

JIS

JAPANESE INDUSTRIAL STANDARD

**Construction of Welded
Aluminium and Aluminium
Alloy Cylindrical Silos**

JIS B 8511—1987

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In the event of any doubt arising,
the original Standard in Japanese is to be final authority.

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Construction of Welded Aluminium and
Aluminium Alloy Cylindrical Silos

B 8511-1987

1. Scope

This Japanese Industrial Standard specifies the construction of welded aluminium and aluminium alloy, hereinafter referred to as the "aluminium", vertical cylindrical vessel to store pulverulent body in height 8 m or under, hereinafter referred to as the "silo".

The silos are divided into two classes of shallow and deep tanks, but this Standard specifies the deep tanks.

- Remarks 1. The deep tank designates the silo in height of its straight shell 1.5 times or over the internal diameter.
2. In this Standard, the units, numerical values and formulae for calculation shown in { } are in accordance with conventional system of units and are appended for informative reference.

2. Materials

2.1 Structural Materials The structural materials to be used for silos shall comply with the following Standards according to the use or shall be equivalent or superior to these in quality.

JIS B 2321

JIS H 4000

JIS H 4040

JIS H 4080

JIS H 4090

JIS H 4100

JIS H 4140

JIS H 5202

2.2 Materials of Accessories The materials to be used in steel accessories shall comply with the following Standards or shall be equivalent or superior to these in quality.

JIS G 3101

JIS G 3106

JIS G 3115

JIS G 3126

JIS G 3201

JIS G 3444

JIS G 3452

JIS G 3454

JIS G 3457

JIS G 3460

JIS G 4051

JIS G 4107

JIS G 4303

2.3 Filler Metals The filler metals to be used for welding the main parts shall comply with the following Standard or shall be equivalent or superior to these in quality.

JIS Z 3232

3. Design

3.1 General The general items for design shall be as follows:

- (1) The silos shall be designed so as to have sufficient strength against static load, but the dynamic loads too shall be taken into consideration.
- (2) As for the form of welded joints and the design of accessories such as nozzles, manholes, etc., JIS B 8502 shall apply, as appropriate.
- (3) The minimum plate thickness of members shall be 3 mm.

3.2 Loads

3.2.1 Static Loads The static loads borne by silo shall be, in general, as follows:

- (1) Loads Due to Self-Weight of Silo In the case where the load due to self-weight of silo (W_s) is to be determined, take the specific gravity of aluminium as 2.7.
- (2) Loads Due to Stored Pulverulent Body In the case where the load due to stored pulverulent body (W_g) is to be determined, use as the density of stored pulverulent body the apparent density of this material.

- (3) Snow Loads As for the snow load (S) per horizontal project area of silo, determine from the unit weight of snow by multiplying with the vertical maximum depth of snow in the region.

3.2.2 Dynamic Loads The load due to wind pressure and the load due to seismic oscillation shall be assumed to act separately and shall be calculated as follows:

- (1) Wind Loads Determine the wind load according to the following formula. However, in the case where the silo is to be installed in the site eventually endangered by strong wind such as seashore, riverside, mountain top, etc., take the wind pressure as 2.1 kN {210 kgf} per 1 m² of maximum vertical sectional area of silo.

$$F_w = A \times (\text{wind pressure}) = A \times (420\sqrt{h}) \dots\dots\dots (1)$$

$$\{F_w = A \times (\text{wind pressure}) = A \times (42\sqrt{h})\}$$

where F_w : wind load (N) {kgf}

A : area subjected to pressure of the part for which the wind pressure is to be determined (m²)

h : height of the part for which the wind pressure is to be determined from ground surface (m)

Remark: For the silo in which the height from the ground surface to the top of silo exceeds 25 m, take as the wind pressure for the exceeding part 2.1 kN {210 kgf} per 1 m² of maximum vertical sectional area of silo.

- (2) Earthquake Loads In the determination of design earthquake load of silo, either one of the following methods shall, in general, apply.

- (2.1) Corrected Seismic Intensity Method Calculate the design yield shearing force in horizontal direction of silo Q_d according to the following formula:

$$\left. \begin{aligned} Q_d &= C \cdot W_t \\ C &= Z_s \cdot I \cdot D_s \cdot \frac{S_{a1}}{g} \end{aligned} \right\} \dots\dots\dots (2)$$

where Q_d : design yield horizontal shearing force in the horizontal direction on base part of silo supporting structure (N) {kgf}

C : design yield shearing force coefficient at base part of silo supporting structure. However, take as $C \geq 0.3 Z_s$.

W_t : design weight imposed on silo base part (N) {kgf}

Z_s : seismic region coefficient (according to the Building Standard Law)

I : use coefficient shown in Table 2

D_s : structural characteristic coefficient

$$D_s = D_r \cdot D_h$$



D_r : coefficient determined by the plastic deformation capacity and in the case of steel construction and aluminium and aluminium alloy construction, take as 0.55.

D_h : coefficient determined by damping property of silo to be in accordance with Table 1.

S_{a1} : design acceleration response spectral value for primary proper period of silo to be the value defined in (2.4) (cm/s^2)

g : gravitational acceleration to be taken as 980 cm/s^2 .

Table 1. Values of D_h

Short side of base bottom plate	Size of base bottom plate	D_h
25 m max.	2000 m^2 max.	1.0
25 to 50 m	2000 to 4000 m^2	1.0 to 0.90
50 m min.	4000 m^2 min.	0.90

In the case where the silo is assumed as a system of n material particles, calculate the design yield horizontal shearing force just under the i -th material particle Q_{di} according to the following formula:

$$Q_{di} = Q_d \frac{\sum_{m=i}^n W_m \cdot h_m}{\sum_{m=1}^n W_m \cdot h_m} \dots\dots\dots (3)$$

where Q_{di} : design yield horizontal shearing force just under i -th material particle in the case where the silo is assumed as a system of n material particles (N) {kgf}

W_i : weight of i -th material particle (N) {kgf}

h_i : height of i -th material particle from ground surface (m)

n : total number of material particles

(2.2) Mode Method In the case where the silo is assumed as a system of n material particles, calculate the design yield horizontal shearing force just under the i -th material particle Q_{di} according to the following formulae. Take the maximum degree of vibrations to be taken into consideration as 2 or over.

$$\left. \begin{aligned} Q_{di} &= \sqrt{\sum_{j=1}^k \left(C_j \sum_{m=i}^n W_m \cdot \beta_j \cdot u_{mj} \right)^2} \\ C_j &= Z_s \cdot I \cdot D_s \cdot \frac{S_{aj}}{g} \end{aligned} \right\} \dots\dots\dots (4)$$

However, take $Q_{di} \geq 0.3 Z_s W_i$.

Herein β_j : stimulus coefficient of j -th proper vibration

$$\beta_j = \frac{\sum_{i=1}^n W_i \cdot u_{ij}}{\sum_{i=1}^n W_i \cdot u_{ij}^2}$$

W_i : weight of i -th material particle (N) {kgf}

u_{ij} : proper mode of i -th degree for j -th material particle

k : maximum degree of vibrations with large effect to earthquake response

j : degree of proper vibration

C_j : yield shearing force coefficient to j -th proper vibration

S_{aj} : design acceleration response spectral value for j -th proper period to be defined according to (2.4) (cm/s^2)

- (2.3) Use Coefficient Set the design divisions according to use of silo by taking into consideration the seriousness of earthquake disaster and the spreading effect of damage to outskirts. Take as the use coefficient of each design division the value given in Table 2.

Table 2. Use Coefficient I

Division of seismic design	Object	Use coefficient I
1	Silo of small scale and containing no dangerous goods.	0.6 min.
2	Silo of large or medium scale, containing no dangerous goods and little in spreading effect of damage.	0.8 min.
4	Silo containing dangerous goods and possible to cause secondary damage.	1.2 min.

- (2.4) Values of Response Spectrums Calculate the value of design velocity response spectrum S_{vj} and the value of design acceleration response spectrum S_{aj} according to the following formulae:

when $T_j < T_G$,

$$S_{vj} = 156 T_j \text{ (cm/s)}$$

$$S_{aj} = 980 \text{ (cm/s}^2\text{)}$$

when $T_j \geq T_G$,

$$S_{vj} = 156 T_G \text{ (cm/s)}$$

$$S_{aj} = 980 \frac{T_G}{T_j} \text{ (cm/s}^2\text{)}$$

where T_j : j -th proper period(s)

T_G : critical period determined by the classification of ground (s) and as given in Table 3.

..... (5)

Table 3. Critical Periods

Classification of ground	Condition of ground	T_g (s)
Class 1	(1) Ground prior to Tertiary, (hereinafter, referred to as bedrock)	0.64
	(2) Diluvium deposit	
	(3) Thickness of alluvium deposit up to bedrock under 10 m	
Class 2	Thickness of alluvium deposit under 25 m and thickness of poor subsoil under 5 m	0.96
Class 3	(1) Ground other than the above	1.28
	(2) Ground with unidentified characteristics	

In the case where the primary proper period of silo T is unknown, it may be taken as $T = 0.6$ s.

- (2.5) Effective Weight of Contained Goods In the calculation of seismic force, it is allowable to use the effective weight reduced adequately, by taking into consideration the damping effect of contained goods at the time of earthquake. However, the reduced effective weight shall not be under 80 % of weight of full load.

- (2.6) Earthquake Load F_e Calculate the earthquake load of silo according to the following formulae (6) and (7).

$$Q_{ei} = \frac{Q_{di}}{B} \dots\dots\dots (6)$$

$$F_e = Q_{ei-1} - Q_{ei} \dots\dots\dots (7)$$

where B : ratio of holding horizontal yield strength of structure against short period permissible yield strength to be within 1.2 to 1.5

Q_{ei} : design shearing force of each part of silo (N) {kgf}

F_e : earthquake load (N) {kgf}

3.2.3 Combination of Loads The combination of loads shall be as given in Table 4.

Table 4. Combinations of Loads of Each Part of Silo

Condition of load		In general case	In the case of heavy snow region
Long period	At ordinary time	$W_s + W_G$	$W_s + W_G + S$
Short period	At time of snow	$W_s + W_G + S$	$W_s + W_G + S$
	At time of storm	$W_s + W_G + F_w$	$W_s + W_G + S + F_w$
	At time of earthquake	$W_s + W_G + F_e$	$W_s + W_G + S + F_e$

Herein W_s : self-weight of silo
 W_G : load due to pulverulent body
 S : snow load
 F_w : wind load
 F_e : earthquake load

3.3 Permissible Tensile Stress and Welded Joint Efficiency

3.3.1 Permissible Tensile Stress The permissible tensile stress of aluminium materials to be used for calculation of strengths shall be as given in Table 5.

Table 5. Permissible Tensile Stresses

Unit: N/mm² {kgf/mm²}

Alloy No.	Quality division	Form ⁽¹⁾	Standard minimum value ⁽²⁾		Permissible tensile stress ⁽⁵⁾						
			Tensile strength	Proof stress	40°C or under	Over 40°C up to 65°C incl.	Over 65°C up to 100°C incl.	Over 100°C up to 125°C incl.	Over 125°C up to 150°C incl.	Over 150°C up to 175°C incl.	Over 175°C up to 200°C incl.
1080 1070	-	Plate, bar, pipe	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	-	Plate, bar, pipe	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	-	Plate	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	-	Bar, pipe, extruded shape, forging	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	-	Plate, bar, pipe, extruded shape	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	-	Plate, bar, pipe, extruded shape	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	-	Plate, pipe	206 { 21 }	78.5 { 7.5 }	58.8 { 6.0 }	58.8 { 6.0 }	-	-	-	-	-
5056	-	Bar, pipe, forging	245 { 25 }	98.0 { 10 }	78.4 { 8.0 }	78.4 { 8.0 }	-	-	-	-	-
5083	-	Plate (thickness 40 mm or under)	275 { 28 }	127 { 13 }	91.2 { 9.3 }	90.2 { 9.2 }	-	-	-	-	-
5083	-	Plate (thickness over 40 mm up to 80 mm incl.)	275 { 28 }	118 { 12 }	91.2 { 9.3 }	90.2 { 9.2 }	-	-	-	-	-
5083	-	Plate (thickness over 80 mm up to 100 mm incl.)	256 { 27 }	108 { 11 }	86.2 { 8.8 }	86.2 { 8.8 }	-	-	-	-	-
5083	-	Bar, pipe, extruded shape, forging	275 { 28 }	108 { 11 }	86.2 { 8.8 }	86.2 { 8.8 }	-	-	-	-	-
6061	T4, T6	Weld	167 ⁽³⁾ { 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	T5, T6	Weld	118 ⁽³⁾ { 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 }
7N 01	T4, T6	Weld	284 ⁽⁴⁾ { 29 }	-	94.1 { 9.6 }	94.1 { 9.6 }	-	-	-	-	-

Notes (1) The plates, bars, pipes, extruded shapes, forgings in the column of form shall comply with the following Standards respectively.

JIS H 4000, JIS H 4040, JIS H 4080, JIS H 4090, JIS H 4100, JIS H 4140

(2) The standard minimum values designate the values of quality division 0.

(3) Value of welded joints

(4) Value of welded joints (minimum value of ordinary temperature aging for 1 month or over after welding)

- (5) The permissible tensile stress of short period shall be 1.5 times the value given in table or proof stress, whichever is smaller.

3.3.2 Welded Joint Efficiency The welded joint efficiency shall be as follows:

- (1) The welded joint efficiency to be used for calculation shall be as given in Table 6.
- (2) The sampling in the case where the radiographic test on partial length given in Table 6 is conducted shall be as follows.
 - (a) Horizontal Joints of Side Plates At each time when the plate thickness, groove and welding procedure change, one place at optional position in the initial 3 m and thereafter one place at optional position in every 30 m over the total length of weld line.
 - (b) Longitudinal Joints of Side Plates At each time when the plate thickness, groove and welding procedure change, one place at optional position in the initial 3 m and thereafter one place at optional position in every 15 m over the total length of weld line.

Table 6. Efficiency of Welded Joints

Classification of welded joint	Efficiency of welded joint %		
	For joint to be conducted by radiographic test on over-all length	For joint to be conducted by radiographic test on partial length	For joint to be not conducted by radiographic test
(1) Butt both side welded joint or butt one side welded joint assumed to be equivalent or superior to this	100	85	70
(2) Butt one side welded joint having used backing metal which remains	90	80	65
(3) Butt one side welded joint other than (1) and (2)	—	—	60
(4) Both side full fillet lap joint	—	—	50

3.4 Design of Shell Part and Hopper Part

3.4.1 Pressure on Shell Part Due to Pulverulent Body The pressure in vertical direction and pressure in horizontal direction due to the stored pulverulent body in silo shall be calculated according to the following formulae: