# PRESSURE THRUST

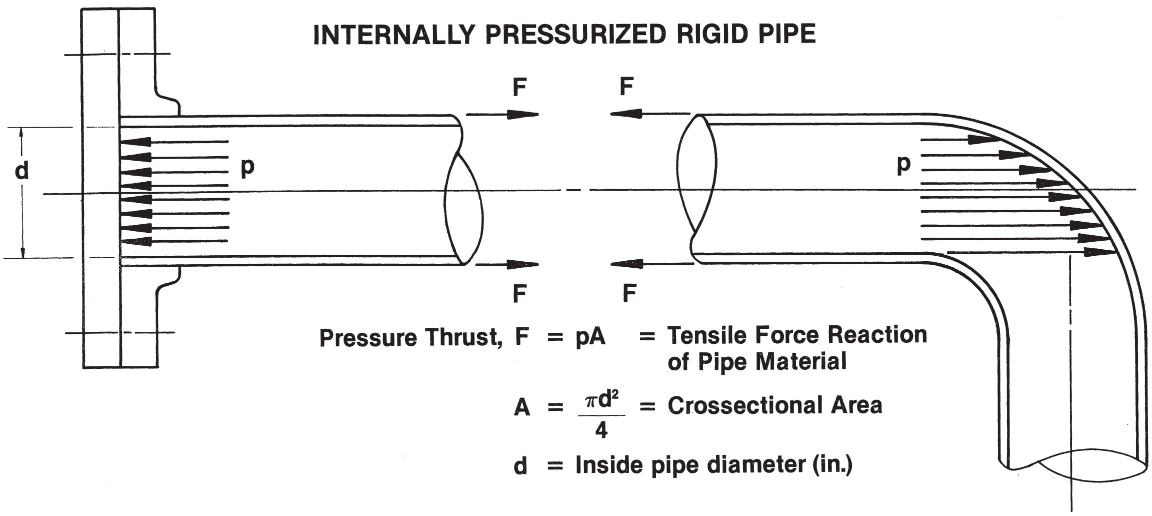
The relationship of pressure (p), force (F), and area (A) is one of the most fundamental equations of physics:

$$F\ (\text{lbs.}) = p\ (\text{psig}) \times A\ (\text{in}^2)$$

When the force is pressure thrust, it becomes the most important characteristic governing the application of expansion joints — metal bellows, packed slip and non-metallic types. In spite of the importance of pressure thrust, it is often misunderstood and difficult to explain. Pressure thrust influences the basic design of the system, i.e., anchored and guided or floating. Additionally, it is the determining factor in the detail design of restrained joints tie rod, gimbal, and hinge hardware must be designed to react the pressure thrust which is significant and a major cost factor.

Pressure thrust is a force equal to the media pressure times the effective crossectional area for internally pressurized systems, or atmospheric pressure (15 psi) times the effective area for internal vacuum. All pipes or ducts with or without expansion joints have pressure thrust which is reacted at each end by anchors such as thrust blocks or rigid equipment, or this reaction is provided by a longitudinal force in the pipe material. Suspended piping such as water lines or sprinkler systems react pressure thrust in this manner.

**INTERNALLY PRESSURIZED RIGID PIPE**



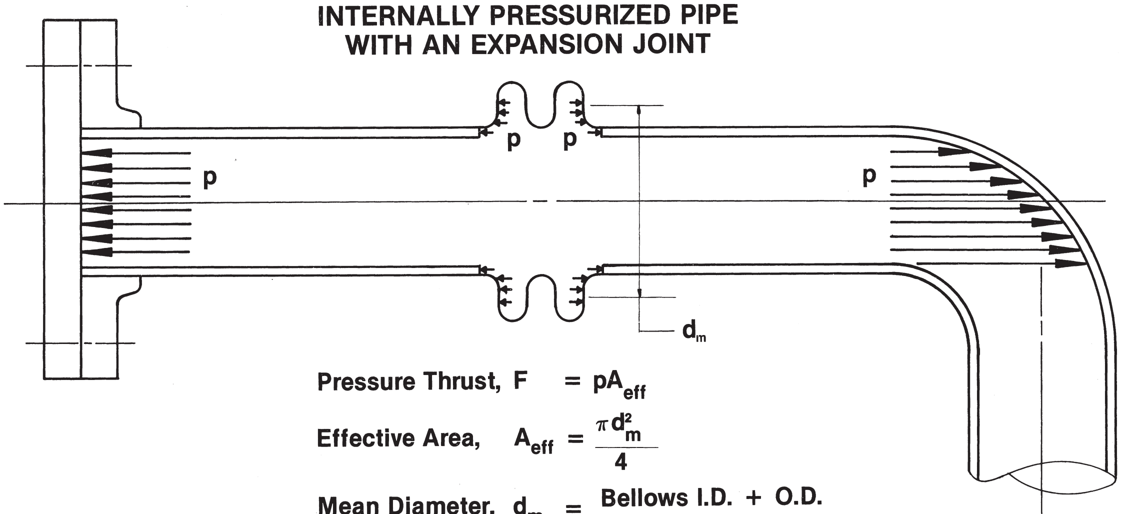

Pressure Thrust, $F = pA$ = Tensile Force Reaction of Pipe Material

$A = \dfrac{\pi d^2}{4}$ = Crossectional Area

$d$ = Inside pipe diameter (in.)

When an unrestrained expansion joint is introduced into the system, this is equivalent to cutting the pipe because the inherent flexibility of the expansion joint bellows makes it unable to transmit the force in the pipe. In addition, the crosssectional area is increased due to the depth of the bellows convolutions.

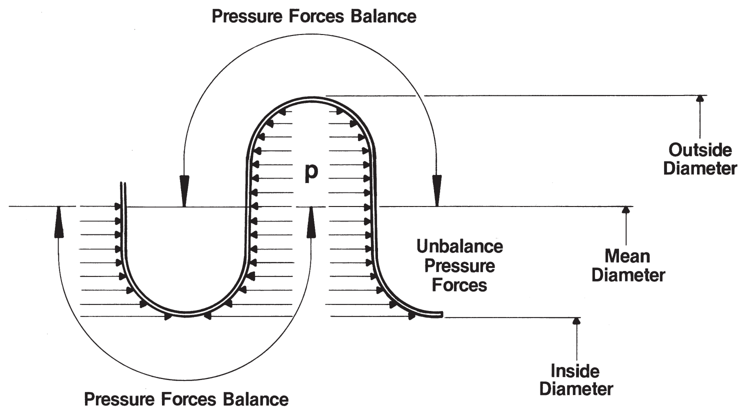
**INTERNALLY PRESSURIZED PIPE WITH AN EXPANSION JOINT**




Pressure Thrust, $F = pA_{eff}$

Effective Area, $A_{eff} = \dfrac{\pi d_m^2}{4}$

Mean Diameter, $d_m = \dfrac{\text{Bellows I.D.} + \text{O.D.}}{2}$

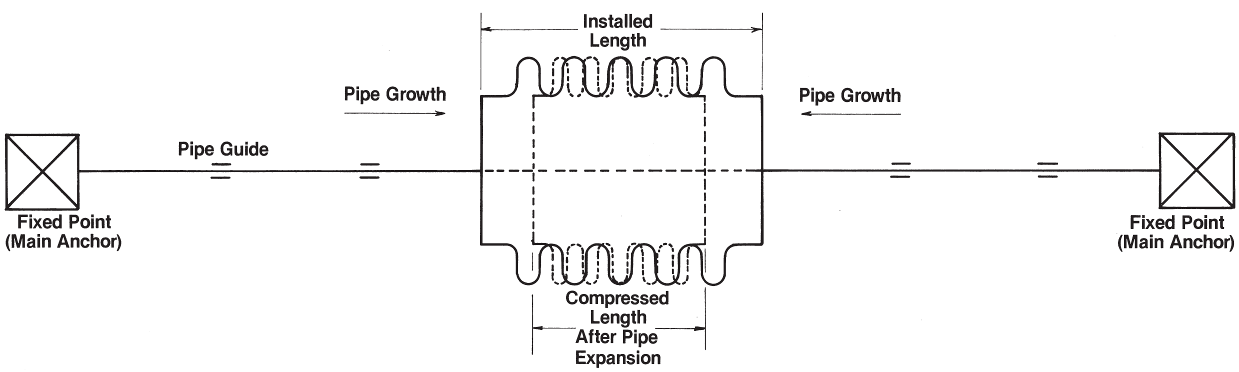



The mean diameter of the bellows determines the effective area for pressure thrust because the other forces created by pressure within the bellows are balanced out as illustrated in this diagram of the crossection of a convolution.

Technically, the effective area is based on the wetted area or surface in contact with the pressurized media. This area will be slightly different from the calculation illustrated because of the material thickness and method of attaching the bellows to the adjoining hardware. This calculation is sufficiently accurate for most applications since the material is very thin relative to the diameters. There are examples such as rubber expansion joints which have thick walls where the actual area should be used.

Metal bellows offer some restraint to pressure thrust as a result of the spring force. However, this reaction is relatively small. For example, a 6″ NPS, 150 psi expansion joint rated for 3″ axial (Hyspan P/N 1501-160-3.0) has an effective area of 33.3 in.$^2$ which results in a pressure thrust of 4995 lbs. at 150 psig. Since the axial spring rate is 348 lb./in., it would require 14.35″ of extension to balance the pressure thrust. This, of course far exceeds the rated travel and would result in destruction of the joint.

Unrestrained expansion joints must be used in anchored and guided systems which require anchors at each end of a pipe run that are sufficient to react the pressure thrust at the highest pressure anticipated. These fixed points insure that the pipe grows (or contracts) and compresses (or extends) the expansion joint. The guides insure that the motion is axial only.




The main anchors also must be designed to react the force resulting from the deflection of the bellows. However, this force is relatively small. From the earlier example of the 6″ NPS, this force is 1044 lbs. at 3″ axial compression (348 lbs./in. × 3″) compared to 4995 lbs. at 150 psig, or 7495 lbs. at 225 psig test pressure. "Main Anchor" refers to an anchor that reacts pressure thrust and spring forces combined. "Intermediate Anchor" refers to anchor reacting bellows spring force only.

One of the most common "don'ts" in piping design is to attempt to substitute tie rods on expansion joints for main anchors. Although the rods will protect the expansion joint, they defeat the purpose of the joint. when a tied joint is pressurized in an unanchored system, it will expand until the rods restrain the pressure thrust. The force to compress it must exceed the pressure thrust and bellows spring force. Without anchors the pipe will grow away from the expansion joint instead of actuating it. In general, tie rods are used for joints that deflect laterally only, are used for flexibility only such as pump connection applications, or used as "limit rods" to prevent overtravel of the bellows.