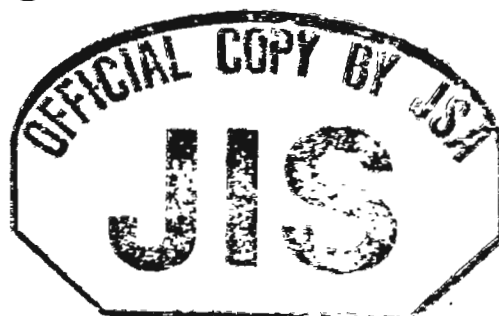


JIS

JAPANESE INDUSTRIAL STANDARD

Welded Steel Tanks for Oil Storage

JIS B 8501-1985



Translation without guarantee
In the event of any doubt arising, the original
standard in Japanese is to be evidence

Translated

by

Japanese Standards Association

1-24, Akasaka 4, Minato-ku
Tokyo 107 Japan

© JSA, 1987

JAPANESE INDUSTRIAL STANDARD

J I S

Welded Steel Tanks for Oil Storage

B 8501-1985

1. Scope

This Japanese Industrial Standard specifies the structures of tanks for storage, under approximately atmospheric pressure, of petroleum which is liquid at a temperature not lower than atmospheric temperature and at the atmospheric pressure or of liquid similar thereto, hereinafter referred to as storage tanks, which are steel total welded circular cylinder storage tanks having fixed roof, floating roof or floating roof with fixed roof having sufficient support force for supporting petroleum storage tank, and their body is assembled by welding on the ground where uniform foundation is provided.

Further, this Standard applies exclusively to the body and attachments specified in this Standard, and does not apply to attachments such as valves, piping, instruments, etc. connected with the nozzle and to foundation, oil preventive embankment, painting, thermal insulating works, etc.

Furthermore, at applying this Standard, at least the following items shall be made clear.

- (1) Earthquake, wind load, fallen snow load and the state of foundation
- (2) Diameter, height or capacity of storage tank
- (3) Type of roof
- (4) Kind and specific gravity of storage liquid
- (5) Value of corrosion allowance
- (6) Temperature of storage tank (metal temperature)
- (7) Fixing position of attachments
- (8) Dimensions, type, number of nozzles, standard of flange

Remarks 1. The units and numerical values given in { } in this Standard are based on the International System of Units (SI) and are appended for informative reference.

2. The attachment means a device that is fixed to the storage tank body by welding or the like.

3. The attaching parts mean those to be attached by using flange and cup ring of nozzle provided on the body. However, the sheathing board (foam dam) of fixed foam extinguisher fitted with the float roof shall be included in the attaching parts.

2
B 8501-1985

2. Materials

2.1 Construction Materials The construction materials used for storage tank shall, as a rule, be those complying with following Standards or those having mechanical properties and chemical components equivalent or superior thereto.

- | | |
|--------------------|---|
| (1) Steel plates | SS 41 of JIS G 3101
JIS G 3106
JIS G 3114
JIS G 3115 |
| (2) Steel sections | SS 41 of JIS G 3101
JIS G 3106
JIS G 3114 |
| (3) Steel pipes | JIS G 3452
STPG 38 of JIS G 3454
STPT 38 of JIS G 3456
STK 41 of JIS G 3444
JIS G 3457
STPL 39 of JIS G 3460 |
| (4) Flange | SS 41 of JIS G 3101
SF 40, SF 45 A of JIS G 3201
S 20 C, S 25 C of JIS G 4051 |
| (5) Bolts and Nuts | SS 41, SS 50 of JIS G 3101
S 20 C, S 25 C, S 45 C of JIS G 4051
SNB 7 of JIS G 4107 |

2.2 Welding Materials The welding materials to be used for welding of each part shall be as follows:

- (1) JIS Z 3211
- (2) JIS Z 3212
- (3) JIS Z 3213
- (4) JIS Z 3311
- (5) JIS Z 3312
- (6) JIS Z 3313
- (7) The wire and flux or shield gas to be used for automatic or semi-automatic welding, hereinafter referred to as the "automatic arc welding", electroslog welding or electrogas arc welding shall be that confirmed that it is suitable for the welding appliance, material and execution method, according to 5.

Remark: In this Standard, out of steel plates, the mild steel means SS 41 of JIS G 3101, SM 41 A of JIS G 3106, SMA 41 of JIS G 3114, and SPV 24 of JIS G 3115, and the high tensile steel means that of which the minimum value of tensile strength of Standard is about 50 to 62 kgf/mm²{ 500 to 620 MPa}.

2.3 Design According to Temperature

2.3.1 Restriction in High Temperature Region The using restriction in high temperature region shall be as follows:

- (1) The storage tank of which using temperature (metal temperature) is designated until 260°C shall be designed according to following (a) to (g).

Further, the storage tank of which using temperature (metal temperature) is designated to exceed 90°C shall not be floating roof type storage tank.

- (a) The design stress of side plate shall be the value for each design metal temperature multiplied by the reducing coefficient of Table 1 [See 3.5.2 (1)].

Table 1

Design metal temperature °C	Reducing coefficient	
	Mild steel	High tensile steel
40 max.	1.0	1.0
90	1.0	0.95
150	0.965	0.89
200	0.935	0.85
260	0.88	0.78

Remark: In the case where the design metal temperature is intermediate value of the above-mentioned, the reducing coefficient shall be obtained by linear interpolation method.

- (b) The design stress of construction supporting the roof shall be the value for each design metal temperature multiplied by the reducing coefficient of Table 2 (see 3.9.2).

Table 2

Design metal temperature	Reducing coefficient
Less than 90	1.0
90	0.91
150	0.88
200	0.85
260	0.80



4
B 8501-1985

- (c) The roof plate thickness of circular conical roof, spherical surface roof, shade shape roof of self-support type and the sectional area A of compression ring required at the top, shall be for each design metal temperature, the value divided by the reducing coefficient of Table [see 3.9.5 (2) and (4), as well as 3.9.7 (2) and (4)]

Table 3

Design metal temperature	Reducing coefficient
Less than 90	1.0
150	0.99
200	0.975
260	0.955

Remark: In the case where the design metal temperature is intermediate value of the above-mentioned, the reducing coefficient shall be obtained by linear interpolation method.

- (d) H_s in 3.7.2 shall be the value multiplied by the reducing coefficient of (c).
- (e) The sectional area A_s of compression ring in 3.9.3 (5) shall be the value divided by the reducing coefficient of (b).
- (f) The sectional area A of compressing ring in 4. (3) of Appended 2 shall be the value multiplied by the reducing coefficient of (b).
- (g) The longitudinal elastic modulus E of steel materials in evaluation of compressive stress generated on side plate shall be the value multiplied by the reducing coefficient of (c).
- (2) To the storage tank designated to exceed 260°C in using temperature (metal temperature) this Standard does not apply.

2.3.2 Restriction in Low Temperature Region The restriction in low temperature region shall be as follows:

Further, concerning the members not specified herein, it shall be dependent upon agreement between the parties concerned.

- (1) For the steel plate to be used for side plate, its allowable lowest metal temperature shall be decided according to its thickness and receiving tensile stress according to the following:
- (a) In the case of materials of JIS G 3106, JIS G 3114 (but except those shown in (b)) and JIS G 3115, which have complied with the respective impact tests specified in corresponding JIS, and where as the design tensile stress, 60 % of the minimum value of yield point or proof stress guaranteed by corresponding JIS or manufacturer is taken, the allowable lowest metal temperature may be in accordance with Table 4. However, in the case where the tensile stress different from this specification is used and

concerning the plate thickness of not more than 12 mm, notwithstanding this specification, it shall be in accordance with Appendix 1.

- (b) SS 41 of JIS G 3101, SM 41 A, SM 50 A, SM 50 YA of JIS G 3106, SMA 41 A, SMA 50 A of JIS G 3114 shall, independently of the allowable stress, be not more than 16 mm in nominal thickness of the material and be used in the range not lower than -10°C in metal temperature.
- (c) In the case where the nominal thickness is not more than 6 mm, the allowable lowest metal temperature where independently of the kind of material and stress can be used without carrying out impact test shall be -20°C .

Table 4. Allowable Lowest Metal Temperature of Steel Material

Unit: $^{\circ}\text{C}$

Material Plate thickness (mm) ⁽¹⁾	SM 41 B SMA 41 B	SM 50 B SMA 50 B	SM 50 YB SM 53 B	SM 41 C SPV 24 SMA 41 C	SM 50 C SMA 50 C	SPV 32	SM 53 C	SPV 36	SM 58 SMA 58	SPV 46	SPV 50
12	-21.0	-15.5	-13.0	-28.0	-22.5	-23.0	-20.0	-20.5	-18.5	-23.0	-21.0
16	-19.0	-13.0	-10.5	-25.5	-20.0	-21.0	-18.0	-18.5	-16.5	-20.5	-19.0
19	-18.0	-11.5	- 9.0	-24.5	-19.0		-16.5		-14.5	-18.5	-17.0
22	-15.5	- 9.5	- 7.0	-22.5	-17.0		-14.0		-12.0	-16.5	-14.5
25	-13.5	- 7.0	- 4.0	-20.5	-14.5		-11.5		- 9.5	-14.0	-12.5
28	-10.5	- 4.0	- 1.0	-17.5	-11.5		- 9.0		- 6.5	-11.5	- 9.5
30	- 8.5	- 1.5	+ 1.0	-15.5	- 9.5		- 6.5		- 4.5	- 9.0	- 7.5
32	- 6.0	+ 1.0	+ 3.5	-13.5	- 7.0		- 4.0		- 2.0	- 7.0	- 5.0
35	- 1.5	+ 4.5	+ 8.5	- 9.5	- 2.5		0		+ 2.0	- 2.5	- 0.5

Note (1) In the case where the plate thickness to be used is intermediate between the values of Table, the allowable lowest metal temperature may be obtained by interpolation method.

- (2) Steel Pipes Used for Nozzle Stub and Neck Part of Manhole
The steel pipes to be used for nozzle stub and neck part of manhole shall be as follows:

- (a) STK 41 of JIS G 3444 shall not be used for parts other than the neck part of manhole of roof.
- (b) SGP of JIS G 3452 shall not be used for the part at lower than 0°C in the lowest metal temperature.
- (c) STPY 41 of JIS G 3457 shall not be used for the part lower than -10°C in the lowest metal temperature.

6
B 8501-1985

- (d) STPG 38 of JIS G 3454, STPT 38 of JIS G 3456 shall not be used for the part lower than -15°C in the lowest metal temperature. When the metal temperature is lower than -15°C , STPL 39 of JIS G 3460 shall be used.
- (3) Flange Materials Used for Nozzle and Manhole The flange materials to be used for nozzle and manhole shall not be used at places lower than the following temperature:
 - (a) For SS 41 of JIS G 3101, -10°C in the lowest metal temperature.
 - (b) For SF 40 A, SF 45 A of JIS G 3201, S 20 C, S 25 C of JIS G 4051, -29°C in the lowest metal temperature.
- (4) Bolt and Nut Materials Used for Nozzle and Manhole The bolt-and-nut materials to be used for nozzle and manhole shall not be used at places where the temperature is lower than the following temperature:
 - (a) For SS 41 of JIS G 3101, 0°C in the lowest metal temperature.
 - (b) For SS 50 of JIS G 3101, S 20 C, S 25 C, S 45 C of JIS G 4051, SNB 7 of JIS G 4107, -29°C in the lowest metal temperature.

Remark: The metal temperature in this Standard means the temperature of metallic materials, and the lowest metal temperature means the design lowest using temperature or water temperature at the leak test by filling water, whichever is lower.

The design lowest using temperature means that the air temperature at the lowest day out of the record of one day average air temperature over as long period as possible in the district where the storage tank is installed, is obtained with added to it 8°C .

Further, in the case where used at a temperature lower than the above limit, the allowable lowest metal temperature shall be affirmed in accordance with Appendix 1, as appropriate.

3. Design

3.1 Strength of Storage Tank

3.1.1 Load Applied to Storage Tank The load to be applied to the storage tank shall, as a rule, be as follows:

- (1) Static Load
 - (1.1) Load by Self-Weight of Storage Tank (Including Attachments and Attached Parts)
 - (1.2) Load by Storage Liquid
 - (1.3) Load by Thermal Insulating Materials
 - (1.4) Fallen Snow Load

(2) Dynamic Load(2.1) Load by Wind Pressure(2.2) Load by Earthquake Moving

Further, the design shall be carried out by considering that the load by wind pressure and the load by earthquake moving act separately.

3.1.2 Calculation of Load In the case of obtaining the loads of 3.1.1, it shall be as follows:

- (1) Specific Gravity of Steel Material In the case where the load by self-weight of storage tank is obtained, the specific gravity of steel material shall be taken as 7.85.
- (2) Specific Gravity of Storage Liquid In the case of obtaining the load by storage liquid, when the specific gravity of the liquid is less than 1, the specific gravity of the liquid shall be taken as 1, and when it is larger than 1, the specific gravity of the liquid, be used.
- (3) Load of Thermal Insulating Material The load of thermal insulating material shall be obtained from the property of the thermal insulating material and the loads of support fittings and protective sheath material be included in it.
- (4) Fallen Snow Load The fallen snow load per horizontal projection area of storage tank shall be calculated according to the following formula:

$$S = p \cdot Z_s \cdot E \cdot R \cdot A$$

where S : fallen snow load applied on roof (kgf){N}
 p : average unit weight over the whole layer for design of snow (kgf/m² for 1 cm of fallen snow) {N/m²}, as shown in Table 5.

Table 5.

Depth of fallen snow cm	p (kgf/m ² /cm){N/m ² /cm}
50 max.	1.0 {10}
100	1.5 {15}
200	2.2 {22}

In the case where the depth of fallen snow is intermediate value of the above values, it shall be obtained by linear interpolation.

8
B 8501-1985

Z_s : depth of fallen snow (cm) for design and shall be determined on the basis of observation date at the construction point.

E : environmental factor, and it shall be taken as 1.0, but when there is a snow-removing and fusing equipment, it may be taken as 0.

R : factor due to roof gradient, and shall be as shown in Table 6.

Table 6

Gradient	R
25° max.	0.9
50° min.	0

In the case where the gradient is intermediate value between 25° and 50°, it shall be obtained by linear interpolation. In the case of the roof having snow stopping and the roof surface material for snow difficult to be fallen, $R = 1.0$.

A : horizontal projection area of roof (m^2)

- (5) Wind Load The wind load by wind pressure shall be calculated according to the following formula:

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

where Q : wind load (kgf){N}

c : shape factor, to be 0.7

A : pressure bearing area, to be the maximum vertical projection area of storage tank (m^2)

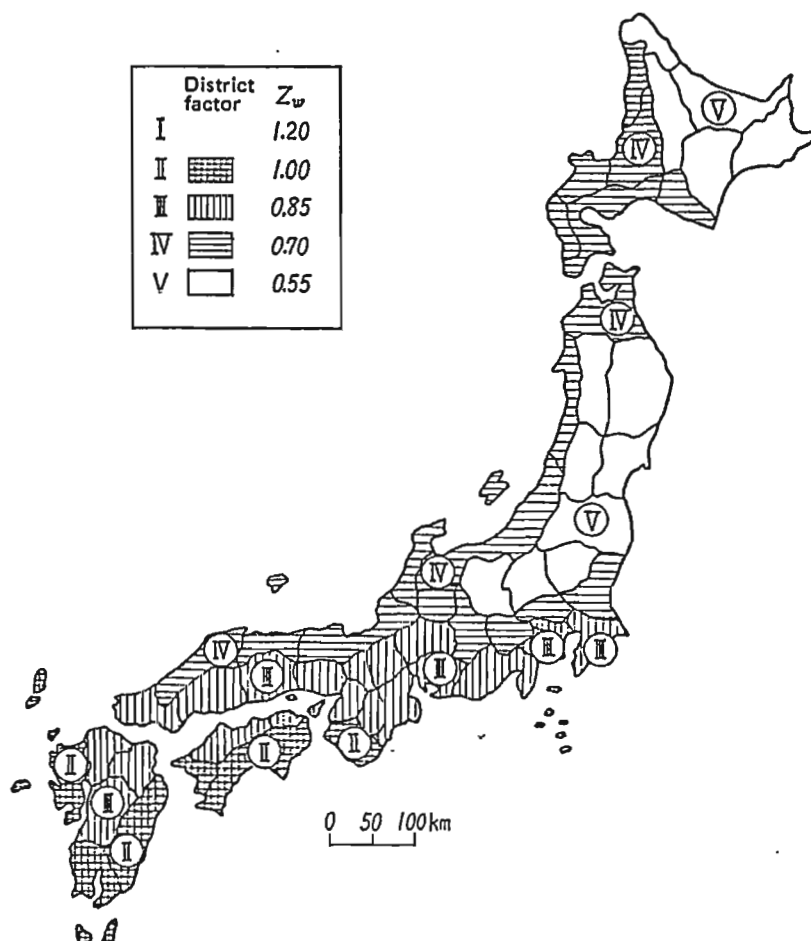
q : wind pressure (kgf/ m^2), $q = 60\sqrt{h} \cdot Z_s$ { $q = 600\sqrt{h} \cdot Z_s$ (N/ m^2)}

h : in a storage tank, height from the ground surface of the part to obtain wind pressure (m)

Z_s : district correction factor to wind pressure, to be as shown in Fig. 1.

However, in the case of place where there is fear of receiving strong wind such as seashore, riverside, mountain, etc. and of the part of storage tank of h exceeding 25 m, $q = 300 Z_s$ kgf/ m^2 { $q = 3000 Z_s$ (N/ m^2)} independently upon h .

Fig. 1. Distric Factor Concerning Wind Pressure
(I Is for Islands at North Latitude 30°C and Southward)



	District	District factor Z_w
(I)	Islands north latitude 30° and southward	1.20
(II)	Districts in Kagoshima Prefecture other than shown in (1), Amakusa District, Honto City, Ushifuka City in Miyazaki Prefecture Kumamoto Prefecture, Hokkaibu District, Tsukumi City, Nankaibu District, Saheki City, Oita City, Ōno District in Nagasaki Prefecture, Saga Prefecture and Oita Prefecture, Kita District, Higashiwa District, Nishiwa District, Ōsu City, Yahatahama City, Kitauwa District, Uwashima City, Minamiwa District in Tokushima Prefecture, Kochi Prefecture and Ehime Prefecture, Tsuna District, Mihara District and Sumoto City in Wakayama Prefecture and Hyogo Prefecture, Izu Islands in Tokyo Metropolis.	1.00

10
B 8501-1985

	District	District factor Z_d
(III)	District in Kumamoto Prefecture other than those shown in (II), in Yamaguchi Prefecture, Hiroshima Prefecture, Okayama Prefecture, and Hyogo Prefecture districts other than shown in (II) and (III) district in Shiga Prefecture, Nara Prefecture, Mie Prefecture, Aichi Prefecture and Gifu Prefecture other than those shown in (IV), districts Shizuoka Prefecture, Kanagawa Prefecture, in Tokyo Metropolis other than those shown in (1) and (II), and Chiba Prefecture.	0.85
(IV)	Mikata District, Sakazaki District, Toyooka City, Ideishi District, Asako District, Yohu District in Shimane Prefecture, Tottori Prefecture and Hyogo Prefecture, Ayabe City, Fukuchiyama City, Amada District, Saga District, Maizuru City, Miyatsu City, Yosa District, Naka District, Sano District and Kumano District in Kyoto Prefecture, Ōno District, Yoshiki District, Takayama City in Fukui Prefecture, Ishikawa Prefecture, Toyama Prefecture and Gifu Prefecture, Kiso District, Matsumoto City, Shioziri City, Okaya City, Suwa District, Suwa City, Chino City, Kamiina District, Ina City, Komagane City, Iida City, Shimoina District in Nagano Prefecture, Nishitagawa District, Higashitagawa District, Tsuruoka City, Sakata City, Awami District, in Akita Prefecture Yamanmoto District, Noshiro City, Oga City, Minamiakita District, Akita City, Kawabe District, Yuri District, Honjo City in Yamanashi Prefecture, Saitama Prefecture, Ibaraki Prefecture, Niigata Prefecture and Yamagata Prefecture, Hokkaido districts contained in each branch office of Toshima, Hiyama, Atoshi, Tanburi, Hidaka, Ishikari, Sorachi, and Rumoe in Aomori Prefecture.	0.70
(V)	Districts other than those shown in (1) to (IV).	0.55

- (6) Load by Earthquake Moving The design earthquake moving for evaluating the seismic intensity to be applied at the time of earthquake or the earthquake resistance of storage tank relative to acceleration, and the design earthquake moving for evaluating the earthquake resistance of storage tank to liquid surface oscillation of storage liquid shall be determined by taking into consideration the district to set the storage tank and the type of surface layer of ground. Further, for calculation of load by earthquake and the like by design earthquake moving, also the response multiplying factor of storage tank shall be considered. The calculation method of those design earthquake moving and response multiplying factor shall be in accordance with the specifications of related laws and regulations.

3.1.3 Strength Design of Body For each part of storage tank body, the strength design shall be carried out according to this Standard body and Appendix 4.

Further, the effects of the following items to the storage tank body shall be taken into consideration, as required.

- (1) Dead loads of attachments such as near-mouth valve, piping, etc. of the bending moment based thereon.
- (2) Thermal stress of body generated according to the effects of temperature of storage liquid.
- (3) Dynamic liquid pressure generated by design earthquake moving,

3.2 Corrosion Allowance In the case where the storage liquid has corrosive property, the minimum dimension required for the member shall be added with required corrosion allowance (concerning the side plate, the required thickness shall be determined according to formula of 3.5.2 (1) and for others, by adding the corrosion allowance to the nominal thickness).

3.3 Using Restriction of Welding The using restriction of welding shall be as follows:

- (1) Fillet welding shall be as follows:
 - (a) In the case where the plate thickness is 4.5 mm, it shall be full penetration fillet welding.
 - (b) In the case where the plate thickness exceeds 4.5 mm, the size of fillet welding shall be made not less than $1/3$ of the thinner plate thickness and its minimum value, be 4.5 mm.
- (2) One side welding lap joint shall be limited exclusively to bottom plate and roof plate.

3.4 Bottom Plates

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

- (1) Joints of bottom plates shall be in accordance with lap joint, butt joint or their combination.
- (2) In the case where the diameter exceeds 30 m or the thickness of side plate of the lowest stage exceeds 15 mm, or high tensile steel is used for side plate, the annular plate shall be provided.
- (3) The lap joints of mutual bottom plates, and bottom plate and annular plate shall be only upper surface welding and be continuous full penetration fillet welding over the whole length of joint. The assembly of three-shut lap parts shall be in accordance with Fig. 2.

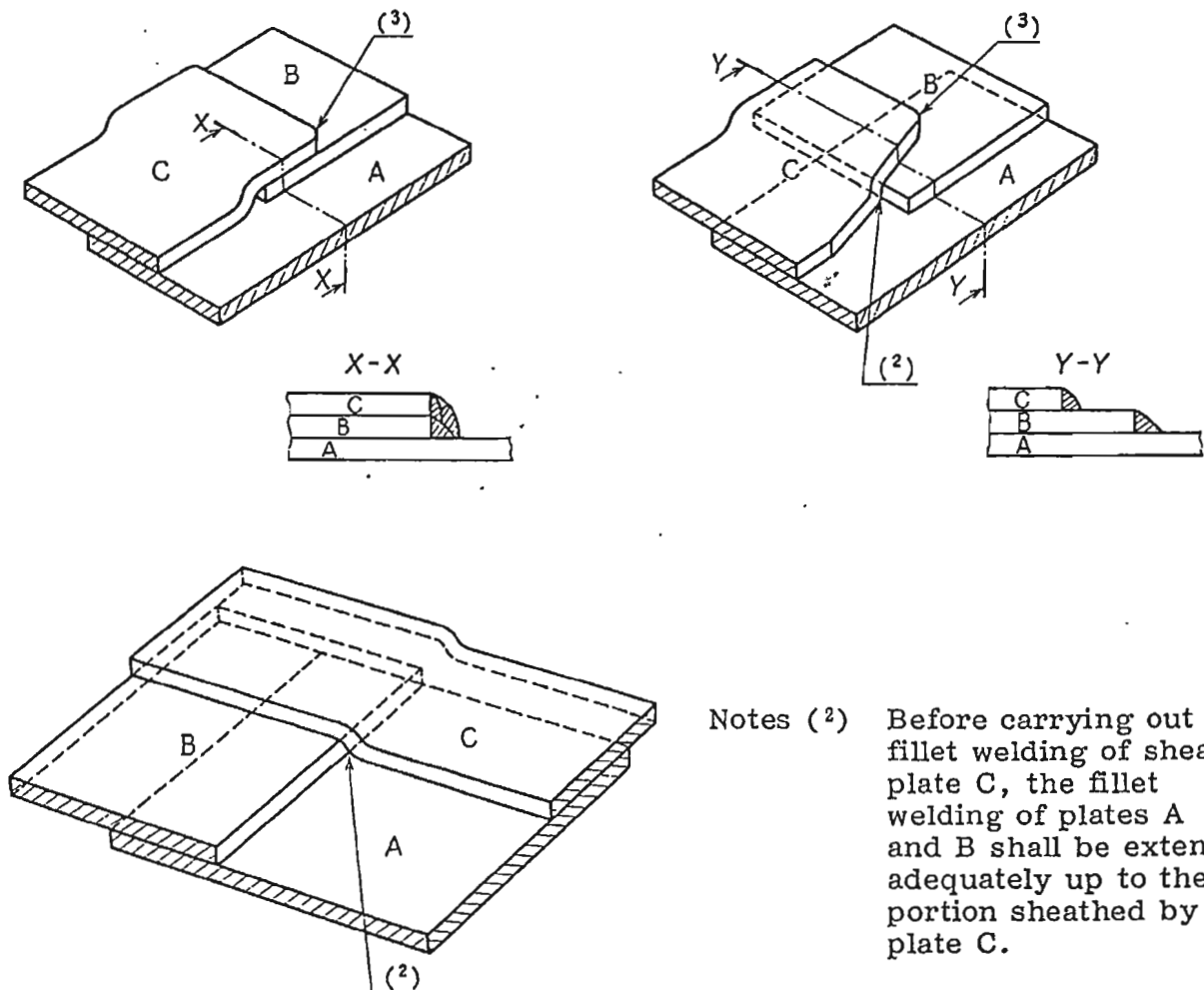
The lap allowance of lap joints shall be in accordance with Fig. 3 (1) (a) and (2)(a), and it, be not less than 25 mm at lap part of mutual bottom plates, and be not less than 60 mm at the part of lapping of bottom plate and annular plate.

- (4) The grooves of butt joints of mutual bottom plates, and bottom plate and annular plate shall be square groove or single V groove, and the root interval shall be maintained correctly. In the case of square groove, the root interval shall be not less than 6 mm.

Further, for welding the backing metal of not less than 3 mm in thickness shall be used at the back side [see Fig. 3 (1)(b) and (2)(b)].

- (5) The assembly of side plate and bottom plate (or annular plate) shall be in accordance with Fig. 4.

Fig. 2. Arrangement of Bottom Plates
Assembly of Three-Shut Lamp Part



Notes (2) Before carrying out fillet welding of sheath plate C, the fillet welding of plates A and B shall be extended adequately up to the portion sheathed by plate C.

(3) This corner part shall be rounded.

Fig. 3. Joint of Bottom Plates

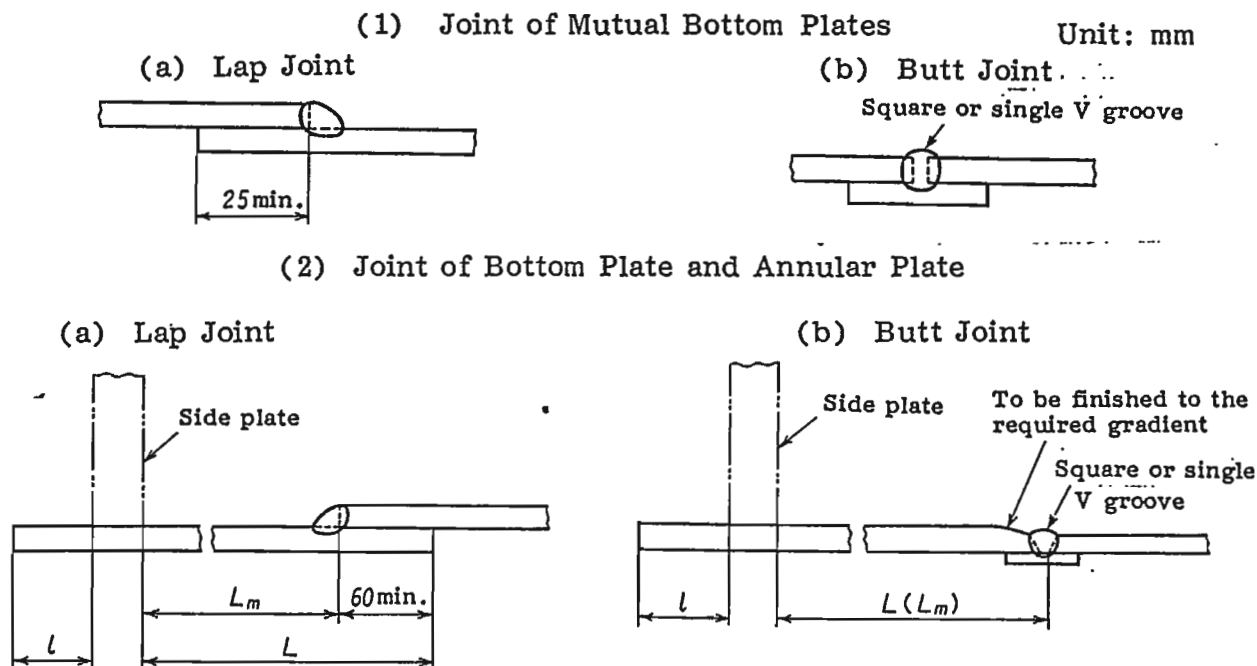
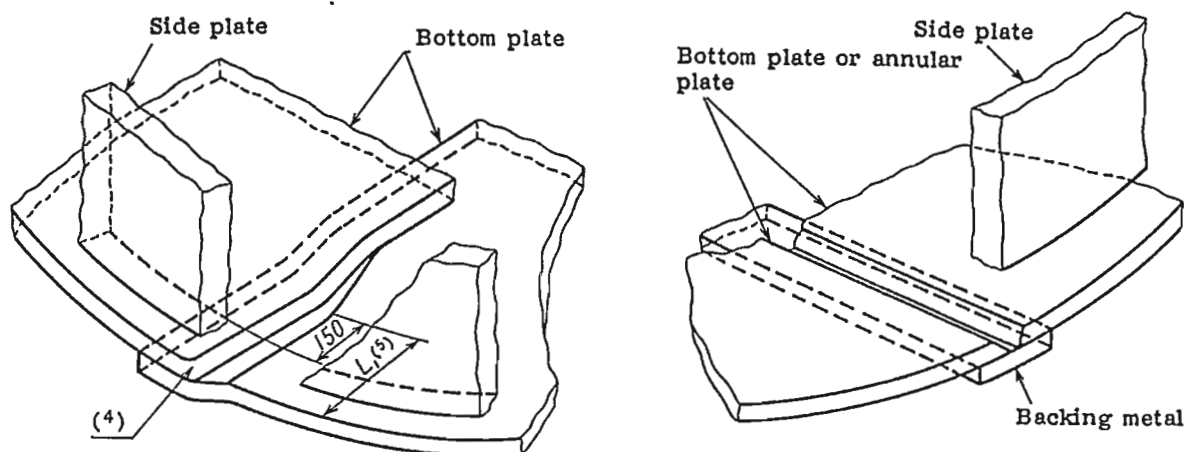


Fig. 4. Assembly of Bottom Plate and Side Plate

- (1) Assembly of Bottom Plate and Side Plate by Using Lap Joint

Unit: mm

- (2) Assembly of Bottom Plate and Side Plate by Using Annular Plate or Butt Joint



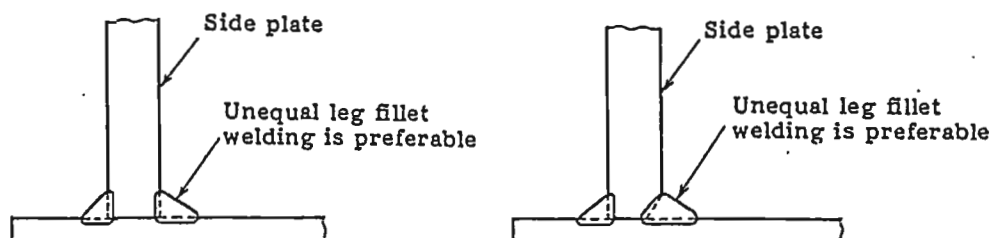
Notes (4) This corner part shall be rounded.

(5) The part of L_1 shall be finished by welding from the inside surface of side plate up to the length of 150 mm at least so that the upper surface of bottom plate becomes smooth.

- (6) The welding of side plate and bottom plate (or annular plate) shall be both-side continuous fillet welding. The size of welding of its inside and outside shall be the thickness of side plate or bottom plate (or annular plate), whichever is thinner. However, the welding size is not required to exceed 13 mm. The welding shape of inside of side plate should preferably be unequal leg fillet welding of which bottom side is made as shown in Fig. 5. In this case, the above-mentioned welding size applies to the shorter leg.

- (7) In the case where the thickness of bottom plate (or annular plate) exceeds 13 mm, the leg of fillet weld of bottom plate side of side plate inside after welding, or in the case of employing the partial penetration welding, the sum of depth of groove and leg of fillet weld of bottom plate side of side plate inside, either of them shall be approximately same dimension as the thickness of bottom plate (or annular plate).

Fig. 5. T Joint of Bottom Plate or Annular Plate with Side Plate



- (8) Annular plates shall be of one side butt welding mutually, and the backing metal of not less than 3 mm in thickness shall be used [see Fig. 4 (2)].
- (9) The interval of weld lines of inside of side plate and bottom plate (annular plate) shall be made not less than the value L_m calculated according to the following formula, provided that L_m shall be not less than 600 mm.

$$L_m = \frac{280t_a}{\sqrt{H}}$$

where L_m : interval of weld lines of side plate inside and bottom plate (annular plate) (mm)

t_a : thickness of annular plate (mm)

H : maximum liquid surface height (m)

- (10) Whichever of lap joint or butt joint may be used, the interval of mutual intersecting points of joint, the interval of intersecting point of joint and the end of weld of T joint made by side plate and bottom plate and the interval between the joint and side plate longitudinal joint, any of them shall be not less than 300 mm

3.4.2 Size of Bottom Plate The size of bottom plate shall be as follows:

- (1) Actual thickness of plate to be used for bottom plate shall not be less than 6 mm.
- (2) The minimum thickness t_a of annular plate shall be in accordance with Table 7.
- (3) The extending dimension L and l from the inside and outside of annular-plate side plate shall be the value not less than the value of Table 7.

Table 7. Each Dimension of Annular Plate

Unit: mm			
Thickness of side plate lowest stage t_s	Extending dimension from side-plate outside surface l	Extending dimension from side-plate in-side surface L	Minimum thickness t_b
$15 < t_s \leq 20$	75	1000	12
$20 < t_s \leq 25$	100	1500	15
$25 < t_s \leq 30$	100	1500	18
$30 < t_s$	100	1500	21

However, in the case of body having anchor, it may be calculated according to the following formula:

$$L_m \geq 1.2 \sqrt{R t_b} \quad (\text{minimum value is 600 mm})$$

where R : inner radius of storage tank (mm)

t_b : thickness of annular plate (mm)

3.5 Side Plates

3.5.1 Arrangement of Side Plates The arrangement of side plates and joints shall be as follows:

- (1) The longitudinal joint shall be butt weld and all of them be full penetration welding [Fig. 6 (1)]
- (2) The horizontal joints, except where the top angle steel is attached by fillet weld lap joint, shall be all butt welds, and be full penetration welds [see Fig. 6 (2)].
- (3) The neighboring upper and lower plates of horizontal joint shall be aligned with surfaces of inside of storage tank. However, as required, these may be so butted that the centers of plate thickness coincide with each other.

Further the positions of longitudinal joints of side plate shall be apart by not less than 5 times the thickness of thicker plate from the longitudinal joints of upper and lower stages.

- (4) The thickness of upper stage plate shall not be made thicker than that of lower stage plate.
- (5) For preventing the flood flow, the side plate shall be extended to the upper part from the maximum using height of liquid as the flood-flow preventive plate.

Fig. 6. Joint of Storage Tank

(1) Longitudinal Joint of Side Plates

(a) Single V Groove Butt Joint



(b) Single U Groove Butt Joint



Documents

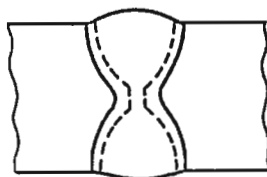
Document Sharing Hub

Fig. 6 (Continued)

(c) Double V Groove Butt Joint



(d) Double U Groove Butt Joint



(e) Square Groove Butt Joint

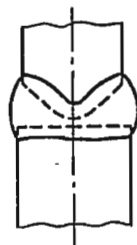


(2) Horizontal Joint of Side Plates

(a) Groove Butt Joint



(b) Double Bevel Groove Butt Joint

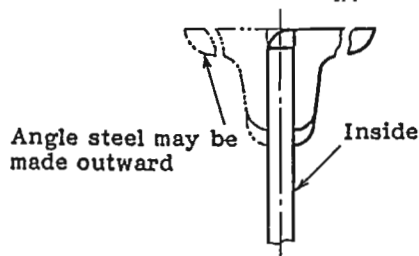
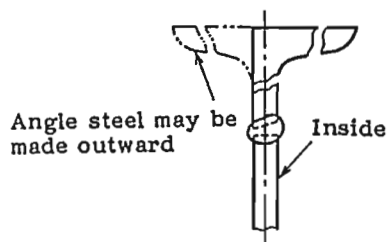


(c) Square Groove Butt Joint



(d) Groove Butt Joint

(e) Fillet Weld Lap Joint



3.5.2 Thickness of Side Plate The thickness of side plate shall be as follows:

- (1) The minimum required thickness of side plate shall be the value calculated according to the following formula, but the thickness of plate including the corrosion allowance to be used for side plate shall not be less than the value of Table 8.

$$t = \frac{D(H-0.3)\rho}{2fm} + c$$

$$\left\{ t = \frac{D(H-0.3)\rho}{0.2fm} + c \right\}$$

where t : minimum required thickness (mm)

D : inner diameter of storage tank

H : height from lower end of stage for plate thickness to be obtained up to the liquid surface (m)
The height of liquid surface shall be the maximum using height.

ρ : specific gravity of storage liquid [see 3.1.2 (2)]

f : design tensile stress of material, to be 60 % of the minimum value of yield point or proof stress guaranteed by corresponding JIS or by manufacturer (kgf/mm²) {MPa}

m : constant to be determined by stage of side plate and by radiographic test or ultrasonic test specified in Appendix 3, to be as follows:

The lowest stage of side plate to be carried out with test of Class A or Class B 0.85

The stage other than the lowest stage of side plate to be carried out with test of Class A 0.85

The stage other than the lowest stage of side plate to be carried out with test of class B 1.00

The maximum plate thickness (nominal) including the the corrosion allowance to be used for side plate not exceeding 12 mm, and not carried out with radiographic test or ultrasonic testing (material of side plate shall, exclusively, be mild steel) 0.7

c : corrosion allowance (mm)

Table 8. Minimum Thickness (Nominal) of Side Plate

Unit: mm

Inner diameter of storage tank (m)	Minimum thickness (nominal)
16 max.	4.5
Exceeding 16 up to and including 35	6
Exceeding 35 up to and including 60	8
Exceeding 60 up to and including 75	10
Exceeding 75	12

- (2) The maximum thickness (nominal) of side plate shall be 38 mm for mild steel and 45 mm for high tensile steel.
- (3) The actual plate thickness to be used for side plate, even when reduced by the tolerance of negative side of Standard, shall not be lower than the value of the minimum required thickness obtained in (1) reduced by 0.25 mm.
- (4) The minimum thickness of flood flow preventive plate shall be in accordance with Table 8.

3.5.3 Top-Part Reinforcement For the fixed-roof and fixed-roof with floating roof storage tanks, the upper edge of side plate at the highest stage shall be attached with angle steel by both-side continuous fillet weld or full-penetration butt weld or the reinforcement, be carried out according to other methods [see Fig. 6 (2) (d) and (e) as well as Fig. 11].

The angle steels or reinforcement members mutually shall be connected by full-penetration butt weld. In the case where the reinforcement is carried out by using angle steel, the minimum dimensions shall be in accordance with Table 9.

Table 9. Minimum Dimensions of Angle Steel
Unit: mm

Inner diameter of storage tank	Dimensions of angle steel
10 max.	L 65 × 65 × 6
Exceeding 10 up to and including 18	L 65 × 65 × 8
Exceeding 18 up to and including 60	L 75 × 75 × 9
Exceeding 60	L 90 × 90 × 10

3.5.4 Allowable Stress of Fillet Weld In the case where the strength of fillet weld to fix the attachments with the side plate is to be obtained, the following values shall be used, and for calculation the theoretical throat, be used.

- (1) In the case where electrode for mild steel is used:

Front fillet weld 9 kgf/mm² { 90 MPa }

Side fillet weld 7 kgf/mm² { 70 MPa }

- (2) In the case where electrode for high tensile steel is used:

Front fillet weld 40 % of minimum value of yield point guaranteed by Standard of base metal or by manufacturer.

Side fillet weld 35 % of minimum value of yield point guaranteed by Standard of base metal or by manufacturer

3.5.5 Reinforcement to Opening Hole of Side Plate The opening hole not less than 85 mm in diameter perforated in the side plate for mounting attachments and the like shall be attached with stiffening member as reinforcement according to the following.

Further, the material of stiffening member shall be same as that of the side plate to be attached with stiffening member.

- (1) The reinforcement shall be in accordance with any one of the following or combination of these:

- (a) Stiffening member
- (b) Seat for attachment
- (c) A part of neck part of attachment

- (d) A part of side plate of thickness exceeding t of 3.5.2 (1) and in the effective range of reinforcement specified in the following.
- (2) The minimum required sectional area of stiffening member shall be calculated according to the following formula:

$$A = d \times t_e$$

where A : minimum required cross sectional area (mm²)
 d : longitudinal diameter of opening hole (mm)
 t_e : value of t of 3.5.2 (1) subtracted by corrosion allowance c

The cross-sectional area of stiffening member shall be measured at longitudinal-center cross sectional area, and only the part in the range equal to the diameter of hole respectively upper and lower from the horizontal center line of opening hole shall be taken as the effective range of the stiffening member.

- (3) The parts shown in (3.2) to (3.4) of the neck part cross-sectional area of attachment, when the conditions of (3.1) are satisfied, may be considered to be a part of cross-sectional area of stiffening member.
- (3.1) The range of neck part cross-sectional area which may be considered to be a part of cross-sectional area of stiffening member shall be in accordance with the following and for others with (3.2) to (3.4).
- (a) When the material of neck part is same as the material of side plate to attach the neck part, or the values of the minimum yield point (or proof stress) and the minimum tensile strength of material Standard of the neck part are respectively not less than 70 %, 80 % of those of the side plate, those may be considered to be a part of stiffening member.
- (b) In the case where the strength of material of neck part is lower than that of the side plate, the effective cross-sectional area shall be obtained by the cross-sectional area as the stiffening member obtained from (3.1) (3.2) (3.3) multiplied by the ratio of (material strength of neck part)/(material strength of side plate).
- In the case where the material strength of neck part is higher than that of side plate, the above-mentioned ratio shall be taken as 1.0.
- (c) In the case where the yield point (or proof stress) of material Standard of neck part is less than 70 % of that of side plate or the tensile strength of material Standard of neck part is less than 80 % of that of side plate, it shall not be made as a part of stiffening member.
- (3.2) The part within the length of 4 times the wall thickness of neck part measured from the outer surface of side plate outwards. In the case where the wall thickness of neck part decreases within this length, the part up to the part varying in wall thickness.
- (3.3) The part in the range of side plate thickness.

- (3.4) In the case where the attachment is extended inward from the side plate, generally the part of length measured from inner surface of side plate inwards similarly as in (3.2).
- (4) The part of stiffening member weld capable of making as a part of sectional area of reinforcement, for outer periphery, shall be the parts of right and left outsides partitioned by a pair of vertical cut lines to the opening hole, and for inner periphery, be whole periphery, provided that these shall be in accordance with the conditions:
- (a) The outer and inner periphery welding of stiffening member shall be carried out over the whole periphery according to continuous welding.
 - (b) The size of weld of inner periphery shall be in accordance with the specifications of 3.10.2 or 3.10.3.
 - (c) The size of weld of outer periphery shall be so determined that it can endure sufficiently the load subtracted from the bearing load of inner periphery weld, provided that its minimum shall be 4.5 mm.

In the case of low type nozzle of Fig. 13 (b) where the stiffening member is connected with the bottom plate, the size of weld of stiffening member with bottom plate shall be in accordance with 3.4.1 (6).

- (5) Interval of mutual opening holes and the distance between the opening hole and the side plate joint shall be as follows:

(5.1) Interval of mutual opening holes.

- (a) In the case where stiffening members are at both sides of opening hole, the distance between toes of fillet welds of stiffening members shall be not less than 8 times the larger fillet size and be not less than 150 mm.

Further, the case where the stiffening member exists at only one side of the opening hole shall be same.

- (b) In the case where there is no stiffening member on either side of opening hole, the distance between toes of fillet welds of nozzles to be attached with the opening hole shall be made not less than 75 mm.

- (5.2) The distance between the opening hole and the side plate joint (in the case where nozzles and the like are attached to the side plate lowest stage).

- (a) After nozzle and the like are attached to the side plate exceeding 12 mm in thickness, in the case where welding post-heat treatment before body assembling is not carried out, the distance between the fillet weld toe of stiffening member or nozzle or the like and the center line of side plate joint shall be not less than 8 times the fillet size and not less than 250 mm.

- (b) After nozzle and the like are attached to the side plate exceeding 12 mm in thickness, in the case where welding post-heat treatment before body assembling is carried out, the distance between the fillet weld toe of stiffening member or nozzle or the like and the center line of side plate longitudinal joint shall be not less than 150 mm, and be not less than 2.5 times the side plate thickness, and the distance to the side plate horizontal point shall be not less than 75 mm and not less than 2.5 times the side plate thickness.
 - (c) In the side plate of not more than 12 mm in thickness, in dependence of existence of welding-post-heat treatment, it shall be same as in (b).
 - (d) In the case where attaching to the stage other than the lowest stage of side plate, it shall be dependent upon agreement between the parties concerned.
- (5.3) Distance between the opening hole and the fillet weld joint of lowest end of side plate.
- (a) In the case of side plate of mild steel: the side manhole shall be in accordance with Fig. 12 and the side nozzle, with Fig. 13.
 - (b) In the case of side plate of high tensile steel: the distance between the fillet weld toe of stiffening member or nozzle or the like and that of the lowest end of side plate shall be not less than 75 mm and not less than 2.5 times the side plate thickness. However, concerning the shape of stiffening member of nozzle with low type flange as shown in Fig. 13, it may be same as in (a).
- (6) The neck parts of nozzle and manhole to be attached to the opening hole shall, in the following case, be carried out with weld-post-heat treatment after welding.
- In the case of side plate of mild steel;
- When the plate thickness of side plate exceeds 25 mm and the nominal diameter of neck part is not less than 300 A;
- In the case side plate of high tensile steel;
- When the plate thickness of side plate exceeds 12 mm and the nozzle (over 50 A) requires the stiffening plate.

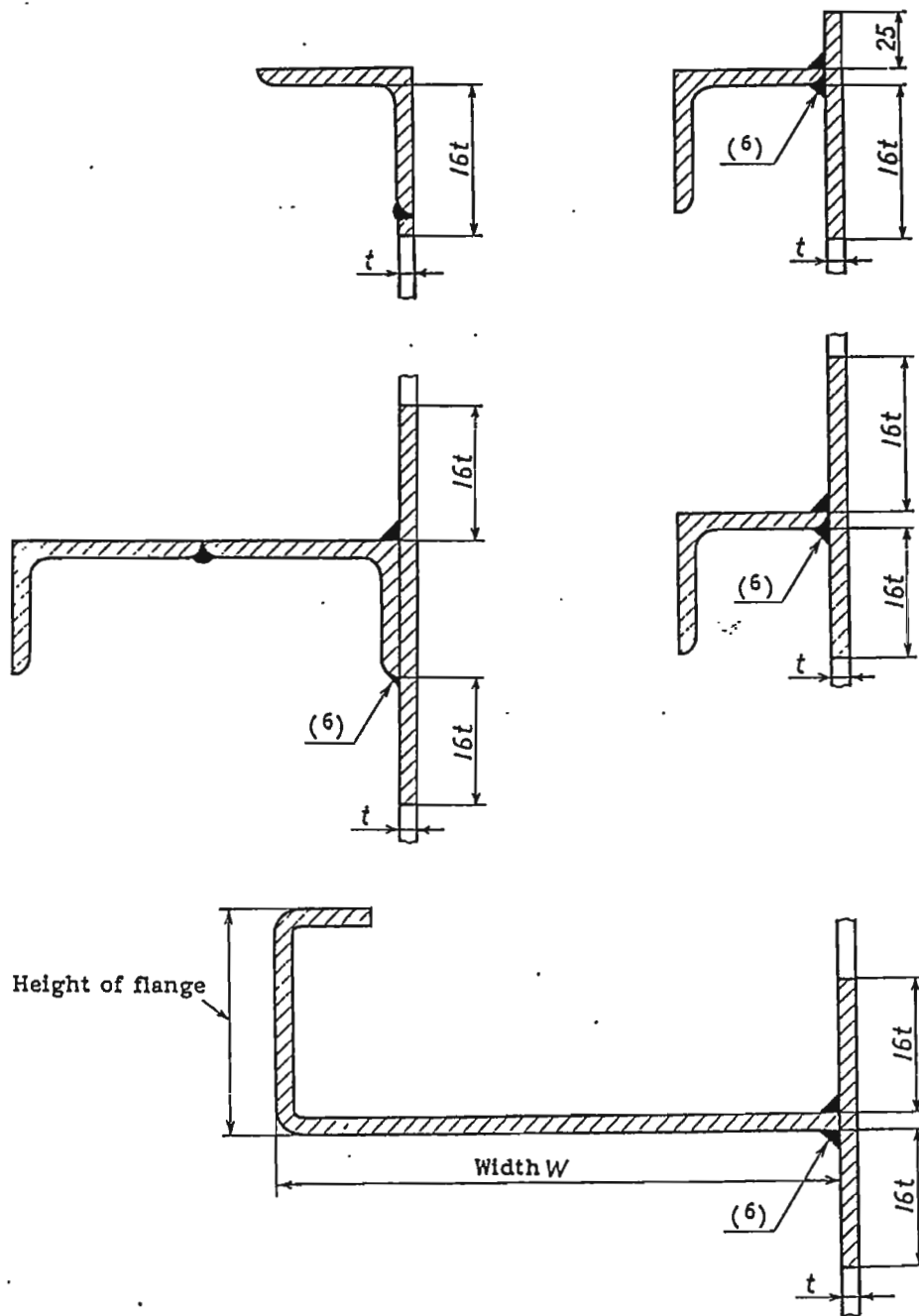
3.6 Stiffening Ring (Wind Girder)

3.6.1 General The floating-roof storage tank shall be so provided with stiffening ring that even when it receives wind it does not deform. The position attaching the stiffening ring shall be the upper end of the highest-stage side plate or near the upper end and outside the side plate.

3.6.2 Required Modulus of Section The required modulus of section of stiffening ring shall be determined by taking into consideration the stiffening ring and a part of side plate to be attached with it, and shall not be not more than the value calculated according to the following formula, provided that a part of side plate means the range of 16 times the side plate thickness excluded by the corrosion allowance at the upper and the lower of the part attaching the stiffening ring (see Fig. 7).

Fig. 7. Standard Shape of Stiffening Ring and Parts of Side Plate to Be Included In Calculation of Modulus of Section

Unit: mm



Note (6) The under side may be of intermittent fillet weld.

$$Z = 0.042 D^3 H_1 \left(\frac{V}{45} \right)^3$$

where

Z: modulus of section (cm³)

D: inner diameter of storage tank (m)

H₁: height of side plate of storage tank (m)

V: design wind velocity to be obtained from 3.1.2 (5). (m/s), h and Z_w shall be in accordance with 3.1.2 (5).

3.6.3 Structure of Stiffening Ring The structure of stiffening ring shall be as follows:

- (1) The stiffening ring shall be of structure of steel sections, steel plates or their combination, and its outer edge be circular shape or polygon.
- (2) The minimum dimensions of angle steel to be used as stiffening ring shall be L 65 × 65 × 6 mm and the minimum thickness (nominal) of steel plate shall be 6 mm.
- (3) When the stiffening ring is set at a lower position by not less than 600 mm measuring from the upper end of the highest stage side plate, the angle steel shown in Table 10 shall, further, be attached outward.

Table 10. Minimum Dimensions of Top Angle Steel

Unit: mm	
Thickness of side plate (nominal)	Dimensions of angle steel
4.5	L 65 × 65 × 6
Exceeding 4.5	L 75 × 75 × 6

- (4) In the case of such structure that water is reserved on the stiffening ring, holes for suitable draining shall be provided.

3.6.4 Stiffening Ring for Corridor In the case where the stiffening ring is utilized as corridor, the width of stiffening ring shall be at least 600 mm from the outermost edge of top angle steel of storage tank, be attached at a position lower by 1000 mm from the top angle steel, and the hand rail be provided at the required part of outside.

3.6.5 Opening Part of Staircase Passing through Stiffening Ring In the case where the circumferential staircase exists outside the side plate and the staircase shall pass through the stiffening ring, the opening part of staircase passing through the stiffening ring shall be of the following structure or that having strength equivalent or superior thereto.

- (1) The modulus of section of the part of stiffening ring positioned at the outside of opening part shall comply with the specifications of 3.6.2, including the portion of changing shape (the parts of sections A-A, B-B, C-C in Fig. 8).
- (2) The long side of opening part shall be reinforced by attaching horizontally the wide width part of flat steel or angle steel, etc. to the side plate contacting the opening part (part of ③ of Fig. 8), and the other side of the opening part shall be reinforced by attaching vertically the wide width part of flat or angle steel, or the like (part of ① of Fig. 8).

The sectional area of reinforcement member shall be not less than the sectional area of side plate part included in calculation of modulus of section of stiffening ring of 3.6.2.

Further, the reinforcement member shall be attached by extending until the distance not less than the minimum width (W) of stiffening ring sectional surface from the end of opening part.

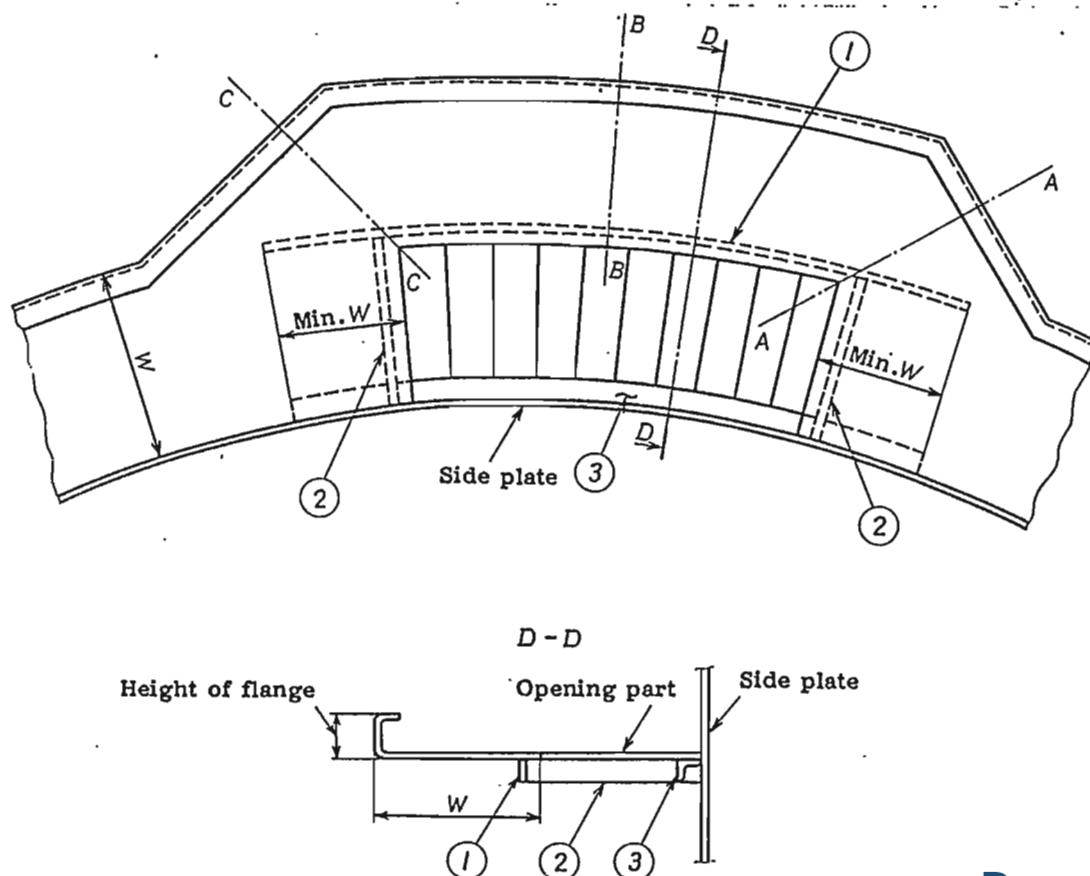
- (3) The reinforcement member of short side of opening part shall be framed with that of long side part and be jointed by such method that these in integral develop the strength (part of ② of Fig. 8).
- (4) A suitable foot confinement and handrail shall be attached to the opening part.

3.6.6 Support of Stiffening Ring In the case where the width W (length of web) of stiffening ring exceeds 16 times the thickness of either web or flange, whichever is thinner, the stiffening ring shall be provided with supports. The supports shall be attached at the suitable interval so that these have sufficient strength relative to the self weight of stiffening ring and other vertical load. However, this interval shall not exceed 24 times the height of flange of outer edge of stiffening ring.

3.6.7 Welding of Stiffening Ring Welding of stiffening ring shall be as follows:

- (1) Welding of joint of ring body of stiffening ring shall be full penetration butt welding.
- (2) Welding of stiffening ring and side plate shall be continuous fillet welding. However, the undersurface may be applied with intermittent fillet welding.

Fig. 8. Opening Part of Staircase Passing through Stiffening Ring



3.7 Intermediate Stiffening Ring (Intermediate Wind Girder)

3.7.1 General All storage tanks shall be so made that local buckling is not generated on side plate due to wind pressure. In the case where the intermediate stiffening ring is required for attaching, it shall be in accordance with 3.7.2 to 3.7.4. However, instead of it, the thickness of side plate may be increased.

3.7.2 Attaching Interval In the case where the requirement of intermediate stiffening ring is discussed, it shall be started from the side plate of the highest stage at first. In the case where the side plate thicknesses in the range of discussion are over not less than two stages and the plate thicknesses of respective stages are different, the weighted average plate thickness shall be used. In the case where the value of discussing interval L exceeds the value of H_2 calculated according to the following formula, the intermediate stiffening ring is required, and the place where the value of L and the value of H_2 become equal shall be taken as the maximum interval.

Further, in the case where the attachment of intermediate stiffening ring of the first stage has become necessary, its position shall be decided, concerning the side plate of the under part, the position of intermediate stiffening ring of the first stage shall be considered to be the top part of side plate to discuss in the similar method; and thereafter this method shall be repeated.

Further, the intermediate stiffening ring shall, as a rule, not be attached within 150 mm from the horizontal joint of side plate.

$$H_2 = 9.46t \sqrt{\left(\frac{t}{D}\right)^3 \left(\frac{45}{V}\right)^3}$$

- where H_2 : interval between the top part angle steel or stiffening ring and the intermediate stiffening ring or between mutual intermediate stiffening rings (m)
- t : weighted average plate thickness according to the thickness of side plate within L removed of the corrosion allowance and the plate width (mm), to be obtained according to
- $$\frac{L_1 t_1 + L_2 t_2 + \dots}{L_1 + L_2 + \dots}$$
- D : inner diameter of storage tank (m)
- V : design wind velocity (m/s), to be obtained from $32 \cdot h^{\frac{1}{4}} \cdot Z_w^{\frac{1}{4}}$
 h, Z_w shall be in accordance with 3.1.2 (5).

3.7.3 Required Modulus of Section The required modulus of section of intermediate stiffening ring shall be determined by considering the intermediate stiffening ring and a part of side plate to be attached with it, and shall not be not less than the value calculated according to the following formula:

$$Z = 0.042 D^3 \cdot H_2 \left(\frac{V}{45}\right)^3$$

- where Z : modulus of section (cm³)
- D : inner diameter of storage tank (m)
- H_2 : attaching interval determined according to 3.7.2 (m)
- V : design wind velocity (m/s), to be obtained from $32 \cdot h^{\frac{1}{4}} \cdot Z_w^{\frac{1}{4}}$
 h, Z_w are in accordance with 3.1.2 (5).

Further, a part of side plate may be contained with the ranges of respective maximum $1.34 \sqrt{Dt}$ (cm) at the upper and the lower parts attaching the intermediate stiffening ring.

where D : inner diameter of storage tank (m)

t : side plate thickness removed of the corrosion allowance at the position attaching the intermediate stiffening ring (mm).

3.7.4 Structure and Welding The structure and welding shall be as follows:

- (1) The structure of intermediate stiffening ring shall be in accordance with 3.6.3 and 3.6.6, and the welding of intermediate stiffening ring, with 3.6.7. However, in the case where the intermediate stiffening is attached to the inside of storage tank, the welding with the side plate may be intermittent welding in both upper and lower surfaces. In this case for welding of upper and lower surfaces, the total length of respective welds shall be not less than 1/2 of peripheral length of storage tank, and the length of each one weld, be not less than 12 times the thickness of side plate removed of the corrosion allowance.
- (2) In the case of attaching the intermediate stiffening ring to the outside of side plate, when staircases exist at the periphery of side plate, the relation between the intermediate stiffening ring and the staircase shall be decided as follows:
 - (a) The width of staircase shall be broadened at the part of intermediate stiffening ring. However, except where the width of intermediate stiffening ring is within 150 mm.
 - (b) In the case where the width of intermediate stiffening ring exceeds 150 mm, the staircase shall be provided with the width of not less than 450 mm at outside of intermediate stiffening ring, or the opening part, be provided at the intermediate stiffening ring to pass the staircase through this.
In the case of providing opening part to the intermediate stiffening ring, its structure shall be in accordance with 3.6.5.

Remark: The width of staircase shall be at least 600 mm according to 3.10.10, Table 21.

3.8 Roofs

3.8.1 Type of Roofs The type of roof shall be as follows:

- (1) Fixed Roofs The fixed roofs shall be as follows according to the shape of roof and type of support.
 - (a) Support Type Circular Conical Roof The shape is approximately circular cone and its supports are independent of existence of posts, conducted by roof bones.
 - (b) Self-Support Type Circular Conical Roof The shape is approximately circular conical shape and its supports are conducted only by peripheral edge of roof plate itself.
 - (c) Support Type Spherical Surface Roof The shape is approximately the spherical surface and its supports are conducted by roof bones.

- (d) Self-Support Type Spherical Surface Roof The shape is approximately the spherical surface and its support is conducted only by the peripheral edge of roof plate itself.
- (e) Self-Support Type Shade Type Roof The shape of horizontal section is regular polygon and a deformed type of self-support spherical surface roof.
- (2) Floating Roof Only the roof floated on the storage liquid.
- (3) Floating Roof with Fixed Roof The floating roof storage tank attached with the fixed roof.

3.9 Design of Roof

3.9.1 Load The design load of roof and its support structures shall be the self weight added with the load not less than 120 kgf {1.2 kN} per 1 m² of horizontal-projection sectional area of the roof.

In the case where the fallen snow load exceeds 60 kgf {600 N} per 1 m², the exceeding part shall be added in calculation and in the case of providing thermal insulating material, its load shall be added in calculation to the above-mentioned value.

To the floating roof of the floating roof storage tank with fixed roof, the load not less than 60 kgf {600 N} per 1 m² of horizontal projection sectional area other than the self-weight.

3.9.2 Design Stress The design stress of support structures shall be as follows. However, in the case where SGP of JIS G 3452, and STPG 38 of JIS G 3454 are used, it shall be the design stress multiplied by coefficient of (minimum tensile strength of Standard of pipe material kgf/mm²)/41 {minimum tensile strength of Standard of pipe material MPa/410}.

(1) Allowable Tensile Stress

- (a) The allowable tensile stress of rolled steel members (including pipes) shall be 14.0 kgf/mm² {140 MPa} concerning the effective section.
- (b) The allowable tensile stress of full penetration butt weld shall be 12.6 kgf/mm² {126 MPa} concerning the thinner plate section.

(2) Allowable Compressive Stress

- (2.1) In the case where the rolled steel member (including pipe) is restricted for lateral deflection, the allowable compressive stress shall be 14.0 kgf/mm² {140 MPa}.
- (2.2) The allowable compressive stress concerning the section of thinner plate of full penetration butt weld shall be 14.0 kgf/mm² {140 MPa}.
- (2.3) The allowable compressive stress of section of compressive member shall be calculated according to the following formulae:

(a) In the case of

$$\frac{L}{r} \leq 120$$

$$\left\{ \left[1 - \frac{\left(\frac{L}{r}\right)^2}{34700} \right] \left[\frac{23.2}{F_s} Y \right] \text{ kgf/mm}^2 \right. \\ \left. \left[1 - \frac{\left(\frac{L}{r}\right)^2}{34700} \right] \left[\frac{232}{F_s} Y \right] \text{ MPa} \right\}$$

(b) In the case of $120 < \frac{L}{r} \leq 131.7$

$$\frac{\left[1 - \frac{\left(\frac{L}{r}\right)^2}{34700} \right] \left[\frac{23.2}{F_s} Y \right]}{1.6 - \frac{1}{200} \left(\frac{L}{r}\right)} \text{ kgf/mm}^2 \\ \left\{ \frac{\left[1 - \frac{\left(\frac{L}{r}\right)^2}{34700} \right] \left[\frac{232}{F_s} Y \right]}{1.6 - \frac{1}{200} \left(\frac{L}{r}\right)} \text{ MPa} \right\}$$

(c) In the case of $131.7 < \frac{L}{r}$

$$\frac{104000 Y}{\left[\left(\frac{L}{r}\right)^2 \right] \left[1.6 - \frac{1}{200} \left(\frac{L}{r}\right) \right]} \text{ kgf/mm}^2 \\ \left\{ \frac{104000 Y}{\left[\left(\frac{L}{r}\right)^2 \right] \left[1.6 - \frac{1}{200} \left(\frac{L}{r}\right) \right]} \text{ MPa} \right\}$$

where L : non-restrictive part length of compressive member (mm) r : minimum radius of gyration of area of the above-mentioned part (mm) F_s : safety factor $\frac{5}{3} + \frac{\left(\frac{L}{r}\right)}{350} - \frac{\left(\frac{L}{r}\right)^2}{18.3 \times 10^4}$ Y : for steel section 1.0

for circular cylinder

where $\frac{t}{R} \geq 0.015$ 1.0

$$\frac{t}{R} < 0.015 \left[\frac{200}{3} \left(\frac{t}{R}\right) \right] \left[2 - \frac{200}{3} \left(\frac{t}{R}\right) \right]$$

 t : thickness of circular cylinder (nominal) (mm); at least 4.5 mm. However, the thickness of circular cylinder (nominal) used as main compressive member shall be 6 mm at minimum. R : outer radius of circular cylinder (mm)However, $\left(\frac{L}{r}\right)$ of main compressive member shall not exceed 180, and $\left(\frac{L}{r}\right)$ of oblique member and other submembers shall not exceed 200.

(3) Allowable Bending Stress

(3.1) The allowable bending stress of tensile side and compressive side generated on steel sections (for example I shape steel, H shape steel) and assembly structure members having symmetrical axis in the load acting surface shall be 15.4 kgf/mm² {154 MPa}. However, following each item shall be satisfied at the same time.

(a) The length of non-restriction part relative to the lateral direction of flange receiving compression shall be not more than 13 times b_f .

(b) $\frac{b_f}{t_f} \leq 17$

(c) $\frac{h}{t} \leq 70$

where b_f : width of flange (mm)
 t_f : thickness of flange (mm)
 h : height of web between inner surfaces of flange (mm)
 t : thickness of web (mm)

(3.2) The allowable bending stress of tensile side and compressive side generated on asymmetrical structural members (for example, angle, channel) shall be 14.0 kgf/mm² {140 MPa}, provided that the support interval in lateral direction of structural members shall be not more than 13 times the width of flange receiving compression.

(3.3) The allowable bending stress of tensile side and compressive side generated on steel sections other than (3.1) and (3.2), assembly structural members and plate girder shall be as follows:

(a) The allowable bending stress of tensile side shall be 14.0 kgf/mm² {140 MPa}.

(b) The allowable bending stress of compressive side of members having symmetrical axis in the load-acting plane shall be calculated according to the following formulae and be whichever is larger.

$$14 - \frac{4}{10000} \left(\frac{l}{r} \right)^2 \text{ kgf/mm}^2$$

$$\left\{ \left[14 - \frac{4}{10000} \left(\frac{l}{r} \right)^2 \right] \times 10 \text{ MPa} \right\}$$

or

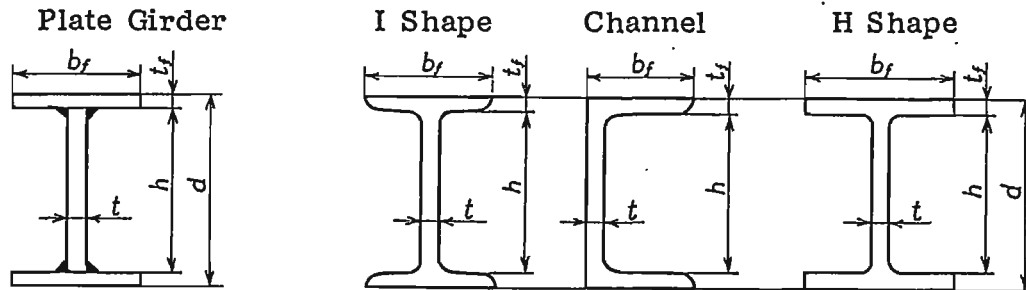
$$\frac{8400}{\frac{l \cdot d}{A_f}} \leq 14.0 \text{ kgf/mm}^2 \quad \left\{ \frac{84000}{\frac{l \cdot d}{A_f}} \leq 140 \text{ MPa} \right\}$$

where l : length of non-restriction part of flange receiving compression (mm)

r : radius of gyration of area (mm) concerning the axis of load-acting plane. However, in the plate girder it shall be the radius of gyration of area of web axis periphery of T shape part consisting of flange and 1/6 of web height.

A_f : sectional area of flange receiving compression (mm²)
 d : distance between outer surfaces of flange of member (mm) [see Fig. 9]

Fig. 9. Dimensions of Structural Members
 Steel Sections



- (c) The allowable bending stress of compressive side of assymetrical side of assymetrical member shall be:

$$\frac{8400}{\frac{l \cdot d}{A_f}} \leq 14.0 \text{ kgf/mm}^2 \left\{ \frac{84000}{\frac{l \cdot d}{A_f}} \leq 140 \text{ MPa} \right\}$$

- (3.4) The rafter contacting the roof plate may be considered that it is sufficiently restricted in lateral direction, except where corresponding to any one of the following.

- (a) Truss and non-full web member
- (b) Rafter exceeding 380 mm in height
- (c) where the pitch of roof exceeds 1/6.

(4) Allowable Shearing Stress

- (a) The allowable shearing stress of fillet welds of fillet weld joint, plug weld joint, slot weld joint and of partial penetration butt weld joint shall be 9.5 kgf/mm² {95 MPa} relative to their throat. However, in the case where the minimum tensile strength of Standard of welding metal exceeds 43 kgf/mm² {430 MPa}, the stress shall be the value of 9.5 kgf/mm² {95 MPa} multiplied by the ratio of it to 43 kgf/mm² {430 MPa}.
- (b) The allowable shearing stress in the case where the following formula is satisfied or stiffener exists on the web shall be 9.1 kgf/mm² {91 MPa} concerning the longitudinal section of beam or girder web.

$$h \leq 60t$$

where h : height of web between flange inner surfaces (mm)

t : thickness of web (mm)

- (c) In the case where the web has no stiffener and $h > 60t$, the average shearing stress concerning the longitudinal section of beam and girder web shall satisfy the following formulae:

$$\frac{V}{A} \leq \frac{13.7}{1 + \frac{1}{7200} \left(\frac{h}{t} \right)^4} \text{ kgf/mm}^2$$

$$\left\{ \frac{V}{A} \leq \frac{137}{1 + \frac{1}{7200} \left(\frac{h}{t} \right)^4} \text{ MPa} \right\}$$

where V : total shearing force (kgf) {N}

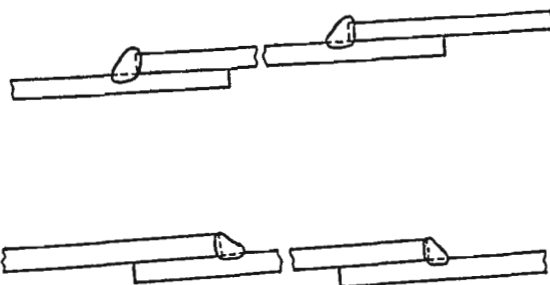
A : overall sectional area of web (mm²)

3.9.3 Fixed Roof The fixed roof shall be as follows:

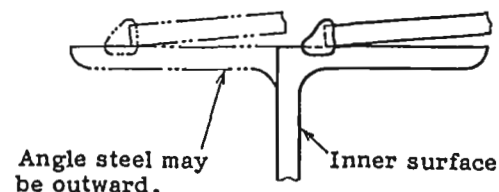
- (1) The attachment of roof plate to reinforcement of storage-tank top part shall be carried out by one-side continuous fillet welding on the upper surface of roof plate, and the size of the fillet weld shall not exceed 4.5 mm.
- (2) The arrangement of roof plates shall be in accordance with Fig. 10. Independently of the shape of roof, collaring may be carried out so that the outer edge of roof plate can be placed flatly on the top reinforcement of side plate in order to be easy in welding.

Fig. 10. Joint of Roof Plates

(a) Joint of Mutual Roof Plates



(b) Joint of Roof Plate and Top Part Reinforcement



- (3) The thickness (nominal) of roof plate shall be 4.5 mm at least. The thickness (nominal) of roof support structures shall be also at least 4.5 mm.
- (4) The roof plate may be reinforced by welding steel sections, but shall not be welded with the roof-support structures. However, where the roof-support structures are provided at outside, the roof plate may be welded with the roof-support structures.
- (5) Taking into consideration the filling discharge amount of storage liquid and the breathing amount due to temperature change, the roof shall be provided with a venthole or an atmospheric air valve.

Further, in the case of any one of the following, further, emergency vent opening shall be provided.

- (a) The size of fillet weld to attach the roof plate to the top reinforcement exceeds 4.5 mm.

- (b) The roof plates are attached to the top reinforcement by both side fillet welding.
- (c) The roof pitch at the outer periphery of roof plates exceeds 1/6.
- (d) The sectional area A of compressing ring shown by oblique line part in Fig. 11 exceeds the value calculated according to A_m of the following formulae:

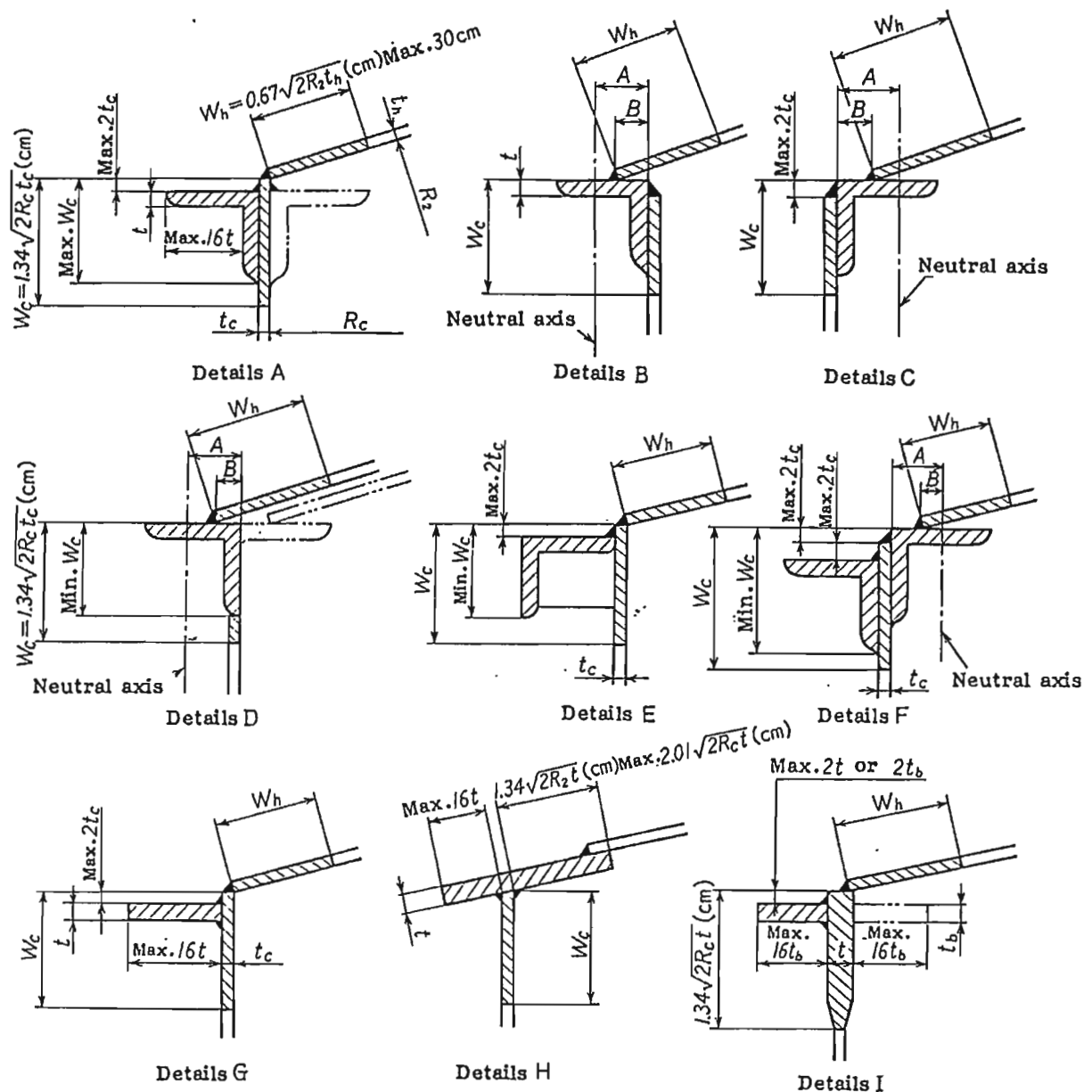
$$A_m = \frac{W}{14\,150 \tan \theta} \text{ (cm}^2\text{)} \quad \left\{ A_m = \frac{W}{141\,500 \tan \theta} \right\}$$

where W : sum of weights of side plates and structures supported by side plate, and roof plate (excluding stiffening ring, staircase, carridor, rafter, girder, etc. supported by roof struts except the roof plate) (kgf) {N}.

θ : angle (degrees) included by roof plate and side plate at attaching part. Refer to Remark of Fig. 11.

- (e) In the case where the roof-support structures are provided outside, and the top reinforcement and the roof-support structures are attached by welding or the like.

Further, the bleeder, atmospheric-air valve and emergency bleeder shall be designed according to Appendix 2.

Fig. 11. Range of Sectional Area A Determined from Attaching Shape of Roof

Remark: In details B, C, D, and F, the attaching position of roof plate shall be $A > B$.

Units of R and t shall be respectively m and mm.

R , and θ shall be taken as shown in following figure. θ in the case of spherical surface roof shall be the angle included by the tangent and the horizontal axis at the roof-plate attaching part.