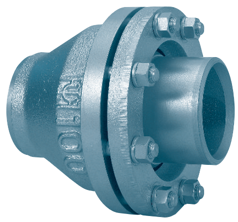
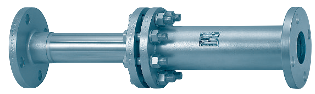
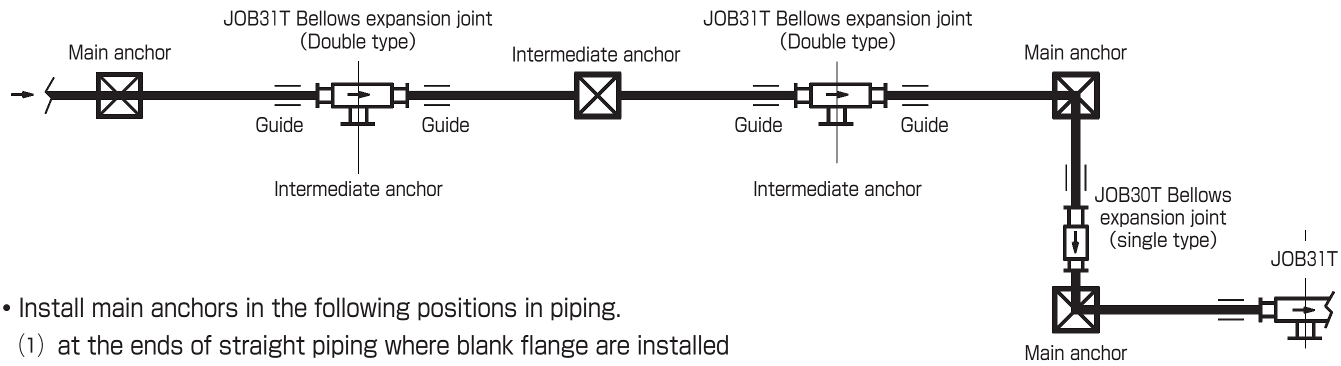
Comparison Table for Expansion Joints

Item \ Type		Bellows expansion joint	Ball joint	Sleeve expansion joint
Appearance		JOB30T・31T Bellows expansion joint 	J102 Ball joint 	Yubar Joint 
Code		Appendix 4 of JIS B 2352	SHASE-S 007	SHASE-S 003
Seal method		Bellows seal	Packing seal	Packing seal
Absorption method		Expansion of bellows	Rotation of ball	Sliding of sleeve
Expansion amount		Normal (Due to limited bellows length)	Large	Large
Lifetime		Short (Depending on operating condition)	Long	Long
Deterioration by long term use		Big (Fatigue of bellows)	Medium	Small (Almost nil)
Applicable pressure test		Low (Depending on bellows characteristics)	High	High
Repair for leakage		Replace by new products	Retightening or replace packing	Retightening or replace packing
Pitting corrosion		May occur	No	No
Direction absorbed	Axial	○	○	○
	Rotation	×	○	○
	Bending	×	○	×
Note		Intermediate anchor of expansion joint is fixed for duplex type	Cooperate with 2 or 3 joints	Suitable for longer piping

Remark SHASE : The Society of Heating, Air-Coditioning and Sanitary Engineers of Japan.

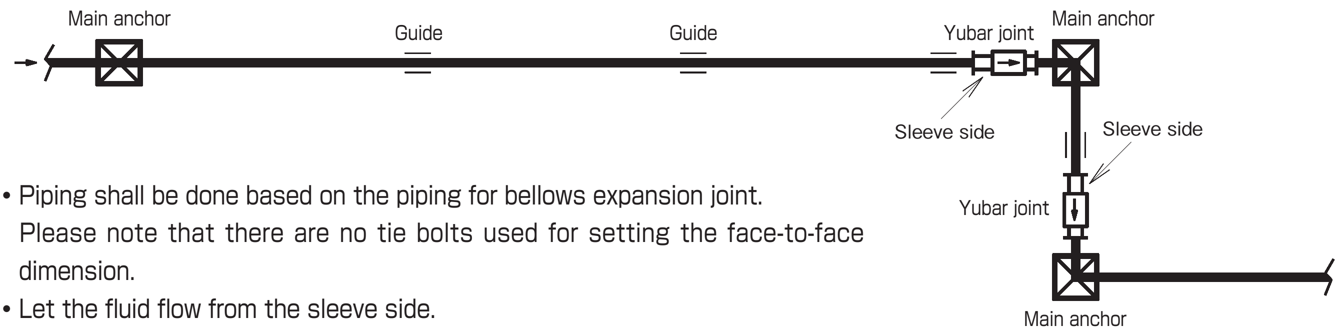
Piping example

Bellows expansion joint



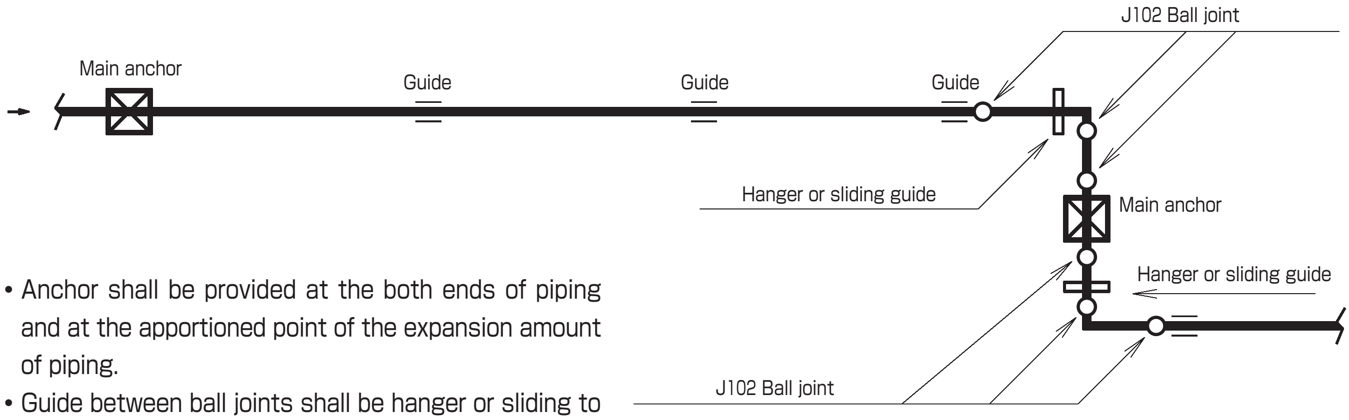
- Install main anchors in the following positions in piping.
  (1) at the ends of straight piping where blank flange are installed
  (2) at bending section where flow direction changes
  (3) in between two expansion joints where piping diameter changes due to the use of a reducer
  (4) in the valve section with a valve installed at the piping section between two expansion joints
  (5) at the inlets of the branch piping with unrestricted expansion joints
- If two or more expansion joints are used between main anchors in piping, intermediate anchor should be provided between expansion joints.
- A single type expansion joint should be installed near the anchor, at either the upstream side or the downstream side.
- Guides should be installed, in order to align the expansion joints and the pipes, and to convey axial force to anchor correctly. As for intervals of guides, refer to page 196 or appendix 3 of JIS B 2352.
- Do not remove tie plates (size : 20—250) or the tie bolts (size : 300—500) used for setting the face-to-face dimensions during hydrostatic tests. They must be removed after the test.

Yubar joint (Sleeve expansion joint)



- Piping shall be done based on the piping for bellows expansion joint. Please note that there are no tie bolts used for setting the face-to-face dimension.
- Let the fluid flow from the sleeve side.
- In principle, Yubar joint should be installed near the anchor in the downstream side.

Ball joint



- Anchor shall be provided at the both ends of piping and at the apportioned point of the expansion amount of piping.
- Guide between ball joints shall be hanger or sliding to cope horizontal movement.

Point of calculation

1 Anchor force

The force on the anchors of bellows expansion joints should be calculated by the force on the anchors in appendix 3 of JIS B 2352 or the following fomulas.

●Main anchor force at straight piping

Bellows expansion joint	Yubar joint	Ball joint
$Fm=Fp+Fk$ ⋯⋯⋯⋯⋯⋯ (1) $Fp=100P\times Ae$ ⋯⋯⋯⋯⋯ (2) $Fk=K\times\delta$ ⋯⋯⋯⋯⋯⋯ (3) $Ft=150P\times Ae$ ⋯⋯⋯⋯⋯ (4)	$Fm=Fp+M$ ⋯⋯⋯⋯⋯⋯ (5) $Fp=100P\times Ae$ ⋯⋯⋯⋯⋯ (6)	Refer to following description

Remark : The force on the main anchors of bellows expansion joints should be the value calculated by formula (1) or formula (4), whichever is larger.

●Main anchor force at bent piping

$Fb=2Fm\sin\frac{\theta}{2}$ or $(Fm_1+Fm_2)\sin\frac{\theta}{2}$ ⋯⋯⋯ (7)

Following force shall be added at fluid of large specific gravity or high velocity.

$Fv=2\times10^{-4}\times Ap\rho v^2\sin\frac{\theta}{2}$ ⋯⋯⋯ (8)

●Intermediate anchor force

For bellows expansion joint $Fk\fallingdotseq K\times\delta$ ⋯⋯⋯ (9)

Remark : For δ, the larger displacement of both sides should be applied.

For Yubar joint M

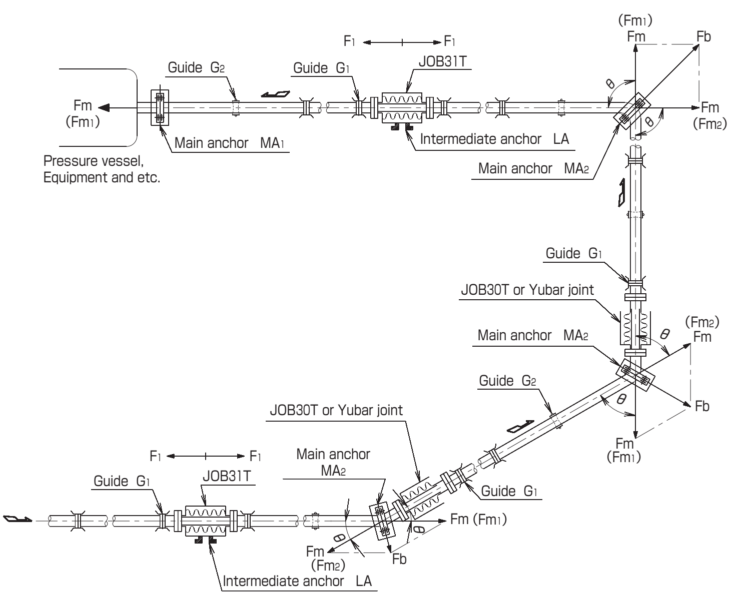


Fig. 1 Force and direction working on main anchor and intermediate anchor

Fm	: Fm_1, Fm_2 Anchor force (Straight piping)	N
Fb	: Anchor force (Bent piping)	N
F_T	: Force on the main anchors (during hydrostatic test)	N
F_1	: Intermediate anchor force	N
Fp	: Static thrust due to internal pressure in the expansion joint	N
Fk	: Force by contraction	N
Fv	: Force by centrifugal force of fluid	N
P	: Fluid pressure	MPa
K	: Spring constant of bellows	N/mm
Ae	: Effective area of bellows	cm^2
Ap	: Sectional area of pipe	cm^2
δ	: Expansion amount	mm
θ	: Angle of bent pipe	℃
ρ	: Density of fluid	kg/m^3
v	: Velocity of fluid	m/s
g	: Gravity acceleration	$980cm/s^2$
M	: Statical friction force of Yubar joint	N

●Notice for anchor design

(1) Anchor shall be designed with enough strength to endure above mentioned force.
Anchor shall endure against vibration due to steam hammer or water hammer.

(2) Anchor may be damaged by piping vibration due to steam hammer or water hammer.
Piping guide shall be provided sufficiently to prevent amplification of piping vibration or provide sufficient strength on main anchor.

Point of calculation

Table 1. Axial force on main Anchor

Type	Item \ Size	20	25	32	40	50	65	80	100	125	150	200	250	300	350	400	450	500
Bellows expansion joint	Effective area of bellows Ae cm^2	9.6		15.0	19.9	33.6	50.8	74.5	118	196	275	446	649	903	1099	1419	1780	2182
	Spring constant K N/mm	101		93	82	79	80	135	169	200	273	348	834	585	645	733	821	909
	Force by design pressure 1.0MPa Fp N	960		1500	1990	3360	5080	7450	11800	19600	27500	44600	64900	90300	109900	141900	178000	218200
	Force by max. contraction 25mm Fk N	2525		2325	2050	1975	2000	3375	4225	5000	6825	8700	20850	14625	16125	18325	20525	22725
	Resultant force at design pressure Fm=Fp+Fk N	3485		3825	4040	5335	7080	10825	16025	24600	34325	53300	85750	104925	126025	160225	198525	240925
	Force by test pressure 1.5MPa F_T N	1440		2250	2985	5040	7620	11175	17700	29400	41250	66900	97350	135450	164850	212850	267000	327300
Yubar joint	Effective area of bellows Ae cm^2	—	8	12.9	16.6	26.4	42.4	58.1	95	143.1	203.6	346.2	530.9	754.8	—	—	—	—
	Thrust by internal pressure 1.0MPa Fp N	—	800	1300	1700	2700	4300	5900	9500	14400	20400	34700	53100	75500	—	—	—	—
	Thrust by internal pressure 2.0MPa Fp N	—	1600	2600	3400	5300	8500	11700	19000	28700	40800	69300	106200	151000	—	—	—	—
	Thrust by internal pressure 3.0MPa Fp N	—	2400	3900	5000	8000	12800	17500	28500	43000	61100	104000	159300	226500	—	—	—	—
	Statical friction force M N	—	3000	3750	4500	6000	7500	9000	12000	15000	18000	24000	30000	36000	—	—	—	—
J102 Ball joint (1)	Thrust at ℓ =1m F_1 N	200		300	400	600	800	1000	1800	2800	4200	8000	12000	17600	—	—	—	—
	Thrust at ℓ =2m F_1 N	100		150	200	300	400	500	900	1400	2100	4000	6000	8800	—	—	—	—
	Thrust at ℓ =3m F_1 N	70		100	140	200	270	340	600	940	1400	2670	4000	5870	—	—	—	—
	Thrust at ℓ =4m F_1 N	50		80	100	150	200	250	450	700	1050	2000	3000	4400	—	—	—	—
	Thrust at ℓ =5m F_1 N	40		60	80	120	160	200	360	560	840	1600	2400	3520	—	—	—	—
	Force at (2) x =1m F_2 N	10	30	60	80	180	390	640	1480	2760	5100	13420	28040	51580	—	—	—	—
	Force at (2) x =2m F_2 N	2.0	3.0	7.0	10	30	50	80	190	350	640	1680	3510	6450	—	—	—	—
	Force at (2) x =3m F_2 N	1.0		2.0	3.0	10	20	30	60	110	190	500	1040	1920	—	—	—	—
	Force at (2) x =4m F_2 N	1.0			2.0	3.0	10		30	50	80	210	440	810	—	—	—	—
	Force at (2) x =5m F_2 N	0.1	0.2	1.0		2.0	4.0	6.0	20	30	50	110	230	420	—	—	—	—

Remark 1. ℓ : Distance between ball joints, x : Distance up to first guide
Note (1) : Torque of ball is based on the condition of steam pressure 1.5MPa (Refer to Fig.14 for different conditions).
(2) : Based on the deflection y=1mm. In case of deflection n mm, the force shall be n times of listed value.

2 Guide

There are two types of guide : one which aligns the expansion joints with the pipes and prevents buckling (G_1) and supports the piping weight (G_2).

(1) Guide for alignment and prevention of buckling G_1

Refer to Fig.3-1 and Fig.3-2. Install guides so that the guide interval from expansion joint to 1st guide (L_1), guide interval from 1st guide to 2nd guide (L_2), and guide interval between intermediate guides (L_3) dose not go beyond the guide interval calculated by following formula (10)~(12). Guide interval (L_3) can be found in Fig.4 when the piping is SGP.

$$L_1 \leqq 40 \cdots\cdots (10)$$

$$L_2 \leqq 140 \cdots\cdots (11)$$

$$L_3 = \frac{1}{1000}\sqrt{\frac{\pi^2 EI}{SF}} \cdots\cdots (12)$$

L_2 : Guide interval m
F : Axial force of piping N
(Fm on page 195 and F_1, F_3, F_4 on page 201)
E : Modulus of longitudinal elasticity
(In case of steel pipe : $E=2.1\times10^5 N/mm^2$)
I : Moment of inertia mm^4
$I=\frac{\pi}{64}(D^4-d^4)$, D : External diameter mm
d : Internal diameter mm
S : Safety factor (min. 3)

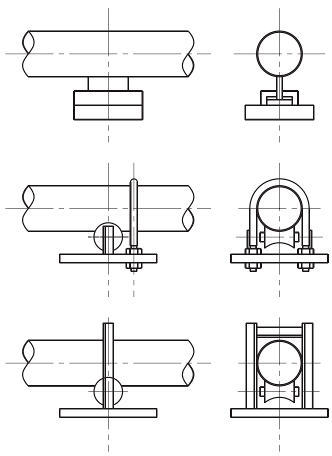


Fig. 2 Example of guide for preventing the buckling

Point of calculation

(2) Guid G_2 for supporting the piping weight

Bending of piping may be caused by the piping weight, fluid weight and etc..

For preventing the bending of piping, it is necessary to provide suitable guides such as roller, support and hanger.

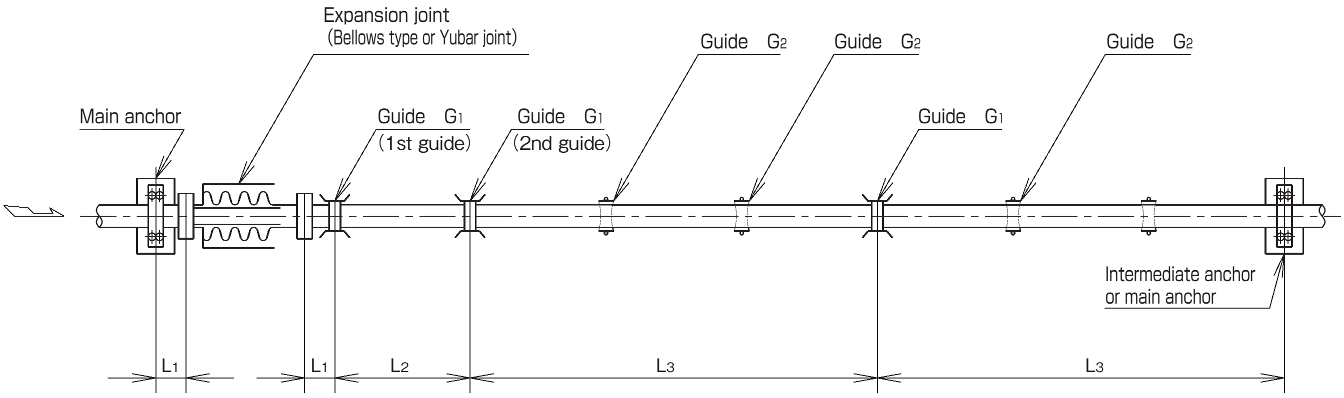


Fig. 3-1 Example of guide for bellows expansion joint or Yubar joint

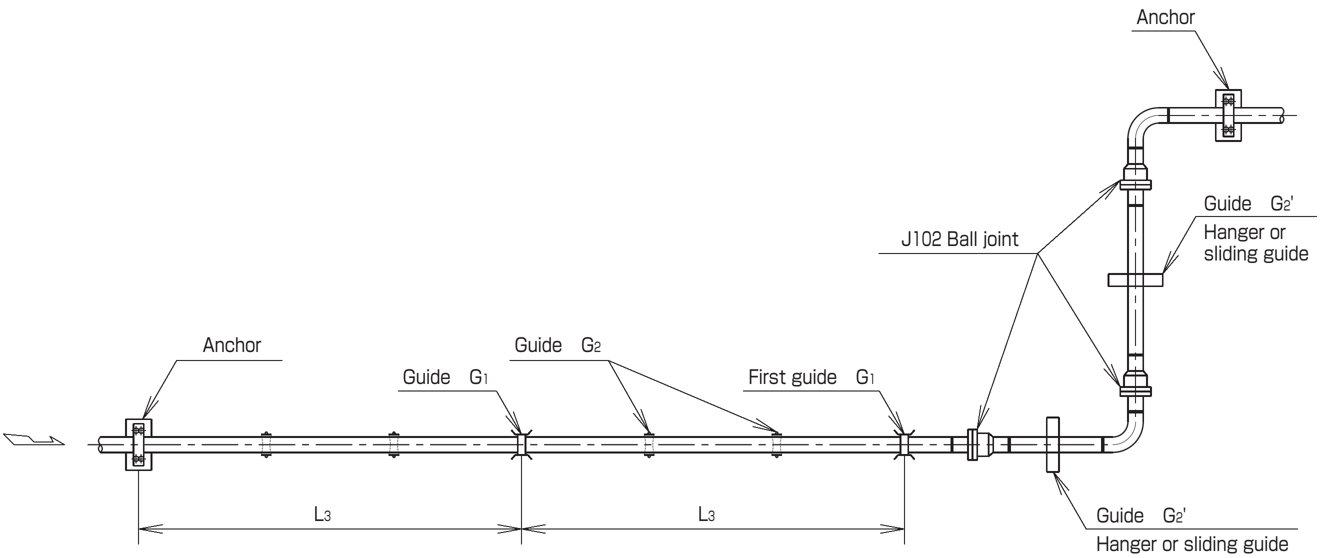


Fig. 3-2 Example of guide for ball joint

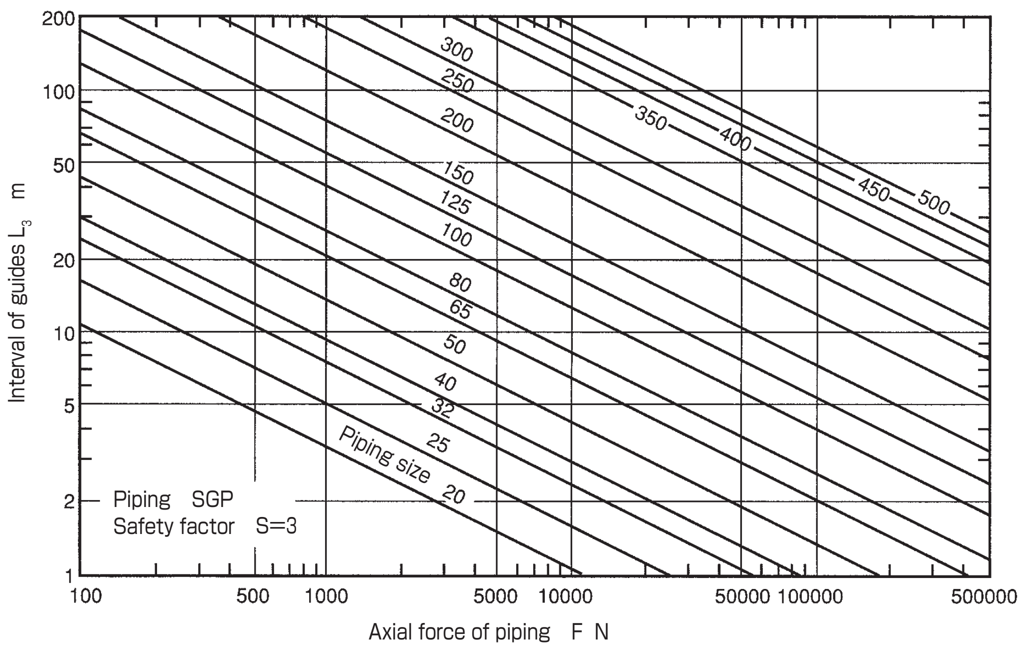


Fig. 4 Interval of guides

Example of calculation

1 Bellows expansion joint

Expansion of piping and selection of expansion joint
Number of expansion joints shall be decided by the following formula (13) and (14).

$$\triangle \ell = \beta (T - t_1) \ell \cdots (13)$$

$$n = \frac{\triangle \ell}{\delta} \cdots\cdots\cdots\cdots (14)$$

$\triangle \ell$: Expansion amount of piping　mm
β : Thermal expansion coefficient　mm/m/℃
Carbon steel　12.0×10^{-3}
Stainless steel　17.0×10^{-3}
T : Max. temperature　℃
t_1 : Min. temperature or ambient temperature　℃
ℓ : Length of piping　m
n : Number of expansion joints
δ : Max. expansion amount of expansion joint　mm
($\delta e + \delta c$ on page 187 and 188)

Example 1
$T \fallingdotseq 151$℃ (Saturate steam at 0.4MPa)
$t_1 = -20$℃ (Min. temperature)
$\ell = 25$m (Length of piping)
$\beta = 12.0 \times 10^{-3}$mm/m/℃
(Thermal expansion coefficient of SGP)
$\triangle \ell = 12.0 \times 10^{-3} \times \{151 - (-20)\} \times 25 \fallingdotseq 52$mm
20% margin should be added to expansion amount of piping
$\triangle \ell = 52 \times 1.2 \fallingdotseq 63$mm
In case of JOB30T

$$n = \frac{63}{35} = 1.8$$

Number of expansion joints is 2 pieces.

Safety factor of expansion amount
Min. 20% margin shall be added to calculated expansion amount, allowing for ambient temperature difference.

Adjustment of face to face length
Face to face dimension for installation shall be adjusted according to following formula.

$$Ls = L_1 - \delta \frac{t_2 - t_1}{T - t_1} \cdots (15)$$

Ls : Face to face length for installation　mm
L_1 : Max. face to face length　mm (See page 187 and 188)
t_2 : Ambient temperature at installation　℃

Example 2
$L_1 = 425$mm
(Max. allowable face to face length of JOB30T 100A)
$\delta = 35$mm (Max. displacement of JOB30T)
$T = 151$℃ (Saturate temperature at 0.4MPa)
$t_1 = -20$℃ (Min. ambient temperature)
$t_2 = 20$℃ (Ambient temperature at installation)

$$Ls = 425 - 35 \times \frac{20 - (-20)}{151 - (-20)} \fallingdotseq 416.8\text{mm}$$

Expansion joint shall be installed with contracting 8.2mm (=425−416.8) from max. allowable face to face length.
When contraction have margin compared with piping expansion, it is possible to install with pre-setting length which has been contracted 10mm from max. face to face length.

2 Yubar joint

Expansion of piping and selection of expansion joint
Example 3
$T \fallingdotseq 170$℃ (Saturate steam at 0.7MPa)
$t_1 = -20$℃ (Min. temperature)
$\ell = 50$m (Length of piping)
$\beta = 12.0 \times 10^{-3}$mm/m/℃
(Thermal expansion coefficient of SGP)
$\triangle \ell = 12.0 \times 10^{-3} \times \{170 - (-20)\} \times 50 \fallingdotseq 114$mm
20% margin should be added to expansion amount of piping
$\triangle \ell = 114 \times 1.2 \fallingdotseq 137$mm
In case of Yubar joint

$$n = \frac{137}{200} = 0.685$$

Number of Yubar joint is 1 piece.

The safety factor of Yubar joint is same as bellows expansion joint.

Adjustment of face to face length at installation
Example 4
$L_1 = 680$mm
(Max. allowable face to face length of Yubar joint 100A on page 192)
$\delta = 200$mm
(Max. displacement of Yubar joint $\delta e + \delta c$ on page 192)
$T \fallingdotseq 170$℃ (Saturate temperature at 0.7MPa)
$t_1 = -10$℃ (Min. ambient temperature)
$t_2 = 20$℃ (Ambient temperature at installation)

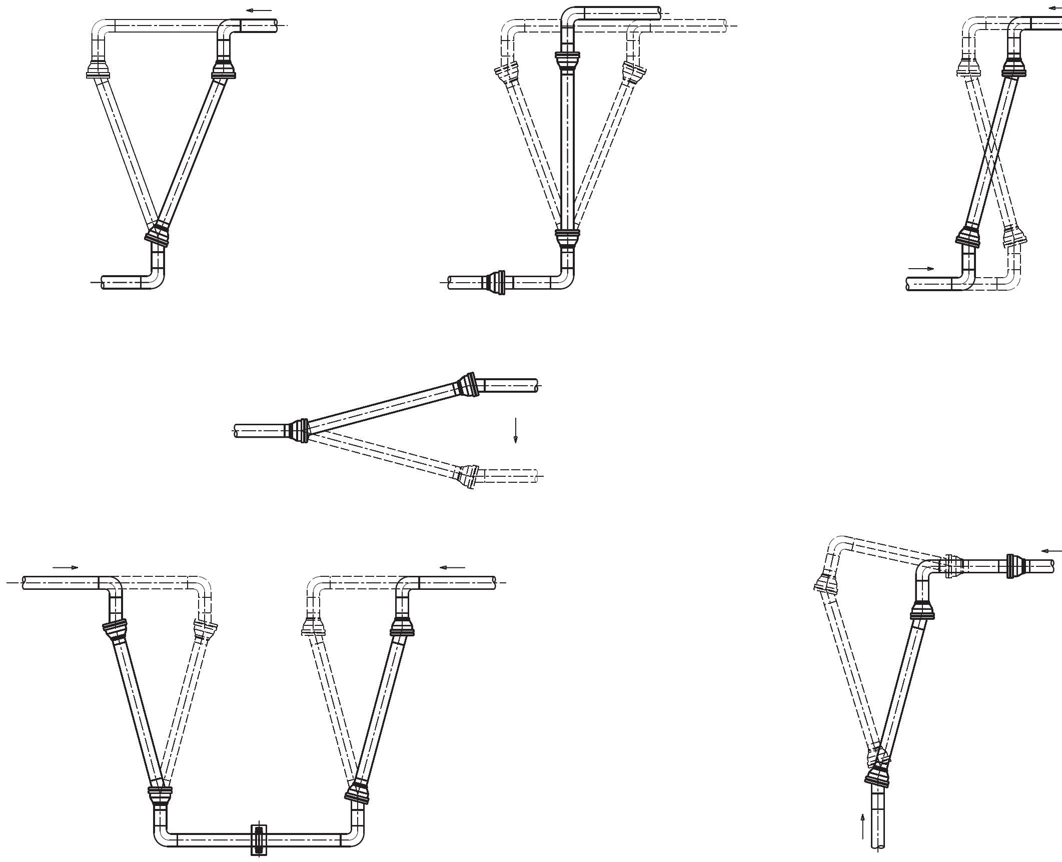
$$Ls = 680 - 200 \times \frac{20 - (-20)}{170 - (-10)} \fallingdotseq 636\text{mm}$$

Yubar joint shall be installed with contracting 44mm (=680−636) from max. allowable face to face length.
When contraction have margin compared with piping expansion, it is possible to install with pre-setting length which has been contracted 40mm from max. allowable face to face length.

Example of calculation

3 How to use the J102 ball joints

Fig. 5 Piping example



Distance between ball joints

Please refer to Fig.6.
When piping is expanded or contracted by ball joints, distance between ball joints is as following formula.

$$\ell \fallingdotseq \frac{\delta}{\sin\theta} \cdots (16)$$

ℓ : Distance between ball joints mm
δ : Expansion of piping mm
θ : Deflection angle of joint

Fig. 7 shows the relation between ℓ, δ and θ.
From Fig.7, ℓ shall be determined so that θ (θ/2 in case of (b) of Fig.7) does not exceed max. allowable angle.
Min. 50% margin shall be added to min. required distance.
ℓ shall be as long as possible to lessen deflection and force at anchor.
Generally, distance between ball joints is as following table.

Size	20−32	40−100	125·150	200	250	300
Distance between ball joints ℓ (m)	0.7−1	1−1.5	1.5−2	2−3	2.5−4	3−5

Deflection of piping

Piping will be deflected due to expansion.
In case of Fig. 6 (a)

$$y = \ell - \sqrt{\ell^2 - \left(\frac{\delta}{2}\right)^2} \cdots\cdots (17)$$

In case of Fig. 6 (b)

$$y = \ell - \sqrt{\ell^2 - \delta^2} \cdots\cdots (18)$$

y : Deflection of piping mm
Longer distance between ball joints (ℓ) will lessen deflection (y).

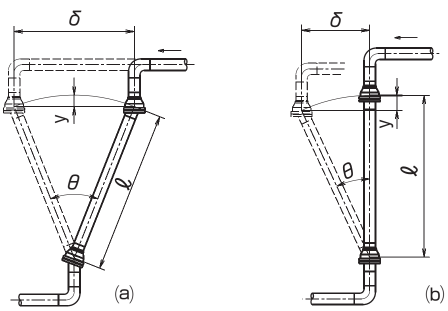


Fig. 6

Example of calculation

Fig. 7　Relation between expansion amount and distance

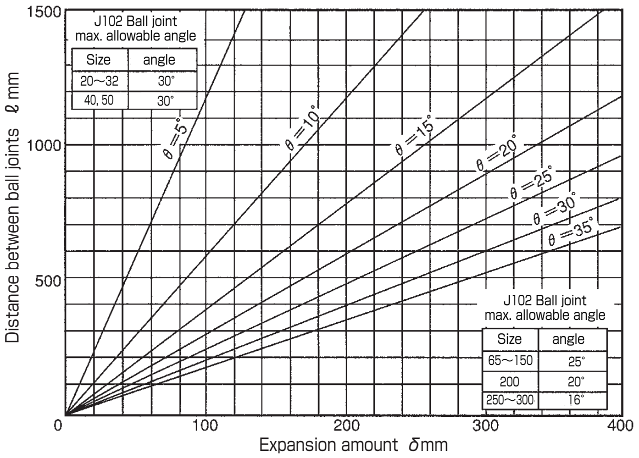
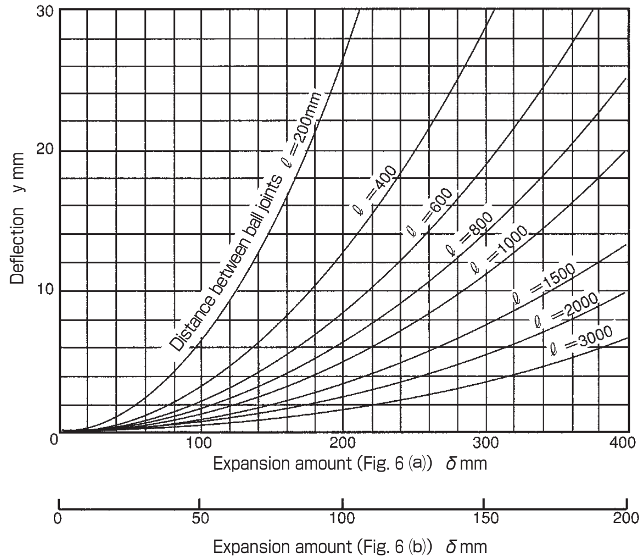


Fig. 8　Relation between expansion amount and deflection



In case of using 3 ball joints

Please refer to Fig. 9.

Deflection of piping shall be absorbed by providing third ball joint at Ⓐ to prevent excess bending stress.

It is same way for the case to absorb two direction expansion of piping. (Refer to Fig. 10)

The distance of ball joints ℓ_1 and ℓ_2 shall be obtained as $\ell_1 = \ell_2$ using the longer expansion amount between δ_1 and δ_2, and added 50% margin.

Displacement angles θ_1 and θ_2 are obtained from distance of ball joints ℓ_1 and ℓ_2.

$\theta_1 + \theta_2 = \theta_3$ shall be within the range of allowable angle.

In case θ_3 is over allowable angle, $\ell_1 = \ell_2$ shall be longer.

In case ball joint Ⓐ is not used, minimum distance to first guide x shall comply with formula ⒆ and Fig. 11.

$$x(\min) = \frac{S}{1000}\sqrt{\frac{3EyD}{2\sigma_a}} \quad \cdots\cdots(19)$$

- x(min) : Min. distance to first guide　m
- D : Outside diameter of piping　mm
- σ_a : Allowable stress of piping (In case of steel piping　σ_a =70N/mm²)
- E : Modulus of longitudinal elasticity (In case of steel piping　E=2.1×10⁵N/mm²)
- S : Safety factor (Min. 2)
- y : Deflection of piping (mm)

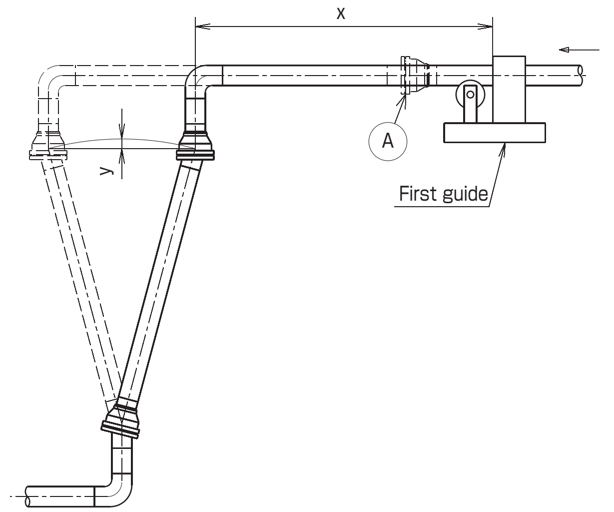


Fig. 9

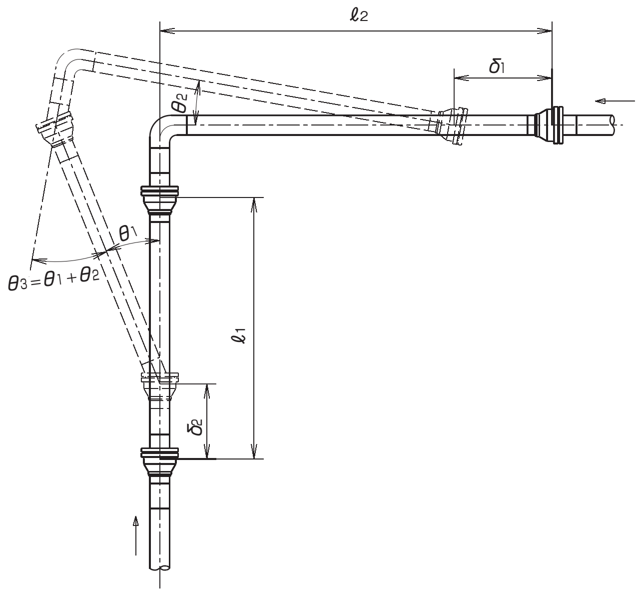


Fig. 10

Example of calculation

Force on anchors and guides

When piping expansion is absorbed by ball joints, friction force arise on the contact face between ball and gasket. The anchor and the guides shall have enough strength to support the friction load calculated by following formula.

$$F_1=\frac{2T\times1000}{\ell_1} \cdots (20)$$

$$F_2=\frac{3EIy}{x^3\times10^9} \cdots (21)$$

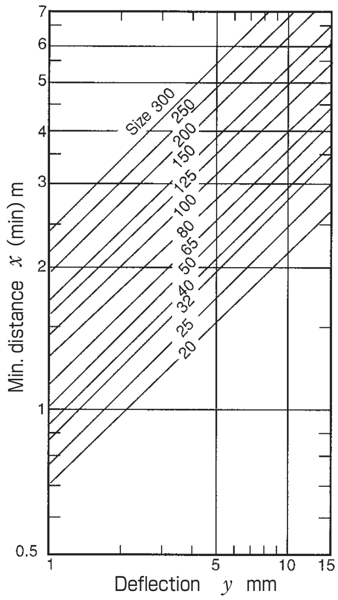
$$F_3=\frac{2T\times1000}{\ell_1} \cdots (22)$$

$$F_4=\frac{2T\times1000}{\ell_2} \cdots (23)$$

In Fig.12, 13 and formula (20)—(23)

- F : Load on fixing point and guide N
- T : Torque of ball joint N・m
- ℓ : Distance between ball joints mm
- x : Distance to first guide m
- y : Deflection of piping mm
- I : Moment of inertia mm^4, $\frac{\pi}{64}(D^4-d^4)$
- d : Inside diameter of piping mm

Fig. 11 Min. distance to first guide



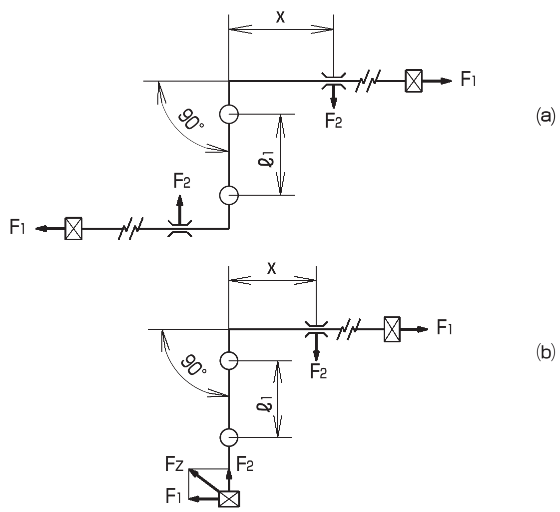


Fig. 12

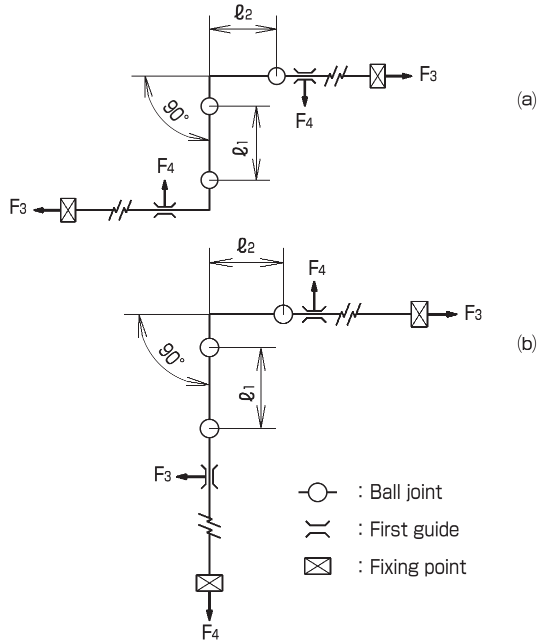
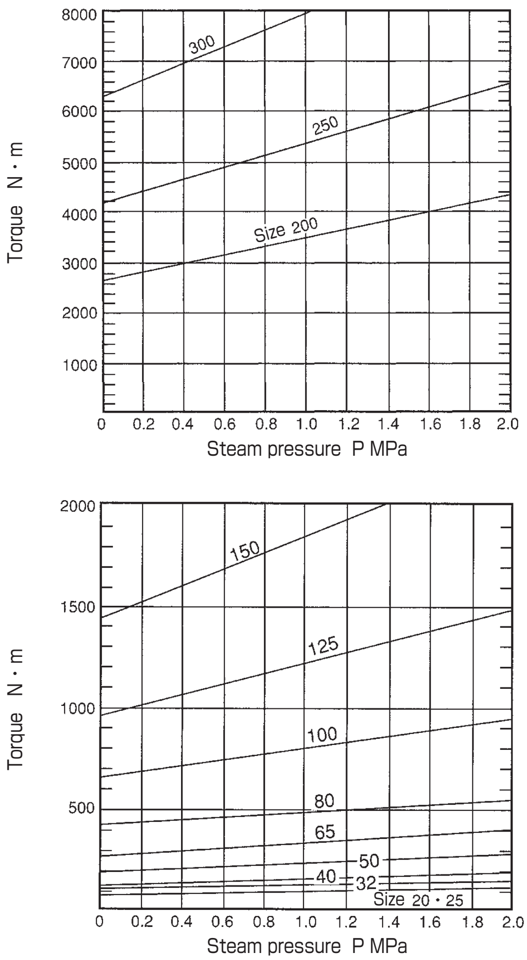


Fig. 13

Fig. 14 Torque of J102 ball joint



Thermal expansion coefficient

Table 2　Thermal expansion coefficient of carbon steel pipe　(10⁻³mm/m/℃)

Max. temperature T(℃) \ Min. temperature t_1(℃)	40	30	20	10	0	−10	−20	−30	−40
−40	10.6	10.5	10.5	10.4	10.3	10.3	10.2	10.1	—
−30	10.7	10.6	10.5	10.5	10.4	10.3	10.3	—	10.1
−20	10.7	10.7	10.6	10.5	10.4	10.4	—	10.3	10.2
−10	10.8	10.7	10.7	10.6	10.5	—	10.4	10.3	10.3
0	10.9	10.8	10.7	10.7	—	10.5	10.4	10.4	10.3
10	11.0	10.9	10.8	—	10.7	10.6	10.5	10.5	10.4
20	11.0	11.0	—	10.8	10.7	10.7	10.6	10.5	10.5
30	11.1	—	11.0	10.9	10.8	10.7	10.7	10.6	10.5
40	—	11.1	11.0	11.0	10.9	10.8	10.7	10.7	10.6
50	11.3	11.2	11.1	11.0	11.0	10.9	10.8	10.8	10.7
60	11.4	11.3	11.2	11.1	11.0	11.0	10.9	10.8	10.8
70	11.4	11.4	11.3	11.2	11.1	11.0	11.0	10.9	10.8
80	11.5	11.4	11.4	11.3	11.2	11.1	11.1	11.0	10.9
90	11.6	11.5	11.4	11.4	11.3	11.2	11.1	11.1	11.0
100	11.7	11.6	11.5	11.4	11.4	11.3	11.2	11.1	11.1
120	11.8	11.7	11.7	11.6	11.5	11.4	11.4	11.3	11.2
140	12.0	11.9	11.8	11.7	11.7	11.6	11.5	11.4	11.4
160	12.1	12.0	11.9	11.9	11.8	11.7	11.6	11.6	11.5
180	12.2	12.2	12.1	12.0	11.9	11.9	11.8	11.7	11.6
200	12.4	12.3	12.2	12.2	12.1	12.0	11.9	11.9	11.8
220	12.5	12.4	12.4	12.3	12.2	12.1	12.1	12.0	11.9

According to SHASE-S 005 (SHASE : The Society of Heating, Air-Conditioning and Sanitary Engineers of Japan)

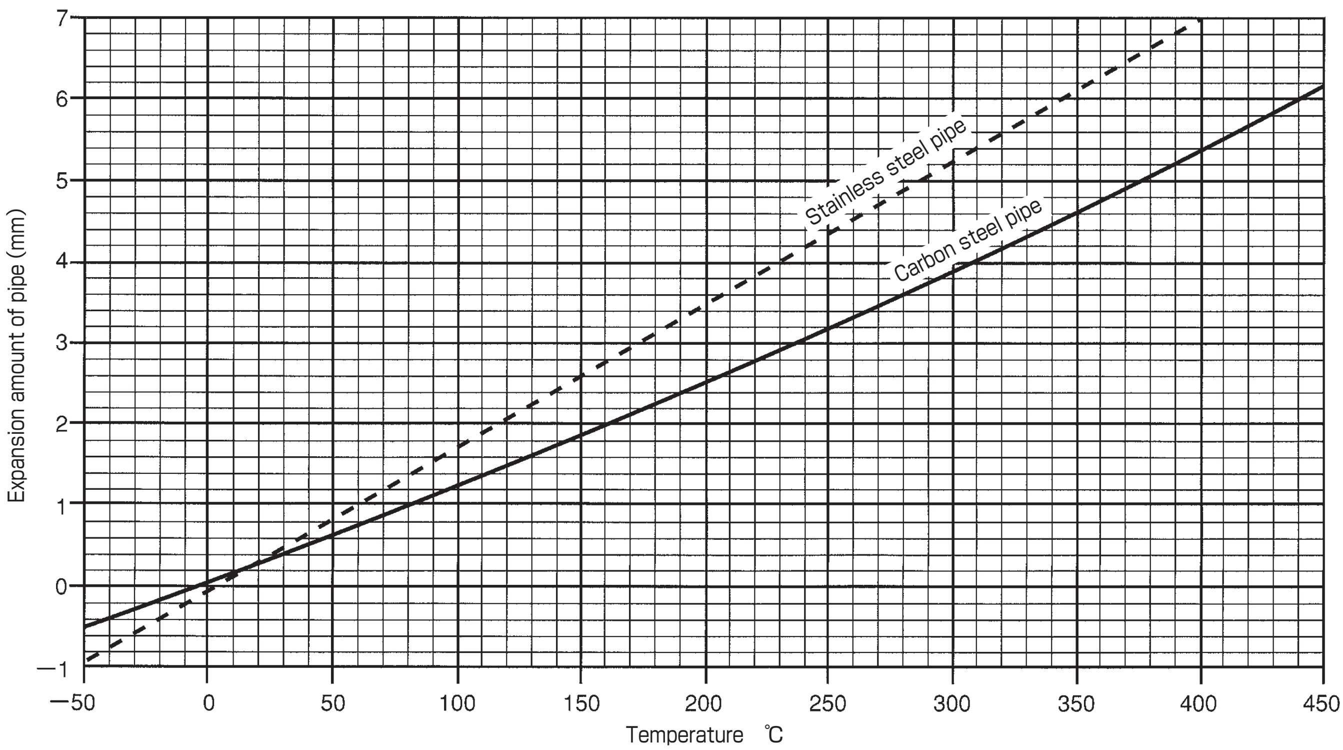


Fig. 15　Expansion amount of carbon steel and stainless steel pipe per 1m and based on 0℃