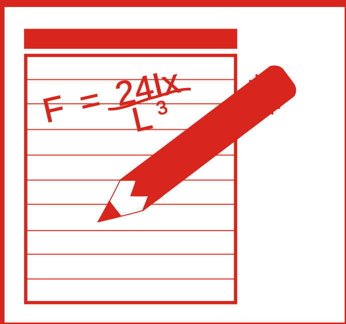
MINIKIN

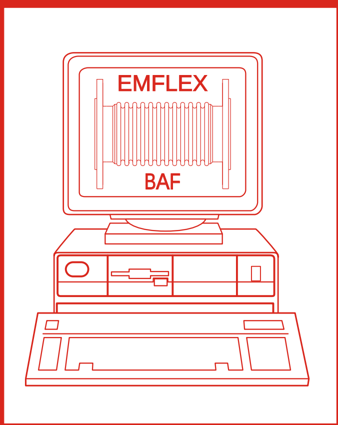
Design Book

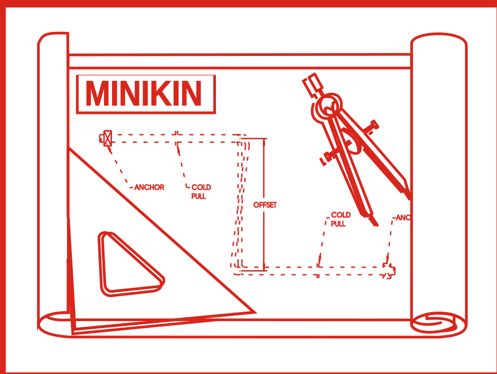
4th Edition

The Application of Expansion Joints to Pipework Systems

With special reference to the Building Services Industry







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This Design Book presented by:

The Application of Expansion Joints to Pipework Systems, with special reference to the Building Services Industry.

Preface

The object of this book is to provide an introduction to the general subject of metallic bellows expansion joints. It is intended to meet the needs of both the student and the engineer in the drawing office or on site, and also to gather and present in an easily assimilated form as much as possible of the type of information that the experienced engineer usually retains in his memory or collects from a variety of sources.

Unlike pipework in power stations and chemical plants, pipework connected with building services is usually not very flexible due to walls, service ducts, long narrow corridors and the need to conceal pipework. Metallic bellows expansion joints can be introduced into pipework systems to provide the necessary flexibility.

Metallic bellows expansion joints are considered a completely reliable and universally accepted device for reducing the stresses created in pipework systems by thermal expansion.

Plastic pipework now features to a greater extent in the building services industry. However, unlike metal pipework, the plastics used have extremely high thermal expansion rates. Thus we have added a section to this book that is specific to alternative expansion joints for plastic pipework; namely rubber bellows expansion joints.

Another addition is the section on expansion joints for duct systems. This section outlines some of the fundamental information that may be required when using duct expansion joints or flexible duct connectors as they are often called.

Metallic expansion joints for exhaust systems are introduced towards the end of the book. It is thought that special mention should be given to this as so often the building services engineer has to become involved with exhaust systems from C.H.P. (Combined Heat and Power) plant etc ; conditions differing from those connected with water or steam.

We have attached appendices to enable the engineer to quickly find data that is directly relevent to the formulae used and examples given throughout the book.

As reference is made to this book, questions about certain aspects will undoubtedly arise. N.Minikin & Sons Ltd welcome any question whether simple or complex; our Design and Applications Department will be pleased to assist.

Thermal Expansion

It is common knowledge that when a pipeline is subjected to a change in temperature it will expand or contract in direct proportion to that change.

To calculate the amount of the expansion in a pipeline three factors have to be considered.

1. Temperature change, usually from 0ºC.
2. Length of straight pipe involved.
3. Coefficient of thermal expansion of the material, which is a fairly constant ratio of the amount of expansion divided by unit length.

The coefficient for carbon steel is: 12.6×10^{-6} per ºC
The coefficient for copper is: 16.4×10^{-6} per ºC

For practical purposes it is useful to produce the expansion ratio of the number of millimetres expansion per metre of pipeline as in the following table.

Table 1	TABLE SHOWING THE EXPANSION RATIO OF PIPES				
Pressure		**Steam or Water Temperature**		**Expansion in millimetres per metre**	
bar	**psi**	**ºC**	**ºF**	**Carbon Steel**	**Copper**
		82	180	1.0	1.3
0	0	100	212	1.3	1.7
1.0	14.5	120	248	1.5	2.0
2.0	29.0	134	272	1.7	2.3
3.0	43.5	144	290	1.8	2.4
4.0	58.0	152	305	1.9	2.5
6.9	100.0	170	338	2.2	2.9
10.0	145.0	184	363	2.3	3.0
13.8	200.0	198	388	2.5	
16.0	232.0	205	400	2.6	
20.7	300.0	217	422	2.7	
25.0	363.0	226	439	2.9	

It is now quite a simple matter of multiplying the ratio by the length of the pipeline in metres.

Example 1:-

Calculate the expansion in a carbon steel pipeline 50 metres in length which is increased in temperature by passing steam at 6.9 bar pressure.

Temperature rise from 0ºC	= 170ºC	
Expansion in mm/metre	= 2.2	
Length of pipeline in metres	= 50	
Total expansion	= 50 x 2.2	= 110mm

Note that the diameter of the pipe does not influence expansion.

Example 2:-

Calculate the expansion in a copper pipeline 80 metres in length which is installed in a building at 20ºC and when in service carries chilled water at 7ºC.

Temperature change	= 7 - 20	= -13ºC
Expansion in mm/metre	= $16.4 \times 10^{-6} \times -13 \times 1000$	= -0.2
Length of pipeline in metres	= 80	
Total expansion	= 80 x -0.2	= -16mm

Note that the temperature change is negative, therefore the pipeline is contracting in length rather than expanding.

Flexibility

In order to route a pipeline between two points certain directional changes normally have to be made in order to avoid equipment, structures, etc. Thus a pipeline usually has a certain inherent flexibility even when routed in its most economical manner. Due to this fact the actual fracture of a pipeline due to expansion alone is a very rare occurance. Problems which occur due to lack of flexibility are leakage of flanges, damage to walls, ceilings and floors.

The subject of flexibility is chiefly concerned with hot pipelines, that is those containing steam or hot water. Temperatures of 200ºC are not uncommon and a pipeline raised to such a temperature will expand 130mm every 50m. However a pipeline subject to only 20ºC change in ambient temperature will expand or contract 25mm every 100m; remember the change in temperature from winter to summer.

Problems now arise for the piping designer and steps must be taken to:

1. Ensure that the pipeline is flexible.

2. Limit the forces and moments which the expanded pipeline will place on any connected equipment, e.g. boiler mounting, header branches, heating radiators fixed to walls, etc.

3. Consider the lateral movement of any branch pipelines, particularly if passing through walls, ceilings and floors.

To protect these vulnerable points suggested in 2 and 3 above, pipe anchors should be employed. Anchors also serve to isolate sections of complicated multiplane pipe systems which helps flexual analysis. Anchors are made by welding or bolting a suitable small "structure" to the pipeline which is then fastened to a suitable column or fixing in service ducts.

Having positioned the anchors the system should be examined for flexibility. If an offset occurs in a straight pipeline between two anchors this could provide enough flexibility. The tables overleaf will be a guide to the lengths of offset required.

The force required to deflect the offset in the pipe can be calculated using the following formulae:-

$F = \frac{24\,IX}{L^3}$ For carbon steel pipes.

$F = \frac{8.4\,IX}{L^3}$ For copper pipes.

where,

F = Force in Newtons.
I = Moment of Inertia in cm^4.(see appendix 3)
X = Expansion in mm.
L = Length of offset in metres.

(see page 6 for derivation of these formulae)

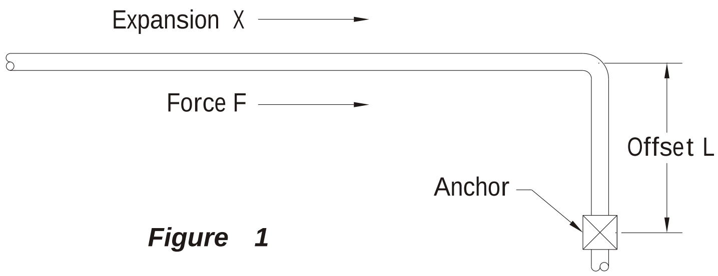


Figure 1

Add to this the force to overcome the friction of the pipe supports, which can be estimated using the method shown under pipe anchors featured later. The longer leg of the bend should be used in this calculation.

The anchors should be designed to withstand this total force both axially and laterally.

Example 1:-

Calculate the force to deflect a 4 metre long, 80mm nominal size medium steel offset when subjected to 20mm movement due to thermal expansion.

$F = \frac{24 \times 97 \times 20}{4^3} = 727.5$ Newtons

Example 2:-

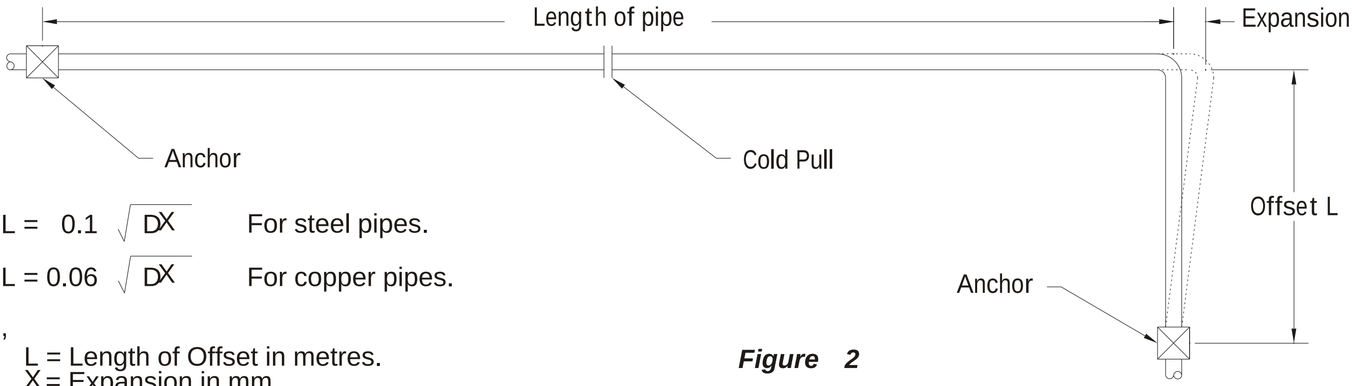
Calculate the force required to deflect a 4 metre long, 76mm nominal size table X copper offset when subjected to 20mm of movement.

$F = \frac{8.4 \times 24.4 \times 20}{4^3} = 64.1$ Newtons

Flexibility of a Pipe with an Offset

Calculate the expansion in the longer leg of a pipe with an offset between the anchors. Read the offsets from the tables below which are shown in metres under the nominal bore. No pipe alignment guides should be fitted and the pipes should be supported by hangers or sliding supports.

If 50% cold pull is applied to the system, which in effect pre-stresses the line, the offsets will absorb twice the expansion.



Offset L = $0.1\sqrt{DX}$ For steel pipes.

Offset L = $0.06\sqrt{DX}$ For copper pipes.

Figure 2

Where,

L = Length of Offset in metres.
X = Expansion in mm.
D = Pipe Nominal Size in mm.

(see page 6 for derivation of these formulae)

Table 2	TABLE SHOWING SINGLE OFFSET SIZE FOR STEEL PIPES (Without Cold Pull)											
EXPANSION	**PIPE NOMINAL SIZE (mm)**											
X	**15**	**20**	**25**	**32**	**40**	**50**	**65**	**80**	**100**	**125**	**150**	**200**
1mm	0.39	0.45	0.50	0.57	0.64	0.71	0.81	0.90	1.00	1.12	1.23	1.42
3mm	0.67	0.78	0.87	0.98	1.10	1.23	1.40	1.55	1.74	1.94	2.12	2.45
5mm	0.87	1.00	1.12	1.27	1.42	1.58	1.81	2.00	2.24	2.50	2.74	3.17
10mm	1.23	1.42	1.58	1.79	2.00	2.24	2.55	2.83	3.16	3.54	3.87	4.47
15mm	1.50	1.73	1.94	2.19	2.45	2.74	3.12	3.47	3.87	4.33	4.75	5.48
20mm	1.73	2.00	2.24	2.53	2.83	3.16	3.61	4.00	4.47	5.00	5.48	6.33
30mm	2.12	2.45	2.74	3.10	3.47	3.87	4.42	4.90	5.48	6.12	6.71	7.75
40mm	2.45	2.83	3.16	3.58	4.00	4.47	5.10	5.66	6.33	7.07	7.75	8.95
60mm	3.00	3.47	3.87	4.38	4.90	5.48	6.25	6.93	7.75	8.66	9.49	10.96
80mm	3.47	4.00	4.47	5.06	5.66	6.33	7.21	8.00	8.95	10.00	10.96	12.65
100mm	3.87	4.47	5.00	5.66	6.33	7.07	8.06	8.95	10.00	11.18	12.25	14.14

Table 3	TABLE SHOWING SINGLE OFFSET SIZE FOR COPPER PIPES (Without Cold Pull)											
EXPANSION	**PIPE NOMINAL SIZE (mm)**											
X	**15**	**22**	**28**	**35**	**42**	**54**	**67**	**76**	**108**	**133**	**159**	**219**
1mm	0.24	0.28	0.32	0.36	0.39	0.44	0.49	0.53	0.63	0.69	0.76	0.89
3mm	0.40	0.49	0.55	0.62	0.67	0.77	0.85	0.91	1.08	1.20	1.31	1.54
5mm	0.52	0.63	0.71	0.80	0.87	0.99	1.10	1.17	1.40	1.55	1.69	1.99
10mm	0.74	0.89	1.01	1.12	1.23	1.40	1.56	1.66	1.97	2.19	2.39	2.81
15mm	0.90	1.09	1.23	1.38	1.51	1.71	1.90	2.03	2.42	2.68	2.93	3.44
20mm	1.04	1.26	1.42	1.59	1.74	1.97	2.20	2.34	2.79	3.10	3.39	3.97
30mm	1.27	1.54	1.74	1.95	2.13	2.42	2.69	2.87	3.42	3.79	4.15	4.87
40mm	1.47	1.78	2.01	2.25	2.46	2.79	3.11	3.31	3.95	4.38	4.79	5.62
60mm	1.80	2.18	2.46	2.75	3.01	3.42	3.81	4.05	4.83	5.36	5.86	6.88
80mm	2.08	2.52	2.84	3.18	3.48	3.95	4.39	4.68	5.58	6.19	6.77	7.94
100mm	2.32	2.82	3.18	3.55	3.89	4.41	4.91	5.23	6.24	6.92	7.57	8.88

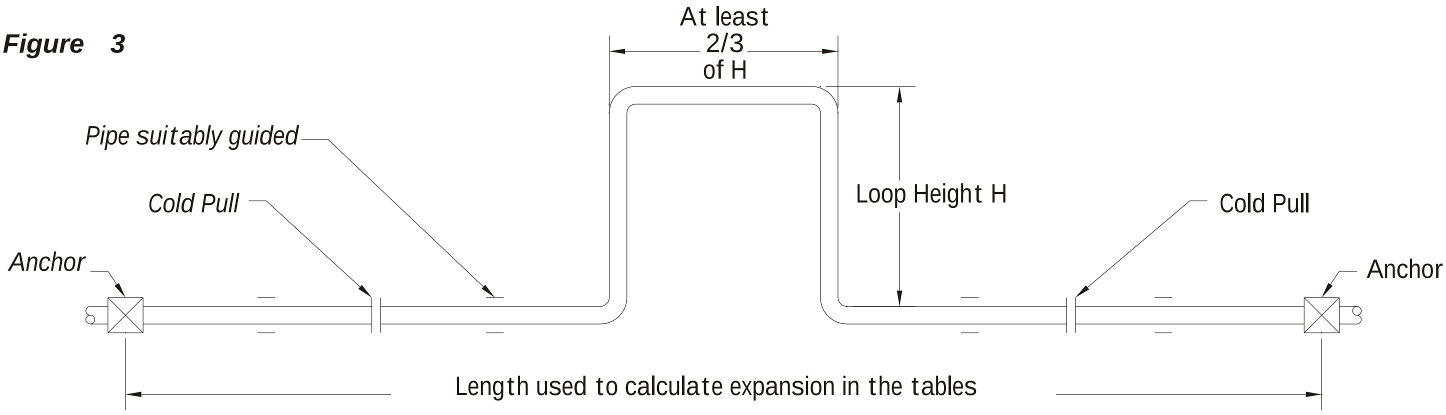
See next page for details regarding pipes with a loop.

Flexibility of a Pipe with a Loop

For an arrangement involving a loop, the expansion used to calculate the offset figures in tables 2 and 3 on page 4 can be halved since the total expansion is being absorbed by two offsets instead of one. Guides are permitted with this arrangement.

If 50% cold pull is applied to the system, which in effect pre-stresses the line, the loop shown will absorb twice the expansion.

Figure 3



Loop Height $H = 0.1\sqrt{\frac{DX}{2}}$ For steel pipes.

Loop Height $H = 0.06\sqrt{\frac{DX}{2}}$ For copper pipes.

Where,
H = Height of Loop in metres.
X = Expansion in mm.
D = Pipe Nominal Size in mm.

Table 4	TABLE SHOWING LOOP HEIGHT FOR STEEL PIPES (Without Cold Pull)											
EXPANSION X	**PIPE NOMINAL SIZE (mm)**											
	15	**20**	**25**	**32**	**40**	**50**	**65**	**80**	**100**	**125**	**150**	**200**
1mm	0.28	0.32	0.36	0.40	0.45	0.50	0.57	0.64	0.71	0.79	0.87	1.00
3mm	0.48	0.55	0.62	0.69	0.78	0.87	0.99	1.10	1.22	1.37	1.50	1.74
5mm	0.61	0.71	0.79	0.90	1.00	1.12	1.28	1.42	1.58	1.77	1.94	2.24
10mm	0.87	1.00	1.12	1.27	1.42	1.58	1.81	2.00	2.24	2.50	2.74	3.17
15mm	1.06	1.23	1.37	1.55	1.74	1.94	2.21	2.45	2.74	3.06	3.36	3.88
20mm	1.23	1.42	1.58	1.79	2.00	2.24	2.55	2.83	3.16	3.54	3.87	4.47
30mm	1.50	1.73	1.94	2.19	2.45	2.74	3.12	3.47	3.87	4.33	4.75	5.48
40mm	1.73	2.00	2.24	2.53	2.83	3.16	3.61	4.00	4.47	5.00	5.48	6.33
60mm	2.12	2.45	2.74	3.10	3.47	3.87	4.42	4.90	5.48	6.12	6.71	7.75
80mm	2.45	2.83	3.16	3.58	4.00	4.47	5.10	5.66	6.33	7.07	7.75	8.95
100mm	2.74	3.16	3.54	4.00	4.47	5.00	5.70	6.33	7.07	7.91	8.66	10.00

Table 5	TABLE SHOWING LOOP HEIGHT FOR COPPER PIPES (Without Cold Pull)											
EXPANSION X	**PIPE NOMINAL SIZE (mm)**											
	15	**22**	**28**	**35**	**42**	**54**	**67**	**76**	**108**	**133**	**159**	**219**
1mm	0.17	0.20	0.23	0.25	0.28	0.31	0.35	0.37	0.44	0.49	0.54	0.63
3mm	0.29	0.35	0.39	0.44	0.48	0.54	0.60	0.64	0.77	0.85	0.93	1.09
5mm	0.37	0.45	0.50	0.56	0.62	0.70	0.78	0.83	0.99	1.10	1.20	1.41
10mm	0.52	0.63	0.71	0.80	0.87	0.99	1.10	1.17	1.40	1.55	1.69	1.99
15mm	0.64	0.77	0.87	0.97	1.07	1.21	1.35	1.43	1.71	1.90	2.07	2.43
20mm	0.74	0.89	1.01	1.12	1.23	1.40	1.56	1.66	1.97	2.19	2.39	2.81
30mm	0.90	1.09	1.23	1.38	1.51	1.71	1.90	2.03	2.42	2.68	2.93	3.44
40mm	1.04	1.26	1.42	1.59	1.74	1.97	2.20	2.34	2.79	3.10	3.39	3.97
60mm	1.27	1.54	1.74	1.95	2.13	2.42	2.69	2.87	3.42	3.79	4.15	4.87
80mm	1.47	1.78	2.01	2.25	2.46	2.79	3.11	3.31	3.95	4.38	4.79	5.62
100mm	1.65	1.99	2.25	2.51	2.75	3.12	3.47	3.70	4.41	4.89	5.35	6.28

The use of cold pull is standard practice but to what extent this is usefully employed is a matter for much deliberation. The usual proceedure is to specify a cold pull equivalent to about half the thermal expansion. This can be measured by leaving a gap between two flanges, which is then tightened up last of all.

Derivation of Formulae

The following details show the derivation of the formula to determine the offset required to absorb the expansion in the length of a pipeline between two anchors, also the formula that can be used to calculate the force required to deflect the offset. These formulae can be used to determine the unrestrained length of a branch from an expanding main pipeline.

The theory is based on the deflection of the offset using formulae for the stress and deflection of a beam. The section of the beam is the cross section of the pipe, and should be considered as a beam fixed at both ends.

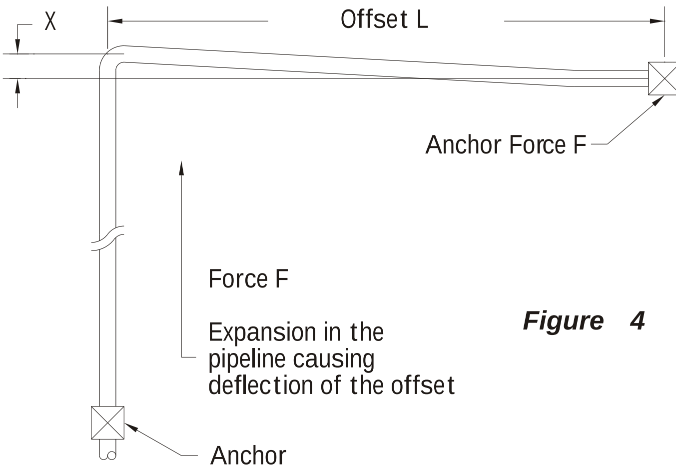


Figure 4

X	=	Deflection in mm.
L	=	Offset in metres.
E	=	Modulus of Elasticity.
f	=	Maximum stress.
I	=	Moment of Inertia in cm^4.
D	=	Pipe nominal size in mm.
F	=	Force in Newtons.
y	=	Distance in mm of the outside of the pipe from the neutral axis.

Bending moment diagram is as follows:-

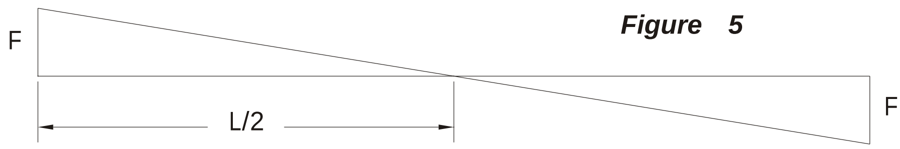


Figure 5

Deflection at mid-point $= \dfrac{X}{2} = \dfrac{F(L/2)^3}{3EI}$

Therefore, $F = \dfrac{12EIX}{L^3}$

Substituting for E,

(For steel pipes $E = 200 \times 10^9$ N/m^2) Therefore, $F = \dfrac{24IX}{L^3}$ For steel pipes.

(For copper pipes $E = 70 \times 10^9$ N/m^2) Therefore, $F = \dfrac{8.4IX}{L^3}$ For copper pipes.

Bending moment $= F \times L/2 = \dfrac{fI}{y}$

Therefore, $FL = \dfrac{2fI}{y}$

From above, $FL = \dfrac{12EIX}{L^2}$

Therefore, $\dfrac{2fI}{y} = \dfrac{12EIX}{L^2}$

$L^2 = \dfrac{6EXy}{f}$

Substituting for E and f and introducing D/2 as y, $L^2 = \dfrac{6 \times 200 \times 10^9 \times XD}{60 \times 10^6 \times 10^3 \times 10^3 \times 2} = \dfrac{DX}{10^2}$

(For steel pipes $E = 200 \times 10^9$ N/m^2)
(For steel pipes $f = 60 \times 10^6$ N/m^2)

Therefore, $L = 0.1\sqrt{DX}$ For steel pipes.

(For copper pipes $E = 70 \times 10^9$ N/m^2)
(For copper pipes $f = 60 \times 10^6$ N/m^2)

Therefore, $L = 0.06\sqrt{DX}$ For copper pipes.

Note that an increase in the allowable stress will result in a reduction of the offset.
To calculate the stress for various offsets use the following formulae:-

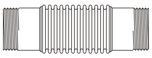
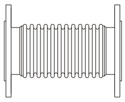
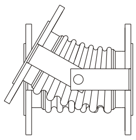
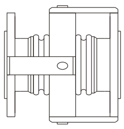
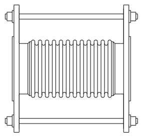
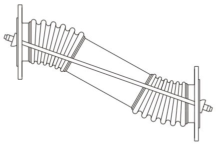
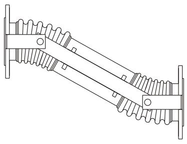
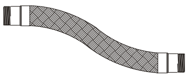
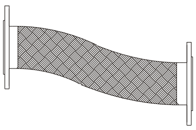
$f = \dfrac{6 \times 10^5\ DX}{L^2}$ For steel pipes.

$f = \dfrac{2.1 \times 10^5\ DX}{L^2}$ For copper pipes.

Selection of Expansion Joints

Having established that natural flexibility cannot deal with the expansion in a pipework system we must now consider which type of expansion joint is best suited to absorb the movement. The possible positions and strength of anchor fixings must first be decided. Where relatively short movements are involved and substantial anchors can be fitted then axial movement joints should be considered. If long movements are involved or anchors would be difficult to fix then angular, gimbal, fully articulated, double hinged or braided joints will need to be used as these impose much lighter forces within the system and can absorb much longer movements. Each of these joints are illustrated below and will be looked at in detail over the next 4 pages with regard to their use in piping systems.

Table 6 TABLE SHOWING METALLIC EXPANSION JOINT TYPES

COMMON NAMES	ILLUSTRATION	EMFLEX TYPES
Axial Single Axial (Screwed)		BAT for steel pipe BATN for copper pipe
Axial Single Axial (Flanged)		BAF for steel pipe BAFN for copper pipe
Angular Hinged Single Hinged		BHF for steel pipe BHFN for copper pipe
Gimbal Universally Hinged		BGF for steel pipe BGFN for copper pipe
Single Articulated Single Tied		BFC for steel pipe BFCN for copper pipe
Fully Articulated Double Tied Tied Lateral		BLF for steel pipe BLFN for copper pipe
Double Hinged Single Plane Articulated Hinged Lateral		BDHF for steel pipe BDHFN for copper pipe
Braided Braided Lateral (Screwed)		BBT for steel pipe BBTN for copper pipe
Braided Braided Lateral (Flanged)		BBF for steel pipe BBFN for copper pipe

For additional information on the EMFLEX types, please refer to the relevent pages within our product catalogue.

AXIAL expansion joints are designed to absorb movements generally between 25mm and 50mm, although longer movements of 75mm are available on request. They are fitted in the pipeline, in line with the movement. They require an anchor each end of the system to resist the pressure force and to compress the bellows. Proper pipe alignment guides are required; see later for details of anchors and guides. Typical arrangements are as follows:-

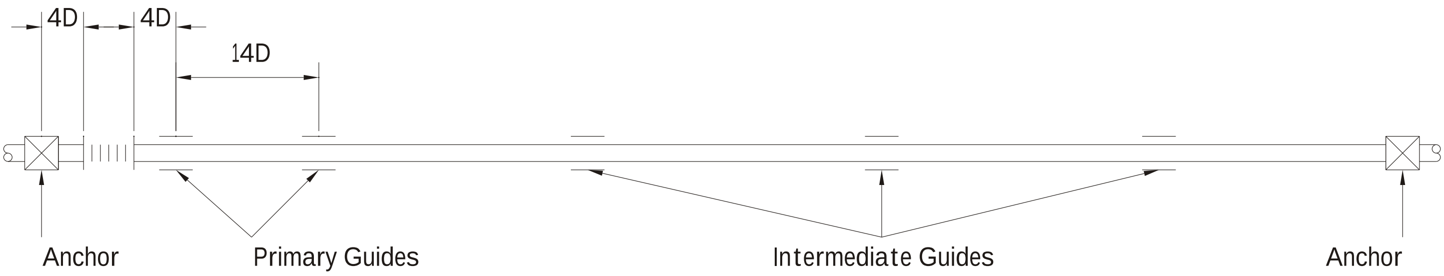


Figure 6

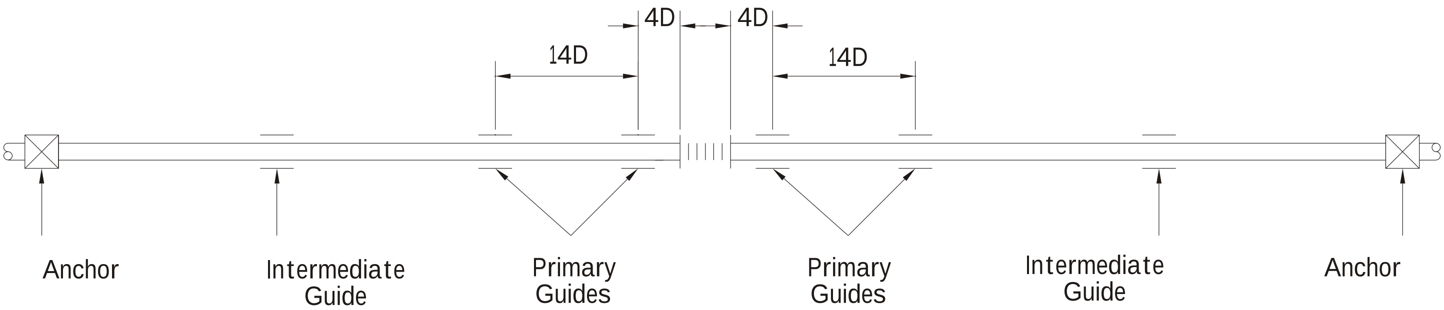


Figure 7

Comparing figures 6 and 7, it can be seen that the axial expansion joint may be positioned anywhere in a straight pipe run. However, the number of primary and intermediate guides required does vary, so it is important to consider carefully options available on site.

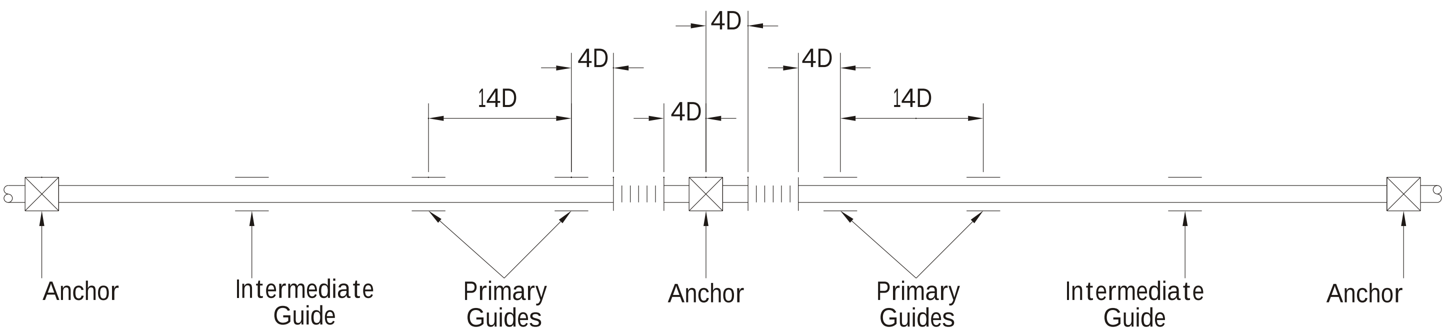


Figure 8

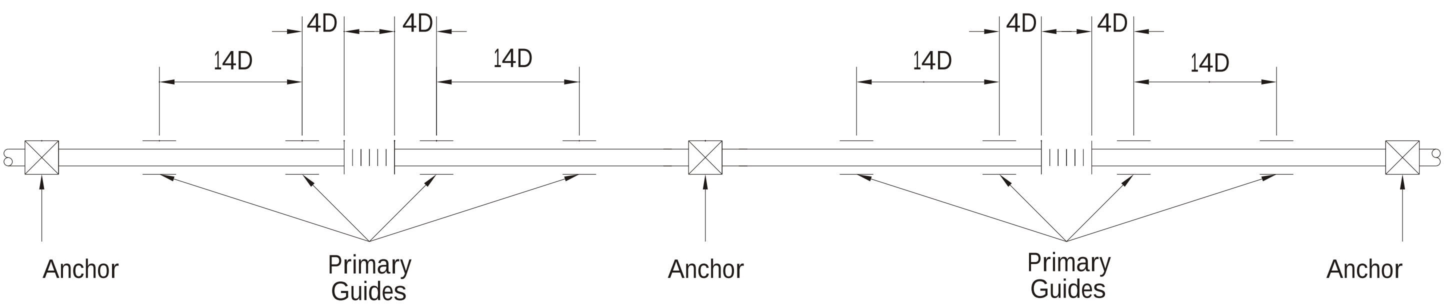


Figure 9

With figures 8 and 9 the same comparison can be made with regard to the numbers of guides. Also consider in these two cases the ease of access for periodic inspection in the future; figure 8 allows for one access point, whereas figure 9 requires two access points.

ANGULAR expansion joints are effectively a hinged bend in a pipeline and allows the pipe to bend (angulate) at a specific point. They are a pressure restrained unit, therefore do not impose large forces on to the pipework. Light anchors are sufficient as these are only required to direct the movement of the pipe in the desired direction.

Angular expansion joints cannot be used singularly; they should be fitted in sets of two or three. Typical arrangements are as follows:-

Two Pin Z System (Used where an articulated or double hinged unit would be extremely long and thus difficult to manoeuvre for installation on site. Two angular units and an intermediate fabricated section of pipe would be easier to move into place)

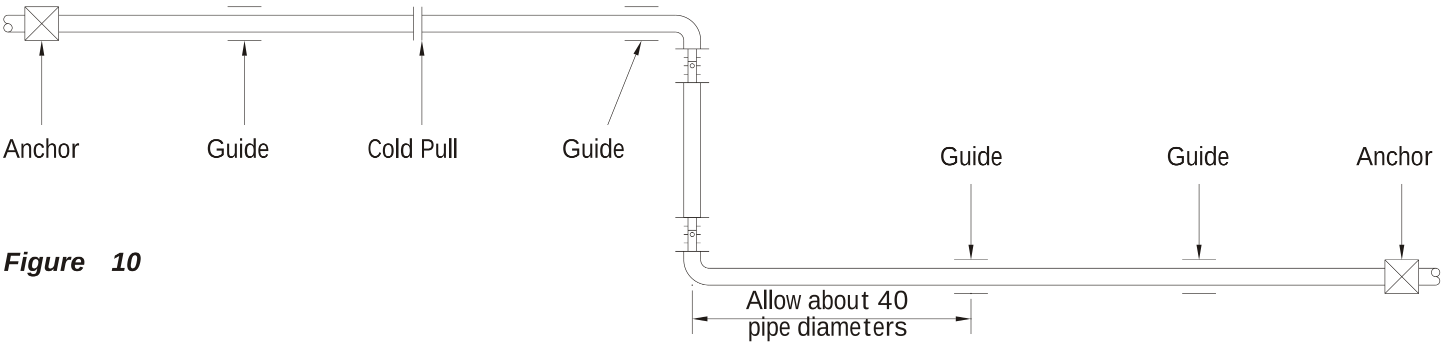


Figure 10

Three Pin Z System (Used where the offset is too small for the use of an articulated or double hinged unit)

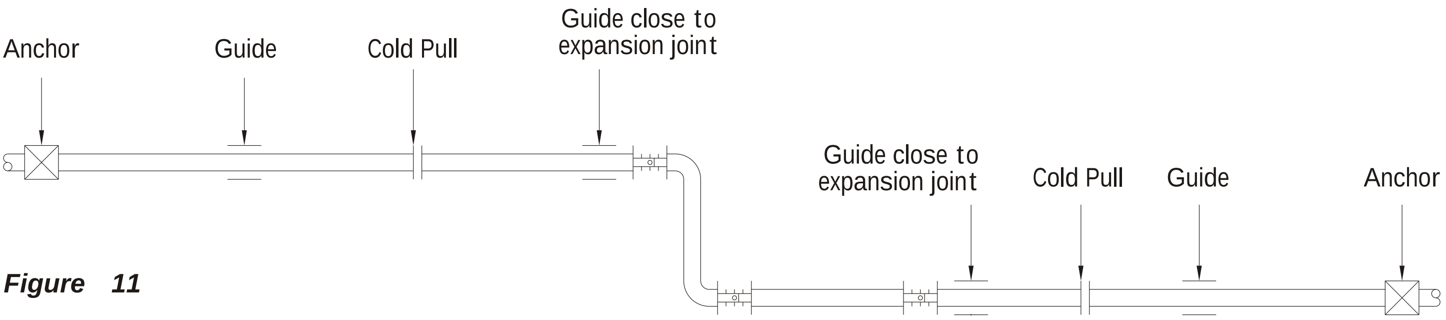
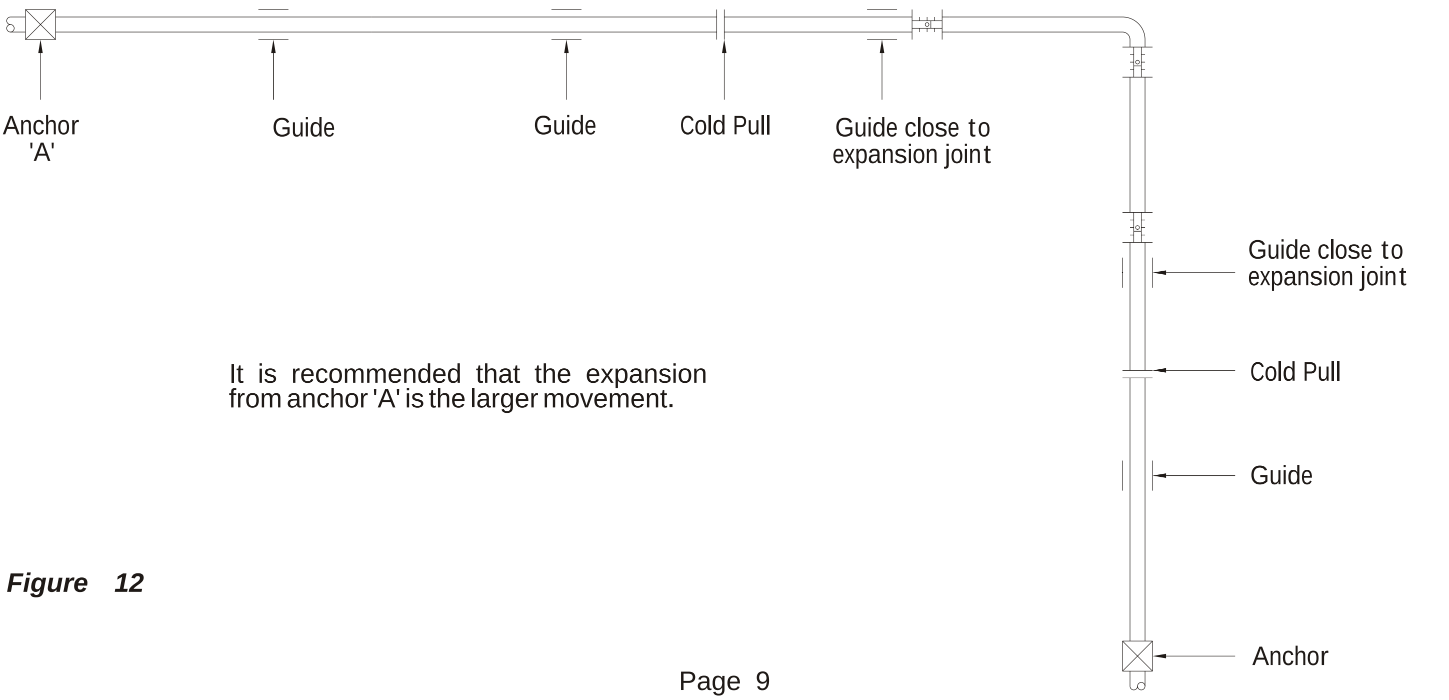


Figure 11

Three Pin L System (This system is usually installed horizontally. It is used where two long runs are at right angles and both movements are to be taken at the bend.)



It is recommended that the expansion from anchor 'A' is the larger movement.

Figure 12

Three Pin U System (Used mainly in long pipelines as an alternative to one or two articulated units. Careful calculation of the length of the loop is required. The system can be installed in any plane, with the loop in any part of the pipe. The loop should be lightly supported with sliding supports to avoid it swinging around. Cold pull should be in proportion to the movement each side of the loop. Note the centre unit takes up twice the angle of the outer units)

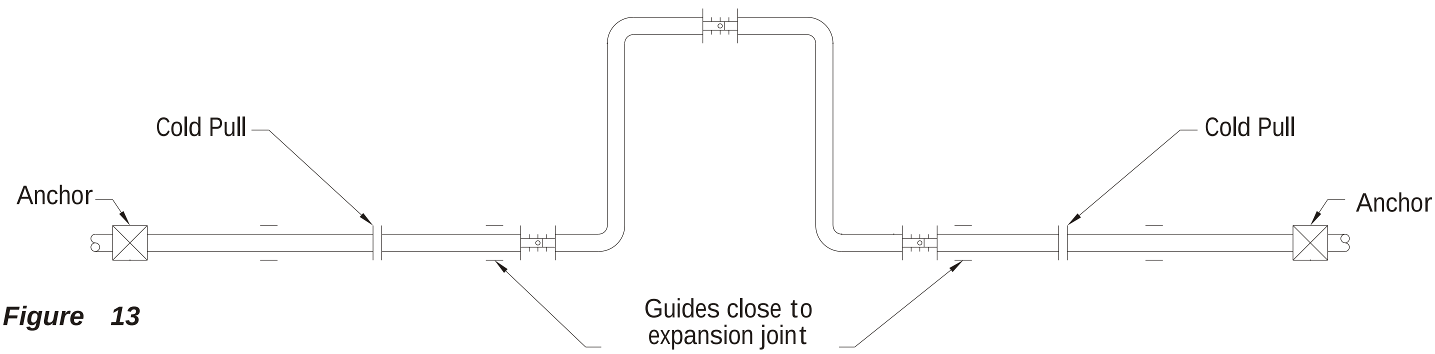


Figure 13

GIMBAL expansion joints are similar in principal to angular units, however, they are in fact a universally hinged device which allows the pipe to bend (angulate) at a specific point in all directions. They are a pressure restrained unit and have similar characteristics to angular units.

Two gimbal units can be used to accept movement from two directions as shown below:-

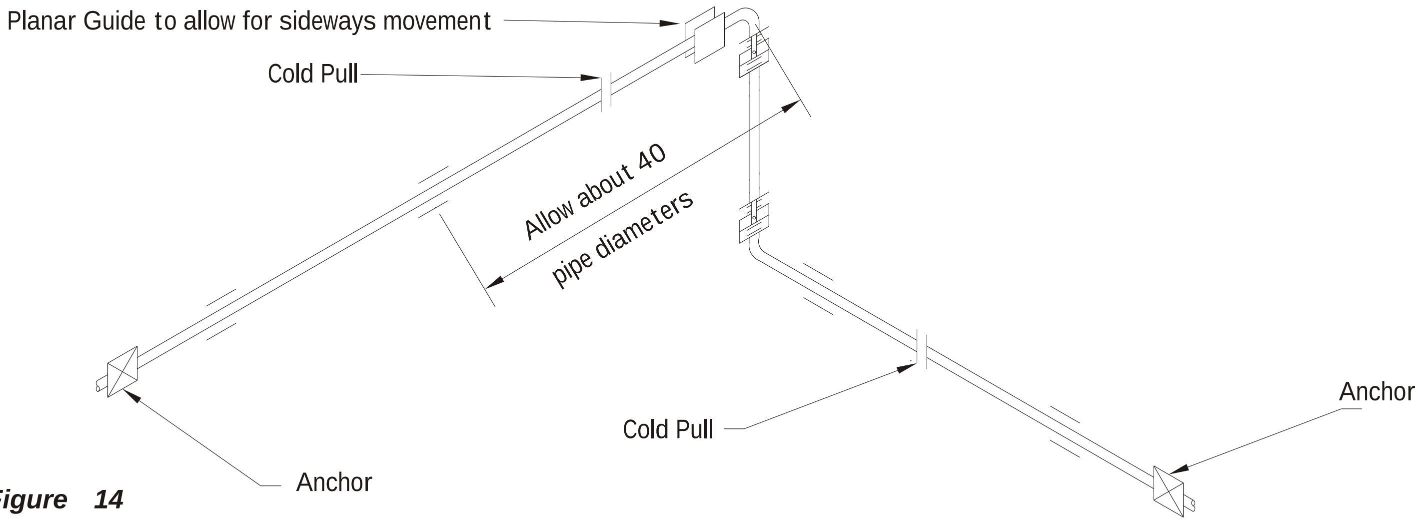


Figure 14

Two gimbal units and one angular unit can be used together as shown below:-

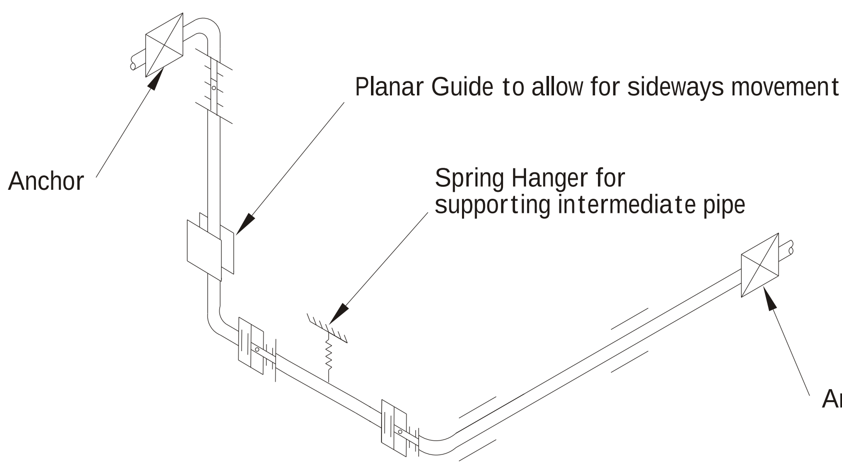


Figure 15

SINGLE ARTICULATED expansion joints are designed to absorb very small amounts of lateral movement or to absorb vibration movement transmitted from items of plant. They must not be used to absorb both types of movement simultaneously. Their mention here is brief as their use as expansion joints is limited by their design; they are however used widely for vibration elimination on plant items operating at high pressures and temperatures.

FULLY ARTICULATED and DOUBLE HINGED expansion joints are effectively two hinged units which allow a section of straight pipe to move laterally. They are a pressure restrained unit, so do not impose large forces on to the pipework. Light anchors are sufficient as these are only required to direct the movement of the pipe in the desired direction.

FULLY ARTICULATED units accept movement in any direction and are installed at right-angles to the expanding pipe. They can be installed horizontally or vertically.

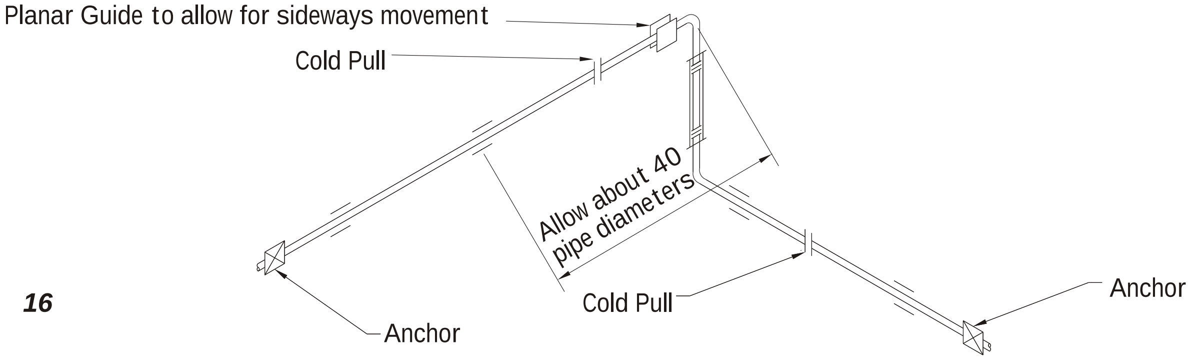


Figure 16

DOUBLE HINGED units only accept movement in one plane and are installed at right-angles to the expanding pipe. They can be installed horizontally or vertically.

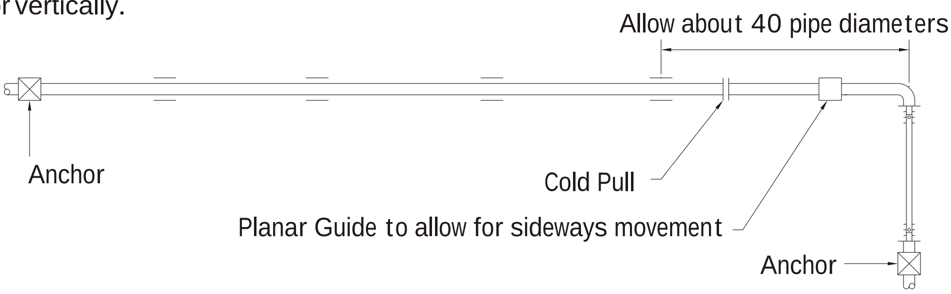


Figure 17

BRAIDED expansion joints are used in a similar manner to fully articulated units. They must be fitted at right-angles to the expanding pipe and require similar treatment regarding anchors and guides; see later for details. A good example of the use of braided units is when they are installed to absorb movement when a branch pipe passes through a wall as shown below:-

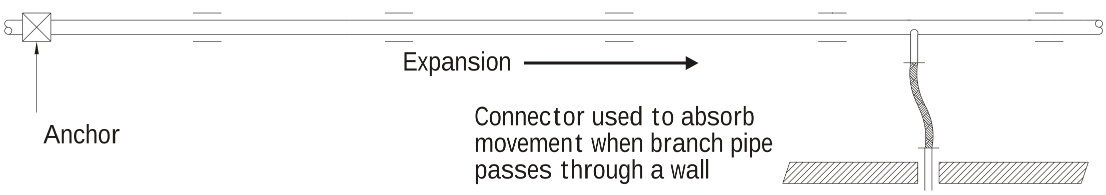


Figure 18

Another particular use for braided units is when pipelines have to cross building movement joints, which require compensation for axial and lateral movement of the pipe in combination. A good example of how to install is where the unit is fitted parallel to the building movement joint as shown below:-

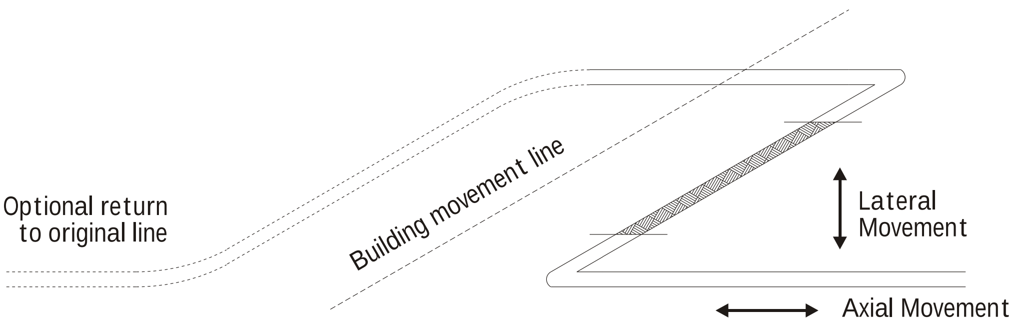


Figure 19

Braided units can be installed in line with the pipeline and will compensate for subsidence in the vertical plane only. Note that some axial movement will occur in the pipeline when lateral movement takes place.

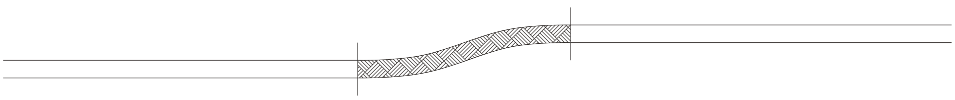


Figure 20

Pipe Anchors

Pipe Anchors for Axial Expansion Joints

Pipe anchors are required to overcome the forces set up when axial expansion joints are under pressure. Two separate conditions can exist as follows:-

1. Pipeline under test pressure. 2. Pipeline under working pressure and temperature.

Each condition must be investigated:-

1. Pipeline under test pressure.
   This force is made up of test pressure x effective area.
2. Pipeline under working pressure and temperature.
   The force is made up of three components;

   a. The force to overcome internal pressure; i.e. working pressure x effective area.
   b. The force to compress the expansion joint. This is calculated by using the force to compress in Newtons/mm from the catalogue and the movement.
   c. The force to overcome the friction of pipe movement, which can be estimated at 30N per metre of pipeline for each 25mm of pipe diameter. This assumes about the worst possible condition of face to face sliding supports. Coefficient of friction about 0.4. If hangers or rollers are used, reduce the figure to 15N per metre of pipeline.

   Thus the Total Force = a + b + c

Expansion joints should not be removed during a pressure test. The purpose of a pressure test is to put the pipeline under stresses greater than those which occur under working conditions. If the expansion joints are removed the anchors and guides are not subjected to any stresses and therefore faults in their design will not show up.

When positioning anchors, great care should be taken to ensure that the main structure to which the anchor is attached, is in fact strong enough to withstand the forces transmitted by the anchor. Also ensure that when a number of pipes are anchored at one point, the total force under working conditions is considered.

Two examples follow showing the anchor forces set up under different conditions. In these examples 1bar = 100 kN/m^2.

Example 1:-

Calculate the anchor force for a 30m long pipeline of 150mm NB at 10 bar working pressure and temperature of 100ºC, with sliding supports.

At 100ºC the expansion in mm/metre is 1.3 Therefore the total expansion is 1.3 x 30 = 39mm.
Test pressure is 1.5 x working pressure = 1.5 x 10 = 15 bar (=1500 kN/m^2)
Effective area can be taken from the product catalogue, in this case = 252 cm^2

For a pipeline under test conditions, TOTAL FORCE = test pressure x effective area = 1500 x 252 x 0.1 = 37,800 N

Working pressure of 10 bar (=1000 kN/m^2)

For a pipeline under working conditions, TOTAL FORCE = a + b + c

$a = 1000 \times 252 \times 0.1 = 25{,}200$ N

$b = 310 \times 39 = 12{,}090$ N

$c = 30 \times 30 \times \frac{150}{25} = 5{,}400$ N

therefore, TOTAL FORCE = 25,200 + 12,090 + 5,400 = 42,690 N

The anchors should be designed to withstand a force of 42,690 Newtons using the usual factor of safety.

Example 2:-

Calculate the anchor force for a 25m long pipeline of 32mm NB at 6 bar working pressure and temperature of 82ºC, using pipe hangers.

At 82ºC the expansion in mm/metre is 1.0 Therefore the total expansion is 1.0 x 25 = 25mm.
Test pressure is 1.5 x working pressure = 1.5 x 6 = 9 bar (=900 kN/m^2)
Effective area can be taken from the product catalogue, in this case = 16 cm^2

For a pipeline under test conditions, TOTAL FORCE = test pressure x effective area = 900 x 16 x 0.1 = 1,440 N

Working pressure of 6 bar (=600 kN/m^2)

For a pipeline under working conditions, TOTAL FORCE = a + b + c

$a = 600 \times 16 \times 0.1 = 960$ N

$b = 15 \times 25 = 375$ N

$c = 15 \times 25 \times \frac{32}{25} = 480$ N

therefore, TOTAL FORCE = 960 + 375 + 480 = 1,815 N

Pipe Anchors on a Riser with Axial Expansion Joints

When designing the bottom anchor for the riser in a tall building, extra care is necessary. Consider a ten-storey block of offices with an average floor spacing of 4 metres.

The head of water in the riser is 40 metres which creates a pressure of 4.0 bar at the bottom of the riser.

On a 150mm nominal size pipe the downward force will be:-

4 x 189.5 x 10 (pressure x area) = 7,580 N.

(area = 18,950mm² = 189.5cm² - see Appendix 3)

The weight of pipe over say 3.5 floors could be supported by the bottom anchor.

Weight of pipe = 3.5 x 4m x 19.2 = 268.8 kg

(weight of 150mm pipe is 19.2 kg/m - see Appendix 3)

Therefore, Force = 2,688 N

The extra pressure on the expansion joint of at least 7 floors water head will be:-

7 x 4m x 0.1 = 2.8 bar.

This must be added to the test pressure when designing the anchor.

When these three extra forces are added together they can show an increase of 50 - 100% in the design figure for the bottom anchor depending on the height of the building.

Full use should be made of cold pull when designing a riser in a tall building, with branches at each floor; lateral movement being limited to a few millimetres say +/-3 mm.

With water temperature of 82ºC the expansion over 4 floors shown in the example will be:-

4 x 4m x 1.0 = 16 mm.

When applying cold pull under these circumstances, note that the expansion joint may be pre-stressed and be at installation length.

It may be that the force on the bottom anchor will prove too much for the floors and walls in a building; in this case a proper duck-foot anchor (see page 15, figure 27) at the very bottom of the riser should be considered.

There are no hard and fast rules as each building is different, bearing in mind the line sizes and strength of the building. If the lateral movement of branches is too much for the length of free pipe, then braided units may be useful.

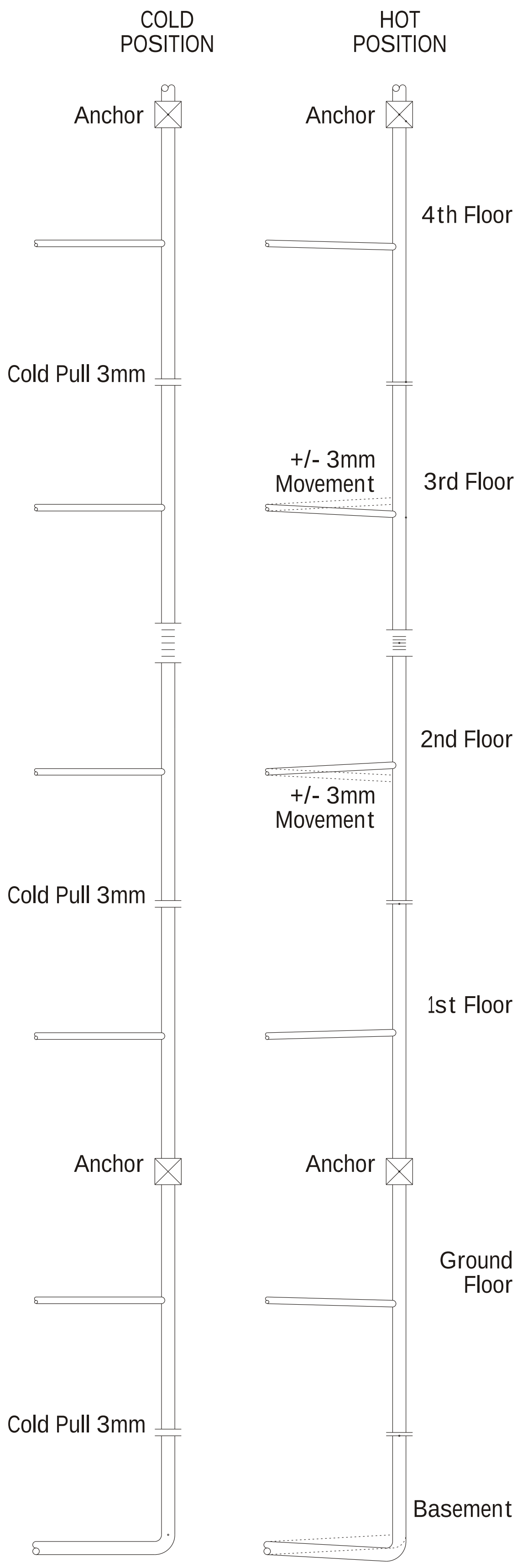


Figure 21 *Figure 22*

Pipe anchors are required to overcome the forces set up when these types of expansion joint are installed in a pipeline under temperature. In a system using these units, pressure plays no part whatsoever; under test conditions no forces are created. Under working conditions the forces created are due to pipeline friction over the supports and the force to move the expansion joint.

As the force required to move the expansion joint is negligible and the forces on the anchors are almost entirely due to friction, it is worth giving some consideration to the type of pipe support to be used to minimise friction.

To minimise the frictional resistance, roller type supports may be used or even special PTFE pad supports. These can have a coefficient of friction as low as 0.03 (less than one tenth of the figure used below).

In the following examples, the friction force is estimated as for axial units using sliding supports. The force to deflect the expansion joint can be taken from our product catalogue.

Example 1:-

Calculate the anchor force for a pipeline of 150mm nominal size at 10 bar working pressure and 120m length, using a fully articulated expansion joint installed in an offset. The pipe is supported on face to face supports.

Total Force = force to deflect expansion joint + force to overcome friction.

Force to deflect expansion joint from literature = 700 N

Force to overcome friction = $30 \times 120 \times \frac{150}{25} = 21{,}600$ N

TOTAL FORCE = 700 + 21,600 = 22,300 N

Note that the force to deflect the expansion joint is negligible. Compare this with the forces involved with the 150mm nominal size axial expansion joint example on page 12.

Example 2:-

Calculate the anchor force for a pipeline of 80mm nominal size, carrying steam at 16 bar pressure. The length of pipe is 30m. A two-pin Z-system, consisting of two angular expansion joints, is installed in the offset with a distance of 1m between the hinge pins. The pipe is supported on hangers.

The force to deflect each expansion joint, taken from the product catalogue is 68 N

Therefore the total force to deflect = 2 x 68 = 136 N

Force to overcome friction = $15 \times 15 \times \frac{80}{25} = 720$ N

TOTAL FORCE = 136 + 720 = 856 N

Note that the length of pipe used to calculate friction forces is measured between the anchor and the expansion joint.

Typical Pipe Anchor Illustrations

We suggest below some examples of pipe anchors designed for small or large forces. All pipes and components shown are either welded or bolted together to provide a suitable anchor point. Good fixing to the building structure is essential, as is the need to use adequate strength materials.

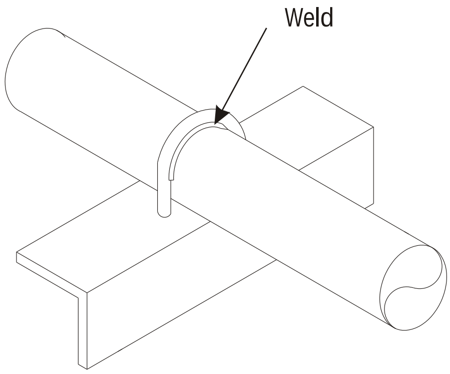


Figure 23 Very Light Anchor

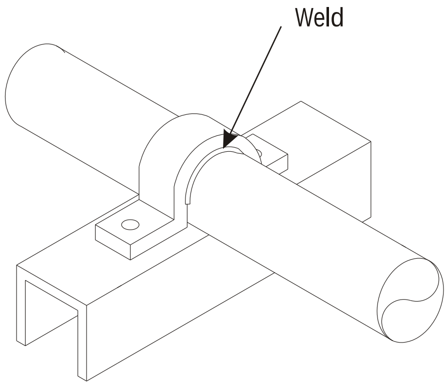


Figure 24 Light Anchor

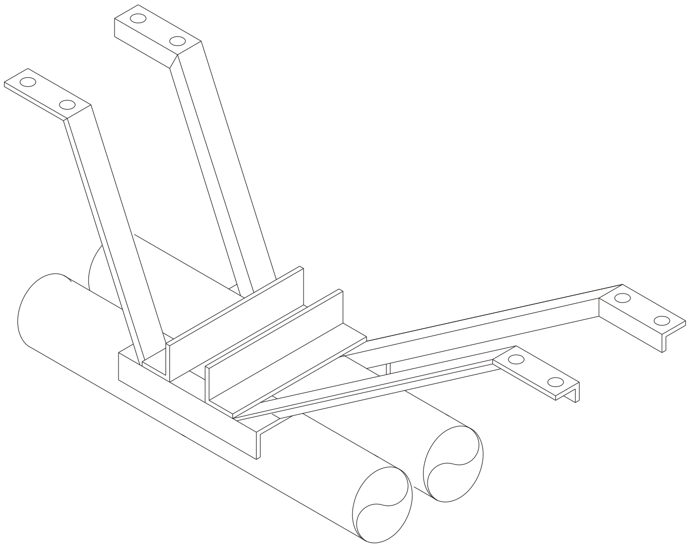


Figure 25 Medium Anchor

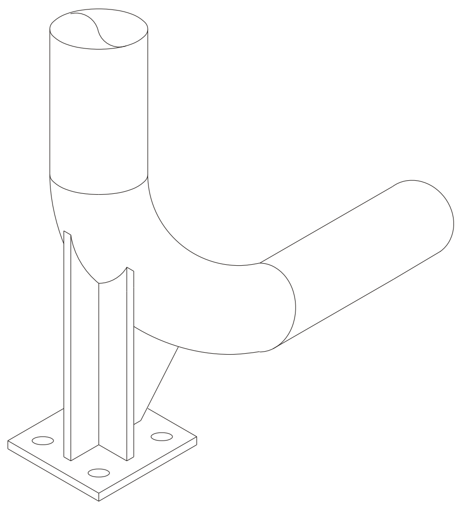


Figure 27 Duck-foot Anchor

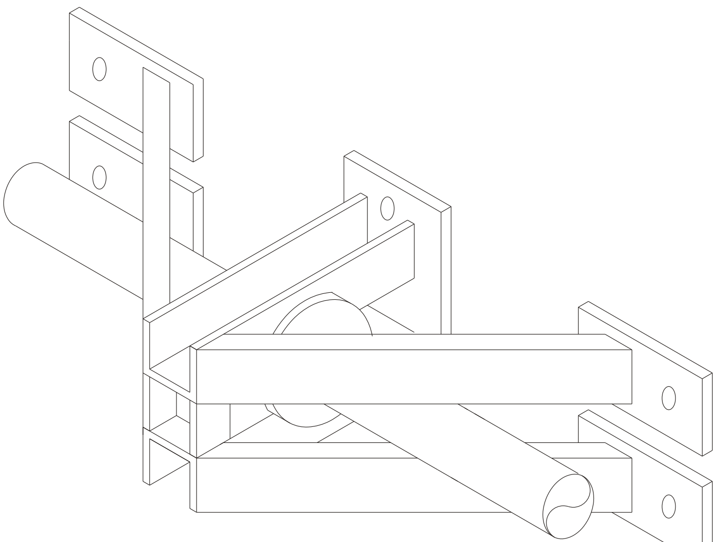


Figure 26 Heavy Anchor

Planar Anchor

A variation of the heavy anchor shown is one where the pipe and flange are not fixed to the steelwork. This variation would allow for sideways motion of the pipe, but still prevents axial or linear motion of the pipe.

Pipe Alignment Guides

Pipe Alignment Guides for use with Axial Expansion Joints (Unrestrained Expansion Joints)

Pipe alignment guides are essential for the correct operation of AXIAL type expansion joints.

A pipeline which contains an expansion joint and is anchored at each end can be considered as a load bearing column. Thus when pressure is applied, guides are necessary to prevent bowing and bending.

The first pipe alignment guide must be located within a distance of 4 pipe diameters or 300mm which ever is the less. The second guide must be located within a distance of 14 pipe diameters from the first pipe guide. These are considered as primary guides. Intermediate guides are required along the rest of the length of the pipe.

When using a single AXIAL joint, position the unit as near as possible to one of the anchors. This can save on the number of guides required, but when using a single AXIAL joint in a pipeline with a number of branches, the joint should be placed so as to minimise the amount of movement on each branch. Use this arrangement when designing risers in service ducts.

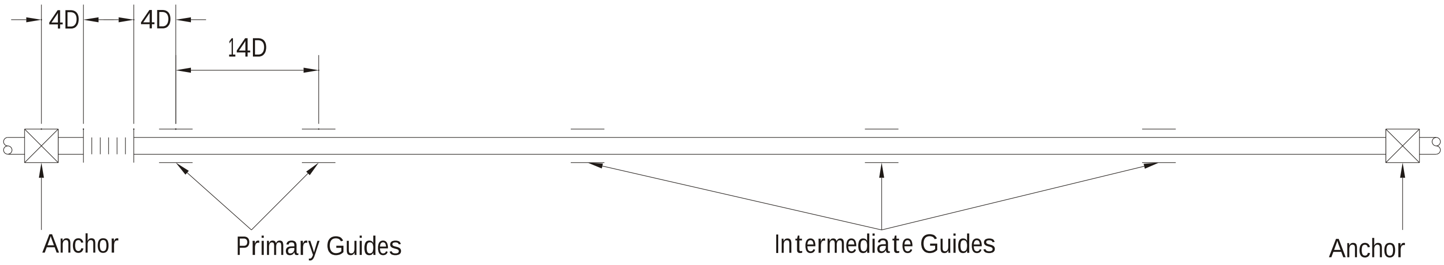


Figure 28

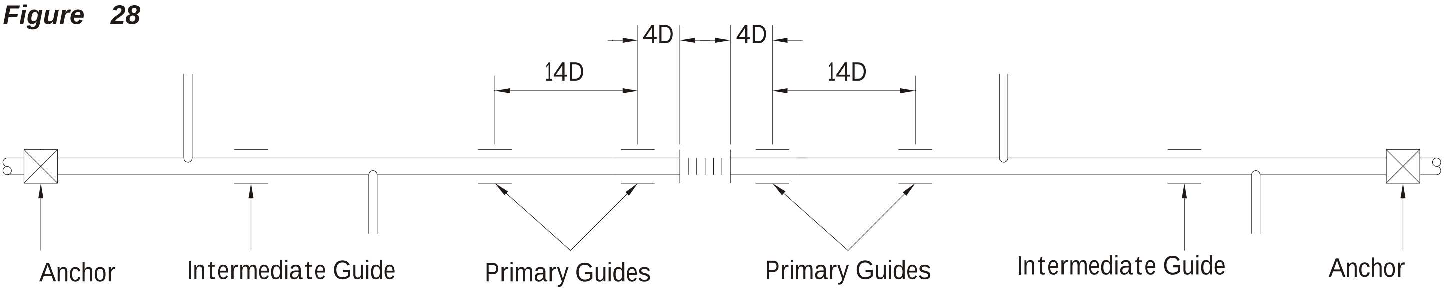


Figure 29

The following tables show the spacing in metres of intermediate guides and are based on the TEST PRESSURE.

Table 7	INTERMEDIATE GUIDE SPACING FOR USE ON STEEL PIPES (With Axial Expansion Joints)											
TEST PRESSURE	**PIPE NOMINAL SIZE (mm)**											
	15	**20**	**25**	**32**	**40**	**50**	**65**	**80**	**100**	**125**	**150**	**200**
6 bar	2.0	3.0	3.5	4.5	5.0	6.0	8.0	9.0	12.0	14.5	15.5	20.0
10 bar	1.5	2.0	2.5	3.5	4.0	4.5	6.5	7.0	9.5	11.5	12.0	16.0
16 bar	1.2	1.7	2.0	2.5	3.0	3.5	5.0	5.5	7.5	9.0	9.5	12.5
25 bar	1.0	1.5	1.7	2.0	2.5	3.0	4.0	4.5	6.0	7.5	8.0	10.0

For copper pipework we recommend that the spacing is reduced by approximately 25% as follows:-

Table 8	INTERMEDIATE GUIDE SPACING FOR USE ON COPPER PIPES (With Axial Expansion Joints)											
TEST PRESSURE	**PIPE NOMINAL SIZE (mm)**											
	15	**22**	**28**	**35**	**42**	**54**	**67**	**76**	**108**	**133**	**159**	**219**
6 bar	1.5	2.2	2.6	3.3	3.7	4.5	6.0	6.7	9.0	10.8	11.6	15.0
10 bar	1.1	1.5	1.8	2.6	3.0	3.3	4.8	5.2	7.1	8.6	9.0	12.0
16 bar	0.9	1.2	1.5	1.8	2.2	2.6	3.7	4.1	5.6	6.7	7.1	9.3
25 bar	0.7	1.1	1.2	1.5	1.8	2.2	3.0	3.3	4.5	5.6	6.0	7.5

For practical purposes a deviation of 10% can be tolerated. Proper guiding of the pipe is essential to ensure straight axial movement of the pipe to the expansion joint. Pipe supports such as drop-rods or hangers are not considered satisfactory as pipe guides. 'U' bolts are not recommended but they may be used on small low pressure screwed pipework.

Pipe alignment guides should be capable of withstanding a lateral force of at least 15% of the anchor force. The lateral movement of the pipeline permitted by the primary guides should be no more than 2mm (+/-1mm) for pipes up to 100mm nominal size and 4mm (+/-2mm) for larger pipes. For intermediate guides the permitted movement should be no more than 4mm (+/-2mm) and 8mm (+/-4mm) respectively.

Pipe Alignment Guides for use with Articulated, Double Hinged, Angular and Gimbal Expansion Joints (Restrained Expansion Joints)

The spacing of pipe alignment guides is dependent on the forces within the pipeline. These forces have already been calculated under anchor design, and the following tables will enable the spacing to be read off in metres, against the anchor force which is in kilo-Newtons.

Table 9	GUIDE SPACING FOR USE ON STEEL PIPES (With Restrained Expansion Joints)											
ANCHOR	**PIPE NOMINAL SIZE (mm)**											
FORCE	**15**	**20**	**25**	**32**	**40**	**50**	**65**	**80**	**100**	**125**	**150**	**200**
1 kN	2.0	3.0	4.0	7.0	9.0	12.0	19.0					
2 kN		2.0	3.0	4.0	6.0	9.0	13.0	17.0	24.0			
4 kN			2.0	3.0	4.0	6.0	9.0	12.0	16.0	22.0	30.0	50.0
8 kN				2.0	3.0	4.0	7.0	8.0	12.0	16.0	21.0	36.0
16 kN					2.0	3.0	4.0	6.0	8.0	12.0	16.0	25.0
32 kN						2.0	3.0	4.0	6.0	8.0	10.0	18.0
64 kN							2.0	3.0	4.0	6.0	8.0	13.0

For copper pipework we recommend that the spacing is reduced by approximately 25% as follows:-

Table 10	GUIDE SPACING FOR USE ON COPPER PIPES (With Restrained Expansion Joints)											
ANCHOR	**PIPE NOMINAL SIZE (mm)**											
FORCE	**15**	**22**	**28**	**35**	**42**	**54**	**67**	**76**	**108**	**133**	**159**	**219**
1 kN	1.5	2.2	3.0	5.2	6.7	9.0	14.2					
2 kN		1.5	2.2	3.0	4.5	6.7	9.7	12.7	18.0			
4 kN			1.5	2.2	3.0	4.5	6.7	9.0	12.0	16.5	22.5	37.5
8 kN				1.5	2.2	3.0	5.2	6.0	9.0	12.0	15.7	27.0
16 kN					1.5	2.2	3.0	4.5	6.0	9.0	12.0	18.7
32 kN						1.5	2.2	3.0	4.5	6.0	7.5	13.5
64 kN							1.5	2.2	3.0	4.5	6.0	9.7

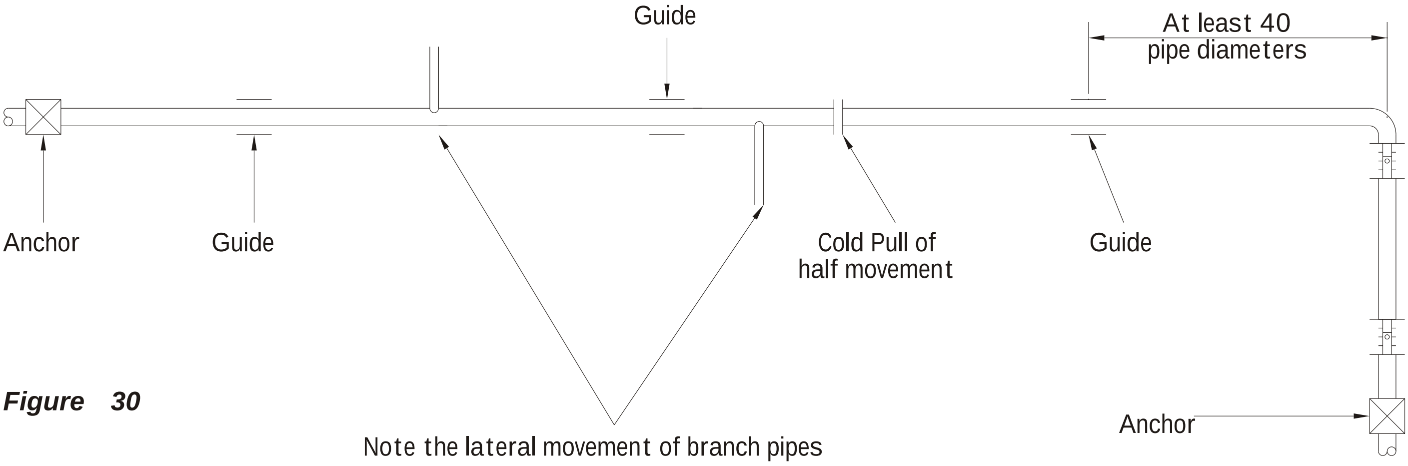


Figure 30

These guides are probably insufficient to support the pipeline, therefore other supports will have to be provided. It is permissible to support the pipe on hangers or drop-rods, thereby reducing the friction force, the dead weight is usually sufficient to keep the pipe aligned. Pipe hangers and drop-rods must be long enough to prevent appreciable rise (uplift) and fall of the pipe due to expansion movement, and also to prevent too much angulation of the drop-rod; (hemispherical supports at the top and link eyes on the bottom will be useful).

Pipe alignment guides should be capable of withstanding a lateral force of at least 15% of the anchor force. The lateral movement should be no more than 4mm (+/-2mm) for pipes up to 100mm nominal size and 8mm (+/-4mm) for larger pipes.

When large pipe movements have to be accommodated ensure that the pipe skids or special supports near the expansion joints are long enough.

Typical Pipe Guide Illustrations

We suggest below some examples of pipe guides for use with different types of expansion joint :-

Strap Guides

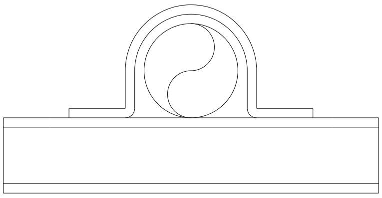


Figure 31 Simple Strap

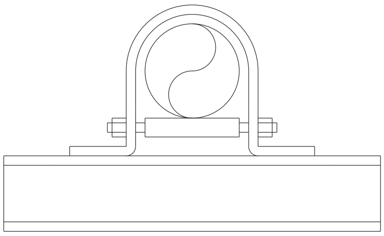


Figure 32 Strap with Tube Roller

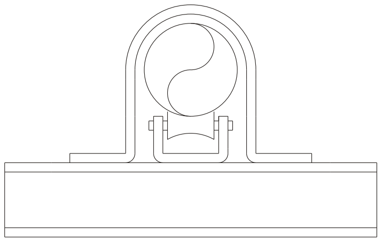


Figure 33 Strap with Roller & Chair

Tube Guides

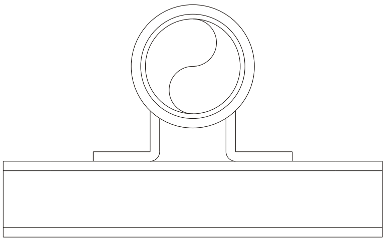


Figure 34 Simple Tube

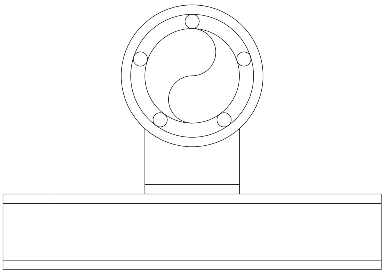


Figure 35 Tube with Spacing Rods

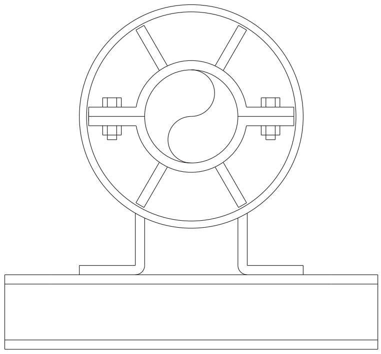


Figure 36 Tube with Spacing Clamp

Tee Guides

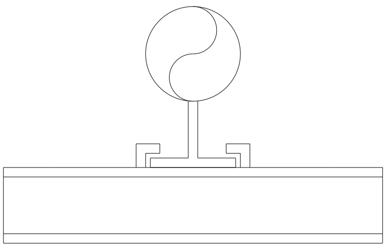


Figure 37 Simple Tee

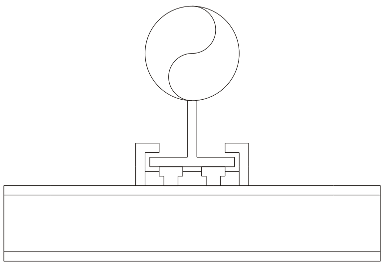


Figure 38 Tee with PTFE Inserts

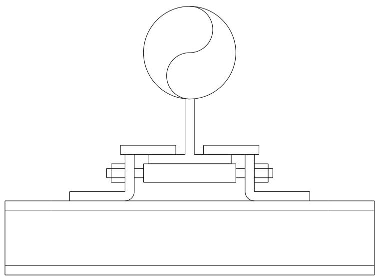


Figure 39 Tee with Tube Roller

Heavy Guides

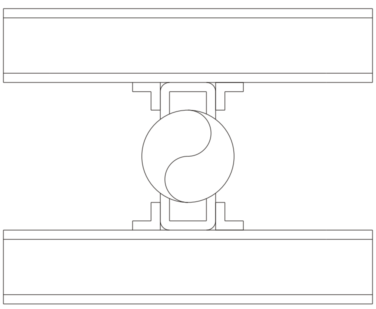


Figure 40 Double U-Section

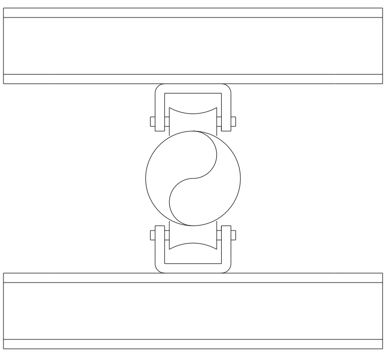


Figure 41 Double Roller & Chair

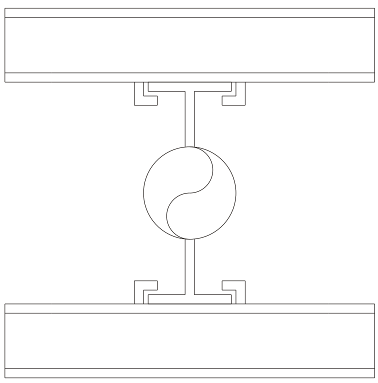


Figure 42 Double Tee

Please note the maximum lateral deflection of the guides with regard to expansion joint type, also the pressure and anchor force limiting factors as dealt with earlier in this book. We appreciate that there are far more designs than we can mention here. The engineer on site will encounter many circumstances which call for adaptation and modification of existing designs; we hope that a few ideas may be taken from the examples above.

Other Consideration

Pipe Insulation

When insulating pipes that contain expansion joints, some points should be noted as follows:-

1. The movement of the expansion joints must not be restricted by the insulation material.
2. The movement of flexing pipe must not be restricted by the insulation material.
3. The insulation material must be removable from the expansion joint to allow for periodic inspection.
4. Care must be taken when considering the type of insulation material to be used, as some materials contain substances that can cause corrosion of the bellows membrane under certain conditions.

Installation Check List

After installation of expansion joints, guides, anchors and supports etc, we recommend that the engineer spends a short time to answer the following questions:-

1. Have the correct type of expansion joint been installed ?
2. Have the expansion joints been installed correctly ?
3. Have the expansion joints, guides and anchors been installed in the correct location ?
4. Has the correct amount of cold pull been applied ?
5. Has sufficient clearance been allowed for correct operation of the expansion joints ?
6. Have the expansion joints been damaged in any way ?
7. Have all transport supports been removed ?

Commissioning

Commissioning of a pipework system usually includes a pressure test, more often than not at a multiple of 1.5x or 2x the intended system working pressure. The pressure test will normally be at ambient temperature.

We do not recommend the practice of removing expansion joints from a system prior to testing. This defeats the object of testing since other system components, such as anchors, guides and supports, are NOT subjected to the larger forces which may be encountered with expansion joints, in particular, axial expansion joints. A second pitfall if expansion joints are not present during the test, is that any leaks in the expansion joint will not become apparent until the system is under working conditions. We recommend that the engineer checks points raised in the following lists:-

Check BEFORE the pressure test:
1. Ensure that the system test pressure does not exceed the maximum for the expansion joints.
2. Ensure that main and intermediate anchors are strong enough to withstand the test pressure.
3. Ensure that primary and intermediate guides are free to allow pipe movement.
4. Ensure that expansion joint moving parts are free to allow movement.

Check DURING the pressure test: WARNING: Take care when checking pressurised components !
1. Check for any evidence of leakage.
2. Check for any pressure loss.
3. Check for malfunction of expansion joints, anchors, guides and supports.
4. Check in particular for any evidence of snaking or squirm in the bellows membrane.
5. Investigate ALL abnormal changes or unexpected occurances.

Check AFTER the pressure test:
1. Ensure that moving components return to original positions.
2. Ensure that any necessary drain down has been accomplished.

Start Up Check:
1. Ensure that chemical additives are correct and will not damage the expansion joint bellows membrane.
2. Ensure that the thermal expansion of the pipework causes movement in the correct manner.
3. Ensure that the expansion joints absorb the movement in the manner for which they were designed.
4. Ensure that all components are still operating within their design limits at maximum system working conditions.
5. Ensure that the system itself is operating within design limits.

We recommend that documentary evidence is made throughout ALL the above stages. If problems arise, the proceedure MUST be halted and correctly investigated.

Operation and Maintenance

We recommend that records of system changes are made, such as temperature, pressure, cycling, pipework modifications etc. Any changes must be evaluated to assess exactly what consequences they may have on system components. We would recommend that the designer of the original system is consulted.

We recommend that periodic inspection of expansion joints is made. All expansion joints have a limited life expectancy; this will have been considered during system design, however early failure sometimes occurs due mainly to secondary factors. It is recommended that during periodic inspection the following factors should be looked for:-
1. Mechanical damage to the bellows convolutions.
2. Corrosion of the bellows convolutions.
3. Loosening of flange bolts or pipe threads.
4. Seizing of guides and supports.
5. Weakening of anchors, guides and supports.
6. Debris or foreign material in the bellows convolutions.
7. Seizing of hinges or ties on expansion joints.

Expansion joints are maintenance free. We can only suggest that, as part of a maintenance program, expansion joints are kept clean and free of foreign material. Corrosion protection must be exercised from day one.

Basic Bellows Design and History

Brief History

The problem of dealing with thermal expansion in pipelines has existed since the first use of pipe itself. Originally pipe bends and horseshoe shaped loops ('lyre' loops) were the only means available to the engineer to solve expansion problems. An early development was the packed slip type joint. This was a big step forward and simplified installations and was used universally. However, these joints required maintenance and were only suitable for moderate temperatures.

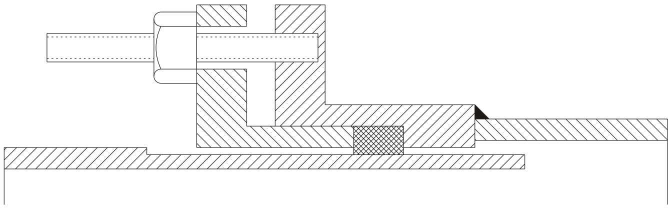


Figure 43

The bellows expansion joint followed and can immediately be seen as 100% leak-proof and maintenance free. Correctly designed and installed the bellows expansion joint is the answer to all problems of pipe expansion.

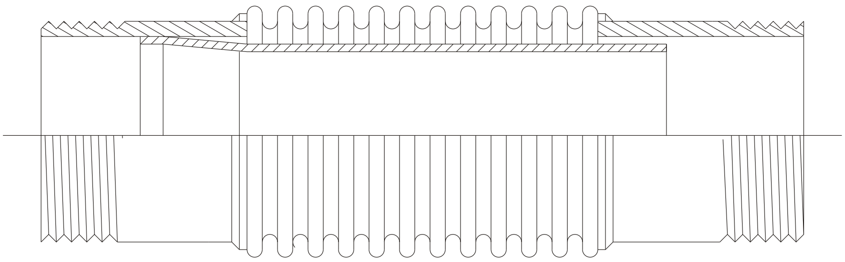


Figure 44

Material Selection and Bellows Construction

Copper and the softer metals were originally used for bellows membranes but stainless steel has proved the best material because it has an elongation figure of about 40% in its annealed condition and is therefore very suitable for the production of thin sheets and the subsequent formation of convolutions.

All except the smallest diameters of bellows are produced originally from flat sheet, rolled into tube and welded to produce a thin walled cylinder ready for convoluting. The preparation of the longitudinal butt weld is of paramount importance and must be carried out under precisely controlled conditions, the quality of weld must be exactly the same as the parent material. Argon arc welding is therefore employed and is a highly developed process exactly suitable for producing the quality of weld required in an expansion joint.

Methods of producing convolutions in the tube vary. There are broadly two processes; mechanical forming and hydraulic forming. Mechanical forming involves rolling the tube between convoluted mandrels or wheels and pressing the convolutions into the tube. Hydraulic forming, as the name implies, involves the use of internal pressure in the tube with hydraulic rams to collapse the tube lengthways into specially designed formers.

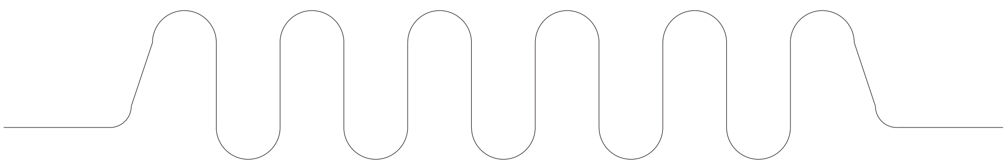


Figure 45

Convolution shapes vary, having particular advantages. The parallel sided convolution (above) is very popular and offers equal extension and compression, but is not very resistant to pressure and soon begins to distort. A re-entrant form (below) produced by pressing up a parallel sided convolution improves its pressure carrying characteristics.

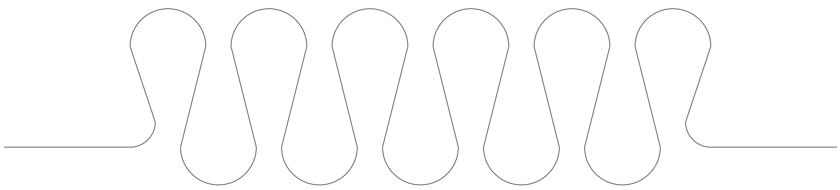


Figure 46

Multiply construction also increases the pressure resistance of all bellows designs. A two ply bellows will withstand twice the pressure of a single ply bellows and whilst the spring rate is doubled the available movement is hardly impaired. A single ply unit of equivalent thickness would be four times stiffer and the movement for the same stress would be halved. Three and four plies are used on high pressures and larger diameters.

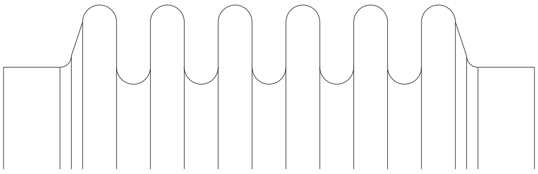


Figure 47 Single ply bellows

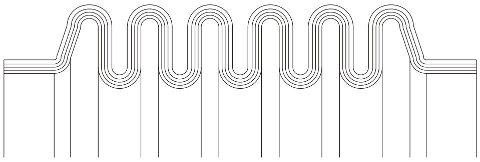


Figure 48 Multi ply bellows

To produce multi-ply bellows, the thin wall tubes are manufactured very accurately and fitted inside each other, prior to the convolutions being formed.
The stress induced in a bellows due to the pressure is of much less importance than the fatigue stress induced by the number of cycles of operation. The life expectancy can be defined as the total number of complete cycles which can be expected from the expansion joint based on data tabulated from tests performed at room temperature under simulated operating conditions. A cycle can be defined as one complete movement of an expansion joint from initial to extreme position and return.
The cycle life expectancy of an expansion joint is affected by various factors such as:

a. Operating pressure.
b. Operating temperature.
c. The material from which the bellows is made.
d. The movement per convolution.
e. The thickness of the bellows.
f. The convolution pitch.
g. Depth and shape of the convolution.
h. Bellows heat treatment.

Any change in these factors will result in a change in the life of the expansion joint. The work hardening of austenitic stainless steel, induced during the forming of convolutions, generally improves the fatigue life of an expansion joint, often to a marked degree, thus it is not normally considered beneficial to heat treat. The necessity for heat treatment of other materials should be considered individually.

Expansion joints can be specially designed for very high cyclic life; however, when this is required the expansion joint manufacturer must be advised of the estimated number of cycles required.

When installing expansion joints, cycle life can be adjusted by varying the proportion of the design movement utilised in a piping system. Typical changes in cycle life are shown in the table below:-

Table 11	TABLE COMPARING % OF DESIGN MOVEMENT WITH % OF EXPECTED CYCLES						
DESIGN MOVEMENT	**125%**	**100%**	**95%**	**85%**	**75%**	**50%**	**25%**
EXPECTED CYCLES	25%	100%	125%	250%	500%	5000%	500,000%

For example, consider an expansion joint that is designed to give 2000 cycles at 50mm movement, but is only required to move by 42.5 mm; i.e. 85% of its design capability. This is shown in table 11 as the % of design movement and equates to 250% expected cycles. This would mean that the expansion joint will in fact operate without failure for 2.5 times the number of design cycles, i.e. 5000 cycles.

Elevated temperatures reduce both the rated movement for a given life cycle and the pressure capabilities of the expansion joint. Temperatures met in the HVAC industry aren't usually high enough to seriously affect the performance of expansion joints. Chrome Molybdenum alloy steel is used by some Continental manufacturers and is marketed in the UK. There is little to recommend this material being used, hence no British manufacturer uses it as first choice. It is basically a carbon steel with a higher percentage of chrome and molybdenum. Its elongation figure is about half that of stainless steel which makes it less suitable for the production of thin sheets and subsequent cold forming. When this material is used in bellows manufacture a single heavy walled tube is formed prior to the convolutions being formed. Production of the convolutions requires a hot rolled process and a few large convolutions are preferred. The stiffness of this type of bellows and the larger area necessitate anchors up to twice as heavy as with stainless steel multi-ply bellows.

Materials such as Incoloy 800, Incoloy 825, Inconel 600, Monel 400 and Hastalloy B & C263 are all suitable materials for bellows manufacture when more arduous conditions exist, such as in petroleum refining and petrochemical manufacture.

Internal sleeves are required where high velocities are encountered, which can set up vibration in the convolutions causing premature failure. Internal sleeves also improve the flow of the medium through the bellows and reduce the pressure drop; they also protect the convolutions from particles or sediment which may become trapped in them and prevent them closing.

External sleeves are fitted where damage to the convolutions is likely, say in an exposed position.

Neither of these sleeves add anything to the stability of the bellows and should not be considered as an alternative to suitable guiding of the expansion joint.

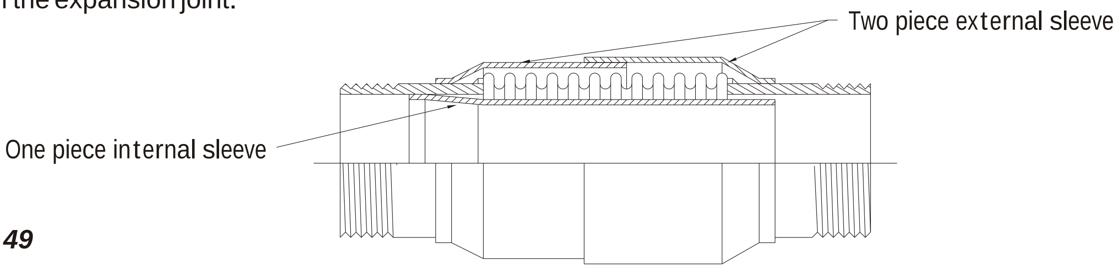


Figure 49

Expansion Joints for Plastic Pipework Systems

Thermal Expansion

Thermoplastics expand and contract much more than metals. In practice because of the low thermal conductivity of plastic compared with metal the entire wall of a plastic pipe does not reach the same temperature as the contents unless the pipe is wholly immersed at the same temperature inside and outside. This means that expansion is frequently less than expected because the mean pipe wall temperature is lower than the contents. The expansion and contraction of plastic pipe is a function of the change in average temperature of the pipe wall. To calculate the pipe wall temperature change, use the equation:-

Change in Temp = (0.65 x Max temp change in pipe contents) + (0.10 x Max temp change of external air)

From the change in temperature calculated, calculate the total expansion using the equation:-

Expansion = Change in Temp x Length of pipe x Coefficient of Thermal Expansion

The Coefficient for ABS is: 10.1×10^{-5} per ºC. The Coefficient for PVC is: 7.0×10^{-5} per ºC.

Flexibility

Wherever possible the pipework should be routed to make best use of the inherent natural flexibility. Where there are insufficient changes in direction to accommodate expansion or contraction, loops can be introduced into the system. As a guide, the following table shows the offsets required for plastic pipework for absorbing movement. Remember a loop is basically two offsets and all offsets can be cold pulled by 50% of the total movement, thus allowing a corresponding lower value of 'X' to be used.

The formula used to calculate the offset is:- $L = 0.03\sqrt{DX}$

Table 12 TABLE SHOWING SINGLE OFFSET SIZE FOR PLASTIC PIPES (Without Cold Pull)

EXPANSION X	PIPE NOMINAL SIZE (mm)											
	20	**25**	**32**	**40**	**50**	**63**	**75**	**90**	**110**	**125**	**140**	**160**
1mm	0.14	0.15	0.17	0.19	0.22	0.24	0.26	0.29	0.32	0.34	0.36	0.38
3mm	0.24	0.26	0.30	0.33	0.37	0.42	0.45	0.50	0.55	0.59	0.62	0.66
5mm	0.30	0.34	0.38	0.43	0.48	0.54	0.58	0.64	0.71	0.75	0.80	0.85
10mm	0.43	0.48	0.54	0.60	0.67	0.76	0.83	0.90	1.00	1.06	1.13	1.20
15mm	0.52	0.58	0.66	0.74	0.83	0.93	1.01	1.11	1.22	1.30	1.38	1.47
20mm	0.60	0.67	0.76	0.85	0.95	1.07	1.16	1.28	1.41	1.50	1.59	1.70
30mm	0.74	0.82	0.93	1.04	1.16	1.31	1.43	1.56	1.73	1.84	1.95	2.08
40mm	0.85	0.95	1.08	1.20	1.34	1.51	1.65	1.80	1.99	2.12	2.25	2.40
60mm	1.04	1.16	1.32	1.47	1.65	1.85	2.01	2.21	2.44	2.60	2.75	2.94
80mm	1.20	1.34	1.52	1.70	1.90	2.13	2.33	2.55	2.82	3.00	3.18	3.40
100mm	1.34	1.50	1.70	1.90	2.12	2.38	2.60	2.85	3.15	3.36	3.55	3.80

Expansion Joint Selection

Where space does not permit the use of natural flexibility, either with offsets or loops, plastic sliding expansion devices or alternatively spherical rubber bellows type expansion joints may be used. The sliding type of unit is normally available from the tube manufacturer and is similar in principal to the packed slip type joint shown on page 20, with the main exception that the seal is created by 'O' rings. Here we shall concentrate on the spherical rubber bellows type of expansion joint.

Rubber expansion joints are capable of axial compression or elongation, as well as lateral deflection and small amounts of angulation. These movements can be utilised in various ways as follows:-

Axial Movement: Expansion joints will be installed in a similar manner to metallic axial expansion joints on page 8 of this book. Untied units may be used.

Lateral Movement: Expansion joints will be installed in a similar manner to single articulated expansion joints on page 10 of this book. Tied or untied units may be used.

Angular Movement: Expansion joints will be installed in a similar manner to angular expansion joints on pages 9 and 10 of this book. Tied units with hemispherical tie-bar assemblies must be used for this type of movement.

Anchors and Guides for Plastic Pipework

Anchors and guides for rubber expansion joints on plastic pipework will be dealt with in a similar manner to metallic expansion joints.

For axial movement joints we would recommend that primary guides are located at 4D and 10D. Intermediate guides for all movement types as the plastic tube manufacturer's recommendations for support centres.

Expansion Joints for Duct Systems

Thermal Expansion

Duct systems, whether metal or plastic, will expand or contract with changes in temperature. Ductwork connected with building services will most often be carrying air at ambient temperatures, therefore low expansion rates; however many cases arise where higher temperatures are involved, therefore increased expansion rates. It may be thought that expansion may not cause problems, however the engineer must investigate whether movement will have any consequences such as buckling of the duct or excessive deflection of in-line equipment on their supports.

Vibration and Plant Movement

Vibration from air handling units and fans etc may or may not cause noise to be transmitted through the ductwork to other areas of the building. If this is the case then the engineer must give consideration to how this can be avoided.

Building Movement Lines

Ductwork often has to cross building settlement or subsidence lines. If the duct itself is not sufficiently flexible to compensate for misalignment and movement, then additional allowance must be made.

Flexibility

Ductwork will most often be supported on drop rods or similar, so that allowance is made for some natural movement or flexibility. If the supports are sufficiently long, the duct will probably move with ease. If, however, the supports are very short, then free movement may be restricted and expansion devices required.

Expansion Joint Selection

Where natural movement or flexibility of the ductwork will not accommodate the problems associated with the points mentioned above, then expansion joints or flexible duct connectors may be used.

This type of device is simply designed and manufactured from various layers of flexible material to create a flexible section for the duct. They are designed to suit system conditions and can compensate for axial, lateral and angular movements, as well as vibration.

Various methods of ductwork fixing can be encountered; in general all types can be accommodated in the design, although from a mechanical point of view it is often desirable to adopt a parallel flange construction. Cross sections may be circular or rectangular.

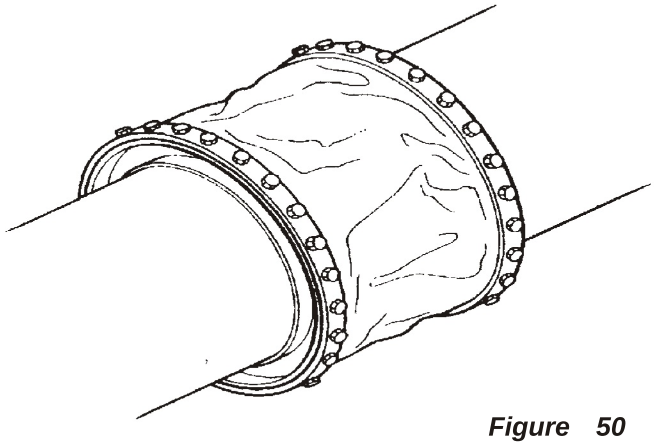


Figure 50

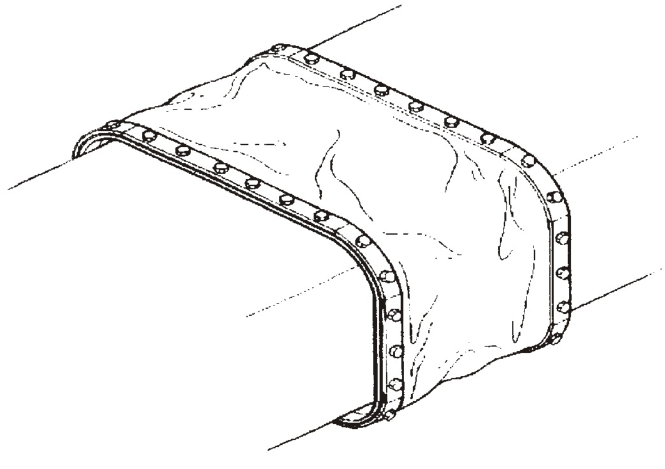


Figure 51

Other material groups may be used for ductwork expansion joints, such as metals, elastomers (rubbers) or plastics. Their use is governed by system requirements, therefore the correct unit must be proposed for each application.

We recommend that our Design and Applications Department is contacted for further advice regarding expansion joints for ductwork systems.

Expansion Joints for Exhaust Pipework Systems

Thermal Expansion

Metal pipes or ducts used as exhaust lines from C.H.P. (Combined Heat and Power) plant, some boiler plant and engines etc are subjected to very high temperatures; much higher than experienced with water or steam. The elevated temperatures produce very high thermal expansion rates.

The following table indicates the expansion ratio of the number of millimetres expansion per metre of pipe at a given temperature.

TABLE 13	TABLE SHOWING THE EXPANSION RATIO OF EXHAUST LINES			
Exhaust Line Temperature		**Expansion in millimetres per metre**		
		18/8 Stainless Steel	**Carbon Steel Carbon Mo. Low Cr.Mo.(up to 3% Cr.)**	**Intermediate Cr.Mo. (5 - 9%)**
^{o}C	**^{o}F**			
200	392	3.40	2.41	2.24
300	572	5.19	3.80	3.56
400	752	7.12	5.34	4.88
500	932	9.16	7.00	6.36
600	1112	11.23	8.67	7.81

Flexibility

The thermal expansion in the exhaust pipes can be calculated from the table above and an assessment made of the inherent natural flexibility of the pipework. Where there is insufficient flexibility to absorb the thermal changes, the engineer must look towards the use of expansion joints.

Exhaust Pulsation

The pulsation from an exhaust will set up vibrations within the pipework and will in turn be transmitted to the supports and the building structure. These vibrations can be absorbed by metallic expansion joints, usually mounted between the vibrating source and the pipework.

Protection of Sensitive Equipment

The turbochargers on generator engines etc are considered as sensitive pieces of equipment. Expansion joints mounted at the outlets will give protection. Engine manufacturers often supply expansion joints for this purpose with their equipment, however, where this is not done, the engineer must make allowance.

Expansion Joint Selection

Many metallic expansion joint types are available for exhaust lines, depending on the movement required and the location within the pipework. Expansion joints mounted directly to the exhaust source will be of multi ply construction and have a low spring rate; those mounted further down the line may be of single or multi ply construction. Our Design and Applications Department should be consulted for the correct selection of the expansion joints.

Anchors and Guides

Due to the relatively low pressures of exhaust systems, the fundamental duties of anchors and guides are not fully considered; this must not be the case. Anchors serve to divide the system into sections to be considered on individual merits. An anchor will normally be positioned after the expansion joint at the outlet of the engine; this will prevent vibrations being transmitted down the line. Anchors may be fitted at the bottom of the main stack to ensure that thermal expansion is vertical. Guiding is essential to ensure that the expansion joints are subjected to movements in the manner to which they were designed.

Exhaust Gases

Where exhaust gases contain such constituents as Sulphur Dioxide, problems can occur with standard stainless steel bellows if the temperature falls below the Sulphuric Acid dew point. Lagging should be used to prevent this where possible; if there is uncertainty then expansion joint materials fit for the purpose must be used.

Other Products

A wide range of equipment, other than expansion joints, is used in the Building Services Industry. Allowance must be made for the compensation of other types of movement or to allow additional movement where necessary. We describe below other products which are related to movement in general:-

Flexible Connectors

Rubber Flexible Connectors

Are normally installed in the pipework to isolate various items of plant which produce noise and vibration. They are capable of absorbing movement in several directions; axial compression, axial elongation and lateral deflection. A small amount of angular movement may also be allowed. They effectively dampen the transmission of sound and vibration from plant items in air conditioning and heating installations.

Braided Flexible Connectors

Are normally used to suppress vibration from pumps and to absorb intermittent lateral movement. They must be installed at right angles to the direction of movement and close to the suction and discharge of pumps. They are often used where the working temperature is too high for rubber flexible connectors.

Fancoil Equipment Connectors

Flexible Hoses

Are normally used as the final connection to fancoil units. They are designed to offer a high degree of flexibility to allow for misalignment of the pipework and the suppression of possible vibration from the fancoil unit.

Quick Release Couplings

Are used in conjunction with flexible hoses on fancoil units. They allow immediate removal of the fancoil unit in the event of a breakdown or for maintenance purposes.

A great deal of time can be saved by an engineer if the need to drain down is eliminated by using flexible hoses and quick release couplings.

Catering Equipment Connectors

Flexible Hoses and Quick Release Couplings

Are used to enable catering appliances to be moved easily for regular cleaning. They are installed between the mains supply and the catering appliance. Used in conjunction with quick release couplings, they enable the appliance to be moved away from its normal position without the need for disconnecting pipe joints.

Anti-vibration Support Equipment

Inertia Bases

Are used beneath mechanical equipment to provide the facility of attaching suitable vibration isolator supports, improving equipment stability and to minimise the vibratory movement and noise transmission due to equipment operation.

Spring Mounts

Are normally used in conjunction with inertia bases to improve equipment stability and to minimise vibratory movement and noise transmission.

Neoprene Mounts

Are used for reducing noise and vibration associated with small pumps, motors and air handling units. They are most appropriately used for equipment speeds in excess of 1500 r.p.m.

Spring Hangers

Are used to provide enhanced acoustic isolation whilst providing high level vibration isolation.

Neoprene Hangers

Are used to reduce the transmission of structure borne noise and vibration from suspended sources, such as ducting, pipework and air handling units.

Conclusion

We do not pretend that we have covered every aspect of the installation of metallic expansion joints, nor covered all there is to know about other expansion joints. Every installation is different, posing different problems. However, our engineers are available to give you every possible assistance and to discuss the layout of your system with regard to the use of expansion joints.

Whilst we have every confidence in the information we have presented, we trust that it will be used with discretion and we must emphasize that we can accept no responsibility for its use. If you are unsure please contact our Design and Applications Department.

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Appendix 1
Flange Data Table

Nominal Size	Flange Table	Outer Dia.	No. of Bolt Holes	Bolt Hole Dia.	Bolt Circle (P.C.D)
	E	95	4	14	67
15mm	F	95	4	14	67
	H	114	4	18	83
	150	89	4	16	60
1/2"	300	95	4	16	67
	6	80	4	11	55
	10	95	4	14	65
	16	95	4	14	65
	25	95	4	14	65
	E	101	4	14	73
20mm	F	101	4	14	73
	H	114	4	18	83
	150	98	4	16	70
3/4"	300	117	4	19	83
	6	90	4	11	65
	10	105	4	14	75
	16	105	4	14	75
	25	105	4	14	75
	E	115	4	14	83
25mm	F	121	4	18	87
	H	121	4	18	87
	150	108	4	16	79
1"	300	124	4	19	89
	6	100	4	11	75
	10	115	4	14	85
	16	115	4	14	85
	25	115	4	14	85
	E	121	4	14	87
32mm	F	133	4	18	98
	H	133	4	18	98
	150	117	4	16	89
1 1/4"	300	133	4	19	98
	6	120	4	14	90
	10	140	4	18	100
	16	140	4	18	100
	25	140	4	18	100
	E	133	4	14	98
40mm	F	140	4	18	105
	H	140	4	18	105
	150	127	4	16	98
1 1/2"	300	155	4	22	114
	6	130	4	14	100
	10	150	4	18	110
	16	150	4	18	110
	25	150	4	18	110
	E	152	4	18	114
50mm	F	165	4	18	127
	H	165	4	18	127
	150	152	4	19	121
2"	300	165	8	19	127
	6	140	4	14	110
	10	165	4	18	125
	16	165	4	18	125
	25	165	4	18	125
	E	165	4	18	127
65mm	F	184	8	18	146
	H	184	8	18	146
	150	178	4	19	140
2 1/2"	300	191	8	22	149
	6	160	4	14	130
	10	185	4	18	145
	16	185	4	18	145
	25	185	8	18	145
	E	184	4	18	146
80mm	F	203	8	18	165
	H	203	8	18	165
	150	191	4	19	152
3"	300	210	8	22	168
	6	190	4	18	150
	10	200	8	18	160
	16	200	8	18	160
	25	200	8	18	160
	E	216	8	18	178
100mm	F	229	8	18	191
	H	229	8	18	191
	150	229	8	19	191
4"	300	254	8	22	200
	6	210	4	18	170
	10	220	8	18	180
	16	220	8	18	180
	25	235	8	22	190
	E	254	8	18	210
125mm	F	279	8	22	235
	H	279	8	22	235
	150	254	8	22	216
5"	300	279	8	22	235
	6	240	8	18	200
	10	250	8	18	210
	16	250	8	18	210
	25	270	8	26	220
	E	279	8	22	235
150mm	F	305	12	22	260
	H	305	12	22	260
	150	279	8	22	241
6"	300	318	12	22	270
	6	265	8	18	225
	10	285	8	22	240
	16	285	8	22	240
	25	300	8	26	250
	E	337	8	22	292
200mm	F	368	12	22	324
	H	368	12	22	324
	150	343	8	22	298
8"	300	381	12	25	330
	6	320	8	18	280
	10	340	8	22	295
	16	340	12	22	295
	25	360	12	26	310
	E	406	12	22	356
250mm	F	432	12	25	381
	H	432	12	25	381
	150	406	12	25	362
10"	300	444	16	29	387
	6	375	12	18	335
	10	395	12	22	350
	16	405	12	26	355
	25	425	12	30	370
	E	457	12	25	406
300mm	F	489	16	25	438
	H	489	16	25	438
	150	482	12	25	432
12"	300	521	16	32	451
	6	440	12	22	395
	10	445	12	22	400
	16	460	12	26	410
	25	485	16	30	430

E = BS10 Table 'E'
F = BS10 Table 'F'
H = BS10 Table 'H'

150 = BS1560 Class 150, ASA 150, ANSI B16.5 Class150.
300 = BS1560 Class 300, ASA 300, ANSI B16.5 Class300.

6 = BS4504 PN6, DIN2501 PN6.
10 = BS4504 PN10, DIN2501 PN10.
16 = BS4504 PN16, DIN2501 PN16.
25 = BS4504 PN25, DIN2501 PN25.

Appendix 2
Useful Conversion Factors

Pressure Units

Symbol	Description	bar	kPa	kN/m^2	psi	atm	m wg
1 bar	Bar		100.0	100.0	14.5037	0.9869	10.1972
1 kPa	Kilopascal	0.01		1.0	0.145	0.0099	0.102
1 kN/m^2	Kilonewton per square metre	0.01	1.0		0.145	0.0099	0.102
1 psi	Pound per square inch	0.0689	6.8948	6.8948		0.0681	0.7031
1 atm	Atmosphere	1.0133	101.3250	101.3250	14.696		10.3323
1 m wg	Metre water gauge	0.0981	9.8067	9.8067	1.422	0.0968	

Vacuum Units

Symbol	Description	mm Hg	in Hg	psi	Torr	bar	atm
1 mm Hg	Millimetre of mercury		0.0394	0.49	1.0	0.0013	0.0013
1 in Hg	Inch of mercury	25.4		0.019	25.4	0.0338	0.0334
1 psi	Pound per square inch	51.7	2.04		51.7	0.0689	0.0681
1 Torr	Torr	1.0	0.0394	0.49		0.0013	0.0013
1 bar	Bar	750	29.53	14.5037	750		0.9869
1 atm	Atmosphere	760	29.92	14.696	760	1.0133	

Linear Units

Symbol	Description	mm	cm	m	in	ft	yd
1 mm	Millimetre		0.1	0.001	0.0394	0.0033	0.0011
1 cm	Centimetre	10		0.01	0.3937	0.0328	0.0109
1 m	Metre	1000	100		39.3701	3.2808	1.0936
1 in	Inch	25.4	2.54	0.0254		0.0833	0.0278
1 ft	Foot	304.8	30.48	0.3048	12		0.3333
1 yd	Yard	914.4	91.44	0.9144	36	3	

Weight Units

Symbol	Description	g	kg	t	oz	lb	tn
1 g	Gramme		0.001	0.000001	0.036	0.0022	0.0000098
1 kg	Kilogramme	1000		0.001	36.413	2.2047	0.0009843
1 t	Tonne (metric)	1000000	1000		36413.44	2204.7222	0.984251
1 oz	Ounce	28.4	0.0284	0.0000284		0.0625	0.0000279
1 lb	Pound	453.6	0.4536	0.0004536	16		0.0004465
1 tn	Ton (imperial)	1016000	1016	1.016	35840	2240	

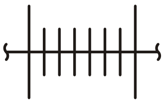
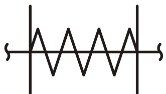
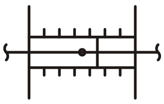
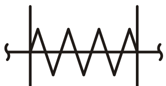
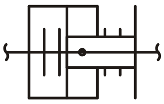
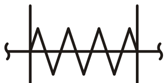
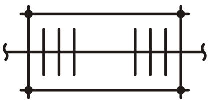
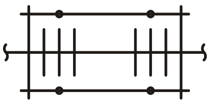
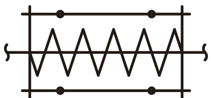
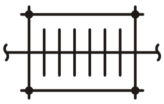
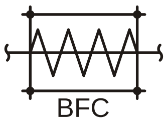
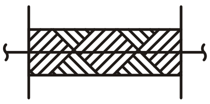
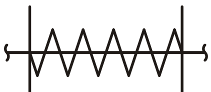
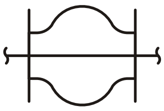
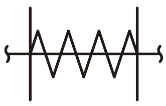
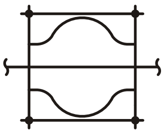
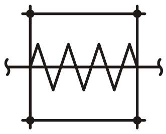
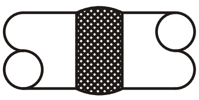
Temperature Units

Symbol	Description	^oC	^oF	^oK
^oC	Degree Celsius		Times 1.8, plus 32	Plus 273.16
^oF	Degree Farenheit	Minus 32, divide 1.8		Divide 1.8, plus 255.38
^oK	Degree Kelvin	Minus 273.16	Minus 255.38, times 1.8	

Appendix 3
Pipe Data Table

Nominal Size	Material	Wall Thick -ness	Max O/D	Min O/D	Mean I/D	Int Cross-section Area	Metal Cross-section Area	Surface Area / Metre Length	Moment Of Inertia	Section Modulus	Pipe Weight	Water Content	Support Centres
		mm	mm	mm	mm	mm^2	mm^2	m^2	cm^4	cm^3	kg/m	l/m	m
15mm	Heavy steel	3.25	21.7	21.1	14.9	175	186	0.067	0.79	0.736	1.45	0.175	2.0
	Medium steel	2.65	21.7	21.1	16.2	205	155	0.067	0.71	0.656	1.22	0.205	2.0
1/2"	Copper (Table X)	0.70	15.045	14.965	13.6	145	31.6	0.047	0.08	0.108	0.28	0.145	1.4
	Copper (Table Y)	1.00	15.045	14.965	13.0	133	44.1	0.047	0.11	0.145	0.39	0.133	1.4
15mm	Copper (Table Z)	0.50	15.045	14.965	14.0	154	22.9	0.047	0.06	0.080	0.20	0.154	1.4
20mm	Heavy steel	3.25	27.2	26.6	20.4	326	243	0.085	1.75	1.29	1.90	0.326	2.4
	Medium steel	2.65	27.2	26.6	21.6	367	203	0.085	1.50	1.11	1.58	0.367	2.4
3/4"	Copper (Table X)	0.90	22.055	21.975	20.2	321	59.6	0.069	0.33	0.303	0.52	0.321	1.4
	Copper (Table Y)	1.20	22.055	21.975	19.6	302	78.3	0.069	0.43	0.387	0.69	0.302	1.4
22mm	Copper (Table Z)	0.60	22.055	21.975	20.8	340	40.2	0.069	0.23	0.210	0.35	0.340	1.4
25mm	Heavy steel	4.05	34.2	33.4	25.7	518	380	0.106	4.29	2.54	2.97	0.518	2.7
	Medium steel	3.25	34.2	33.4	27.3	586	312	0.106	3.70	2.20	2.44	0.586	2.7
1"	Copper (Table X)	0.90	28.055	27.975	26.2	540	76.7	0.085	0.71	0.504	0.68	0.540	1.7
	Copper (Table Y)	1.20	28.055	27.975	25.6	516	101	0.085	0.91	0.650	0.89	0.516	1.7
28mm	Copper (Table Z)	0.60	28.055	27.975	26.8	565	51.7	0.085	0.49	0.347	0.46	0.565	1.7
32mm	Heavy steel	4.05	42.9	42.1	34.3	927	490	0.134	9.16	4.31	3.84	0.926	2.7
	Medium steel	3.25	42.9	42.1	35.9	1016	461	0.134	7.74	3.64	3.14	1.016	2.7
1 1/4"	Copper (Table X)	1.20	35.07	34.99	32.6	837	128	0.110	1.83	1.043	1.12	0.837	1.7
	Copper (Table Y)	1.50	35.07	34.99	32.0	806	158	0.110	2.22	1.270	1.39	0.806	1.7
35mm	Copper (Table Z)	0.70	35.07	34.99	33.6	889	75.5	0.110	1.11	0.635	0.67	0.889	1.7
40mm	Heavy steel	4.05	48.8	48.0	40.2	1272	566	0.152	13.98	5.79	4.43	1.271	3.0
	Medium steel	3.25	48.8	48.0	41.9	1376	461	0.152	11.78	4.87	3.61	1.376	3.0
1 1/2"	Copper (Table X)	1.20	42.07	41.99	39.6	1234	154	0.132	3.21	1.528	1.36	1.234	2.0
	Copper (Table Y)	1.50	42.07	41.99	39.0	1197	191	0.132	3.93	1.869	1.69	1.197	2.0
42mm	Copper (Table Z)	0.80	42.07	41.99	40.4	1284	104	0.132	2.20	1.048	0.91	1.284	2.0
50mm	Heavy steel	4.50	60.8	59.8	51.3	2070	784	0.189	30.8	10.2	6.17	2.070	3.4
	Medium steel	3.65	60.8	59.8	53.0	2205	651	0.189	26.2	8.7	5.10	2.205	3.4
2"	Copper (Table X)	1.20	54.07	53.99	51.6	2095	199	0.170	7.0	2.573	1.76	2.095	2.0
	Copper (Table Y)	2.00	54.07	53.99	50.0	1965	327	0.170	11.1	4.101	2.88	1.965	2.0
54mm	Copper (Table Z)	0.90	54.07	53.99	52.2	2145	150	0.170	5.3	1.963	1.33	2.145	2.0
65mm	Heavy steel	4.50	76.6	75.4	67.0	3530	1005	0.239	64.5	17.0	7.90	3.530	3.7
	Medium steel	3.65	76.6	75.4	68.7	3700	831	0.239	54.5	14.3	6.51	3.700	3.7
2 1/2"	Copper (Table X)	1.20	66.75	66.60	64.3	3245	247	0.209	13.2	3.97	2.18	3.245	2.0
	Copper (Table Y)	2.00	66.75	66.60	63.1	3125	406	0.209	21.3	6.38	3.58	3.125	2.0
67mm	Copper (Table Z)	1.00	66.75	66.60	64.7	3285	206	0.209	11.1	3.34	1.82	3.285	2.0
80mm	Heavy steel	4.85	89.5	88.1	79.0	4905	1285	0.279	114	25.6	10.1	4.905	3.7
	Medium steel	4.05	89.5	88.1	80.7	5115	1080	0.279	97.0	21.8	8.47	5.115	3.7
3"	Copper (Table X)	1.50	76.3	76.15	73.2	4210	352	0.239	24.4	6.45	3.11	4.210	2.4
	Copper (Table Y)	2.00	76.3	76.15	72.2	4100	467	0.239	31.9	8.43	4.11	4.100	2.4
76mm	Copper (Table Z)	1.20	76.3	76.15	73.8	4280	283	0.239	19.9	5.22	2.50	4.280	2.4
100mm	Heavy steel	5.40	114.9	113.3	103.3	8380	1840	0.358	272	47.7	14.4	8.380	4.1
	Medium steel	4.50	114.9	113.3	105.1	8680	1540	0.358	231	40.6	12.1	8.680	4.1
4"	Copper (Table X)	1.50	108.25	108.0	105.1	8680	504	0.340	71.4	13.21	4.45	8.680	2.7
	Copper (Table Y)	2.00	108.25	108.0	103.1	8355	832	0.340	115	21.41	7.33	8.355	2.7
108mm	Copper (Table Z)	1.20	108.25	108.0	105.7	8780	405	0.340	71.2	10.66	3.57	8.780	2.7
125mm	Heavy steel	5.40	140.6	138.7	127.7	13050	2270	0.438	520	73.4	17.8	13.05	4.4
	Medium steel	4.85	140.6	138.7	129.8	13250	2065	0.438	470	67.4	16.2	13.25	4.4
5"	Copper (Table X)	1.50	133.5	133.25	130.4	13350	621	0.419	134	20.26	5.47	13.35	3.0
	Copper (Table Y)												
133mm	Copper (Table Z)	1.50	133.5	133.25	130.4	13350	621	0.419	134	20.26	5.47	13.35	3.0
150mm	Heavy steel	5.40	166.1	164.1	154.3	18700	2700	0.518	862	105	21.2	18.70	4.8
	Medium steel	4.85	166.1	164.1	155.3	18950	2455	0.518	787	95.4	19.2	18.95	4.8
6"	Copper (Table X)	2.00	159.5	159.25	155.4	18950	988	0.501	304	38.42	8.71	18.95	2.7
	Copper (Table Y)												
159mm	Copper (Table Z)	1.50	159.5	159.25	156.4	19200	743	0.501	230	29.09	6.55	19.20	2.7
200mm	Steel	4.88			209.3	34400	3280	0.689	1880	172	25.9	34.42	5.1
250mm	Steel	6.35			260.4	53250	5320	0.859	4745	347	42.0	53.24	5.8
300mm	Steel	7.14			309.6	75300	7080	1.018	8865	547	55.8	75.30	6.1

Appendix 4
Standard Symbols

Equipment Name	Drawing Symbol	Optional Symbol Identify exact type with text
Axial Expansion Joint		 BAF
Angular Expansion Joint		 BHF
Gimbal Expansion Joint		 BGF
Fully Articulated Expansion Joint		 BLF
Double Hinged Expansion Joint		 BDHF
Single Articulated Expansion Joint		 BFC
Braided Expansion Joint		 BBF
Untied Rubber Expansion Joint		
Tied Rubber Expansion Joint		
Duct Expansion Joints		

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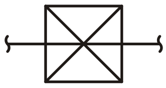
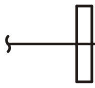
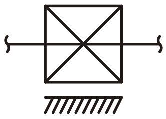
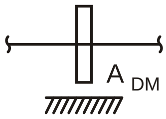
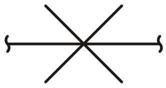
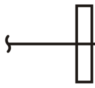
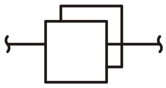
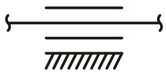
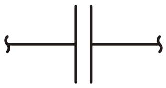
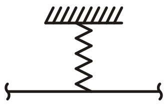
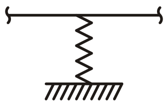
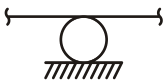
Main Anchor		 A_M
Directional Main Anchor		 A_{DM}
Intermediate Anchor		 A_I
Guide		
Planar Guide		
Cold Pull		
Spring Support Spring Hanger		
Support		
Roller Support		

Appendix 5
Glossary of Terms

Anchor
A fixed datum point in the pipework from which expansion occurs. See also: Main Anchor, Intermediate Anchor and Planar Anchor.

Angular Rotation
The relative displacement of the two ends of an expansion joint perpendicular to its longitudinal axis.

Axial Compression
The dimensional shortening of an expansion joint along its longitudinal axis.

Axial Extension
The dimensional lengthening of an expansion joint along its longitudinal axis.

Bellows
The flexible element of an expansion joint.

Cold Pull
The initial deflection imposed on an expansion joint, either at the factory or during installation on site, so that the full movement capability of the unit is available for absorbing movement. Also known as cold draw.

Cyclic Life
The minimum number of cycles of movement at the specified condition which an expansion joint is designed to withstand without failure.

Effective Area
The cross-sectional area of the expansion joint over which the pressure is assumed to act.

Expansion Joint
A device for absorbing dimensional changes, such as those caused by thermal expansion or contraction of a pipeline or duct.

External Sleeve
A device used to provide limited protection of the exterior of the expansion joint from foreign objects or mechanical damage. Also known as outer sleeve or shroud.

Intermediate Anchor
An anchor which is designed to withstand the bellows thrust due to flow, spring forces, etc., but not the thrust due to pressure.

Internal Sleeve
A device which shields the bellows from direct contact with the flow of fluid. Also known as a liner, flow sleeve or telescopic sleeve.

Lateral Deflection
The relative displacement of the two ends of an expansion joint perpendicular to its longitudinal axis. Also known as lateral offset, lateral movement, shear or traverse movement.

Main Anchor
An anchor which is designed to withstand the full bellows thrust due to pressure, flow, spring forces, etc.

Movement
The various dimensional changes an expansion joint is required to absorb, such as those resulting from thermal changes within a piping system.

Pipe Guide
A device which permits a pipeline incorporating expansion joints to move freely in one direction only.

Pipe Support
A device designed to carry the weight of a pipe, its contents, insulation, etc.

Planar Anchor
An anchor which is designed to absorb loading in one direction whilst permitting movement in another direction. This device may be a main or intermediate anchor, depending upon the application involved. Also known as directional anchor or restraint.

Planar Guide
A device which permits movement of the pipeline in one plane only. Also known as directional guide.

Pressure Thrust
The force acting along the longitudinal axis of the bellows due to pressure.

Squirming
The visible indication of instability in an expansion joint. Also known as cockling.

Tie Rods
Devices, usually in the form of rods or bars, attached to the expansion joint assembly, whose primary function is to restrain the pressure thrust due to internal pressure.

N.MINIKIN AND SONS LIMITED
CONDITIONS OF BUSINESS

1.00
The following conditions ("the Conditions") apply to and are deemed to be incorporated in all contracts for the sale of Goods by N. Minikin & Sons Limited ("the Company") to the buyer and the provision of advice or other services ("Services") by Salesmen or Engineers employed by the Company either during telephone negotiations or site or office visits and the Buyer acknowledges that these Conditions exclusively define the relationship and agreement between the Company and Buyer and that they supersede all other agreements and conditions between the parties. No variation in these Conditions, expressed or implied, shall be accepted by the Company unless expressly agreed in writing and signed by a director of the Company and signed on behalf of the Buyer

2.00
To the extent that these Conditions limit or exclude the liability of the Company to the Buyer or any person claiming through or under the buyer such limitation or exclusion of liability is imposed to avoid the need for the Company to increase the level of its insurance against the risks so limited or excluded, and thereby to minimise the cost to the Buyer of the Goods or Services supplied. If the Buyer nevertheless wishes the Company to be responsible for risks, or liability which is otherwise limited or excluded by these Conditions, then the Company will, at its option, quote an alternative price for the supply of the Goods or Services to reflect the additional cost of obtaining the appropriate additional insurance or other appropriate cover

3.00
All orders for the Goods made by the Buyer, orally or by telephone, shall be confirmed to the Company by the Buyer, in writing (including telex or fax) within 48 hours of being received by the Company whereupon a binding contract for the purchase by the Buyer of the Goods comprised in the order upon these Conditions shall be concluded. Any order made by the Buyer is subject to acceptance by the Company and a Contract will only be formed when the Company has accepted the Buyer's offer to buy

4.00
CANCELLATION AND RETURNS

4.01
No cancellation by the Buyer is permitted except where previously agreed in writing by a Director of the Company

4.02
The Buyer will in the event of cancellation by the Buyer not previously agreed as aforesaid indemnify the company fully against all expenses incurred up to the time of such cancellation together with by way of liquidated damages a sum of 50% of the contract price such sum being intended to represent a genuine pre-estimate by the Company and the Buyer of the loss (apart from the said expenses) suffered by the Company by reason of such cancellation and which shall be paid by the Buyer to the Company forthwith on cancellation

4.03
Goods supplied cannot be returned for credit without the previous approval in writing of the Company. A minimum handling charge of 30% will be made on the value of the Goods returned together with all carriage charges shall be paid by the Buyer. Specially manufactured items cannot be returned after delivery and orders for such items cannot be cancelled

5.00
DELIVERY

5.01
The Buyer shall accept delivery by the Company or its agents on the date, or within the time period stipulated by the Company. However, any time or period for delivery stipulated by the Company shall be deemed an estimate only and the Company shall not be liable in any way for the costs and consequences of any delay except where the parties agree otherwise in writing

5.02
The Company may make and the Buyer shall accept deliveries of the Goods comprised in any order by instalments

5.03
Delivery will be made by or on behalf of the Company to anywhere within the United Kingdom specified by the Buyer. Delivery to the Buyer's carrier or agent shall be deemed to be delivery to the buyer for the purpose of these Condition of Business

6.00
TERMS OF PAYMENT

6.01
Unless otherwise expressly agreed in writing in accordance with Condition 1 payment for the Goods or Services will be made within 30 days after the end of the month in which the Goods or Services in question are delivered or rendered to the Buyer (except for any of the Goods in respect of which a claim has been made by the Buyer in accordance with Condition 12.00 hereof) No discount or allowance shall be made (unless otherwise agreed). Interest on any overdue account may be charged on a day to day basis, with monthly rests, at a rate of 4% above the base lending rate of National Westminster Bank Plc from time to time, whether before or after judgement

6.02
Value Added Tax at the rate from time to time ruling shall be added to the price and shall form part of the purchase price of the Goods or Services for the purpose of these Conditions

7.00
If the Buyer fails to make payment in accordance with Condition 6.00 the Company reserves the right to discontinue, defer or suspend the supply to the buyer of any other of the Goods or Services contracted to be supplied and the Company shall be entitled to claim against the Buyer for any loss or damage whatsoever sustained by it in consequence thereof

8.00
If the Buyer shall be unable or unwilling for any reason to take delivery of the Goods or Services on the specified date or within the specified period, delivery shall for the purposes of calculating time for payment in accordance with Condition 6.00 be deemed to have taken place 14 days after the said date or period. The Company reserves the right to charge the Buyer for the cost of storage, labour, insurance and transport if the Buyer shall be unable or unwilling to take delivery of the Goods or Services as aforesaid

9.00
PRICE

9.01
The Goods or Services will be sold to the Buyer at the prices agreed at time of order placed by the Buyer. The Company reserves the right to increase prices specified in the price list issued by the Company without notice to take account of any change in cost of wages, materials, insurance, transport, duty, tax, surcharge or levy of any kind

9.02
Any price quoted by the Company or contained in any order or contract shall be valid only for 28 days from the date of such quotation, order or contract

9.03
Carriage by the Company's normal transport in Great Britain is paid on orders over 750 value. Delivery of export orders will be F.O.B. the relevant United Kingdom port. Special packing or special delivery requirements will be charged extra

9.04
The Company shall not be liable for any loss whatsoever or howsoever arising caused by its non-delivery or by the failure to make Goods available ready for collection on the due date

10.00
PROPERTY OF THE GOODS

10.01
Notwithstanding risk in the Goods passes to the Buyer as soon as the Goods become ascertained Goods and subject as provided below, the Goods shall remain the sole and absolute property of the Company and title to and legal and equitable ownership of the Goods shall not pass to the Buyer until payment is received by the Company for all monies due from the buyer to the Company in respect of all Goods supplied by the Company to the Buyer and the buyer acknowledges that until such payment is made in full it is in possession of the Goods solely as a fiduciary for the Company

10.02
If Goods the property of the Company are admixed with Goods being the property of the Buyer or are processed or incorporated therein the product thereof will become or deemed to be the sole and exclusive property of the Company

10.03
If Goods the property of the Company are admixed with Goods the property of any person other than the Buyer or are processed or incorporated therein the product thereof shall become or deemed to be owned in common with that other person in proportion to the respective invoice values of the Goods comprised in such product

10.04
The Buyer is licensed by the Company to use or to agree to sell the Goods provided that the entire proceeds of sale of such Goods (or if such Goods have been converted into some other product or mixed with other Goods being the property of some person other than the Buyer a fair proportion of the proceeds of sale) are held in trust for the Company are not mixed with other monies or paid into an overdrawn bank account and shall at all times be identifiable as the Company's money

10.05
Until title to the Goods passes to the buyer the Goods shall be kept separate and distinct from all other property of the Buyer and of third parties and in good condition and stored in such a way as to be clearly identifiable as belonging to the Company and the buyer will not cause or permit or suffer any labels, badges, serial numbers, packaging or other means of identification of the Goods to be removed or obscured

10.06
Without prejudice to any other right or remedies available to it the Company may for the purpose of recovering its Goods and at any time before payment to it of all monies due from the Buyer enter upon any premises where such goods are stored or where they are reasonably thought to be stored and may re possess the same

10.07
If the Buyer being an individual commits any act of bankruptcy or enters into or takes steps to enter into an individual voluntary arrangement under the Insolvency Act 1986 or being a company enters into liquidation (whether compulsory or voluntary) or has a receiver appointed over the whole or any part of its assets or is the subject of an administration order or any person becomes entitled to exercise the powers conferred on an administrative receiver and any payment due from the Buyer to the Company is overdue in whole or in part or the Buyer is unable to meet its obligations as and when they fall due then the Company may (without prejudice to any of its other rights) recover or re-sell the Goods or any of them and may enter upon the Buyer's premises by its servants or agents, for that purpose

11.00
11.01 Where the Goods are ordered by reference to any sample the Company shall use its best endeavours to ensure that the bulk corresponds with the sample

11.02
The Company warrants that the Goods supplied or Services given to the Buyer will be suitable for the primary purpose for which the Goods and Services given is/are made and normally used. Subject thereto no warranty is given or to be implied as to the suitability of the Goods or Services given for any particular purpose or for use under any specific conditions unless such purpose or conditions have been previously agreed in writing by the Company

11.03
In connection with the supply of the Goods the Company warrants to the Buyer in the terms implied by Section 12 of the Sale of Goods Act 1979 as to title, quiet possession and freedom from encumbrances of the Goods but except as aforesaid and without prejudice to the generality of paragraphs 12.01 and 12.02 of these Conditions, the Company gives no warranty whether expressed or implied, by law or otherwise as regards the Goods supplied by it provided that in the event of the Company's negligence nothing herein shall limit or exclude the Company's liability for personal injury or death

11.04
Subject to the operation of any other specific provisions of these Conditions the Buyer's remedies against the Company in respect of any liability of the Company, whether in contract or in tort, shall not exceed the sum of 50,000 or the invoice value of the Goods directly giving rise to the claim or loss (whichever is less) for the Buyer's direct financial loss and any indirect or consequential loss (including loss of profit) suffered by the Buyer or for any claim made against the Buyer by a third party

12.00
Subject to the provisions of paragraph 11.00:-

12.01
All claims for loss caused by damage in transit, in storage or on delivery by the Company must be notified in writing by the Buyer to the Company within three days after receipt of the Goods and must within seven days thereafter be supported by a detailed written claim by the Buyer to the Company

12.02
All claims for non delivery, shortages, variances in design, or incorrect specification must be notified to the Company by the Buyer verbally or by telephone, telex, or fax no later than three days after the date of delivery in the case of claims for variances in design or incorrect specification and no later than 48 hours after the date for delivery in the case of claims for non delivery and shortages and in all such cases confirmed in writing no later than seven days after the date of delivery and it is expressly provided that no claims for shortages, variances in design or incorrect specification shall be accepted in whole or in part if the Goods in question have been installed or cut or worked-upon by the Buyer or its employees or agents

12.03
The risk of accidental loss whilst the Goods are being returned will be borne by the Buyer

12.04
Time shall be of the essence in respect of any notification to be given by the Buyer to the Company in accordance with this paragraph 12

13.00
Any failure on the part of the Company to exercise, or any delay by the Company in exercising, any right or remedy available to it, whether contained in these Conditions or otherwise, shall not operate as a waiver of such right nor shall any single or partial exercise by the Company of such right or remedy preclude the exercise, successively or concurrently of any right or remedy. Subject to the provisions of Condition 1, no waiver by the Company, whether as a part of the course of dealings between the Company and the Buyer, or otherwise of any time limit specified in these Conditions shall be effective

14.00
The Company shall not be liable or deemed to be in default for any delay or failure to perform its obligations under these Conditions if such delay or failure results directly or indirectly from any cause beyond the reasonable control of the Company, including, but not limited to, acts or restrains of government or governmental agencies, force majeure, act of God, war, riot, civil or criminal disturbance, insurrection, accidents, fire, explosion, earthquake, flood, the elements, strikes, labour disputes, shortages of suitable material, labour or transport

15.00
The Company shall be entitled forthwith to terminate any contract incorporating these Conditions and payment thereunder shall immediately become due if the Buyer shall make any default in or commit a breach of these Conditions or of any of its obligations to the Company or if any distress or execution shall be threatened or levied on the Buyer's property or assets, or if the Buyer shall make or offer to make any arrangement or composition with creditors or seek to obtain pursuant to statute or otherwise any moratorium with creditors or shall pass any resolution or shall suffer a petition to be presented for the winding-up of the Buyer (other than for the purpose of a solvent amalgamation or reconstruction notified to the Company) or if a receiver or manager of the Buyer's undertaking, property or assets or any part thereof shall be appointed without prejudice or any claim or right the Company might otherwise make or exercise

16.01
All contracts incorporating these Conditions shall be interpreted in accordance with the laws of England and shall be enforceable in the English Courts

16.02
Any contract incorporating these Conditions may not be assigned by the Buyer without the prior written consent of the Company

16.03
The obligations of the Company may be performed in whole or in part by its authorised distributors sub-contractors or agents at the discretion of the Company

16.04
In making these Conditions the Company does so for itself and for and on behalf of every employee servant sub-contractor or agent of the Company and the Buyer hereby confirms that any exemption from liability granted to the Company by these Conditions shall also extend to any such employee servant sub-contractor or agent of the Company

16.05
Any notice sent under a contract incorporating these Conditions shall be sent to the registered office of the Company or the Buyer (as the case may be) and shall be deemed duly given by letter 48 hours after being posted by pre-paid registered post or if delivered by hand at the time of delivery or if given by telex or fax when the sender shall receive the answerback of the recipient sent

ALSO AVAILABLE TO THE ENGINEER

* Technical Advice
* CIBSE Recognised CPD Courses
* Slide Rule: Expansion Joint Calculator
* Standard Specifications
* Technical Reports
* Product Catalogue
* Installation Instructions
* Quality Assurance to BS EN ISO 9002

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