PRESSURE THRUST

INTRODUCTION - Pressure thrust is a natural result of using an **UNRESTRAINED** expansion joint. When this type of joint is used properly, it is the most flexible, cheapest and easiest type of joint to use. However, extra engineering time and construction cost must be expended in the design and construction of the pipe line. If the joint is not properly engineered, a major failure could occur. Table 1 provides the pressure thrust force that will be developed at various sizes and pressures.

Nom Pipe Size (in)	Pipe ID Area (in^2)	Pressure Thrust (P_t)			
		15 Lb (lbs)	150 Lb (Lbs)	300 Lb (Lbs)	450 Lb (Lbs)
1	.86	13	130	260	389
2	3.36	50	503	1,007	1,510
4	12.7	191	1,910	3,819	5,729
6	28.9	433	4,333	8,667	13,000
8	50.0	750	7,504	15,008	22,512
10	78.8	1,183	11,828	23,656	35,484
12	113	1,696	16,964	33,929	50,894
16	183	2,740	27,398	54,796	82,194
20	291	4,366	43,656	87,312	130,968
24	425	6,368	63,684	127,367	191,051
32	767	11,505	115,049	230,097	345,146
36	976	14,639	146,386	292,772	439,158
48	1753	26,302	263,018	526,035	789,053
60	2757	41,358	413,578	827,157	…

PRESSURE THRUST vs DIAMETER
Table 1

NOMENCLATURE

A_{eff}......... Bellows effective area, in^2.
P_t .... Longitudinal pressure thrust force due to pressure, lb.
ID_{pip}....... Pipe inside diameter, in.
P .... Design pressure of the line, psi
P_c........... Force required to compress or extend the bellows element plus any additional friction forces due to guides etc, lbs.
R_{pip} .... Pipe radius, in.
t_{pip}.......... Pipe wall thickness, in.
α_C.......... Circumferential stress due to pressure, psi.
α_L.......... Longitudinal stress due to pressure, lb.

DISCUSSION - In order to explain pressure thrust and it's effects, it is first necessary to understand the relationship between pressure and force. When pressure is applied to a closed container, the pressure will act against all surfaces to develop a force on that surface. This concept can be illustrated by imagining a tin can being pressurized, see figure 1. It is easy to see that as the pressure is increased, the can will begin to bulge in the middle and also at the ends.

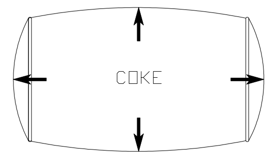
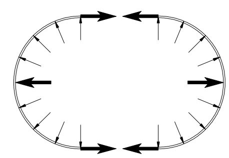


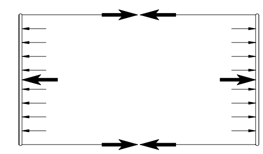
Fig. 1

The reason for the bulging can be explained by taking a section through the tin can, see Figure 2 & 3. The pressure will react against the wall of the tin can radially and also at the ends.



HOOPS STRESS
Fig. 2

$$\alpha_C = \frac{P \cdot R}{t}$$



LONGITUDINAL STRESS
Fig. 3

$$\alpha_L = \frac{P \cdot R}{2 \cdot t}$$

The general formulas for each of the resulting stresses are provided under the appropriate figure. It is seen that the longitudinal stress (α_L) will generally be one half of the circumferential stress. For this reason, the longitudinal stress is often over looked. Normally all loads cancel each other.

When an **UNRESTRAINED** expansion joint is introduced into the system, it is similar to introducing a spring into the tin can, see figure 4.

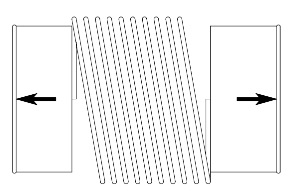


Fig. 4

The pressure thrust force (P_c) acting at the ends of the can will not be restrained by the spring. The spring will start to spread apart until it is pulled completely apart, see figure 5.

Piping Solutions Group:
P.O. Box 10
Pine Valley, Ca. 91962
(619) 473-8248

Senior Operations LLC, Pathway Div:
2400 Longhorn Industrial Dr
New Braunfals, Texas 37830
(830) 629-8080

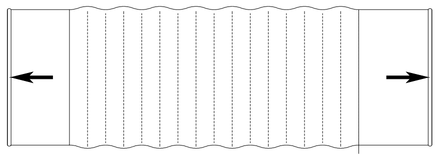


Fig. 5

In order to prevent this from happening a main anchor strong enough to hold the line together must be installed on both ends of the expansion joint, see figure 6.

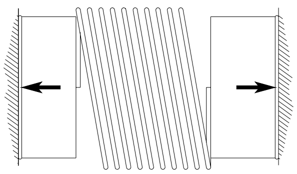


Fig. 6

In a piping system, see Figure 7, the pressure thrust will develop at the elbows and be transmitted down the pipe line in tension and cancel with the equal and opposite pressure thrust. However, when an **UNRESTRAINED** expansion joint is used, most of the pressure thrust develops at the elbows or operating equipment and can not be transmitted down the pipe and must be restrained by anchors, see figure 8.

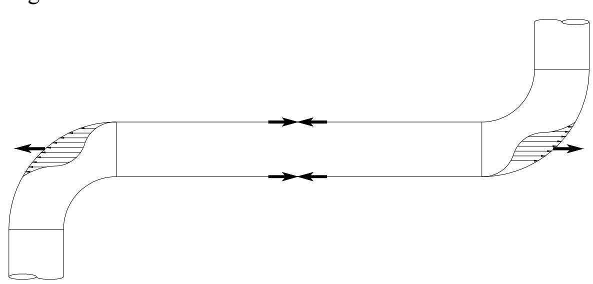


Fig. 7

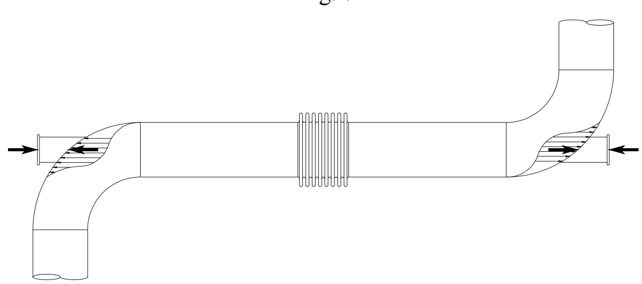


Fig. 8

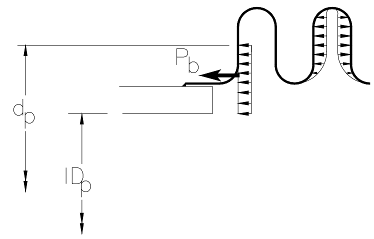


Fig 9.

Also, a very small amount of the force will develop at the bellows itself, see figure 9, and be transmitted down the pipe in compression. For this reason, pipelines with **UNRESTRAINED** expansion joints operate in compression instead of tension and require additional guiding for compression stability. The standards of EJMA contain guidelines for guiding **UNRESTRAINED** expansion joints. The actual compressive pressure thrust force created by a bellows may be calculated by:

$$P_b = P \bullet \pi \bullet (d_p^2 - ID_{pip}^2) / 4$$

CONCLUSION - When using **UNRESTRAINED** expansion joints, the main thrust anchors should be designed for a pressure thrust force equal to:

$$A_{eff} = d_p^2 \bullet / 4$$
$$P_o = P \bullet A_{eff} + P_c$$

The pipeline will be operating under a compressive (tension for vacuum) force equal to:

$$P_b = P \bullet \pi \bullet (d_p^2 - ID_{pip}^2) / 4$$

The pipeline should be guided in accordance with the EJMA standards.

This discussion has dealt only with **UNRESTRAINED** expansion joints, this type of joint can deflect in any direction (axial, lateral, angular or torsional). They also have no hardware to transmit the pressure thrust or system dead weights. There are a number of joints which can restrain pressure thrust such as tied, hinge, gimbaled, etc. but when the hardware is added, a degree of freedom is also eliminated. The standards of EJMA contain a detailed discussion of the various styles of expansion joints and their application and is recommended reading.

Piping Solutions Group:
P.O. Box 10
Pine Valley, Ca. 91962
(619) 473-8248

Senior Operations LLC, Pathway Div:
2400 Longhorn Industrial Dr
New Braunfals, Texas 37830
(830) 629-8080