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JAPANESE INDUSTRIAL STANDARD

Bellows type expansion joints

JIS B 2352—1994

Translated and Published

by

Japanese Standards Association

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

JAPANESE INDUSTRIAL STANDARD
JIS B 2352-1994
Bellows type expansion joints

October, 1996

ERRATA

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Subclause 3.3(1)

Replace the equation (2)

$$e_y = \frac{3d_p Y}{L + X_c} \dots\dots\dots (2)$$

by the following :

$$e_y = \frac{3d_p Y}{N (L + X_c)} \dots\dots\dots (2)$$

Remarks: This errata is for correcting the first edition of this Standard.
Japanese Standards Association

JAPANESE INDUSTRIAL STANDARD

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Bellows type expansion joints

B 2352-1994

1. **Scope** This Japanese Industrial Standard specifies the bellows type expansion joints (hereafter referred to as "pipe joints") of nominal pressure 10 K to be used for absorbing the expansion and contraction of the pipes in axial direction resulting from temperature changes in the pipings for steam, air, gas, water, oil, etc.

Remarks 1. The strength evaluation standards and installation standards of the pipe joints of nominal pressure 10 K and other than 10 K (those different in construction from the pipe joints specified in the text, such as universal type and hinged type, are also included) are given in Informative reference 1 and 2.

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

3. In this Standard, the units and numerical values given in () are based on the traditional units, and are appended for informative reference.

Informative reference: The nominal pressure 10 K generally means that the maximum working pressure is 0.98 MPa (10 kgf/cm²) (see 4.).

2. **Definitions** For the main terms used in this Standard, the definitions in JIS B 0151 apply.

3. **Types** The types of the pipe joints shall be as given in Table 1 according to the construction of bellows, coupling system, uses, and sizes of pipe joints (nominal diameters). The sizes of pipe joints shall be 500 or under for the uses of symbol A and 50 or over for the uses of symbol B.

Table 1. Types

Construction of bellows		Coupling system	Symbol of use	Size of pipe joint (nominal diameter)
With rods and without reinforcing rings	Single style, Double style	Welded type,	A,	15, 20, 25, 32, 40, 50,
With rods and reinforcing rings		Flanged type	B	65, 80, 100, 125, 150,
With outer cylinder				200, 250, 300, 350, 400, 450, 500, 550, 600, 650

Remarks 1. The symbols of uses shall indicate the following division of use:

A : pipe joints to be used mainly for cooling and heating, air conditioning and sanitary piping

B : pipe joints to be used mainly for industrial pipings

2. The size of pipe joints shall indicate the nominal diameter of the pipe to be connected.

4. Maximum working pressure When the state of fluid is steam, air, gas, water or oil at 220°C or lower, the maximum working pressure of the pipe joints shall be 0.98 MPa {10 kgf/cm²}.

5. Construction The fundamental construction of the pipe joints shall be the single style with rods and without reinforcing rings, double style with rods and without reinforcing rings, single style with rods and reinforcing rings, double style with rods and reinforcing rings, single style with outer cylinder and double style with outer cylinder, according to the construction and the number of combined bellows.

In addition, the welded type in the coupling system shall be of the construction to connect with the pipes by butt welding, attaching the end pipes to the front and rear of the bellows, and the flanged type shall be of the construction to connect with the pipes by pipe flanges, attaching the end pipes and pipe flanges to the front and rear of the bellows. The basic dimensions of the pipe flanges to be used for the flanged pipe joints shall be in accordance with JIS B 2210.

Further, examples of the fundamental construction of the pipe joints shall be given in Figs. 1 to 6.

Remarks 1. The construction other than those given in Figs. 1 to 6 may be permissible, according to the combination of the components of the pipe joints.

2. The numbers of components of the pipe joints given in Figs. 1 to 6 shall indicate the names of the components as follows:

① bellows ② end pipe ③ pipe flange ④ outer cylinder
⑤ inner cylinder ⑥ reinforcing ring or adjusting ring (see 3.4.4 Remarks 2. of Informative reference 1) ⑦ stay bolt
⑧ set bolt ⑨ anchor base ⑩ stay plate ⑪ supporting ring

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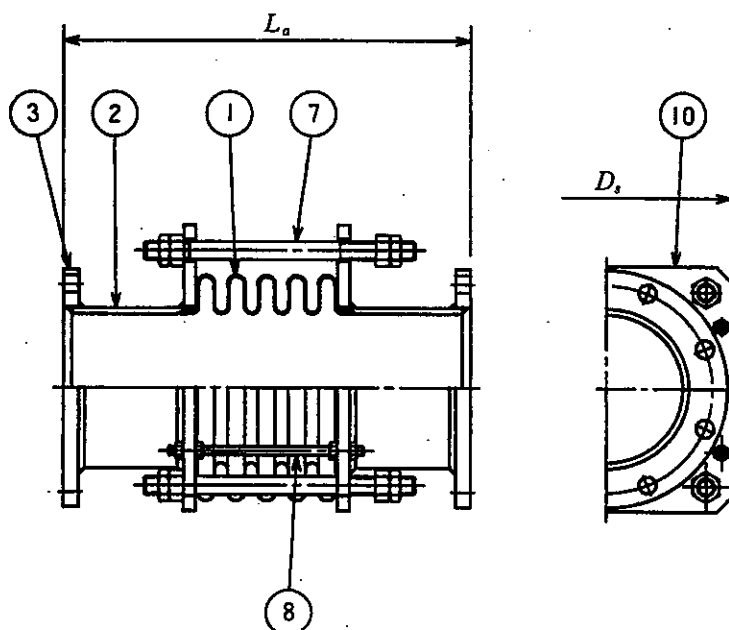
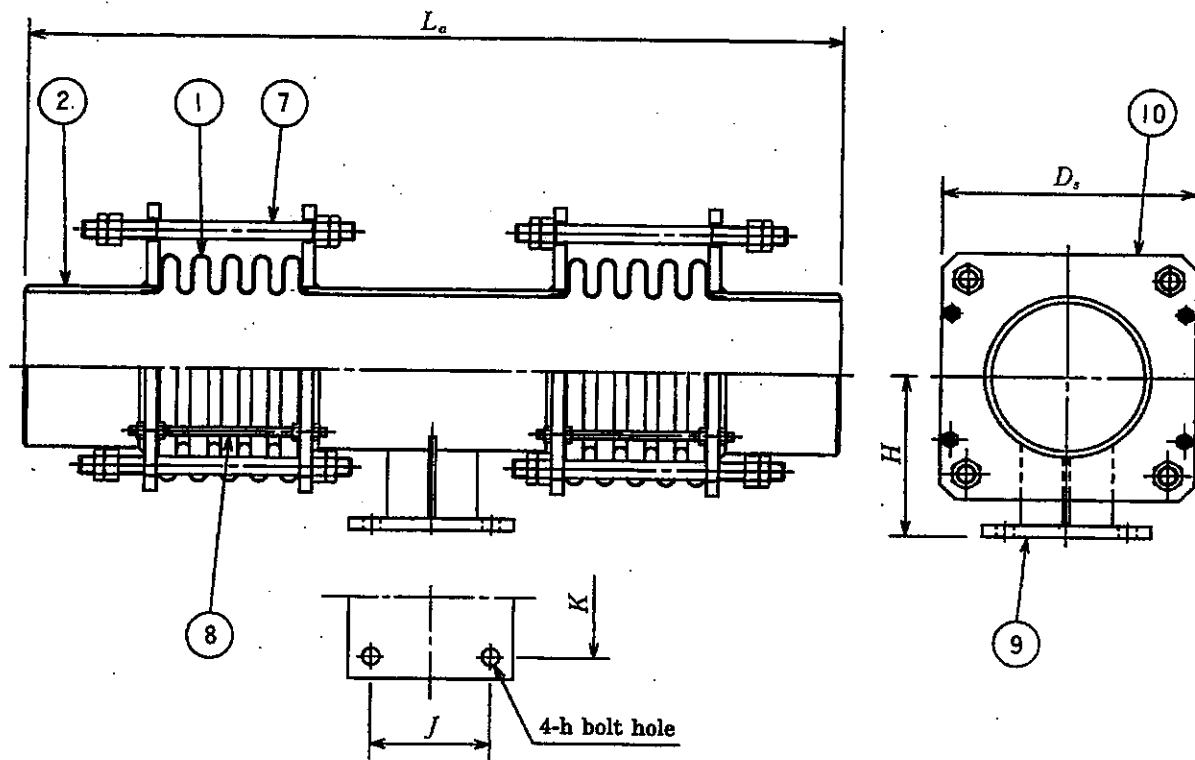


Fig. 2. Double style with rods and without reinforcing rings
Welded type



Flanged type

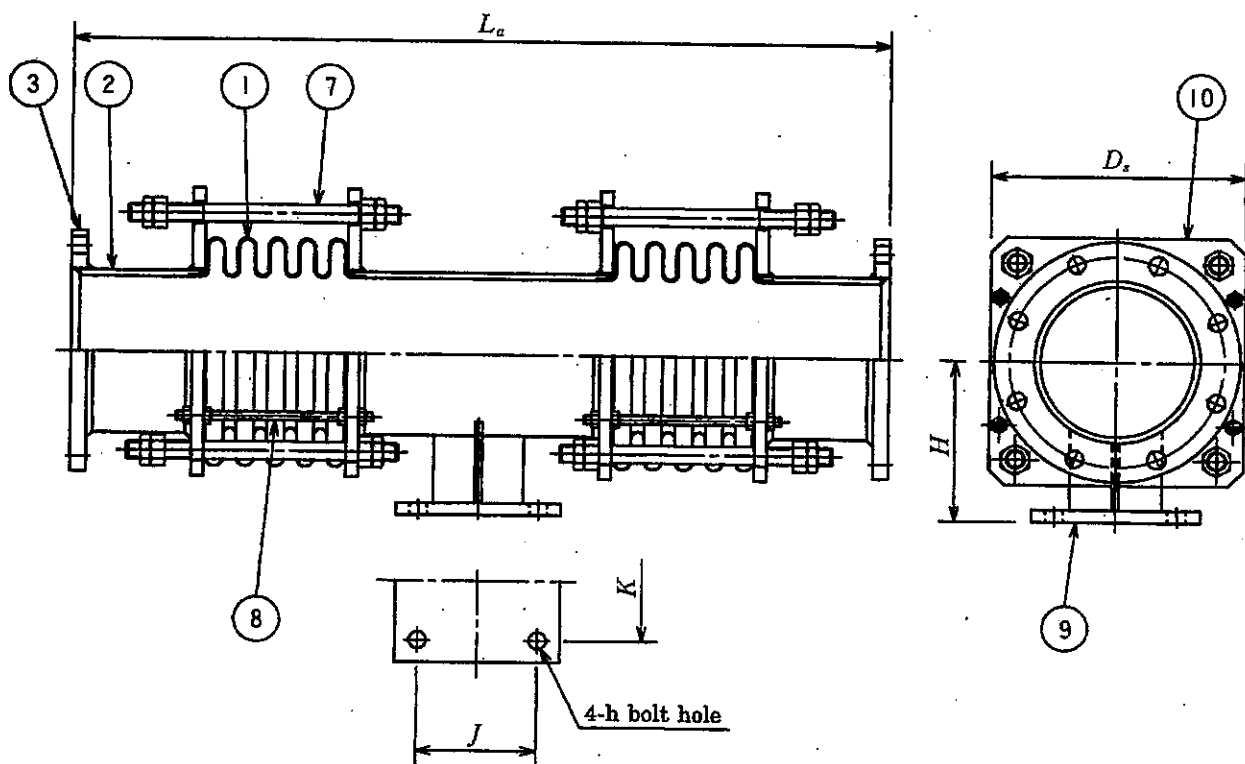
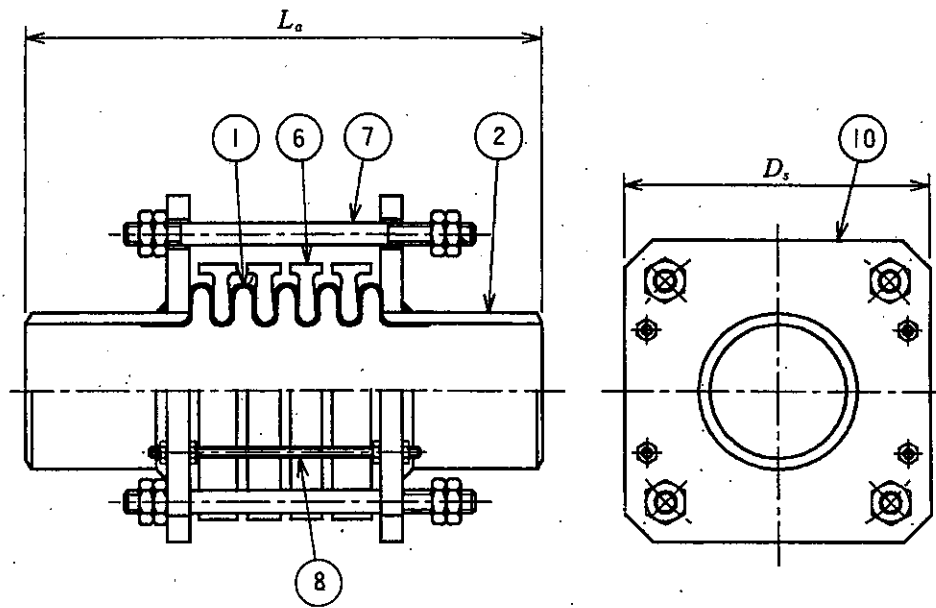


Fig. 3. Single style with rods and reinforcing rings
Welded type



Flanged type

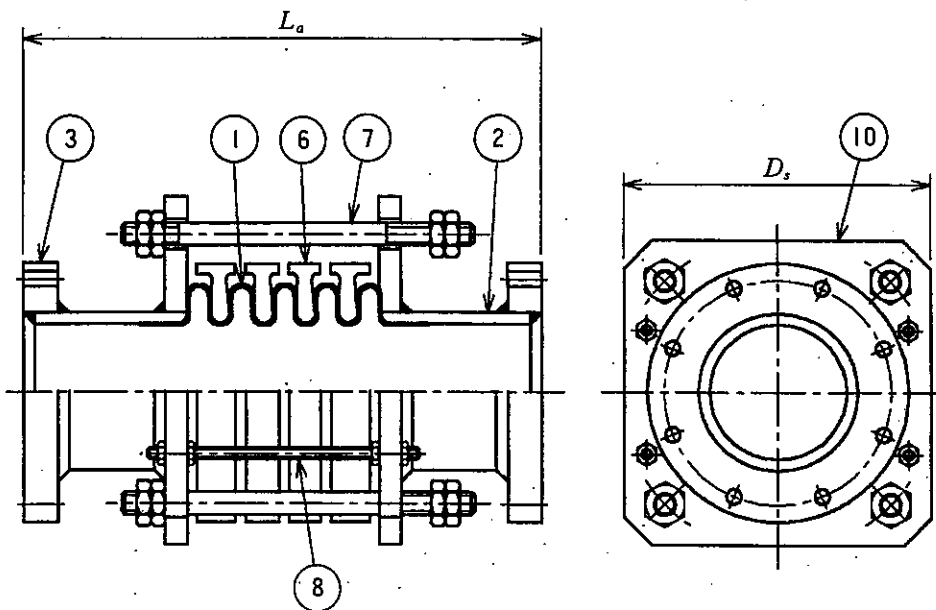
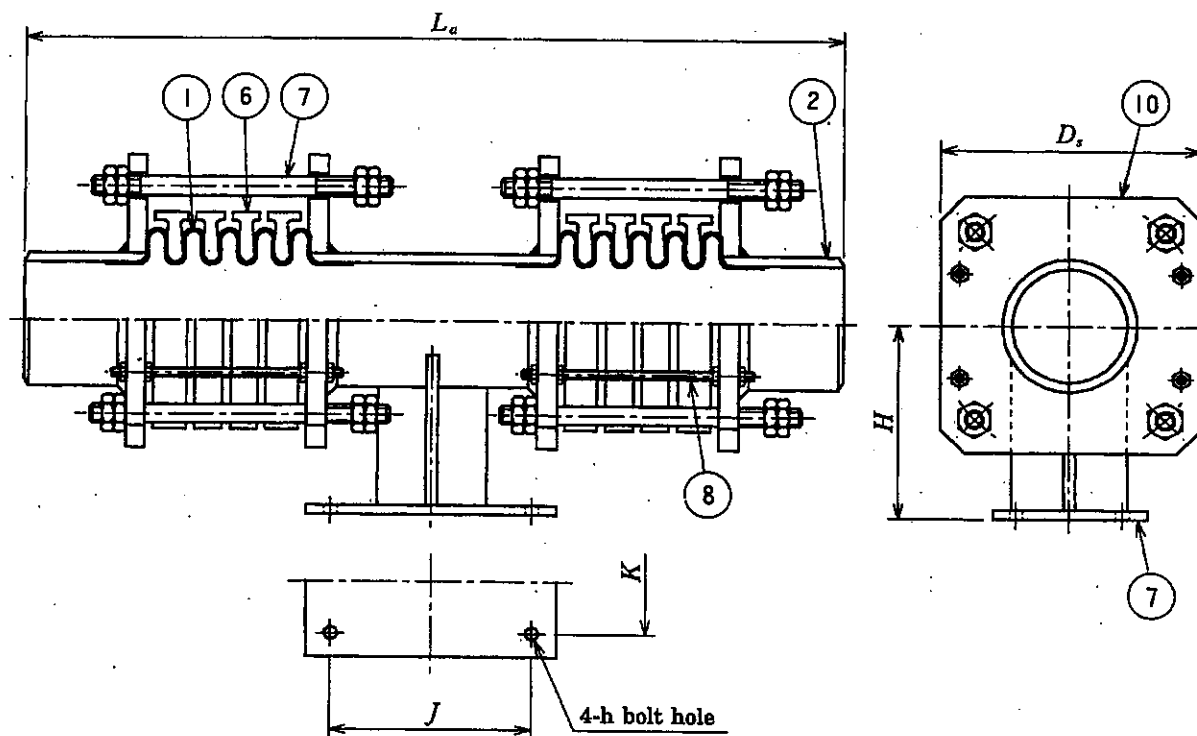


Fig. 4. Double style with rods and reinforcing rings
Welded type



Flanged type

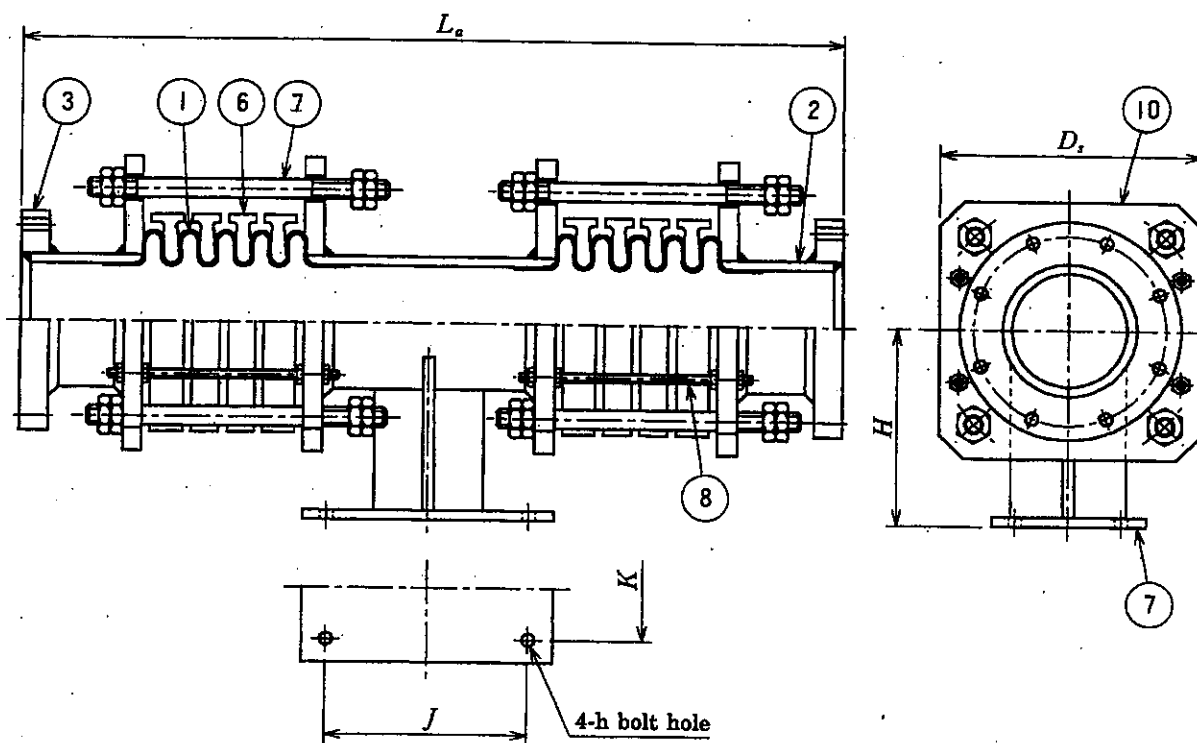
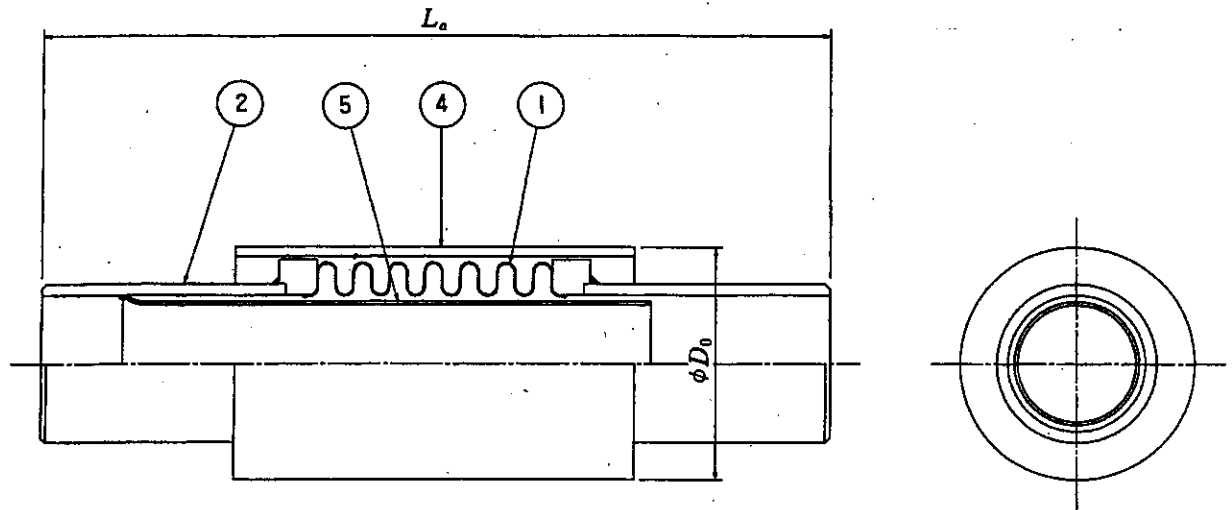


Fig. 5. Single style with outer cylinder (with inner cylinder)

Welded type



Flanged type

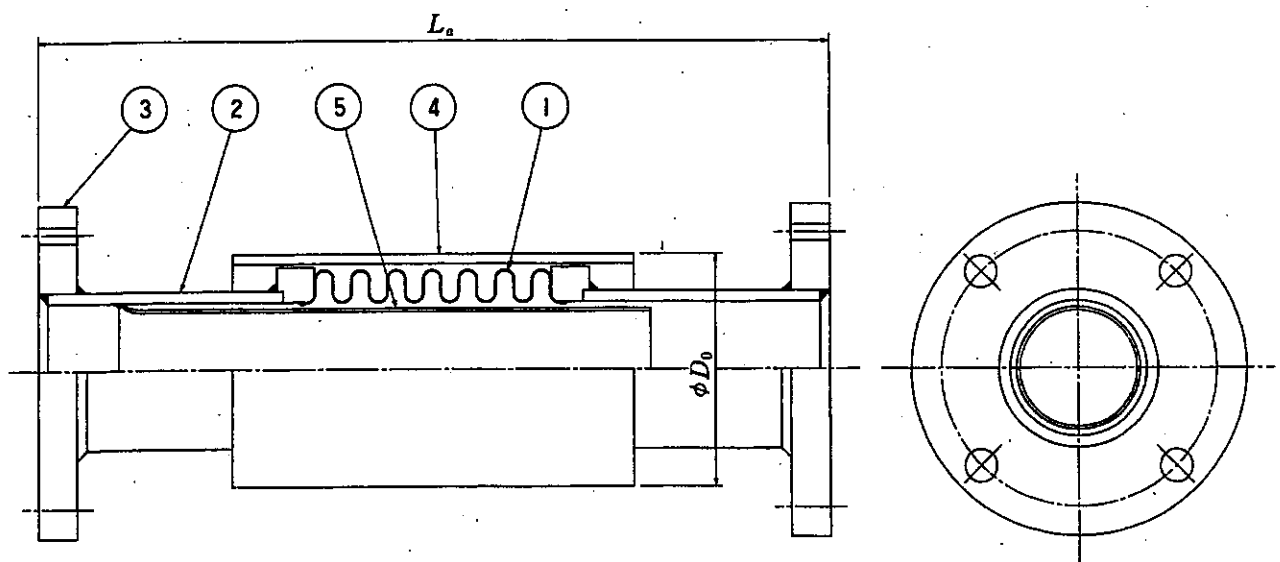
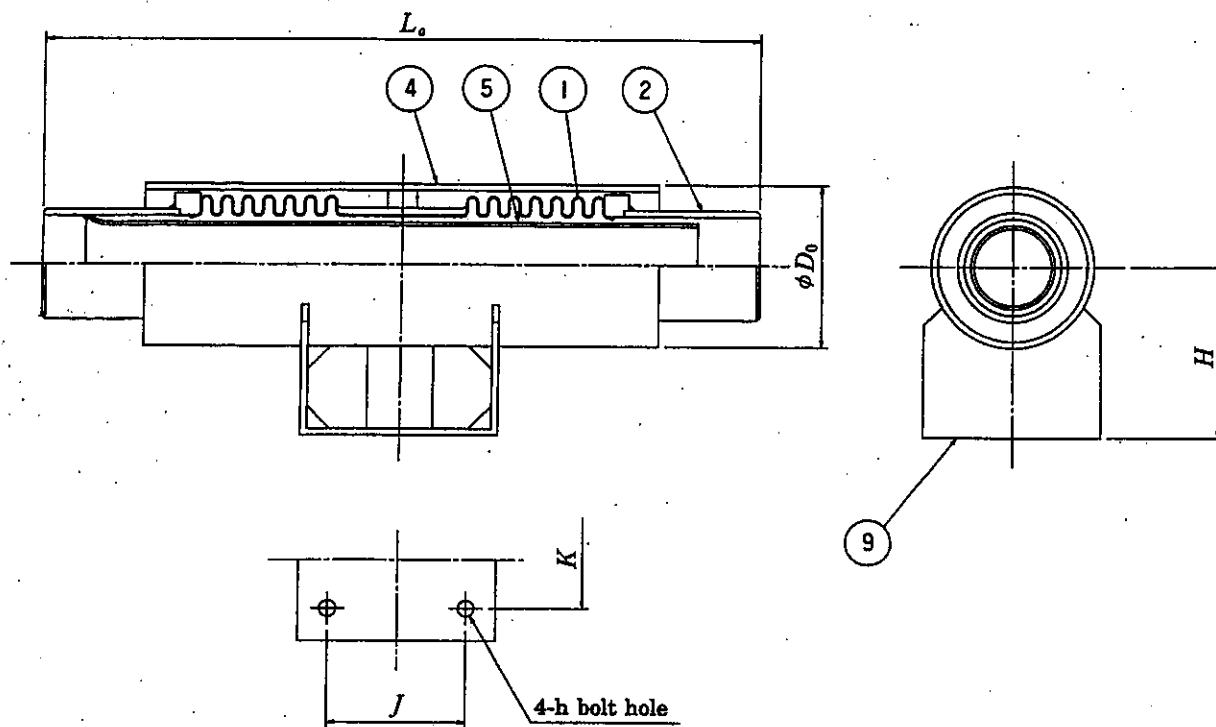
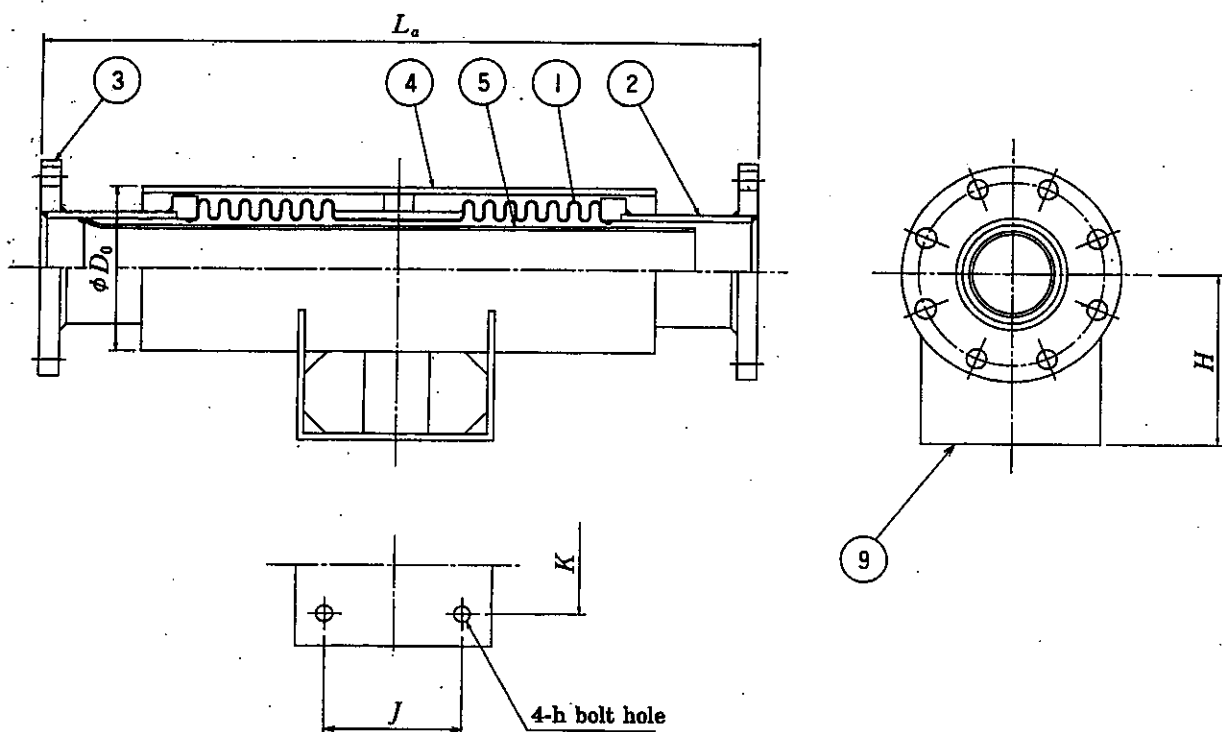


Fig. 6. Double style with outer cylinder (with inner cylinder)
Welded type



Flanged type



6. Dimensions and maximum displacement in axial direction The dimensions and maximum displacement in axial direction of the pipe joints shall be in accordance with Tables 2 to 5, according to the number of combined bellows and uses.

Further, the free length L_a in the Tables means the length under the conditions where the internal pressure, compression load and tensile load are not loaded. For the pipe joints having the adjusting mechanism of setting the face-to-face dimension, this means the length before adjusting the setting.

Table 2. Single style A

Unit: mm																			
Size of pipe joint (nominal diameter)		15	20	25	32	40	50	65	80	100	125	150	200	250	300	350	400	450	500
Face-to-face dimension	Free length ⁽¹⁾ L_a	365						415			440			465			490		
	Maximum working length L_e	375						425			450			475			500		
	Minimum working length L_c	340						390			415			440			465		
Maximum displacement in axial direction δ		35																	
Maximum outer diameter (informative reference)	D_0	160			170	180	200	220	240	280	320	360	430	520	580	650	700	750	800
	D_s	120			130	140	150	160	180	210	240	270	320	400	450	500	550	600	650

Note ⁽¹⁾ The tolerances on the free length L_a shall be $\pm 1\%$.

Table 3. Single style B

Unit: mm																	
Size of pipe joint (nominal diameter)		50	65	80	100	125	150	200	250	300	350	400	450	500	550	600	650
Face-to-face dimension	Free length L_a	500			650			700			850			900			
	Maximum working length L_e	517.5			677.5			727.5			885			935			
	Minimum working length L_c	482.5			622.5			672.5			815			865			
Tolerances on free length L_a		±3															
Maximum displace- ment in axial direction δ		35			55						70						
Maximum outer diameter (informative reference)	D_0	225	245	255	290	355	370	435	520	570	630	720	780	865	900	950	1 000
	D_s	170	190	220	240	280	310	360	415	490	540	610	650	710	740	800	850

Table 4. Double style A

Unit: mm

Unit: mm

Size of pipe joint (nominal diameter)		15	20	25	32	40	50	65	80	100	125	150	200	250	300	350	400	450	500	
Face-to-face dimension	Free length ⁽¹⁾ L_a	680						780		880		930		980		1 030		1 080		
	Maximum working length L_e	700						800		900		950		1 000		1 050		1 100		
	Minimum working length L_c	630						730		830		880		930		980		1 030		
Maximum displacement in axial direction δ		70																		
Maximum outer diameter (informative reference)	D_o	160			170	180	200	220	240	280	320	360	430	520	580	650	700	750	800	
	D_s	120			130	140	150	160	180	210	240	270	320	400	450	500	550	600	650	
Dimensions of anchor base	Height to the center of pipe joint H		100			120		130	140	150	170	200	220	250	300	350	450	500	550	600
	Pitch of bolt hole	J	100			100			120		120		160		180	200	250	300	350	400
		K	60			70		80	100	110	130	150	180	220	280	300	350	400	450	500
	Diameter of bolt hole h		12					15			19		23	25	27		33		39	
	Designation of thread of bolt		M10					M12			M16		M20	M22	M24		M30		M36	

Note (1) The tolerances on the free length L_a shall be $\pm 1\%$.

Table 5. Double style B

Unit: mm

Size of pipe joint (nominal diameter)		50	65	80	100	125	150	200	250	300	350	400	450	500	550	600	650	
Face-to-face dimension	Free length L_a	1 000			1 300			1 400			1 700			1 800				
	Maximum working length L_b	1 035			1 355			1 455			1 770			1 870				
	Minimum working length L_c	965			1 245			1 345			1 630			1 730				
Tolerances on free length L_a		± 6																
Maximum displacement in axial direction δ		70			110						140							
Maximum outer diameter (informative reference)	D_0	225	245	255	290	355	370	435	520	570	630	720	780	865	900	950	1 000	
	D_s	170	190	220	240	280	310	350	415	470	515	575	635	690	740	800	850	
Dimensions of anchor base	Height to the center of pipe joint H		125	135	145	165	190	200	240	280	310	350	390	440	480	530	580	630
	Pitch of bolt hole	J	100	120				130	150	170	180	200	220	230	250	270	320	340
		K	80	100	110	130	150			170	180	200	220	230	250	270	320	340
	Diameter of bolt hole h		15			19		23		25	27	29	33	35				
	Designation of thread of bolt		M12			M16		M20		M22	M24	M27	M30	M33				

7. **Materials** As for the materials of the components of the pipe joints, it is preferable to refer to Table 6.

Table 6. Materials of components

Name of component	Materials (informative reference)
Bellows	SUS304, SUS304L, SUS316, SUS316L, SUS317, SUS317L of JIS G 4305
End pipe	FC200 of JIS G 5501 SGP of JIS G 3452 STPG370 of JIS G 3454 STPY400 of JIS G 3457 SS400 of JIS G 3101
Pipe flange	FC200 of JIS G 5501 SS400 of JIS G 3101 S20C, S25C of JIS G 4051
Outer cylinder	SGP of JIS G 3452 SS400 of JIS G 3101 STK400 of JIS G 3444
Inner cylinder	SGP of JIS G 3452 SS400 of JIS G 3101 SUS304 of JIS G 4305
Adjusting ring	FC150, FC200 of JIS G 5501 SS400 of JIS G 3101 AC3A of JIS H 5202
Bolt	SS400 of JIS G 3101 S15C, S25C of JIS G 4051

8. **Inspections** The inspections of the pipe joints shall be in accordance with the following:

- (1) **Appearance inspection** The appearance inspection shall be carried out by the visual inspection before and after the assembling, and the bellows, end pipes and the welds of pipe flange parts and pressure portions shall be free from cracks, harmful flaws, blow holes, etc. in use.

Further, the inner faces shall be free from adhesion of foreign substances, and be clean.

- (2) **Dimensional inspection** The dimensional inspection shall be made by direct measurement using the measuring instruments, and the results shall conform to Tables 2 to 5 of 6. or the values defined upon agreement between the parties concerned with delivery.

- (3) Pressure inspection In the pressure inspection, the hydraulic pressure or pneumatic pressure of 1.5 times the maximum working pressure is applied and held for 5 min under the condition of keeping the free length or the length after adjusting the setting, and there shall be no breakage, leakage and permanent deformation.
- (4) Leakage inspection In the leakage inspection, under the condition of keeping the free length or the length after adjusting the setting, the pneumatic pressure or gas pressure of the maximum working pressure is applied, and held for 1 min or over in case of throwing into water to inspect, and for 5 min or over in case of applying the sparkling liquid, and there shall be no leakage.

9. Designation The pipe joints shall be designated by the number or title of this Standard, construction of bellows, coupling system, symbol of use, nominal pressure and size of pipe joint (nominal diameter).

Example 1. JIS B 2352 With rods and without reinforcing rings
Double style Welded type B10-200

Example 2. Bellows type expansion joint With outer cylinder
Single style Flanged type A10-100

10. Marking The pipe joints shall be marked with the following information by the nameplate or casting.

As required, the document in which the matters to be attended such as the adjustment of face-to-face dimension and setting are stated shall be appended to the products.

- (1) Symbol of use, nominal pressure and size (nominal diameter) of pipe joint
- (2) Manufacturer's name or abbreviation
- (3) Year and month of manufacture or its abbreviation
- (4) Arrow mark indicating the direction of flow (for with inner cylinder)

Attached Table 1. Cited standards

JIS B 0151	Glossary of terms for iron and steel pipe fittings
JIS B 2210	Basic dimensions of ferrous material pipe flanges
JIS G 3101	Rolled steel for general structure
JIS G 3444	Carbon steel tubes for general structural purposes
JIS G 3452	Carbon steel pipes for ordinary piping
JIS G 3454	Carbon steel pipes for pressure service
JIS G 3457	Arc welded carbon steel pipes
JIS G 4051	Carbon steels for machine structural use
JIS G 4305	Cold rolled stainless steel plates, sheets and strip
JIS G 5501	Grey iron castings
JIS H 5202	Aluminium alloy castings

Informative reference 1. Strength evaluation standards for bellows type expansion joints

This informative reference describes the strength evaluation standards for the bellows part of not only the bellows type expansion joints of nominal pressure 10 K specified in the text, but also the bellows type expansion joints of other nominal pressures and of different construction (universal type, hinged type, gimbal type, etc.), and this does not constitute a part of the provisions.

1. Scope This informative reference indicates the strength evaluation standards of the bellows parts of the bellows type expansion joints (hereafter referred to as "pipe joints") to be used for absorbing the displacement of the pipes in the axial direction, lateral direction, axial bending, etc. resulting from temperature changes in the pipings for steam, air, gas, water, oil or the like. The strength evaluation of the bellows parts is the evaluation by the type test or the strength calculation.

Remarks: The pipe joints corresponding to this informative reference are the bellows type expansion joints specified in JIS B 0151.

2. Evaluation by type test

2.1 Type test The evaluation by the type test applies to the pipe joints for use A specified in the text and the pipe joints of continuous lot product. The tests in 2.2 are carried out, manufacturing, in advance, those of the same shape as the pipe joints intended to produce.

Further, the pipe joints used in the tests shall not be used in the actual pipings.

2.2 Test items and procedures The test items and procedures are in accordance with the following:

- (1) Dimensional inspection
- (2) Test of displacement in axial direction
- (3) Pressure test
- (4) Durability test

2.3 Dimensional inspection The dimensional inspection is in accordance with 8. (2) of the text.

2.4 Test of displacement in axial direction The measurements are to be carried out by using the equipment which allows the pipe joint to displace in the axial direction, and the results shall conform to the values in Table 2 or Table 4 of the text or the values as determined by the agreement between the parties concerned with delivery.

2.5 Pressure test The pressure test is in accordance with 8. (3) of the text.

2.6 Durability test In the durability test, the displacement tests of 3000 times in repetition number are carried out between the maximum working length and the minimum working length under the atmospheric pressure, and the results shall conform to 8. (4) of the text.

3. Evaluation by strength calculation

3.1 Strength calculation The evaluation by the strength calculation applies to the pipe joints for use B specified in the text and the pipe joints of order production, and the calculating method is in accordance with 3.4, 3.5 or as agreed upon between the parties concerned with delivery.

3.2 Symbols The symbols to be used in the strength calculation are in accordance with the following (see Informative reference 1 Fig. 1 and Informative reference 1 Fig. 2):

- A_b : $(0.571q + 2W) t_p n$, cross sectional area of one bellows convolution (mm^2)
- A_r : cross sectional area of reinforcing ring portion (mm^2)
- A_f : cross sectional area of reinforcing ring fastener (mm^2)
- d : outside diameter of bellows end portion (mm)
- d_p : $d + W$, mean diameter of bellows (mm)
- W : convolution height of bellows (mm)
- q : convolution pitch of bellows (mm)
- t : nominal thickness of one ply of bellows (mm)
- t_p : $\left(\frac{d}{d_p}\right)^{0.5} t$, calculated thickness of one ply of bellows (mm)
- n : number of plies of thickness " t "
- N : number of convolutions in one bellows
- R : ratio of the internal pressure force resisted by bellows members to that by reinforcing members
- R_1 : $\frac{A_b E_b}{A_r E_r}$, in case of integrated type reinforcing ring, ratio of the internal pressure force resisted by bellows members, to that by reinforcing members
- R_2 : $\frac{A_b E_b}{d_p} \left(\frac{l_f}{A_f E_f} + \frac{d_p}{A_r E_r} \right)$, in case of split type reinforcing ring, ratio of the internal pressure force resisted by bellows members to that by reinforcing ring fastener
- l_f : effective length of one reinforcing ring fastener (mm)
- C : effective length of one bellows (mm)
- L : effective length of bellows portion (including intermediate pipe) (mm)
- C_p : correction coefficient of bending stress calculation due to pressure (in accordance with Informative reference 1 Fig. 3)
- C_f : correction coefficient of membrane stress calculation due to movement of bellows (in accordance with Informative reference 1 Fig. 4)

- C_d : correction coefficient of bending stress calculation due to movement of bellows (in accordance with Informative reference 1 Fig. 5)
- k : $0.3 - \left(\frac{100}{1048P^{1.5} + 320} \right)^2$, correction coefficient of bellows with reinforcing rings
- K : $\frac{3L^2 - 3CL}{3L^2 - 6CL + 4C^2}$, equivalent movement correction coefficient of double style (universal type) bellows
- E_b : Young's modulus at design temperature of bellows material (N/mm²)
- E'_b : Young's modulus at ordinary temperature of bellows material (N/mm²)
- E_r : Young's modulus at design temperature of reinforcing ring member (N/mm²)
- E_f : Young's modulus at design temperature of reinforcing ring fastener (N/mm²)
- f_{iu} : theoretical spring constant per convolution of bellows without reinforcing rings (N/mm)
- f_{ir} : theoretical spring constant per convolution of bellows with reinforcing rings (N/mm)
- P : maximum working pressure (design pressure) (MPa)
- P_s : design limit internal pressure due to buckling condition (MPa)
- H : Pd_pq , circumferential load acting on bellows and reinforcing rings (N)
- T_f : $\frac{S_{uc} + 4S_h}{2S_{uc}}$, temperature correction coefficient of fatigue life evaluation of bellows
- S_{uc} : standardized minimum tensile strength of bellows material (N/mm²)
- S_h : permissible stress at design temperature of bellows material (N/mm²)
- S_y : yield point or 0.2 % proof stress of bellows material at design temperature (N/mm²)
- S_{hr} : permissible stress of reinforcing ring material at design temperature (N/mm²)
- S_{hf} : permissible stress of reinforcing ring fastener at design temperature (N/mm²)
- N_c : permissible number of repetitions of bellows
- N_s : number of repetitions of design specification (actual number of repetitions)
- S_{cmp} : circumferential membrane stress due to pressure (N/mm²)
- S_{mmp} : axial membrane stress due to pressure (N/mm²)
- S_{mbp} : axial bending stress due to pressure (N/mm²)
- S_{mmd} : membrane stress due to total movement per convolution of bellows (N/mm²)
- S_{mbd} : bending stress due to total movement per convolution of bellows (N/mm²)

- RS_{cmp} : circumferential tensile stress of reinforcing ring due to pressure (N/mm²)
- FS_{cmp} : circumferential tensile stress of reinforcing ring fastener due to pressure (N/mm²)
- S_p : bellows stress due to pressure (N/mm²)
- S_d : stress due to total movement per convolution of bellows (N/mm²)
- S_t : stress range due to pressure and total movement per convolution of bellows (N/mm²)
- X : $|X_e| + |X_c|$, total axial displacement (mm)
- X_e : axial displacement on the elongated side (indicated in positive figure) (mm)
- X_c : axial displacement on the contracted side (indicated in negative figure) (mm)
- Y : $|Y_n| + |Y_o|$, total lateral displacement (mm)
- Y_n : lateral displacement on the positive side (indicated in negative figure) (mm)
- Y_o : lateral displacement on the reverse side (indicated in positive figure) (mm)
- θ : $|\theta_n| + |\theta_o|$, total axial bending displacement (rad)
- θ_n : axial bending displacement on the positive side (indicated in negative figure) (rad)
- θ_o : axial bending displacement on the negative side (indicated in positive figure) (rad)
- e : $e_x + e_y + e_\theta$, total movement per convolution of bellows (mm)
- e_x : movement per convolution of bellows due to total axial displacement (mm)
- e_y : movement per convolution of bellows due to total lateral displacement (mm)
- e_θ : movement per convolution of bellows due to total axial bending displacement (mm)

3.3 Movement per convolution of the bellows The movement per convolution of the bellows is in accordance with the following (see Informative reference 1 Figs. 6 to 9)

(1) Movement per convolution of single style bellows

$$e_x = \frac{X}{N} \dots\dots\dots (1) \quad e_y = \frac{3d_p Y}{L + X_c} \dots\dots\dots (2) \quad e_\theta = \frac{d_p \theta}{2N} \dots\dots\dots (3)$$

(2) Movement per convolution of double style bellows

$$e_x = \frac{X}{2N} \dots\dots\dots (4)$$

$$e_y = \frac{Kd_p Y}{2N (L - C + 0.5X_c)} \dots\dots\dots (5)$$

3.4 Strength calculation formulae I of bellows (in accordance with ASME/ANSI B 31.3 Appendix X, as appropriate)

3.4.1 Bellows without reinforcing rings

3.4.1.1 Calculating formulae of stress values due to pressure and evaluation standards The calculating formulae of stress values due to pressure and evaluation standards are in accordance with the following:

(1) Circumferential membrane stress due to pressure

$$S_{cmp} = \frac{H}{2A_b} \dots\dots\dots (6)$$

(2) Axial membrane stress due to pressure

$$S_{mmp} = \frac{PW}{2nt_p} \dots\dots\dots (7)$$

(3) Axial bending stress due to pressure

$$S_{mbp} = \frac{P}{2n} \left(\frac{W}{t_p} \right)^2 C_p \dots\dots\dots (8)$$

(4) Restrictions of bellows stress values due to pressure The bellows stress values due to pressure shall not exceed the restrictions of the following formulae (9), (10) and (11).

Furthermore, S_h is the value referring to the fundamental permissible stresses of bellows materials at design temperature in the Attached Tables 1.1, 1.2 and 2.1 of JIS B 8270.

$$S_{cmp} \leq S_h \dots\dots\dots (9) \quad S_{mmp} \leq S_h \dots\dots\dots (10) \quad S_{mbp} \leq 1.5 S_h \dots\dots\dots (11)$$

3.4.1.2 Calculating formulae of stress values due to total movement per convolution of bellows The calculating formulae of stress values due to total movement per convolution of bellows are in accordance with the following:

(1) Axial membrane stress due to total movement per convolution

$$S_{mmd} = \frac{E_b t_p^2}{2W^3 C_f} e \dots\dots\dots (12)$$

(2) Axial bending stress due to total movement per convolution

$$S_{mbd} = \frac{5E_b't_p}{3W^2C_d} e \dots\dots\dots (13)$$

3.4.1.3 Theoretical spring constant per convolution of bellows The theoretical spring constant per convolution of bellows is in accordance with the following:

$$f_{iu} = \frac{1.7d_p E_b t_p^3 n}{W^3 C_f} \dots\dots\dots (14)$$

3.4.2 Bellows with reinforcing rings

3.4.2.1 Calculating formulae of stress values due to pressure and evaluation standards The calculating formulae of the stress values due to pressure and the evaluation standards are in accordance with the following:

(1) Circumferential membrane stress due to pressure

$$S_{cmp} = \frac{H}{2A_b} \left(\frac{R}{R+1} \right) \dots\dots\dots (15)$$

For integrated type reinforcing ring, $R = R_1$.

For split type reinforcing ring, $R = R_2$.

(2) Axial membrane stress due to pressure

$$S_{mmp} = \frac{P(W - kq)}{2nt_p} \dots\dots\dots (16)$$

(3) Axial bending stress due to pressure

$$S_{mbp} = \frac{p}{2n} \left(\frac{W - kq}{t_p} \right)^2 C_p \dots\dots\dots (17)$$

(4) Restrictions of bellows stress value due to pressure The bellows stress value due to pressure shall not exceed the restrictions of the following formulae (18), (19) and (20).

Furthermore, S_h is the value referring to the fundamental permissible stresses of bellows materials at the design temperature in the Attached Tables 1.1, 1.2, and 2.1 of JIS B 8270.

$$S_{cmp} \leq S_h \dots\dots\dots (18) \quad S_{mmp} \leq S_h \dots\dots\dots (19) \quad S_{mbp} \leq 3.0S_h \dots\dots\dots (20)$$

- (5) Circumferential tensile stress of reinforcing ring portion due to pressure

$$RS_{cmp} = \frac{H}{2A_r} \left(\frac{1}{R_1 + 1} \right) \dots\dots\dots (21)$$

- (6) Circumferential tensile stress of reinforcing ring fastener due to pressure

$$FS_{cmp} = \frac{H}{2A_f} \left(\frac{1}{R_2 + 1} \right) \dots\dots\dots (22)$$

- (7) Restrictions of stress values of reinforcing ring due to pressure The stress values of the reinforcing ring due to pressure [RS_{cmp} and FS_{cmp} obtained from the formulae (21) and (22)] shall not exceed the permissible stresses S_{hr} and S_{hf} .

Further, S_{hr} and S_{hf} are the values referring to the fundamental permissible stresses of the reinforcing ring materials and reinforcing ring fastener materials at the design temperature in Attached Tables 1.1, 1.2, 2.1 and 2.2 of JIS B 8270.

3.4.2.2 Calculating formulae of stress values due to total movement per convolution of bellows The calculating formulae of the stress values due to the total movement per convolution of bellows shall be in accordance with the following:

- (1) Axial membrane stress due to total movement per convolution of bellows

$$S_{mmd} = \frac{E_b' t_p^2 e}{2 (W - kq)^3 C_f} \dots\dots\dots (23)$$

- (2) Axial bending stress due to total movement per convolution of bellows

$$S_{mbd} = \frac{5E_b' t_p e}{3 (W - kq)^2 C_d} \dots\dots\dots (24)$$

3.4.2.3 Theoretical spring constant per convolution of bellows The theoretical spring constant per convolution of the bellows is in accordance with the following:

$$f_{ir} = \frac{1.7d_p E_b t_p^3 n}{(W - kq)^3 C_f} \dots\dots\dots (25)$$

3.4.3 Permissible number of repetitions of bellows The permissible number of repetitions of the bellows is in accordance with the following:

$$S_t = 0.7 (S_{mmp} + S_{mbp}) + (S_{mmd} + S_{mbd}) \dots\dots\dots (26)$$

(1) Permissible number of repetitions of bellows without reinforcing rings

$$N_c = \left(\frac{8356T_f}{S_t - 242.6} \right)^{3.4} \dots\dots\dots (27)$$

(2) Permissible number of repetitions of bellows with reinforcing rings

$$N_c = \left(\frac{21442T_f}{S_t - 175.1} \right)^{2.9} \dots\dots\dots (28)$$

(3) It shall be $N_c \geq N_s$.

(4) The formula (27) and formula (28) apply only to the austenitic stainless steels and high nickel alloys.

(5) The Tables 3 and 5 in the text are designed under the conditions of the bellows material SUS304, design temperature 220°C, design pressure 1 MPa and design specification number of repetitions (N_s) 1000 times in accordance with the calculation formulae 3.3 and 3.4.

3.4.4 Design limit pressures In the case other than the bellows with adjusting rings, the pressure values P_s obtained from the following formulae shall be the maximum working pressure or over. When the buckling preventing device is installed, this is exempted from application.

- Remarks
1. The number of convolutions (N) of the universal type pipe joint is defined as the sum of the number of convolutions of respective bellows.
 2. Since the adjusting ring is so constructed as to not only function as the reinforcing ring but also limit the movement of the bellows in compressing direction and prevent buckling, the bellows with adjusting rings do not require this calculation.

(1) Bellows without reinforcing rings

$$P_s = \frac{0.3\pi f_{iu}}{N_q^2} \dots\dots\dots (29)$$

(2) Bellows with reinforcing rings

$$P_s = \frac{0.3\pi f_{ir}}{N_q^2} \dots\dots\dots (30)$$

3.5 Strength calculation formulae II of bellows (Kellogg's formula)

3.5.1 Calculating formulae of stress values due to pressure and evaluation standards The calculating formulae of stress values due to pressure and the evaluation standards are in accordance with the following. And the shapes of the applicable bellows shall be those within the following range (see Informative reference 1 Figs. 1 and 2):

$$\frac{W}{3} \leq \frac{q}{2} < W$$

- (1) Stress due to pressure of bellows without reinforcing rings and restriction of stress value

$$S_p = \frac{PW^2}{2nt^2} \dots\dots\dots (31)$$

S_p obtained from the formula (31) shall not exceed the yield point or 0.2 % proof stress (S_y) of the bellows material at the design temperature. Where, S_y is the value referring to the Attached Table 5.2 of JIS B 8270.

- (2) Stress due to pressure of bellows with reinforcing rings and restriction of stress value

$$S_p = \frac{PW}{nt} \dots\dots\dots (32)$$

The value (S_p) of stress due to pressure obtained from formula (32) shall not exceed the permissible stress (S_h) of bellows material at the design temperature. Where, S_h is the value referring to the fundamental permissible stress of the bellows materials at the design temperature in Attached Tables 1.1, 1.2 and 2.1 of JIS B 8270.

3.5.2 Calculating formula of stress value due to total movement per convolution of bellows and stress evaluation formula The calculating formula of the stress value due to the total movement per convolution of the bellows and the stress evaluation formula are in accordance with the following:

- (1) Stress due to total movement per convolution of bellows (irrespective of presence of reinforcing rings)

$$S_d = \frac{0.75E_bte}{(0.5q)^{0.5}W^{1.5}} \dots\dots\dots (33)$$

- (2) Permissible number of repetitions of bellows

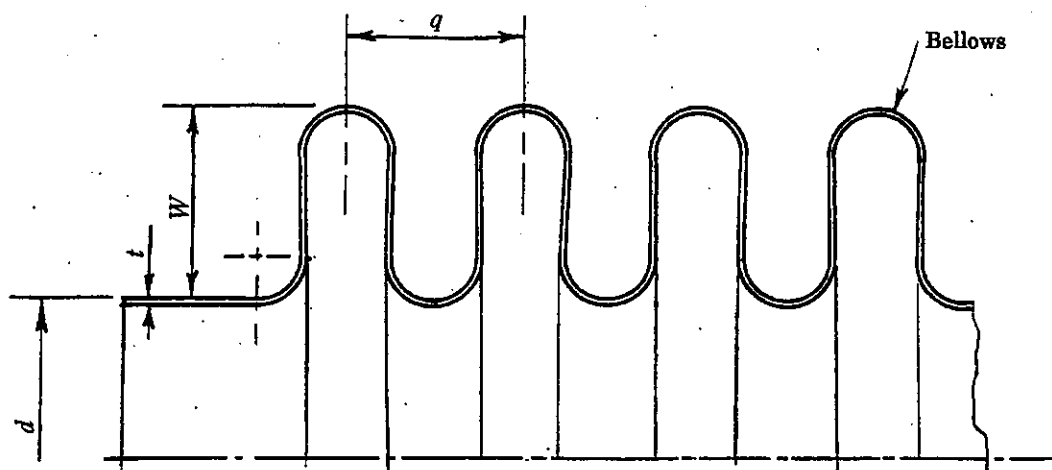
$$N_c = \left(\frac{11033}{S_p + S_d} \right)^{3.5} \dots\dots\dots (34)$$

The permissible number of repetitions (N_c) of the bellows calculated from formula (34) shall be the design specification number of repetitions (actual number of repetitions) (N_s) or over.

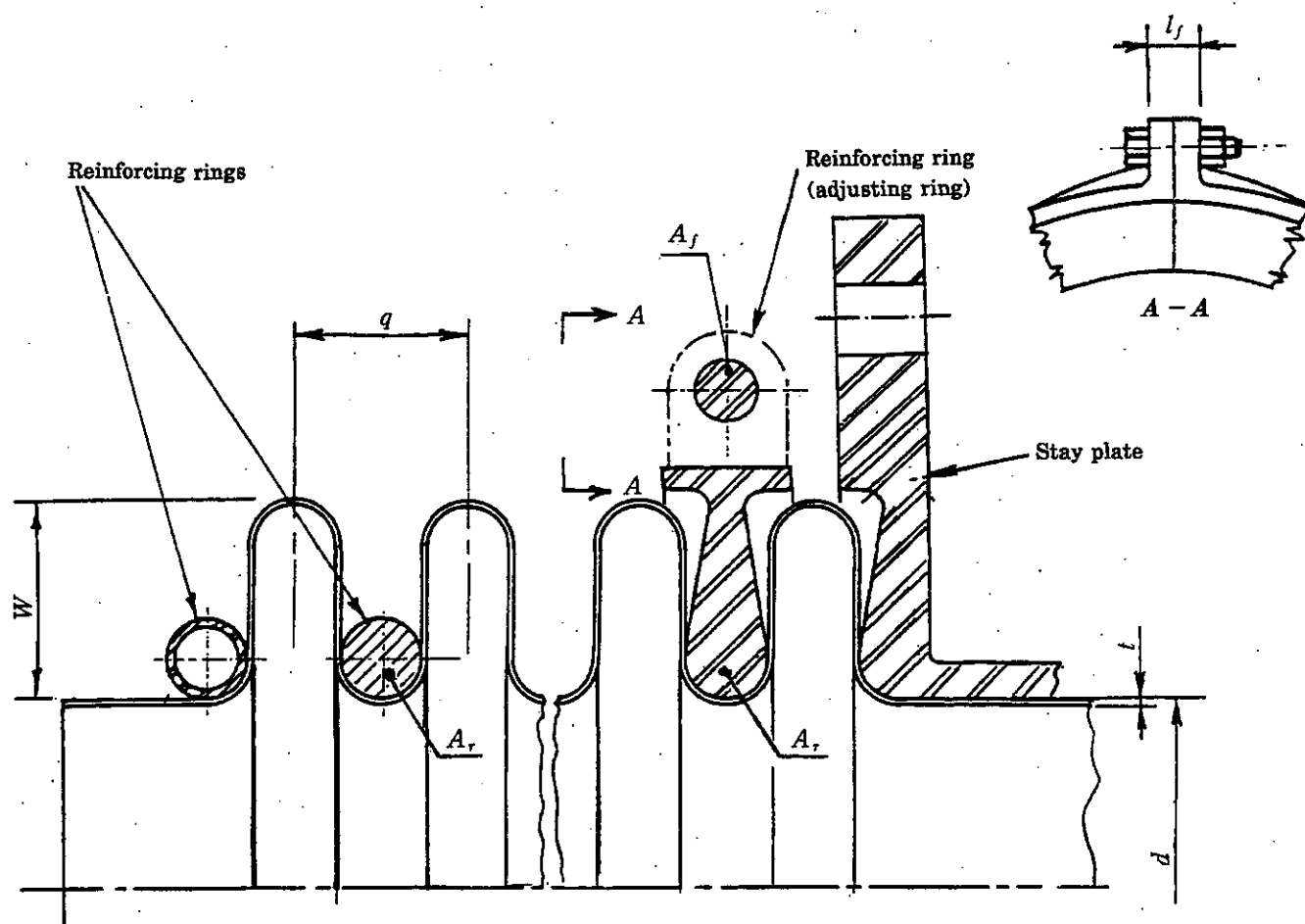
The formula (34) applies only to the austenitic stainless steels and high nickel alloys.

3.6 Confirmation on movement range of bellows As to the bellows with adjusting rings, the calculated value of the dimension of the clearance between the adjusting ring and the stay plate or the dimension of clearance between the adjusting rings each other, and as to the bellows other than this, the movement on the contracted side of the bellows, shall be confirmed that these are not exceeding the limit movement per convolution defined by the pipe joint manufacturer.

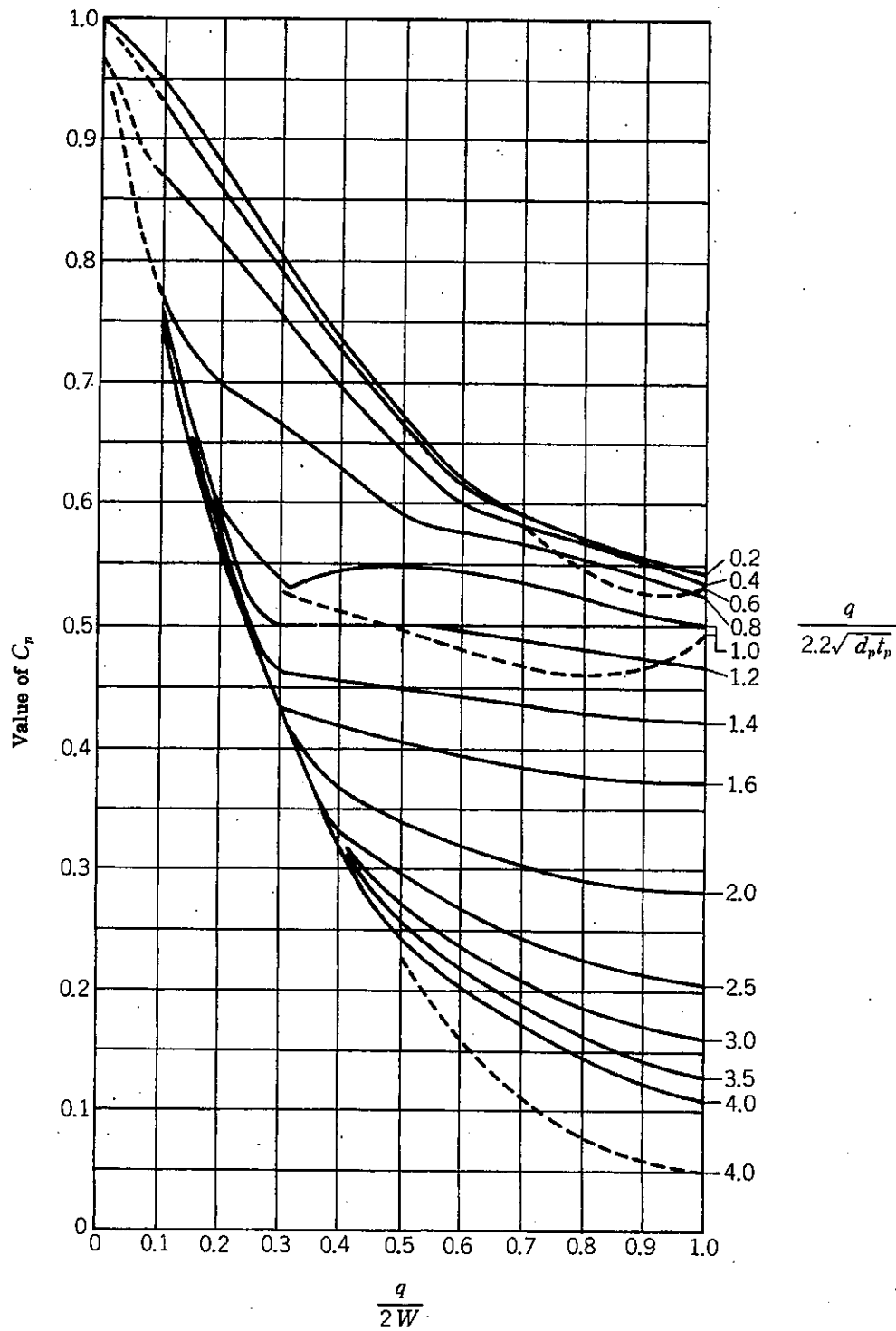
Informative reference 1 Fig. 1. Dimensions of respective parts of bellows without reinforcing rings



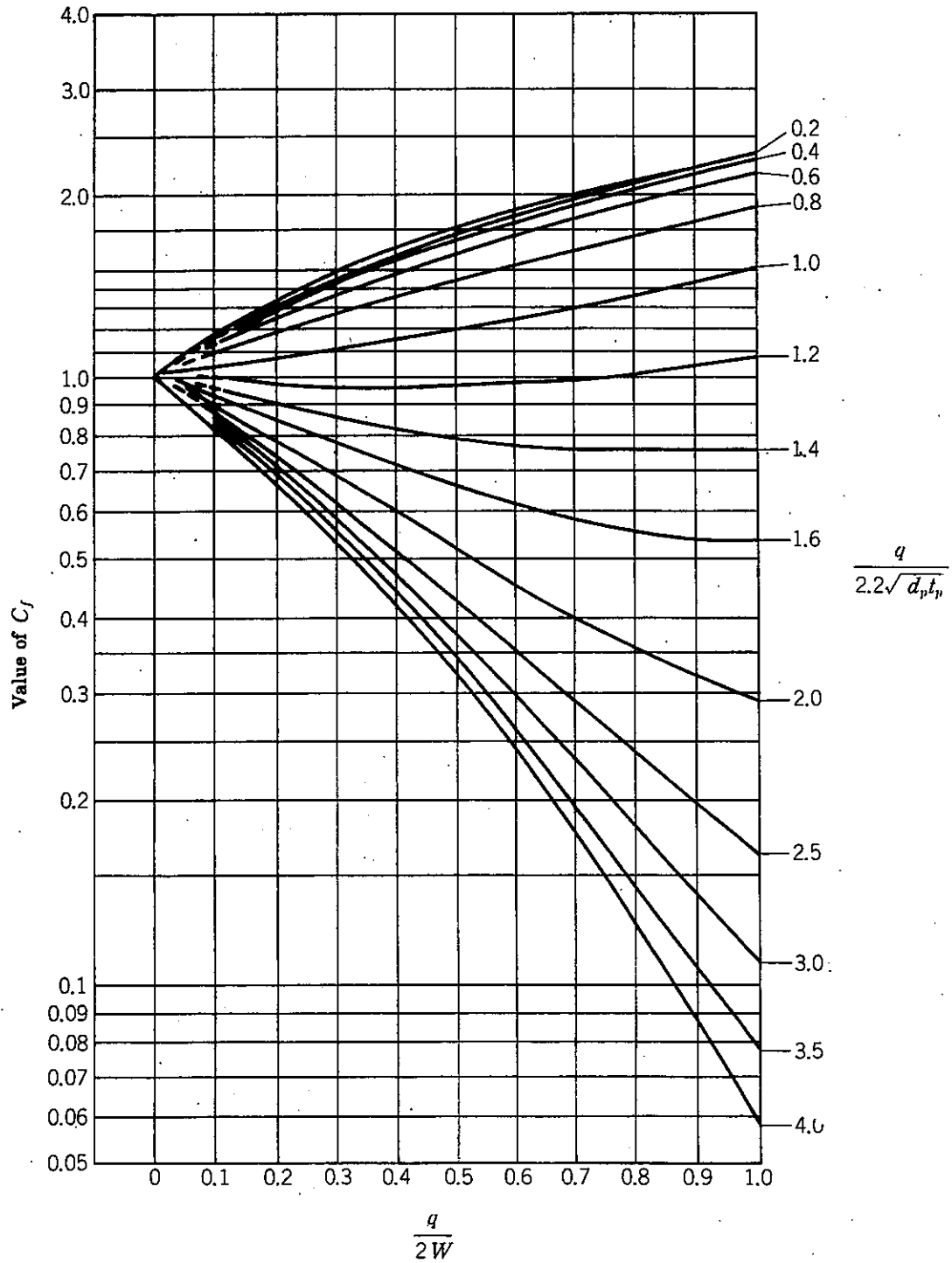
Informative reference 1 Fig. 2. Dimensions of respective parts of bellows with reinforcing rings



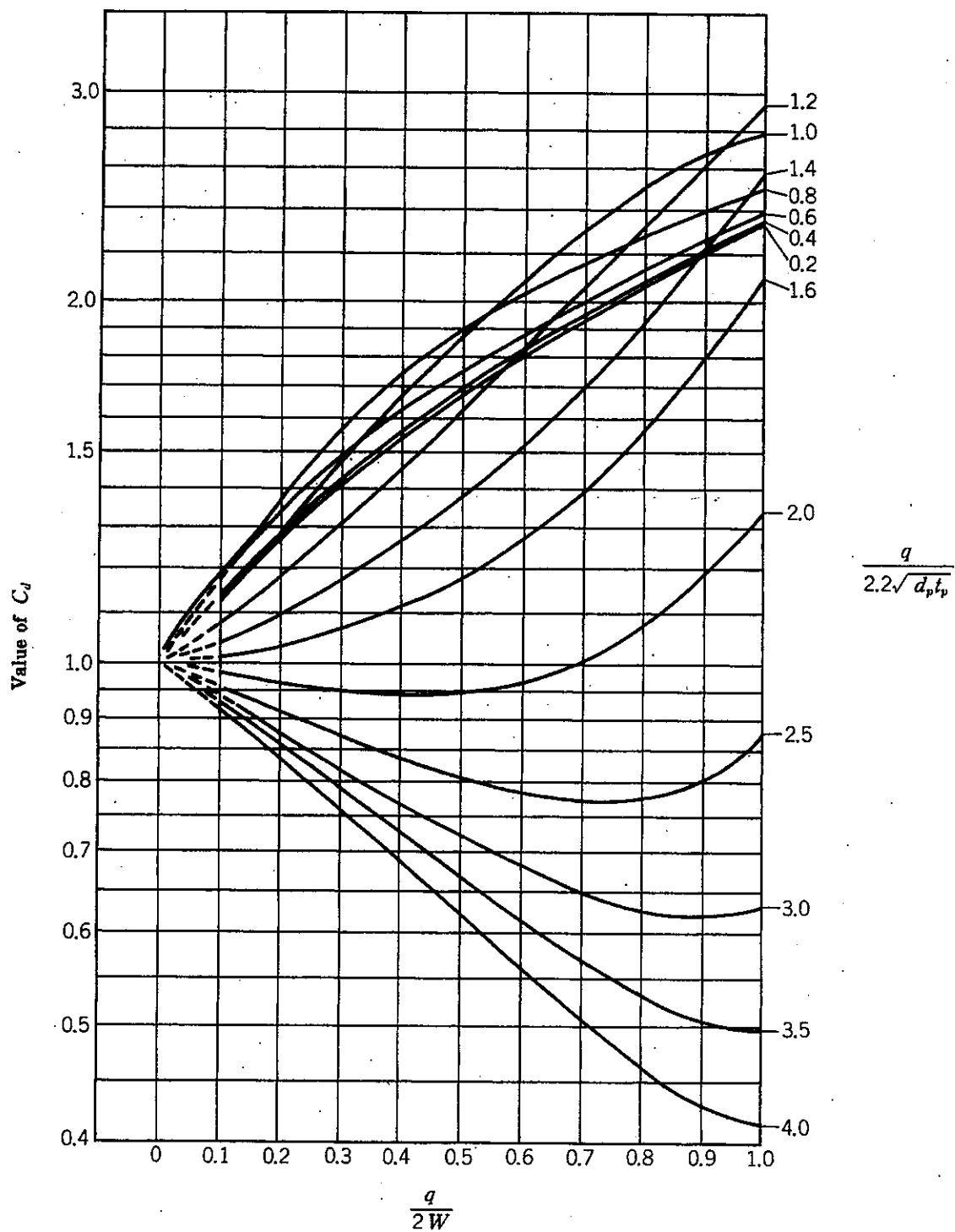
Informative reference 1 Fig. 3. Correction coefficient of bending stress calculation of bellows due to pressure (C_p)



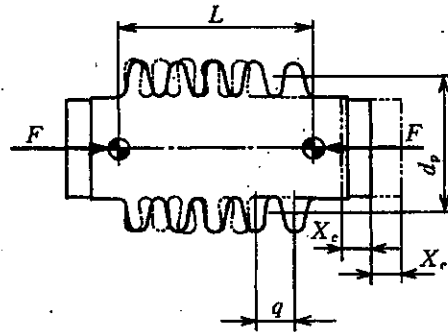
Informative reference 1 Fig. 4. Correction coefficient of membrane stress calculation of bellows due to movement (C_f)



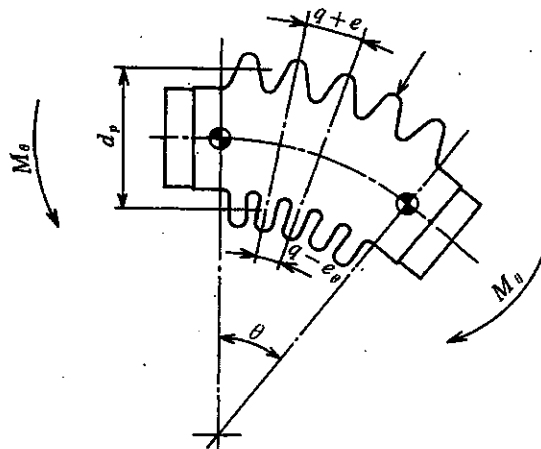
Informative reference 1 Fig. 5. Correction coefficient of bending stress calculation of bellows due to movement (C_d)



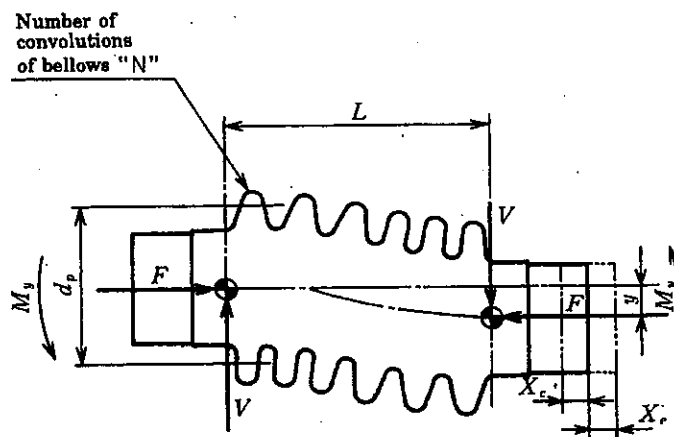
Informative reference 1 Fig. 6. Deformed state of bellows at the displacement in axial direction (X) and points of application ($\odot$) of external forces (F)



Informative reference 1 Fig. 7. Deformed state of bellows at the displacement in axial bending (θ) and points of application ($\odot$) of bending moment (M_θ)

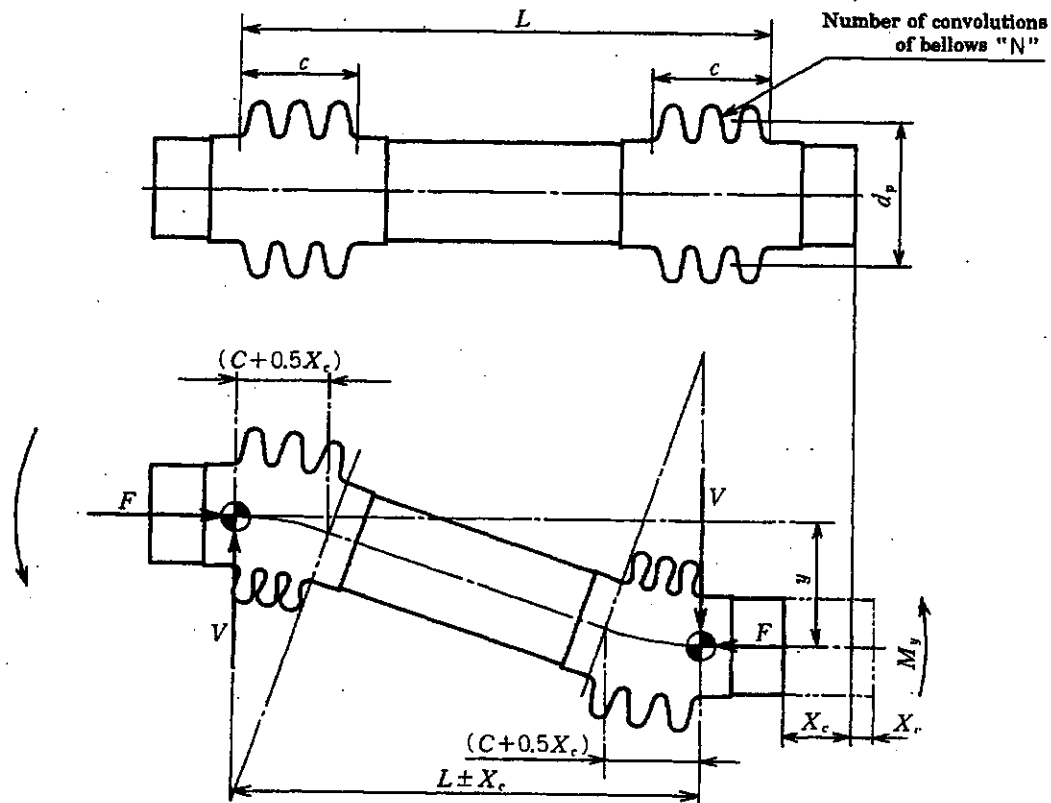


Informative reference 1 Fig. 8. Deformed state of single style bellows at the displacements in axial direction (X) and lateral direction (Y), and points of application ($\odot$) of external forces (F , V) and bending moment (M_y)



Number of
convolutions
of bellows "N"

Informative reference 1 Fig. 9. Deformed state of double style bellows (universal type) at the displacements in axial direction (X) and lateral direction (Y), and points of application ($\odot$) of external forces (F , V) and bending moment (M_y)



Informative reference 2 Installation standards
for bellows type expansion joints

This informative reference describes the matters to be attended and installation standards for the design and execution in the case where not only the bellows type expansion joints of nominal pressure 10 K specified in the text but also those of other nominal pressures and of different construction (universal type, hinged type, gimbal type, etc.) are used for the pipings, and it does not constitute a part of provisions.

1. Scope This informative reference indicates the necessary installation standards for the design and execution of pipings using the bellows type expansion joints (hereafter referred to as "pipe joints") to be used for absorbing the displacement of the pipes in axial direction, in lateral direction, axial bending, etc. resulting from temperature changes in the pipings of steam, air, gas, water, oil or the like.

Remarks: The pipe joints corresponding to this informative reference are the bellows type expansion joints specified in JIS B 0151.

2. Symbols The symbols to be used in this informative reference are in accordance with 3.2 of Informative reference 1 and the following:

- f_w : spring constant per convolution of bellows (N/mm)
- f_e : spring constant per convolution of bellows by experiment (N/mm)
- f : spring constant per convolution of bellows by Kellogg's formula (N/mm)
- X_s : preset quantity in axial direction (elongation is expressed in positive figure, and contraction in negative figure) (mm)
- Y_s : preset quantity in lateral direction (positive side direction is expressed in negative figure, and the reverse in positive figure) (mm)
- θ_s : preset quantity in axial bending (positive side direction is expressed in negative figure, and the reverse in positive figure) (rad)
- F : reaction force to axial displacement (N)
- V : reaction force to lateral displacement (N)
- M_y : reaction bending moment of bellows to lateral displacement (N·m)
- M_θ : reaction bending moment of bellows to axial bending displacement (N·m)
- F_M : spring reaction of bellows (F or V) (N)
- F_S : $aP\{0.01 aP\}$, static thrust due to internal pressure of pipe joint (N)
- a : $0.25 \pi d_p^2$, effective cross sectional area of bellows (mm²)
- F_G : frictional force of pipe guiding device (N)
- F_{MA} : load which acts on the main anchor of straight pipe part (N)
- α : angle between the centerline of curved pipe and that of straight pipe (°)

- F_{MA1} : load which acts on the main anchor on the upstream side of curved pipe (N)
- F_{MA2} : load which acts on the main anchor on the downstream side of curved pipe (N)
- F_{MB} : load which acts on the main anchor of curved pipe (N)
- F_{IA} : load which acts on the intermediate anchor (N)
- D : outside diameter of pipe (mm)
- L_1 : interval between No. 1 pipe guiding device and the pipe joint (mm)
- L_2 : interval between No. 1 pipe guiding device and No. 2 pipe guiding device (mm)
- L_3 : interval between the intermediate pipe guiding devices (mm)
- E_p : Young's modulus of material of pipe at design temperature (N/mm²)
- I_p : geometrical moment of inertia of pipe cross section (mm⁴)
- Δl : thermal expansion or contraction in length of pipe (mm)
- β : linear expansion coefficient of pipe (°C⁻¹)
- T : maximum working temperature of pipe (maximum design temperature) (°C)
- t_1 : minimum working temperature of pipe (minimum design temperature) (°C)
- t_2 : air temperature at the time of attaching pipe joint (°C)
- l : length of piping (mm)
- L_s : attaching face-to-face length of pipe joint (mm)
- L_e : maximum face-to-face length of pipe joint (mm)
- δ : maximum axial displacement of pipe joint (mm)
- n_e : number of pipe joints

3. Reaction force and reaction bending moment of bellows

3.1 Calculation formulae of reaction force and reaction bending moment of bellows

3.1.1 Spring constant per convolution of bellows For the spring constant per convolution (f_w) of bellows, the spring constant per convolution of the bellows by experiment (f_e) or the theoretical spring constant per convolution of the bellows ⁽¹⁾ is used.

Note ⁽¹⁾ For the bellows without reinforcing rings, f_{iu} of the formula (14) of Informative reference 1 is used, and for the bellows with reinforcing rings, f_{ir} of the formula (25) is used.

3.1.2 Movement per convolution of bellows The movement per convolution of bellows for obtaining the reaction force and reaction bending moment of the bellows is obtained in accordance with the following calculation formulae.

Remarks: The values of the movement per convolution (e_x , e_y , e_θ) are applicable to the calculation for obtaining the reaction force or reaction bending moment, and not applicable to the calculation for obtaining the permissible number of repetitions of bellows given in 3. of Informative reference 1.

- (1) The value X of larger one of $X = X_c + X_s$ or $X = X_c + X_s$ is used.

$$e_x = \frac{X}{N} \quad \text{Single style bellows}$$

$$e_x = \frac{X}{2N} \quad \text{Double style bellows}$$

- (2) The value Y of larger one of $Y = Y_n + Y_s$ or $Y = Y_n + Y_s$ is used.

$$e_y = \frac{3d_p Y}{N(L + X)} \quad \text{Single style bellows}$$

$$e_y = \frac{Kd_p Y}{2N(L - C + 0.5X)} \quad \text{Double style bellows (universal type)}$$

- (3) The value θ of larger one of $\theta = \theta_n + \theta_s$ or $\theta = \theta_n + \theta_s$ is used.

$$e_\theta = \frac{d_p \theta}{2N}$$

3.1.3 Reaction force of bellows to axial displacement The reaction force of bellows to axial displacement is in accordance with the following:

$$F = f_w e_x$$

3.1.4 Reaction force of bellows to lateral displacement The reaction force of bellows to lateral displacement is in accordance with the following:

$$V = \frac{f_w d_p e_y}{2L}$$

3.1.5 Reaction bending moment of bellows The reaction bending moment of bellows is in accordance with the following:

- (1) To lateral displacement

$$M_y = \frac{f_w d_p e_y}{4000}$$

- (2) To axial bending displacement

$$M_o = \frac{f_w d_p e_o}{4000}$$

3.1.6 Reaction forces of bellows of pressure balanced type pipe joints The reaction forces of bellows of pressure balanced type pipe joints are in accordance with the following:

- (1) In case of the axial displacement of the pressure balanced type pipe joint indicated in Fig. 3515-1 of JIS B 0151,

$$F = f_w (e_{x1} + e_{x2}) \text{ (small-diameter bellows)} + f_w e_x \text{ (large-diameter bellows)}$$

Informative reference:

The pressure balanced type pipe joint is constituted of small-diameter

(1) bellows + large-diameter bellows + small-diameter (2) bellows ,

and is so constructed as to absorb the static thrust due to pressure by the restraining device (tie rod or the like). When the small-diameter (1) bellows of this pipe joint is used in single style and the small-diameter (2) bellows in universal type, the movement per convolution of the bellows to axial displacement is e_{x1} on the small-diameter (1) bellows side and e_{x2} on the small-diameter (2) bellows side, and in some cases, the movement per convolution of the both bellows are different. Therefore, the movement per convolution of the small-diameter side bellows of this pipe joint shall be $(e_{x1} + e_{x2})$ (small-diameter bellows).

- (2) In case of axial displacement of the pressure balanced type pipe joint indicated in Fig. 3515-2 of JIS B 0151,

$$F = f_w [e_x \text{ (main-pipe side)} + e_x \text{ (balanced side)}]$$

3.2 Reaction force and reaction bending moment of Kellogg's formula The reaction force and reaction bending moment of the bellows in accordance with 3.5 of Informative reference 1 are obtained as follows:

- (1) As to the spring constant per convolution of the bellows (f_w), f obtained from the Kellogg's formula as given in the following is used.

$$f = \frac{2E_b d_p t^3 n}{3 (0.5q)^{0.5} W^{2.5}}$$

- (2) The movement per convolution of the bellows is in accordance with 3.1.2.
(3) The reaction force of the bellows to axial displacement is in accordance with 3.1.3.
(4) The reaction force of the bellows to lateral displacement is in accordance with 3.1.4.

- (5) The reaction bending moment of the bellows is in accordance with 3.1.5.
- (6) The reaction force of the bellows of the pressure balanced type pipe joint is in accordance with 3.1.6.

4. Anchors, pipe guiding devices and pipe supporting devices

4.1 Main anchors

4.1.1 Positions requiring main anchors In the piping system, the positions given in the following are to be equipped with the main anchors.

- (1) End portion of straight piping equipped with a shut-off plate
- (2) Bent pipe portion where the direction of flow changes
- (3) The portion between the two pipe joints where the pipings diameters are different at the reducer
- (4) The piping portion between the two pipe joints where a valve is installed
- (5) The entrance of a side branch including an unrestrained pipe joints into the main piping

4.1.2 Loads which act on main anchor The main anchor, its accessories and the structures to which these are to be attached (machinery, turbine, compressor or heat exchanger also functions as an anchor) shall be so designed as to withstand the working load derived from summation of corresponding one of the loads caused by the pipe joints, which are different according to the conditions of piping and obtained from the following calculation formulae (1) to (3), and the loads considered in general piping design [which are the loads due to masses of pipings, attachments, insulating materials, fluid or the like, load (F_G) due to frictional force with pipe guiding devices, larger one of wind load or seismic load, etc.]

An example of the design and execution of the piping including pipe joints is given in Informative reference 2 Fig. 1. When such pipe joints (pressure balanced type, gimbal type, hinged type, universal type, etc.) among those specified in JIS B 0151 that restrain the static thrust (F_S) due to internal pressure are used, the load due to the pipe joints can be reduced to the load value acting on the intermediate anchor of 4.2.2.

- (1) Load acting on the main anchor at end portion of straight piping
[the loads acting on the main anchors of (4) and (5) in 4.1.1 are the same as this].

$$F_{MA} = F_S + F_M + F_G = aP + F_M + F_G$$

- (2) Load acting on the main anchor at intermediate straight pipe portion of pipe joints with different diameters

$$\begin{aligned} F_{MA} &= (F_{S1} + F_{M1} + F_{G1}) \text{ (large-diameter pipe side)} \\ &\quad - (F_{S2} + F_{M2} + F_{G2}) \text{ (small-diameter pipe side)} \\ &= (a_1 - a_2)P + (F_{M1} - F_{M2}) + (F_{G1} - F_{G2}) \end{aligned}$$

(3) Load acting on the main anchor at bent pipe portion

$$F_{MB} = (F_{MA1} + F_{MA2}) \sin \frac{\alpha}{2}$$

4.2 Intermediate anchors

4.2.1 Positions requiring intermediate anchors When 2 pieces or over of pipe joints are used between the main anchors in a piping system, an intermediate anchor shall be provided in the middle of respective pipe joints.

4.2.2 Load acting on intermediate anchor

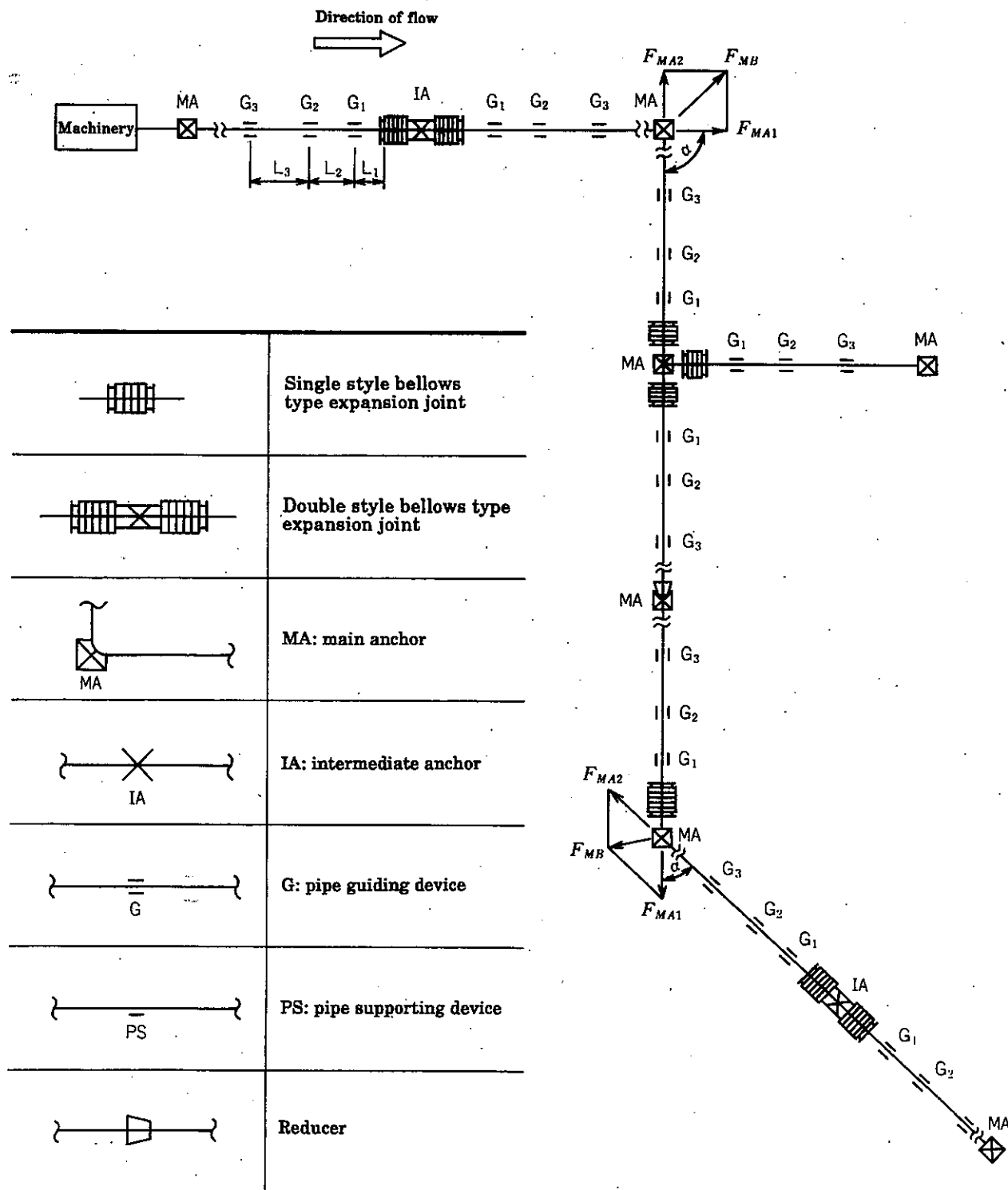
$$F_{IA} = (F_{M1} + F_{G1})_{\text{(upstream side)}} - (F_{M2} + F_{G2})_{\text{(downstream side)}}$$

On the upstream side and downstream side of an intermediate anchor, when the pipes to be connected are equal in diameter and the number of pipe guiding devices on both sides is the same, F_{M2} and F_{G2} are equal to F_{M1} and F_{G1} respectively, and opposite in sign, so that the load acting on the intermediate anchor is zero, $F_{IA} = 0$. However, in some cases, the pipe line is heated gradually from one side, and it results in such a case where one side of the pipe portion expands more than the other pipe portion.

Therefore, when $F_{IA} = 0$, the load acting from either side of the upstream or downstream is necessary to be added to the load considered in the general piping design (details are in accordance with 4.1.2).

Namely, $F_{IA} = F_{M1} + F_{G1}$.

Informative reference 2 Fig. 1. Example of applying pipe joints for absorbing axial displacement of pipe line



4.3 Pipe guiding device

4.3.1 Installing interval of pipe guiding devices for axial displacement In the piping using the pipe joints for absorbing axial displacement, the pipe guiding devices (G) shall be installed to align pipe joint and pipe and transmit the force necessary for axial movement smoothly.

As given in Informative reference 2 Fig. 2, the installing intervals of respective pipe guiding devices such as the interval (L_1) from the pipe joint to No. 1 pipe guiding device, the interval (L_2) to No. 2 pipe guiding device and the interval (L_3) to the intermediate pipe guiding device shall not exceed the interval values obtained from the calculating formulae given in the following (1) to (3).

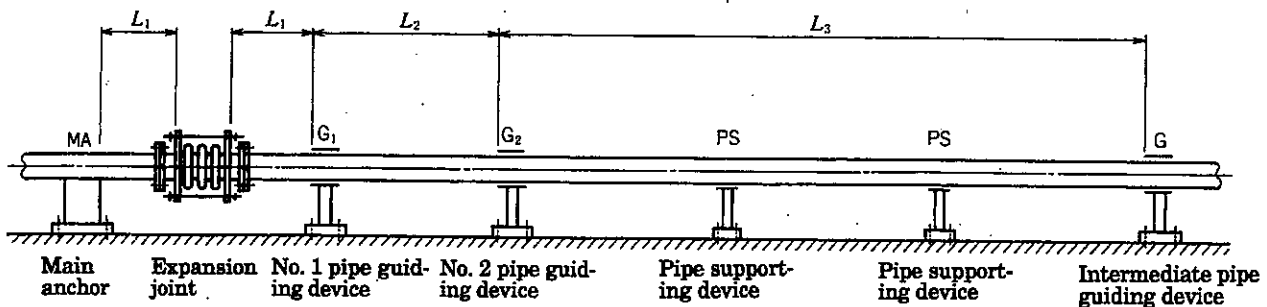
Remarks: As to the pipings using the carbon steel pipes for pressure pipings, when the pipe joints only for axial displacement are used, the intervals of the intermediate pipe guiding devices may be obtained from Informative reference 2 Fig. 3 instead of the calculation of (3).

$$(1) \quad L_1 \leq 4D$$

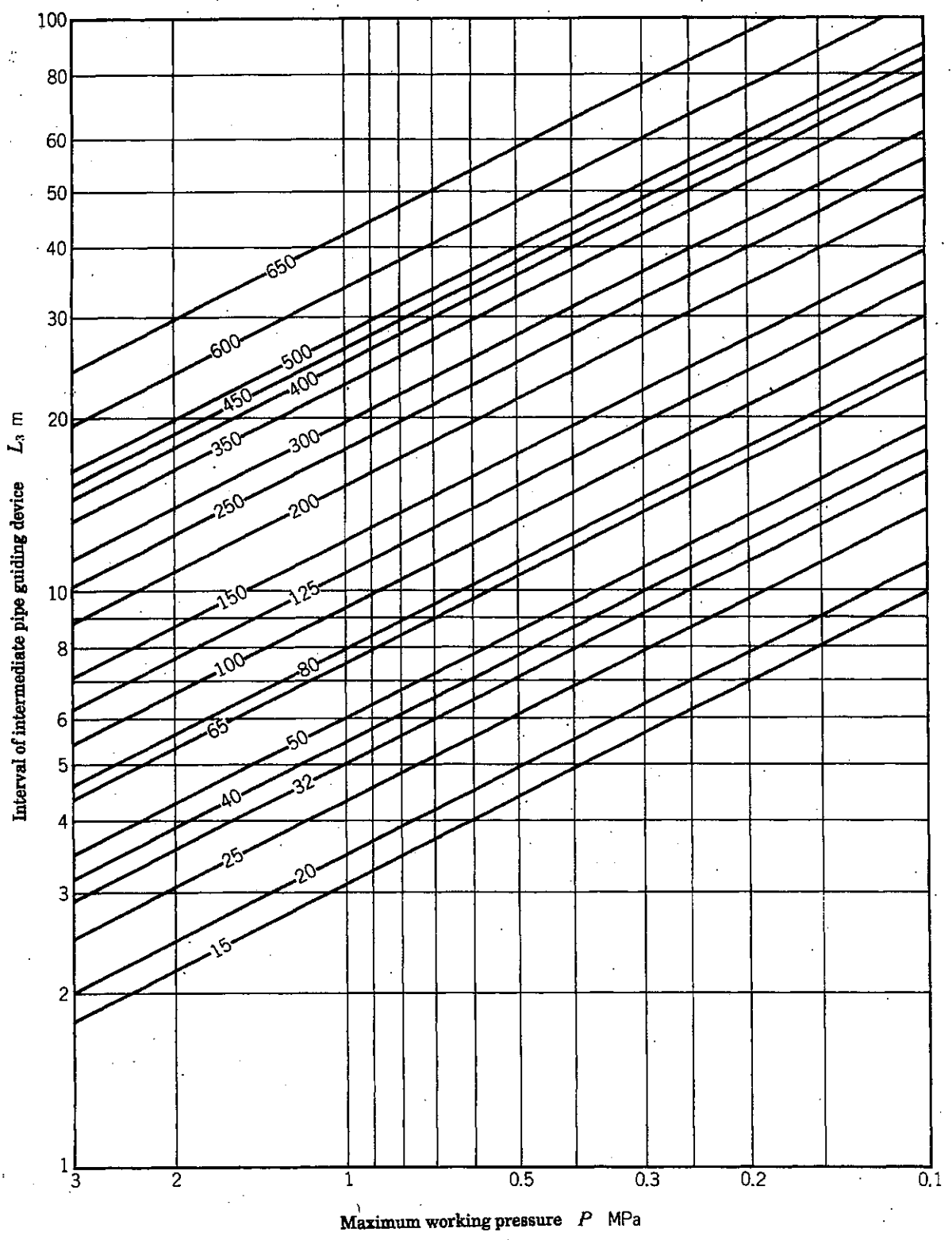
$$(2) \quad L_2 \leq 14D$$

$$(3) \quad L_3 \leq 0.00157 \left(\frac{E_p I_p}{F_s + F_M} \right)^{0.5}$$

Informative reference 2 Fig. 2. Installation intervals of pipe guiding devices for axial displacement

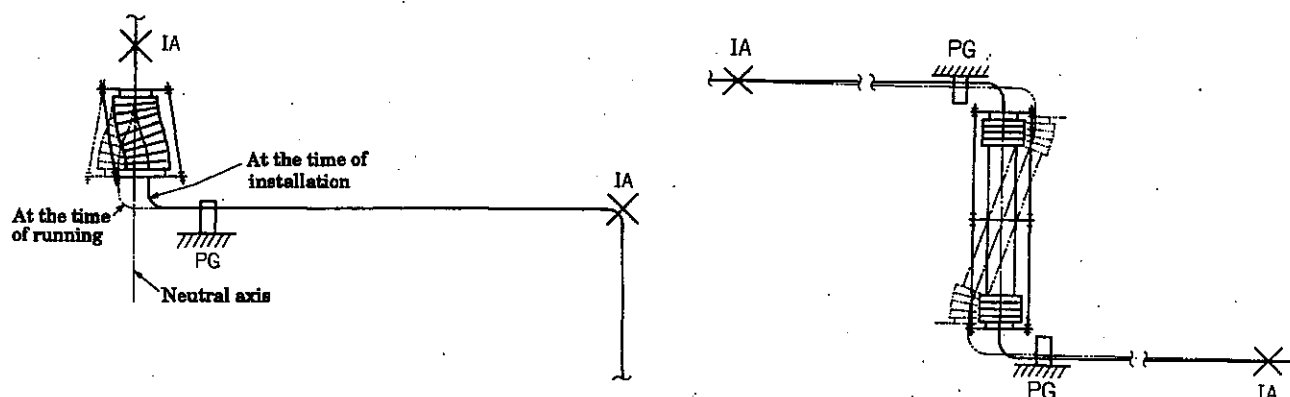


Informative reference 2 Fig. 3. Maximum intervals of intermediate pipe guiding device according to nominal diameters of pipes

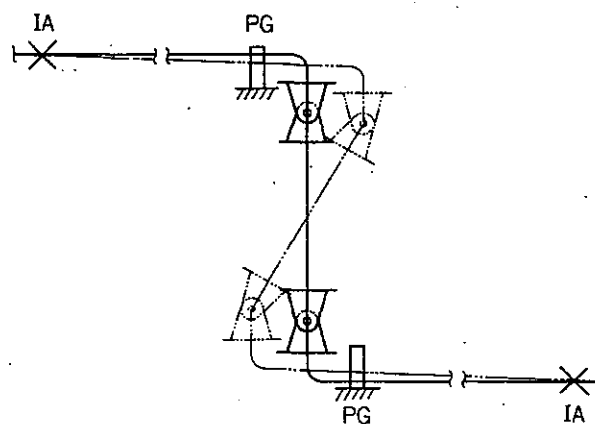


4.3.2 Installation of pipe guiding device for lateral displacement In the pipings using the pipe joint to absorb lateral displacement, it is necessary to install a planar pipe guiding device (PG) which permits the deflection of the pipe or the movement of the pipe resulting from absorption of lateral displacement and controls the direction as given in Informative reference 2 Fig. 4, in order to cope with the change in length of the pipe joint at the position where the pipe joint has been displaced laterally.

Informative reference 2 Fig. 4. Installation of pipe guiding device for lateral displacement



	Bellows type expansion joint with rods
	Universal bellows type expansion joint
	Hinged bellows type expansion joint
	IA: intermediate anchor
	PG: planar pipe guiding device



4.4 Pipe supporting device The pipings shall be installed with the anchors, pipe supporting devices, and the pipe supporting devices (U-bolts, roller supports, spring hangers, etc.) for supporting the self mass of the pipings and the fluid included therein.

The pipe supporting devices are installed in the gist as given in Informative reference 2 Fig. 2 considering the deflection between pipe guiding devices due to the self mass of the pipings.

5. Installation of pipe joints

5.1 Number of installing pipe joints The thermal expansion or contraction length of the piping is obtained from (1) of the following according to the temperature conditions of fluid, the air temperatures of the place where the piping is to be installed, the piping materials and piping lengths, and the number of installing pipe joints is obtained in accordance with (2).

- (1) Thermal expansion or contraction length of piping (Δl) The linear expansion coefficient (β) of piping is in accordance with Attached Table 4.2 of JIS B 8270.

$$\Delta l = \beta (T - t_1) l$$

- (2) The number of pipe joints (n_e) The maximum axial displacement (δ) of pipe joint is in accordance with Tables 2 to 5 in the text.

$$n_e = \frac{\Delta l}{\delta}$$

5.2 Preset of pipe joint The preset of the pipe joint is in accordance with the following:

- (1) The manufacturer of the pipe joints shall design the pipe joints, including the preset specifications necessary for installation.
- (2) The pipe joints shall be installed, adjusting the positions to be installed in advance, under the conditions in accordance with the preset specifications.

5.2.1 Adjustment of attaching face-to-face dimension by preset in axial direction Since the thermal elongation of the piping is absorbed by the contraction of the pipe joint, and the thermal contraction is absorbed by the elongation of the pipe joint, prior to attaching the pipe joint the attaching face-to-face length is obtained from the following formula, considering the preset quantity, by the air temperature at the time of attaching, working temperature range and the maximum axial displacement:

$$L_s = L_e - \delta \frac{t_2 - t_1}{T - t_1}$$

5.2.2 Adjustments of preset in lateral direction and preset in axial bending
When the thermal expansion or contraction of pipings are absorbed by lateral displacement and axial bending displacement of pipe joints, the necessary preset specifications for the pipe joint is obtained with being included in the pipe joint design, considering the restrictions on the construction of the pipe joint (the clearance between neighboring adjusting rings, clearance between the inner cylinder and the end pipe, contact of the moving portion of restraining device supporting point, etc.), load restriction of pipe joint, etc.

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