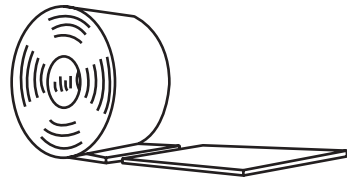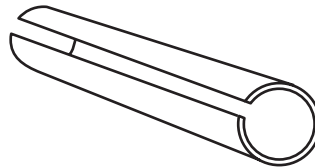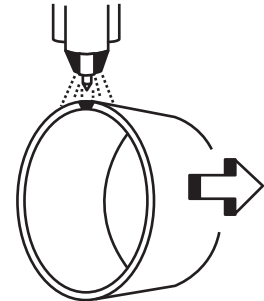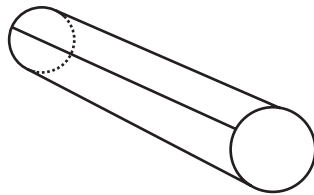# Expansion Joints

Fabrication procedure

Cutting of the thin bellows layers

Rolling on roller bending machine

• Welding of the outer and inner layer
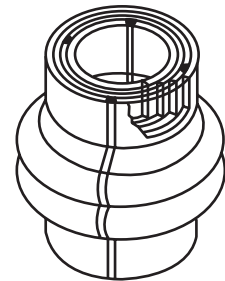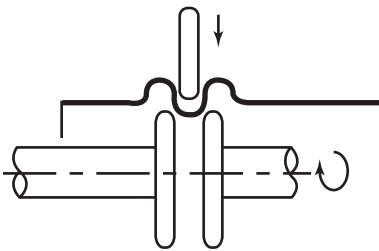• Radiography & Liquid Penetrant test

polishing
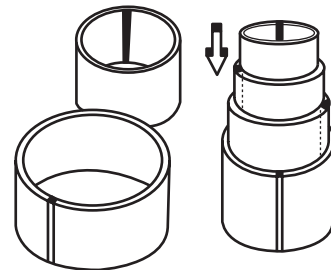
Preparation of the and welded inner and outer layer
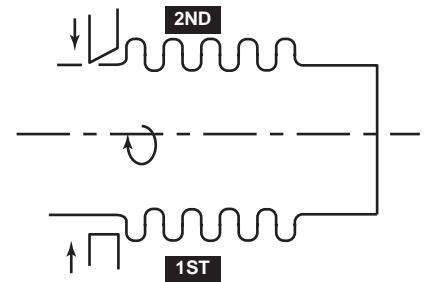
Multiply bellows, with 4 welded layer
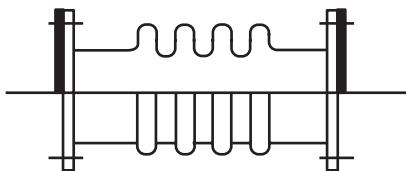
Roll forming by wheel or hydraulic powered forming

Multiply expension bellows after forming

2ND

1ST

Edge Cutting

Weld attachment to the shell, or fittings

■ Pneumatic test

■ Hydrostatic test

■ Heat resistant paint coating

1.Expansion Joint

The selection of the optimum expansion joint depends on a technical as well as an economical aspect.

With many years of experience in design, production and marketing of expansion joints, we are competitive and specialized on the know-how on the solution for demand required in a technical and economical view.

Therefore, it will always be highly appreciated to contact to us in case that you need our assistance.

We look forward to serving you.

2.Application

Engineering products, expansion joint & flexible products, which can absorb thermal and mechanical movements in pipe-work and duct systems, provide solution to engineering problems all over the world. Application are as diverse as there are industries.

There are applications in

Process Engineering
Power Generation Manufacturing
Petrochemical
Construction
Cryogenic
Metallurgy
Nuclear
Heating Ventilating and A/C
Aerospace
Automotive
Combustion Engine

3.The Bellows

The bellows is the basic element of expansion joint, which can be made by mechanical and hydraulic forming as the requirement in MEGAFLEXON facility.

The mechanical forming, which is also known as roll forming, involves passing the tube through progressively deeper convoluted mandrels and gradually and cause realy fatigue failure by friction due to the concentration of local hardness. MEGAFLEXON can produce up to 8,000mm size as per the requirement.

The hydraulic forming is a method in which forming tube is slowly compressed with low hydraulic pressure towards the inside after placing restraining rings around the forming tube and sealing both ends, and subsequently it leads to producing far better qualitive product than the

mechanical forming does as it gives uniform hardening all over the world. In this method, MEGAFLEXON can produce up to 1,500 mm in nominal diameter.

All bellows are formed in their cold state without heat treatment but it can be heat treated, in case that specially required.

The physical capacity of bellows to absorb movement is determined by the number of corrugations, height (H), pipe diameter (D), spacing (L), radius (r), thickness of material (t), and number of layers (n).

The basic constituent element of expansion joint, bellows, can be specified, considering on movement, pressure, temperature, service life and corrosion rate required.

Our standard material for the circular type bellows is austentic steel, that is, AISI 304 and 316. In addition, other special Nickel based alloy material, like as Inconel, Incoloy, Monel and Hasteloy, can be applied on the servicing of agressive fluid.

Fig. 1
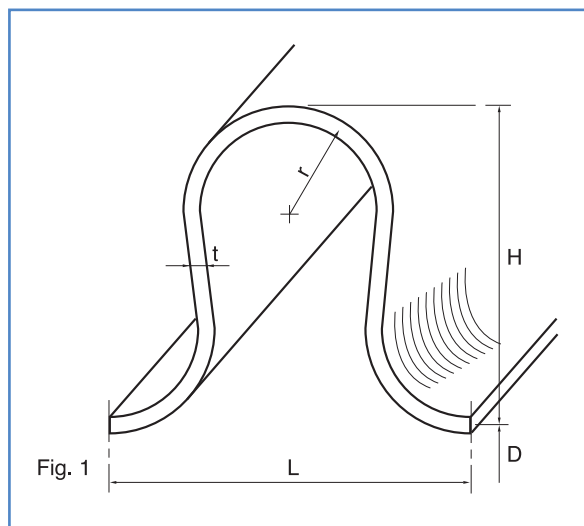
The below can be helpful for your consideration on bellows and other main part material of expansion joint for the selection as per the specification required.

Basically, austenitic steel is resistant to both high temperature and a agressive media. It has a good mechanical properties as well when it comes to the effect of continuous motion in axial, lateral and angular direction.

MEGAFLEXON bellows have been improved to achieve an optimized relationship between the various parameters, so that the bellows can withstand the greatest possible load without fail on normal operating condition.

Basically, we carefully consider following criteria in designing bellows.

a) The geometrically stable state in a hydro test pressure of 1.5 times design pressure.
b) The stability for a hydro-test pressure of 1.5 x design pressure at least without permanent changes in shape of leaks develops.
c) The reliable warranty service life of at least 7,000 cycles with nominal

movements and design pressure.

    d) Calculation for bellows designs are carried out to be in accordance with
EJMA (Standard of the Expansion Joint Manufacturers Association)
Ⅴ. Ⅵ. Ⅶ Edition.

  It is essential that the weld in the bellows be as strong as the surrounding material.

  Welding is done by qualified welders using machines specially built for the purpose. Welds comply with every metallugical requirement with regard to durability and strength, documented by the certified procedure test.

4.The thermal expansion of pipe

  The extent of expansion depends on the temperature difference, the expansion coefficient and the length of the pipe. The expansion coefficient varies from one material to another and is also dependent on the temperature, as it increase as the temperature rises.

  The coefficient list, graphical chart and calculation example are shown on the Reference Data. H.

5.Installation instruction for MEGAFLEXON axial expansion joints.
   Pipe laying

  On installing pipelines, care should be taken that the pipe is laid in a straight line. Fixing points should be located in such a way that the pipe expands correctly in relation to the type of expansion joint chosen.

5.1 Guide

  Especially, to operate the expansion joint effectively and positively, a guide pipe which slides smoothly with less friction should be provided between the fixing point and the expansion joint. The distance between the expansion joint and the guide adjacent therto should be determined to be L1, L2 shown in fig.

5.2 Guide bearings

  Guide bearing, which protect the pipe-work against bending in all directions, should be of the slide or roller type. Pendent suspension is not recommended. Only one axial expansion joint may be fitted between 2 fixing points. Guide bearing should be placed at the maximum intervals.

5.3 Fixing points, or main anchor

Pipelines in which expansion joints are to be installed should be secured with fixing points. The fixing points must be sturdly enough to absorb the forces originating from the expansion joint and the frictional resistance of the guide bearing.

That is, stress on the main fixing point Fh is composed of the resulting forces coming from;
a) The spring constant Ca, which is the force it takes to move the bellows 1 mm axially or laterally. Since the spring constant is a theoretical calculation, a deviation of +- 30% from the values specified on the data sheets must be expected.
b) Tensile stress from the highest operating pressure of P bar affecting the active area Ab mm2 of the bellows.

Nominal Dia (mm)	80	100	125	150	200	250	300	350	400	450	500	600	800	1000	1200	1500	1800
L1 (m)	0.3	0.4	0.5	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.4	3.2	4.0	4.8	6.0	7.2
L2 (m)	1.1	1.4	1.8	2.1	2.8	3.5	4.2	4.9	5.6	6.3	7.0	8.4	11.2	14.0	16.8	21.0	25.2

$$L3 = 1.571 \cdot \sqrt{\frac{EI}{PA \pm Fex}} \cdot 10^{-3} \quad .... \quad (37)$$

L3 = Maximum intermediate quide space(M)
E = Young's modulus of pipe material(kg/mm²)
I = Moment of inertia of pipe(mm⁴)
P = Design pressure(kg/Cm²)
A = Bellows effective area(mm²)
F = Bellows initial spring rate per one corrugation(kg/mm/corr.)
ex = Axial stroke of bellows per one corrugation(mm/corr.)

When bellows is compressed in operation, use(+) | F · ex | ;when extended, use(-) | F · ex |

INTERMEDIATE GUIDE SPACING L3(M)

MAX.WORKING PRESSURE(kg/cm²)

Anchor   1st Guide   2st Guide   All other Guide
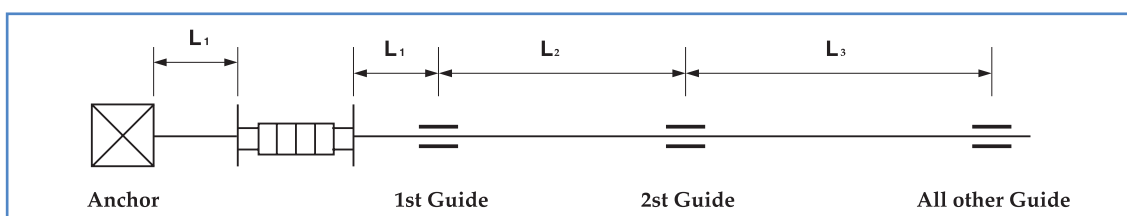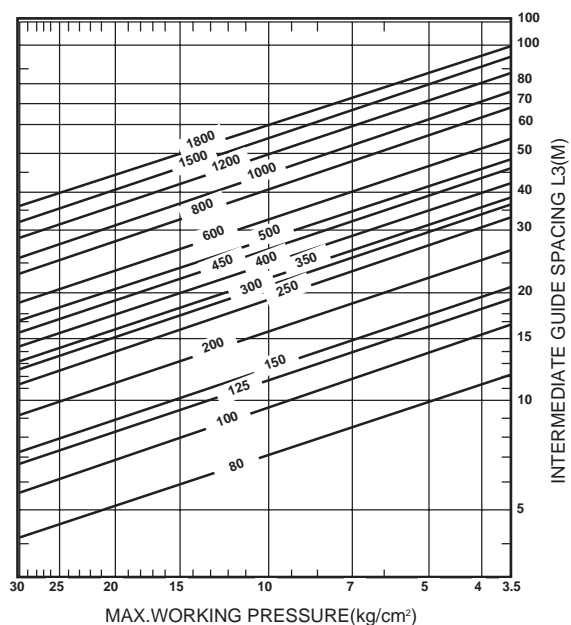
c) The inherent resistance of the expansion joint, which is the product of the spring constant kgf/mm and the expansion for the section of pipe.
d) Addition for friction force from guides between two fixing points.

Stress on intermediate fixing points Fm is calculated as the sum of the above stresses b) and c), since tensile stress for the same pipe dimension is entirely absorbed by Fh.

5.4 Pre-stressing

MEGAFLEXON standard expansion joints are dimensioned to absorb +/- movements from the neutral position of the bellows, with half being absorbed by each: +/- 20 mm = 40 mm total movement, +/- 7 Deg. = 14 Deg. total movement. It is possible to pre-stress the expansion joint in order to make full use of the working range of the bellows. If calculation show that a total movement of 30 mm should be used, it is possible to use to advantage an expansion joint with +/- 15 mm movement which has been half percent prestressed to = 30mm instead of an expansion joint with +/- 30mm movement. It should be noted, however, that it is not wrong to use an expansion joint with a movement of +/- 30mm.

The following parameters should be taken into account when verifying pre-stressing.

1) The overall dimensions at installation temperature
2) The neutral length of the expansion joint before prestressing
3) The total movement of the expansion
4) The highest operating temperature to occur
5) The lowest operating temperature to occur
6) The installation temperature

It is very important that the expansion joint is installed in its optimum position, as this will produce the best combination of movement and service life in the bellows.
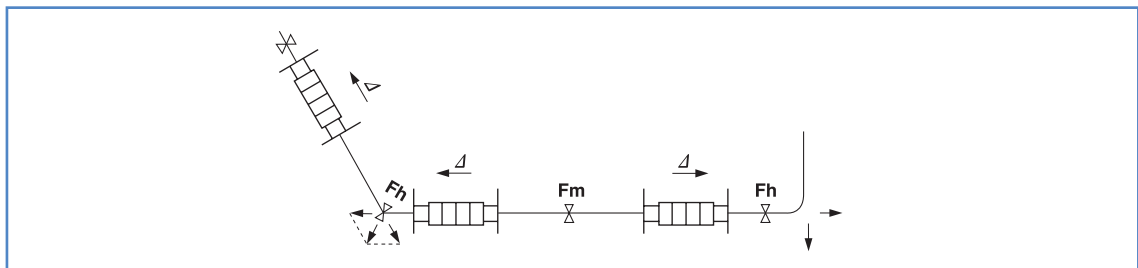
6.Method of Setting

Please take NOTE of the following matters with respect to the operation of expansion joint.

6.1 Removal of set bolt

Expansion joint is provided with a set bolt or set bar that is painted yellows and used for adjusting dimension. Always remove this set bolt after piping in completed.

6.2 Inhibition of gas cutting of set bolt

Always use wrench for removing the set bolt.
Absolutely avoid gas cutting since if frequently may damage bellows.

6.3 Protecting from welding spark

Do not allow welding spark and grinder spark to come into direct contact with bellows. Always cover the bellows when you carry out these operations near the expansion joint.

6.4 Prohibition of arc in continuity test

Absolutely avoid the contact of electrode and earth wire with bellows in the continuity test.

6.5 Direction of flow

Generally, the direction of flow is defined. Mount the joint in the direction of arrow. Take care where the direction of flow is not restricted, as is the case of hinged type, universal type, etc.

6.6 Direction of mounting hinged type

Particularly in the hinged type, hinge arm is mounted on both side of bellows. Hence, mount the hinge arm parallel to the direction of expansion and contraction.

6.7 Preset

Generally the expansion joint is set, taking the mounting temperature into consideration. Please contact us when the application and the temperature are remarkably different form those set.

6.8 Use caution with sea water

Take care of installation site and maintenance since, particularly, STS-304 is easily affected by sea water (Cl ion). Contact us before you install it for sea water piping.

DESIGN OF EXPANSION JOINT

■ Requirements for the Design

The following are requirements for the design of the Expansion joint.

These requirements shall be fulfilled through your inquiry.

1. Pipe size	Nominal diameter of pipe size, and longitudinal and lateral diamension of square type.
2. Standard of pipe, wall thickness, material	Standard of pipe(SPP, SPPS38, SPW, etc.), schedule no. In the case of nonstandardized pipe, outside(or inside) diameter, wallthickness, material.
3. Connection	Beveling configuration(distinction between internal and external, angle, etc.) in welding, standards, dimension, material, etc., in flange connection, and particularly standards(API, TAYLOR, etc.) in more than 650mm(26") shall not be forgotten.
4. Fluid	Needed for selecting the material for bellows.
5. Pressure	Needed for selection of type.
6. Temperature	Needed for selecting the material and type of bellows.
7. Movement and direction	Needed for selecting the number of corrugations, single and double.If these data are not manifest, contact us with respect to pipe length(distance between the ficing points) and temperature. (We will calculate them).
8. Material for bellows	We select the most suitable, depending upon the fluid, temperature and pressure. However, examine and enter the temperature of fluid, the property of material, etc., if you particularly want to specify.
9. Presence of inspection by authorities concerned and in attendance thereof	Always enter the necessity of inspection in the attendance of the Korean governments. LR, NK, ABS, DNV, etc., or similar inspection. Further, enter also the necessity of normal inspection in the presence of your company and of X-ray inspection.
10. Equation to be used in calcuation	Generally, we carry out the calculation based upon the equation derived from the experimental value. If you particularly specify the Kellogg Company's or number of expansion cycles, enter that specification.
11. Others	Consult readily with us about the use of Expansion joint when it is used in a special atmosphere, when the fixing points are not provided, etc. We will assist you in the examination of pipe line, the selection of material and type, the calculation of load in the fixing points, etc.

Pressure Resistent Strength

  The capability of a bellows to resist pressure is measured primarily by hoop stress or S2 from the standards of the EJMA. Basically S2 is the stress which runs circumferencially around bellows due to the pressure difference between the inside and the outside of the bellows. Also, the ability to carry pressure is also limited by meridional bending stress, or bulge stress, S4 which runs longitudinal to the bellows side wall and it is a measure of the tendency of the bellow's convolution to become less U-shaped and more spherical due to residual stress originated from the bellows forming procedure.

1.Bellows circumferential membrane stress due to internal pressure

$$S_2 = \frac{P \cdot Dm}{2ntp}\left(\frac{1}{0.571+2W/q}\right) \quad \text{-------------------- without control ring type}$$

$$S_2' = \frac{H}{2Ac}\left(\frac{R}{R+1}\right) \quad \text{-------------------- with control ring type}$$

2.Bellows meridional membrane stress due to internal pressure

$$S_3 = \frac{P \cdot W}{2n \cdot tp} \quad \text{-------------------- without control ring type}$$

$$S_3' = \frac{0.85 \cdot P \cdot (W-Crq)}{2 \cdot n \cdot tp} \quad \text{-------------------- with control ring type}$$

3.Bellows meridional bending stress due to internal pressure

$$S_4 = \frac{P}{2 \cdot n}\left(\frac{W}{tp}\right)^2 Cp \quad \text{-------------------- without control ring type}$$

$$S_4' = \frac{0.85 \cdot P}{2 \cdot n}\left(\frac{W-Crqtp}{tp}\right)^2 Cp \quad \text{-------------------- with control ring type}$$

Notation

Cp : Pressure factor
Dm : The effective diameter of bellows(mm)
W : The convolution height of bellows(mm)
n : No. of ply
P : Design Pressure(kgf/cm^2)
Sa : Allowable stress on bellows material at design temperature(kgf/mm^2)
D : The inside diameter of bellows(mm)

q : Bellows pitch(mm)

t : Bellows thickness(mm)

$tp : t \cdot \left(\dfrac{D}{Dm} \right)^{0.5}$

$Cr :$ The height factor of bellows $= 0.3 - \left(\dfrac{100}{0.6P^{1.5}+320} \right)^2$

Ar : The cross sectional area of reinforcement ring(mm²)

Ac : The cross sectional area per one bellows convolution(mm²)

R : The reaction force ratio by reinforcement ring and bellows due to internal

pressure $= \left(\dfrac{Ac \cdot Eb}{Ar \cdot Er} \right)$

H : Total internal pressure $= P \cdot Dm \cdot q$

The example of calculation

1.Free Type

Nominal Diameter : 300A

Design Temperature : 400 Deg. C

Bellows Material : A240 T304

W : 42mm

q : 45mm

t : 1.0mm

Dm : 346mm

Cp : 0.52

n : 1

P : 2kgf/cm²

1)S2, bellows circumferential membrane stress due to internal pressure

$$S2 = \frac{P \cdot Dm}{2 \cdot n \cdot tp} \times \left(\frac{1}{0.571+2W/q} \right) = \frac{0.02 \times 346}{2 \times 1 \times 0.93} \times \left(\frac{1}{0.571+2 \times 42/45} \right) = 1.53\,kg/mm^2$$

2)S3, bellows meriodinal membrane stress due to internal pressure

$$S3 = \frac{P \cdot W}{2 \cdot n \cdot tp} = \frac{0.02 \times 42}{2 \times 1 \times 0.93} = 0.45\,kg/mm^2$$

3)S4, bellows meriodinal bending stress due to internal pressure

$$S4 = \frac{P}{2n} \left(\frac{W}{tp} \right)^2 Cp = \frac{0.02}{2 \times 1} \left(\frac{42}{0.93} \right)^2 \times 0.52 = 10.6\,kg/mm^2$$

2.Control Ring Type

Nominal Diameter : 300A
Design Temperature : 400 Deg. C
Bellows Material : A240 T304
W : 42mm
q : 45mm
t : 1.0mm
Dm : 346mm
Cp : 0.52
n : 1.0
P : 10kgf/sq · cm
Ar : (the cross sectional area of control ring) : $78\mathrm{mm}^2$
Ac : $(0.571q+2W) \times tp \times n$
R : 1.25
Cr : 0.2024
Eb : $17,997\mathrm{kgf/mm}^2$
H : 1557kg
Er : $18,911\mathrm{kgf/mm}^2$

1)S2, bellows circumferential membrane stress due to internal pressure

$$S2 = \frac{H}{2Ac} \cdot \left(\frac{R}{R+1}\right) = \frac{1557}{2 \times (0.571 \times 45 + 2 \times 42)} \times \left(\frac{1.25}{1.25+1}\right) = 3.974\mathrm{kgf/mm}^2$$

2)S3, bellows meriodinal membrane stress due to internal pressure

$$S3 = \frac{0.85 \cdot P \cdot (W0 - Cr \cdot q)}{2 \cdot n \cdot tp} = \frac{0.85 \times 0.1 \times (42 - 0.2024 \times 45)}{2 \times 1 \times 0.93} = 1.503\mathrm{kgf/mm}^2$$

3)S4, bellows meriodinal bending stress due to internal pressure

$$S4 = \frac{0.85 \cdot P}{2 \cdot n}\left(\frac{W - Crq}{tp}\right)^2 Cp = \frac{0.85 \times 0.1}{2 \times 1} \times \left(\frac{42 - 0.2024 \times 45}{0.93}\right)^2 \times 0.52$$

$$= 27.64\mathrm{kgf/mm}^2$$
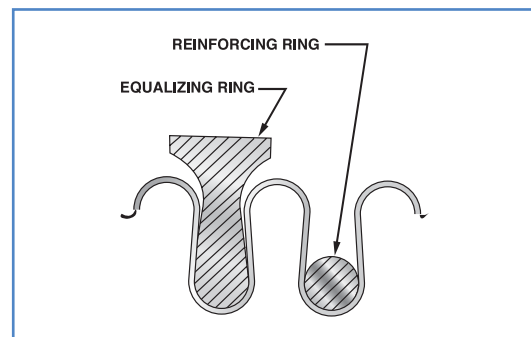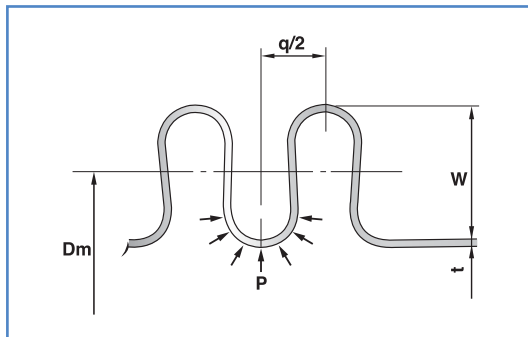
Allowable expansion amount

Assuming that the allowable expansion amount per one corrugation of bellows is 'e'mm, we can calculate the allowable displacement in each respectively follows.

1) Allowable axial expansion amount

Single System $X = e \cdot n$

Double System $X = 2 \cdot e \cdot n$

2) Allowable lateral displacement

Single System $Y = n \cdot C \cdot e/3\, Dp$

Double System

(1)Universal type $Y = 2 \cdot n \cdot (L1-c) \cdot e/\alpha \cdot Dp$

(2)Hinged, gimbal type $Y = 2 \cdot n \cdot L2 \cdot e/Dp$

3) Allowable bending angle(single system hinged, gimbal, free type)

$\theta = 2 \cdot 180 \cdot e/\pi Dp$

Allowable bending radius(free type, flexible hose)

$R = Dp \cdot W/e$

Notation

X = Axial movement

Y = Lateral displacement

θ = Bending angle

R = Bending radius

e = Allowable expansion amount per one corrugation of bellows

n = Number of corrugation of bellows(one sied in double)

C = Length of bellows(one side double system)

L1 = Total length of bellows containing intermediate pipe of double system

L2 = distance between hinge pins of hinged type

α = Factors depending on the ratio of bellows length of double system bellows
    to total on

The above is the allowable expansion amount general complex displacement such as:

1.Displacement in 3 directions X,Y and Z

2.Displacement in 2 directions X and Y

3.Displacement in direction X and the bending angle

4.Lateral displacement in 2 directions X and Z etc.

is frequently requested. In this case the allowable expansion is calculated according to the following calculation method.

$e \geq ex + ey + e\theta$

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1)Single System

ex $\quad = X/n$

ey $\quad = 3 \cdot Dp \cdot Y/n \cdot C$

e$\theta \quad = Dp \cdot \pi \cdot \theta/2 \cdot n \cdot 180$

2)Double System

ex $\quad = X/2n$

ey $\quad = \alpha \cdot Dp \cdot Y/2 \cdot n(L1\text{-}C)$

$\alpha \quad = 3 \cdot L^2 \text{-} 3 \cdot C \cdot L/3 L^2 \text{-} 6 \cdot C \cdot L + 4C^2$

■ Point of Application of External forces and Moments

$$\alpha = \frac{3L^2 - 3CL}{3L^2 - 6CL + 4C^2} \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (23)$$

L/2C
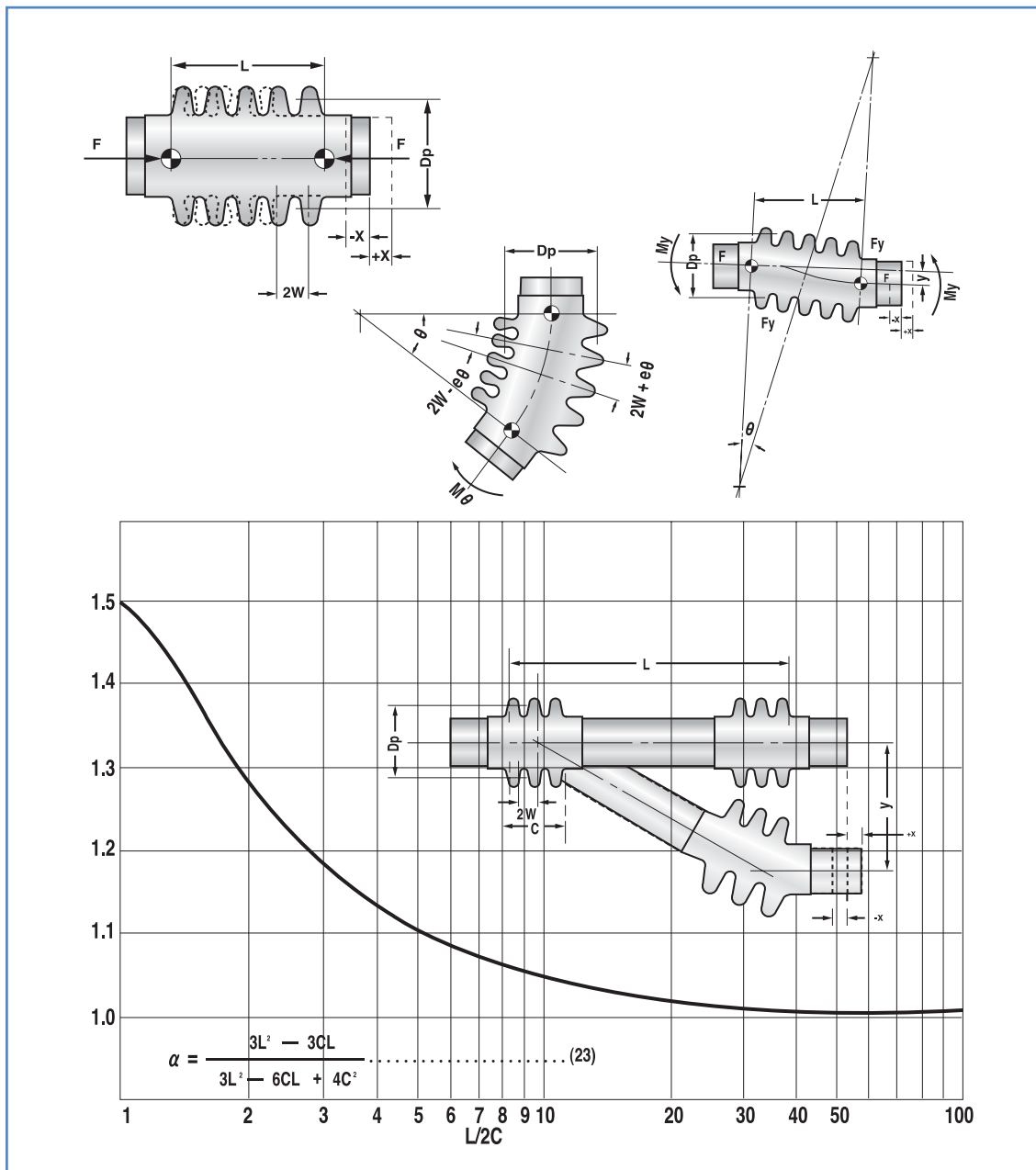
MATERIAL TABLE FOR MAIN PARTS OF EXPANSION JOINTS

■ Classification According to Working Temperature
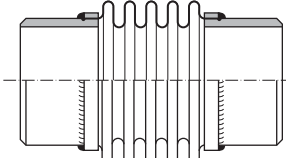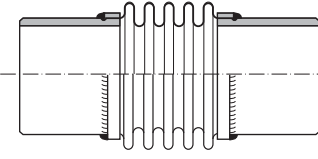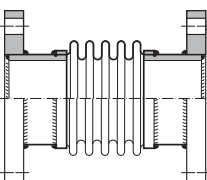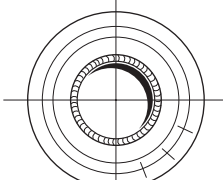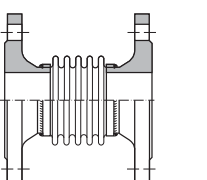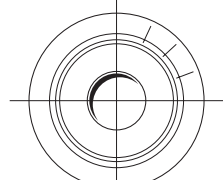
Temperature / Parts name	-200°C~-20°C	-20°C~350°C	350°C~450°C	450°C~600°C
Flange	STS304	SS41, S25C, SF45	SF45, F-12	F-12
Pipe	STS304	SGP, SS41, STPG38	STPG38, SB42	STS304, STS321
Stay flange	STS304	SS41	SB42, F-12	F-12
Bellows	STS304	STS304, STS316	STS304, STS316, STS321	STS321, STS316L
Control ring	STS304, AC-7A	SC20, AC-7A	SC-37, SS41	F-12
Guide bolt	STS304	S20C~35C, SCM-3	SCM-3	STS304, SCM-3
Nut	STS304	S20C~35C, SCM-3	SCM-3	STS304, SCM-3
Sleeve	STS304	STS304, SS41	STS304	STS321
Stopper pipe	STS304	SS41, STPG38	SB42, STPG38	F-12, STS304

■ Bellows Materials of Anticorrosive Expansion Joints
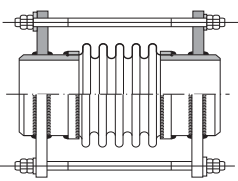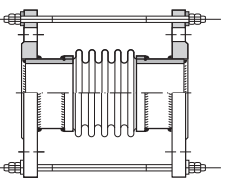
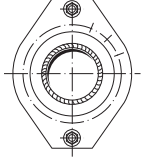| Temperature / Fluid	30°C	Intermediate temperature	Near boiling point
Nitric acid	STS304	STS304	STS304
Sulfuric acid	STS316	INCOLOY825	INCOLOY825
Sulfurous acid	STS316	STS316, STS317	INCOLOY825
Acetic acid	STS304, STS316	STS316, STS317	STS317L, 144ML
Phosphoric acid	STS304	STS316, STS317	STS317L, INCOLOY825
Hydrochloric acid	STS316, STS317	INCOLOY825	-
Alkali	STS304	STS304, STS304L	STS304L, STS347
Ammonia	STS304	STS304, STS304L	STS304L, STS347
Brine	STS316	STS317, M-5, 144M	INCOLOY825

INDEX
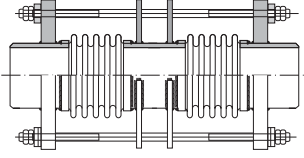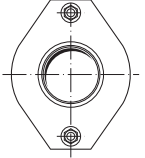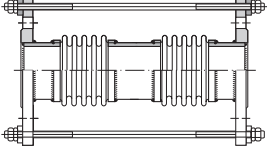
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EXPANSION JOINT & FLEXIBLE PRODUCTS
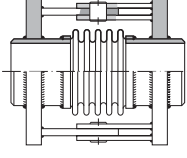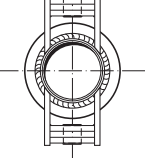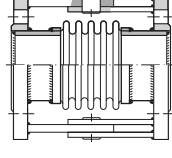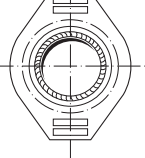
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