

JIS

JAPANESE INDUSTRIAL STANDARD

**Construction of Welded
Aluminium and Aluminium
Alloy Storage Tanks**

JIS B 8502—1986

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by

Japanese Standards Association



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JAPANESE INDUSTRIAL STANDARD

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Construction of Welded Aluminium and
Aluminium Alloy Storage Tanks

B 8502-1986

1. Scope

This Japanese Industrial Standard specifies the structure of the cylinder type fixed roof storage tanks of aluminium and aluminium alloy welded construction not higher than 8 m, which are used for storage of liquid chemicals at normal pressure, hereinafter referred to as the "storage tanks". However, storage tanks for low temperature use are excluded.

This standard applies only to the bodies and accessories specified in this standard, and does not apply to valves connected with nozzles, accessories such as pipings and measuring instruments, and to foundations, oil preventive dikes, coatings and heat insulation works.

Remark: The units and numerical values given in { } in this Standard are based on the traditional units and are currently the criteria in force.

2. Materials

2.1 General The materials used for the storage tanks shall be selected among those materials which are sufficiently corrosion-proof against the stored liquids.

2.2 Constructing Materials The constructing materials used for the storage tanks shall generally be in compliance with the following standards or equal or superior to those.

JIS H 4000

JIS H 4040

JIS H 4080

JIS H 4090

JIS H 4100

JIS H 4140

JIS B 2321

2.3 Materials for Accessories The materials used for steel accessories shall generally be in compliance with the following standards or those which are equal or superior to these.

SS 41 of JIS G 3101

JIS G 3106

JIS G 3115

JIS G 3126

SF 40 and SF 45 of
JIS G 3201

STK 41 of JIS G 3444

JIS G 3452

STPG 38 of JIS G 3454

JIS G 3457

STPL 39 of JIS G 3460

S 20 C, S 25 C and
S 45 C of JIS G 4051

SNB 7 of JIS G 4107

JIS G 4303



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However, those materials which co-exist with aluminium alloys in the storage tank or attached to their exteriors shall be sufficiently treated with the corrosion protection.

2.4 Filler Metals The filler metals used for welding of principal parts shall generally be in compliance with the following standard or equal or superior to those.

JIS Z 3232

3. Design

3.1 Strength of Storage Tank

3.1.1 Loads Applied to Storage Tank The loads applied to the storage tank shall generally be as the following:

(1) **Static Loads:**

- (a) Load due to self weight (including accessories) of storage tank
- (b) Load due to stored liquid
- (c) Load due to heat insulating materials
- (d) Snow loading

(2) **Dynamic Loads:**

- (a) Load due to wind pressure
- (b) Load due to earthquake

However, the load due to wind pressure and the load due to earthquake shall be designed assuming that these act separately.

3.1.2 Calculation of Loads In obtaining the loads given in 3.1.1, the following shall be complied with.

- (1) **Specific Gravities of Materials** In obtaining the load due to self-weight of the storage tank, the specific gravity of aluminium material shall be taken as 2.7 and that of steel material as 7.8.
- (2) **Specific Gravities of Stored Liquids** In obtaining the load due to stored liquid, the specific gravity of the liquid shall be taken as 1, where true specific gravity of the liquid is smaller than 1, and where greater than 1, the true specific gravity of the liquid shall be used.
- (3) **Load of Heat Insulating Materials** Loads of supporting fittings and protective coating materials shall be included in the load of heat insulating materials.
- (4) **Snow Loading** The snow loading per horizontal projected area of the storage tank shall be given by multiplying the unit weight of snow by a vertical deepest depth of snow in this locality.

The unit weight of snow shall be assumed as 20 N { 2 kgf } or more per horizontal projected area 1 m² for each 1 cm of snow.

- (5) Wind Loading The wind loading due to wind pressure is given by the following formula:

$$Q = c \cdot q \cdot A$$

where Q : wind loading (N {kgf})

c : shape coefficient accounted as 0.7

A : wind pressured area which stands for the maximum vertical projection area of the storage tank (m^2)

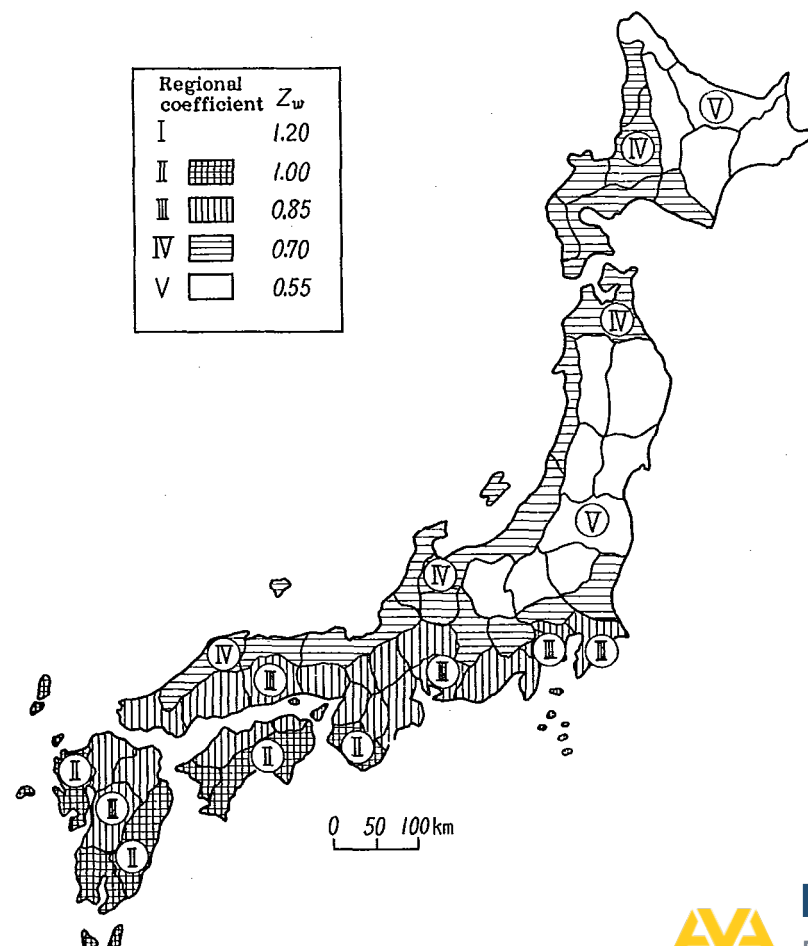
q : wind pressure $q = 600\sqrt{h} \cdot Z_w$ (N/m^2) { $q = 60\sqrt{h} \cdot Z_w$ (kgf/m^2) }

h : height of the portion from the ground level where the wind pressure is given (m)

Z_w : regional compensation coefficient of the wind pressure as given in Figure 1

However, at such places as sea shore, river side and top of mountain where a strong wind is conceivable, or at a portion of storage tank h of which exceeds 25 m, $q = 3000 Z_w \text{ N}/\text{m}^2$ { $q = 300 Z_w \text{ kgf}/\text{m}^2$ } shall be given whatever h is.

Fig. 1. Regional Coefficient Pertaining to Wind Pressure (Region I Contains Islands Southern than 30° North Latitude)



	Region	Regional coefficient Z_w
I	Islands located southern than 30° NL	1.20
II	Other districts than those shown in (I) within Kagoshima prefecture, Miyazaki prefecture, Amakusa district, Hondo city and Ushibuka city in Kumamoto prefecture, Nagasaki prefecture, Saga prefecture, Kitaamabe district, Usuki city, Tsukumi city, Minamiamabe district, Saiki city, Oita city and Ono district in Oita prefecture, Tokushima prefecture, Kochi prefecture, Kita district, Higashiwa district, Nishiwa district, Ozu city, Yawatahama city, Kitauwa district, Uwajima city and Minamiwa district in Ehime prefecture, Wakayama prefecture, Tsuna district, Mihara district and Sumoto city in Hyogo prefecture, Izu Islands in Tokyo	1.00
III	Other districts than these shown in (II) within Kumamoto prefecture, Other districts than these shown in (II) within Oita prefecture, Other districts than these shown in (II) within Ehime prefecture, Yamaguchi prefecture, Hiroshima prefecture, Okayama prefecture, Other districts than these shown in (II) and (IV) within Hyogo prefecture, Osaka prefecture, Other districts than these shown in (IV) within Kyoto prefecture, Shiga prefecture, Nara prefecture, Mie prefecture, Aichi prefecture, Other districts than these shown in (IV) within Gifu prefecture, Shizuoka prefecture, Kanagawa prefecture, Other districts than these shown in (I) and (II) within Tokyo, Chiba prefecture	0.85
IV	Shimane prefecture, Tottori prefecture, Mikata district, Kinokuni district, Toyooka city, Izushi district, Asago district and Yabu district in Hyogo prefecture, Ayabe city, Fukuchiyama city, Amata district, Kasa district, Maizuru city, Miyazu city, Yosa district, Naka district, Takeno district and Kumano district in Kyoto prefecture, Fukui prefecture, Ishikawa prefecture, Toyama prefecture, Ono district, Yoshiki district and Takayama city in Gifu prefecture, Kiso district, Higashichikuma district, Minamiazumi district, Matsumoto city, Shiojiri city, Okaya city, Suwa district, Suwa city, Chino city, Kamiina district, Ina city, Komagane city, Iida city and Shimoina district in Nagano prefecture, Yamanashi prefecture, Saitama prefecture, Ibaragi prefecture, Niigata prefecture, Nishitagawa district, Higashitagawa district, Tsuruoka city, Sakata city and Akumi district in Yamagata prefecture, Yamamoto district, Noshiro city, Oga city, Minamiakita district, Akita city, Kawabe district, Yuri district and Honjo city in Akita prefecture, Aomori prefecture, Oshima-shicho, Hiyama-shicho, Shiribeshi-shicho, Iburishicho, Hidaka-shicho, Ishikari-shicho, Sorachi-shicho and Rumoi-shicho in Hokkaido	0.70
V	Regions other than those included in I to IV	0.55

(6) Earthquake Compression stress in axial direction caused on the shell plate by the earthquake is given by the following formula:

$$\sigma_b = \frac{N}{A} + \frac{M}{Z}$$

where σ_b : compression stress in axial direction caused on the shell plate by earthquake (N/mm²{kgf/mm²})

N : loading obtained by deducting the liquid loading from the static loading of the upper portion of storage tank higher than the height to be considered (N {kgf})

A : sectional area of the shell plate at the height to be considered being given as πDt (mm²)

M : loading obtained by multiplying 80 % of the body static loading of the upper portion higher than the height to be considered by 0.3 of seismic coefficient and height of centre of gravity of the portion (N·mm{kgf·mm})

Z : sectional modulus of the shell plate at the height to be considered being given as $\frac{\pi}{4} D^2 t$ (mm²)

t : thickness obtained by subtracting corrosion allowance from the used thickness of shell plate at the height to be considered (mm)

D : inner diameter of the storage tank (mm)

3.1.3 Strength Design of Tank Body The storage tank shall be subjected to strength calculations in accordance with 3.4, 3.5 and 3.6, and further shall be investigated on the following matters to ascertain that no hindrance will occur.

- (1) **Overturn of Tank Body** Regarding the overturn of the tank body, generally the wind loading for empty liquid and the earthquake loading for full liquid are calculated, and the results shall prove safety for whichever of the larger overturn moment.
- (2) **Sliding of Tank Body** Regarding the sliding of the tank body, it shall generally be safe for the wind loading and the earthquake loading.
- (3) **Buckling of Shell Plate Due to Earthquake** In order to prevent the buckling of shell plate from the earthquake the plate thickness of the lowest step of shell plate shall at least satisfy the following equation: However, σ_b shall not exceed 90 % of the yield strength.

$$\sigma_b \leq \frac{0.4 Et}{1.5 D}$$

where E : modulus of longitudinal elasticity of aluminium, assumed as $6.86 \times 10^4 \text{ N/mm}^2 \{7000 \text{ kgf/mm}^2\}$.

3.2 Corrosion Allowance Where the stored liquid is corrosive, necessary corrosion allowance shall be added to the minimum dimension required for the member.

3.3 Joints

3.3.1 Size of Welding Zone The sizes of welded zone shall be as follows:

- (1) In the case of butt welding, it shall be the size of theoretical throat.
- (2) In the case of fillet welding, it shall be the size of fillet weld.

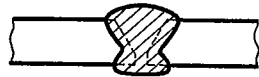
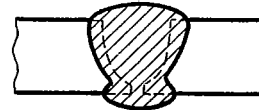
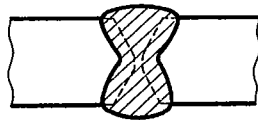
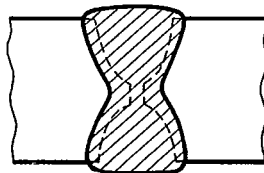
3.3.2 Restrictions in Use of Welding The restrictions in use of welding shall be as follows:

- (1) The minimum size of fillet welding shall be as follows:
 - (a) In the case of plate thickness 4 mm, the size of fillet weld shall be 4 mm or more.
 - (b) In the case of plate thickness exceeding 4 mm, the size of fillet weld shall be not less than the plate thickness of the thinner one.
- (2) Single-welded lap joints are permissible only for bottom plates, roof plates, and accessories.
- (3) Lap welded joints shall be lapped not less than five times the nominal thickness of the thinner plate.

3.3.3 Joints in Storage Tank The joints in the storage tank body shall generally conform to Fig. 2 (1) to (6).

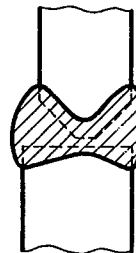
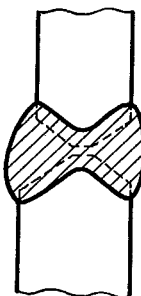
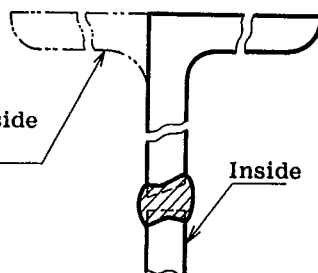
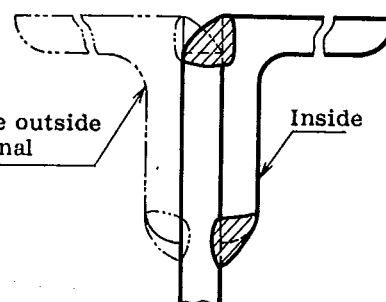
Fig. 2. Joint in Storage Tank

(1) Vertical Joint in Shell

(a) V-groove
Butt joint⁽¹⁾(b) U-groove
Butt joint⁽¹⁾(c) X-groove
Butt joint(d) H-groove
Butt joint(e) I-groove
Butt joint⁽¹⁾

Note ⁽¹⁾ The case of double-side welding is shown. Single-welded butt joint equal or superior to this is allowable.

(2) Horizontal Joint in Shell

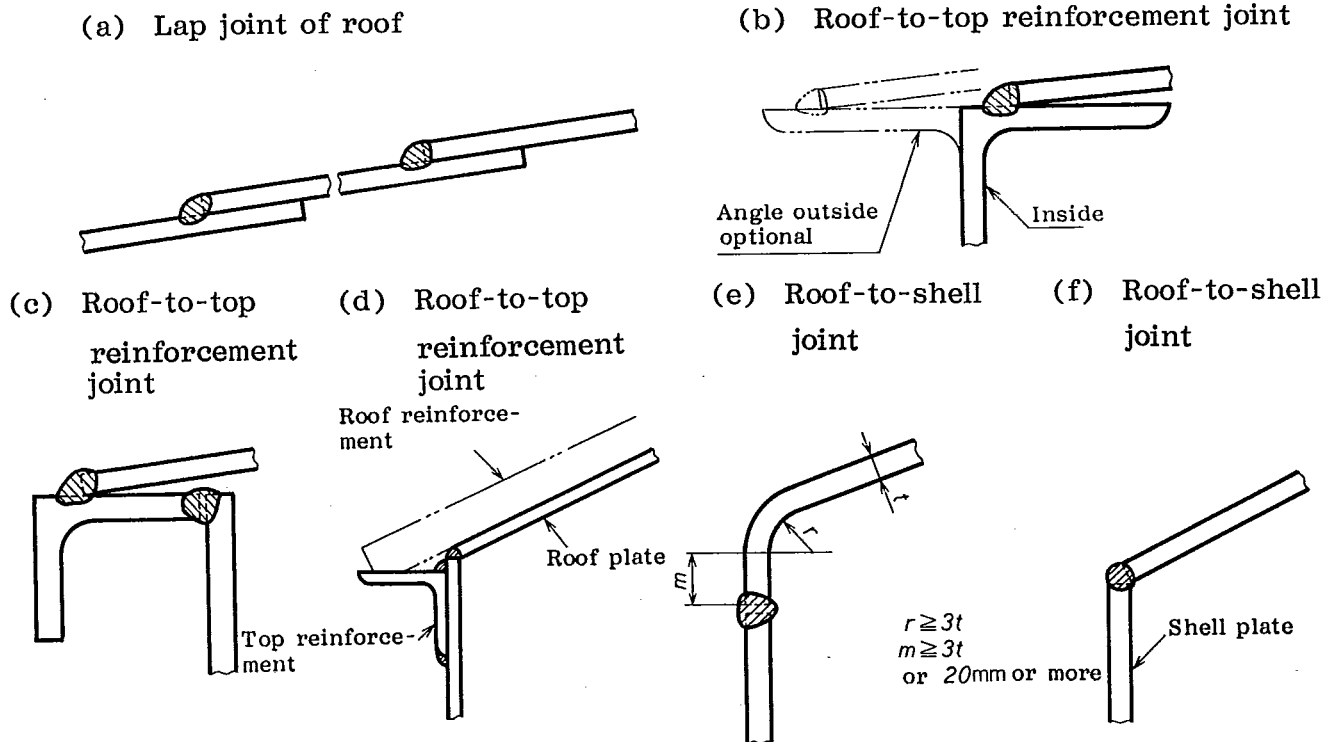
(a) I-groove
Butt joint⁽²⁾(b) V-groove
Butt joint⁽²⁾(c) V-groove
Butt joint⁽²⁾(d) K-groove
Butt joint(e) X-groove
Butt joint(f) V-groove
Butt joint⁽²⁾(g) Fillet weld
Lap joint

Note ⁽²⁾ The case of double-side welding is shown. Single-welded butt joint equal or superior to this is allowable.

Remark: Groove shape in the case where the large difference is there between the plate thickness of upper shell plate and lower

Fig. 2 (Continued)

(3) Roof Joints



(4) Bottom Plate Joints

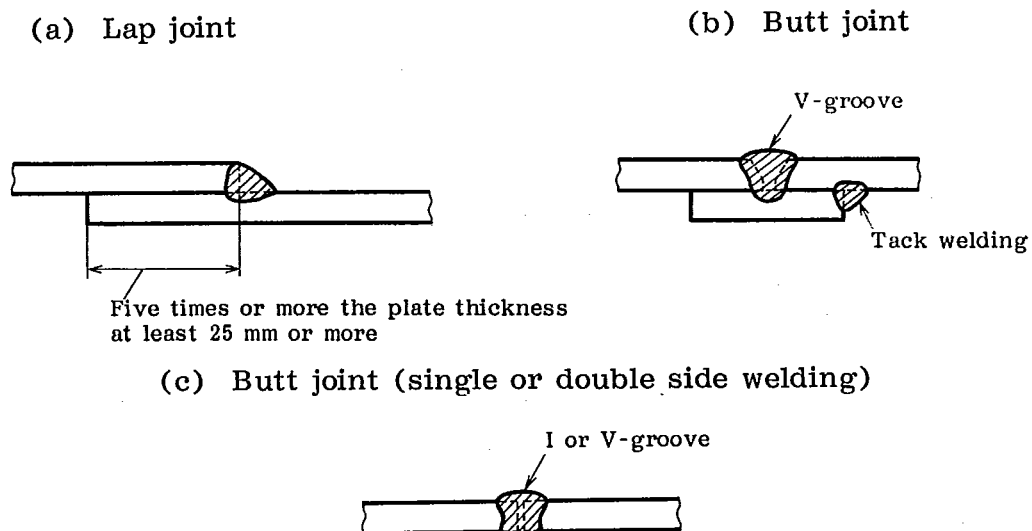
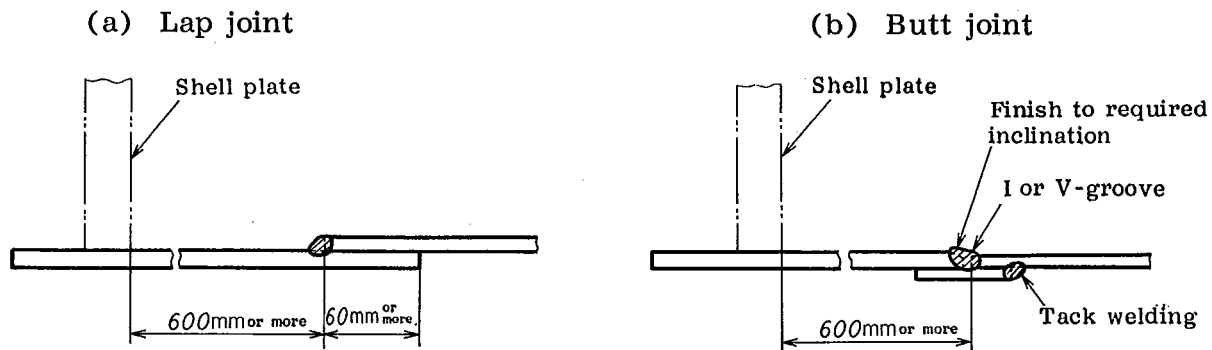
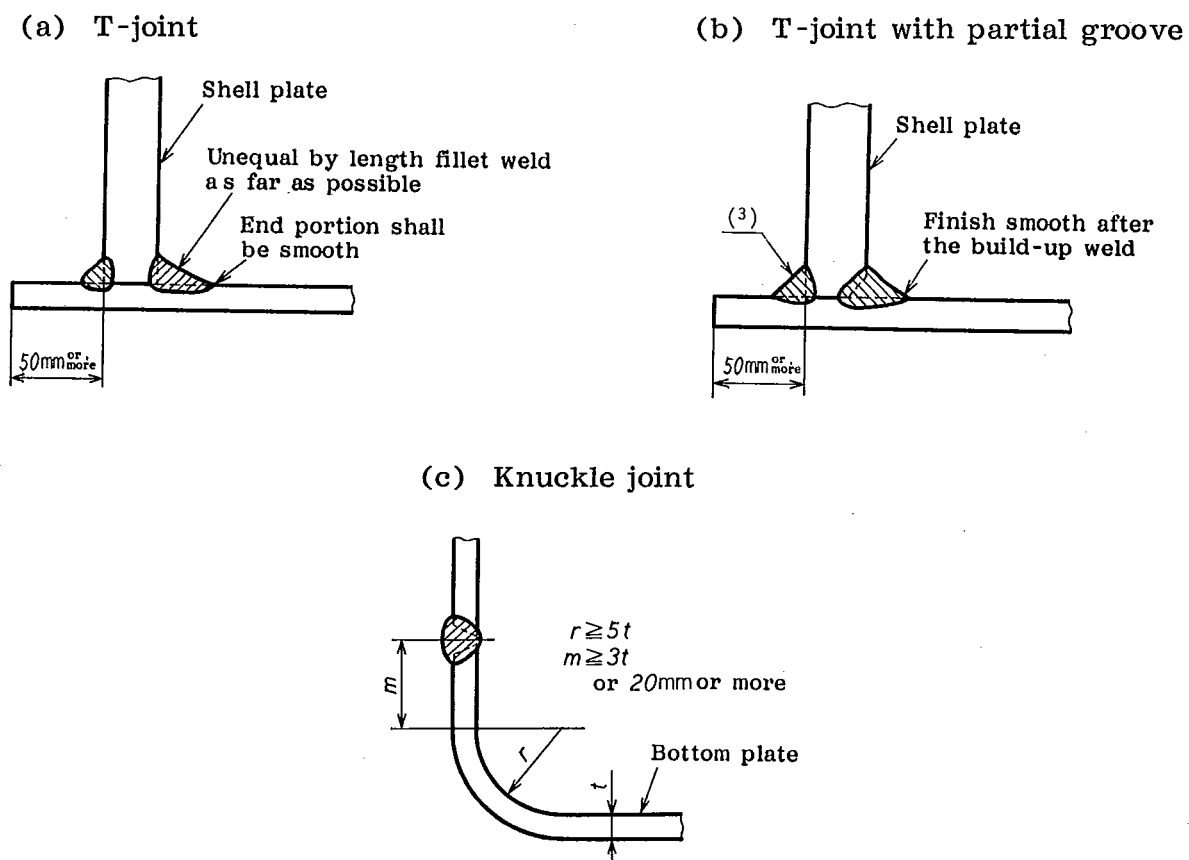


Fig. 2 (Continued)

(5) Bottom Plate-to-Annular Plate Joint



(6) Bottom Plate or Annular Plate-to-Shell Plate Joint



Note (3) Outside may have the partial groove as well as inside.

3.3.4 Efficiency of Welded Joint Efficiency of welded joint shall be as follows:

- (1) The efficiency of welded joint used in calculation shall comply with Table 1.
- (2) The efficiency of welded joint being subject to the partial ray radiographic test shown in Table 1 can be used only for the joints being subject to the radiographic test shown in sub-clause 7.3.3.
 - (a) Horizontal Joint in Shell At an optional position within the initial length of 3 m at every time of change of the plate thickness, groove and welding method, and then at an optional position in every 30 m ranging over the total length of the welded line.
 - (b) Vertical Joint in Shell At an optional position within the initial length of 3 m at every time of change of the plate thickness, groove and welding method, and then at an optional position in every 15 m ranging over the total length of welded line.
 - (c) When the plate thickness of the lowest course shell is over 20 mm, the efficiency shall be measured at as nearest the bottom plate as possible for every vertical joint on the lowest shell.

Table 1. Efficiency of Welded Joint

Type of welded joint	Efficiency of welded joint %		
	Subject to full ray radio-graphic test	Subject to partial ray radiographic test	Not subject to radio-graphic test
(1) Double side butt welding or the single side welded butt joint assumed same or superior to the former	100	85	70
(2) Single side welded butt joint using the backing metal which is remained	90	80	65
(3) Single side welded butt joint in other cases than (1) and (2)	—	—	60
(4) Double side full thickness fillet weld lap joint	—	—	50

3.4 Bottom Plates

3.4.1 Arrangement of Bottom Plates The arrangement of the bottom plates and the joints shall be as follows:

- (1) The joints of the bottom plates consist of lap joints, butt joints or combination of both.
- (2) The portions of base plate to which the shell plates are welded shall generally conform to Fig. 3 (2).
- (3) The lap joints for the bottom plates each other and the bottom plate to annular plate shall be welded only on the upper faces and be continuous-full-thickness-fillet welded over whole length of the joint.

Lap allowances shall be five times the plate thickness for bottom plates each other, at least 25 mm, and be 60 mm or more for the bottom plate to annular plate [see Fig. 2 (4) (a) and (5)(a)].

- (4) Grooves of butt joints for bottom plates each other and base plate to annular plate shall be I-shape or V-shape.
In the welding, backing strip of not less than 4.5 mm may be used on back side [see Fig. 2 (4)(b), (c) and (5)(b)].
- (5) The welding of shell plate to bottom plate or to annular plate shall be both sides continuous fillet weld T joint, and its size of weld shall be not less than the thickness of the thinner plate whichever of shell plate and bottom plate or annular plate [see Fig. 2 (6)].
- (6) Material of the bottom plates or annular plates on which the shell plates are mounted shall be the same as that of the lowest course shell plates.
- (7) In the case of single butt welding of the annular plates each other, backing strip of not less than 4.5 mm in thickness shall be used [see Fig. 3 (3)].

The annular plate shall be such that the interval between the shell plate and the end of bottom plate is 600 mm or more at its narrowest portion.

- (8) In the case of welding of bottom plates, where either the lap joint or butt joint is used, interval between intersections of joints each other and that between intersection of joints and end of T joint of shell plate, and interval between joint and shell plate vertical joint shall all be taken as not less than 300 mm.
- (9) The bottom plate shall be finished so that the protruding extended dimension outwards from the shell plate makes not less than 50 mm from the outside face of the shell plate [see Fig. 2 (6)(a) and (b)].
- (10) The bottom plate, which is processed as the end plate, may be butt welded with the shell plate. In this case Fig. 2 (6)(c) shall be referred to.

3.4.2 Thickness of Bottom Plate Thickness of the bottom plate shall be as the following:

- (1) Thickness of the bottom plate (nominal thickness) shall be 4.5 mm minimum.
- (2) The minimum value of thickness (nominal thickness) of the bottom plate or annular plate on which the shell plate is mounted shall conform to Table 2.

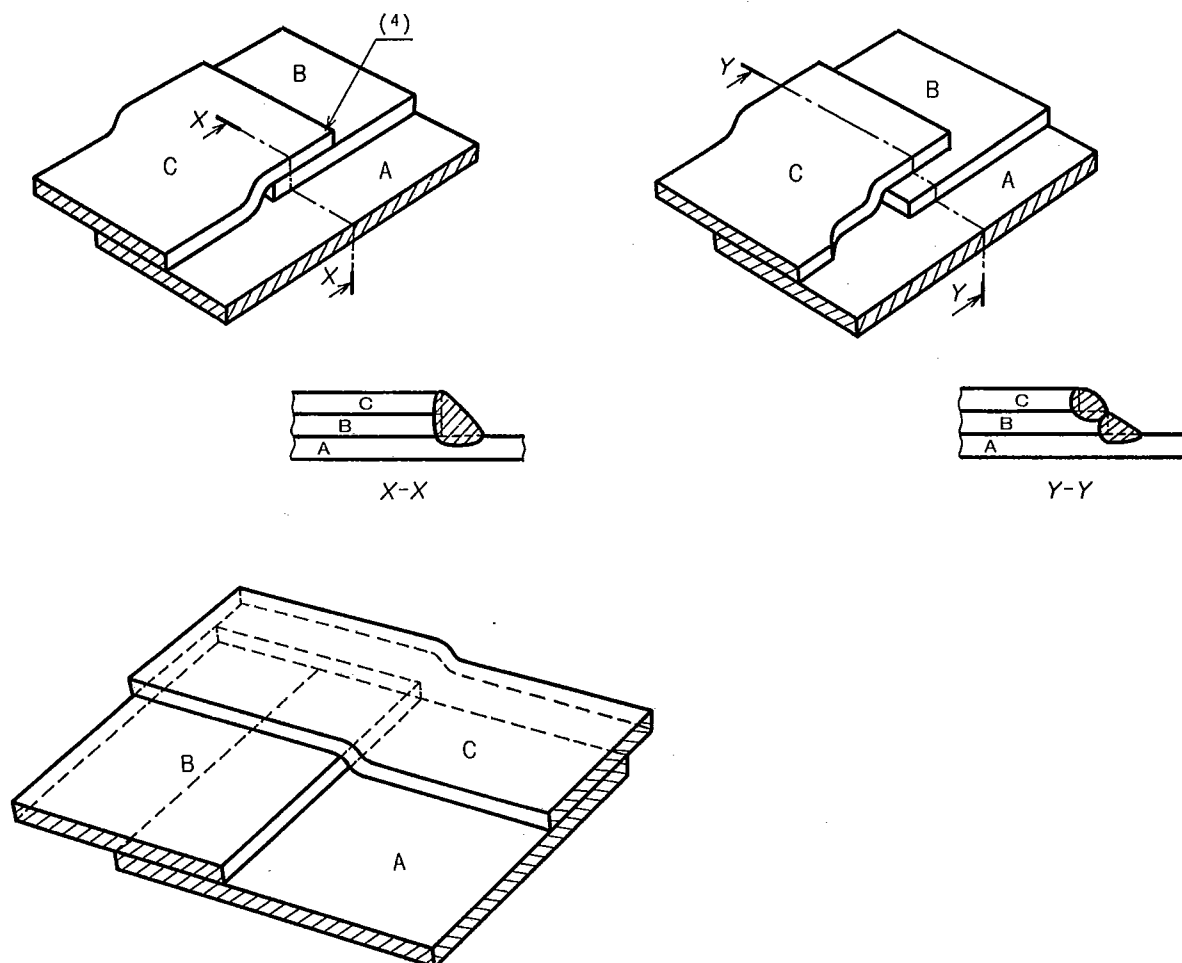
Table 2. Thickness of Bottom Plate or Annular Plate on which Shell Plate Is Mounted

Unit: mm

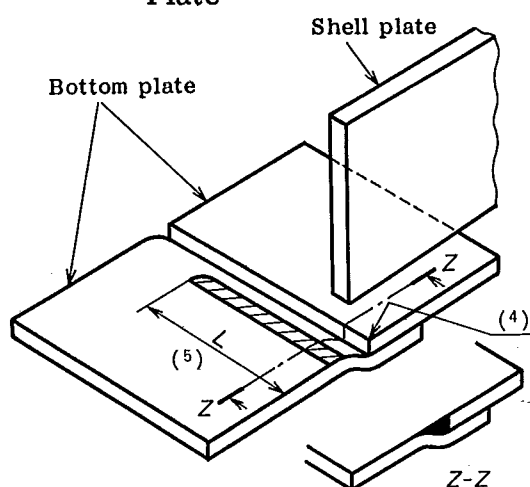
Thickness of lowest course of shell plate	Thickness of bottom plate or annular plate on which shell plate is mounted
Less than 6	4.5
6 or over to 9 excl.	6
9 or over to 16 excl.	8
16 or over	10

Fig. 3. Arrangement of Bottom Plates

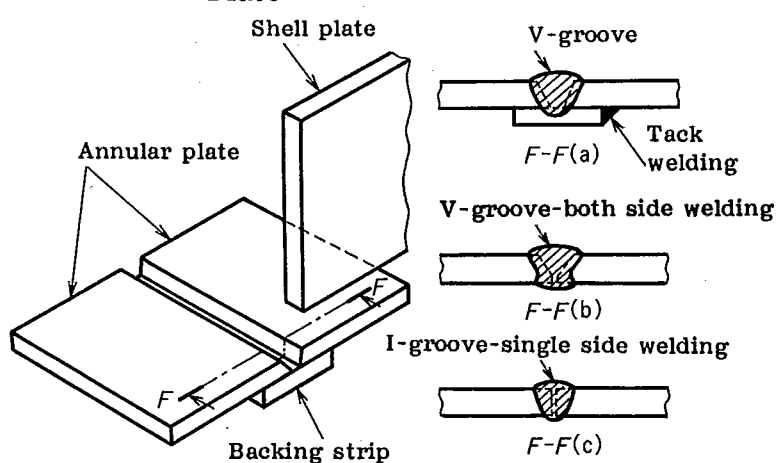
(1) Set-up of Layered Portion of Three Plates



(2) Set-up of Shell Plate and Bottom Plate



(3) Set-up of Shell Plate and Annular Plate



Notes (4) This corner portion is rounded or be chipped off to a degree not impedimental in welding.

(5) Portion L, in a length of 150 mm min. from inside face of the shell plate, is build-up-welded and finished so that the upper face of the bottom plate becomes smooth.

Remark: A indicates the plate of the lower most layer, B that of the middle layer and C that of the upper most layer.

3.5 Shell Plates

3.5.1 Arrangement of Shell Plate The arrangement of shell plates and joints shall be as the following:

- (1) Vertical joints and horizontal joints shall be butt welded joints with complete penetration.
- (2) Neighbouring upper and lower plates of a horizontal joint shall be arranged in a plane on the inside face of the storage tank. However, if required, these may be butt jointed so that the centres of plate thickness will coincide each other.
- (3) Plate thickness of upper course shall not be thickened than that of the lower course.
- (4) The shell plates shall be extended above the maximum working height of the liquid as the over-flow preventing plate for the purposes of preventing over-flow.

3.5.2 Thickness of Shell Plates The thickness of the shell plate shall be as the following:

- (1) The minimum necessary thickness of the shell plate shall be the value calculated from the following equation. However, it shall not be smaller than 4.5 mm (nominal thickness).

$$t = \frac{D (H-0.3) \rho}{0.2 \sigma_a \eta} + c \quad \{ t = \frac{D (H-0.3) \rho}{2 \sigma_a \eta} + c \}$$

where

- t : minimum necessary thickness of shell plate (mm)
- D : inside diameter of the storage tank (m)
- H : height from lower end of the course where the plate thickness is required to the liquid level (m)
- ρ : specific gravity of the stored liquid [see 3.1.2 (2)]
- σ_a : allowable tensile stress of parent material according to Table 4 (N/mm²{kgf/mm²})
- η : efficiency of welded joint according to 3.3.4
- c : corrosion allowance (mm)

- (2) Actual thickness of plates used for shell plates shall be not less than the minimum necessary thickness (t) obtained from the calculation of (1).

3.5.3 Top Reinforcement In reinforcing the top portion, angles shall be attached by welding as reinforcement to the upper rim of the upper-most course of shell plates by double continuous fillet weld or V-shaped or Vee-shaped groove butt weld [see Fig. 2 (2)(f) and (g)].

In this case, angles may be welded either in outwards or inwards.

Furthermore, the angles shall be joined each other by complete penetration butt welding. Minimum dimensions of the angles shall conform to Table 3.

Table 3. Minimum Dimensions of Angle

Unit: mm

Inside diameter of storage tank (m)	Dimensions of angle
10 or under	L 65 x 65 x 6
Over 10 up to 18	L 65 x 65 x 8
Over 18	L 75 x 75 x 9

3.5.4 Allowable Stresses for Fillet Welds The shearing strengths of the fillet welds for the attachments to the shell plates shall be 60 % of the allowable tensile stress given in Table 4. However, theoretical throat of weld shall be used in calculation.

Table 4. Allowable Tensile Stress

Unit: N/mm² { kgf/mm² }

Alloy No.	Temper	Shapes ⁽⁶⁾	Specified minimum strength		Allowable tensile stresses						
			Tensile strength	Yield strength	40°C or below	Over 40°C to 65°C or below	Over 65°C to 100°C or below	Over 100°C to 125°C or below	Over 125°C to 150°C or below	Over 150°C to 175°C or below	Over 175°C to 200°C or below
1080 } 1070 }	(7)	Sheets, bars, tubes	53.9 { 5.5 }	14.7 { 1.5 }	11.8 { 1.2 }	11.8 { 1.2 }	10.8 { 1.1 }	9.8 { 1.0 }	8.8 { 0.9 }	8.8 { 0.9 }	6.9 { 0.7 }
1050	(7)	Sheets, bars, tubes	58.8 { 6.0 }	19.6 { 2.0 }	15.7 { 1.6 }	13.7 { 1.4 }	12.8 { 1.3 }	11.8 { 1.2 }	10.8 { 1.1 }	9.8 { 1.0 }	7.8 { 0.8 }
1100 } 1200 }	(7)	Sheets	73.5 { 7.5 }	24.5 { 2.5 }	21.6 { 2.2 }	19.6 { 2.0 }	19.6 { 2.0 }	18.6 { 1.9 }	16.7 { 1.7 }	13.7 { 1.7 }	10.8 { 1.1 }
1100 } 1200 }	(7)	Bars, tubes, extruded shapes, die forgings	73.5 { 7.5 }	19.6 { 2.0 }	15.7 { 1.6 }	13.7 { 1.4 }	12.8 { 1.3 }	11.8 { 1.2 }	10.8 { 1.1 }	9.8 { 1.0 }	7.8 { 0.8 }
3003 } 3203 }	(7)	Sheets, bars, tubes, extruded shapes	93.1 { 9.5 }	32.3 { 3.5 }	27.4 { 2.8 }	26.5 { 2.7 }	25.5 { 2.6 }	23.5 { 2.4 }	21.6 { 2.2 }	16.7 { 1.7 }	12.8 { 1.3 }
5052 } 5652 }	(7)	Sheets, bars, tubes, extruded shapes	177 { 18 }	63.7 { 6.5 }	51.0 { 5.2 }	51.0 { 5.2 }	51.0 { 5.2 }	51.0 { 5.2 }	37.2 { 3.8 }	28.4 { 2.9 }	24.5 { 2.5 }
5154 } 5254 }	(7)	Sheets, tubes	206 { 21 }	78.5 { 7.5 }	58.8 { 6.0 }	58.8 { 6.0 }	—	—	—	—	—
5056	(7)	Bars, tubes, die forgings	245 { 25 }	98.0 { 10 }	78.4 { 8.0 }	78.4 { 8.0 }	—	—	—	—	—
5083	(7)	Sheets (Thickness 40 mm max.)	275 { 28 }	127 { 13 }	91.2 { 9.3 }	90.2 { 9.2 }	—	—	—	—	—
5083	(7)	Sheets (Thickness over 40 mm to 80 mm or under)	275 { 28 }	118 { 12 }	91.2 { 9.3 }	90.2 { 9.2 }	—	—	—	—	—
5083	(7)	Sheets (Thickness over 80 mm to 100 mm or under)	256 { 27 }	108 { 11 }	86.2 { 8.8 }	86.2 { 8.8 }	—	—	—	—	—
5083	(7)	Bars, tubes, extruded shapes, die forgings	275 { 28 }	108 { 11 }	86.2 { 8.8 }	86.2 { 8.8 }	—	—	—	—	—
6061	T 4, T 6	Welded zone	167 ⁽⁸⁾ { 17 }	—	54.9 { 5.6 }	53.9 { 5.5 }	52.0 { 5.3 }	50.0 { 5.1 }	46.1 { 4.7 }	39.2 { 4.0 }	29.4 { 3.0 }
6063	T 5, T 6	Welded zone	118 ⁽⁸⁾ { 12 }	—	39.2 { 4.0 }	38.3 { 3.9 }	36.3 { 3.7 }	34.3 { 3.5 }	32.4 { 3.3 }	25.5 { 2.6 }	17.8 { 1.8 }
7 N 01	T 4, T 6	Welded zone	284 ⁽⁹⁾ { 29 }	—	94.1 { 9.6 }	94.1 { 9.6 }	—	—	—	—	—

Notes ⁽⁶⁾ Sheets, bars, tubes, extruded shapes, and die forgings in columns of shapes indicate the following standards respectively.

JIS H 4000, JIS H 4040, JIS H 4080, JIS H 4100 and JIS H 4140.

Notes (7) Specified minimum strength indicates the value of temper 0.

(8) Values for welded joint.

(9) Value for welded joint (the lowest value of normal temperature aging for not less than one month after welding)

3.5.5 Reinforcement of Openings in Shell Plates Openings of diameter 85 mm or larger cut in the shell plates for attaching accessories shall be equipped with reinforcements as follows.

Materials for the reinforcements shall be same as that of the shell plates to be equipped.

(1) The reinforcement shall be any one of the items given in the following, or a combination of these.

(a) A reinforcing element

(b) A seat of accessory

(c) A part of neck of an accessory

(d) An exceeding amount of minimum necessary thickness (t) of 3.5.2 (1) within the plate thickness of the shell plate, lying within the effective ranges of reinforcements of the following (2), (3), (4) and (5).

(2) Minimum necessary cross-sectional area of reinforcement element shall be as follows:

$$A = d \times t_a$$

where A : minimum necessary cross-sectional area (mm^2)

d : vertical diameter of the opening (mm)

t_a : a value subtracted by corrosion allowance c from the minimum necessary thickness t of 3.5.2 (1).

The cross-sectional area of a reinforcing element shall be measured at the vertical central cross-sectional area of the opening and only the part which lies within the range above and below the horizontal centre line of the opening respectively by the diameter of the hole shall be considered as the efficient range of the reinforcing element.

(3) The following portions of the area of the neck of an accessory may be considered as the cross-sectional area of reinforcing element.

(a) That portion within a length equal to four times the neck-wall thickness measured outwardly from the outside surface of the shell plate. However, if the neck-wall thickness is reduced within this length, it shall be to the point of transition.

- (b) That portion lying within the shell plate thickness.
- (c) If the accessory is extending inwardly from the inside surface of the shell plate, it shall generally be that portion, the length of which is measured inwardly from the inside surface of the shell plate as specified in (a).
- (4) Portions which may be considered as a part of reinforcing cross-sectional area in the welded zone of the reinforcing element shall be outside portions of both in right and left sides compartmented by a pair of vertical tangents to the opening for the outer periphery, and be overall periphery for the inner periphery. However, the following conditions shall be complied with.
 - (a) Outer periphery and inner periphery weldings of the reinforcing element shall also be continuous welded over the total periphery.
 - (b) Sizes of fillet weldings shall conform to 3.3.1.
- (5) Where two or more openings are installed in close location, the intervals between toes of weld on outer peripheries of respective reinforcing elements shall be not less than eight times the thickness of the thicker reinforcing element or that of the thicker shell plate. However, the reinforcement of openings which are extremely in close location shall be made by one piece of reinforcing plate in accordance with 3.5.5 (2).

3.6 Roof

3.6.1 Roof Types The roof types shall be as follows:

- (1) Supported Cone Roof A roof formed to approximately a cone, supported by rafters, no matter how, with or without columns.
- (2) Self-Supporting Cone Roof A roof formed to approximately a cone, supported only at its periphery.
- (3) Self-Supporting Dome Roof A roof formed to approximately a sphere, supported only at its periphery.
- (4) Self-Supporting Umbrella Roof A modified self-supporting dome roof of which horizontal section is a regular polygon.

3.6.2 Load of Roof The designed load of the roof and its supporting structures shall be the load added not less than 1.2 kN {120 kgf} per horizontal projected area of the roof 1 m² to the self weight. If the snow loading exceeds 600 N {60 kgf} per 1 m², the excess value shall be added, and if the heat insulating material is provided, this load shall be added to the above value.

3.6.3 Design Stresses The design stresses shall be as follows:

- (1) Allowable Tensile Stress The allowable tensile stress shall conform to Table 4.
- (2) Allowable Shearing Stress The allowable shearing stress shall be 0.6 times the allowable tensile stress σ_a of Table 4.