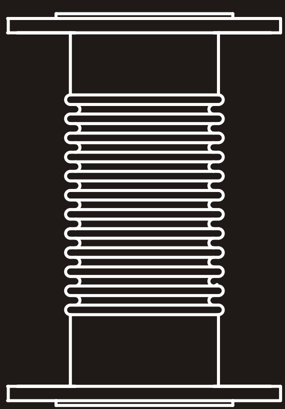
PIPE SOLUTIONS

Solving thermal expansion, building settlement movement, noise, vibration, de-aeration & dirt problems in pipes and plant

TECHNICAL REFERENCE GUIDE

THERMAL PIPE EXPANSION



Pipe Solutions Ltd., Head Office, Hornbeam Park Oval, Harrogate, HG2 8RB
Tel:01423-878888 Fax:01423-878880 Email:sales@pipesolutions.co.uk
Website:www.pipesolutions.co.uk

CONTENTS

INTRODUCTION

Pipe Solutions Ltd are a wholly independent company established with the aim of providing the engineering industry with a one stop shop for solving the problems of thermal expansion, building settlement movement, noise, vibration, de-aeration and dirt removal in pipes and plant, whilst providing an unequaled portfolio of expansion joints, flexible connectors, flexible hoses and couplings, vibration isolators and air removal equipment.

Technical expertise, quality products, professional market support and a value led pricing policy enable Pipe Solutions Ltd to achieve success in the mechanical engineering industry.

A Quality Management System approved by Lloyd's Register Quality Assurance and certified to BS EN ISO 9001:2000 enables all in house operations to be completed to the satisfaction of all Pipe Solutions Ltd clients. From a ‘helping hand’ to a 'complete solution', you are assured of the highest standard.

Specially developed computer software enable the whole support team to accurately deliver exactly what is required; from providing prompt product proposals and technical data to timely product despatches and invoicing.

Pipe Solutions Ltd guarantee customer care. Every team member is committed to the customer. If you are made a promise, it will be honoured. Tasks that are clearly not achievable will not be taken on and you will be told immediately. We build our reputation on integrity and honesty.

Pipe Solutions - put us to the test !

PLEASE CONTACT SOON:

PIPE SOLUTIONS

Solving thermal expansion, building settlement movement, noise, vibration, de-aeration & dirt problems in pipes and plant

Pipe Solutions Ltd, Head Office, Hornbeam Park Oval, Harrogate, HG2 8RB
Tel:01423-878888 Fax:01423-878880
Email:sales@pipesolutions.co.uk Website:www.pipesolutions.co.uk

INVESTOR IN PEOPLE

LLOYD'S REGISTER QUALITY ASSURANCE · ISO9001

THERMAL EXPANSION

All pipes and vessels expand and contract in direct proportion to a temperature change. This can be due to the temperature of the flowing media or from surrounding ambient temperature. Wind chill and solar gain are also factors that should be considered.

Expansion and contraction can be calculated mathematically using the formula:-

$X = L \times (T_1 - T_2) \times C_{Exp}$

Where,

X	=	Expansion or Contraction (m)
L	=	Length of pipe or vessel (m)
T_1	=	Starting Temperature (ºC)
T_2	=	Final Temperature (ºC)
C_{Exp}	=	Coefficient of Thermal Expansion

Coefficients of Thermal Expansion for various common materials are shown right:-

Coefficients of Thermal Expansion for Common Pipe Materials			
METALS		PLASTICS	
Material	Coefficient	Material	Coefficient
Copper	16.4×10^{-6}	ABS	100×10^{-6}
Carbon Steel	12.2×10^{-6}	PVCU	80×10^{-6}
Stainless Steel (Austenitic)	16.3×10^{-6}	PVCC	70×10^{-6}
Stainless Steel (Ferritic)	10.9×10^{-6}	PE	200×10^{-6}
Cast Iron	11.0×10^{-6}	PP	150×10^{-6}

Expansion rates of common materials at various temperature changes are as follows:-

Temp. Change	Rates of Thermal Expansion for Common Pipe Materials (mm/m)								
ºC	Copper	C.Steel	S.Steel	Cast Iron	ABS	PVCU	PVCC	PE	PP
10	0.16	0.12	0.16	0.11	1.00	0.80	0.70	2.00	1.50
20	0.33	0.24	0.33	0.22	2.00	1.60	1.40	4.00	3.00
30	0.49	0.37	0.49	0.33	3.00	2.40	2.10	6.00	4.50
40	0.66	0.49	0.65	0.44	4.00	3.20	2.80	8.00	6.00
50	0.82	0.61	0.82	0.55	5.00	4.00	3.50	10.00	7.50
60	0.98	0.73	0.98	0.66	6.00	4.80	4.20	12.00	9.00
70	1.15	0.85	1.14	0.77			4.90		10.50
80	1.31	0.98	1.30	0.88			5.60		12.00
90	1.48	1.10	1.47	0.99					
100	1.64	1.22	1.63	1.10					
110	1.80	1.34	1.79	1.21					
120	1.97	1.46	1.96	1.32					
130	2.13	1.59	2.12	1.43					
140	2.30	1.71	2.28	1.54					
150	2.46	1.83	2.45	1.65					
160	2.62	1.95	2.61						
170	2.79	2.07	2.77						
180	2.95	2.20	2.93						
190	3.12	2.32	3.10						
200	3.28	2.44	3.26						
210		2.56	3.42						
220		2.68	3.59						
230		2.81	3.75						
240		2.93	3.91						
250		3.05	4.08						
260		3.17	4.24						
270		3.29	4.40						
280		3.42	4.56						
290		3.54	4.73						
300		3.66	4.89						

PROBLEMS TO OVERCOME

Exceeding Allowable Stresses

When the pipe is free to move, problems tend not to exist so often. However, when the pipe is restricted from moving freely, large forces and moments are imposed on pipe supports, anchors and connections to vessels, plant, etc. As a result, the allowable stress on the pipe and the fixed points may well be exceeded, leading to premature failure.

Pipe Bowing and Buckling

Other expansion related problems may also start to occur, such as the pipe buckling or bowing. This is often the direct result of a pipe growing in length between two fixed points. Although the fixed points (anchors) may not be over-stressed and remain intact, the pipe is being compressed like a column and could potentially buckle.

Building Settlement Movement

Whenever pipes are routed across structural movement joints in buildings, roads, bridges, etc., they will be subjected to differential displacements. These must be taken into consideration when designing the pipe system.

Vessel Settlement

Pipes may be installed with rigid connections to vessels used for storage of fluids. These installations will probably be made whilst the vessel is empty. However, when the vessel is filled, the weight of the fluid may cause settlement of the foundations or compression of spring mountings. These must be taken into consideration when designing the pipe system.

Plant Vibration and Start-up

Whenever equipment that is installed on anti-vibration mountings starts-up or runs-down, it will pass through the resonant frequency of the vibration isolation system. At this point, the equipment will move more than during normal operating conditions. These movements or displacements will be imposed on the pipework connections and may overstress or fatigue the pipe and or plant nozzles. Expansion bellows can relieve these stresses and also reduce the transmission of noise and vibration to the pipe system.

Water Hammer and Flow Induced Movement and Vibration

Turbulent and high velocity flow of liquids in pipes can cause pipe displacements where the liquid acts upon direction changes and reductions in the pipe system. Where a system process uses automated valves, fast closure times can cause water hammer. Expansion bellows and flexible hoses can help with relieving stresses in the pipe.

Wind Loading on Supporting Structures

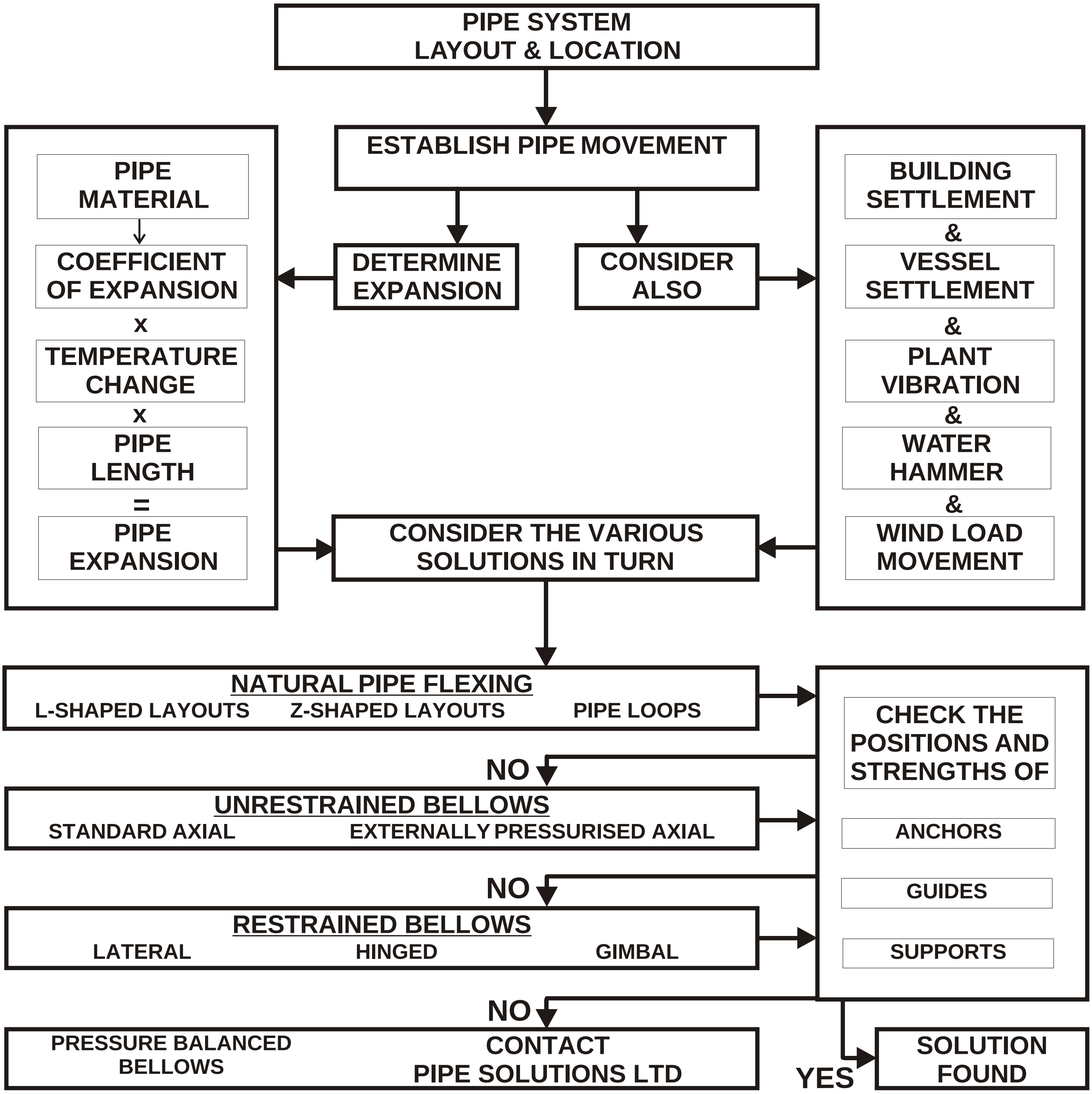
High wind speeds naturally buffer buildings, bridges, gantries, etc. The forces developed may cause the structure to sway, which will in turn displace the pipework. If there is a possibility of displacements being imposed on the pipe, then they must be taken into consideration when designing the pipe system.

METHODICAL APPROACH

There is no such thing as a "correct solution" as many can exist. However taking a methodical approach will unveil the possible solutions that can solve the expansion problems.

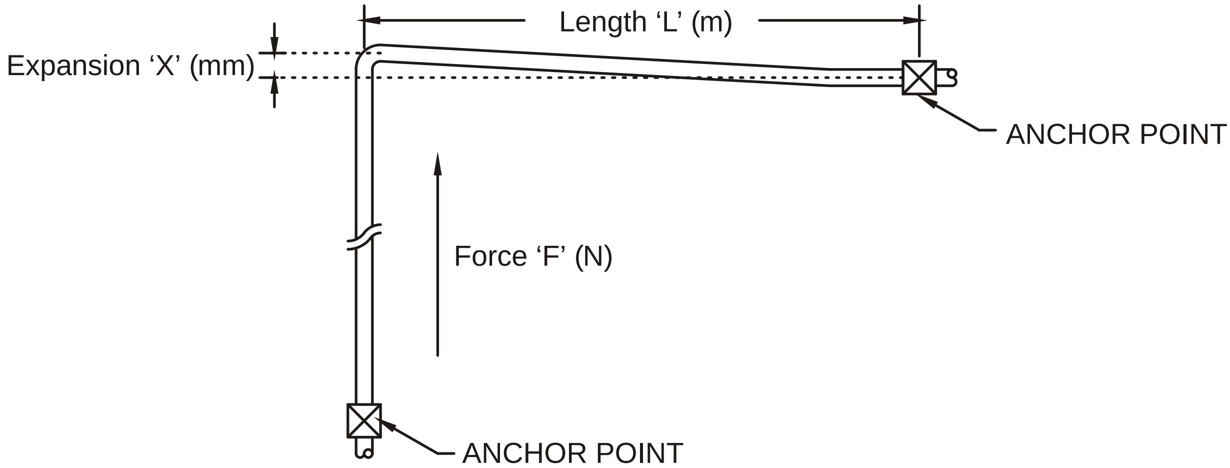
Many factors must be taken into consideration. The following information should be gathered before different methods are considered:-

- Pipe Material (Expansion Coefficients)
- Pipe Nominal Size (and Gauge, Wall Thickness or Schedule)
- Pipe Length, Location and Layout
- Temperature (Minimum, Maximum and Starting Temperature)
- Pressure (Working and Test)
- Connection and Branch Points
- Building Structure (Position and Strength of Walls, Floors, Soffits, Mezzanines, etc)



NATURAL FLEXIBILITY SOLUTION

The majority of pipe systems have direction changes due to the routing through buildings and structures, over and under roads, etc. This introduces 'natural' or 'inherent' flexibility into the pipe system. The ability of the pipe to bend is a function of pipe material, nominal size, wall thickness, and length allowed to deflect. The result of the pipe being able to bend is to reduce the forces acting within the system and to reduce the pipe stresses.



The length of pipe required to bend can be calculated mathematically using the formulae:-

For carbon steel pipes, $L = \text{sqrt}(D \times X) \times 0.10$ For copper pipes, $L = \text{sqrt}(D \times X) \times 0.06$

Where, L = Length (m)
D = Pipe Nominal Diameter (mm)
X = Expansion (mm)

The force required to bend this length of pipe can be calculated mathematically using the formulae:-

For carbon steel pipes, $F = (24 \times I \times X) \div L^3$ For copper pipes, $F = (8.4 \times I \times X) \div L^3$

Where, F = Force (N)
I = Moment of Inertia (cm^4)
X = Expansion (mm)
L = Length (m)

The moment of inertia (2nd moment of area) can be calculated mathematically using the formula:-

$$I = \frac{3.142}{64}(D^4 - d^4)$$

Where, D = Pipe Outer Diameter
d = Pipe Internal Diameter

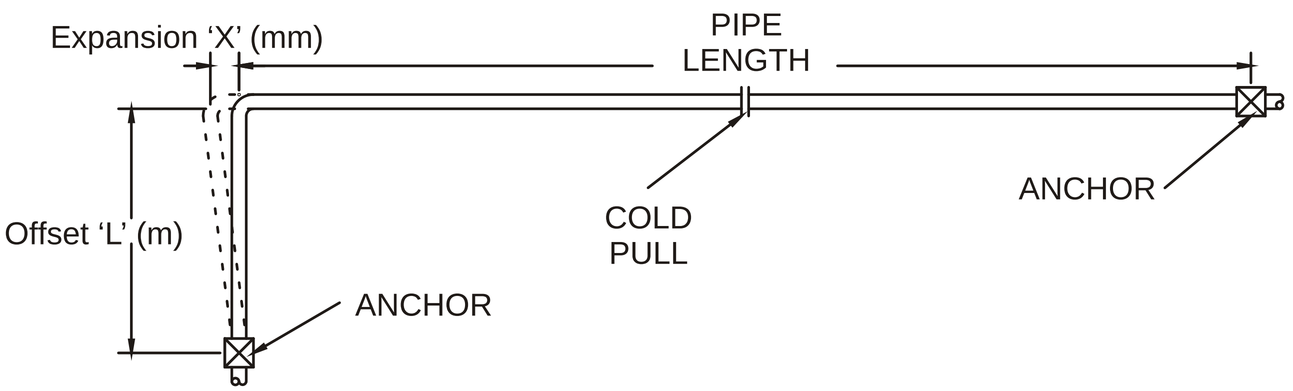
The stress developed in the bending pipe can be calculated mathematically using the formulae:-

For carbon steel pipes, $S = (6 \times 10^5 \times D \times X) \div L^2$ For copper pipes, $S = (2.1 \times 10^5 \times D \times X) \div L^2$

Where, S = Stress (N/m^2)
D = Pipe Nominal Diameter (mm)
X = Expansion (mm)
L = Length (m)

PIPE BRANCH & OFFSET FLEXIBILITY

The following tables provide an easy look-up for the branch or offset length required to bend by various amounts of expansion or contraction, for both carbon steel and copper pipes. If 50% cold pull is used, the branch or offset will accommodate twice the movement; for look-up purposes, use half the amount of expansion or contraction.

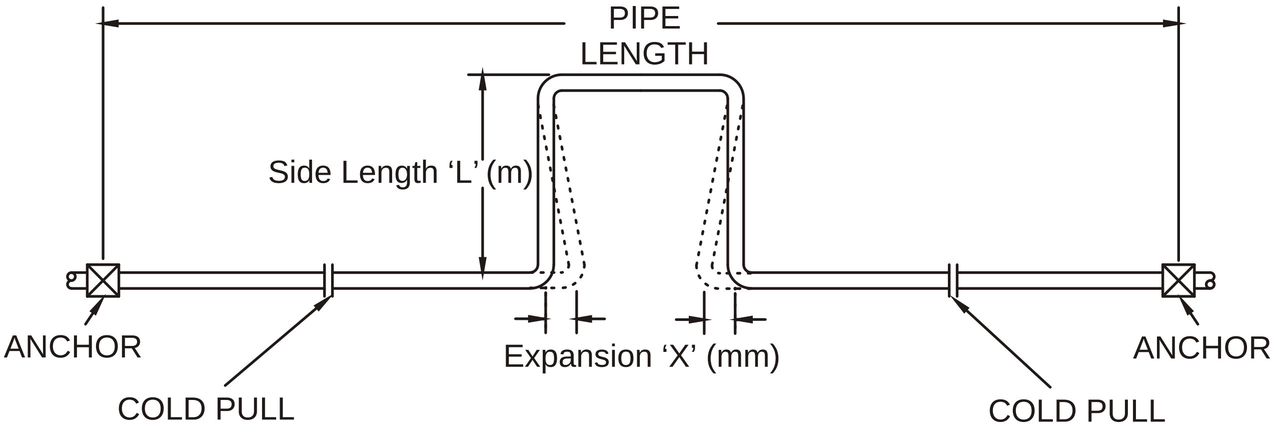


Expansion 'X'	Branch or Offset Length 'L' (m) required for the stated Carbon Steel Pipe Size (No Cold Pull)										
(mm)	15mm	20mm	25mm	32mm	40mm	50mm	65mm	80mm	100mm	125mm	150mm
1	0.387	0.447	0.500	0.566	0.632	0.707	0.806	0.894	1.000	1.118	1.225
2	0.548	0.632	0.707	0.800	0.894	1.000	1.140	1.265	1.414	1.581	1.732
3	0.671	0.775	0.866	0.980	1.095	1.225	1.396	1.549	1.732	1.936	2.121
4	0.775	0.894	1.000	1.131	1.265	1.414	1.612	1.789	2.000	2.236	2.449
5	0.866	1.000	1.118	1.265	1.414	1.581	1.803	2.000	2.236	2.500	2.739
10	1.225	1.414	1.581	1.789	2.000	2.236	2.550	2.828	3.162	3.536	3.873
15	1.500	1.732	1.936	2.191	2.449	2.739	3.122	3.464	3.873	4.330	4.743
20	1.732	2.000	2.236	2.530	2.828	3.162	3.606	4.000	4.472	5.000	5.477
25	1.936	2.236	2.500	2.828	3.162	3.536	4.031	4.472	5.000	5.590	6.124
30	2.121	2.449	2.739	3.098	3.464	3.873	4.416	4.899	5.477	6.124	6.708
35	2.291	2.646	2.958	3.347	3.742	4.183	4.770	5.292	5.916	6.614	7.246
40	2.449	2.828	3.162	3.578	4.000	4.472	5.099	5.657	6.325	7.071	7.746
45	2.598	3.000	3.354	3.795	4.243	4.743	5.408	6.000	6.708	7.500	8.216
50	2.739	3.162	3.536	4.000	4.472	5.000	5.701	6.325	7.071	7.906	8.660
60	3.000	3.464	3.873	4.382	4.899	5.477	6.245	6.928	7.746	8.660	9.487
70	3.240	3.742	4.183	4.733	5.292	5.916	6.745	7.483	8.367	9.354	10.247
80	3.464	4.000	4.472	5.060	5.657	6.325	7.211	8.000	8.944	10.000	10.954
90	3.674	4.243	4.743	5.367	6.000	6.708	7.649	8.485	9.487	10.607	11.619
100	3.873	4.472	5.000	5.657	6.325	7.071	8.062	8.944	10.000	11.180	12.247

Expansion 'X'	Branch or Offset Length 'L' (m) required for the stated Copper Pipe Size (No Cold Pull)										
(mm)	15mm	22mm	28mm	35mm	42mm	54mm	67mm	76mm	108mm	133mm	159mm
1	0.232	0.281	0.317	0.355	0.389	0.441	0.491	0.523	0.624	0.692	0.757
2	0.329	0.398	0.449	0.502	0.550	0.624	0.695	0.740	0.882	0.979	1.070
3	0.402	0.487	0.550	0.615	0.673	0.764	0.851	0.906	1.080	1.198	1.310
4	0.465	0.563	0.635	0.710	0.778	0.882	0.982	1.046	1.247	1.384	1.513
5	0.520	0.629	0.710	0.794	0.869	0.986	1.098	1.170	1.394	1.547	1.692
10	0.735	0.890	1.004	1.122	1.230	1.394	1.553	1.654	1.972	2.188	2.392
15	0.900	1.090	1.230	1.375	1.506	1.708	1.902	2.026	2.415	2.680	2.930
20	1.039	1.259	1.420	1.587	1.739	1.972	2.196	2.339	2.789	3.095	3.383
25	1.162	1.407	1.587	1.775	1.944	2.205	2.456	2.615	3.118	3.460	3.783
30	1.273	1.541	1.739	1.944	2.130	2.415	2.690	2.865	3.415	3.790	4.144
35	1.375	1.665	1.878	2.100	2.300	2.608	2.906	3.095	3.689	4.094	4.476
40	1.470	1.780	2.008	2.245	2.459	2.789	3.106	3.308	3.944	4.376	4.785
45	1.559	1.888	2.130	2.381	2.608	2.958	3.295	3.509	4.183	4.642	5.075
50	1.643	1.990	2.245	2.510	2.750	3.118	3.473	3.699	4.409	4.893	5.350
60	1.800	2.180	2.459	2.750	3.012	3.415	3.804	4.052	4.830	5.360	5.860
70	1.944	2.355	2.656	2.970	3.253	3.689	4.109	4.376	5.217	5.789	6.330
80	2.078	2.517	2.840	3.175	3.478	3.944	4.393	4.678	5.577	6.189	6.767
90	2.205	2.670	3.012	3.367	3.689	4.183	4.659	4.962	5.915	6.564	7.177
100	2.324	2.814	3.175	3.550	3.888	4.409	4.911	5.231	6.235	6.920	7.566

PIPE LOOP FLEXIBILITY

The following tables provide an easy look-up for the length of the loop sides required to bend by various amounts of expansion or contraction, for both carbon steel and copper pipes. If 50% cold pull is used, the loop will accommodate twice the movement; for look-up purposes, use half the amount of expansion or contraction.



Expansion 'X'	Loop Side Length 'L' (m) required for the stated Carbon Steel Pipe Size (No Cold Pull)										
(mm)	15mm	20mm	25mm	32mm	40mm	50mm	65mm	80mm	100mm	125mm	150mm
1	0.274	0.316	0.354	0.400	0.447	0.500	0.570	0.632	0.707	0.791	0.866
2	0.387	0.447	0.500	0.566	0.632	0.707	0.806	0.894	1.000	1.118	1.225
3	0.474	0.548	0.612	0.693	0.775	0.866	0.987	1.095	1.225	1.369	1.500
4	0.548	0.632	0.707	0.800	0.894	1.000	1.140	1.265	1.414	1.581	1.732
5	0.612	0.707	0.791	0.894	1.000	1.118	1.275	1.414	1.581	1.768	1.936
10	0.866	1.000	1.118	1.265	1.414	1.581	1.803	2.000	2.236	2.500	2.739
15	1.061	1.225	1.369	1.549	1.732	1.936	2.208	2.449	2.739	3.062	3.354
20	1.225	1.414	1.581	1.789	2.000	2.236	2.550	2.828	3.162	3.536	3.873
25	1.369	1.581	1.768	2.000	2.236	2.500	2.850	3.162	3.536	3.953	4.330
30	1.500	1.732	1.936	2.191	2.449	2.739	3.122	3.464	3.873	4.330	4.743
35	1.620	1.871	2.092	2.366	2.646	2.958	3.373	3.742	4.183	4.677	5.123
40	1.732	2.000	2.236	2.530	2.828	3.162	3.606	4.000	4.472	5.000	5.477
45	1.837	2.121	2.372	2.683	3.000	3.354	3.824	4.243	4.743	5.303	5.809
50	1.936	2.236	2.500	2.828	3.162	3.536	4.031	4.472	5.000	5.590	6.124
60	2.121	2.449	2.739	3.098	3.464	3.873	4.416	4.899	5.477	6.124	6.708
70	2.291	2.646	2.958	3.347	3.742	4.183	4.770	5.292	5.916	6.614	7.246
80	2.449	2.828	3.162	3.578	4.000	4.472	5.099	5.657	6.325	7.071	7.746
90	2.598	3.000	3.354	3.795	4.243	4.743	5.408	6.000	6.708	7.500	8.216
100	2.739	3.162	3.536	4.000	4.472	5.000	5.701	6.325	7.071	7.906	8.660

Expansion 'X'	Loop Side Length 'L' (m) required for the stated Copper Pipe Size (No Cold Pull)										
(mm)	15mm	22mm	28mm	35mm	42mm	54mm	67mm	76mm	108mm	133mm	159mm
1	0.164	0.199	0.224	0.251	0.275	0.312	0.347	0.370	0.441	0.489	0.535
2	0.232	0.281	0.317	0.355	0.389	0.441	0.491	0.523	0.624	0.692	0.757
3	0.285	0.345	0.389	0.435	0.476	0.540	0.601	0.641	0.764	0.847	0.927
4	0.329	0.398	0.449	0.502	0.550	0.624	0.695	0.740	0.882	0.979	1.070
5	0.367	0.445	0.502	0.561	0.615	0.697	0.777	0.827	0.986	1.094	1.196
10	0.520	0.629	0.710	0.794	0.869	0.986	1.098	1.170	1.394	1.547	1.692
15	0.636	0.771	0.869	0.972	1.065	1.207	1.345	1.432	1.708	1.895	2.072
20	0.735	0.890	1.004	1.122	1.230	1.394	1.553	1.654	1.972	2.188	2.392
25	0.822	0.995	1.122	1.255	1.375	1.559	1.736	1.849	2.205	2.446	2.675
30	0.900	1.090	1.230	1.375	1.506	1.708	1.902	2.026	2.415	2.680	2.930
35	0.972	1.177	1.328	1.485	1.627	1.844	2.055	2.188	2.608	2.895	3.165
40	1.039	1.259	1.420	1.587	1.739	1.972	2.196	2.339	2.789	3.095	3.383
45	1.102	1.335	1.506	1.684	1.844	2.091	2.330	2.481	2.958	3.282	3.589
50	1.162	1.407	1.587	1.775	1.944	2.205	2.456	2.615	3.118	3.460	3.783
60	1.273	1.541	1.739	1.944	2.130	2.415	2.690	2.865	3.415	3.790	4.144
70	1.375	1.665	1.878	2.100	2.300	2.608	2.906	3.095	3.689	4.094	4.476
80	1.470	1.780	2.008	2.245	2.459	2.789	3.106	3.308	3.944	4.376	4.785
90	1.559	1.888	2.130	2.381	2.608	2.958	3.295	3.509	4.183	4.642	5.075
100	1.643	1.990	2.245	2.510	2.750	3.118	3.473	3.699	4.409	4.893	5.350

EXPANSION JOINT SOLUTION

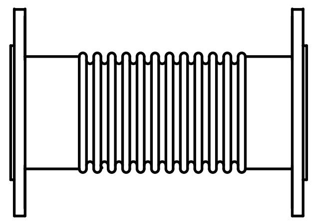
If natural flexibility is insufficient, or the resultant forces are excessive, then expansion joints are the next solution. However, there are several different models and it must be decided which is the best for the pipe system being designed.

The possible positions and strengths of anchors and guides must be considered. Different models of expansion joint, when combined with the pipe system parameters, will impose different forces.

The expansion joints can be divided into two main groups. These are 'unrestrained' and 'restrained' expansion joints. All expansion joints fall into one of these groups as illustrated below:-

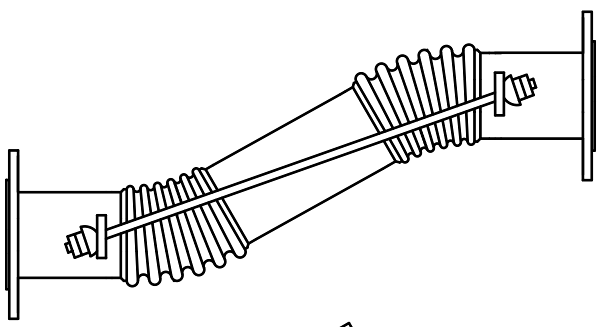
UNRESTRAINED EXPANSION JOINTS

The AXIAL expansion joint is the only model that falls into the unrestrained group. Generally they are designed to accommodate movements of between 25mm and 50mm. They are limited to axial travel only and must be suitably anchored and guided so as to prevent damage. The only exception to this rule is on very low pressure systems up to 2 Bar, such as combined heat and power exhaust applications.

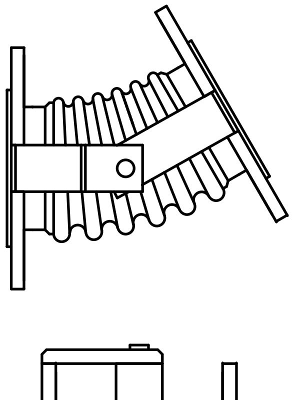


RESTRAINED EXPANSION JOINTS

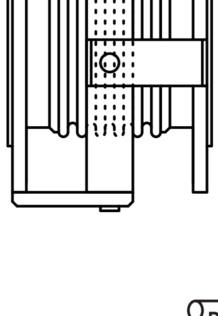
There are several expansion joint models that fall into the restrained group. With all these models, anchor forces are generally lower than with unrestrained expansion joints, and furthermore, fewer pipe guides are required.



LATERAL expansion joints can be designed to accommodate very large movements. They are limited to lateral travel only. FULLY ARTICULATED models can allow lateral movement in any direction from their main axis. DOUBLE HINGED models can allow lateral movement in one plane only.



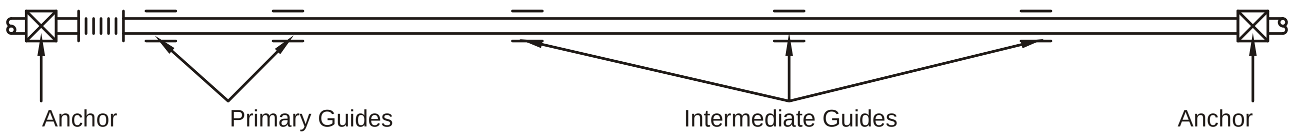
HINGED expansion joints, when used in sets of 2 or 3, can be designed to accommodate very large movements. They are limited to angular travel only, but effectively create articulating sections of pipe when used with a 2nd or 3rd unit. They are also known as ANGULAR expansion joints.

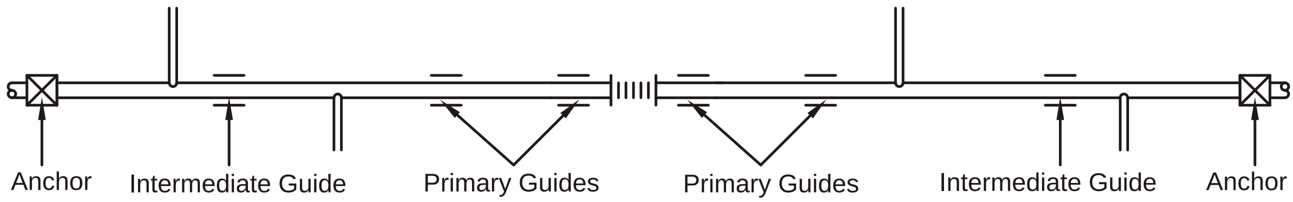


GIMBAL expansion joints are similar in principle to the HINGED model, but they are able to angulate in any direction from their main axis. When used in sets of 2 or 3, or in conjunction with HINGED models, they can be designed to accommodate very large movements.

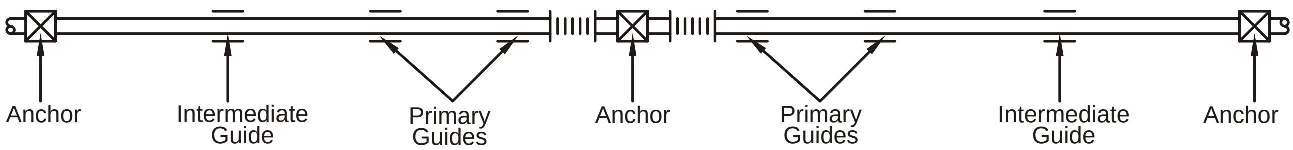
TYPICAL 'AXIAL' INSTALLATIONS

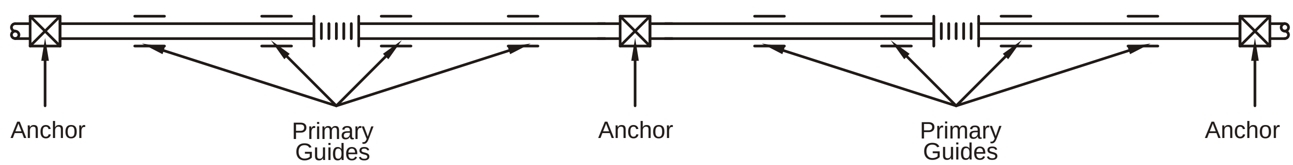
The unrestrained AXIAL expansion joint must only be used in straight pipe runs that have been adequately anchored and guided. Typical layouts are illustrated below:-





Comparing the two diagrams above, 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 varies, so it is important to carefully consider the options available on site.

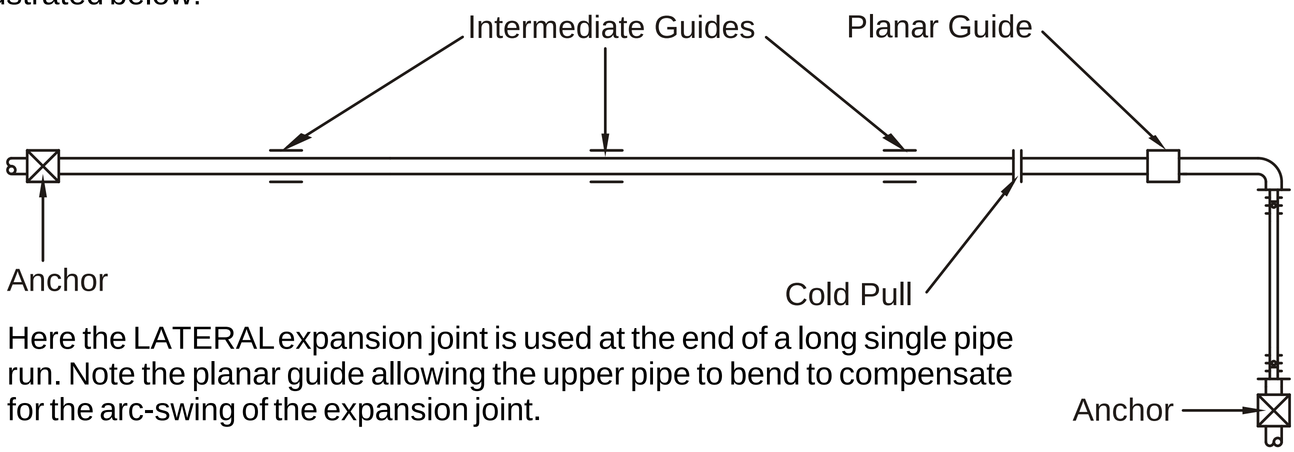




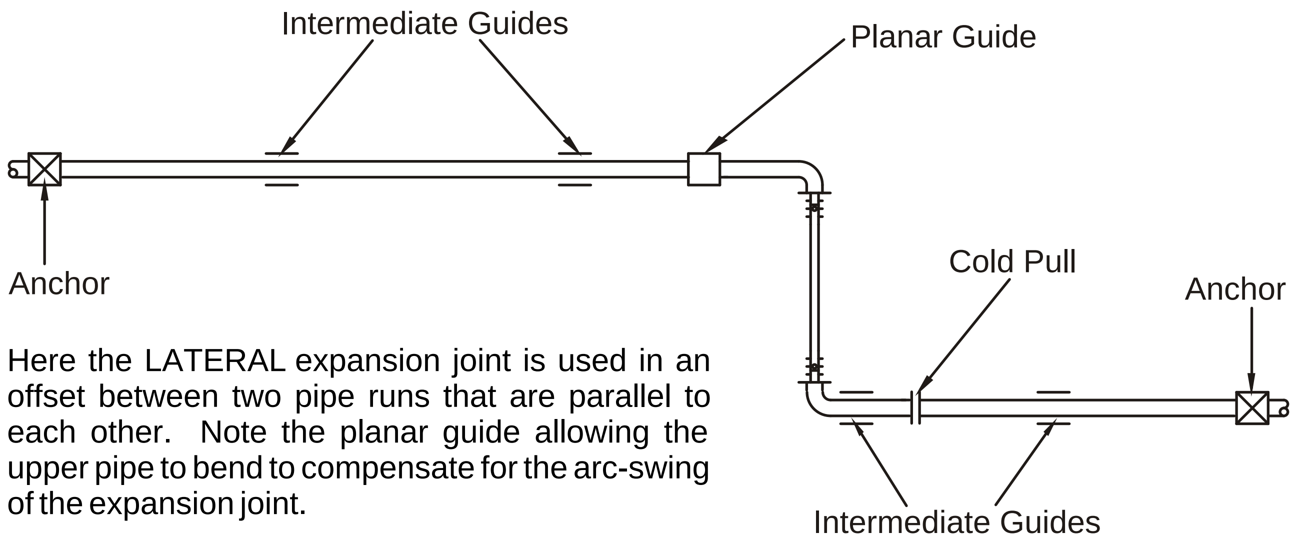
The same comparison with regard to the numbers of guides can be made for the above two diagrams. Also consider in these two cases the ease of access for periodic inspection in the future; i.e. one access point, or two access points.

TYPICAL 'LATERAL' INSTALLATIONS

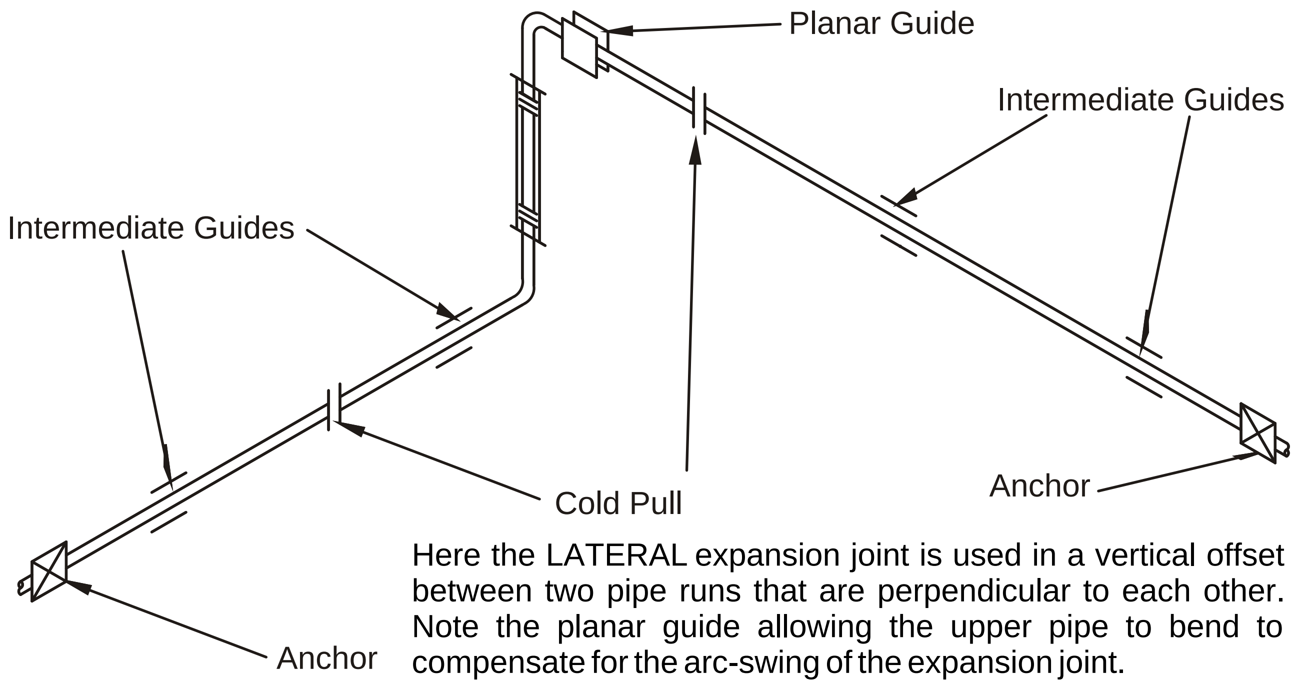
The restrained LATERAL expansion joint can be used in pipe runs that contain direction changes, or they can be used at intersections of two pipe runs that do not run parallel. Typical layouts are illustrated below:-



Here the LATERAL expansion joint is used at the end of a long single pipe run. Note the planar guide allowing the upper pipe to bend to compensate for the arc-swing of the expansion joint.



Here the LATERAL expansion joint is used in an offset between two pipe runs that are parallel to each other. Note the planar guide allowing the upper pipe to bend to compensate for the arc-swing of the expansion joint.

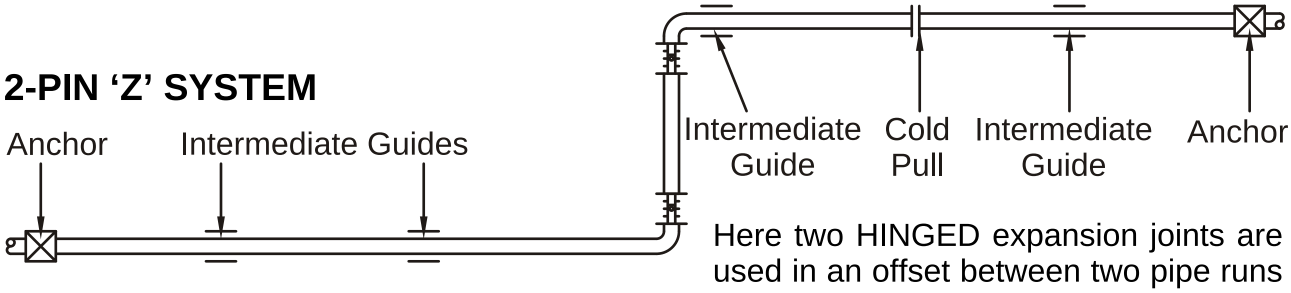


Here the LATERAL expansion joint is used in a vertical offset between two pipe runs that are perpendicular to each other. Note the planar guide allowing the upper pipe to bend to compensate for the arc-swing of the expansion joint.

TYPICAL ‘HINGED’ INSTALLATIONS

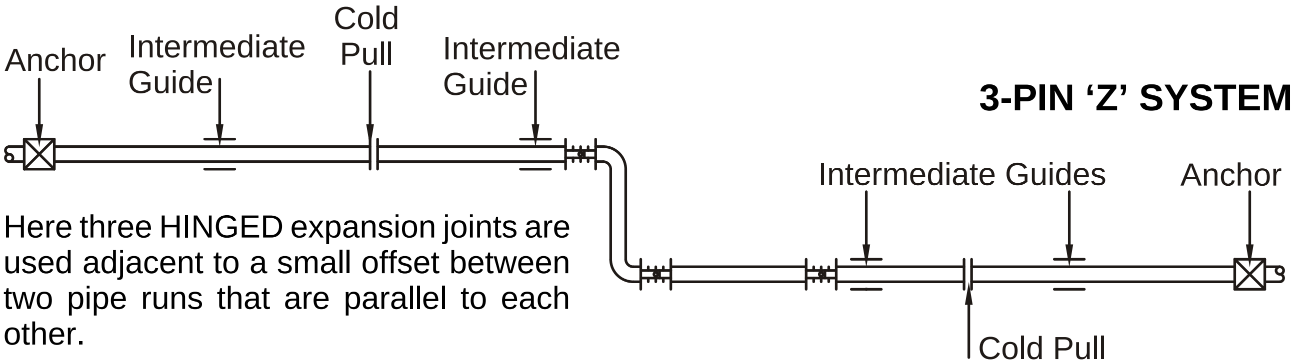
The restrained HINGED expansion joint can be used in sets of 2 or 3 in pipe runs that contain direction changes, or they can be used at intersections of two pipe runs that are not parallel.
Typical layouts are illustrated below:-

2-PIN ‘Z’ SYSTEM



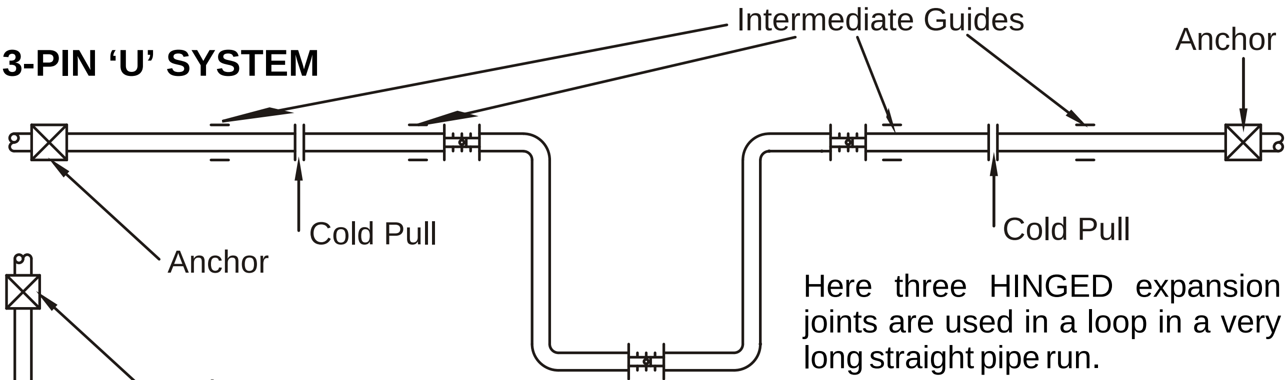
Here two HINGED expansion joints are used in an offset between two pipe runs that are parallel to each other.

3-PIN ‘Z’ SYSTEM



Here three HINGED expansion joints are used adjacent to a small offset between two pipe runs that are parallel to each other.

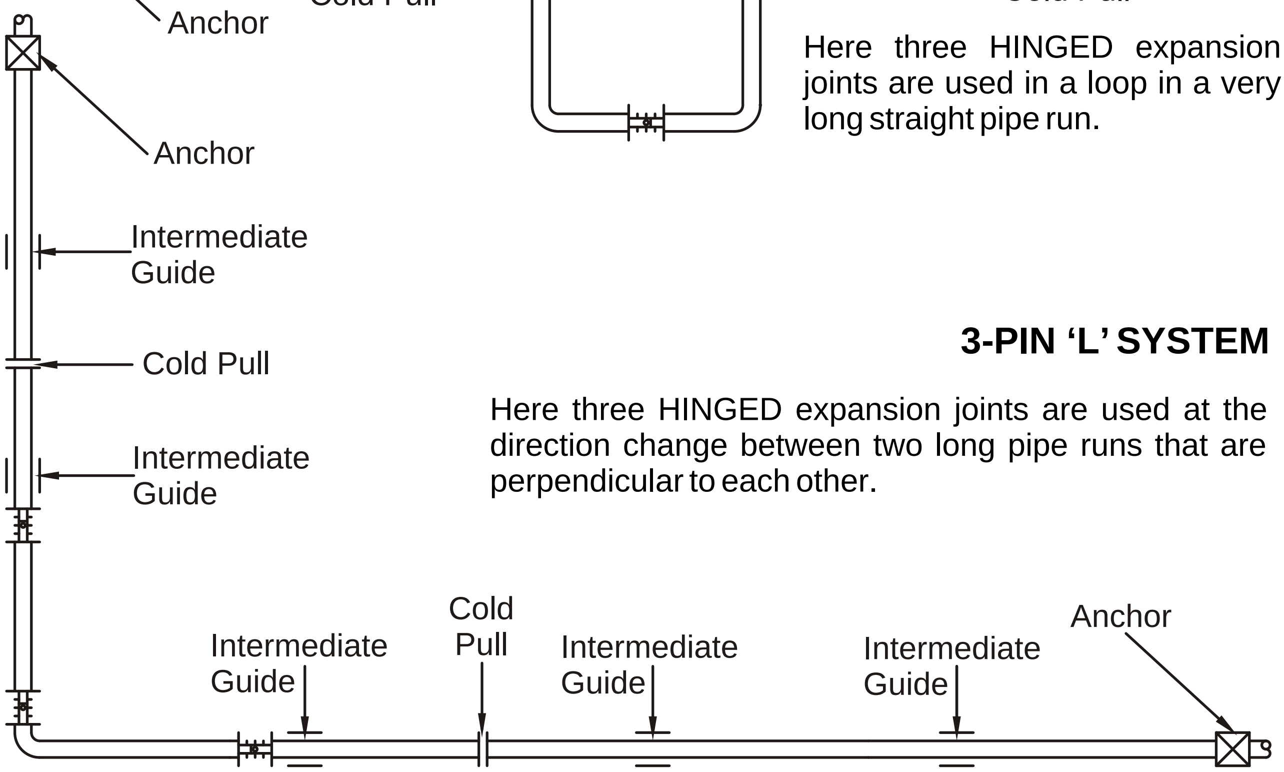
3-PIN ‘U’ SYSTEM



Here three HINGED expansion joints are used in a loop in a very long straight pipe run.

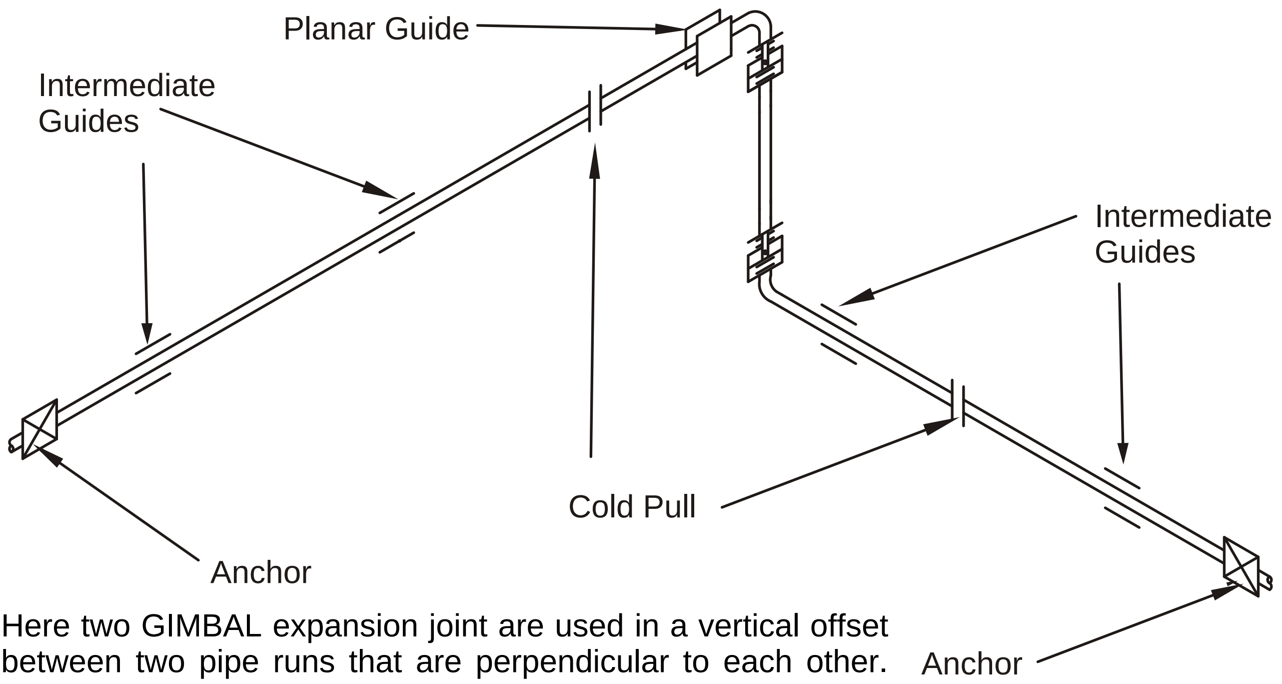
3-PIN ‘L’ SYSTEM

Here three HINGED expansion joints are used at the direction change between two long pipe runs that are perpendicular to each other.

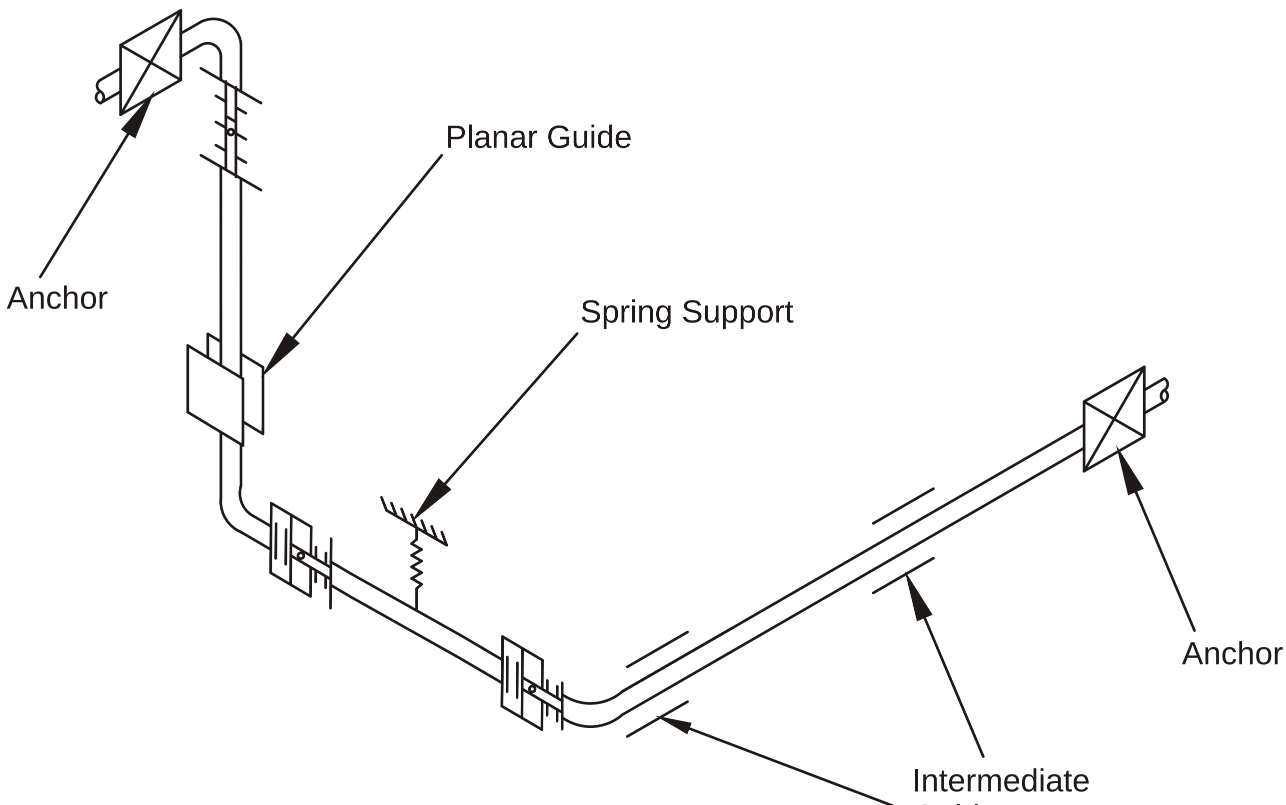


TYPICAL 'GIMBAL' INSTALLATIONS

The restrained GIMBAL expansion joint can be used in sets of 2 alone, or in a set of 2 with 1 Hinged expansion joint. They can be used in pipe runs that contain direction changes, or they can be used at intersections of two pipe runs that do not run parallel. Typical layouts are illustrated below:-



Here two GIMBAL expansion joint are used in a vertical offset between two pipe runs that are perpendicular to each other. Note the planar guide allowing the upper pipe to bend to compensate for the arc-swing of the expansion joint.



Here two GIMBAL expansion joints are used in conjunction with one HINGED expansion joint to accommodate thermal expansion in a complex multi-directional pipe system.

PIPE ANCHORS

Pipe anchors are required to control pipe expansion or contraction, and for 'natural' flexibility or expansion joints to function as designed. The forces acting on the pipe anchors will comprise one or more of the following:-

- Friction force of the pipe moving over the supports, relative to pipe slope
- Bending force of the offset or branch
- Spring force of the bellows of the expansion joint
- Pressure thrust force of unrestrained expansion joints
- Centrifugal force of the flowing media acting on pipe direction changes
- Wind loading force relative to wind speed and height above ground
- Dead weight force of pipe, media, insulation and components

Each of these forces are considered separately over the next few pages as follows:-

Friction Force

As the pipe expands or contracts over its supports, it encounters friction. The anchors must resist this friction force, which is a function of the weight of the pipe, insulation and contents, coefficient of friction and the slope of the pipe. For vertical pipes (risers), friction forces are small, but can be estimated at 15% of the anchor force multiplied by the coefficient of friction.

The friction force can be calculated mathematically using the formula:- $F = M \times G \times C_{Friction}$

Where,
F = Force (N)
M = Mass (kg)
G = Gravitational Acceleration (9.81m/s^2)
$C_{Friction}$ = Coefficient of Friction

Coefficients of friction vary. As a guide, use the following:-

Steel on P.T.F.E.	=	0.03
Point Contact steel on steel	=	0.20
Line Contact steel on steel	=	0.25
Edge Contact steel on steel	=	0.30
Face to Face Contact steel on steel	=	0.40

Coefficient of Friction	Friction force (N) for 1m horizontal length of water filled insulated* BS1387 heavy steel pipe										
	15mm	20mm	25mm	32mm	40mm	50mm	65mm	80mm	100mm	125mm	150mm
0.03	0.5	0.6	1.0	1.4	1.7	2.4	3.4	4.4	6.7	9.1	11.7
0.2	3.1	4.3	6.9	9.4	11.2	16.3	22.6	29.4	44.7	60.6	78.3
0.25	3.9	5.4	8.6	11.8	14.0	20.4	28.2	36.8	55.9	75.8	97.9
0.3	4.7	6.5	10.3	14.1	16.8	24.4	33.8	44.1	67.1	90.9	117.4
0.4	6.3	8.6	13.7	18.8	22.4	32.6	45.1	58.9	89.5	121.3	156.6

**Insulation is 50mm thick and has a density of 200kg per cubic metre*

Bending Force

As the pipe expands or contracts it may try to bend offsets at the end of the run, or branches off the main pipe. The anchors must resist this bending force, which is a function of the moment of inertia of the pipe, the amount of expansion, and the length of pipe able to bend.

The bending force can be calculated mathematically using the formulae:-

For carbon steel pipes, $F = (24 \times I \times X) \div L^3$ For copper pipes, $F = (8.4 \times I \times X) \div L^3$

Where,			
	F	=	Force (N)
	I	=	Moment of Inertia (cm^4)
	X	=	Expansion (mm)
	L	=	Length (m)

Expansion (mm)	Force (N) to bend a 2m length of BS1387 heavy steel pipe by the stated expansion										
	15mm	20mm	25mm	32mm	40mm	50mm	65mm	80mm	100mm	125mm	150mm
1	2.4	5.3	12.9	27.5	41.9	92.4	193.5	342.0	816.0	1560.0	2586.0
2	4.7	10.5	25.7	55.0	83.9	184.8	387.0	684.0	1632.0	3120.0	5172.0
3	7.1	15.8	38.6	82.4	125.8	277.2	580.5	1026.0	2448.0	4680.0	
4	9.5	21.0	51.5	109.9	167.8	369.6	774.0	1368.0	3264.0		
5	11.9	26.3	64.4	137.4	209.7	462.0	967.5	1710.0			
10	23.7	52.5	128.7	274.8	419.4						
15	35.6	78.8	193.1								
20	47.4	105.0									
25	59.3										
Blank spaces indicate that the pipe would be overstressed											

Spring Rate Force

As the pipe expands or contracts it may need to deflect expansion joints installed in the pipe system. The anchors must resist the force required to overcome the 'spring' of the bellows, which is a function of the amount of expansion and the linear or angular spring rate of the bellows, which can be found on expansion joint data sheets.

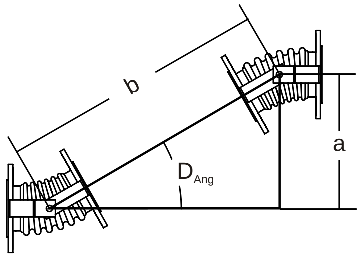
The spring force can be calculated mathematically using the formulae:-

For axial expansion joints, $F = D_{Lin} \times S_{Lin}$

Where,			
	F	=	Force (N)
	D_{Lin}	=	Linear Deflection (mm)
	S_{Lin}	=	Linear Spring Rate (N/mm)

For hinged expansion joints, $F = (D_{Ang} \times S_{Ang}) \div L$

Where,			
	F	=	Force (N)
	D_{Ang}	=	Angular Deflection* (deg)
	S_{Ang}	=	Angular Spring Rate (Nm/deg)
	L	=	Length of pipe between bellows centres (m)



* Angular Deflection is calculated using the formula:- $D_{Ang} = \sin^{-1}(a \div b)$

It is often easier to use the maximum force to deflect when it is stated on the expansion joint data sheets, even though the expansion joint is not being fully deflected.

Pressure Thrust Force

As the pipe expands it may need to deflect axial expansion joints installed in the pipe system. The anchors must be able to resist the pressure thrust force which is present whenever unrestrained (axial) expansion joints are used. This force is a function of the effective area of the bellows and the working or test pressure at the expansion joint location.

The pressure thrust force can be calculated mathematically using the formulae:-

For working conditions, $F = A_E \times P_{working} \times 0.1$ For test conditions, $F = A_E \times P_{test} \times 0.1$

Where,
- F = Force (N)
- A_E = Effective Area (cm^2), taken from data sheets
- $P_{Working}$ = Working Pressure (kN/m^2)
- P_{Test} = Test Pressure (kN/m^2), often 1.5x working pressure
- 0.1 = Correction Factor, due to measurement units used

Pressure		Pressure Thrust Force (N) exerted by Axial Expansion Joints at the stated pressure										
(kN/m^2)	(bar)	15mm	20mm	25mm	32mm	40mm	50mm	65mm	80mm	100mm	125mm	150mm
100	1	60	80	100	190	230	350	530	720	1110	1690	2340
200	2	120	160	200	380	460	700	1060	1440	2220	3380	4680
300	3	180	240	300	570	690	1050	1590	2160	3330	5070	7020
400	4	240	320	400	760	920	1400	2120	2880	4440	6760	9360
500	5	300	400	500	950	1150	1750	2650	3600	5550	8450	11700
600	6	360	480	600	1140	1380	2100	3180	4320	6660	10140	14040
700	7	420	560	700	1330	1610	2450	3710	5040	7770	11830	16380
800	8	480	640	800	1520	1840	2800	4240	5760	8880	13520	18720
900	9	540	720	900	1710	2070	3150	4770	6480	9990	15210	21060
1000	10	600	800	1000	1900	2300	3500	5300	7200	11100	16900	23400
1100	11	660	880	1100	2090	2530	3850	5830	7920	12210	18590	25740
1200	12	720	960	1200	2280	2760	4200	6360	8640	13320	20280	28080
1300	13	780	1040	1300	2470	2990	4550	6890	9360	14430	21970	30420
1400	14	840	1120	1400	2660	3220	4900	7420	10080	15540	23660	32760
1500	15	900	1200	1500	2850	3450	5250	7950	10800	16650	25350	35100
1600	16	960	1280	1600	3040	3680	5600	8480	11520	17760	27040	37440
2000	20	1200	1600	2000	3800	4600	7000	10600	14400	22200	33800	46800
2400	24	1440	1920	2400	4560	5520	8400	12720	17280	26640	40560	56160

Centrifugal Force

As the media flows through the pipe, it encounters bends. At these bends the flowing media exerts a centrifugal force on the pipe. The anchors (and guides) may have to resist this centrifugal force, which is a function of the media density, media velocity, area of the bend, bend angle, and G.

The centrifugal force can be calculated mathematically using the formula:- $F=(D \times V^2 \times A \times \text{Sin } B_{Ang}) \div G$

Where,
- F = Force (N)
- D = Density of the media (kg/m^3)
- V = Velocity (m/s)
- A = Area of the bend on which the flowing media acts (cm^2)
- B_{Ang} = Bend Angle (degrees)
- G = Gravitational Acceleration ($9.81 m/s^2$)

Velocity (m/s)	Centrifugal force (N) for water flowing round a 90deg steel pipe bend at the stated velocity										
	15mm	20mm	25mm	32mm	40mm	50mm	65mm	80mm	100mm	125mm	150mm
0.5	47	84	134	231	313	502	843	1165	1978	3019	4317
1.0	187	334	534	926	1254	2009	3372	4661	7910	12075	17269
1.5	420	753	1202	2083	2821	4521	7587	10488	17798	27168	38856
2.0	747	1338	2136	3704	5016	8038	13487	18645	31641	48300	69077
3.0	1681	3010	4806	8333	11286	18085	30347	41952	71192	108674	155424

Water dens ity at 20C is 1000kg/m3

Wind Loading Force

Wind loading forces occur significantly at high wind velocity on exposed sites. The anchors (and guides) have to resist this wind loading force, which is a function of the wind velocity, height above ground, and area of the side of the pipe (and insulation).

The wind loading force can be calculated mathematically using the formula:- $F = F_{wind} \times A_{Effective}$

Where, F = Force (N)
F_{Wind} = Lateral Wind Force (N/m^2)
$A_{Effective}$ = Effective Area (m^2)

Wind Velocity (m/s)	Wind Type	Lateral Wind Force (N/m2)	Lateral Wind Loading Force (N) per metre length of Insulated BS1387 Heavy Steel Pipes										
			15mm	20mm	25mm	32mm	40mm	50mm	65mm	80mm	100mm	125mm	150mm
		Effective Area (m2)	*0.122*	*0.127*	*0.134*	*0.143*	*0.149*	*0.161*	*0.177*	*0.189*	*0.215*	*0.241*	*0.266*
5	Gentle Breeze	16	2.0	2.0	2.1	2.3	2.4	2.6	2.8	3.0	3.4	3.9	4.3
10	Fresh Breeze	63	7.7	8.0	8.4	9.0	9.4	10.1	11.2	11.9	13.5	15.2	16.8
15	Moderate Gale	139	17.0	17.7	18.6	19.9	20.7	22.4	24.6	26.3	29.9	33.5	37.0
20	Fresh Gale	250	30.5	31.8	33.5	35.8	37.3	40.3	44.3	47.3	53.8	60.3	66.5
25	Whole Gale	390	47.6	49.5	52.3	55.8	58.1	62.8	69.0	73.7	83.9	94.0	103.7
30	Storm	563	68.7	71.5	75.4	80.5	83.9	90.6	99.7	106.4	121.0	135.7	149.8
35	Hurricane	761	92.8	96.6	102.0	108.8	113.4	122.5	134.7	143.8	163.6	183.4	202.4
40		1000	122.0	127.0	134.0	143.0	149.0	161.0	177.0	189.0	215.0	241.0	266.0

Based on an Insulation Thickness of 50mm

Dead Weight Force

Dead weight forces must always be taken into account when designing anchors, guides and supports. The anchors (and guides when used to support the pipe) have to resist these dead weight forces.

This is very important when designing anchors for vertical pipes (risers) in tall buildings.

The dead weight forces can be calculated mathematically using the formula:-

$$F = (M_{pipe} + M_{media} + M_{insulation}) \times G \times L$$

Where, F = Force (N)
M_{pipe} = Mass of Pipe per metre (kg/m)
M_{media} = Mass of Media per metre (kg/m)
$M_{insulation}$ = Mass of Insulation per metre (kg/m)
G = Gravitational Constant (9.81)
L = Length of pipe (m)

Component	Mass (kg/m) for Pipe, Water Contents and Insulation for BS1387 Heavy Steel Pipes										
	15mm	20mm	25mm	32mm	40mm	50mm	65mm	80mm	100mm	125mm	150mm
Pipe	1.45	1.90	2.97	3.84	4.43	6.17	7.90	10.10	14.40	17.80	21.20
Water	0.18	0.33	0.52	0.93	1.27	2.07	3.53	4.91	8.38	13.05	18.70
Insulation	2.30	2.40	2.60	2.90	3.10	3.50	4.00	4.40	5.20	6.00	6.80
TOTAL	3.93	4.63	6.09	7.67	8.80	11.74	15.43	19.41	27.98	36.85	46.70

Insulation is 50mm thick with density of 200kg/m3

Do not forget to add the mass of any other pipe fittings such as valves, strainers, de-aerators, etc.

PIPE GUIDES

Pipe guides are required to control the direction of pipe expansion or contraction, and for the 'natural' flexibility or expansion joint solution to function as designed.
They should be capable of withstanding a lateral force of 15% of the total force acting on the pipe anchor. The lateral force could act in any direction that is perpendicular to the pipe axis. This is advised in the Standards of the Expansion Joint Manufacturers Association (EJMA).

The pipe guide spacings can be calculated mathematically using the formula:-

$L_{Guide} = (3.142 / f_{Guide}) \times \mathrm{sqrt}[\,(E \times I) / (F \times S)\,]$

Where,
- L_{Guide} = Length between Guides (m)
- f_{Guide} = Guide Factor
- E = Modulus of Elasticity (10^9 N/m^2)
- I = Moment of Inertia (cm^4)
- F = Total Buckling Force (N)
- S = Safety Factor (3 is recommended)

The values for Guide Factor [f_{Guide}] for the pipe section being guided is based as follows:-
When both sides of the expansion joint are axially guided (close tolerance), take $f_{Guide} = 0.5$
When both sides are simply supported (roller/chair), take $f_{Guide} = 1.0$

Modulus of Elasticity [E] values for various common materials are shown right:-

Modulus of Elasticity for Common Pipe Materials (Approximate)			
METALS		**PLASTICS**	
Material	**Modulus** (10^9 N/m^2)	**Material**	**Modulus** (10^9 N/m^2)
Copper	70	ABS	1.8
Carbon Steel	200	PVCU	3.0
Stainless Steel (Austenitic)	190	PVCC	2.8
Stainless Steel (Ferritic)	190	PE	0.7 to 0.9
Aluminium	65	PP	0.9 to 1.5

The moment of inertia can be calculated mathematically using the formula:-

$$I = \frac{3.142}{64}(D^4 - d^4)$$

Where,
- D = Pipe Outer Diameter
- d = Pipe Internal Diameter

The Total Buckling Force [F] for the pipe section comprises several components:-

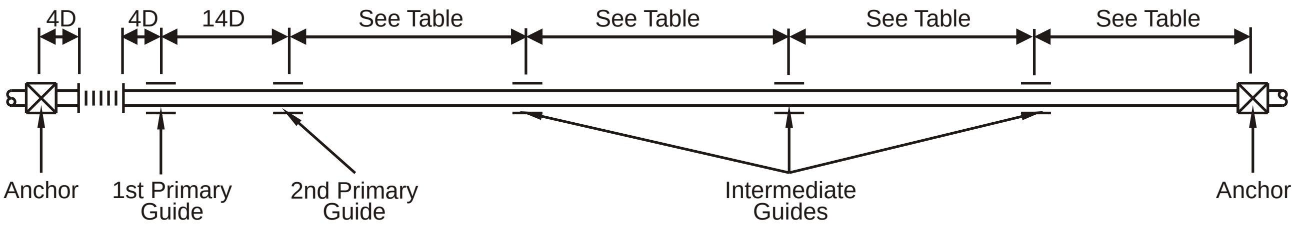
For standard axial expansion joints (unrestrained) the components will usually be:-
Friction Force + Spring Rate Force + Pressure Thrust Force

For lateral, hinged and gimbal expansion joints (restrained) the components will usually be:-
Friction Force + Spring Rate Force

For natural flexing pipe installations, such as offsets and loops, the components will usually be:-
Friction Force + Bending Force

Please refer to the previous section headed PIPE ANCHORS for force calculations.

Pipe Guides used with Unrestrained Expansion Joints



Primary Guides

These are of paramount importance when considering unrestrained or axial expansion joints. There should be a maximum of 4 pipe diameters from the expansion joint to the 1st guide and 14 pipe diameters from the 1st to the 2nd guide. This is advised in BS6129.
If the expansion joint is positioned adjacent to an anchor, then the distance to the anchor should be a maximum of 4 pipe diameters.

Intermediate Guides

These are required at intervals to prevent bowing or buckling of the pipe between the 2nd primary guide and the anchor. The spacing between these guides depends on the pipe nominal size, material, wall thickness and forces acting along the pipe.

The pipe guide spacings can be calculated mathematically using the previous formula:-

$$L_{Guide} = (3.142 / f_{Guide}) \times \text{sqrt}[\,(E \times I) / (F \times S)\,]$$

As both sides of axial expansion joints must always be guided (close tolerance as detailed below), a value of 0.5 is taken for the Guide Factor [f_{Guide}].
The Pressure Maximum is taken as the system test pressure.
The Bellows Effective Area (A_E) is taken from data sheets.

Test Pressure Max. (Barg)	Intermediate Guide Spacing (m) for BS1387 Medium Steel Pipes used with Axial Exp Joints										
	15mm	20mm	25mm	32mm	40mm	50mm	65mm	80mm	100mm	125mm	150mm
Modulus of Elasticity, E	*200*	*200*	*200*	*200*	*200*	*200*	*200*	*200*	*200*	*200*	*200*
Moment of Inertia, I	*0.71*	*1.5*	*3.7*	*7.74*	*11.78*	*26.2*	*54.5*	*97*	*231*	*470*	*787*
Guiding Factor, G	*0.5*	*0.5*	*0.5*	*0.5*	*0.5*	*0.5*	*0.5*	*0.5*	*0.5*	*0.5*	*0.5*
Bellows Effective Area (cm2)	*6*	*8*	*10*	*19*	*23*	*35*	*53*	*72*	*111*	*169*	*234*
2.5	3.5	4.4	6.2	6.5	7.3	8.9	10.4	11.9	14.8	17.1	18.8
6	2.3	2.9	4.0	4.2	4.7	5.7	6.7	7.7	9.6	11.0	12.1
10	1.8	2.2	3.1	3.3	3.7	4.4	5.2	6.0	7.4	8.6	9.4
16	1.4	1.8	2.5	2.6	2.9	3.5	4.1	4.7	5.9	6.8	7.4
25	1.1	1.4	2.0	2.1	2.3	2.8	3.3	3.8	4.7	5.4	6.0
(Support Centres)	***2.0***	***2.4***	***2.7***	***2.7***	***3.0***	***3.4***	***3.7***	***3.7***	***4.1***	***4.4***	***4.8***
Support Centres as found in CIBSE Guide B											

When considering copper pipes, reduce the intermediate guide spacing by approximately 30% because copper is more flexible than steel and will tend to bow or buckle more easily.

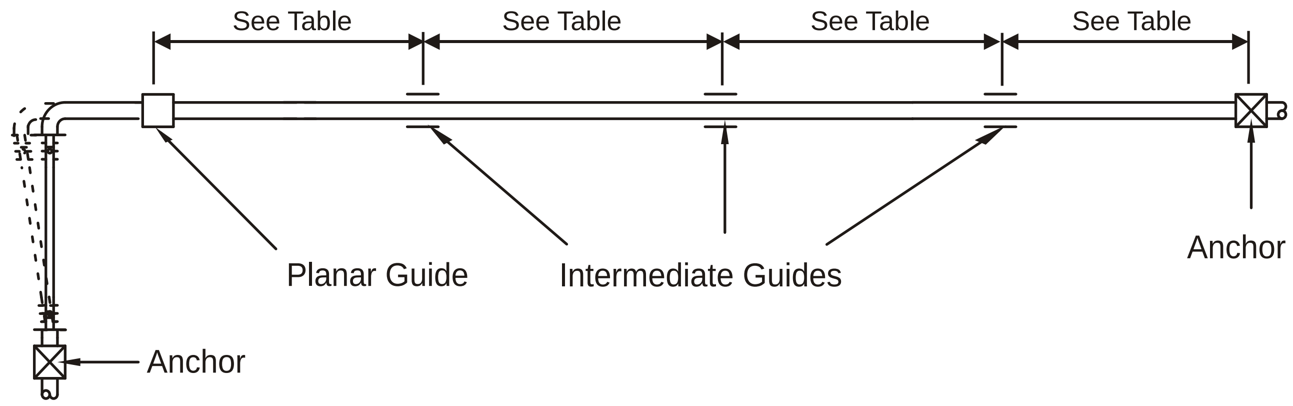
The effectiveness of pipe guides to direct the expansion movement towards an axial expansion joint depends on the clearance between the pipe and the guide.

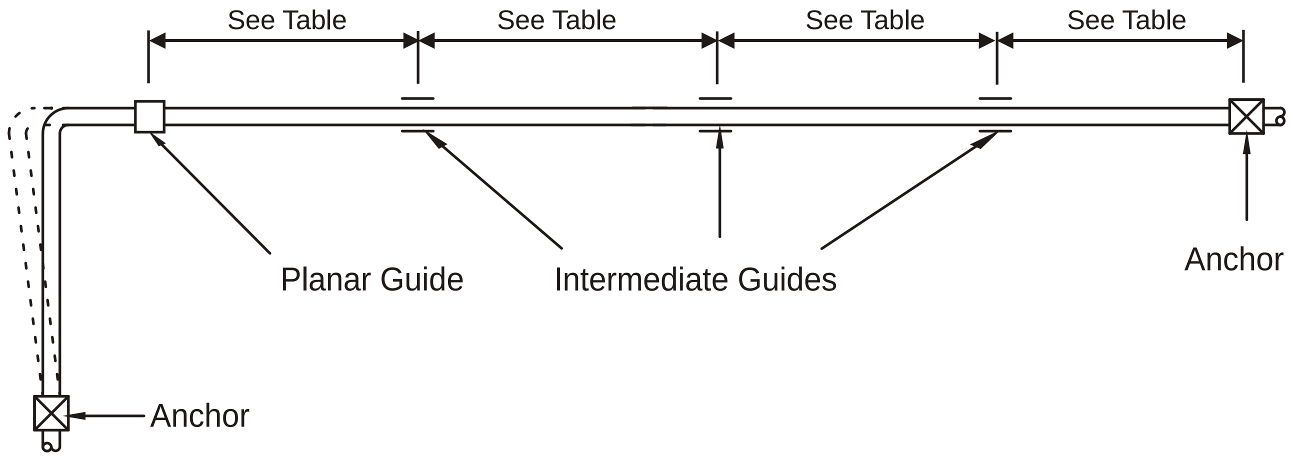
For primary guides, an annulus of 1mm (i.e. 1mm all-round clearance) is recommended for pipes up to 150mm NB. Larger pipes may have an annulus of 2mm (i.e. 2mm all-round clearance).

For intermediate guides, an annulus of 2mm (i.e. 2mm all-round clearance) is recommended for pipes up to 150mm NB. Larger pipes may have an annulus of 4mm (i.e. 4mm all-round clearance).

NOTE: as horizontal pipes may naturally sit on the bottom of the guide, then the clearance above the pipe will be twice the clearances stated above.
Further information regarding pipe guides and supports can be found in BS3974.

Pipe Guides used with Restrained Expansion Joints or 'Natural' Flexing Pipe





When considering pipe guides for use with restrained expansion joint systems or natural flexing pipe systems, the spacing depends on the pipe nominal size, material, wall thickness and forces acting along the pipe.
The previous formula enables us to tabulate guide spacings based on the largest anchor force.

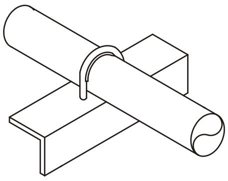
Anchor Force Max. (N)	Guide Spacing (m) for BS1387 Medium Steel Pipes used with Restrained EJs / 'Nat' Flexing										
	15mm	20mm	25mm	32mm	40mm	50mm	65mm	80mm	100mm	125mm	150mm
Modulus of Elasticity, E	200	200	200	200	200	200	200	200	200	200	200
Moment of Inertia, I	0.71	1.5	3.7	7.74	11.78	26.2	54.5	97	231	470	787
Guiding Factor, G	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
1000	1.37	1.99	3.12	4.51	5.57	8.31	11.98	15.98	24.66	35.18	45.52
2000	0.97	1.41	2.21	3.19	3.94	5.87	8.47	11.30	17.44	24.87	32.19
3000	0.79	1.15	1.80	2.61	3.22	4.79	6.92	9.23	14.24	20.31	26.28
4000	0.68	0.99	1.56	2.26	2.78	4.15	5.99	7.99	12.33	17.59	22.76
5000	0.61	0.89	1.40	2.02	2.49	3.71	5.36	7.15	11.03	15.73	20.36
6000	0.56	0.81	1.27	1.84	2.27	3.39	4.89	6.52	10.07	14.36	18.58
7000		0.75	1.18	1.71	2.10	3.14	4.53	6.04	9.32	13.30	17.20
8000			1.10	1.60	1.97	2.94	4.23	5.65	8.72	12.44	16.09
9000				1.50	1.86	2.77	3.99	5.33	8.22	11.73	15.17
10000					1.76	2.63	3.79	5.05	7.80	11.12	14.39
20000						1.86	2.68	3.57	5.51	7.87	10.18
30000							2.19	2.92	4.50	6.42	8.31
40000								2.53	3.90	5.56	7.20
50000									3.49	4.97	6.44
60000										4.54	5.88
70000											5.44
(Support Centres)	***2.0***	***2.4***	***2.7***	***2.7***	***3.0***	***3.4***	***3.7***	***3.7***	***4.1***	***4.4***	***4.8***
Support Centres as found in CIBSE Guide B - Safety Factor used is 3											

For these guides, the clearance between the pipe and the guide is not so critical as compared to those for axial expansion joints. An annulus of 2mm (i.e. 2mm all-round clearance) is recommended for pipes up to 150mm NB. Larger pipes may have an annulus of 4mm (i.e. 4mm all-round clearance).

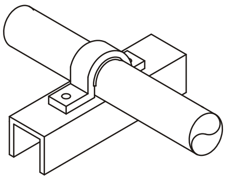
TYPICAL ANCHORS, GUIDES & SUPPORTS

Having covered the important calculations relating to anchors and guides over the last few pages, it seems appropriate to show some typical examples.

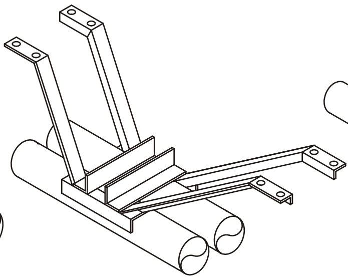
ANCHORS



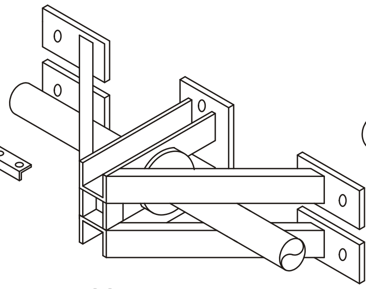
Very Light



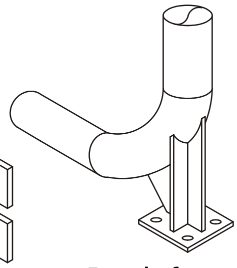
Light



Medium

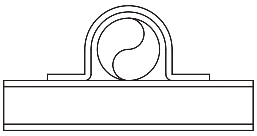


Heavy

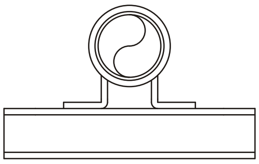


Duck-foot

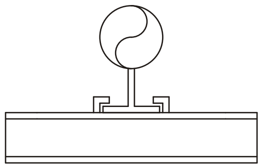
GUIDES



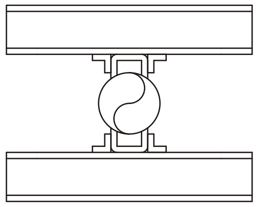
Saddle / Strap



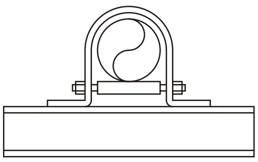
Tubular



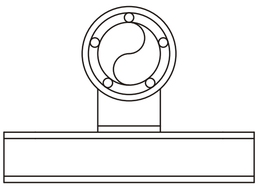
T-Slide



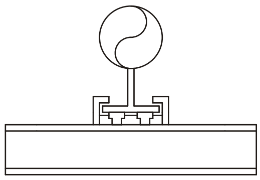
Double Channel Slide



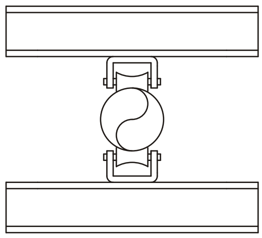
Roller / Strap



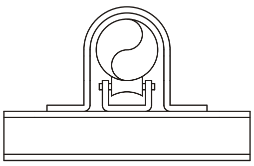
Tube with Spacing Rods



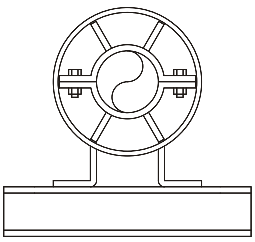
T-Slide with PTFE Inserts



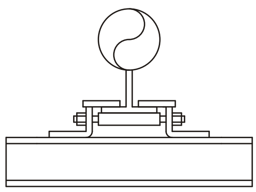
Double Roller and Chair



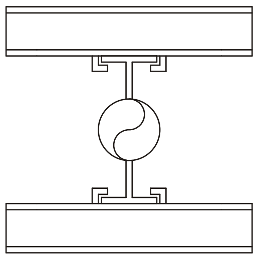
Roller, Chair & Guide



Tube with “Spider” Clamp

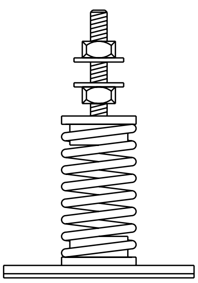


T-Slide with Roller

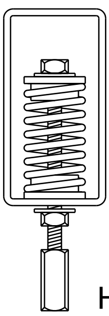


Double T-Slide

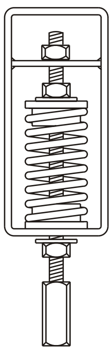
SPRING SUPPORTS



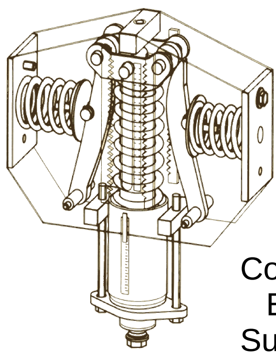
Spring Mounts



Spring Hangers



Positional Spring Hangers



Constant Effort Supports

COLD PULL (COLD DRAW)

Cold pull or cold draw is applicable to the 'natural' flexing solution, as well as unrestrained and restrained expansion joint solutions.

Cold pull effectively has the potential to halve the movement being imposed on the pipe offset, loop or expansion joint.

50% Cold Pull

By applying 50% of the expansion in a pipe run as cold pull, a pipe offset or loop is then only required to deflect by a smaller amount, effectively reducing the stresses.

Another way of considering cold pull is that a pipe offset or loop can accommodate more expansion if it is pre-set to position that returns to the neutral position when the pipe is subjected to half the temperature rise, and moves beyond the neutral position when full temperature is reached.

100% Cold Pull

There are occasions when 100% cold pull is best. For example, when considering very high temperature pipes that are subjected to continuous heat (e.g. steam, MTHW or HTHW distribution mains), the working stress in the bellows convolutions can be reduced dramatically if they come to rest in their neutral position.

Pre-Cold Pulled Expansion Joints

Axial expansion joints are often supplied with cold pull applied in the factory. This is good practice as it relieves the engineer on site from applying cold pull on each pipe run. However, where there is a temperature drop after the axial expansion joints have been installed, then models allowing expansion and contraction must be specified.
Restrained expansion joints such as the angular and lateral models are not usually supplied pre-cold pulled.

Applying Cold Pull to Unrestrained Expansion Joint Systems

Having calculated the amount of cold pull, a block of timber of thickness equal to the cold pull amount is placed between 2 flanges, either between the axial expansion joint flange and the mating flange, or between 2 mating flanges further down the pipe run before the anchor. The pipe installation, together with anchors and guides is then fully completed. The block of timber can be removed and the gap drawn togther with long high tensile bolts, remembering the gasket of course. The long bolts must not be replaced with standard length bolts and the location must be clearly identified as the COLD PULL position so that future engineers can identify it as such .

Applying Cold Pull to Restrained Expansion Joint Systems and Natural Flexing Pipe

The process is carried out in the same way, with the exception that if there are 2 significant pipe runs with the expansion 'pushing' towards the same expansion system, then 2 cold pull positions are recommended.

OTHER CONSIDERATION

Pipe Insulation / Lagging

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

The movement of the expansion joints must not be restricted by the insulation material.
The movement of flexing pipe must not be restricted by the insulation material.
The insulation material must be removable from the expansion joint to allow for periodic inspection.
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, the engineer must consider the following questions:-

Have the correct type of expansion joints been installed ?
Have the expansion joints been installed correctly ?
Have the expansion joints, guides and anchors been installed in the correct location ?
Has the correct amount of cold pull (cold draw) been applied ?
Has sufficient clearance been allowed for correct operation of the expansion joints ?
Have the expansion joints been damaged in any way ?
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.
Removing expansion joints from a system prior to testing is NOT good practice. This defeats the object of testing because other system components, such as anchors, guides, supports, etc are NOT subjected to the larger forces which may be encountered with expansion joints, in particular, axial expansion joints. Also, if expansion joints are not present during the test, any leaks in the expansion joint will not become apparent until the system is under working conditions. The engineer must check points as follows :-

Check BEFORE the pressure test:

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

Check DURING the pressure test: WARNING: Take care when checking pressurised components !

Check for any evidence of leakage.
Check for any pressure loss.
Check for malfunction of expansion joints, anchors, guides and supports.
Check in particular for any evidence of snaking or squirm in the bellows membrane.
Investigate ALL abnormal changes or unexpected occurance.

Check AFTER the pressure test:

Ensure that moving components have returned to their original positions.
Ensure that any necessary drain down has been accomplished.

Start Up Check:

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

Records must be made throughout ALL of the above stages. If problems arise, the procedure MUST be halted and investigated.

Operation and Maintenance

Records of system changes must be made, such as temperature, pressure, cycling, pipework mod's etc. Any changes must be evaluated to assess exactly what consequences they may have on system components. Consult the designer of the original system.

Periodic inspection of expansion joints must be 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. During periodic inspection the following factors should be looked for:-

Mechanical damage to the bellows convolutions.
Corrosion of the bellows convolutions.
Loosening of flange bolts or pipe threads.
Seizing of guides and supports.
Weakening of anchors, guides and supports.
Debris or foreign material in the bellows convolutions.
Seizing of hinges or ties on expansion joints.

Expansion joints are maintenance free. As part of a maintenance program, expansion joints must be kept clean and free of foreign material. Corrosion protection must be exercised from day one. Soldering flux is HIGHLY CORROSIVE to bellows convolutions.

STEAM DATA

Gauge Pressure (Barg)	Temperature (°C)	Specific Volume (m^3/kg)	Density (kg/m^3)
0	100.0	1.694	0.590
1.0	120.2	0.886	1.129
2.0	133.5	0.606	1.651
3.0	143.6	0.462	2.163
4.0	151.8	0.375	2.668
5.0	158.8	0.316	3.169
6.0	165.0	0.273	3.666
7.0	170.4	0.240	4.161
8.0	175.4	0.215	4.653
9.0	179.9	0.194	5.144

Gauge Pressure (Barg)	Temperature (°C)	Specific Volume (m^3/kg)	Density (kg/m^3)
10.0	184.1	0.177	5.650
20.0	212.4	0.100	10.043
30.0	233.8	0.067	15.004
40.0	250.3	0.050	20.092
50.0	263.9	0.039	25.355
60.0	275.6	0.032	30.826
70.0	285.8	0.027	36.536
80.0	295.0	0.024	42.517
90.0	303.3	0.020	48.828
100.0	311.0	0.018	55.494

WATER FILLED PIPE AND INSULATION WEIGHTS

Nominal Size (mm)	Insulation Weight (kg/m) Calcium Silicate *Density = 200kg/m^3			Water Filled Pipe Weight at Varying Wall Thickness (kg/m)											
				Steel BS1387		Steel BS3601 BS3602									Copper BS2871
	25mm Thick	50mm Thick	75mm Thick	'Heavy' Wall	'Medium' Wall	4.0 mm	5.0 mm	6.3 mm	8.0 mm	10.0 mm	12.5 mm	16.0 mm	20.0 mm	25.0 mm	Table 'X'
15	0.7	2.3	4.6	1.6	1.4	1.8	2.1	2.4							0.4
20	0.8	2.4	4.8	2.2	2.0	2.5	2.9	3.4							0.8
25	0.9	2.6	5.1	3.5	3.0	3.4	4.0	4.6	5.3						1.2
32	1.1	2.9	5.6	4.8	4.2	4.7	5.5	6.4	7.4						2.0
40	1.2	3.1	5.8	5.7	5.0	5.6	6.5	7.5	8.8	10					2.6
50	1.3	3.5	6.4	8.2	7.3	7.7	8.8	10.2	11.9	14	16				3.9
65	1.6	4.0	7.1	11.4	10.2	11	12	14	16	19	22	25	29		5.4
80	1.8	4.4	7.8	15	14		15	17	20	23	27	31	36		7.3
100	2.2	5.2	8.9	23	21		22	25	28	33	38	44	51	58	13.1
125	2.6	6.0	10.2	31	30		30	33	38	43	50	58	67	77	18.8
150	3.0	6.8	11.4	40	38		40	44	50	56	64	75	86	99	27.7
200	3.8	8.4	13.7						74	83	93	108	123	142	
250	4.6	10.1	16.1						104	115	129	147	167	192	
300	5.4	11.6	18.6							150	166	188	213	243	
350	6.2	13.2	21.0							174	192	216	244	277	
400	7.0	14.8	23.3							215	236	264	296	335	
450	7.8	16.3	25.7							260	283	316	352	397	
500	8.6	17.9	28.0							310	336	372	413	463	
600	10.1	21.0	32.8							421	452	496	546	606	

Comparative Densities:-
Glass Mineral Wool = 16 to 80kg/m^3 , Rock Mineral Wool = 3 to 200kg/m^3 , Rigid Polyurethane Foam = 50kg/m^3, Phenolic Foam = 35 to 60kg/m^3

DIMENSIONAL PIPE DATA

Nominal Size	Material BS1387 Steel BS2871 Copper	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 Mod -ulus	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	406	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

PIPE SOLUTIONS LIMITED CONDITIONS OF BUSINESS

1. THESE CONDITIONS
1.1. These Conditions also apply to the provision of advice or other services by employees of Pipe Solutions Limited
1.2. The Buyer acknowledges that these Conditions exclusively define the relationship and agreement with Pipe Solutions Limited and that they supersede all other agreements and Conditions
1.3. No variation in these Conditions, expressed or implied, shall be accepted by the Pipe Solutions Limited unless expressly agreed in writing and signed by a Director of Pipe Solutions Limited and signed on behalf of the Buyer

2. LIABILITY
2.1. These Conditions limit or exclude the liability of Pipe Solutions Limited to avoid the need for Pipe Solutions Limited to increase the level of it's insurance against the risks so limited or excluded, and thereby to minimise the cost of the Products or Services supplied to the Buyer
2.2. If the Buyer nevertheless requires Pipe Solutions Limited to be responsible for risks or liability which is otherwise limited or excluded by these Conditions, then Pipe Solutions Limited will, at it's option, quote an alternative price for the supply of the Products or Services to reflect the additional cost of obtaining the appropriate additional insurance or other appropriate cover

3. ORDERS
3.1. All orders for the Products made by the Buyer shall be confirmed to Pipe Solutions Limited by the Buyer in writing within 24 hours of being received by Pipe Solutions Limited
3.2. Upon receipt of the Buyer's written order confirmation by Pipe Solutions Limited, a binding Contract for the purchase of the Products comprised in the order shall be concluded
3.3. Any order made by the Buyer is subject to acceptance by Pipe Solutions Limited and a Contract will only be formed when Pipe Solutions Limited has accepted the Buyer's offer to buy
3.4. Records held and procedures adopted by Pipe Solutions Limited in relation to orders placed by the Buyer are prima facie evidence that the Buyer has used or ordered the Product indicated

4. CANCELLATIONAND RETURNS
4.1. The Buyer is not permitted to cancel the Contract, except where previously agreed in writing by a Director of Pipe Solutions Limited
4.2. In the event of cancellation by the Buyer, the Buyer will fully indemnify Pipe Solutions Limited against all expenses incurred up to the time of the cancellation

5. DELIVERY
5.1. The Buyer will accept delivery of the Products by Pipe Solutions Limited or its agents on the date, or within the time period stipulated by Pipe Solutions Limited
5.2. Any time or period for delivery stipulated by Pipe Solutions Limited shall be deemed an estimate only and Pipe Solutions Limited shall not be liable for the costs and consequences of any delay
5.3. Delivery will be made by or on behalf of Pipe Solutions Limited 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 Conditions
5.4. Pipe Solutions Limited shall not be liable for any loss whatsoever or howsoever arising caused by its non-delivery or by failure to make Products available ready for collection on the due date

6. PAYMENT
6.1. Unless otherwise agreed in writing, payment for the Products or Services will be made within 30 days from the invoice date
6.2. Unless otherwise agreed in writing, no payment discount or allowance will be made
6.3. Interest on any overdue account may be charged on a day to day basis at a rate of 6% above the Bank of England base lending rate
6.4. Value Added Tax at the ruling shall be added to the price and shall form part of the purchase price of the Products or Services for the purpose of these Conditions
6.5. If the Buyer fails to make payment in accordance with these Conditions or other written agreement, Pipe Solutions Limited reserves the right to discontinue, defer or suspend the supply of the contracted Products or Services to the Buyer, and to refer the Buyer's information to a debt collection or credit reference agency without notice to the Buyer

7. PRICE
7.1. The Products or Services will be sold to the Buyer at the prices agreed at the time the order is made by the Buyer
7.2. Pipe Solutions Limited reserves the right to increase any fees once each year to reflect changes in the British economy
7.3. Any price quoted by Pipe Solutions Limited or contained in any order or contract shall be valid only for 28 days from the date of such quotation, order or contract

8. PROPERTY
8.1. The Products shall remain the sole and absolute property of Pipe Solutions Limited and title to and legal and equitable ownership of the Products shall not pass to the Buyer until payment is received by Pipe Solutions Limited for all monies due from the Buyer
8.2. The Buyer acknowledges that until payment for the Products is made in full, the Buyer is in possession of the Products solely as a fiduciary for Pipe Solutions Limited
8.3. Without prejudice to any other right or remedies available to it, Pipe Solutions Limited may for the purpose of recovering its Products, and at any time before payment to it of all monies due from the Buyer, enter upon any premises where such Products are stored, or where they are reasonably thought to be stored, and may repossess the Products

9. PRODUCTS
9.1. Where the Products are ordered by reference to any sample, Pipe Solutions Limited shall endeavour to ensure that the Products match the sample
9.2. Pipe Solutions Limited warrants that the Products supplied to the Buyer will be suitable for the primary purpose for which the Products are made and normally used
9.3. No warranty is given or is implied as to the suitability of the Products for any particular purpose or for use under any specific conditions unless such purpose or conditions have been previously agreed in writing by Pipe Solutions Limited
9.4. Other than in relation to personal injury or death, to the extent permitted by law, Pipe Solutions Limited are not liable to the Buyer or anyone claiming through the Buyer for any loss or damage or costs sustained or incurred by the Buyer, it's employees, contractors or agents or any third party, arising in any way in connection with this agreement or from the use of, or the supply of the Products
9.5. To the extent permitted by law, Pipe Solutions Limited exclude, without limiting the above, liability to the Buyer for consequential loss including, without limitation, loss of profits or business

10. CLAIMS
10.1. All claims for loss caused by damage in transit, in storage or on delivery by Pipe Solutions Limited must be notified in writing by the Buyer to Pipe Solutions Limited within three days after receipt of the Products and must within seven days thereafter be supported by a detailed written claim by the Buyer to Pipe Solutions Limited
10.2. All claims for non-delivery, shortages, variances in design, or incorrect specification must be notified to Pipe Solutions Limited by the Buyer in writing no later than three days after the date of delivery
10.3. No claims for shortages, variances in design or incorrect specification shall be accepted in whole or in part by Pipe Solutions Limited if the Products in question have been installed or cut or worked-upon by the Buyer or its employees or agents
10.4. The risk of accidental loss whilst the Products are being returned will be borne by the Buyer

11. OBLIGATIONS
11.1. Pipe Solutions Limited 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 Pipe Solutions Limited.
11.2. Delay or failure includes, but is not limited to, acts or restraints 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
11.3. The obligations of Pipe Solutions Limited may be performed in whole or in part by its authorised distributors, sub-contractors or agents

12. TERMINATION
12.1. Pipe Solutions Limited 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 Pipe Solutions Limited, and have not remedied the same within 10 days of receiving Notice from Pipe Solutions Limited, or if a receiver, provisional liquidator, or administrator or other like person is appointed over any of the Buyer's undertakings or assets or if the Buyer enters into an arrangement with any of it's creditors or becomes insolvent or otherwise is unable to pay it's debts when they fall due

13. ENGLISH LAW
13.1. Any contract incorporating these Conditions shall be interpreted in accordance with the English law and shall be enforceable in the English Courts

14. CONTRACT ASSIGNMENT
14.1. Any contract incorporating these Conditions may not be assigned by the Buyer without the prior written consent of Pipe Solutions Limited

15. RESERVED RIGHTS
15.1. Pipe Solutions Limited reserve the right to obtain credit information from a credit reporting agency and information about the Buyer's commercial activities or commercial credit worthiness from a business which provides that information, to enable Pipe Solutions Limited to apply a credit policy
15.2. Pipe Solutions Limited reserve the right to use any company or organisation that provides invoice discounting or credit factoring services
15.3. Pipe Solutions Limited reserve the right to suspend the Buyer's access to Products or Services if there is reasonable cause to do so, or as a result of a direction from any government or other authority

16. PRODUCT USE
16.1. The Buyer will agree that the Products will be used as designated by Pipe Solutions Limited and in accordance with any current standard or code of practice
16.2. Pipe Solutions Limited may advise the Buyer from time to time, but does not carry responsibility for the installation or implementation of the advice given
16.3. The Buyer will not, nor will allow others to engage in any activity that is in breach of, or fail to comply with, any applicable law, rule, regulation, standard or code of practice
16.4. The Buyer must, at no cost to Pipe Solutions Limited, ensure full, free and safe access to our Products in order for us to inspect the same
16.5. The Buyer must provide Pipe Solutions Limited with information that is required in relation to the supply of the Products
16.6. The Buyer is solely responsible for the use of the Products and for all payment of fees arising from the use or provision of the Products whether or not the user had the Buyer's authority
16.7. Pipe Solutions Limited reserves the right to have any Product fully tested and examined following a reported failure

17. EXEMPTION FROM LIABILITY
17.1. In making these Conditions Pipe Solutions Limited does so for itself and for and on behalf of every employee, sub-contractor or agent of Pipe Solutions Limited and the Buyer hereby confirms that any exemption from liability granted to Pipe Solutions Limited by these Conditions shall also extend to any such employee, sub-contractor or agent of Pipe Solutions Limited

18. NOTICE
18.1. Any Notice sent under a contract incorporating these Conditions shall be sent to the registered office of Pipe Solutions Limited 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

PIPE SOLUTIONS LTD PROVIDE THE ENGINEER WITH:

Impartial Technical Help

CPD Technical Training Courses

Site Attendance - Surveys and Sign-offs

Technical Reports and Submittals

Prompt Proposals and Quotations

Help with Specification Clauses

Product Data Sheets and Catalogue

Detailed Installation Instructions

Operating & Maintenance Instructions

Web Site for Information Downloads

Quality Management System

TECHNICAL REFERENCE GUIDES COVER:

Vibration and Noise Control

De-aeration and Dirt Removal

Thermal Pipe Expansion

(all publications are available on CD ROM or from our Website)

Pipe Solutions Ltd., Head Office, Hornbeam Park Oval, Harrogate, HG2 8RB
Tel:01423-878888 Fax:01423-878880 Email:sales@pipesolutions.co.uk
Website:www.pipesolutions.co.uk