## Thrust Restraint Design of Vertical Offsets and Tees

There are numerous fitting combinations and configurations that are used in the everyday construction of pressurized water lines. This report describes vertical offsets, tees, and using joint restraint products to simplify their installation. The use of joint restraint products virtually eliminates thrust blocks and tie rods.

### Vertical Offsets

The installation of vertical offsets is very common in the laying of underground water lines. Very often, these offsets are required to go around non-removable obstructions. Some obstructions for example, are gravity ravine crossings, sewer and drainage lines, or other utilities difficult to relocate. It is usually a simple matter in laying a new pressure line to go up and over or down and under the obstruction.

Let's evaluate the offset by breaking it into its two components, a vertical down-bend (on the high side of the offset) and a vertical up-bend (on the low side of the offset). With a horizontal bend, we learned that soil provides frictional resistance and passive bearing resistance to contain the forces involved in a change of direction of a pipeline. Since the resultant thrust force at a vertical up-bend is directed toward a "trench wall", or the bottom of the trench, both frictional and bearing resistance forces interact with the pipeline to counteract the thrust forces. Therefore, the thrust restraint equation for this bend is the same as that for the horizontal bend.

$$L = S_f \bullet P \bullet A \bullet \tan(\theta/2) / F_S + R_S / 2$$

Where:

| | | | |
|---|---|---|---|
| | $L$ | = | length of pipe restrained, ft |
| | $S_f$ | = | safety factor |
| | $P$ | = | test pressure of the line, PSI |
| | $A$ | = | cross sectional area of the pipe, sq. in. |
| | $\theta$ | = | bend angle, degrees |
| | $F_S$ | = | frictional resistance of the soil, lbs/ft |
| | $R_S$ | = | passive bearing resistance of the soil, lbs/ft |

The vertical down-bend, however, has a force that is directed toward the top of the trench where there is not a sufficient amount of support from the surrounding soil to provide any significant bearing resistance. Only frictional resistance comes into play at this bend.

The thrust restraint equation for the vertical down-bend is:

$$L = S_f \bullet P \bullet A \bullet \tan(\theta/2) / F_S$$

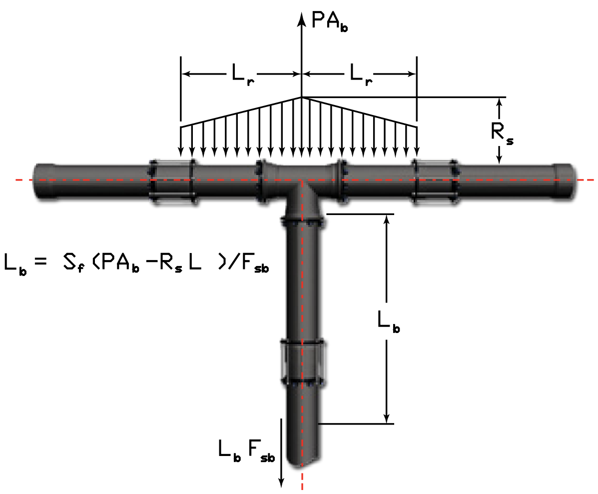
When an offset is required, restrained length calculations are made on the fittings individually. In most cases, the restrained lengths between the upper and lower bends will overlap. This should not cause concern. As an example, let us look at a twelve inch line that requires lowering of four feet to route around an existing storm sewer. The calculated restrained length for the upper bend is twenty-one feet and five feet for the lower bend. Since 45 degree bends are used, it is determined that the distance between the bends is almost six feet.

If a single piece of pipe is used between the bends, the requirement for "no unrestrained joints within the calculated length" is easily met on both sides of the lower fitting. The length requirement of twenty-one feet for the upper bend will necessitate some additional restraint along the upper horizontal pipe length. This requirement is usually met by the restraining of only one additional joint. One might deduce that the line is restrained for twenty-one feet on the lower side of the bend as well. This length would include the six feet from bend to bend and the restrained length requirement of five feet for the lower bend. This is not the case in this installation. Since all of the joints between the two bends are restrained, there is no component force directed toward the upper bend. The restrained length requirements, therefore, are met without restraining fifteen feet past the lower bend. For this installation only five joint restraint products are required. There are two at each bend and one more on the horizontal line at the upper fitting.

Naturally, if the distance between the fittings is greater than the calculated length of both of the fittings, then the appropriate lengths of pipe need restraint. One way to reduce the restrained length requirements of horizontal or vertical bends is to use fittings with smaller bend angles. By changing to 22.5 degree bends in the example above, the upper restrained length is reduced from twenty-one feet to ten feet. The lower bend restrained length is reduced from five feet to three feet. The distance between the bends increases from six to ten feet.

## Tees

Tees also require two restrained lengths. The first is the length along each side of the run of the tee that is restrained, $L_r$. The second is the length along the branch that is restrained, $L_b$.




Unless there are bends in close proximity to the tee, there are no forces along the run of the pipeline that would try to separate the joints of the tee. As stated in an earlier article, the forces along a straight run of pipe are equal, opposite, and cancel out. The separating force comes from the branch and compares to that of a dead end. Since the branch effectively "dead ends" at the tee, the thrust force acts in that direction and has a magnitude that is equal to the internal pressure multiplied by the cross sectional area of the branch.

In a restrained joint system, the force at the tee is balanced by the soil in two areas. The first is the area of the pipe that is behind the tee. This is the area in which a thrust block is normally poured. The restrained length of pipe, $L_r$, along the run of the tee and on each side of the tee encounters passive bearing resistance from the soil that acts perpendicularly to the tee. The restrained length along the branch of the tee connection, $L_b$, provides frictional resistance that involves the entire circumference of the branch piping.

The actual pipe lengths that are installed at the branch of a tee in the field are generally not known while the system is designed. Therefore, a minimum restrained length, $L_r$, is specified during the design process so that the restrained length, $L_b$, is calculable. An $L_r$ of ten feet is used for most calculations. With larger pipe sizes, that also involve large diameter branches, the calculated $L_b$ is very long. In these cases, the use of an $L_r$ of twenty feet will reduce $L_b$. Conversely, in some branch reducing tees where the run size is much greater than the branch, shorter lengths of $L_r$ are used. It is possibly unnecessary to restrain the run joints of the tee. The restrained length requirement for the branch is determined by the following equation:

$$L_b = S_f \bullet (P \bullet A_b - R_s \bullet L_f)/F_{sb}$$

Where:

| | | | |
|---|---|---|---|
| Where: | $L_b$ | = | length along tee branch restrained, ft. |
| | $L_r$ | = | length restrained on each side of the run of the tee, ft. |
| | $A_b$ | = | cross sectional area of the branch pipe, sq. in. |
| | $R_s$ | = | passive bearing resistance for the run, lbs/ft. |
| | $F_{sb}$ | = | frictional resistance for the branch, lbs/ft. |

## Hydrant Leads

This discussion leads to a special pipeline application that involves tees, which is the application of hydrant leads. The use of joint restraint products greatly simplifies the installation of hydrant leads. Typically, the length of the pipe between the branch of a tee and a hydrant is relatively small. As a result, all joints from the tee to the hydrant are restrained. This includes any valves or other appurtenances that are involved. By restraining all of the joints along the branch, all of the thrust forces are eliminated, therefore, a restrained length calculation for the tee is not required. In this case, the only reason to restrain the joints on the run of the tee is if they lie within the restrained length requirements of a nearby fitting. By implementing joint restraint products in the design, it is now possible to simply install the hydrant lead, support and bed the hydrant in accordance with the hydrant manufacturer's recommendations, and open the valve to charge the hydrant. By liberating the installation from concrete thrust blocks, the hydrant installation is completed and the hydrant is placed into service quickly. Also, hydrant weep holes are no longer filled with concrete and are able to drain freely.

## Summary

The complications usually involved with restraining vertical down-bends with thrust blocks is easily eliminated with a properly designed, restrained pipeline. This enables the construction of a pipeline to flow more smoothly. Also, the installation of tees, and especially hydrant laterals, becomes very simple and straight forward with the use of joint restraint products. Add to that the field adaptability and high pressure capacity of the Megalug restraint, and you have a system that gives you reliable performance and simple installation.

Reference


Ductile Iron Pipe Thrust Restraint Design Handbook, EBAA Iron Sales, Inc., 1993.



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