

JAPANESE
INDUSTRIAL
STANDARD

Translated and Published by
Japanese Standards Association

JIS B 8265 : 2017

**Construction of pressure vessel —
General principles**

ICS 23.020.30

Reference number : JIS B 8265 : 2017 (E)

PROTECTED BY COPYRIGHT

B 8265 : 2017

Date of Establishment: 2000-03-27

Date of Revision: 2017-11-25

Date of Public Notice in Official Gazette: 2017-11-27

Investigated by: Japanese Industrial Standards Committee

Standards Board for ISO area

Technical Committee on Industrial Machinery

JIS B 8265 : 2017, First English edition published in 2018-09

Translated and published by: Japanese Standards Association
Mita MT Building, 3-13-12, Mita, Minato-ku, Tokyo, 108-0073 JAPAN

In the event of any doubts arising as to the contents,
the original JIS is to be the final authority.

© JSA 2018

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from the publisher.

Printed in Japan

PROTECTED BY COPYRIGHT

Contents

	Page
1 Scope	1
1.1 Applicable pressure vessels	1
1.2 Scope of pressure vessels	2
2 Normative references	2
3 Terms and definitions	7
4 Materials	8
4.1 General	8
4.2 Steel materials	10
4.3 Allowable stress of materials	11
4.4 Various properties of materials	12
5 Design	13
5.1 General	13
5.2 Shell and head	15
5.3 Cover plate	18
5.4 Bolted flange	18
5.5 Hole	18
5.6 Bonding of nozzle stub and tube	18
5.7 Tubesheet	19
5.8 Flat head supported by stay	19
5.9 Expansion joint	19
6 Welding	20
6.1 General	20
6.2 Weld joint efficiency	46
6.3 Butt welding	47
6.4 Plug welding	50
6.5 Welding of shell and tubesheet or flat head	50
6.6 Postweld heat treatment	51
6.7 Welder	51
7 Manufacturing	51
7.1 General	51
7.2 Circularity of shell by diameter method	52
7.3 Manufacturing tolerances on head	55
7.4 Installation of stay	56
8 Tests and inspections	57
8.1 Mechanical tests on butt welded joint	57
8.2 Nondestructive examinations on welded joints	59

8.3	Nondestructive examination methods and judgment of results	60
8.4	Retest of nondestructive examination	62
8.5	Pressure test	63
8.6	Leak test	64
8.7	Final inspection	64
9	Safety devices	65
9.1	General	65
9.2	Instrumentation facility	65
10	Marking and conformity assessment	65
10.1	Marking	65
10.2	Conformity assessment	65
Annex A (normative)	Correspondence between P-number given in Annex A of JIS B 8285 and P-number given in ASME	66
Annex B (normative)	Allowable tensile stress of materials	67
Annex C (normative)	Specific materials	119
Annex D (normative)	Mechanical and physical properties of materials	128
Annex E (normative)	Shells and heads of pressure vessels	148
Annex F (normative)	Hole reinforcing of pressure vessels	204
Annex G (normative)	Bolted flanges of pressure vessels	224
Annex H (normative)	Flat face flanges using full face non-metallic gaskets	244
Annex I (normative)	Metallic face contact flanges	248
Annex J (normative)	Reverse flanges	268
Annex K (normative)	Tubesheet of pressure vessels	274
Annex L (normative)	Cover plates of pressure vessels	280
Annex M (normative)	Plates supported by stays of pressure vessels	287
Annex N (normative)	Expansion joints of pressure vessels	292
Annex O (normative)	Mechanical tests on welded joints of pressure vessels	297
Annex P (normative)	Pressure test on pressure vessels	301
Annex Q (normative)	Ligament efficiency of cylindrical shell	303
Annex R		309
Annex S (normative)	Postweld heat treatment	310
Annex T (normative)	Allowable pressure verification test	324
Explanatory note (extract)	Technical background (Criteria for allowable tensile stress)	331

Foreword

This Japanese Industrial Standard has been revised by the Minister of Health, Labour and Welfare and the Minister of Economy, Trade and Industry, through deliberations at the Japanese Industrial Standards Committee in accordance with the Industrial Standardization Law.

Consequently **JIS B 8265:2016** is replaced with this Standard.

This **JIS** document is protected by the Copyright Law.

Attention is drawn to the possibility that some parts of this Standard may conflict with patent rights, applications for a patent after opening to the public or utility model rights. The relevant Ministers and the Japanese Industrial Standards Committee are not responsible for identifying any of such patent rights, applications for a patent after opening to the public or utility model rights.

The figures and tables marked with † in this standard, were adapted from the ASME Boiler and Pressure Vessel Code© 2015 by The American Society of Mechanical Engineers with the written consent of the ASME Code & Standards Department. No additional translation or reproduction may be made of these materials without the prior written consent of ASME.

Construction of pressure vessel — General principles

1 Scope

1.1 Applicable pressure vessels

This Japanese Industrial Standard applies to the construction of pressure vessels with the design pressure of less than 30 MPa. Pressure vessels herein refer to the vessels which retain the pressure, contain fluids which generate the pressure, or those which retain the external pressure. Pressure vessels given in **a)** to **f)** below are excluded.

This Standard and **JIS B 8267** differ in the specifications of allowable stress of materials, impact test, etc.

NOTE : The pressure, unless otherwise specified, means the gauge pressure.

- a) Those specified in other Japanese Industrial Standards ¹⁾
- b) Those made of non-metallic materials
- c) Those used for atomic energy
- d) Those of riveted or soldered structure
- e) Those exposed to direct fire
- f) Those with special structures ²⁾ or for special applications ³⁾

Notes ¹⁾ Examples of Japanese Industrial Standards are shown below.

JIS B 8267 *Construction of pressure vessel*

JIS B 8266 *Alternative standard for construction of pressure vessels*

JIS B 8201 *Stationary steel boilers — Construction*

JIS B 8240 *Construction of pressure vessels for refrigeration*

JIS B 8241 *Seamless steel gas cylinders*

JIS B 8248-1 *Cylindrical layered pressure vessels — Part 1 : General standards*

JIS B 8248-2 *Cylindrical layered pressure vessels — Part 2 : Alternative standards*

JIS B 8501 *Welded steel tanks for oil storage*

²⁾ Such as those with complicated shapes, flat-bottom cylindrical tanks for low temperature and tanks with membrane structure.

³⁾ Pressure retaining parts of rotating or reciprocating machines such as oil hydraulic machines, water hydraulic machines, pumps, compressors, turbines, internal combustion engines, water pressure cylinders or pneumatic pressure cylinders.

1.2 Scope of pressure vessels

1.2.1 The scope of pressure vessels shall include the main body of pressure vessels [shells, heads and nozzle stubs (nozzles) directly connected to them], and the pressure retaining parts given in a) to c) below.

- a) In the case of the tubes bonded to shells, heads or nozzle stubs (directly connected to them) of pressure vessels, the pressure retaining parts shall be from the bonded joints (welded joint, screw joint or bolted flanged tube joint) up to the parts given in 1) to 3) below.
 - 1) In the case of the welded joint, up to the groove face of the circumferential joint of the tube nearest to the welded joint (excluding the circumferential joint)
 - 2) In the case of the screw joint (including the tube joint with inside screw), up to the threaded portion of the tube side of screw joint
 - 3) In the case of the bolted flanged tube joint, up to the flange face of the tube side of the bolted flanged tube joint (including bolts and nuts)
- b) In the case of the direct welding of non-pressure member onto the pressure retaining part, up to the welded joint
- c) Up to the cover plate such as a manhole and a hand-hole which retain the pressure (including the bonded joint)

1.2.2 Valves may be included in the scope of pressure vessels.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this Standard. For standards indicated below, only the editions of the indicated year shall be applied and any revisions (including amendments) made thereafter shall not be applied.

JIS B 0190 : 2010 *Glossary of terms used in construction of pressure vessels*

JIS B 2220 : 2012 *Steel pipe flanges*

JIS B 2239 : 2013 *Cast iron pipe flanges*

JIS B 2240 : 2006 *Copper alloy pipe flanges*

JIS B 2241 : 2006 *Aluminium alloy pipe flanges*

JIS B 2290 : 1998 *Vacuum technology — Flange dimensions*

JIS B 8210 : 2017 *Safety devices for protection against excessive pressure — Safety valves*

JIS B 8226-1 : 2011 *Bursting disc safety devices — Part 1 : General*

JIS B 8226-2 : 2011 *Bursting disc safety devices — Part 2 : Combination with safety valve*

JIS B 8226-3 : 2011 *Bursting disc safety devices — Part 3 : Application, selection*

and installation

- JIS B 8266 : 2006 *Alternative standard for construction of pressure vessels*
- JIS B 8267 : 2015 *Construction of pressure vessel*
- JIS B 8274 : 2008 *Flat tubesheet for pressure vessels*
- JIS B 8285 : 2010 *Welding procedure qualification test for pressure vessels*
- JIS G 0404 : 2014 *Steel and steel products — General technical delivery requirements*
- JIS G 0581 : 1999 *Methods of radiographic examination for steel castings*
- JIS G 0582 : 2015 *Automated ultrasonic examination of steel pipes and tubes*
- JIS G 0801 : 2008 *Ultrasonic testing of steel plates for pressure vessels*
- JIS G 3101 : 2015 *Rolled steels for general structure*
- JIS G 3103 : 2012 *Carbon steel and molybdenum alloy steel plates for boilers and pressure vessels*
- JIS G 3106 : 2015 *Rolled steels for welded structure*
- JIS G 3114 : 2016 *Hot-rolled atmospheric corrosion resisting steels for welded structure*
- JIS G 3115 : 2016 *Steel plates for pressure vessels for intermediate temperature service*
- JIS G 3116 : 2013 *Steel sheet, plates and strip for gas cylinders*
- JIS G 3118 : 2010 *Carbon steel plates for pressure vessels for intermediate and moderate temperature services*
- JIS G 3119 : 2013 *Manganese-molybdenum and manganese-molybdenum-nickel alloy steel plates for boilers and pressure vessels*
- JIS G 3120 : 2014 *Manganese-molybdenum and manganese-molybdenum-nickel alloy steel plates quenched and tempered for pressure vessels*
- JIS G 3126 : 2015 *Carbon steel plates for pressure vessels for low temperature service*
- JIS G 3127 : 2013 *Nickel steel plates for pressure vessels for low temperature services*
- JIS G 3131 : 2011 *Hot-rolled mild steel plates, sheet and strip*
- JIS G 3201 : 2008 *Carbon steel forgings for general use*
- JIS G 3202 : 2008 *Carbon steel forgings for pressure vessels*
- JIS G 3203 : 2008 *Alloy steel forgings for pressure vessels for high-temperature service*
- JIS G 3204 : 2008 *Quenched and tempered alloy steel forgings for pressure vessels*

- JIS G 3205 : 2008 *Carbon and alloy steel forgings for pressure vessels for low-temperature service*
- JIS G 3206 : 2008 *High strength chromium-molybdenum alloy steel forgings for pressure vessels under high-temperature service*
- JIS G 3214 : 2009 *Stainless steel forgings for pressure vessels*
- JIS G 3452 : 2016 *Carbon steel pipes for ordinary piping*
- JIS G 3454 : 2012 *Carbon steel tubes for pressure service*
- JIS G 3455 : 2016 *Carbon steel pipes for high pressure service*
- JIS G 3456 : 2016 *Carbon steel pipes for high temperature service*
- JIS G 3457 : 2016 *Arc welded carbon steel pipes*
- JIS G 3458 : 2013 *Alloy steel pipes*
- JIS G 3459 : 2016 *Stainless steel pipes*
- JIS G 3460 : 2013 *Steel tubes for low temperature service*
- JIS G 3461 : 2012 *Carbon steel boiler and heat exchanger tubes*
- JIS G 3462 : 2016 *Alloy steel tubes for boiler and heat exchanger*
- JIS G 3463 : 2012 *Stainless steel boiler and heat exchanger tubes*
- JIS G 3464 : 2013 *Steel heat exchanger tubes for low temperature service*
- JIS G 3467 : 2013 *Steel tubes for fired heater*
- JIS G 3468 : 2016 *Large diameter welded stainless steel pipes*
- JIS G 3601 : 2012 *Stainless-clad steels*
- JIS G 3602 : 2012 *Nickel and nickel alloy clad steels*
- JIS G 3603 : 2012 *Titanium clad steels*
- JIS G 3604 : 2012 *Copper and copper alloy clad steels*
- JIS G 4051 : 2016 *Carbon steels for machine structural use*
- JIS G 4053 : 2016 *Low-alloyed steels for machine structural use*
- JIS G 4107 : 2010 *Alloy steel bolting materials for high temperature service*
- JIS G 4108 : 2010 *Alloy steel bars for special application bolting materials*
- JIS G 4109 : 2013 *Chromium-molybdenum alloy steel plates for boilers and pressure vessels*
- JIS G 4110 : 2015 *High strength chromium-molybdenum and chromium-molybdenum-vanadium alloy steel plates for pressure vessels under high-temperature service*
- JIS G 4303 : 2012 *Stainless steel bars*
- JIS G 4304 : 2015 *Hot-rolled stainless steel plate, sheet and strip*

JIS G 4305 : 2015	<i>Cold-rolled stainless steel plate, sheet and strip</i>
JIS G 4311 : 2011	<i>Heat-resisting steel bars and wire rods</i>
JIS G 4312 : 2011	<i>Heat-resisting steel plate, sheet and strip</i>
JIS G 4901 : 2008	<i>Corrosion-resisting and heat-resisting superalloy bars</i>
JIS G 4902 : 1991	<i>Corrosion-resisting and heat-resisting superalloy plates and sheets</i>
JIS G 4903 : 2008	<i>Seamless nickel-chromium-iron alloy pipes</i>
JIS G 4904 : 2008	<i>Seamless nickel-chromium-iron alloy heat exchanger tubes</i>
JIS G 5101 : 1991	<i>Carbon steel castings</i>
JIS G 5102 : 1991	<i>Steel castings for welded structure</i>
JIS G 5111 : 1991	<i>High tensile strength carbon steel castings and low alloy steel castings for structural purposes</i>
JIS G 5121 : 2003	<i>Corrosion-resistant cast steels for general applications</i>
JIS G 5122 : 2003	<i>Heat-resistant cast steels and alloys for general applications</i>
JIS G 5131 : 2008	<i>High manganese steel castings</i>
JIS G 5151 : 1991	<i>Steel castings for high temperature and high pressure service</i>
JIS G 5152 : 1991	<i>Steel castings for low temperature and high pressure service</i>
JIS G 5201 : 1991	<i>Centrifugally cast steel pipes for welded structure</i>
JIS G 5202 : 1991	<i>Centrifugally cast steel pipes for high temperature and high pressure service</i>
JIS G 5526 : 2014	<i>Ductile iron pipes</i>
JIS G 5527 : 2014	<i>Ductile iron fittings</i>
JIS H 3100 : 2012	<i>Copper and copper alloy sheets, plates and strips</i>
JIS H 3250 : 2015	<i>Copper and copper alloy rods and bars</i>
JIS H 3300 : 2012	<i>Copper and copper alloy seamless pipes and tubes</i>
JIS H 3320 : 2006	<i>Copper and copper alloy welded pipes and tubes</i>
JIS H 4000 : 2017	<i>Aluminium and aluminium alloy sheets, strips and plates</i>
JIS H 4040 : 2015	<i>Aluminium and aluminium alloy bars and wires</i>
JIS H 4080 : 2015	<i>Aluminium and aluminium alloy extruded tubes and cold-drawn tubes</i>
JIS H 4090 : 2006	<i>Aluminium and aluminium alloy welded pipes and tubes</i>
JIS H 4100 : 2015	<i>Aluminium and aluminium alloy extruded profiles</i>
JIS H 4140 : 1988	<i>Aluminium and aluminium alloy forgings</i>

- JIS H 4301 : 2009 *Lead sheets and plates and hard lead sheets and plates*
- JIS H 4311 : 2006 *Lead and lead alloy tubes for common industries*
- JIS H 4551 : 2000 *Nickel and nickel alloy plate, sheet and strip*
- JIS H 4553 : 1999 *Nickel and nickel alloy bars*
- JIS H 4600 : 2012 *Titanium and titanium alloys — Sheets, plates and strips*
- JIS H 4630 : 2012 *Titanium and titanium alloys — Seamless pipes*
- JIS H 4631 : 2012 *Titanium and titanium alloys — Tubes for heat exchangers*
- JIS H 4635 : 2012 *Titanium and titanium alloys — Welded pipes*
- JIS H 4650 : 2016 *Titanium and titanium alloys — Bars*
- JIS H 5120 : 2016 *Copper and copper alloy castings*
- JIS H 5121 : 2016 *Copper alloy continuous castings*
- JIS H 5202 : 2010 *Aluminium alloy castings*
- JIS H 5302 : 2006 *Aluminium alloy die castings*
- JIS Z 2242 : 2005 *Method for Charpy pendulum impact test of metallic materials*
- JIS Z 2305 : 2013 *Non-destructive testing — Qualification and certification of NDT personnel*
- JIS Z 2320-1 : 2007 *Non-destructive testing — Magnetic particle testing — Part 1 : General principles*
- JIS Z 2320-2 : 2007 *Non-destructive testing — Magnetic particle testing — Part 2 : Detection media*
- JIS Z 2320-3 : 2007 *Non-destructive testing — Magnetic particle testing — Part 3 : Equipment*
- JIS Z 2343-1 : 2001 *Non-destructive testing — Penetrant testing — Part 1 : General principles — Method for liquid penetrant testing and classification of the penetrant indication*
- JIS Z 3060 : 2015 *Method for ultrasonic testing for welds of ferritic steel*
- JIS Z 3080 : 1995 *Methods of ultrasonic angle beam examination for butt welds of aluminium plates*
- JIS Z 3081 : 1994 *Methods of ultrasonic angle beam examination for welds of aluminium pipes and tubes*
- JIS Z 3082 : 1995 *Methods of ultrasonic examination for T type welds of aluminium plates*
- JIS Z 3104 : 1995 *Methods of radiographic examination for welded joints in steel*
- JIS Z 3105 : 2003 *Methods of radiographic examination for welded joints in aluminium*

- JIS Z 3106 : 2001 *Methods of radiographic examination for welded joints in stainless steel*
- JIS Z 3107 : 2008 *Methods of radiographic examination for titanium welds by X-ray*
- JIS Z 3121 : 2013 *Methods of tensile test for butt welded joints*
- JIS Z 3122 : 2013 *Methods of bend test for butt welded joint*
- JIS Z 3801 : 1997 *Standard qualification procedure for manual welding technique*
- ISO 3183 *Petroleum and natural gas industries — Steel pipe for pipeline transportation systems*
- ASME B16.5 : 1996 *Pipe Flanges and Flanged Fittings*
- ASME B16.9 : 1993 *Factory-Made Wrought Buttwelding Fittings*
- ASME B16.11 : 1991 *Forged Fittings, Socket-Welding and Threaded*
- ASME B16.15 : 1985 *Cast Copper Alloy Threaded Fittings*
- ASME B16.24 : 1991 *Cast Copper Alloy Pipe Flanges and Flanged Fittings*
- ASME B16.28 : 1986 *Wrought Steel Buttwelding Short Radius Elbows and Returns*
- ASME B16.47 : 1996 *Large Diameter Steel Flanges*
- ASME Section II : 1998 (up to 1998 Addenda)
- ASME Section VIII Division 1 : 1998 (up to 1998 Addenda)

3 Terms and definitions

For the purpose of this Standard, the terms and definitions given in **JIS B 0190**, and the following apply.

3.1 calculated thickness

thickness required for the strength calculation

3.2 thickness

generic term for the nominal thickness and the actual thickness

3.3 nominal thickness

nominal dimension of thickness of plates, tubes, etc.

3.4 pressure retaining part

part of pressure vessel which retains the pressure exceeding 0 MPa on inside surface or outside surface, or the strengthened member subjected to the load caused by pressure

The following **a)** and **b)** are excluded.

- a) Construction inside the pressure vessel but not purposing the pressure retaining (a baffle, a guide pipe, etc.)

- b) Non-pressure member such as lining and plating applied to the pressure retaining part

3.5 design temperature

highest and lowest temperatures at which a pressure vessel may be used, set by considering the conditions of starting, operating, suspending, abnormality, environment, etc.

3.6 design pressure

highest pressure up to which a pressure vessel may be used (lowest pressure if it is equal to or lower than the atmospheric pressure).

For the pressure vessel such as a heat exchanger which is divided into several pressure chambers and any one of which is at a pressure equal to or lower than the atmospheric pressure, the maximum differential pressure shall be used as the design pressure. If two or more pressure chambers are connected by piping without valves, the differential pressure may be used as the design pressure.

3.7 carbon steel

steel of classification symbol corresponding to P-number 1 given in Table A.1 of **JIS B 8285** or steel similar to these

In addition, P-number and group number of specific materials specified in 4.1 c) shall be in accordance with Part D of **ASME** (The American Society of Mechanical Engineers) Section II, and Table A.1 of **JIS B 8285** is replaced by "Part D of **ASME** Section II" (hereafter, the same). Correspondence between P-number given in Table A.1 of **JIS B 8285** and P-number given in **ASME** is given in Table A.1.

3.8 low alloy steel

steel of classification symbols corresponding to P-numbers 3, 4 and 5 (for specific materials, P-number 5 refers to P-numbers 5A, 5B and 5C), 9A and 9B given in Table A.1 of **JIS B 8285**, and any steel similar to these

3.9 stainless steel

steel of classification symbols corresponding to P-numbers 6, 7, 8A and 8B given in Table A.1 of **JIS B 8285**, and any steel similar to these

4 Materials

4.1 General

Materials used for pressure vessels shall be the specified materials, equivalent materials and specific materials as given in a) to d) below.

- a) **Specified materials** Materials given in Table B.1 to Table B.5.
- b) **Equivalent materials** Materials conforming to any of 1) to 4) below.
- 1) Materials of which the chemical compositions and mechanical properties are equivalent to those of specified materials, but the range of plate thickness differs.

If the restriction for ranges of plate thickness are given in Table B.1 to Table B.5, the equivalent materials may be used only within the range of plate thickness of specified materials.

- 2) Materials of which the chemical compositions and mechanical properties are equivalent to those of specified materials, but the production methods or the shapes differ (for example, difference between casting products and steel sheets).
 - 3) Materials of which the chemical compositions and mechanical properties are equivalent to those of specified materials, but revision years of normative references differ.
 - 4) Materials of which the chemical compositions, testing methods and sampling methods of test pieces of mechanical properties are equivalent to those of specified materials, and the test results are equivalent to those of specified materials.
- c) **Specific materials** Materials given in 1) and 2) below.
- 1) Materials specified in Part UCS, Part UNF, Part UHA, Part UCL and Part UHT of **ASME Section VIII Division 1** (hereafter referred to as Part), that satisfy all of the conditions as given in 1.1) to 1.3) below.
 - 1.1) Materials given in Table C.1 to Table C.13
 - 1.2) Minimum tensile strength and minimum yield point of materials in the allowable stress table given in paragraph 23 of Part and UG23 of Part UG
 - 1.3) Usage restriction shown in Part
 - 2) Materials used for pipe flanges and flanged fittings specified in **ASME** standards that are given in 2.1) to 2.7) below shall be the materials of **ASTM** (American Society for Testing and Materials) standards, and are as given in Table C.1 to Table C.12. In this case, the symbols (SA/SB) in **ASME** standard of the material numbers in Table C.1 to Table C.12 are replaced by the symbols (A/B) of **ASTM** standard.
 - 2.1) ASME B16.5 : 1996 *Pipe flanges and flanged fittings*
 - 2.2) ASME B16.9 : 1993 *Factory-made wrought butt welding fittings*
 - 2.3) ASME B16.11 : 1991 *Forged fittings, socket-welding and threaded*
 - 2.4) ASME B16.15 : 1985 *Cast copper alloy threaded fittings*
 - 2.5) ASME B16.24 : 1991 *Cast copper alloy pipe flanges and flanged fittings*
 - 2.6) ASME B16.28 : 1986 *Wrought steel butt welding short radius elbows and returns*
 - 2.7) ASME B16.47 : 1996 *Large diameter steel flanges : NPS 26 through NPS 60*
- d) **Working temperature range of materials** As given in 1) and 2) below. In the following, the minimum working temperature shall be as given in Table R.5 of **JIS B 8267** or specifications separately given ⁴⁾.
- Note ⁴⁾ Specifications separately given refer to those given in applicable laws and regulations or in other standards.

- 1) **Working temperature range of base metals** As given in 1.1) or 1.2) below.
 - 1.1) Working temperature range of allowable tensile stress given in Table B.1 to Table B.5 shall apply to the specified materials and equivalent materials.
 - 1.2) Working temperature range that uses the maximum working temperature specified in the column of VIII-1 of **ASME Section II** Part D Table 1A or Table 1B shall apply to the specific materials.
- 2) **Working temperature range of clad steel** As given in 2.1) or 2.2) below.
 - 2.1) Working temperature range that uses the maximum working temperature of base metal or that of cladding metal, whichever is lower, shall apply when the strength of cladding metal is incorporated in the strength calculation.
 - 2.2) Working temperature range of allowable tensile stress of base metal when the strength of cladding metal is not incorporated in the strength calculation.

4.2 Steel materials

4.2.1 Usage restriction of materials

Usage of materials shall be restricted as given in **a)** and **b)** below.

- a) **General usage restriction** Materials containing carbon over 0.35 % (cast analysis value) shall not be used for the welded joint.
- b) **Usage restriction of materials listed in Table B.1 and Table B.2** Use of materials listed in Table B.1 and Table B.2 and equivalent materials shall be restricted as given in 1) to 3) below.
 - 1) Materials in **JIS G 3106** (excluding SM400A, SM490A and SM490YA) and **JIS G 3114** (excluding SMA400AW, SMA400AP, SMA490AW and SMA490AP) shall not be used for the shells, heads and other pressure retaining parts of pressure vessel with the design pressure of over 3 MPa.
 - 2) Materials of **JIS G 3101** (SS330 and SS400), **JIS G 3106** (SM400A, SM490A and SM490YA), **JIS G 3114** (SMA400AW, SMA400AP, SMA490AW and SMA490AP) and those given in **JIS G 3457** shall not be used for the pressure retaining parts listed in 2.1) to 2.4) below.
 - 2.1) Shells, heads and other pressure retaining parts of pressure vessels with the design pressure of over 1.6 MPa.
 - 2.2) Shells having Group A joint and heads having welded joint of the pressure vessels with the design pressure of over 1 MPa.
 - 2.3) Shells, heads and other pressure retaining parts which have welded joints with base metal thickness of over 16 mm.
 - 2.4) Shells, heads and other pressure retaining parts containing lethal substances or toxic substances
 - 3) Materials of **JIS G 3452** shall not be used for the pressure retaining parts listed in 3.1) to 3.3) below.

- 3.1) Pressure retaining parts with the design pressure of over 1 MPa
- 3.2) Pressure retaining parts with the design temperature of below 0 °C or over 100 °C. For the pressure retaining parts containing compressed air, vapour or water, they can be used up to 200 °C, and for those containing fluid with the design pressure of less than 0.2 MPa, they may be used up to 350 °C.
- 3.3) Pressure retaining parts containing lethal substances, toxic substances or liquefied gas with the design pressure of over 0.2 MPa

4.3 Allowable stress of materials

4.3.1 Allowable tensile stress of materials

The allowable tensile stress of materials at the design temperature shall be as given in a) to f) below.

- a) Table B.1 to Table B.3 show the allowable tensile stress of steel materials.
- b) Table B.4 shows the allowable tensile stress of non-ferrous metallic materials.
- c) Table B.5 shows the allowable tensile stress of materials for bolts.
- d) In Table B.1 to Table B.5, the allowable tensile stress of materials at the temperature below 40 °C shall be the values in the column “Below 40 °C.”
- e) Allowable tensile stress of equivalent materials at the design temperature shall be the allowable tensile stress of specified materials of which the chemical compositions and mechanical properties are equivalent to those.
- f) Allowable tensile stress of specific materials at the design temperature shall be as given in 1) and 2) below.
 - 1) Allowable tensile stress shall be the value obtained by multiplying the value specified in **ASME Section II** Part D (unit : ksi) by 6.89 to three significant digits [fourth significant and lower digits are truncated (unit : N/mm²)]. In this case, the temperature shall be the value converted from °F into °C and rounded to the whole number.
 - 2) Allowable tensile stress at temperatures below –29 °C (–20 °F) shall be the value of allowable tensile stress at –29 °C.

4.3.2 Allowable shear stress

The allowable shear stress of materials at the design temperature shall be 0.8 times the value of allowable tensile stress.

4.3.3 Allowable compression stress

The allowable compression stress of materials at the design temperature shall be either the allowable tensile stress or the allowable buckling stress, whichever is smaller. The allowable buckling stress shall be as given in a) or b) below.

- a) **Cylindrical shell**

$$\sigma_{cr} = \frac{0.3Et}{D_m(1+0.004E/\sigma_y)}$$

where, D_m : mean diameter of cylindrical shell (mm)
 E : longitudinal elastic coefficient of material at design temperature (N/mm²)
 t : calculated thickness of cylindrical shell (mm)
 σ_{cr} : allowable buckling stress (N/mm²)
 σ_y : yield point or 0.2 % proof stress of material at design temperature (N/mm²)

- b) **Tube** According to Formula (1) when the following conditional equation is satisfied or Formula 2) when not satisfied.

$$\text{Conditional equation} \quad \sqrt{\frac{2\pi^2 E}{\sigma_y}} \leq \frac{kl}{i}$$

where, a : cross-sectional area of tube (mm²)
 I : geometrical moment of inertia of tube (mm⁴)
 i : radius-of-gyration of area of tube (mm)
 $i = \sqrt{I/a}$
 k : factor shown below depending on tube support method

Support method	Factor
Supported between tubesheets	0.6
Supported between tubesheet and baffle	0.8
Supported between baffles	1.0

l : support span of tube (mm)

E and σ_y : as given in a).

$$1) \quad \sigma_{cr} = \frac{\pi^2 E}{2 \left(\frac{kl}{i} \right)^2}$$

$$2) \quad \sigma_{cr} = \frac{\sigma_y}{2} \left(1 - \frac{\frac{kl}{i}}{2 \sqrt{\frac{2\pi^2 E}{\sigma_y}}} \right)$$

where, E, i, k, l, σ_{cr} and σ_y : as given in a) and b).

4.3.4 Allowable bending stress

The allowable bending stress of materials at the design temperature shall be 1.5 times the value of allowable tensile stress, unless otherwise specified in specifications separately given.

4.4 Various properties of materials

Various properties of materials at the design temperature shall be as given in a) to g)

below.

- a) Table D.1 shows the longitudinal elastic coefficient of materials.
- b) Table D.2 shows the linear expansion coefficient of materials.
- c) Table D.3 shows the yield point or the 0.2 % proof stress of carbon steels and low alloy steels.
- d) Table D.4 shows the yield point or the 0.2 % proof stress of stainless steels.
- e) Table D.5 shows the yield point or the 0.2 % proof stress of stainless cast steels.
- f) Table D.6 shows the yield point or the 0.2 % proof stress of nickel-chrome iron alloys (P-number 43 and 45 given in Table A.1 of **JIS B 8285**).
- g) Table D.7 shows the yield point or the 0.2 % proof stress of non-ferrous metallic materials.

5 Design

5.1 General

5.1.1 Dimensions used in design

Dimensions not including the corrosion allowance shall be used in the design of pressure vessels.

5.1.2 Load

The loads to be considered in the design, in addition to the pressure (internal or external pressure), shall include the following loads, if necessary.

- a) Load by own-weight and internal fluid
- b) Load by piping, auxiliaries, etc. fixed to pressure vessel
- c) Load by wind, snow coverage and earthquake
- d) Load by heat (temperature)
- e) Repeated load and dynamic load
- f) Load by handling, transportation, installation, etc.

5.1.3 Minimum thickness

The minimum thickness of pressure retaining part shall be the thickness given in **a)** or **b)** below. However, this does not apply to the bellows-type expansion joints, heat exchanger plates of plate type heat exchangers, double tubes (inner and outer tubes) of nominal diameter 150A or less of double tube heat exchangers, and heat exchanger tubes of nominal diameter 150A or less of multitube heat exchangers.

When corrosion or erosion is predicted in the materials used for the pressure retaining parts of pressure vessel, suitable corrosion allowance shall be provided.

- a) **Carbon steel and low alloy steel** 2.5 mm or more
- b) **Stainless steel, nickel-chrome iron alloy and non-ferrous metallic materials** 1.5

mm or more

5.1.4 Clad steel

Clad steels shall be as given in **a)** to **c)** below.

- a) The strength of cladding metal may be incorporated to the calculation of the strength of clad steel. The allowable tensile stress of clad steel in the case above shall be as given in the following formula.

$$\sigma_a = \frac{\sigma_b t_b + \sigma_c t_c}{t_b + t_c}$$

where,

- t_b : thickness of base metal (mm)
- t_c : thickness of cladding metal (mm)
- σ_a : allowable tensile stress of clad steel at design temperature (N/mm²)
- σ_b : allowable tensile stress of base metal at design temperature (N/mm²)
- σ_c : allowable tensile stress of cladding metal at design temperature (N/mm²)

- b) Clad steel shall be the specified materials given in **1)** to **7)** below. When incorporating the strength of cladding metal for clad steel of **5)** to **7)**, the shear strength test is required.
- 1) Class 1 of **JIS G 3601**
 - 2) Class 1 of **JIS G 3602**
 - 3) Class 1 of **JIS G 3603**
 - 4) Class 1 of **JIS G 3604**
 - 5) SA263 of **ASME** Section II
 - 6) SA264 of **ASME** Section II
 - 7) SA265 of **ASME** Section II
- c) When the quality of overlay welding is equivalent to or better than that of the cladding metal, this overlay welding may be regarded as the cladding metal, and the allowable tensile stress of clad steel in **a)** is applicable.

5.1.5 Hole provided in pressure vessel

Holes provided in the pressure vessels shall be as given in **a)** to **c)** below.

- a) Pressure vessels shall be provided with holes for inspection, repairing, cleaning, etc. However, not applicable to the pressure vessels given in **1)** to **5)** below.
- 1) Those with inner diameter of shell of 300 mm or less.
 - 2) Those with inner diameter of shell of 500 mm or less and equipped with two or more removable tubes with outer diameter of 40 mm or more.
 - 3) Those with removable heads, cover plates, etc. whose sizes are not less than those

of the hole specified in **b)**.

- 4) Those requiring air-tight structure and free from possibility of corrosion or erosion, to which two or more removable tubes with the outer diameter of 40 mm or more are fixed.
 - 5) Those such as heat exchangers for which no holes for inspection, repairing, cleaning, etc. are required because of their structures, shapes or applications.
- b) Number and dimensions of the holes in **a)** shall be as given in 1) to 3) below depending on the inner diameter of shell.
- 1) **When inner diameter of shell is over 300 mm up to and including 500 mm** Provide two or more ellipse holes with the major axis of 75 mm or more and the minor axis of 50 mm or more, or circular holes with the diameter of 75 mm or more.
 - 2) **When inner diameter of shell is over 500 mm up to and including 1 000 mm** Provide one or more manholes shaped in an ellipse with the major axis of 375 mm or more and the minor axis of 275 mm or more, a circle with the diameter of 375 mm or more, or an oval with the major axis of 400 mm or more and the minor axis of 250 mm or more. However, manholes are not necessary when two or more holes are provided one or more of which is an ellipse with the major axis of 90 mm or more and the minor axis of 70 mm or more, or a circle with the diameter of 90 mm or more.
 - 3) **When inner diameter of shell exceeds 1 000 mm** Provide one or more manholes specified in 2).
- c) If necessary, draining and venting holes shall be provided.

5.1.6 Allowable pressure verification test

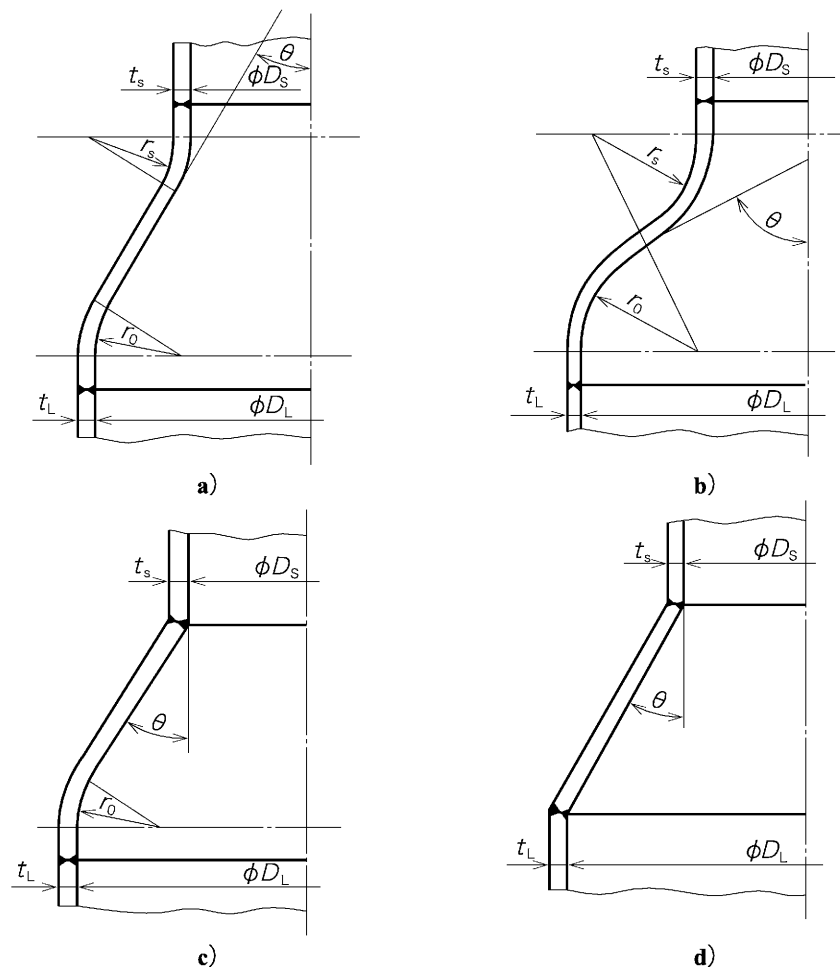
If 5.2 to 5.9 are not applicable to the pressure vessels or the pressure retaining parts thereof due to their uniqueness of shape, Annex T is applicable.

5.2 Shell and head

5.2.1 Shells which retain internal pressure

Shells which retain internal pressure shall be as given in **a)** to **d)** below.

- a) **Cylindrical shell** Calculated thickness of cylindrical shell shall conform to **E.2.2**.
- b) **Spherical shell** Calculated thickness of spherical shell shall conform to **E.2.3**.
- c) **Conical shell** Figure 1 shows shapes of conical shell. Calculated thickness of conical shell shall conform to **E.2.4**.



- Meanings of symbols in diagram are as given in E.2.1.
- Shape of conical shell using 9 % nickel steel shall be as given in a).
- Restrictions to the radius of roundness and the straight-line aligned to the roundness shall conform to Annex E.

Figure 1 Shapes of conical shell †

d) Bent tube Calculated thickness of bent tubes shall conform to E.5.

5.2.2 Heads which retain internal pressure

Heads which retain internal pressure not supported by stay shall be as given in a) to g) below.

a) Figure 2 shows shapes of head.

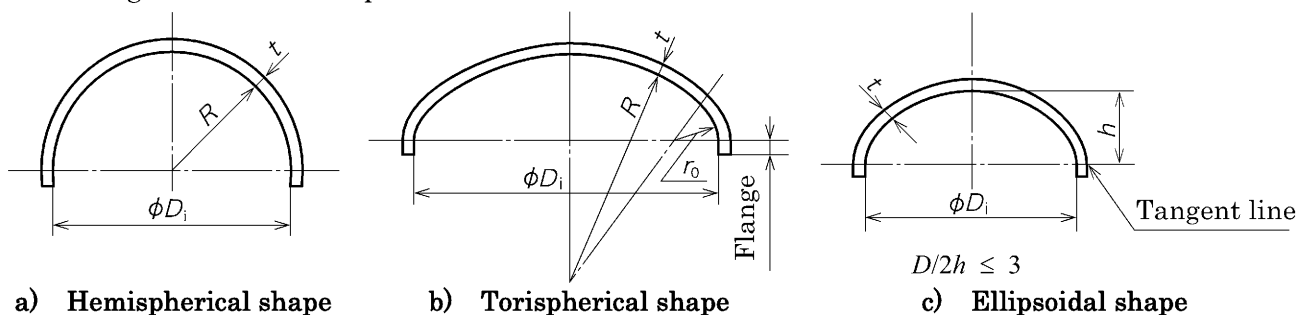
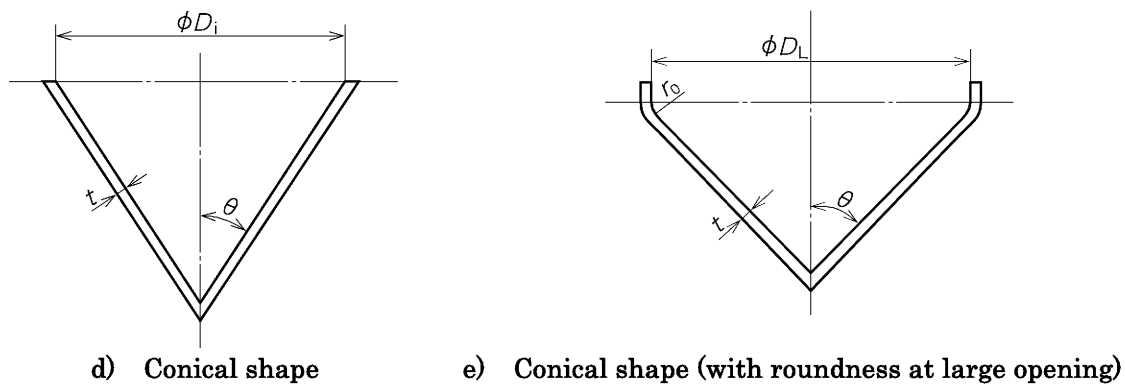


Figure 2 Shapes of head †



- Meanings of symbols in diagram are as given in **E.2.1** and **E.3.1**.
- Shapes of head using 9 % nickel steel shall be as given in **a)** to **c)**.
- Restriction on shape of head shall conform to Annex E.

Figure 2 (concluded) †

- b) General items of heads shall be as given in 1) to 3) below.
- 1) Calculated thickness of flange of flanged heads [see **a)** to **c)** and **e)** of Figure 2] shall be obtained according to the formula for cylindrical shells of the same inner diameter [see **5.2.1 a)**].
 - 2) Figure 4 shows necessary length of flange when welding the head to the cylindrical shell.
 - 3) Welding of head and shell of different thicknesses shall conform to **6.3.2**.
- c) Calculated thickness of hemispherical head [see Figure 2 a)] shall conform to **E.3.2**.
- d) Calculated thickness of torispherical head [see Figure 2 b)] shall conform to **E.3.3**.
- e) Calculated thickness of ellipsoidal head [see Figure 2 c)] shall conform to **E.3.4**.
- f) Calculated thickness of conical heads [see Figure 2 d) or e)] shall conform to **E.3.5**.
- g) Calculated thickness of flat heads not supported by stay, which are to be attached by welding or screwing, shall conform to **E.3.6**.

5.2.3 Shells which retain external pressure

The calculated thickness of shells which retain external pressure shall be as given in **a)** to **c)** below.

- a) Calculated thickness of cylindrical shell shall conform to **E.4.2**.
- b) Calculated thickness of spherical shell shall conform to **E.4.3**.
- c) Calculated thickness of conical shell shall conform to **E.4.4**.

5.2.4 Heads which retain external pressure

The calculated thickness of heads which retain external pressure shall be as given in **a)** to **d)** below.

- a) Calculated thickness of hemispherical head shall conform to **E.4.5 a)**.

- b) Calculated thickness of torispherical head shall conform to **E.4.5 b)**.
- c) Calculated thickness of ellipsoidal head shall conform to **E.4.5 c)**.
- d) Calculated thickness of conical head shall conform to **E.4.5 d)**.

5.2.5 Reinforcements for shell which retains external pressure

Reinforcements for shell which retains external pressure shall be as given in **a)** and **b)** below.

- a) Stiffening rings for cylindrical shell shall conform to **E.4.6**.
- b) Reinforcements for cylindrical shell and conical shell, or reinforcements for ends of cylindrical shell and conical head shall conform to **E.4.7**.

5.2.6 Ligament efficiency of cylindrical shell

Ligament efficiency of cylindrical shell shall conform to Annex Q.

5.3 Cover plate

Cover plates shall be as given in **a)** to **c)** below.

- a) Flat bolted cover plates shall conform to **L.3**.
- b) Fit-in type flat circular cover plates shall conform to **L.4**.
- c) Flat flanged torispherical cover plates shall conform to **L.5**.

5.4 Bolted flange

Structures of bolted flanges shall be as given in **a)** and **b)** below.

- a) Flanges in accordance with **JIS B 2220** (excluding the thin flange in Table 16), **JIS B 2239**, **JIS B 2240**, **JIS B 2241**, **JIS B 2290**, **ASME B16.5**, **ASME B16.24** and **ASME B16.47**, or those flanges conforming to the specifications that are equal or superior to these may be used. Materials of flanges shall conform to Clause 4.

When the specified flange is used within the pressure-temperature reference range (pressure-temperature rating) corresponding to the material number given in standards, the stress calculation is omissible.

- b) When the specified flange in **a)** is not used, the stress calculation of flange according to Annex G to Annex J is required.

5.5 Hole

Holes provided in the pressure retaining parts shall be as given in **a)** and **b)** below.

- a) **Shapes, dimensions and reinforcing of holes** Shapes, dimensions and reinforcing of holes shall conform to Annex F.
- b) **Holes on or in vicinity of welded joints** Holes on or in vicinity of welded joints shall conform to **F.12**.

5.6 Bonding of nozzle stub and tube

Bonding of nozzle stub and tube (hereafter referred to as nozzle stub unit) to the

shell, head, etc. shall be as given in **a)** or **b)** below.

a) **Weld bonding** Weld bonding of nozzle stub unit shall be as given in 1) and 2) below.

- 1) Figure 6 to Figure 9 show welded joints of nozzle stub unit.
- 2) Strength of the welded joint of nozzle stub and reinforcement shall conform to **F.13**.

b) **Screw-bonding** As given in 1) and 2) below.

- 1) Figure 10 shows an example of welded joint when a tube joint with inside screw is used.
- 2) In the case where the hole of shell, head, etc. is taper threaded for tubes and the nozzle stub unit is screw-bonded, the thickness of shell, head, etc. and the number of mating threads according to the nominal designation of tube threads shall be not less than the value given in Table 1.

Table 1 Thickness of shell, head, etc. and number of mating threads

Nominal designation of tube threads	Thickness of shell, head, etc. mm	Number of mating threads
R½, R¾	11	6
R1, R1¼, R1½	15	7
R2	18	8
R2½, R3	25	8
R4, R5, R6	32	10
PT8	38	12
PT10	41	13
PT12	45	14

5.7 Tubesheet

Tubesheets shall be as given in **a)** or **b)** below, depending on the structures of heat exchangers, evaporators, condensers and the like.

a) **Tubesheet not supported by stay** Tubesheets not supported by stay shall conform to Annex K.

b) **Tubesheet supported by stay** Tubesheets supported by stay shall conform to Annex M.

5.8 Flat head supported by stay

Flat heads supported by stay shall conform to Annex M.

5.9 Expansion joint

Expansion joints shall conform to Annex N.

6 Welding

6.1 General

6.1.1 Welded joint

Welded joints of pressure vessels shall be as given in **a)** to **c)** below.

- a) The tensile strength of welded joint shall be not less than the tensile strength specified in the material standard of base metal (in the case of dissimilar welded joint, whichever is smaller). When aluminium and aluminium alloy, copper and copper alloy, titanium and titanium alloy, or 9 % nickel steel are used as base metals, the value not more than the allowable tensile stress of base metals may be used as the allowable tensile stress of welded joints, in which case, the tensile strength of welded joint needs only to be four times or more the allowable tensile stress of welded joints.
- b) Materials of the nozzle stub and the reinforcement which are welded to the pressure vessel made of 9 % nickel steel shall be 9 % nickel steel or austenitic stainless steel which is not hardened by the heat treatment (only the material of which yield point or proof stress specified in material standards is within the range of ± 20 % of the yield point or proof stress specified in material standards of 9 % nickel steel).
- c) Welded joints shall have sufficient penetration and shall have no cracks or harmful flaws such as undercuts, overlaps, craters, slag inclusion, blowholes or jig traces.

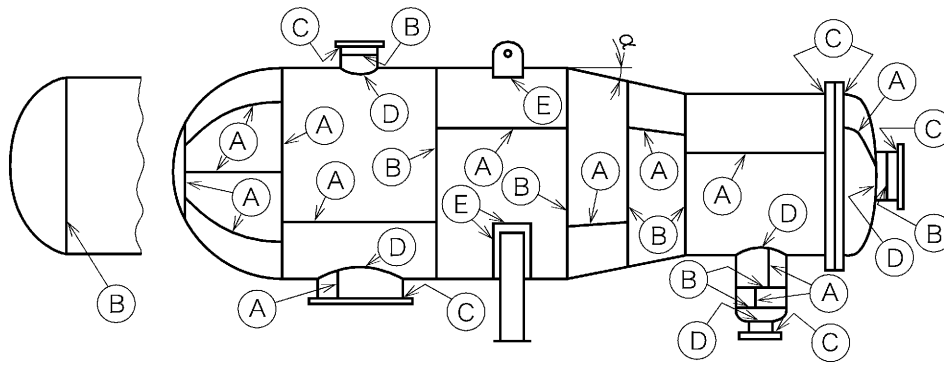
6.1.2 Welding method

Welding shall conform to the welding procedure specified in **JIS B 8285** or the method confirmed beforehand by the separately specified test method, according to the welding methods, types of base metals, types of welding materials, pre-heating temperatures, heat treatment methods and types of shielding gas.

6.1.3 Classification of welded joints by position

Welded joints of the pressure retaining part or of the non-pressure member directly welded to the pressure retaining part shall be classified into the following A to E. Figure 3 shows a typical example.

Category A to Category E are as given in **a)** to **e)** below.



Meanings of symbols in diagram are as given below.

Ⓐ to Ⓔ : Category A to Category E in classification of welded joint

α : half of apex angle of cone, symbol θ in E.2.1

For welded joint of end of conical shell and cylindrical shell, butt joint when $\alpha \leq 30^\circ$ and corner joint when $\alpha > 30^\circ$.

Figure 3 Classification of welded joints by position†

a) **Category A** Welded joints given in 1) to 3) below shall be of Category A.

- 1) Longitudinal joints of cylindrical shells, conical shells, nozzle stubs, connecting pressure chambers, etc.

NOTE : Connecting pressure chamber refers to a pressure chamber crossing the shell or head of pressure vessels, such as sump and dome.

- 2) Welded joints of spherical shells, heads, flat heads or cover plates.
- 3) Circumferential joints to weld hemispherical heads to cylindrical shells, conical shells, nozzle stubs to connecting pressure chambers.

b) **Category B** Welded joints given in 1) and 2) below shall be of Category B.

- 1) Circumferential joints of such as cylindrical shells, conical shells, nozzle stubs and connecting pressure chambers, including joints to weld the cylindrical shells or nozzle stubs at large opening or small opening of conical shells.
- 2) Circumferential joints to weld heads other than hemispherical heads to cylindrical shells, conical shells, nozzle stubs or connecting pressure chambers.

NOTE : Those butt-welding joints which have hubs to weld the nozzle stubs or connecting pressure chambers to shells or heads, etc. shall be of Category B [see Figure 6 e)].

c) **Category C** Welded joints given below shall be of Category C.

Circumferential joints to weld flat heads, tubesheets, flanges or stub ends to cylindrical shells, conical shells, heads, nozzle stubs or connecting pressure chambers.

d) **Category D** Welded joints given in 1) and 2) below shall be of Category D.

- 1) Joints to weld nozzle stubs or connecting pressure chambers to cylindrical shells, spherical shells, conical shells, heads, flat heads or cover plates.

2) Joints to weld nozzle stubs and connecting pressure chambers.

e) **Category E** Welded joints given below shall be of Category E.

Joints to weld structures such as stiffening rings, supports (skirt supports, saddle supports, leg supports, lug supports, etc.) and non-pressure members directly to the pressure retaining parts.

6.1.4 Types and scope of welded joint of pressure retaining part

Types and scope of welded joint of pressure retaining part shall be as given in Table 2. Figure 4 to Figure 14 show details of welded joints.

Table 2 Types and scope of welded joint of pressure retaining part

Type of joint		Scope
B-1 joint	Butt joint by double-side welding with full penetration or butt joint by one-side welding which is equivalent or superior thereto ^{a)} [see Figure 4 a), Figure 5 a), Figure 6, 1) to 4) of Figure 11 a), Figure 13 e), Figure 13 f), and 1) of Figure 14 b)]	All joints of Category A to Category E.
B-2 joint	Butt joint by one-side welding which uses and leaves the backing. Backing shape is continuous and the edges shall be butt welded. Butt welded joint given in b) and c) of Figure 4 shall be B-2 joint.	All joints of Category A to Category D except joggled lap welding. Joggled lap welding given in Figure 4 c) is used only for joints of Category B and Category C.
B-3 joint	Butt joint by one-side welding not using backing except B-1 joint and B-2 joint.	Circumferential joints of Category A to Category C of which nominal thickness is 16 mm max. and the outer diameter is 610 mm max.
L-1 joint	Lap fillet welded joint by double-side full thickness [see Figure 4 d)]	Joints of Category A of which nominal thickness is 10 mm or less, of Category B and Category C of which nominal thickness is 16 mm or less. Lapping of plates is required to be four times or more the nominal thickness of inside plate (at least 25 mm). For shells and heads, see Figure 4 d).
L-2 joint	Lap fillet welded joint by one-side full thickness with plug welding [see Figure 4 e)]	Circumferential joint of Category B where head other than hemispherical head of outer diameter 610 mm or less is welded to shell of nominal thickness 12 mm or less. Distance from centre of plug welding to edge of plate is required to be 1.5 times or more the plug hole diameter.

Table 2 (concluded)

L-3 joint	Lap fillet welded joint by one-side full thickness without plug welding [see Figure 4 f)]	a) When retaining external pressure, circumferential joint of Category A and Category B where head of nominal thickness 16 mm or less is welded to shell [see f-3) of Figure 4]. b) Circumferential joint of Category A and Category B where head is welded to shell with an inner diameter of 610 mm or under and a calculated thickness of 6 mm or under [see f-1) and f-2) of Figure 4].
FP joint	Joint in which two members are welded by corner joint or T-joint at right angles or at some angles each other by full penetration groove weld [See b-1) to b-3) of Figure 5, Figure 7, Figure 8, a-1) b-1) and c-1) of Figure 10, 5) to 8) of Figure 11 a), 1) of Figure 11 b), 5) of Figure 12 b), a) to d) of Figure 13 and 4) of Figure 14 b). Among these, 2-2) of Figure 5 b-2), Figure 8, Figure 13 d), and 4) of Figure 14 b) show the combination use with FW joint.]	All joints of Category C to Category E. FP joint may be used in combination with FW joint.
PP joint	Joint in which two members are welded by corner joint or T-joint at right angles or parallel each other by partial penetration groove weld [See 2), 4) to 9) of Figure 9 a), 1) to 3) of Figure 9 b), c-2) and e) of Figure 10, 9-1), 9-2), 10-1), 10-2), 11-1) and 11-2) of Figure 11 a), 2), 2-3), 2-4), 3-1), 3-2), 4-1), 4-2), 5-1), 5-2) of Figure 11 b) and b) 3) and c) 2) of Figure 14. Among these, 2) and 4) to 9) of Figure 9 a), c-2) of Figure 10, 9-1) and 9-2) of Figure 11 a), 2-3), 2-4), 3-1) and 3-2) of Figure 11 b) and 3) of Figure 14 b) show the combination use with FW joint.]	All joints of Category C to Category E. PP joint may be used in combination with FW joint.
FW joint	Joint in which two members are fillet welded at almost right angles each other [See b-4) of Figure 5, a)1), a)3), a)10), a)11) and b)4) of Figure 9, a-2), b-2) and d) of Figure 10, 2-1) and 2-2) of Figure 11 b), 1) to 4) of Figure 12 b) and a), b)2) and c)1) of Figure 14, except the lap fillet welded joint by full thickness.]	All joints of Category C to Category E.
Note ^{a)} Butt joint by one-side welding which is equivalent or superior to the butt joint by double-side welding with full penetration refers to a) and b) below. a) Butt joint by one-side welding with sufficient penetration and smooth back surfaces by penetration bead welding or the method of fusible insert to root. In this case, use the filler metal completely fused by welding for the fusible insert. b) Butt joint by one-side welding which uses backing, and after removal of the backing, finished in the same surface as the base metal.		

6.1.5 Distance between adjacent longitudinal joints

When two or more shells are connected, the distance between the centres of each longitudinal joint of adjacent shells shall be five or more times the largest nominal thickness of base metal. This restriction does not apply if the radiographic examination

over the length of 100 mm from the intersection between the circumferential joint and the longitudinal joint is performed, and the acceptance criteria thereof is satisfied. However, welding in such a way that the longitudinal joint intersects with the circumferential joint should be avoided.

6.1.6 Welding of stiffening ring, support structure and non-pressure member

Welding of stiffening ring, support structure and non-pressure parts shall be as given in a) to e) below.

a) **Welding of stiffening ring** Welding of stiffening ring to the cylindrical shell retaining external pressure, the conical shell and the end of cylindrical shell and conical shell shall be the full penetration welding around the whole circumference of stiffening ring or the welding in which both sides of stiffening ring are welded. The welding in which the both sides of stiffening ring are welded shall be as given in 1) to 3) below. Figure 12 shows details of welded joints.

- 1) Stiffening rings shall be welded in contact with the shell.
- 2) Welding on both sides shall be the continuous welding, intermittent welding or the combination thereof. When intermittent welding is employed on both sides, the sum of welded joint length shall be half or more (one third or more when welding stiffening ring inside the shell) of the external circumference of the shell. Also, the distance between the welded joints adjacent each other shall not exceed 8 times (12 times when welding stiffening ring inside the shell) the thickness of shell as given in Note a) to Figure 12 a).

If the continuous welding is performed on one side and intermittent welding is performed on the other side, see Figure 12 a) 3).

- 3) Leg length of fillet weld shall be 6 mm or more, and not less than the thickness of shell or the thickness of stiffening ring at the welding position, whichever is smaller.

b) **Welding of skirt support** Welding of skirt support shall be as given in 1) to 3) below. Figure 13 shows details of welded joints.

- 1) Skirt support shall be welded in contact with the shell or the head.
- 2) Continuous welding shall be employed.
- 3) Full penetration welding shall be employed, and the minimum thickness from root to toe of welded joint shall be not less than the thickness of skirt support.

c) **Welding of saddle support, leg support, lug, wear plate and non-pressure member** Welding of saddle support, leg support, lug, wear plate and non-pressure member shall be as given in 1) to 4) below. Figure 14 shows details of welded joints.

- 1) Saddle support, leg support, lug, wear plate and non-pressure member shall be welded in contact with the shell or the head.
- 2) Continuous welding shall be employed.
- 3) Full penetration welding or double-side welding shall be employed for saddle support, leg support, lug and non-pressure member. In the case of double-side

welding, fillet welded joint, groove welded joint or the combination thereof shall be employed. The sum of throat thickness of fillet weld and groove depth of groove weld shall be half or more of the thickness of saddle support, leg support, lug or non-pressure member [see 2) and 3) of Figure 14 b)]

- 4) In the case of wear plate, fillet welded joint, groove welded joint or the combination thereof shall be employed. The sum of throat thickness of fillet weld and groove depth of groove weld shall be half or more of the thickness of wear plate [see 1) and 2) of Figure 14 c)]
- d) **Strength of welded joint** Sufficient strength of welded joint of support structure, wear plate and non-pressure member shall be confirmed, in which case, the allowable stress of groove weld and fillet weld used for the confirmation shall conform to F.13 c).
- e) **Postweld heat treatment of welded joint** Shall conform to Annex S.

Unit: mm

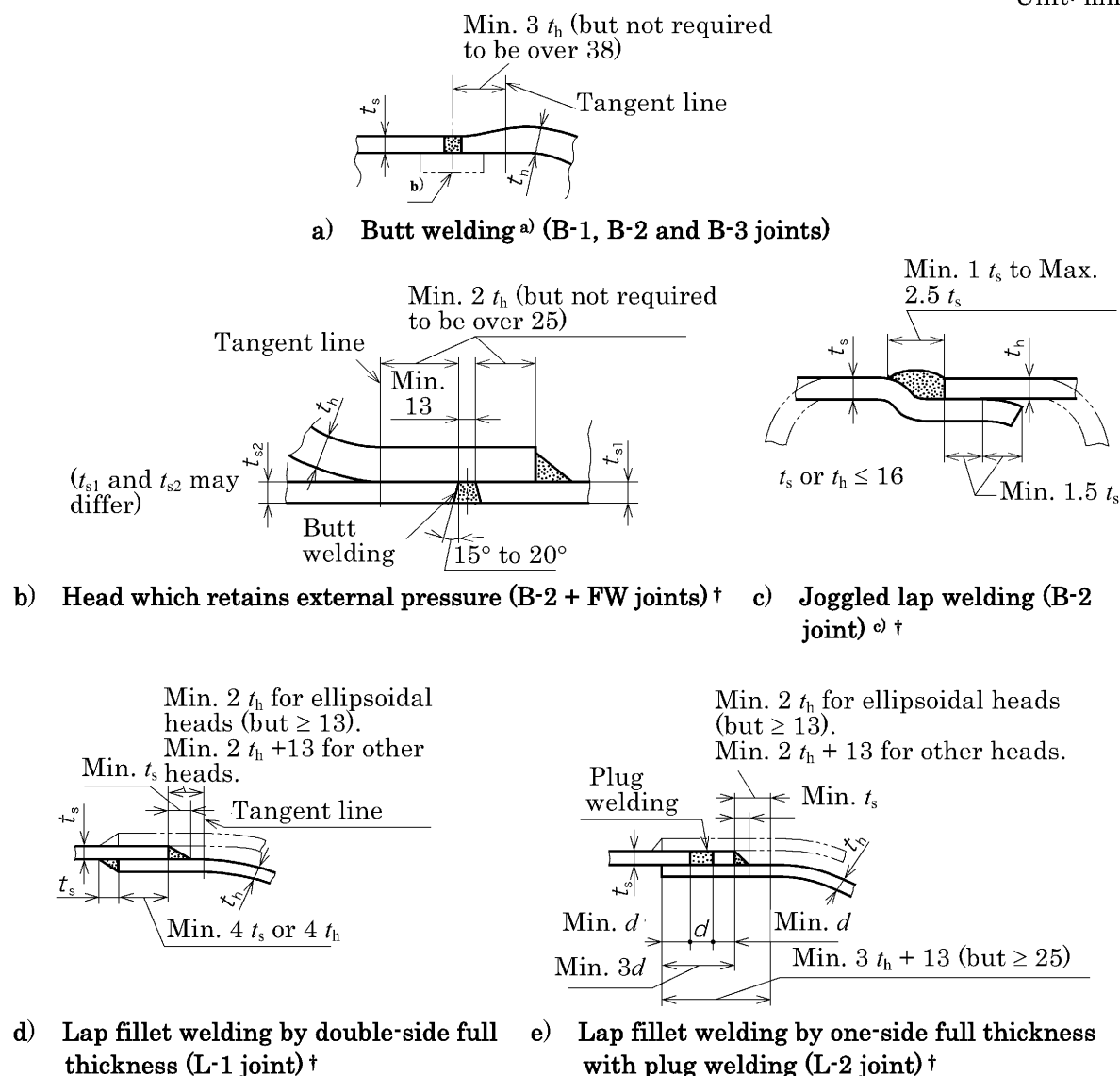
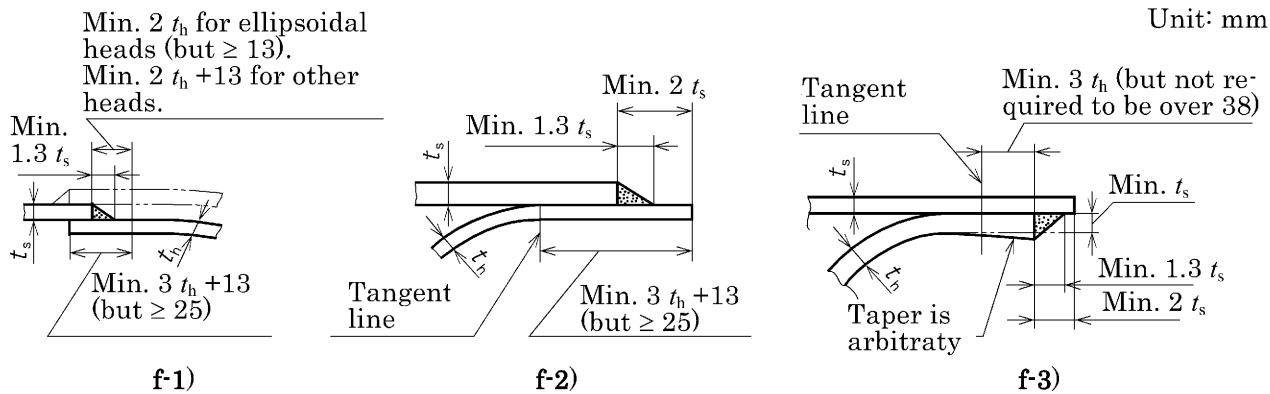


Figure 4 Welded joint of shells and heads (B-1 to L-3 joints)

Unit: mm



f) Lap fillet welding by one-side full thickness (L-3 joint) †

— Meanings of symbols in diagram are as given below.

t_h : nominal thickness of head (mm) t_s : nominal thickness of shell (mm)

d : hole diameter of plug welding (mm)

— Notes a) When taper is required according to 6.3.2.

b) When using backing in B-2 joint

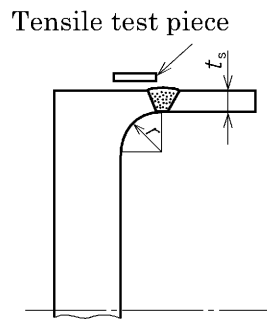
c) Welded joint of hemispherical head and shell shall be as given in 1) and 2) below.

1) t_s or $t_h \leq 10$ mm

2) thickness difference between t_s and $t_h \leq 2.5$ mm

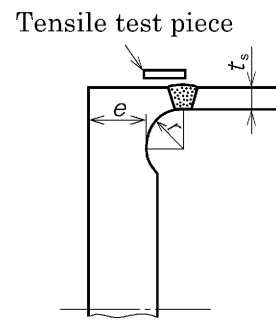
Figure 4 (concluded)

Unit: mm



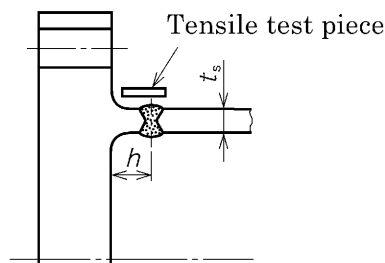
When $t_s > 38$
 r (but not required to be over 19) $\geq 0.25 t_s$
 When $t_s \leq 38$ $r \geq 10$

1)



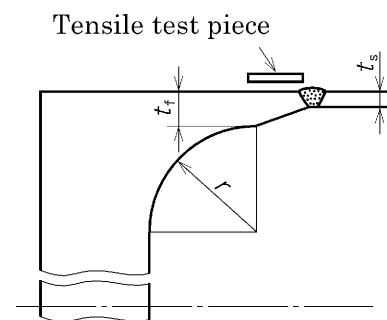
When $t_s > 38$
 r (but not required to be over 19) $\geq 0.25 t_s$
 When $t_s \leq 38$ $r \geq 10$
 $e \geq t_s$

2)



h (but not required to be over 50) $\geq 1.5 t_s$ (but ≥ 19)

3)



$t_f \geq 2 t_s$
 $r \geq 3 t_f$

4)

— Meanings of symbols in diagram are as given below.

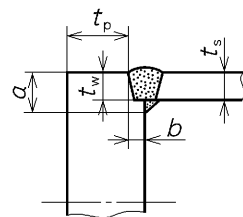
t : calculated thickness of tubesheet or flat head (mm)
 t_s : nominal thickness of shell (mm)
 r : radius of corner roundness of tubesheet or flat head (mm)
 e, t_f, h : dimensions shown in diagram (mm)

— Welding of members of different thicknesses shall conform to 6.3.2.

a) **Butt welding of shell and tubesheet with hubs or flat head with hubs**
 (B-1, B-2 and B-3 joints)

Figure 5 Welded joint of shell and tubesheet or flat head †

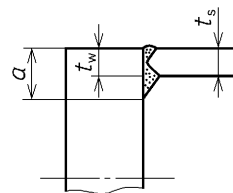
Unit: mm



$$a + b \geq 2 t_s$$

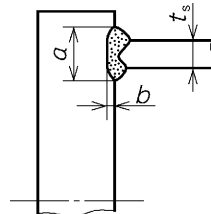
$$t_w \geq t_s$$

1-1)



$$a \geq 2 t_s$$

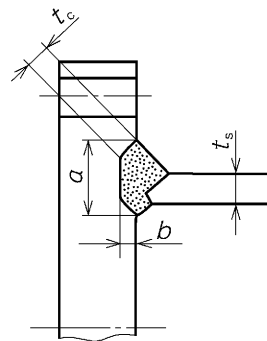
1-2)



$$a + b \geq 2 t_s$$

Weld metal at b may be overlaying before welding, and $b = 0$ is permissible.

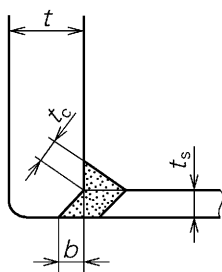
2)



$$a + b \geq 2 t_s$$

$b = 0$ is permissible.

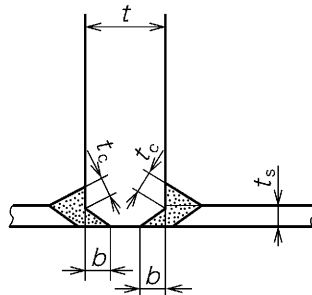
3)



$$b = 2 t_r$$

$$t \geq b \geq 1.25 t_s$$

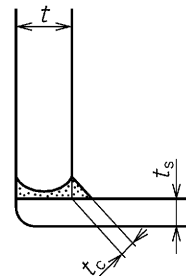
4)



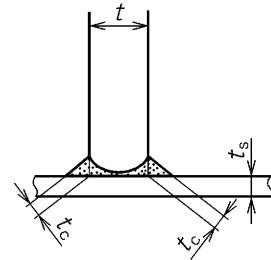
$$b = 2 t_r$$

$$t \geq b \geq 1.25 t_s$$

5)



6)



7)

Meanings of symbols in diagram are as given below.

a and b : dimensions shown in diagram

t and t_s : as given in a)

t_c : throat thickness of fillet welding, which is not less than $1.4 t_r$ or $0.7 t_s$, whichever is smaller (mm)

For 4) to 7) in diagram, not less than $0.7 t_s$ or 6 mm, whichever is smaller (mm)

t_p : not less than t_s or 6 mm, whichever is smaller (mm)

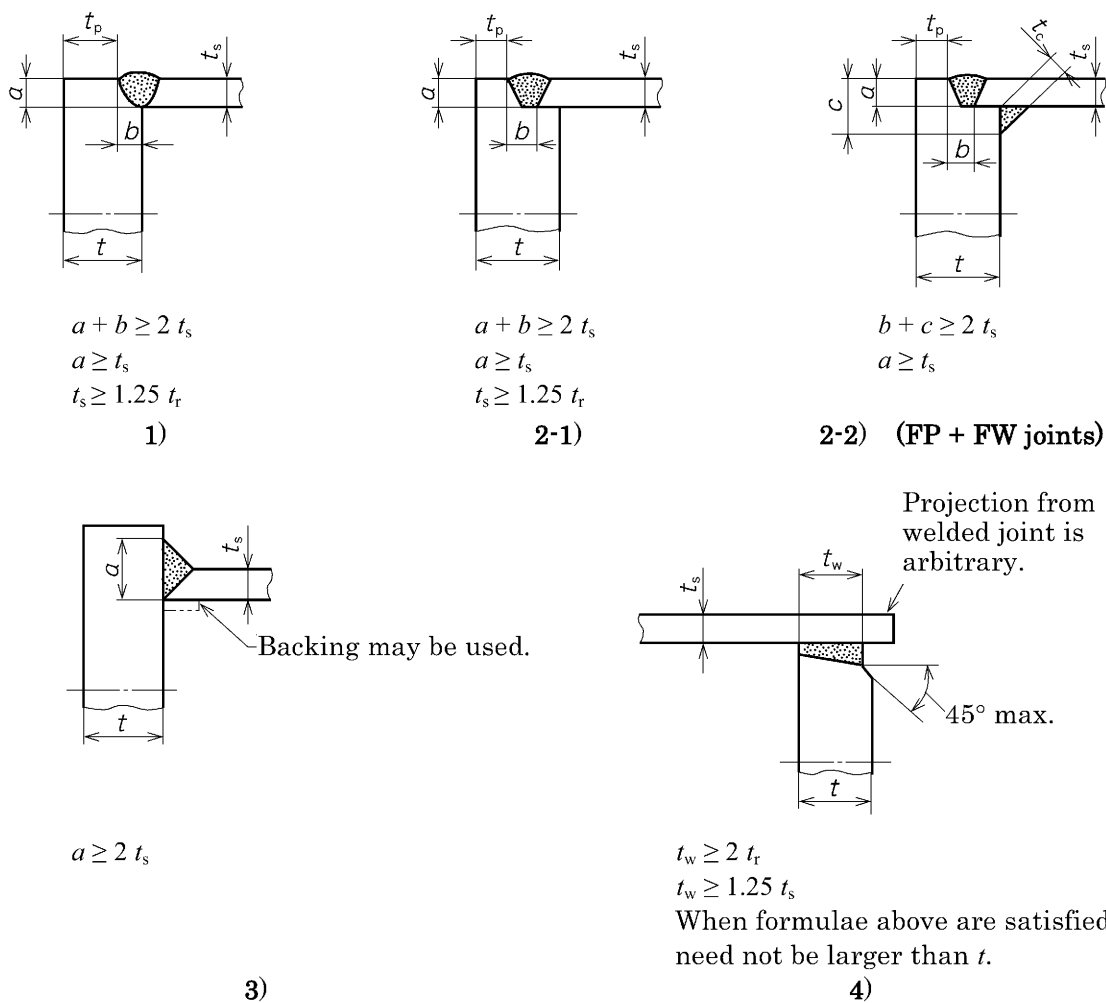
t_r : calculated thickness of shell (mm)

t_w : groove depth of groove welding (mm)

b-1) Groove welding of double-side full penetration (FP joint)

b) Welding of shell and tubesheet or flat head (FP and FW joints)

Figure 5 (continued) †



Meanings of symbols in diagram are as given below.

a , b and c : dimensions shown in diagram (mm)

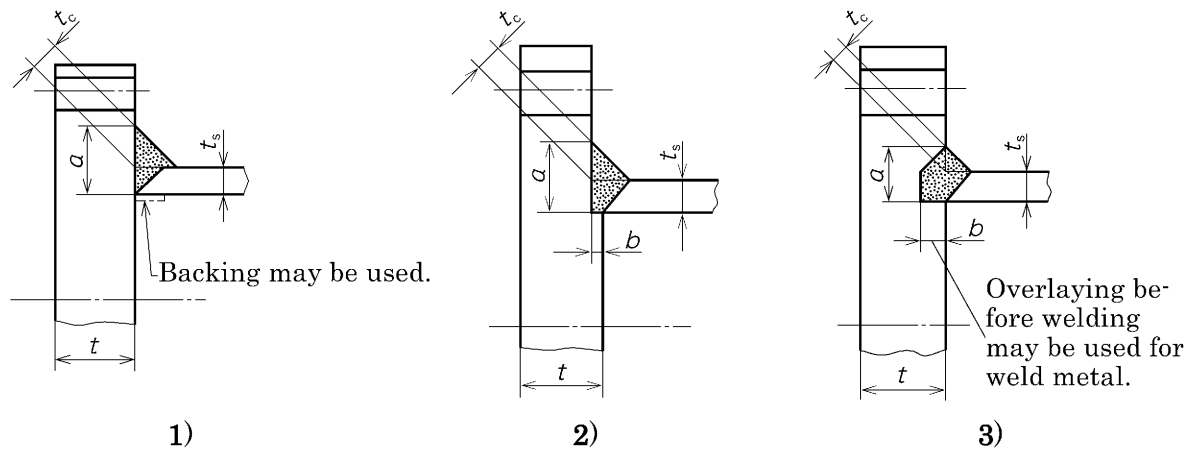
t and t_s : as given in a)

t_c , t_p , t_r , and t_w : as given in b-1).

b-2) Groove welding of one-side full penetration (FP joint)

b) Welding of shell and tubesheet or flat head (FP and FW joints) (continued)

Figure 5 (continued) †



$$a + b \geq 2 t_s$$

$$a \geq t_s$$

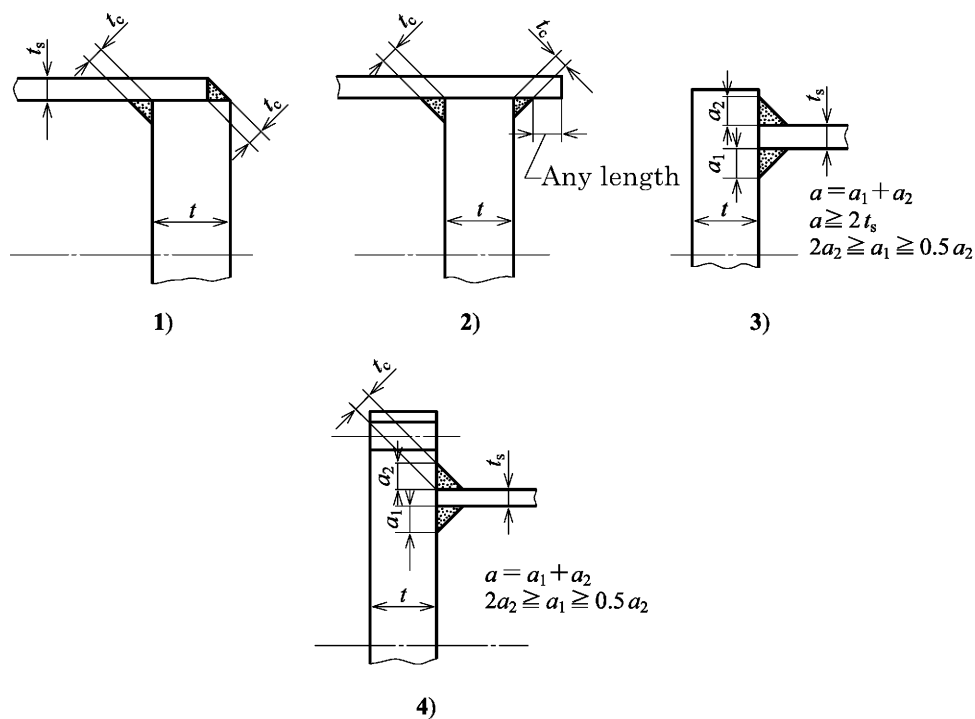
Meanings of symbols in diagram are as given below.

a and b : dimensions shown in diagram (mm)

t_s and t : as given in a)

t_c : as given in b-1)

b-3) Groove welding of one-side full penetration of shell and tubesheet with bolted flange (FP joint)



Meanings of symbols in diagram are as given below.

a , a_1 and a_2 : dimensions shown in diagram (mm)

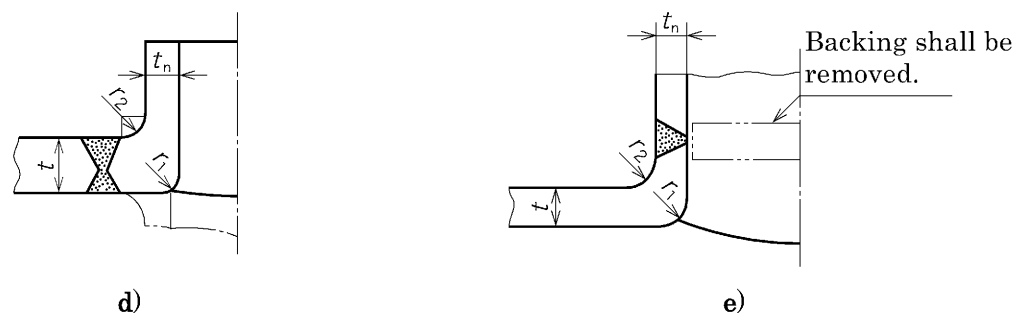
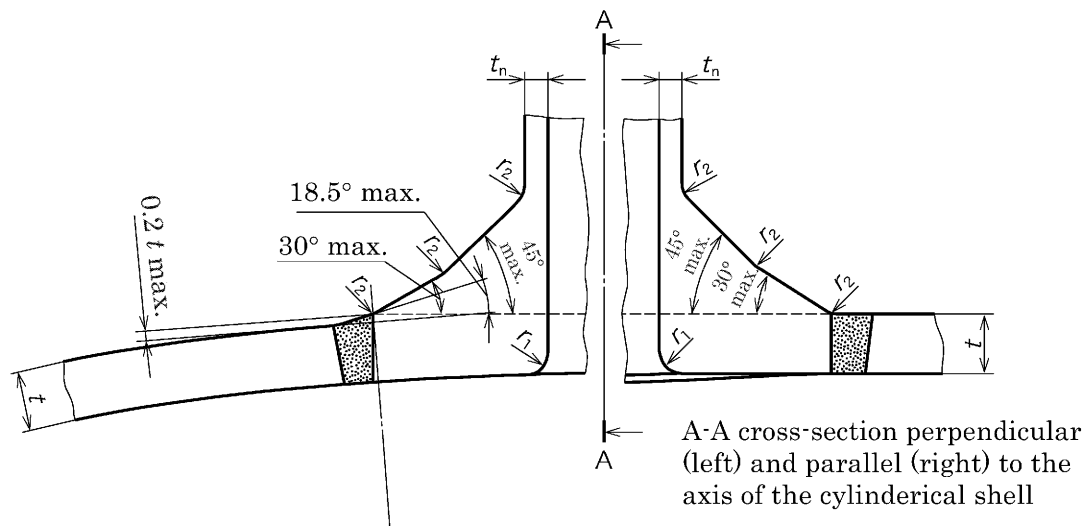
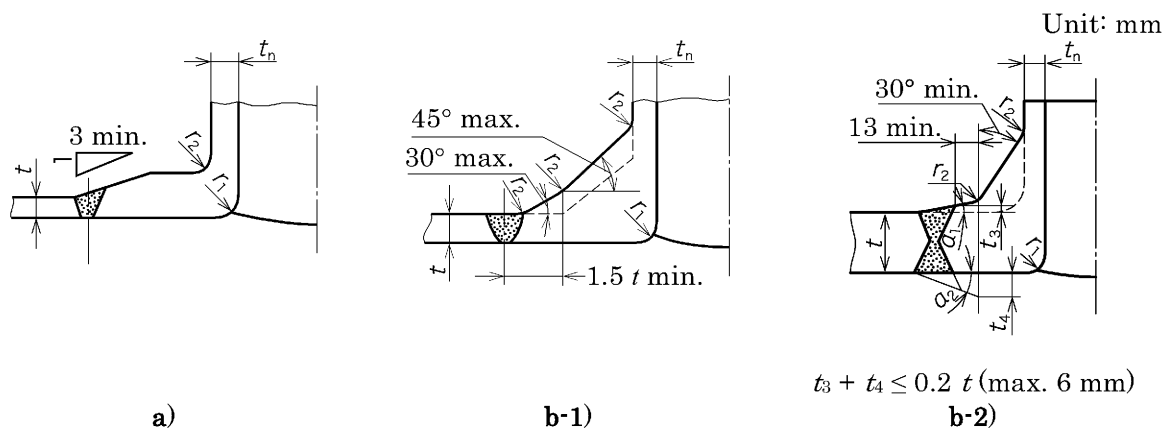
t and t_s : as given in a)

t_c : as given in b-1), provided that t_c in 1) and 2) is not less than $0.7t_s$ (mm)

b-4) Fillet welding (FW joint)

b) Welding of shell and tubesheet or flat head (FP and FW joints) (concluded)

Figure 5 (concluded) †



Meanings of symbols in diagram are as given below.

- t : nominal thickness of shell or head (mm)
- t_n : nominal thickness of nozzle stub unit (mm)
- r_1 : not less than $0.25 t$ or 19 mm, whichever is smaller (mm)
- r_2 : not less than 19 mm

Figure 6 Butt welded joint of nozzle stub unit (B-1 joint)†

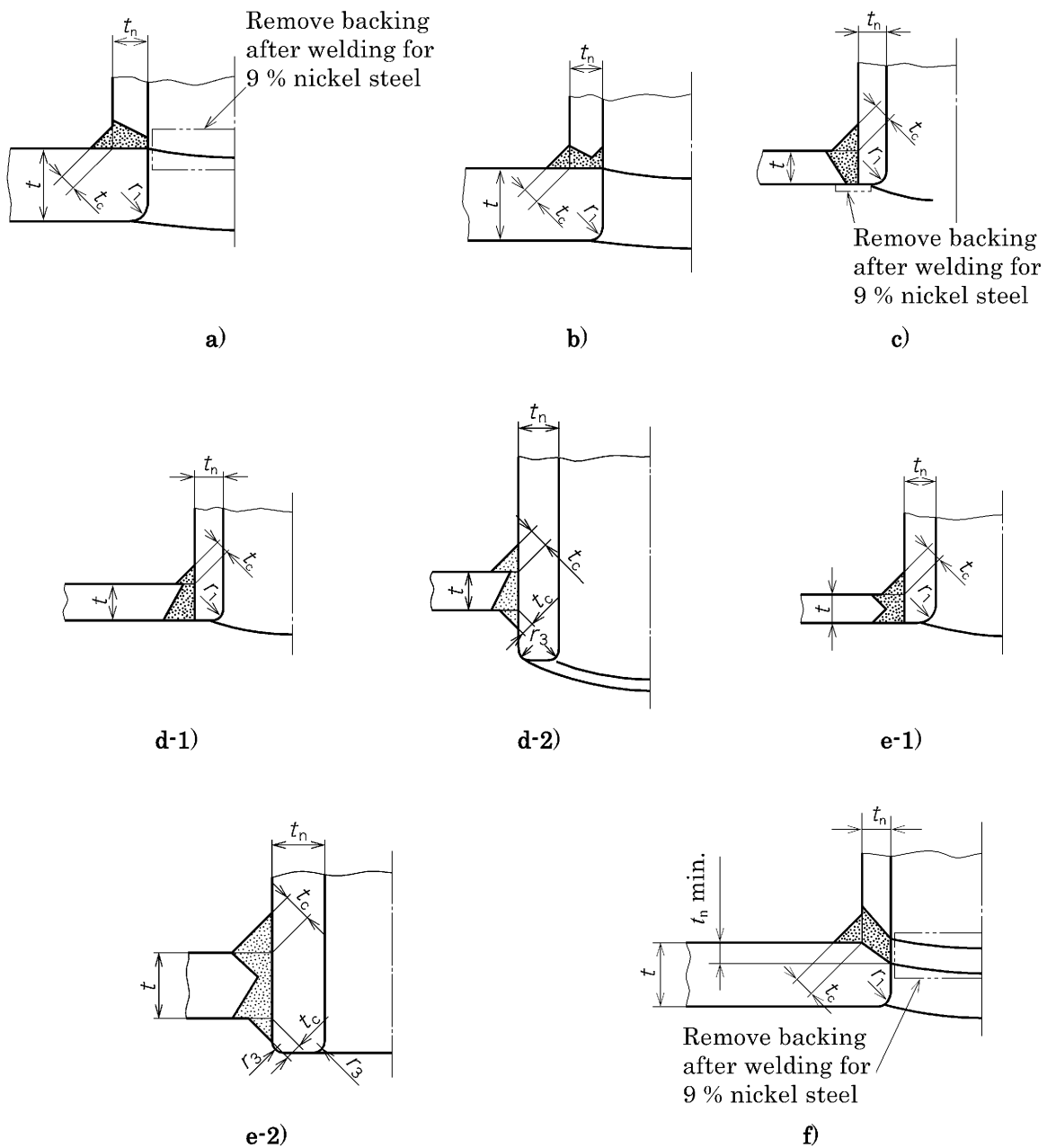
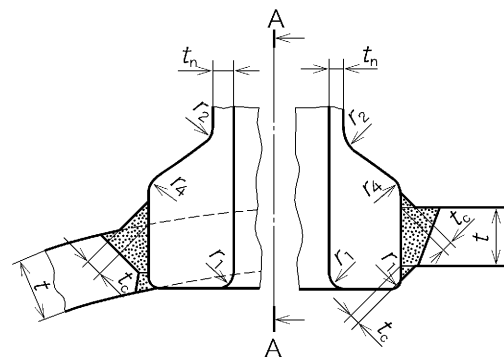


Figure 7 Full penetration welded joint of nozzle stub unit (FP joints) †



A-A Cross-section perpendicular (left) and parallel (right) to axis of cylindrical shell

g)

Meanings of symbols in diagram are as given below.

t : nominal thickness of shell or head (mm)

t_c : throat thickness of fillet welding, not less than 6 mm or $0.7 t_m$, whichever is smaller (mm)

t_m : thickness of thinner member to be welded or 19 mm, whichever is smaller (mm)

t_n : nominal thickness of nozzle stub unit (mm)

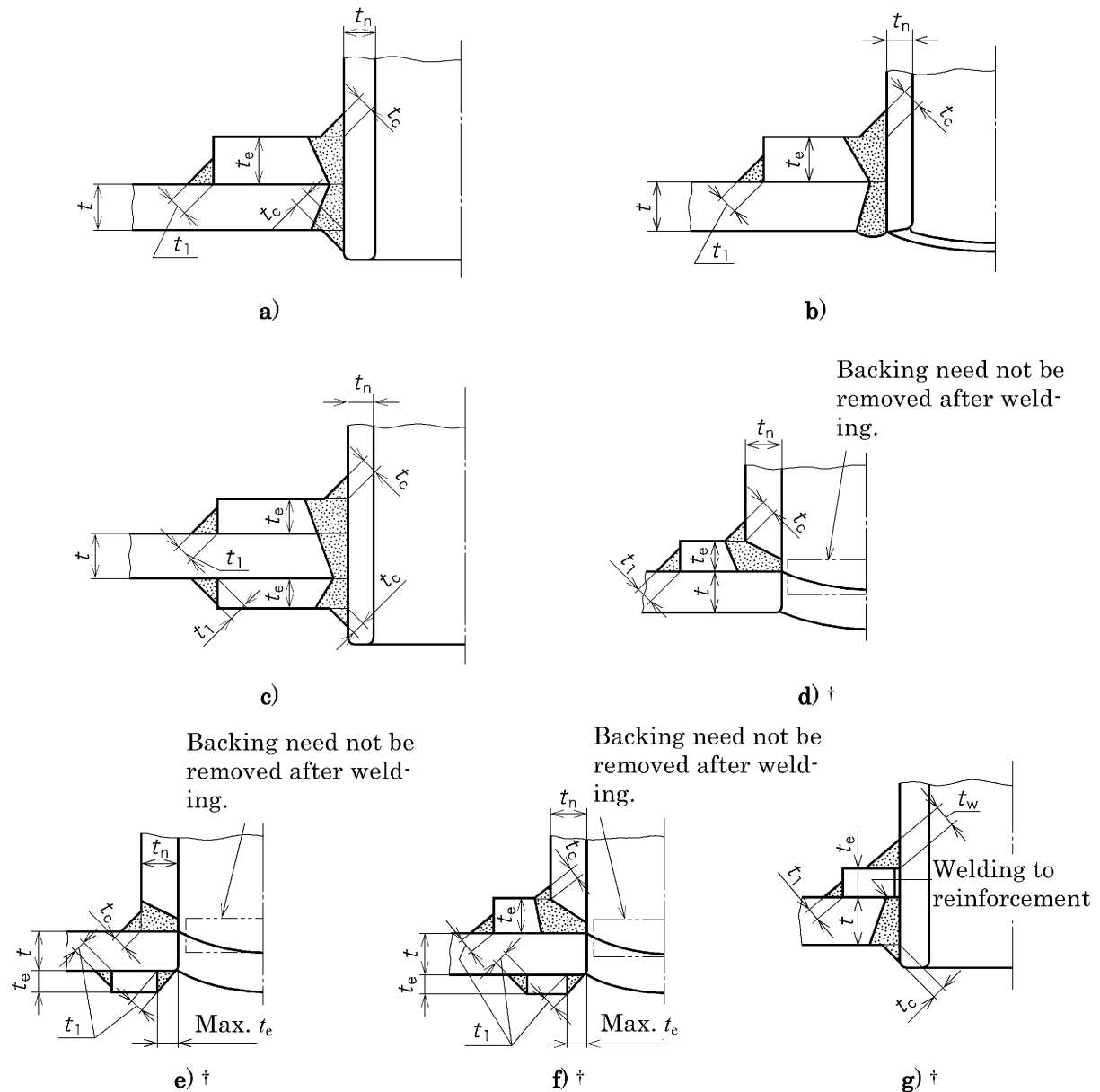
r_1 : from $1/8 t$ to $1/2 t$ for 9 % nickel steel (mm)

r_2 : not less than 19 mm for 9 % nickel steel (mm)

r_3 : from $1/8 t_n$ to $1/2 t_n$ for 9 % nickel steel (mm)

r_4 : not less than 6 mm for 9 % nickel steel (mm)

Figure 7 (concluded) †



Meanings of symbols in diagram are as given below.

- t : nominal thickness of shell or head (mm)
- t_1 : throat thickness of fillet welding, not less than $0.5 t_m$ (mm)
- t_c : throat thickness of fillet welding, not less than 6 mm or $0.7 t_m$, whichever is smaller (mm)
- t_e : nominal thickness of reinforcement (mm)
- t_m : thickness of thinner member to be welded or 19 mm, whichever is smaller (mm)
- t_n : nominal thickness of nozzle stub unit (mm)
- t_w : throat thickness of fillet welding or dimension shown in diagram, not less than $0.7 t_m$ (mm)

Figure 8 Joint combining full penetration welding of nozzle stub unit and reinforcement (FP joint) and fillet welding (FW joint)

Unit: mm

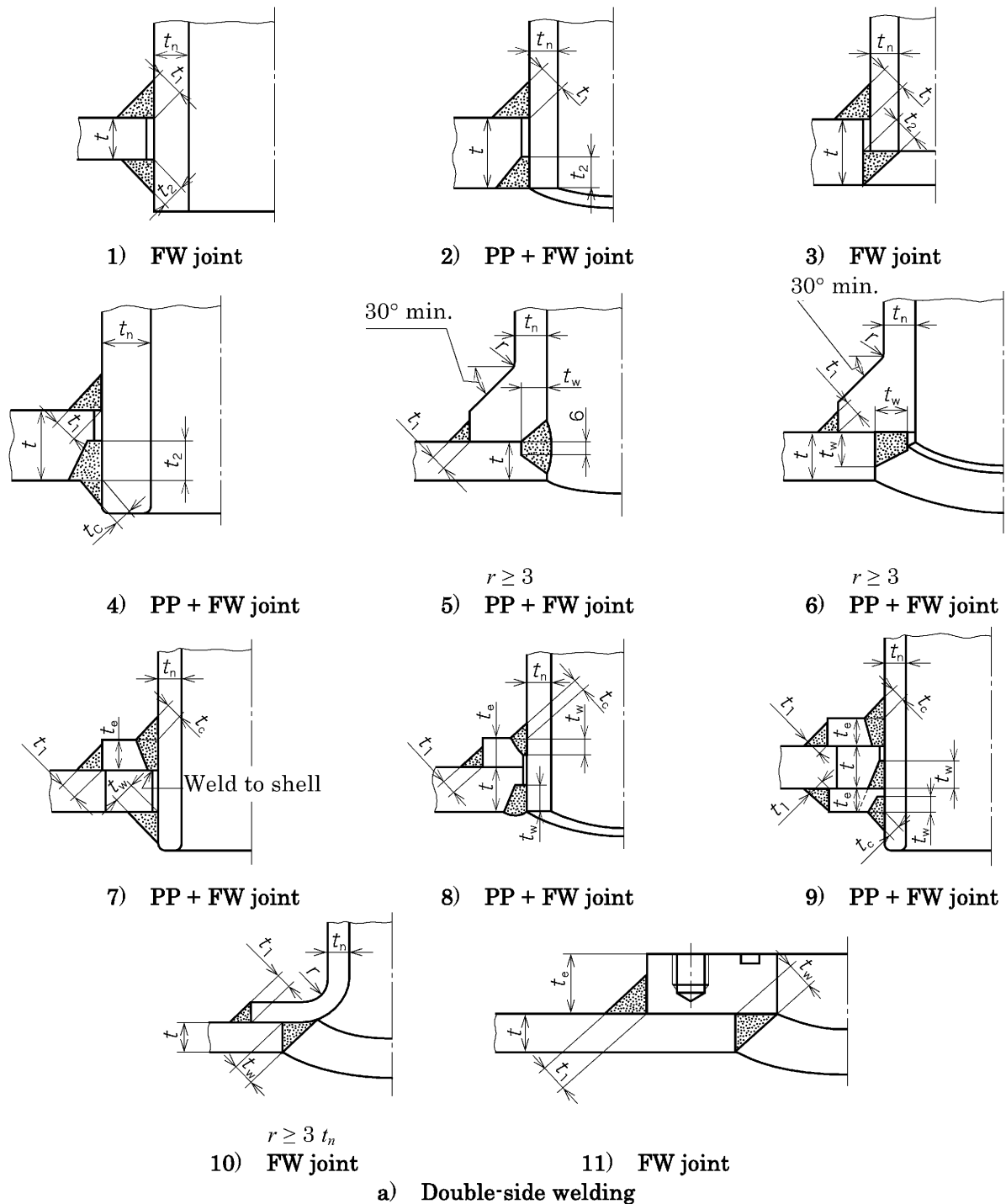


Figure 9 Joint of nozzle stub unit by partial penetration welding (PP joints) and fillet welding (FW joints) †

Meanings of symbols in diagram are as given below.

r : radius of corner roundness (mm)

t : nominal thickness of shell or head (mm)

t_1 : throat thickness of fillet welding, not less than $0.5 t_m$ (mm)

t_2 : throat thickness of fillet welding or groove depth of groove welding, $t_1 + t_2 \geq 1.25 t_m$ (mm)

t_c : throat thickness of fillet welding or groove depth of groove welding, not less than 6 mm or $0.7 t_m$, whichever is smaller (mm)

t_e : nominal thickness of reinforcement (mm)

t_m : thickness of thinner member to be welded or 19 mm, whichever is smaller (mm)

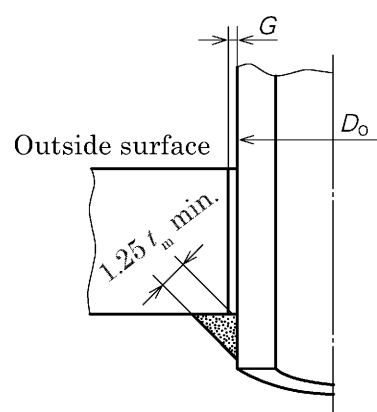
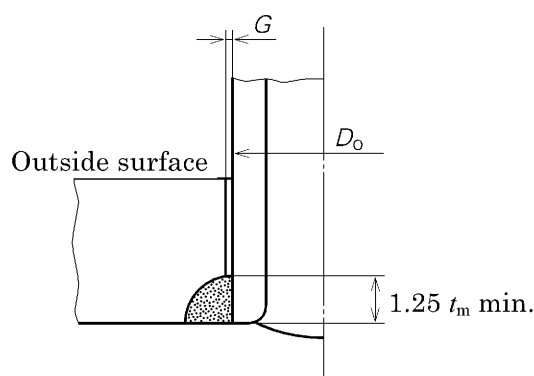
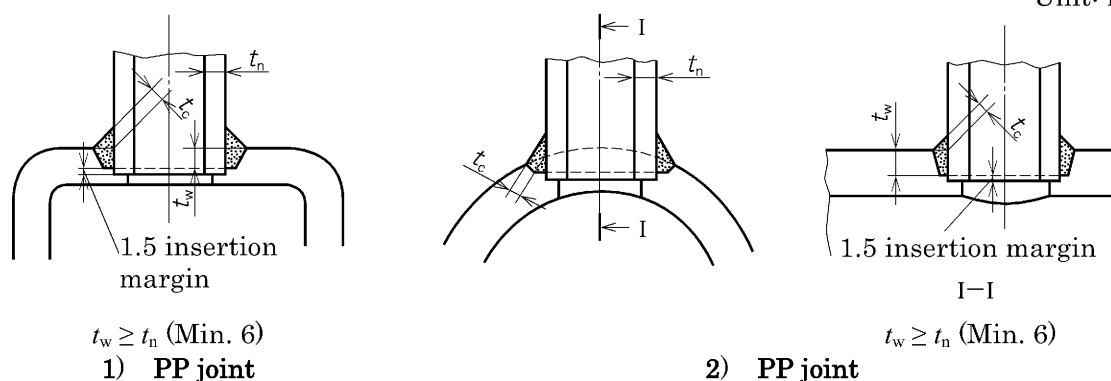
t_n : nominal thickness of nozzle stub unit (mm)

t_w : dimension shown in diagram, not less than $0.7 t_m$ (mm)

a) Double-side welding (concluded)

Figure 9 (continued) †

Unit: mm



— Meanings of symbols in diagram are as given below.

D_o : outside diameter of nozzle stub unit (mm)

G : maximum radial gap between outer diameter of nozzle stub unit and diameter of hole as given in **a)** and **b)** below

a) When subjected to no load, $G = 3$ mm

b) When subjected to load,

$D_o \leq 25$ mm : $G = 0.13$ mm

$25 \text{ mm} < D_o \leq 100$ mm : $G = 0.25$ mm

$100 \text{ mm} < D_o \leq 170$ mm : $G = 0.38$ mm

t_n , t_c and t_m : as given in **a)**

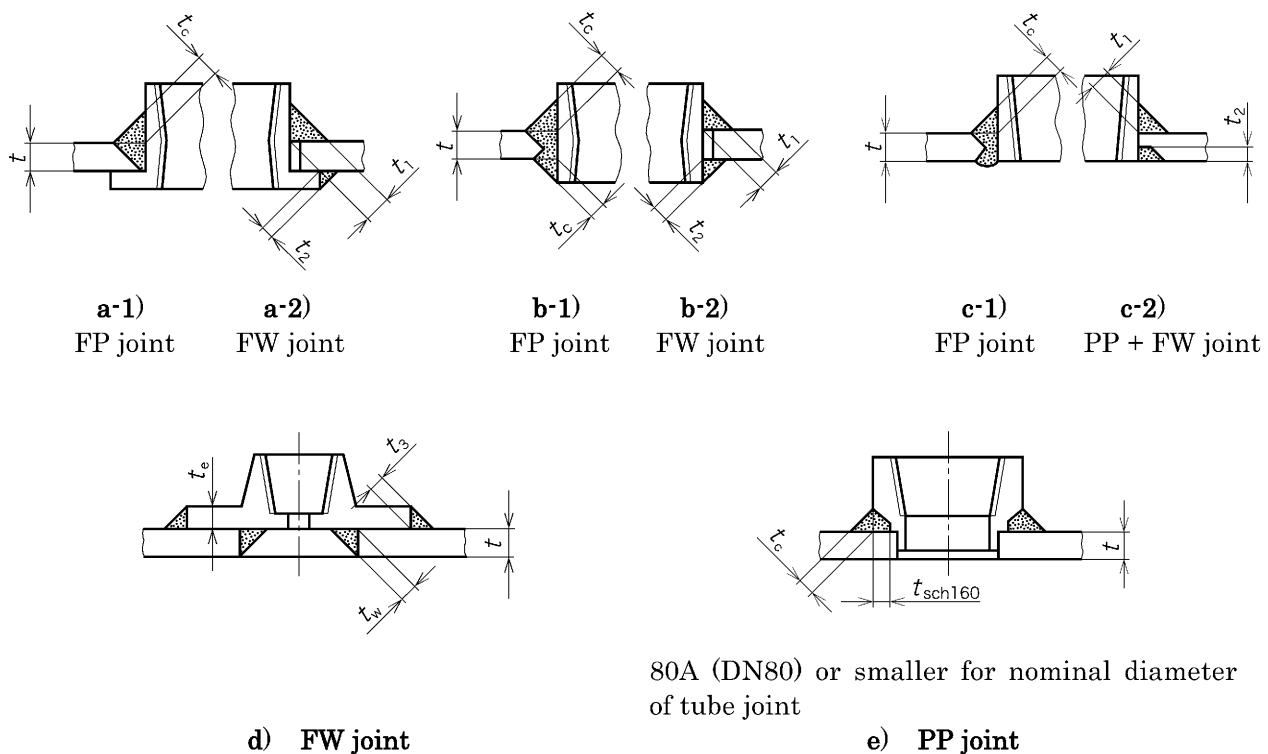
t_w : dimension shown in diagram, not less than t_n (mm) and at least 6 mm

— Nominal diameter of tube shall not exceed 150A.

— In calculation of hole reinforcement, the strength of tube inserted in the case of 3) and 4) shall not be incorporated in the strength calculation.

b) One side welding

Figure 9 (concluded) †



80A (DN80) or smaller for nominal diameter of tube joint

Meanings of symbols in diagram are as given below.

t : nominal thickness of shell or head (mm)

t_1, t_2, t_3 and t_c : throat thickness of fillet welding (mm)

t_1 and t_2 : not less than 6 mm or $0.7 t_m$, whichever is smaller, and in the case of **a-1)** and **a-2)**,
 $t_1 + t_2 \geq 1.25 t_m$ (mm)

When nominal diameter of tube joint is 80A (DN80) or smaller, t_1 and t_2 of partial penetration welding (PP joint) and fillet welding (FW joint) shall be not less than 2.5 mm or $0.7 t_m$, whichever is smaller.

t_3 : at least $0.5 t_m$ (mm)

t_c : not less than 6 mm or $0.7 t_m$, whichever is smaller (mm)

t_e : thickness of flange of tube joint (mm)

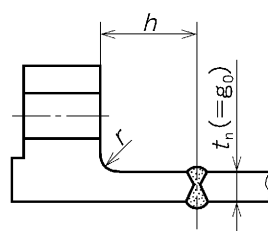
t_m : thickness of thinner member to be welded or 19 mm, whichever is smaller (mm)

t_{sch160} : thickness of schedule 160 (mm)

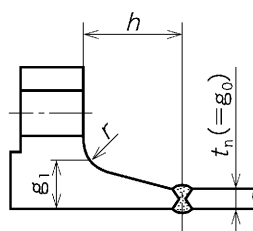
t_w : dimension shown in diagram, not less than $0.7 t_m$ (mm)

Figure 10 Welded joint of tube joint with inner screw †

Unit: mm



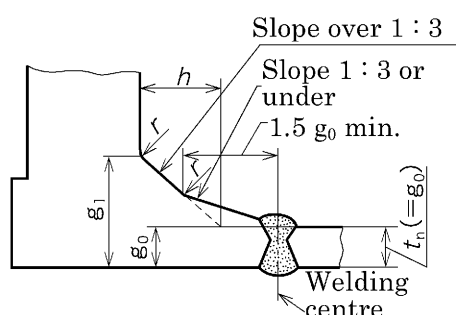
$$h \geq 1.5 t_n$$



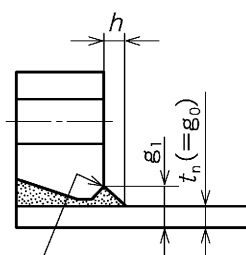
$$h \geq 1.5 g_0$$

Apply 3) or 4) when slope of hub near flange exceeds 1 : 3.

1) B-1 joint

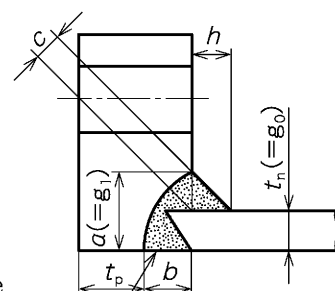


2) B-1 joint



0.25 g_0 but not less than 6, the minimum for either leg. This weld may be machined to make round as shown in 1) in which case $g_1 = g_0$

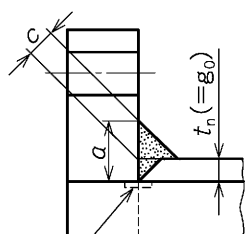
3) B-1 joint



Full penetration with back gouging.

$$a + b \geq 3 t_n$$

4) B-1 joint



If both sides are not welded, use backing and it need not be removed after welding.

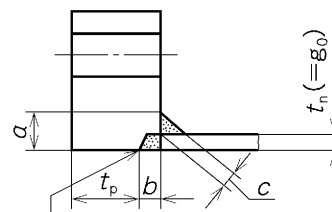
$$a \geq 3 t_n$$

7) FP joint

5) FP joint



6) FP joint



Full penetration shall be realized by back gouging.

$$a + b \geq 3 t_n$$

8) FP joint

Meanings of symbols in diagram are as given below.

g_0 : thickness of hub tip or t_n (mm)

g_1 : thickness of hub at back face of flange (mm)

a and b : dimensions shown in diagram (mm)

c : not less than t_n or t_x , whichever is smaller (mm)

h : length of hub

r : radius of corner roundness, not less than 0.25 g_0 (mm) and at least 4.5 mm

t_n : nominal thickness of shell or nozzle stub (mm)

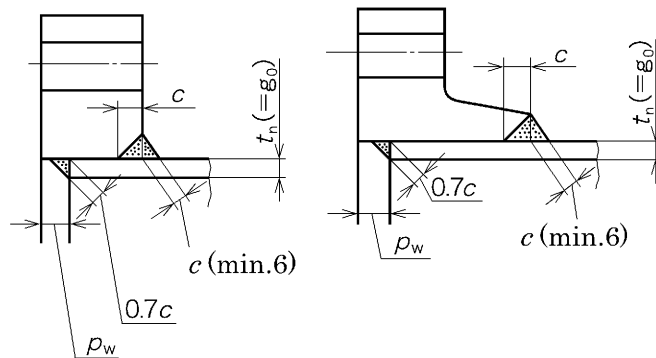
t_p : dimension shown in diagram not less than t_n , t_x or 6 mm, whichever is smaller (mm)

t_x : 2 g_0 when calculated as integral flange (mm) and at least 6 mm

a) Integral flange

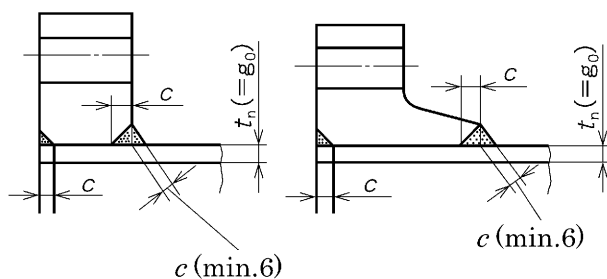
Figure 11 Welded joint of shell or nozzle stub and flange †

Unit: mm



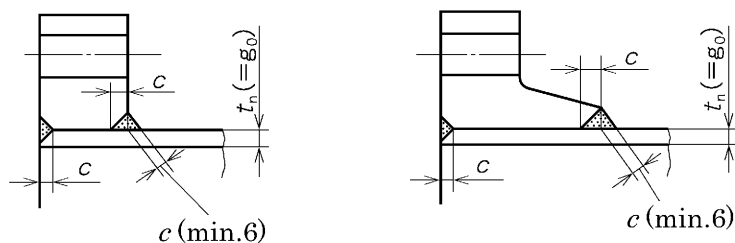
9-1) PP + FW joint

9-2) PP + FW joint



10-1) PP joint

10-2) PP joint



11-1) PP joint

11-2) PP joint

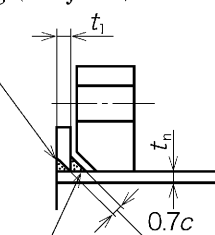
Meanings of symbols in diagram are as given below.

- c : not less than t_n or t_x , whichever is smaller (mm)
- g_0 : thickness of hub tip or t_n (mm)
- p_w : dimension shown in diagram, not more than $c + 6$ (mm)
- t_n : nominal thickness of shell or nozzle stub (mm)
- t_x : $2 g_0$ (mm) when calculated as integral flange and at least 6 mm

a) Integral flange (concluded)

Figure 11 (continued) †

Single side or both side welding (FP joint) ^{a)}



This weld may be machine-finished to make round corners to fit to the opponent loose flange.

$$t_1 \geq t_n$$

Meanings of symbols in diagram are as given below.

c : not less than t_n or t_x , whichever is smaller (mm)

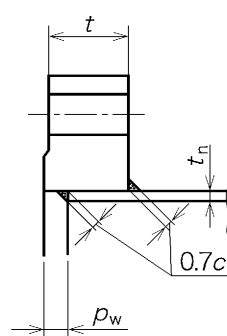
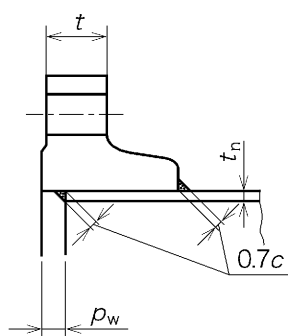
t_1 : nominal thickness of lap (stub end) (mm)

t_n : nominal thickness of shell or nozzle stub (mm)

t_x : twice the calculated thickness (mm) of shell or nozzle stub for internal pressure, and at least 6 mm

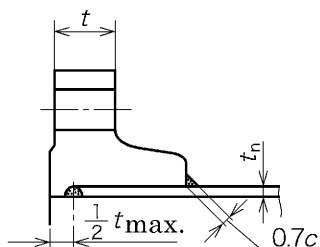
Note ^{a)} In order to weld lap (t_1) and shell or nozzle stub (t_n), in full penetration, the entire thickness of t_1 or t_n , may be welded. The gasket contact face shall be machine-finished.

1) Lap-joint flange

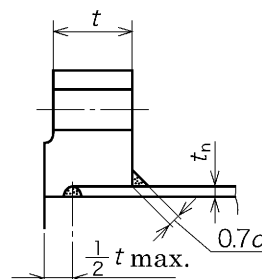


When slope of hub is not more than 6° , apply $g_0 = g_1$.

2-1) FW joint



2-2) FW joint



When slope of hub is not more than 6° , apply $g_0 = g_1$.

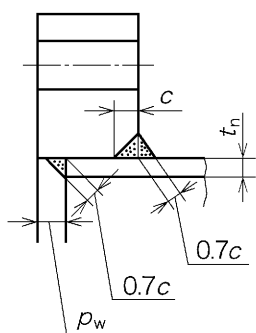
2-3) PP + FW joint

2-4) PP + FW joint

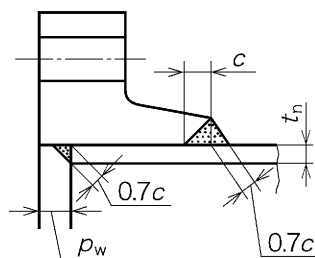
2) Slip-on flange

b) Loose flange

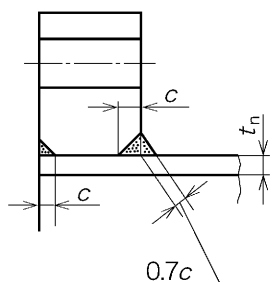
Figure 11 (continued) †



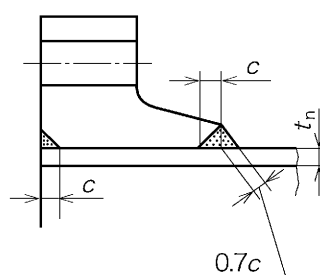
3-1) PP + FW joint



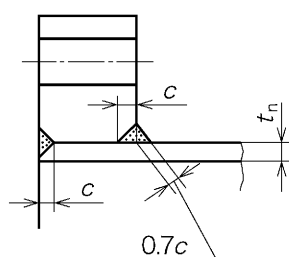
3-2) PP + FW joint



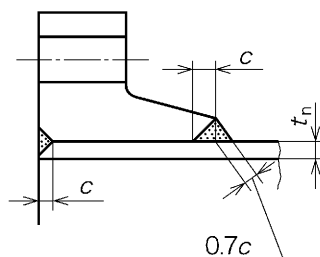
4-1) PP joint



4-2) PP joint



5-1) PP joint



5-2) PP joint

— Meanings of symbols in diagram are as given below.

c : not less than t_n or t_x , whichever is smaller (mm)

p_w : dimension shown in diagram, not more than $c + 6$ (mm)

t : thickness of flange (mm)

t_n : nominal thickness of shell or nozzle stub (mm)

t_x : twice the calculated thickness (mm) of shell or nozzle stub for internal pressure, and at least 6 mm

— In 3-1) to 5-2), apply the following.

g_0 : thickness of hub tip $g_0 \leq 16$ (mm)

B : inner diameter of flange $B/g_0 \leq 300$

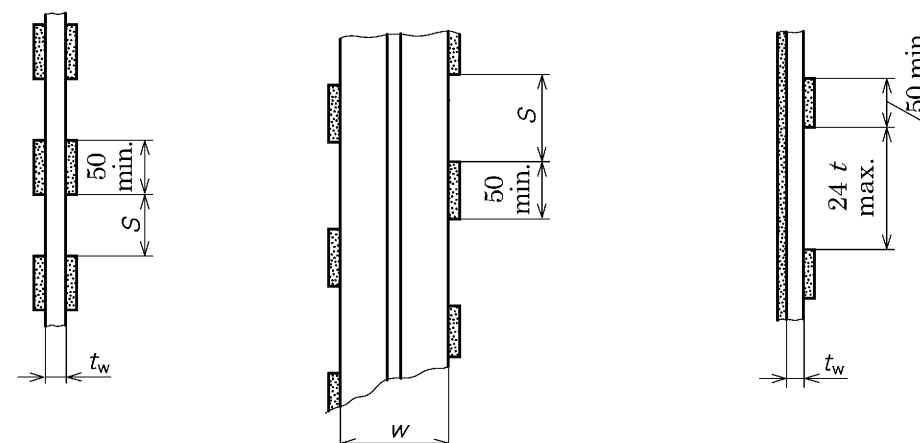
Design pressure ≤ 2 (MPa)

Design temperature ≤ 370 (°C)

b) Loose flange (concluded)

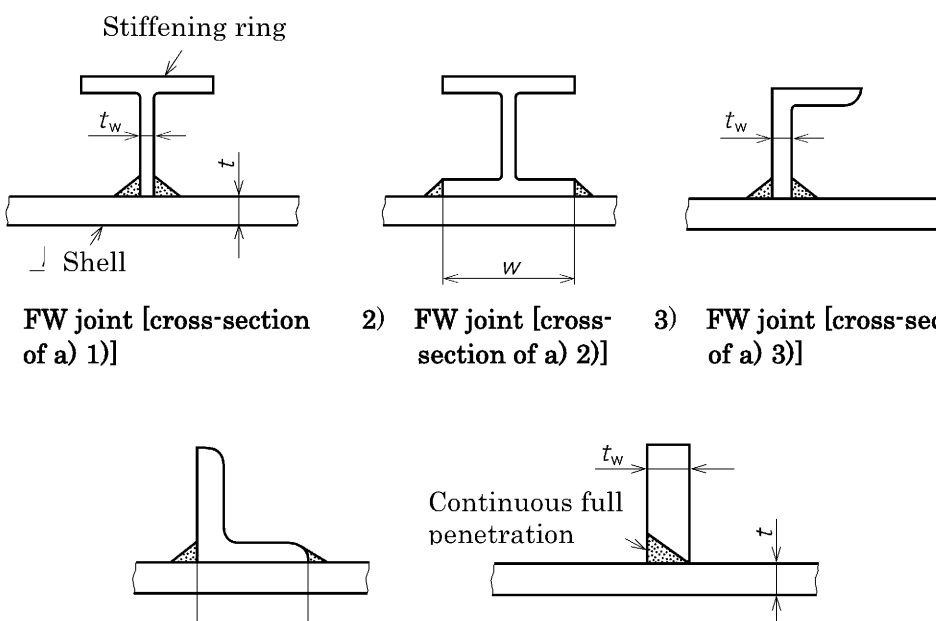
Figure 11 (concluded) †

Unit: mm

- 
- 1) Chain intermittent welding ^{a)} $t_w \leq 25$
- 2) Staggered intermittent welding ^{a)} $w \leq 25$
- 3) One side continuous, another side intermittent welding ^{b)} $t_w \leq 25$

Note ^{a)} When welding stiffening ring outside the shell $S \leq 8 t$
 When welding stiffening ring inside the shell $S \leq 12 t$

a) Gap between welded joints for intermittent welding

- 
- 1) FW joint [cross-section of a) 1)]
- 2) FW joint [cross-section of a) 2)]
- 3) FW joint [cross-section of a) 3)]
- 4) FW joint $w \leq 25$
- 5) FP joint

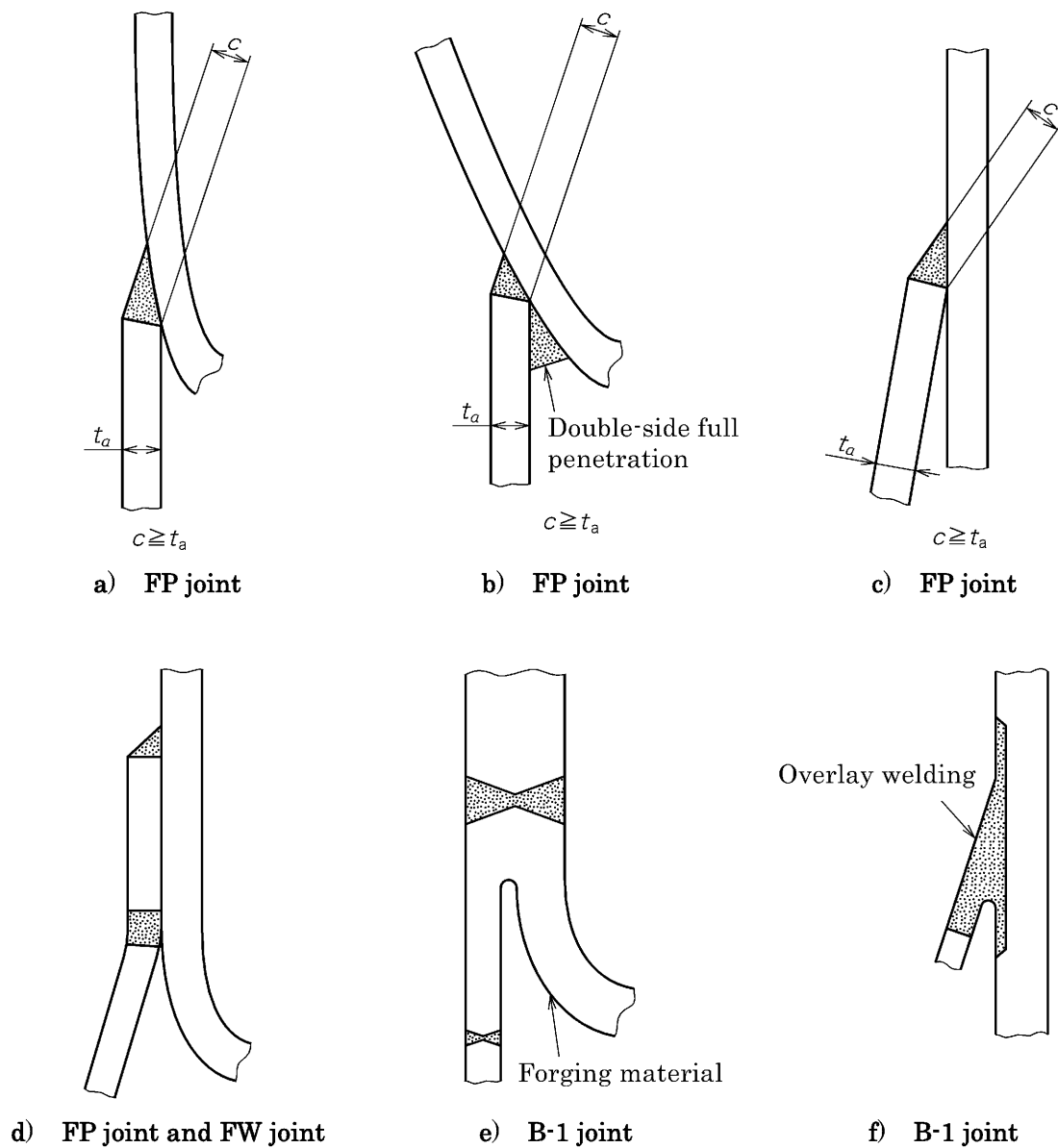
Meanings of symbols in diagram are as given below.

t : nominal thickness of shell (mm)

t_w or w : thickness of stiffening ring (mm)

b) Weld form

Figure 12 Welded joint of shell and stiffening ring †

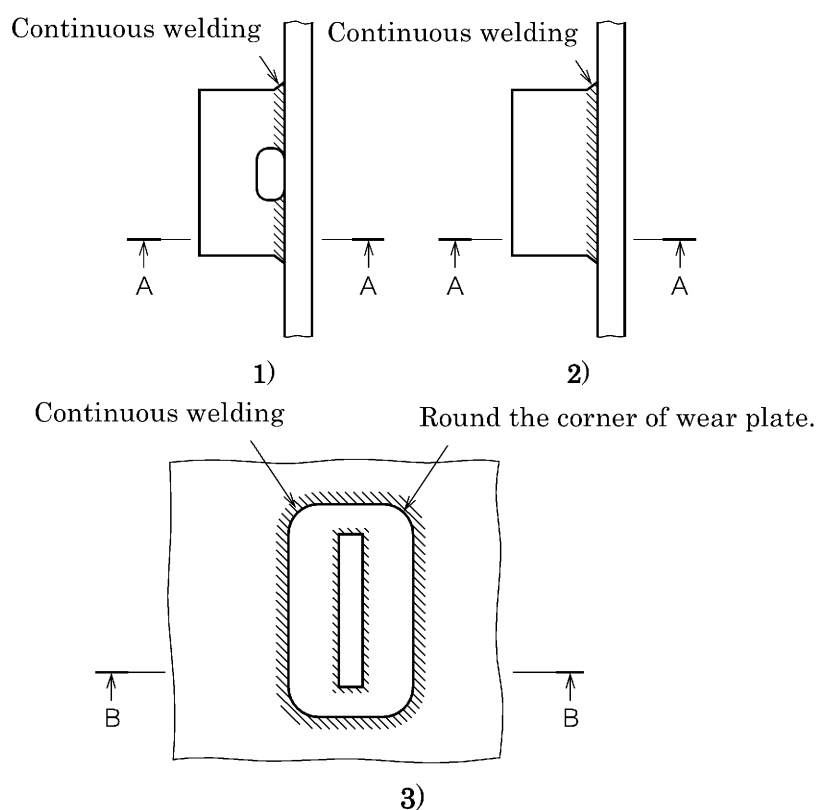


Meanings of symbols in diagram are as given below.

c : minimum thickness from root to toe of welded joint (mm)

t_a : thickness of skirt support (mm)

Figure 13 Welded joint of skirt support †



a) Welded joint of saddle support, leg support and lug (FW joint)

Unit: mm

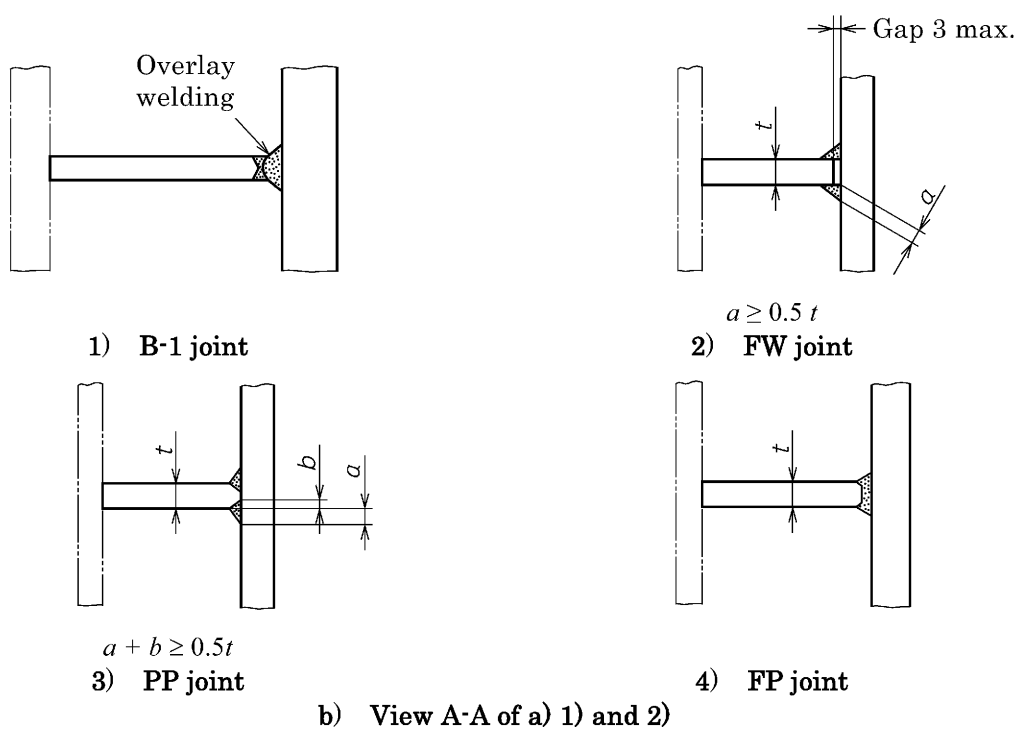


Figure 14 Welded joint of saddle support, leg support, lug, etc. †