Quick Check on Piping Flexibility

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VISUAL CHECK

The visual check is the first important examination on anything we do. If the design looks strange, then most likely something is wrong with it. By now we at least know that we can not run a piping straight from one point to another. This also applies to the situation when there are two or more line stops installed at a straight header as shown in Figure 5. The line stop or axial stop acts directly against the expansion of the pipe. When two axial stops installed on the same straight leg, the thermal expansion of the pipe located between the stops has no place to relieve.

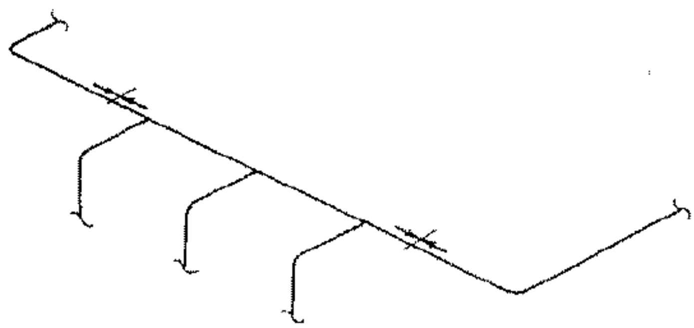


Figure 5

The visual check of the piping flexibility is to look for the pipe legs located in the direction perpendicular to the line connecting the two anchor or other restraint points. The length of the leg is the direct measure of the flexibility. Therefore, the key is to locate the availability of the perpendicular leg and to determine if the length of the leg is sufficient. The required leg length can be estimated by the rule of thumb equation (1) derived by the guided cantilever approach, for steel pipes.

$$\ell = 5.5\sqrt{D\Delta} \qquad (1)$$

where,

ℓ = leg length required, ft
D = pipe outside diameter, in
Δ = expansion to be absorbed, in

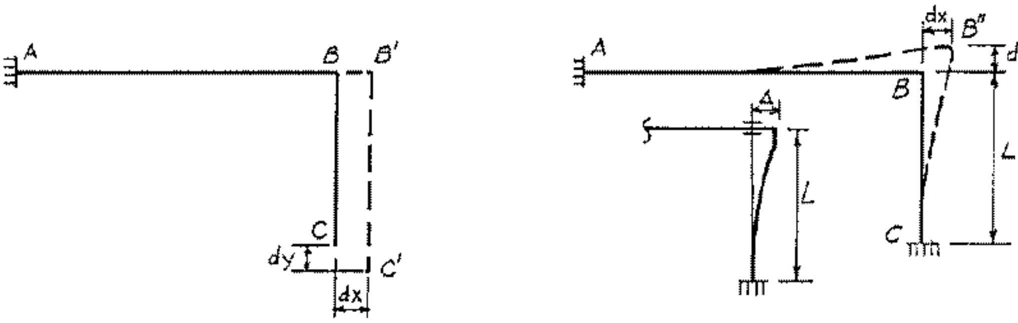
To use Equation (1) efficiently the expansion rate of the pipe has to be remembered. Table 1 shows the expansion rates of carbon and stainless steel pipes at several operating temperatures. The rate at other temperature can be estimated by proportion. By combining Equation 1 and Table 1, the designer can estimate the leg length required without needing a pencil. For instance, an 80 feet long 6-inch carbon steel pipe operating at 600F expands about 4 inches which requires a 30 feet leg to absorb it. It should be noted that an expansion loop is considered as two legs with each leg absorbs one half of the total expansion.

Table 1

		Expansion Rate, in/100 ft pipe				
	Temp,F	70	300	500	800	1000
Carbon Steel		0	1.82	3.62	6.7	8.9
Stainless Steel		0	2.61	5.01	8.8	11.5

HAND CALCULATION

There are several simplified calculations can be performed quickly with hand. The most popular one is the so called guided cantilever approach. The method can be explained using the L-bend given in Figure 6 as an example. When the system is not constrained the



(a) Free Expansion (b) Constrained Expansion

Figure 6

points B and C will move to B' and C' respectively due to thermal expansion. The end point C moves dx and dy respectively in X- and Y- directions, but no internal force or stress will be generated. However, in the actual case the ends of the piping are always constrained as shown in Figure 6(b). This is equivalent in moving the free expanded end C' back to the original point C forcing the point B to move to B". The dx is the expansion from leg AB, and dy from leg CB. The deformation of each leg can be assumed to follow the guided cantilever shape. This is conservative because the end rotation is ignored. The force and stress of each leg can now be estimated by the guided cantilever formula. The leg AB is a guided cantilever subject to dy displacement and leg CB a guided cantilever subject to dx displacement respectively.

From the basic beam theory, the moment and displacement relation of a guided cantilever is

$$M = \frac{6\,E\,I}{L^2}\Delta, \qquad F = \frac{2\,M}{L} \tag{2}$$

For thin wall pipes, Equation (2) can be further reduced. By using $I=\pi r^3 t$ and $S=M/(\pi r^2 t)$, the above equation becomes

$$S = \frac{6\,E\,r}{L^2}\Delta = \frac{E\,D\,\Delta}{48\,\ell^2} \tag{3}$$

where, S = thermal expansion stress, psi
E = modulus of elasticity, psi
r = mean radius of the pipe, in
Δ = total expansion to be absorbed, in
L = length of the leg perpendicular to , in
ℓ = length in feet unit, ft
D = outside diameter of the pipe, in

Equation (3) is a convenient formula for the quick estimation of the expansion stress. By pre-setting E=29.0x10 psi and S=20000 psi, Equation (3) becomes Equation (1) used in finding the leg length required for steel pipes.

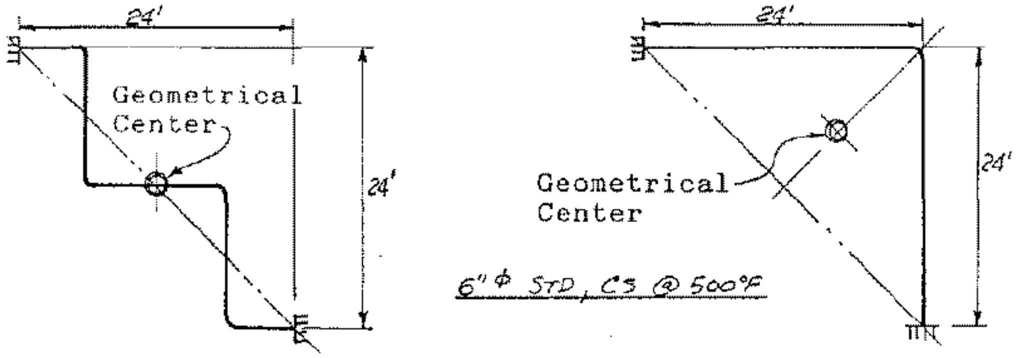
The other formula can be used for the quick check is the one given in ANSI B31 Piping Codes. The Code uses Equation (4) as a measure of adequate flexibility, subjects to other requirements of the Code.

$$\frac{D\,y}{(L-U)^2} < 0.03 \tag{4}$$

where, D = outside diameter of the pipe, in
y = resultant of total displacement to be absorbed, in
L = developed length of piping between anchors, ft
U = straight line distance between anchors, ft

Equation (4) is actually equivalent to Equation (1), if (L-U) is considered as the perpendicular leg length.

Equation (4) has to be used with great care, because the same extra length of pipe can have very diferent effects depending on the ways the pipe is laid-out. Normally more flexibility will be achieved if the pipe is placed farther away from the elastical or geometrical center. For instance with the same extra length of piping, when it is laid-out as shown in Figure 7 (a) it has much higher flexibility than when it is laid-out as in Figure 7 (b). Designers often have the misconception about the amount of flexibility can be provided by the zig-zag arrangement. Due to the extra elbows placed in the layout, one tends to think that additional flexibility should have been created. Unfortunately, the additional flexibility from the elbows is not enough to compensate the loss of flexibility due to the placement of pipe toward the geometrical center.



(a) Stress = 13764 psi (b) Stress = 8226 psi

Figure 7

MICRO COMPUTER APPROACH

Currently most large engineering companies use CAD system to do the piping design. It is possible that one day the system will be able to tell you if you need any extra flexibility, as soon as you place the line on the screen. However, before that time comes, we still have to survive the current situation to be able to see the good thing coming. Nevertheless, the technology of the micro computer has advanced enough for us to perform accurate flexibility analyses right beside the drafting board.

The micro computer programs are normally so user friendly that it takes only a couple of hours to master their usage. With respect to the flexibility check, a piping designer can do almost as good a job as a stress engineer can. What it is needed is to enter the pipe and geometrical information to the program which will almost instantly give you the forces and stresses expected in the system. From that information, the designer can then decide if additional loops or offsets are required.

The use of the micro computer differs substantially depending on the individual program setup. Each program has its preferred method of entering the data and generating the output. Appendix A shows the sample operating procedure using PENG.QFLEX program to analyze the simple system given in Figure 8.

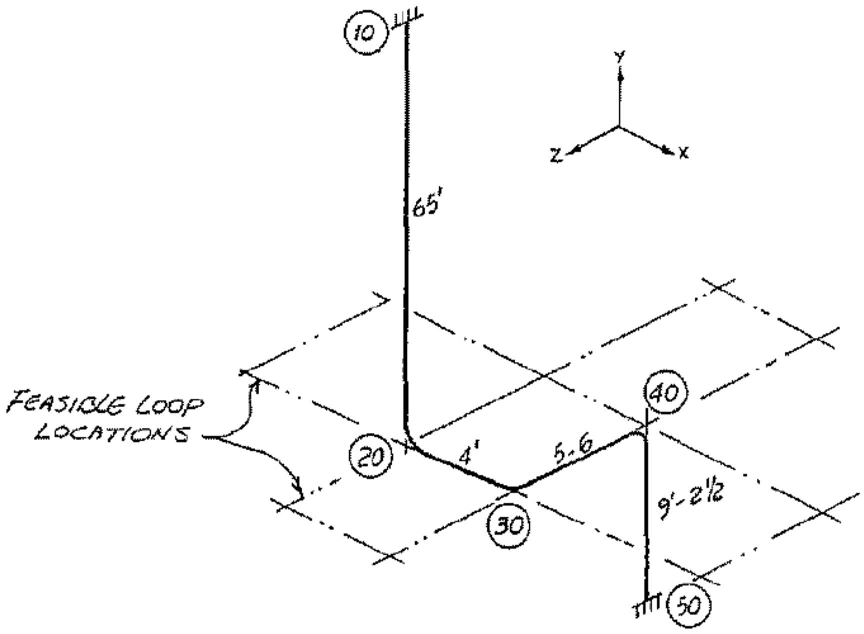


Figure 8

Once it is determined that an expansion loop is required, the loop can be placed at one of the feasible locations before the area is congested by other layouts. This also saves the iterative process between the piping designers and the stress engineers.

CONCLUSION

The traditional piping design procedure depends heavily on the stress engineer to check piping flexibility. With the availability of quick methods in checking the flexibility, the designer can now layout the pipe to provide the proper flexibility at the very beginning. This substantially reduces the number of iterations required between the piping designer and the stress engineer. The cost of the plant can be reduced by the shorter schedule and less manpower required.