lethal substances.
- (b) Those of which design pressures are exceeding 1.8 MPa {18 kgf/cm²}.
- (c) Those of which design temperatures are under -30°C or over 350°C .

5.3.2 Heat treatments of steel materials As to the ferritic materials, when as rolled or normalizing has been specified and other than these have not been specified on the heat treatment condition in the applicable material standard, normalizing, normalizing and tempering or thermo-mechanical control process may be carried out as required. The normalizing, in this case, the accelerated cooling for enhancing the tension characteristics and impact characteristics and the tempering to be carried out in succession to these shall be included.

5.3.3 Sampling method of test materials and test pieces The test materials and test pieces shall be sampled in accordance with the following prescriptions. However, the impact test pieces, in the case where the impact tests are to be carried out particularly in accordance with 5.3.5, shall not be limited to these.

(1) **Definitions of thickness** In the prescriptions of 5.3.3, the definition of thickness shall be in accordance with the following:

(1.1) **Plate** The dimension measured vertically to the rolled face shall be called as the thickness.

(1.2) **Forgings** It shall be as given in the following according to the shapes.

- (a) **Hollow forgings** The thickness between the inner face and the outer face shall be called as the thickness (thickness in radial direction).
- (b) **Flat disc shaped forgings** The length measured in axial direction shall be called as the thickness (length in axial direction $\leq$ outside diameter).
- (c) **Flat ring shaped forgings** When the dimension in axial direction is 50 mm or under, the dimension in axial direction shall be called as the thickness. When the dimension in axial direction exceeds 50 mm, the thickness measured in radial direction shall be called as the thickness (when the length in axial direction is smaller than the thickness in radial direction).
- (d) **Forgings of square section without hole** The length of the side of the smaller one of the section shall be called as the thickness.

(1.3) **Castings** For the castings of the ordinary shape, it shall be the same as the forgings.

(2) The sampling method of the test materials and test pieces of iron and steel materials to be used for the 1st-class vessels shall be in accordance with the following. However, the impact test pieces, in the case where the impact tests are carried out particularly in accordance with 5.3.5, shall not be limited to these.

(2.1) **Steel plates** The steel plates shall be in accordance with the following:

- (a) The sampling method of test materials, number and sampling positions of test pieces shall be in accordance with the prescriptions of applicable material standard. However, the sampling positions of the test pieces of the steel plates of 50 mm or over in nominal thickness shall be at places $1 t$ apart from whichever end faces of the material subjected to the heat treatment. Where, t : nominal thickness of material.
- (b) When the test pieces are sampled from the steel plates or test materials which have been subjected to normalizing (including accelerated cooling), normalizing and tempering, or quenching and tempering, these shall be in accordance with the applicable material standards, as well as be sampled from the positions conforming to (4.3) from the heat treated end.
- (c) When the hubs for the purpose of butt welding with flat heads, tube sheets, flanges, etc. are cut out from the plate, test pieces shall be sampled additionally from the positions indicated in Attached Figs. 2 (1) (a) to (c).

(2.2) Steel pipes The steel pipes shall be in accordance with the following:

- (a) The sampling method of test materials and number and sampling positions of test pieces shall be in accordance with the applicable material standards.
- (b) When the test pieces are sampled from the steel pipes subjected to normalizing (including accelerated cooling), these shall be in accordance with the applicable material standards, as well as be sampled from the positions conforming to (4.3) from the heat treated end.

(2.3) Bar steel and bolt material The bar steel and bolt material shall be in accordance with the following:

- (a) For the bar steel of under 50 mm in diameter or thickness, the test pieces shall be sampled in accordance with the prescriptions of applicable material standards.
- (b) For the bar steel of 50 mm or over in diameter or thickness, the test pieces shall be at the places of at least $\frac{1}{4} t$ (t is diameter or thickness of bar steel) from the surface of material or rolled face, and also the end face of the test pieces shall be apart by not less than the diameter or thickness of the bar steel from the end part of the bar steel subjected to heat treatment.
- (c) For the bolt material, the test pieces shall be sampled in accordance with the prescriptions of the applicable material standards.
- (d) When the bar steels or bolt materials are heat treated, the test pieces shall be sampled from the positions satisfying (4.3) from the heat treated ends.

(2.4) Forgings The forgings shall be in accordance with the following:

- (2.4.1) The sampling method of test material, number and sampling positions of test pieces shall be in accordance with the applicable material standards and JIS G 0306.

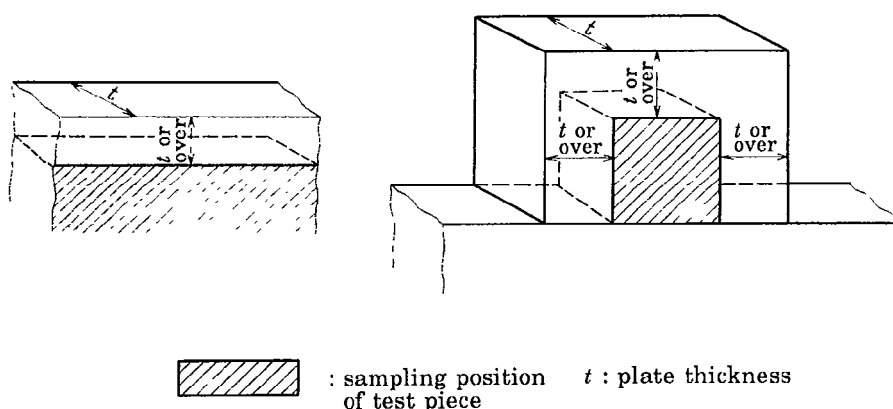
- (2.4.2) As to the steel forgings exceeding 50 mm in thickness, when the accelerated cooling is to be carried out at time of normalizing or when the quenching and tempering is to be carried out, the sampling of test pieces shall be in accordance with one of the following:
- (a) The test pieces shall be sampled in parallel to the main forging direction from the pads or extended parts of the steel forgings. In this case, the axes of test pieces shall be at least $\frac{1}{4} T$ from one of the heat treated face of the steel forging or forged steel material, as well as shall be the positions at least T apart from the second heat treated face. Where, T : the maximum heat treated thickness of steel forgings (hereafter, the same as this.)
 - (b) For the steel forgings of nozzles, thick walled tube sheets, flanges and other complicated shapes which are formed or machined to the similar shapes of products prior to the heat treatment, test pieces shall be sampled in parallel to the main forging direction from the pads or extended parts of the steel forgings. The sampling positions shall be the places apart from the heat treated faces by not less than the largest one of the distances between the predetermined high tensile stress face and the nearest heat treated face to that, as well as shall be the places at least two times the above-mentioned distance apart from the second heat treated face. However, the test pieces shall be 20 mm or over apart from the heat treated face and be 40 mm or over apart from the second heat treated face.
 - (c) The test pieces of the flat ring and simple ring shaped steel forging may be sampled from the steel forging materials separately manufactured so as to satisfy the following conditions. The axis of the test piece shall be the position at least $\frac{1}{4} T$ apart from one of the heat treated face, and shall be at least T apart from the second heat treated face.
 - (c-1) It shall be the same melt and the same forging ratio substantially as the steel forgings, as well as shall be subjected to the heat treatment of the same type.
 - (c-2) The heat treatment shall be carried out under the same conditions in the same heat treatment furnace as the steel forgings.
 - (c-3) The thickness shall be the nominal heat treatment thickness of steel forgings.
- (2.5) Steel castings The steel castings shall be in accordance the following.
- (2.5.1) The sampling method of test materials, number and sampling positions of test pieces shall be in accordance with the prescriptions of applicable material standards and 3.2 (Mechanical tests) of JIS G 0307.
 - (2.5.2) When normalizing (including accelerated cooling), normalizing and tempering, or quenching and tempering is to be carried out, test pieces shall be sampled in accordance with the following:
 - (a) For the steel castings of 50 mm or under in the maximum thickness, test pieces may be sampled from the test materials in accordance with the applicable material standards.

- (b) For the steel castings exceeding 50 mm in the maximum thickness, test pieces shall be sampled from the steel casting as it is or its extended part. In this case, the longitudinal centre axis of the test pieces shall be at least $\frac{1}{4} T$ from one of the heat treated face, and shall be the position at least T apart from the second heat treated face. Where, T : the maximum heat treatment thickness of steel casting.
- (c) For the steel castings exceeding 50 mm in the maximum thickness which are the large shape steel castings to be cast or machined to the similar shape of the steel castings prior to heat treatment, test pieces shall be sampled from the pads or extended parts of steel castings. The sampling position shall be apart from the heat treated face by not less than that of the maximum one among the distances between the preliminarily designated high tensile stress face and the nearest heat treatment face to that, and also shall be that place at least two times the above-mentioned distance from the second treated face. However, the test pieces shall be 20 mm or over apart from the heat treated face and 40 mm or over from the second heat treated face.
- (d) When the approval of the purchaser has been obtained in advance, test pieces may be sampled from the separately cast test material satisfying the following conditions. The test pieces shall be at the position of $\frac{1}{4}$ the thickness or the nearer position to this as far as possible, and also shall be at the position apart from the second heat treated face by not less than the thickness.
 - (d-1) It shall be the same melt as the steel castings, and be the same casting method as the product substantially.
 - (d-2) It shall be subjected to the heat treatment in the same heat treatment furnace under the same conditions as the steel castings.
 - (d-3) It shall be the same nominal thickness as the steel castings.
- (3) The sampling method of test material of iron and steel materials to be used for the 2nd-class vessels or 3rd-class vessels, the number and sampling positions of test pieces shall be in accordance with the prescriptions of the respective applicable standards and JIS G 0307.
- (4) Heat treatments of test pieces The heat treatments of test pieces shall be in accordance with the following:
 - (4.1) When a ferritic material is heat treated, test pieces shall be sampled from the materials which have been subjected to heat treatment. However, when otherwise specified, this shall be exempt from application.
 - (4.2) When the heat treatment is carried out, after a test material has been cut off from the material body, test pieces shall be sampled from this test body, after the prescribed heat treatment has been carried out on the test material which has been cut off from the materials.

- (4.3) When the heat treatment is of normalizing, or quenching and tempering, the test material shall be cooled in accordance with one of the following method at a speed of the same degree and not faster as the cooling speed in the case of the normalizing or quenching of the material body. However, as regards the temperature range of 400°C or under and a part of the steel casting in the case of normalizing, this shall be omitted when otherwise specified.
- (a) From the heat treated end of the materials or test materials, the test pieces shall be sampled from the positions apart at least one time the thickness of the material or test material (diameter or diagonal distance for bar materials).
- (b) At the material end from which the test pieces are to be sampled, a steel strap having the equal width to the thickness of material so as to satisfy (a) shall be attached by the partial joint penetration welding (see Fig. 5.1).

Fig. 5.1 Essentials of sampling test pieces

- (1) When sampled from body (2) When sampled from test material



- (c) The thermal shielder or thermal insulator shall be used at the material end from which the test piece is sampled.
- (d) There is an equipment which is capable of regulating cooling curve data of material and cooling speeds of the test material. By using this equipment, the test material shall be cooled so that within 20 s in time difference and within 15°C in temperature difference with the cooling curve of the material are obtained.
- (4.4) When the material is cladded or cladded by welding prior to be normalized or cooled rapidly from the austenitizing temperature, the test material shall have been cladded or cladded by welding to that of the same thickness as the body prior to the heat treatment as this.
- (4.5) When the heat treatment corresponding to the heat treatment after welding of vessels is carried out for the test materials, the holding time of 80 % or over the total holding time of heat treatment after welding to which this material is actually subjected may be considered to be the holding time of one time continuously.

5.3.4 Nondestructive tests of iron and steel materials The nondestructive tests which shall be carried out in accordance with the prescriptions of JIS standardized materials shall be in accordance with the following:

(1) The nondestructive tests of iron and steel materials given in Attached Table 1.1 to be employed for 1st-class vessels shall be in accordance with the following:

- (1.1) Steel plates All of the steel plates exceeding 50 mm in nominal thickness shall be subjected to the ultrasonic testing, and the results shall conform to JIS G 0801.
- (1.2) Steel forgings All of the steel forgings exceeding 50 mm in nominal thickness shall be in accordance with the following requirements, and also shall be subjected to the ultrasonic testing in accordance with JIS G 0587. In this case, rings, flanges and other hollow steel forgings of which ratio of outside diameter to inside diameter being 1.4 or under shall be subjected to the ultrasonic testing by normal beam technique or angle beam technique, and other steel forgings shall be subjected to the ultrasonic testing by normal beam technique.

(a) Time of flaw detection The time of flaw detection shall generally be after the final heat treatment (excluding strain relieving annealing) for acquiring the mechanical properties of steel forgings.

In addition, the flaw detecting range shall be the overall region of the steel forgings. However, when the shape of the steel forging disturbs the perfect ultrasonic testing, it shall be carried out under the conditions where the perfect flaw detection is possible before the final heat treatment. In this case, the possible overall region shall also be flaw detected after the final heat treatment.

(b) Acceptance criteria In 8. (Grade classification) of JIS G 0587, those of the following grades shall be considered to be acceptance:

- (b-1) In the grade classification of independent defect echo, those of grade 1, grade 2 and grade 3.
- (b-2) In the grade classification of lowering amount of bottom echo due to defect, those of grade 1, grade 2 and grade 3.
- (b-3) The grade classification of aggregated defects shall be as agreed between the parties concerned.

(1.3) Clad steels The stainless clad steels (excluding overlaid clad steels) of 8 mm or over in nominal thickness (including clad material) shall be subjected to ultrasonic testing on joined parts in accordance with 5. (Ultrasonic testing) of JIS G 0601, and the results shall conform to the class 1 F of Table 3 (Joined conditions) specified in 6. (Joined conditions) of JIS G 3601.

For the overlaid clad steels, it shall be in accordance with the requirements of (3) of 6. (Joined conditions) of JIS G 3601.

(2) The nondestructive tests of iron and steel materials given in Attached Table 1.2 to be used for 1st-class vessels shall be in accordance with the following:

- (2.1) Steel plates All of the steel plates exceeding 100 mm in nominal thickness shall be subjected to the ultrasonic testing and the results shall conform to JIS G 0801.
- (2.2) Steel forgings The ultrasonic testing of the steel forgings shall be in accordance with the following:
- (2.2.1) All of the steel forgings of carbon steel and low alloy steel of 100 mm or over in nominal thickness shall be subjected to ultrasonic testing in accordance with JIS G 0587. In this case, hollow steel forgings of rings, flanges and others, of which ratio of outside diameter to inside diameter being 1.4 or under shall be subjected to ultrasonic testing by angle beam technique and other steel forgings to ultrasonic testing by normal beam technique. The time and acceptance criteria of ultrasonic testing shall conform to the requirements of (1.2) (a) and (b).
- (2.2.2) All of the stainless steel forgings of 100 mm or over in nominal thickness shall be subjected to the ultrasonic testing in accordance with JIS Z 2344, other than in accordance with the requirements of the following (2.2.3) to (2.2.5). In this case, the hollow steel forgings of rings, flanges and others and those of 1.4 or under in ratio of outside diameter to inside diameter shall be subjected to the ultrasonic testing by the angle beam technique specified in the following (2.2.4) and other steel forgings by the normal beam technique specified in (2.2.3). The time of ultrasonic testing shall be in accordance with (1.2) (a).
- In addition, the acceptance criteria shall be in accordance with the following (2.2.5).
- (2.2.3) Normal beam ultrasonic testing method The normal beam ultrasonic testing method shall be in accordance with the following:
- (a) Flaw detection shall be carried out from two directions approximately in right angles as far as possible.
- For hollow steel forgings, flaw detection shall be made from the circumferential face and the face vertical to axis, and for disc shaped steel forgings, from one of the plane and circumferential face.
- (b) The diameter of vibrator shall be 20 mm to 30 mm. However, the vibrator of other diameter may be used if required.
- (c) The test frequency shall be 2 MHz. However, when the transmission of ultrasonic wave is insufficient due to the size of the material, crystal grain size or microscopic structure, 1 MHz may also be used.
- (d) As to the working sensitivity, the height of the first time bottom echo from the portion where no defect echo of steel forging is presented shall be adjusted to 80 % the scale height of the Braun tube. The adjustment of this working sensitivity shall be carried out on each thickness of steel forgings. At the portion where the detecting face is not parallel to the bottom face, the adjusted sensitivity may be used at the portion where the thickness of adjoining parallel portions as close as possible is the same or larger.
- (2.2.4) Angle beam ultrasonic testing method The angle beam ultrasonic testing method shall be in accordance with the following:

- (a) The flaw detection shall be carried out in circumferential direction as far as the thickness or shape of steel forgings is permissible.
- (b) The dimensions of the vibrator shall be 10 mm × 10 mm, 20 mm × 20 mm or 28 mm × 28 mm, and refraction angle shall be 45°. However, the detection probe of other dimensions or refraction angle may be used as required.
- (c) The test frequency shall generally be 1 MHz. However, if 1 MHz is not appropriate, 2 MHz may be allowed to use.
- (d) The comparison test piece shall be worked so that the ultrasonic attenuation degree becomes the same as the steel forging to be inspected, and be heat treated.
- (e) As to the artificial flaw of comparison test piece, the rectangular shaped artificial flaw of whichever of equal to the smaller one of 9 mm or 3 % the thickness in depth, approximately 25 mm in length, and at most two times the depth in width shall be worked on the steel forging or comparison test piece.
- (f) As to the working sensitivity, the echo height when the artificial flaw of steel forging or comparison test piece has been flaw detected by $\frac{1}{2}$ skip or 1 skip shall be adjusted to 80 % the scale plate. Further, the echo height from the artificial flaw is obtained by 1 skip or 2 skips at this sensitivity, and the distance-amplitude characteristic curve connecting this vertex of echo and the preceeding vertex of echo is obtained, and consider this to be the comparison line.
- (g) All of the conditions, such as surface finish conditions, frequency, adjusting conditions of equipment, shape of detecting probe, and coupling medium to be used for sensitivity adjustment, shall be the same during the actual testings.

(2.2.5) Acceptance criteria The acceptance criteria shall be in accordance with the following:

- (a) When the echoes given in the following have been detected, it shall be judged whether its abnormal part is a defect or not by the route of beam, scanning characteristics, etc., and it shall be deemed rejectable when being judged as defect.

For normal beam detection:

An echo accompanied with the vanishment of bottom face echo not originated in the shape of steel forging. Herein, the vanishment of bottom face echo means that the height of bottom face echo becomes 5 % or under the scale plate.

For angle beam detection:

An echo exceeding the comparison line.

- (b) The steel forging from which the echoes as given in the following have been recognized shall be informed of the generating states of the echo to the purchaser before shipment, and shall acquire its approval.

For normal beam detection:

- (b-1) An echo exceeding the height of bottom face echo (echo of which $\frac{F_1}{B_F}$ exceeds 100 %)

- (b-2) A travelling echo accompanied with the attenuation of bottom face echo (the travelling echo means that echo which travels on the time axis of the Braun tube at a comparatively constant height according to the travel of the detecting probe.)

For angle beam detection:

- (b-3) An echo exceeding 50 % the comparison line
- (b-4) The group of defective echoes having the height of 50 % or under the comparison line (the group of echoes means that in which three pieces or more of defective echoes exceeding 10 % the comparison line are included in the volume of 50 cubic mm or under.)
- (2.3) Clad steels The ultrasonic testing on the joining parts of the clad steels shall be the same as the requirements of (1.3).
- (2.4) Steel castings The steel castings shall be subjected to the radiographic testing or ultrasonic testing and magnetic particle testing or liquid penetrant testing in accordance with the testing methods and testing ranges given in the following:
- (2.4.1) Radiographic testing The radiographic testing shall be applied to all of the parts of 300 mm or under in thickness of the cast steels, and the testing method shall be in accordance with JIS G 0581, and the judgment of defects shall be in accordance with the following:
- (a) The ill deposition of cracks, chaplets at time of casting and inferiority in welding by inserts shall be deemed rejectable.
- (b) Blowholes, sand inclusions and inclusions, and shrinkage cavities, when these are conforming to the grades of Table 5.1, shall be deemed acceptable.

Table 5.1 Acceptance grades of blowholes, sand inclusion and inclusion, and shrinkage cavities

Type of defect		Wall thickness of test parts	
		25 mm or under	Over 25 mm
Blowhole		Grade 1	Grade 2
Sand inclusion and inclusion		Grade 1	Grade 2
Shrinkage cavities	Linear shaped	Grade 1	Grade 2
	Arborescent	Grade 1	Grade 2

Remarks: As to the shrinkage cavity of test part of 50 mm or over in wall thickness, when its position has been confirmed that it exists within $\frac{1}{3}$ the center of wall thickness, its acceptance grade may be deemed as grade 2.

(2.4.2) Ultrasonic testing The part of steel casting exceeding 300 mm in thickness, as far as possible, shall be subjected to the ultrasonic testing by normal beam technique. The test shall be in accordance with the following requirements and also with JIS Z 2344.

- (a) The time of flaw detection shall be after the final heat treatment for acquiring the mechanical properties of steel castings.
- (b) The surfaces of steel castings to be tested shall be free from scales, sands, etc. and be such a condition as not disturbing the transmission of ultrasonic wave, and be made flat and smooth by grinding, machining and the like, as required.
- (c) The diameter of detecting probe shall be 20 mm to 30 mm. However, the detecting probe of other diameter may also be used, as required.
- (d) The test frequency shall be 1 MHz. However, other frequency may also be used, for the purpose of assuming the positions and properties of defects.
- (e) The comparison test piece to be used for adjusting the working sensitivity shall be that of having the metallic structure equal to the steel castings. However, when it has been confirmed that the ultrasonic wave attenuation degree is equal, the materials of other property may also be used.

The dimensions of comparison test piece shall be as given in Table 5.2 and Fig. 5.2. However, the comparison test piece 6-B shall be used when the detecting distance exceeds 350 mm.

Table 5.2 Dimensions and numbers of comparison test pieces

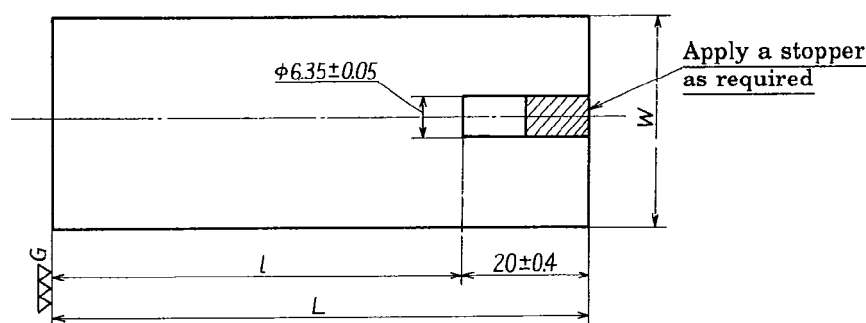
Unit: mm			
l	L	$W^{(2)}$	Number
25	45 ± 3	50 min.	6-025
50	70 ± 3	50 min.	6-050
75	95 ± 3	50 min.	6-075
150	170 ± 3	75 min.	6-150
250	270 ± 3	100 min.	6-250
$B^{(1)}$	$B \pm 20$	125 min.	6-B

Notes ⁽¹⁾ B shall be the thickness of steel casting.

⁽²⁾ W shall be the width or diameter.

Fig. 5.2 Comparison test pieces

Unit: mm



- (f) The working sensitivity shall be so adjusted that the echo F from the flat bottom hole of comparison test piece No. 6-250 becomes 10 % the scale plate. By detecting the other comparison test piece with this sensitivity, the curve connecting the vertices of echoes F from respective flat bottom holes shall be considered to be the comparison line. When the wall thicknesses of steel castings are over 250 mm up to and including 350 mm, the comparison line shall be elongated.

When the thickness of material exceeds 350 mm, the comparison line shall be prepared by so adjusting that the echo height from the flat bottom hole of 6-B test piece becomes 10 %.

Next, in order to correct the difference of working sensitivities due to the difference between the surface roughness of steel casting and the roughness of detecting face of the comparison test piece, the height of bottom face echo shall be obtained by the above-mentioned sensitivity, selecting that of the nearest in wall thickness of steel casting among the test pieces, at the position where the influence of the flat bottom hole and side faces are the smallest. Next, placing the detection probe on the steel casting, and adjusting the bottom face echo height so as to coincide with that of the comparison test piece, this shall be considered to be working sensitivity.

- (g) When the echoes given in the following have been detected in the results of the testing, whether the abnormal part is a defect or not shall be judged from the beam route, scanning characteristics, etc., and when it has been judged as defect, it shall be deemed as rejection.
- (g-1) That of which area of the abnormal part indicating the echo exceeding the comparison line exceeds 20 cm².
 - (g-2) That of which maximum length of the abnormal part indicating the echo exceeding the comparison line exceeds 65 mm.
 - (g-3) When there are two or more of abnormal parts indicating the echoes exceeding the comparison line on the same plane, and the mutual distance is smaller than the maximum length of the abnormal part of the larger one, that of which range of these abnormal parts group exceeds 20 mm².

(g-4) The echo which has accompanied the vanishment of bottom face echo not originated from the shape of steel casting. Herein, the vanishment of bottom face echo means that the height of bottom face echo becomes 5 % or under the scale plate.

(2.4.3) Magnetic particle testing The steel castings of magnetic material shall generally be magnetic particle tested on overall surfaces in accordance with JIS G 0565.

The judgement of defects shall be in accordance with the following:

- (a) When circular defect magnetic particle pattern is presented, and it conforms to the standard given in Table 5.3, it shall be deemed acceptable.
- (b) When linear defect magnetic particle pattern is presented, and it conforms to the standard given in Table 5.3, it shall be deemed acceptable.

Table 5.3 Maximum length or sum of lengths of circular defect magnetic particle patterns and linear defect magnetic particle patterns

Unit: mm

Nominal thickness of detection part	Maximum length or sum of lengths of defect magnetic particle patterns
20 or under	4
Over 20 up to and incl. 60	8
Over 60	16

- (c) When scattered defect magnetic particle patterns are presented, and these conform to the sum of lengths of defect magnetic particle patterns given in Table 5.3, it shall be deemed acceptable.

(2.4.4) Liquid penetrant testing The steel castings of non-magnetic materials shall be subjected to the fluorescence liquid penetrant testing or visible dye penetrant testing in accordance with JIS Z 2343 as appropriate on overall faces as far as possible.

The judgement of defects shall be in accordance with the magnetic particle testing as appropriate. However, when cracks or hot tears are presented, it shall be deemed rejectable.

- (3) The nondestructive test of the iron and steel materials given in Attached Table 2.1 to be used for the 2nd-class vessels or 3rd-class vessels shall generally be in accordance with the applicable material standards, however, when it is necessary on account of design conditions, or required by the user, necessary nondestructive testings shall be carried out additionally by designating the prescriptions of JIS standardized materials. In this case, necessary non-destructive testings and acceptance criteria thereof shall be in accordance with the prescriptions of (2) as appropriate.

5.3.5 Notch toughness and low temperature working limit The notch toughness and low temperature working limit shall be in accordance with the following:

- (1) **Materials for 1st-class vessels other than bolt materials** The materials given in Attached Table 1.2 shall not be used at other temperatures than in the temperature range corresponding to the fundamental permissible stresses given in Attached Table 1.2 (excluding the temperatures being attached with *). However, when it conforms to one of the conditions given in the following, it can be used at the lower temperature than given in Attached Table 1.2. The fundamental permissible stress in this case shall be the value at 0°C.
 - (1.1) **Materials to which impact test is specified** For the materials conforming to 5. where the requirements of 2 mm V notch Charpy impact test of which values of strength and absorption energy specified in its standard are in the relationship given in Table 5.4, these can be used to the temperatures obtained in accordance with Fig. 5.3 or Fig. 5.4. The temperatures of intermediate thickness shall be obtained by the rule of three sum. However, for the following materials of (a) to (c), this Standard shall not be applied, but respective material standards apply.
 - (a) JIS G 3127
 - (b) STPL 450 {STPL 46} and STPL 690 {STPL 70} of nickel steel pipes of JIS G 3460
 - (c) STBL 450 {STBL 46} and STBL 690 {STBL 70} of nickel steel pipes of JIS G 3464

Table 5.4 Relationship between strength and absorption energy of material

Division	Tensile strength and yield point of materials	Absorption energies of materials	
		Other than steel castings	Steel castings
1	(1) That of specified minimum tensile strength is under 450 N/mm ² (45.9 kgf/mm ²) and specified minimum yield point or proof stress is under 320 N/mm ² (32.6 kgf/mm ²)	27 J (2.8 kgf · m) or over	
2	(1) That of specified minimum tensile strength is 450 N/mm ² (45.9 kgf/mm ²) or over to and excl. 600 N/mm ² (61.2 kgf/mm ²) and specified minimum yield point or proof stress is under 450 N/mm ² (45.9 kgf/mm ²) (2) That of specified minimum yield point or proof stress is 320 N/mm ² (32.6 kgf/mm ²) or over to and excl. 450 N/mm ² (45.9 kgf/mm ²) and specified minimum tensile strength is under 600 N/mm ² (61.2 kgf/mm ²)	40 J (4.1 kgf · m) or over	27 J (2.8 kgf · m) or over
3	(1) That of specified minimum tensile strength is 600 N/mm ² (61.2 kgf/mm ²) or over (2) That of specified minimum yield point or proof stress is 450 N/mm ² (45.9 kgf/mm ²) or over	47 J (4.8 kgf · m) or over	Not applicable

Remarks 1. When the absorption energy value specified in the material standard is different from the absorption energy value specified in each division of the above Table, Fig. 5.3 or Fig. 5.4 shall apply assuming that the test temperature is increased or decreased by the value of the following Table.

Correction temperatures for test temperatures

Unit: °C

Required absorption energy of each division J (kgf · m)	Absorption energy specified in material standard J (kgf · m)			
	20 {2.0}	27 {2.8}	40 {4.1}	47 {4.8}
27 {2.8}	+ 5	—	−10	−15
40 {4.1}	+15	+10	—	− 5
47 {4.8}	+20	+15	+ 5	—

2. For the material in accordance with JIS G 3126, Table 5.4 (including Remarks 1.) and Fig. 5.3 or Fig. 5.4 shall apply by shifting the impact test temperature specified in the standard to the lower temperature side by 13°C considering the absorption energy in this case to be 47 J (4.8 kgf · m).

Fig. 5.3 Lowest workable temperatures of materials when used as welded

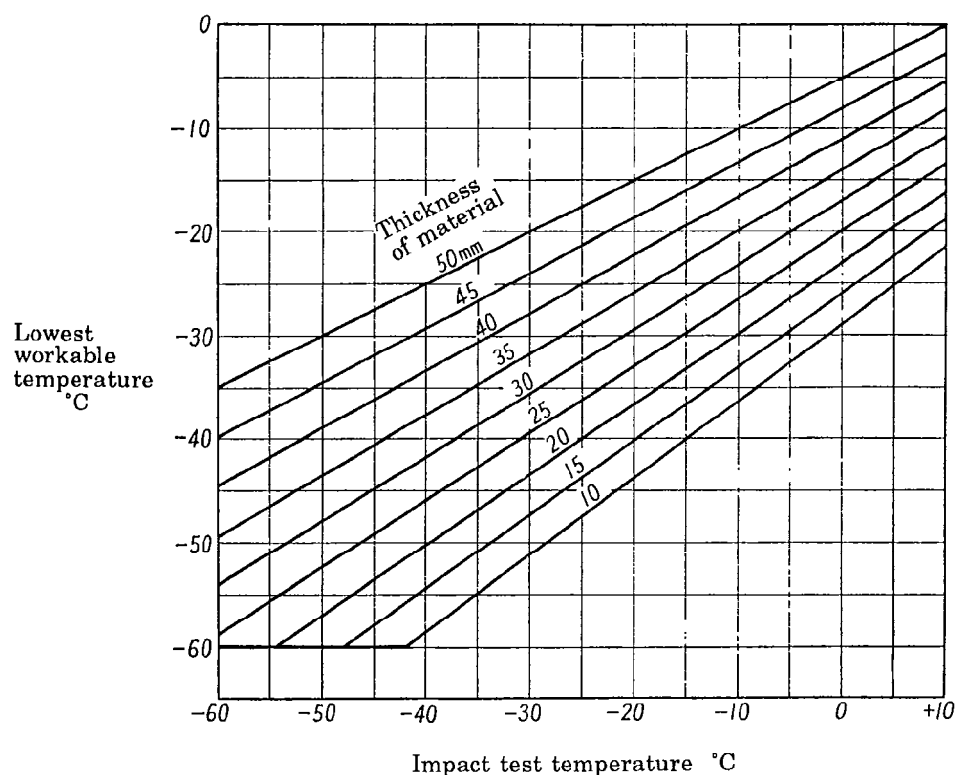
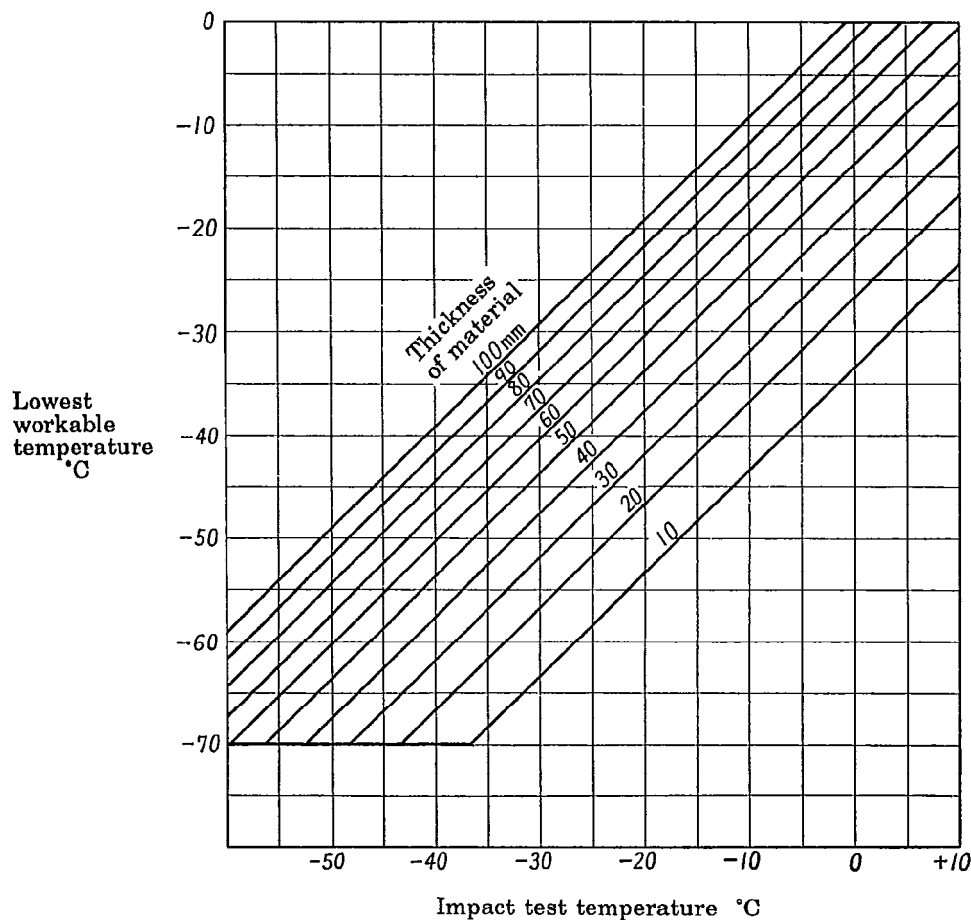


Fig. 5.4 Lowest workable temperatures of materials when used subjected to heat treatment after welding



- (1.2) Handling when impact test has been executed The materials being attached with * mark in Attached Table 1.2, when subjected to the impact test in accordance with the requirements of the following (1.2.1) to (1.2.4) at the temperatures attached with * mark and has passed this, may be used up to the temperature⁽³⁾ which is obtained by applying the prescriptions of (1.1). However, the lowest permissible metal temperature of pressure vessels manufactured from the iron and steel materials other than austenitic stainless steel shall be in accordance with Table 5.5.

Note ⁽³⁾ In the results of the test at the temperature attached with * mark, when the lowest workable temperature becomes under the temperature attached with * mark, it may be used up to that temperature.

Table 5.5 Relationship between the lowest permissible metal temperature and the impact test temperature of vessels manufactured from the iron and steel materials other than austenitic stainless steel

Type of vessel		At the time of running ⁽⁴⁾	At the time of pressure test ⁽⁵⁾	At the time to start running ⁽⁶⁾
General vessels	As welded	The same as the impact test temperature	To be raised by 17°C higher than the impact test temperature	The same as the impact test temperature ⁽⁸⁾
	That has been heat treated after welding	The same as the impact test temperature	The same as the impact test temperature	The same as the impact test temperature ⁽⁸⁾
Vessels containing lethal substances	As welded	Do not use		
	That has been heat treated after welding	⁽⁹⁾	⁽⁹⁾	⁽⁸⁾ ⁽⁹⁾
Vessels to be used for low temperature equipments ⁽⁷⁾	As welded	The same as the impact test temperature ⁽¹⁰⁾	To be raised by 17°C higher than the impact test temperature	The same as the impact test temperature ⁽⁸⁾
	That has been heat treated after welding	The same as the impact test temperature	The same as the impact test temperature	The same as the impact test temperature ⁽⁸⁾

- Notes
- (4) The lowest permissible metal temperature at the time of running shall indicate the temperature at which the maximum running pressure (or design pressure) may be allowed to be loaded.
- (5) The lowest permissible metal temperature at the time of pressure test shall indicate the temperature at which the hydraulic or pneumatic test pressure may be allowed to be loaded.
- (6) The lowest permissible metal temperature at the time to start running shall indicate the temperature which is permissible at the time to start running.
- (7) The low temperature equipment means that of which metal temperature becomes under -10°C not from the atmospheric conditions but by the running conditions.
- (8) When the pressure does not exceed 20 % the test pressure, it may be lower than the lowest permissible metal temperature of the vessels.
- (9) When the nominal thickness exceeds 25 mm, it shall be taken as 11°C higher than the impact test temperature at each increase of 25 mm or its fraction. However, it shall not be necessary to take higher exceeding 33°C than the impact test temperature.
- (10) It shall be limited when the mounting welds of nozzle and other portions of larger local stress are to be heat treated after welding. In other cases, it shall be taken as 17°C higher than the impact test temperature.

(1.2.1) The number and sampling method of impact test pieces shall be in accordance with the prescriptions relating to the impact test of material standards given in the following according to the shapes of products. However, the materials subjected to the heat treatment shall conform to the requirements of 5.3.3 (4.3) relating to the sampling positions of test pieces from the heat treated ends.

- (a) Steel plates The steel plates shall be in accordance with the requirements of (2) (number of impact test pieces) and (4) (sampling position of impact test pieces) of 9.2.1 (test in general) of JIS G 3115.
- (b) Steel pipes for piping The steel pipes for piping shall be in accordance with the requirements of 9.5 (Charpy impact test) of JIS G 3460.
- (c) Steel pipes for heat exchanger The steel pipes for heat exchanger shall be in accordance with the requirements of 9.5 (Charpy impact test) of JIS G 3464.
- (d) Steel forgings The steel forgings shall be in accordance with the requirements of (1.2) (sampling method of test pieces) and 1.3 (number of test specimens and test pieces) of 4.2.2 (sampling method of test specimens and test pieces, the number and test method) of JIS G 0306.
- (e) Steel castings The steel castings shall be in accordance with the requirements of 3.2.1 (test specimens) and 3.2.2 (types and methods of mechanical tests) of JIS G 0307.

(1.2.2) The impact test pieces and impact test method shall be in accordance with the following:

- (a) Impact test pieces The test pieces No. 4 specified in JIS Z 2202. However, the notches shall be cut into the direction of thickness.
- (b) Impact test method The impact test method shall be in accordance with JIS Z 2242.

(1.2.3) The impact test temperature shall be the temperature attached with * marks in Attached Table 1.2.

(1.2.4) The Charpy absorption energy shall be not less than the value given in Table 5.4 according to the material strengths. The absorption energy given in Table 5.4 shall apply to the mean value from three test pieces, and the absorption energy of individual test piece shall be not less than 70 % the value given in Table 5.4.

The absorption energy, where subsize test pieces have been used, shall be not less than the value being multiplied with the coefficient given in Table 5.6 corresponding to the difference between the thickness of material and the thickness of test piece sampled from that.

When the value of absorption energy has failed to conform the requirement, acceptance or rejection may be determined by carrying out the reinspection in accordance with the requirements of JIS G 0303.

Table 5.6 Coefficients when subsize test pieces have been used

	Sectional dimensions of test piece mm	10 × 7.5	10 × 5
Coeffi- cient	When the difference of thickness between the material and the test piece is not more than 3 mm	0.75	0.5
	When the difference of thickness between the material and the test piece exceeds 3 mm	0.83	0.67

Remarks: The numerical values obtained by multiplying the coefficient, when the unit of absorption energy being J, shall be rounded off to the 1st place of integer (in the case of kgf · m, to the 1st place of decimal) in accordance with JIS Z 8401.

- (1.3) When working stress is low That of which primary general membrane stress at the design temperature becomes 42 N/mm^2 (4.2 kgf/mm^2) or under, the materials attached with * marks of Attached Table 1.2 may be used to the temperatures attached with * marks without subjected to the impact test.
- (1.4) Thin materials in thickness The killed steel material of seamless steel pipes under 10 mm in thickness and the material other than seamless steel pipe under 5 mm in thickness may be used without carrying out impact test up to the temperature given in Table 5.7, according to the ratios of manganese to carbon among the chemical components specified in the material standard.

Table 5.7 Lowest workable temperature usable without impact test

Unit: °C

Type of steel	When it is used as welded state	When it is heat treated after welding
Carbon steels and carbon manganese steels of 2.5 or over in the ratio of manganese to carbon	- 30	- 50
Fine particle carbon manganese steels of 4.5 or over in the ratio of manganese to carbon	- 50	- 50

- (2) Materials for 2nd-class vessels and 3rd-class vessels other than bolt material
The materials given in Attached Table 2.1 and to which impact tests are specified in Notes shall be those which pass the impact tests specified in (2.1) to (2.4).
- (2.1) The number and sampling method of impact test pieces shall be in accordance with (1.2.1).
- (2.2) The impact test pieces and impact test method shall be in accordance with (1.2.2).
- (2.3) The impact test shall be carried out at the lowest working temperature or under of pressure vessels.

- (2.4) The Charpy absorption energy shall be not less than the value given in Table 5.8, according to the material strengths. The absorption energy, when the subsize test pieces have been used, shall be used by translating into the minimum absorption energy value when the subsize test pieces given in Table 5.9 have been used, according to the dimensions of test pieces which have been used the values given in Table 5.8.

When the value of the absorption energy has failed to conform, the acceptance or rejection may be determined by carrying out the reinspection in accordance with the prescriptions of JIS G 0303.

Table 5.8 Minimum absorption energy values

Minimum tensile strength of material	Minimum absorption energy values	
	Mean value of 3 pieces	Minimum value of 1 piece
Under 490 N/mm ² {50 kgf/mm ² }	21 J (2.1 kgf · m)	14 J (1.4 kgf · m)
490 N/mm ² {50 kgf/mm ² } or over	27 J (2.8 kgf · m)	21 J (2.1 kgf · m)

Table 5.9 Minimum absorption energy values when subsize test pieces have been used

Dimensions of test piece	Value of full size	Values of corresponding subsize			
	10 × 10 × 55 mm	10 × 7.5 × 55 mm	10 × 5 × 55 mm	10 × 2.5 × 55 mm	
Minimum absorption energy values	27 J (2.8 kgf · m)	23 J (2.3 kgf · m)	19 J (1.9 kgf · m)	14 J (1.4 kgf · m)	
	21 J (2.1 kgf · m)	17 J (1.7 kgf · m)	14 J (1.4 kgf · m)	10 J (1.0 kgf · m)	
	14 J (1.4 kgf · m)	12 J (1.2 kgf · m)	9 J (0.9 kgf · m)	7 J (0.7 kgf · m)	

- (3) Bolt materials The bolt materials shall be in accordance with the following:
- (3.1) The materials given in Attached Tables 3.1 and 3.2 shall not be used at the temperature of other temperature ranges corresponding to the fundamental permissible stresses given in respective Attached Tables.
- (3.2) All of the materials given in Attached Table 3.1, and the materials given in Attached Table 3.2 shall be those which have passed, carrying out the impact test specified in the following in accordance with the Note of Attached Table.
- The number of test pieces and sampling method shall be in accordance with the prescriptions of JIS G 4108.
 - The shapes and dimensions of test pieces shall be in accordance with test piece No. 4 specified in JIS G 2202.
 - The impact test method shall be in accordance with JIS Z 2242.

- (d) The test temperature shall be the working temperature. However, when the working temperature exceeds 0°C, the test temperature shall be 0°C.
- (e) As to the absorption energy, the mean value of the three test pieces shall be 40 J (4.1 kgf · m) or over and the value of one test piece shall be 34 J (3.5 kgf · m) or over.
- (f) When the value of absorption energy has failed to conform to the prescriptions, the acceptance or rejection may be determined by carrying out the retest in accordance with the prescriptions of JIS G 0303.

5.4 Nonferrous metal materials The nonferrous metal materials shall be in accordance with 5.1, and otherwise the tests and inspections thereof shall be in accordance with the following:

5.4.1 Sampling methods of test materials and test pieces Irrespective of the grades of pressure vessels, the sampling method of the test materials of nonferrous metal materials, number and sampling positions of test pieces shall be in accordance with applicable material standards.

5.4.2 Heat treatments of test materials Irrespective of the grades of pressure vessels, the heat treatments of test materials shall be in accordance with the following:

- (1) The test materials representing the members which are subjected to heat treatments during manufacture of pressure vessels shall be heat-treated in accordance with the heat treatment conditions to be applied to the pressure vessels. In this case, the heat treatment conditions shall be determined upon agreement between the parties concerned. The heating speed, holding time of heat treatment temperature and cooling speed shall be those representing the test treatment conditions to be applied to the pressure vessels.
- (2) When the test material from which the test pieces are employed is not of that of being attached to the body, the size of the test material shall be of sufficient size to represent the cooling speed of materials to be used for the manufacture of pressure vessels.
- (3) In any case, the dimensions of test material shall be at least $3t \times 3t \times t$. Where, t is the nominal thickness.

In addition, the sampling positions of test pieces shall be at least t apart from either end face of the test material.

5.4.3 Nondestructive tests of nonferrous metal materials The nondestructive tests to be performed by designating to the prescriptions of JIS standardized materials shall be in accordance with the following:

- (1) The nondestructive tests of the nonferrous metal materials given in Attached Table 1.3 used for the 1st-class vessels shall be in accordance with the following:
 - (1.1) **Plates** The plates exceeding 100 mm in nominal thickness shall be subjected to the ultrasonic testing in accordance with the following:
 - (a) The normal beam technique shall be used.

- (b) The vibrating probe shall be of the circular shape of 20 mm to 30 mm in diameter or square shape of 25 mm in side.
 - (c) The test frequency shall be of an appropriate one according to the types of material.
 - (d) As to the working sensitivity, the height of the 1st time bottom face echo from the defect free portion of plate shall be adjusted to 80 % the scale height of Braun tube.
 - (e) That plate which presents the defect echo accompanied with the vanishment of bottom face echo not originated from the shape of the plate shall be deemed to be rejectable. The vanishment of bottom face echo, herein, means that the bottom face echo height becomes 5 % or under the scale plate.
- (1.2) Forgings The forgings exceeding 100 mm in nominal thickness shall be subjected to the ultrasonic testing in accordance with the following:
- (a) The cubic forging blocks shall be tested by the normal beam technique from right angled two directions approximately, as far as possible.
 - (b) The hollow shaped forgings including flanges and ring shaped forgings shall be tested by the angle beam technique using the contact method or immersion technique. These hollow forgings, unless those of difficult in angle beam technique on account of thickness or shape, shall be tested from both directions of one vertical face to axis and peripheral direction.
 - (c) The flat disc shaped forgings shall be tested from both of one of the flat planes and circumferencial face.
 - (d) The forgings shall be flaw detected of the whole volume of the material at any time during manufacture. For the material to be subjected to the heat treatment, it should be tested after the final heat treatment, however, when it is unable to carry out perfectly on account of the shape, retest shall be performed on the range capable of being tested, as far as possible, after the final heat treatment.
 - (e) The normal beam technique shall be in accordance with (1.1) (b) to (e).
 - (f) In the angle beam technique by the contact method, the detecting probe of 45 degrees and 25 mm × 25 mm or 25 mm × 38 mm of an appropriate frequency, shall be used.
 - (g) In the angle beam technique by the immersion method, the detecting probe of 19 mm in diameter, having appropriate injection angle, and an appropriate frequency, shall be used.
 - (h) The angle beam detection shall be adjusted sensitivity by the notch of whichever of the smaller one of 9.5 mm in depth or 3 % the nominal thickness of the material to be tested and about 25 mm in length and at least two times the depth in width.
 - (i) In the angle beam technique, when the defects of one piece or more have been found, and the echoes thereof are larger than the echo from the notch of comparison test piece, it shall be deemed to be rejectable.

- (2) The nondestructive tests of the nonferrous metal materials given in Attached Table 2.2 to be used for the 2nd-class vessels or 3rd-class vessels shall be in accordance with the applicable material standards.

5.5 Casting quality coefficient The fundamental permissible stresses of castings to be used for the 2nd-class vessels or 3rd-class vessels shall be multiplied with the casting quality coefficient defined as follows according to the degrees of non-destructive tests. However, iron castings and malleable iron castings are excluded.

- (1) The casting quality coefficient for the standstill castings tested in accordance with the minimum requirements of material standard shall be taken as 0.8. The centrifugal castings, after having been subjected to the test in accordance with the minimum requirements of the material standards, and after heat treatment, the surfaces of which shall be machine finished to $6.35\ \mu\text{m}$ or under in center line mean roughness. In this case, the casting quality coefficient shall be 0.85.
- (2) For the steel castings of carbon steel, low alloy steel or high alloy steel, when the additional tests as follows are performed in addition to the requirements of (1), the higher casting quality coefficient may be employed.
- (2.1) Carrying out the radiographic test in accordance with JIS G 0581 on the portions⁽¹¹⁾ liable to present defects of total number of products (including the case of one piece.), those which have passed grade 3 and upward respectively for the defects of three types defined in the Standard may be considered to be 0.9.

Note ⁽¹¹⁾ Portions where defects are liable to take place mean the following portions: In the standstill castings, the places where cross-sections change abruptly, such as the joining part for casting, riser, gate or injection opening. In the centrifugal castings, interpreting those as the places where any abrupt change in cross-section takes place, these mean the places of the periphery of between each end and at least 76 mm and the place added with one place of the circumference zone of 76 mm in width, and these shall be considered to include the range where the most strict indication patterns are to be detected by other testing methods.

- (2.2) The overall surfaces of total number of products (including the case of one piece) shall be subjected to the magnetic particle testing in accordance with JIS G 0565 or to the fluorescent liquid penetrant testing or dyeing liquid penetrant testing, and those which have passed the following acceptance criteria may be deemed as 0.9.
 - (a) The judgement of defects, where circular indications are found, shall be in accordance with 5.3.4 (2.4.3) (a).
 - (b) The judgement of defects, where linear indications are found, shall be in accordance with 5.3.4 (2.4.3) (b).
 - (c) The judgement of defects, where scattering indications are found, shall be in accordance with 5.3.4 (2.4.3) (c).

- (d) The judgements of the defects of liquid penetrant testing shall be in accordance with the magnetic particle testing, as appropriate. However, when cracks or hot tears are found, it shall be deemed rejectable.
- (2.3) Among the five pieces which have been manufactured at first from each mold of new design or modified design, taking three pieces or more, and five pieces or one piece from each fraction thereof from the manufacture thereafter, the radiographic testing in accordance with JIS G 0581 shall be carried out on the portions where defects are liable to take place, and further the magnetic particle testing in accordance with JIS G 0565 or the liquid penetrant testing in accordance with JIS Z 2343 shall be carried out, and those which have passed the acceptance criteria in accordance with the requirements of (2.1) and (2.2) respectively may be deemed to be 0.9.
- (2.4) Carrying out the test in accordance with the requirements of (2.1) and (2.2) on the total number of products (including the case of one piece), those which have passed the judgement of defect may be deemed to be 1.0.
- (3) For the nonferrous metal castings, ductile iron castings and malleable iron castings defined in Annex 5, when all of the following requirements (a) to (c) or the requirements of (d) are satisfied in addition to the minimum requirements of (1), 0.9 may be allowed to employ.
- (a) Each casting of which overall surface and exposed portions by machining process or drilled hole shall be subjected to the magnetic particle testing or liquid penetrant testing, and the results shall pass the judgement of defects specified in (2.2).
- (b) Taking three pieces or more among five pieces which have been manufactured at first from each mold of new design or modified design, and five pieces or one piece from each fraction thereof in the manufacture of thereafter, all of the parts from which defects are liable to take place are cut and subjected to the magnetic particle testing or liquid penetrant testing, and the results shall pass the judgement criteria in accordance with the prescriptions of (2.2), or subjected to the radiographic testing, and shall pass the judgement criteria of (2.1).
- (c) The rest of the castings other than those subjected to the radiographic testing in (b) shall be subjected to the magnetic particle testing or liquid penetrant testing on all of the portions where defects are liable to take place, and the results shall pass the acceptance criteria specified in (2.2).
- (d) For the casting of one piece, all of the portions where defects are liable to take place shall be subjected to the radiographic testing, and the results shall pass the acceptance criteria specified in (2.1).

Remarks: For example, those which have been machine worked so that all of the portions where defects are liable to take place, such as the drill holes of tube plate (the interval of holes shall be not larger than the thickness of the casting), are capable of being subjected to the magnetic particle testing or liquid penetrant testing may be substituted by this test in lieu of the cutting test or radiographic testing specified in (3) (b).