

27. Thrust Restraint Design for Buried Piping.

a. General.

- 1) This section presents the design methodology to be used when providing thrust restraint for buried pressurized piping. It includes guidelines for the design of thrust blocking using the standard details and special design requirements for non-standard thrust blocks and restrained joint pipe.
- 2) For pipe sizes larger than 24-inch, consider the cost of using one of the approved restrained joints or providing concrete thrust blocking to restrain the pipe or fitting. If the cost is approximately equal, design for concrete thrust blocks and if the restrained joints are considerably less expensive, then design for restrained joints unless otherwise directed.
- 3) In a pressurized buried pipeline such as a water main or sewage force main, thrust forces act on the pipe where changes in fluid velocity, changes in pipe size or changes in pipeline direction occur. This is generally at fittings such as plugs, caps, valves, tees, bends or reducers.
- 4) Thrust forces may also occur at the locations where new pipe is connected in-line to a different type of existing pipe with different sealing diameters. A significant example of this is the connection of large diameter Prestressed Concrete Cylinder Pipe (PCCP) and Ductile Iron Pipe (DIP). A thrust force is created at this type of connection in the same manner as a reducer, see Unbalanced Thrust at Connections to Existing Water Pipelines, in this section.

b. General Requirements for Concrete Thrust Blocks.

- 1) Always consider the thrust forces in the design of buried pressurized pipelines, since it may cause separation of the joints and leakage of the pipeline. The most fundamental approach to resist a thrust force is to install a non-reinforced poured-in-place concrete block at the fitting.
- 2) The basic type of non-reinforced concrete block used for bends, tees, plugs and caps is referred to here as a concrete thrust block, but may also be referred to as an anchorage or buttress.
- 3) When concrete thrust blocks are used for fittings in close proximity to each other, ensure that no part of the blocks overlap and that the passive pressure soil zones do not overlap which could cause construction problems or block failure. See Passive Soil Pressure for Concrete Thrust Blocks, in this section.
- 4) Locate the thrust block such that its passive pressure zone of influence does not affect other utilities or structures.
- 5) Provide a minimum soil cover of one (1) foot over all thrust blocks. For thrust blocks in existing or proposed roads or road rights of way, provide a minimum one and one half (1-1/2) feet of soil cover, unless otherwise directed or approved.

c. Standard Design for Concrete Thrust Blocks.

- 1) Thrust blocks for pipelines 16-inch and smaller.
 - a) The dimensions and design details for concrete thrust blocks for pipe sizes 16-inch and smaller diameter are provided in the Standard Details. As long as the conditions which are specified in the notes on the blocking standard details are met for the particular application, then the



standard detail applies and can be simply referenced on the contract drawings. If any of the conditions on the standard detail cannot be met, then special design blocking is required as indicated below. Also, see Part Three, Section 6, Modifications to Specifications and Standard Details.

- b) If the design pressure for the project is significantly less than the design pressure used for the standard detail blocking, such as for low pressure treatment plant process piping, sewage force mains, etc., then evaluate the economics of downsizing the standard detail blocking accordingly, depending on the number of blocks required, design costs, etc. If the design requires the standard details to be modified, see the requirements for Special Design Concrete Thrust Blocks indicated below.

2) Soil investigation requirements for the use of standard design blocking.

- a) A soil boring is generally required near the proposed thrust block location, see Part Three, Section 20, Geotechnical and Corrosion Submittals, for soil boring location requirements. Use the information on the boring logs to confirm items b) and c) below, prior to using the blocking standard details.
- b) Elevation of groundwater table must be below the bottom of the block for upper vertical bends or the invert of the pipe for all other blocks. If the actual groundwater table is higher than the above, then evaluate the standard block size for submerged conditions and note that a special design block may be required.
- c) The soil at the proposed thrust block location and elevation shall not be soft with standard penetration test blow count (N) equal to or less than four (4), nor shall the soil be organic. If these conditions exist, then special design blocking is required. Other alternatives such as replacing the in-situ soil with structural fill within the zone of influence of the thrust block or restraining the pipe instead of using a block may also be considered.

d. Special Design for Concrete Thrust Blocks.

- 1) Pipe larger than 16-inch diameter and other cases not covered by the Standard Details. Special design blocking is required according to the guidelines in this section. Submit special design calculations, which are signed and sealed by a State of Maryland registered professional engineer, for each special design along with the drawings (plan and profile). In general, the special design dimensions can be called out on the drawings for the variable dimensions shown on the standard details without providing a detail of the block on the drawings. For information on changing specifications and standard details, see Part Three, Section 6 (Modifications to Specifications and Standard Details).
- 2) Guidelines for special design blocking are as follows:
 - a) Soil investigation requirements for special design blocking.
 - (1) Soil boring is required at or near the proposed location of the special design thrust block. Extend the soil boring below the invert of the pipe at least ten (10) feet, or to the estimated base elevation of the thrust block, whichever is greater.



- (2) Perform Standard Penetration Tests (SPT) at two and one half (2.5) foot intervals for the upper ten (10) feet of the boring and then every five (5) feet thereafter. If cohesive soils are encountered, obtain undisturbed samples near the springline of the pipe. Perform confined compression strength and Atterberg limit tests on the samples.
- (3) The soil boring along with the laboratory tests shall provide sufficient information to determine the following:
 - (a) Classification of soils in accordance with the Unified Soil Classification System (ASTM D 2487).
 - (b) Field density from SPT and shear strength from unconfined compression tests or SPT.
 - (c) Coefficients of lateral earth pressure.
 - (d) Groundwater level, at completion and at twenty four (24) hours after the completion of the boring and removal of the augers and any casings.
- b) Block configuration. Thrust blocks shall generally be configured similar to those shown in the standard details. A rectangular shaped front face shall be used for the blocks for horizontal bends, reducers, tees, plugs and caps if possible. The reasonable range of depth to width ratio for the rectangular face shall be between 1 and 3.
- c) Internal design pressure.
 - (1) Water pipelines. Compute the total internal design pressure used for blocking design according to Part One, Section 5 (Total Internal and Transient Pressures). Generally, the thrust restraint is designed for the total pressure. Under some special circumstances, the necessary test pressure may be lower or higher than this total pressure. Consult WSSC as to which pressure is to be used for the thrust restraint design.
 - (2) Pipelines other than water pipelines. Determine the total internal design and test pressure for pipelines other than water pipelines, such as sewage force mains, treatment plant pressure piping, etc., and use the appropriate pressure for the special design blocking.
- d) Design thrust force (F) for fittings.
 - (1) When calculating thrust forces, use the outside diameter (OD) or joint sealing diameter. The sealing diameter is the internal diameter of the gasket at the bell, where the internal water pressure comes in contact.
 - (2) Horizontal (HB), Upper Vertical (UVB) and Lower Vertical (LVB) Bends. Calculate the design thrust force or resultant force for bends.
$$F = 2 P A \sin (\Theta \div 2)$$
Where:
 - P = design pressure
 - A = cross sectional area of pipe
 - Θ = angle of the bend
 - (3) Plugs and caps. Use the full thrust force, which is equal to the design pressure (P) times the cross sectional area (A) of the pipe. ($F = P A$)



- (4) Tees, TS&V and TA&V. Use the full thrust force, which is equal to the design pressure (P) times the cross sectional area (A) of the branch pipe. $(F = P A)$
- (5) Reducers. The design thrust force for reducers is equal to the design pressure (P) times the difference of the cross sectional areas of the large (A_1) and small end (A_s) sizes of the reducer.
 $F = P (A_1 - A_s)$
- e) Appropriate earth pressure theories to be used when designing thrust blocks.
- (1) Horizontal bends, reducers, tees, TS&V, TA&V, plugs and caps.
- (a) Design horizontal bends, reducers, tees, TS&V, TA&V, plugs and caps using one of the appropriate earth pressure theories indicated below and state the specific references used in the design calculations.
- Design Method for Vertical Anchor Slabs in Sand, N. Krebs Ovesen and Helle Stromann. See pages 1481 to 1500, Performance of Earth and Earth-Supported Structures, Volume 1 Part 2, ASCE, 1972.
- Design for Unbalanced Thrust for Buried Water Conduits, Charles A. Manganaro, see pages 705 to 716, Journal AWWA, June 1968.
- (b) Do not use a design concept based on bearing capacity.
- (c) For blocks in cohesive soils, evaluate the soil resistance in terms of short and long term shear strengths and use the lowest resistance between the two for the design.
- (d) Calculated net soil resistance for the block is to be at least 1.5 times the design thrust force.
- (2) Upper vertical bends. Design the thrust blocks for upper vertical bends such that the sum of the effective weight of the concrete, bend and fluid is equal to or greater than the vertical component of the design thrust force.
- (3) Lower vertical bends. Design the thrust blocks for lower vertical bends such that the contact pressure at the bottom of the block is within the allowable soil bearing capacity.

e. Design Example: Horizontal Bend Concrete Thrust Blocks.

Determine size of a thrust block required for a 30"-1/8 (45°) HB at Station 0 + 00.

For this example, "Ovesen and Stromann" method was used.

Design Parameters:

Ground surface elevation at the fitting = 134.4 Fitting invert elevation = 127.4.

HHG (High Hydraulic Grade) = 325 ft Surge pressure = 80 lb/in²

Pipe outside diameter (OD) = 32.00 inches (ANSI/AWWA C150/A21.50)

For obtaining HHG and surge pressure, see Part One, Section 5 (Total Internal and Transient Pressures).

Determine the passive soil pressure zone.

A review of the plans reveals that there are no existing or proposed utilities, structures, etc., anywhere close to the passive pressure soil zone behind the proposed thrust block, see Passive Soil Pressure for Concrete Thrust Blocks, in this section.



Determine if special detail is required.

Standard Detail B/1.0 for horizontal bends thrust blocks only includes up to 16-inch diameter water mains, therefore, this is a special design. Design the block using the same general block configuration as the standard detail and determine the required special design dimensions. If the assumptions and limitations indicated in the "notes" on the standard detail are consistent with the particular special design, then generally the special design dimensions can be indicated in a note on the contract drawings referencing Standard Detail B/1.0 without providing a detail of the block on the plans. This is true for this case, therefore the special design dimensions are determined as follows:

Determine soil design parameters.

A soil boring located at the proposed fitting supports the following soil design parameters:

$$\begin{aligned} & \text{Silty Sand} && \text{No Groundwater} \\ \gamma &= \text{soil unit weight} &= & 120 \text{ lb/ft}^3 \\ \phi &= \text{soil friction angle} &= & 25^\circ \\ k_a &= \text{active earth pressure coefficient} &= & 0.41 \\ & \text{Where } k_a = (1 - \sin \phi) \div (1 + \sin \phi) \end{aligned}$$

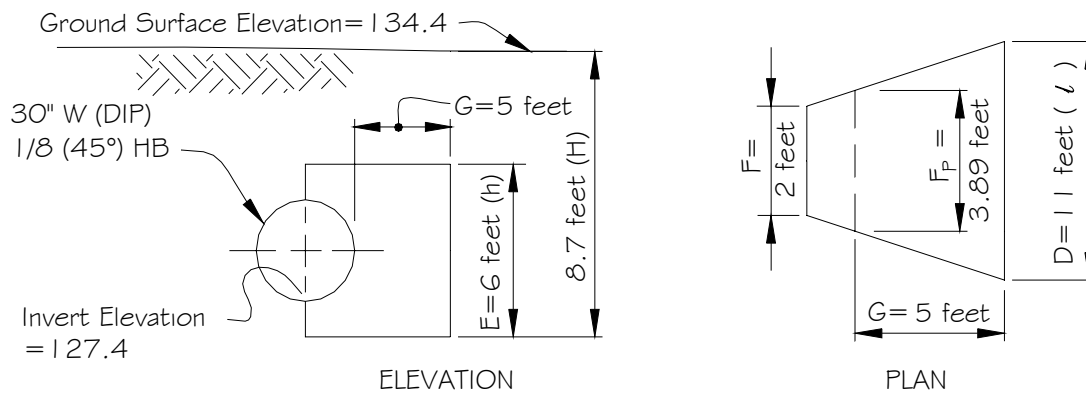
For soil boring requirements, see Part Three, Section 20, (Geotechnical and Corrosion Submittals).

Determine design pressure:

$$\begin{aligned} P &= \text{design (total) pressure} = ((\text{HHG} - \text{pipe invert}) \times 0.433) + \text{surge} \\ &= ((325 - 127.4) \times 0.433) + 80 \\ P &= 165.63 \text{ lb/in}^2 \end{aligned}$$

Determine thrust force - Horizontal Bend:

$$\begin{aligned} R &= \text{thrust (resultant horizontal force)} = 2 P A \sin (\Theta \div 2) \\ \text{Where: } P &= \text{design (total) pressure} & A &= \text{pipe cross sectional area} = \\ & & &= (\pi \times (\text{OD})^2) \div 4 \\ & & &= (3.1415927 \times (32.00)^2) \div 4 \\ \Theta &= 45^\circ \text{ (for a 1/8 HB)} & & A = 804.25 \text{ in}^2 \\ R &= 2 (165.63 \text{ lb/in}^2) (804.25 \text{ in}^2) \sin (45^\circ \div 2) \\ R &= 101,952.93 \text{ lb} \end{aligned}$$



SKETCH "II"

Example of Concrete Thrust Block For Horizontal Bend



Assume a block size and determine the weight of the proposed block per foot width:

wt = weight of the concrete block/ft width $\gamma_c = 150 \text{ lb/ft}^3$ (unit weight of concrete)

Using Standard Detail B/1.0, assume the following block dimensions, see Sketch "KK":

F = 2 feet E = 6 feet D = 11 feet G = 5 feet $F_p = 3.89$ feet

$$\begin{aligned} \text{wt} &= G E ((F_p + D) \div 2) \gamma_c = 5 \text{ ft} \times 6 \text{ ft} \times ((3.89 \text{ ft} + 11 \text{ ft}) \div 2) \times 150 \text{ lb/ft}^3 \\ &= 223.35 \text{ ft}^3 \times 150 \text{ lb/ft}^3 = 33,502.5 \text{ lb} \div \text{width} = 33,502.5 \text{ lb} \div 11 \text{ ft} \end{aligned}$$

$$\text{wt} = 3045.68 \text{ lb/ft}$$

Determine normal active earth pressure:

$$\begin{aligned} E^a &= \text{normal active earth pressure} \\ &= 1/2 \gamma H^2 k_y^a \\ &= 1/2 \times 120 \text{ lb/ft}^3 \times (8.7 \text{ ft})^2 \times 0.41 \\ E^a &= 1861.97 \text{ lb/ft} \end{aligned}$$

Determine tangential active earth pressure:

$$\begin{aligned} F^a &= \text{tangential active earth pressure} \\ &= E^a \tan \phi \\ &= 1861.97 \text{ lb/ft} \tan 25^\circ \\ F^a &= 868.25 \text{ lb/ft} \end{aligned}$$

Determine earth pressure coefficient for tangential earth pressure in front of block:

$$\begin{aligned} k_y \tan \delta_y &= \text{earth pressure coefficient for tangential earth pressure in front of block} \\ &= (G + F^a) \div (1/2 \gamma H^2) \\ &= (3045.68 \text{ lb/ft} + 868.25 \text{ lb/ft}) \div (1/2 \times 120 \text{ lb/ft}^3 \times (8.7 \text{ ft})^2) \\ k_y \tan \delta_y &= 0.86 \end{aligned}$$

Determine earth pressure coefficient for normal earth pressure in front of block:

$$\begin{aligned} k_y &= \text{earth pressure coefficient for normal earth pressure in front of block} \\ &\text{Obtain from Figure "J", for } (k_y \tan \delta_y = 0.86 \text{ and } \phi = 25^\circ) \\ k_y &= 3.25 \end{aligned}$$

Determine anchor resistance:

$$\begin{aligned} A^o &= \text{anchor resistance} \\ &= (1/2 \gamma H^2 k_y) - E^a \\ &= (1/2 \times 120 \text{ lb/ft}^3 \times (8.7 \text{ ft})^2 \times 3.25) - 1861.97 \text{ lb/ft} \\ &= 14,759.55 \text{ lb/ft} - 1861.97 \text{ lb/ft} \\ A^o &= 12,897.58 \text{ lb/ft} \end{aligned}$$

Determine effective block length:

$$\begin{aligned} l^e &= \text{effective block length.} \\ (l^e - l / H + h) &= (11 - 1) \div (8.7 + 6) \\ (l^e - l) \div (H + h) &= 0.24 \quad \text{Obtain from Figure "K", for } 0.68 \\ l^e &= 0.24 \times (H + h) + l \quad \text{(rearrange terms to solve for } l^e) \end{aligned}$$

Where:

$$\begin{aligned} h \text{ (assumed block height)} &= 6 \text{ feet} & H \text{ (depth to bottom of block)} &= 8.7 \text{ feet} \\ l \text{ (assumed block length)} &= 11 \text{ feet} \end{aligned}$$

$$l^e = 0.24 \times (6 \text{ ft} + 8.7 \text{ ft}) + 11 \text{ ft}$$

$$l^e = 14.53 \text{ feet}$$

Determine anchor resistance ratio:

$$\begin{aligned} A^s / A^o &= \text{anchor resistance ratio} \\ &\text{Obtain from Figure "I", for } (h / H = 6 \div 8.7 = 0.69) \\ A^s / A^o &= 0.95 \end{aligned}$$



Determine the anchor resistance or load capacity of block:

$$\begin{aligned} Q &= \text{anchor resistance} \\ &= A^{\circ} (A^s / A^{\circ}) I^{\circ} \\ &= 12,897.58 \text{ lb/ft} \times 0.95 \times 14.53 \text{ ft} \\ Q &= 178,031.75 \text{ lb} \end{aligned}$$

Determine factor of safety of assumed block size:

$$\begin{aligned} FS &= \text{Factor of Safety} = 1.5 \\ &= Q \div R \\ &= 178,031.75 \text{ lb} \div 101,952.93 \text{ lb} \\ FS &= \underline{1.74} > 1.5 \therefore \underline{\mathbf{O.K.}} \end{aligned}$$

Summary: The assumed block size is adequate, provide this note, either in the "Blocking Notes" or the "General Notes". "Block 30"-1/8 HB at Station 0+00 with concrete according to Standard Detail B/1.0 using the following block dimensions: D = 11'-0", E = 6'-0", F = 2'-0" and G = 5'-0."

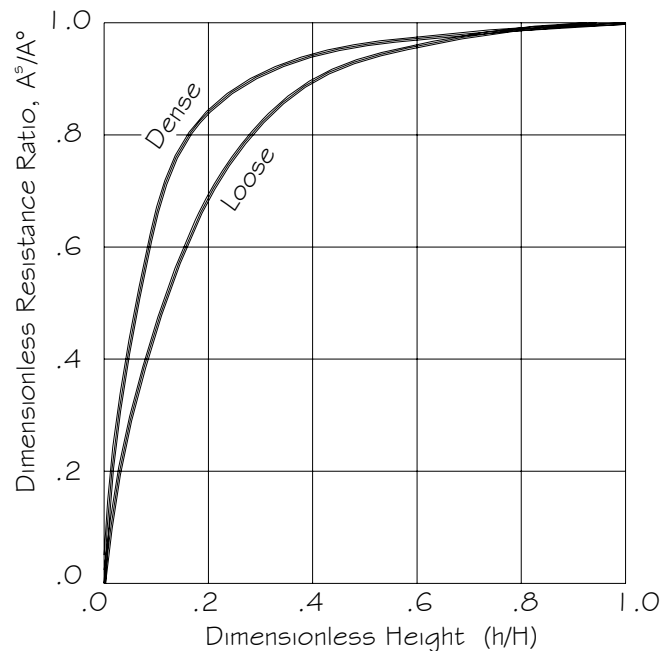


FIGURE "I"

Dimensionless Anchor Resistance Ratio, A^s/A^o



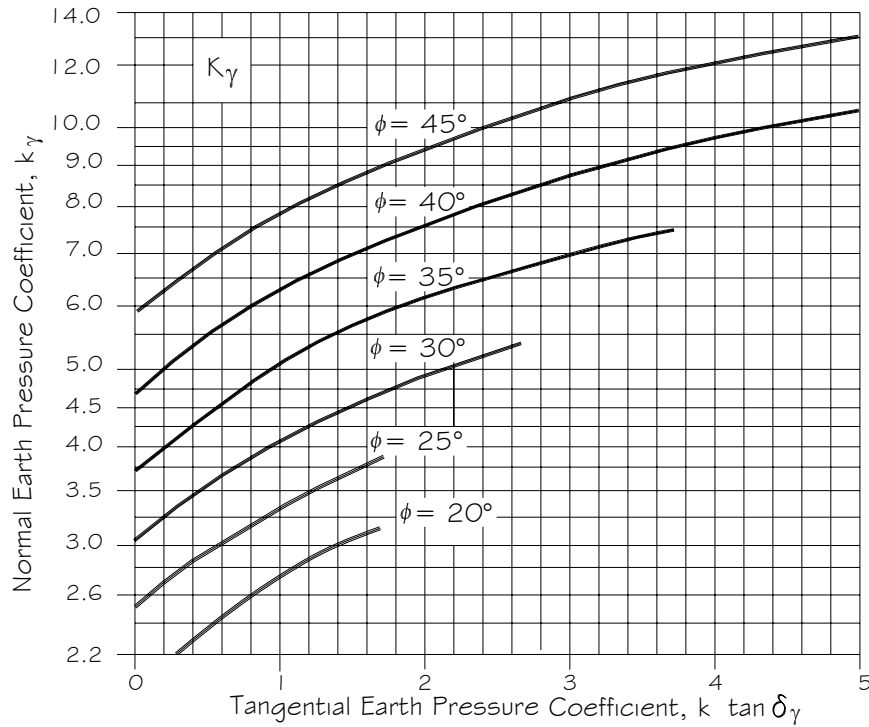


FIGURE "J"

Earth Pressure Coefficient for Normal Earth Pressure in Front of Block

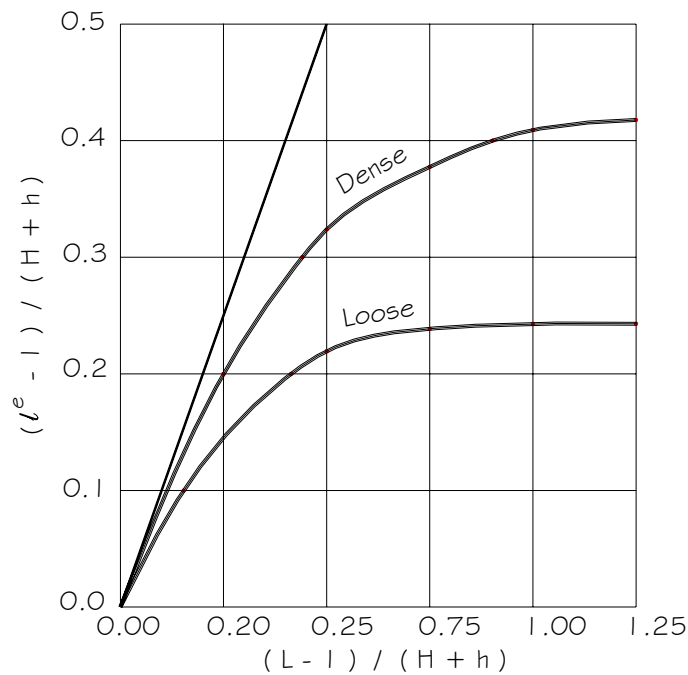


FIGURE "K"

Dimensionless Anchor Resistance Ratio, $(l^e - l) / (H + h)$



f. Design Example: Upper Vertical Bend Concrete Thrust Blocks.

Determine size of a thrust block required for a 30"-1/8 (45°) UVB at Station 1 + 00

$$\begin{aligned} \text{Ground surface elevation at the fitting} &= 134.4 & \text{Fitting invert elevation} &= 127.4. \\ \text{HHG (High Hydraulic Grade)} &= 325 \text{ ft} & \text{Surge pressure} &= 80 \text{ lb/in}^2 \\ \text{Pipe outside diameter (OD)} &= 32.00 \text{ inches (ANSI/AWWA C150/A21.50)} \end{aligned}$$

For obtaining HHG and surge pressure, see Part One, Section 5 (Total Internal and Transient Pressures).

Determine if special design is required.

Standard Detail B/1.7 for upper vertical bend thrust blocks only includes up to 16-inch diameter water mains, therefore this is a special design. Design the block using the same general block configuration as the standard detail and as shown on Sketch "JJ". Determine minimum dimensions of the concrete block needed to offset the vertical component of the thrust, generated by the 30"-1/8 UVB. The final shape of the block will need to be determined based on its constructability.

Determine soil design parameters.

A soil boring located at the proposed fitting supports the following soil design parameters:

Silty Sand High Groundwater, Submerged Condition

For soil boring requirements, see Part Three, Section 20 (Geotechnical and Corrosion Submittals).

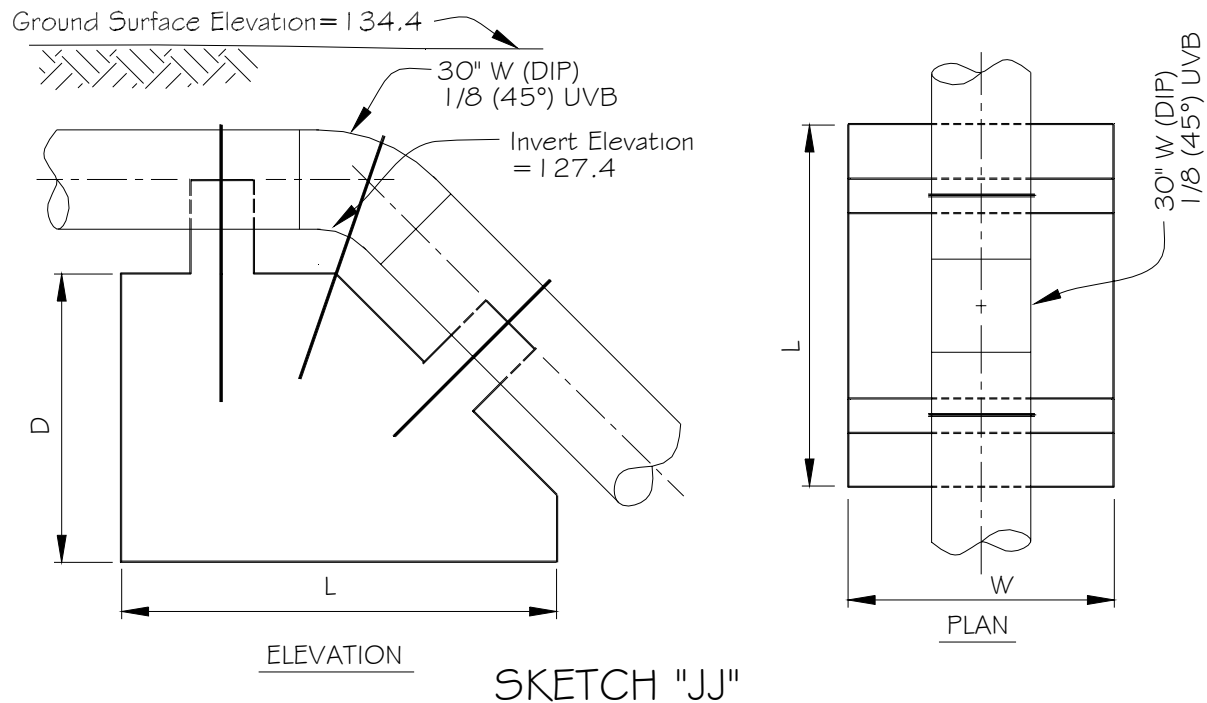
Determine design pressure:

$$\begin{aligned} P &= \text{design (total) pressure} = ((\text{HHG} - \text{pipe invert}) \times 0.433) + \text{surge} \\ &= ((325 - 127.4) \times 0.433) + 80 \\ P &= 165.63 \text{ lb/in}^2 \end{aligned}$$

Determine thrust force

$$\begin{aligned} R_v &= \text{thrust (resultant force)} = 2 P A \sin (\Theta \div 2) \\ \text{Where: } P &= \text{design (total) pressure} & A &= \text{pipe cross sectional area} \\ & & &= (\pi \times (\text{OD})^2) \div 4 \\ \Theta &= 45^\circ \text{ (for a 1/8 HB)} & &= (3.1415927 \times (32.00)^2) \div 4 \\ & & A &= 804.25 \text{ in}^2 \\ R_v &= 2 \times (165.63 \text{ lb/in}^2) \times (804.25 \text{ in}^2) \times \sin (45^\circ \div 2) \\ R_v &= 101,952.93 \text{ lb} \end{aligned}$$





Example of Concrete Thrust Block For Upper Vertical Bend

Assume a block size and determine the weight of the proposed block:

$$W_b = \text{weight of the concrete block} \quad \gamma_w = 62 \text{ lb/ft}^3 \quad (\text{unit weight of water})$$

$$\gamma_c = 150 \text{ lb/ft}^3 \quad (\text{unit weight of concrete})$$

Using Sketch "LL" and Standard Detail B/1.7, assume the following block dimensions:

$$D = 9 \text{ feet} \quad L = 12 \text{ feet} \quad W = 12 \text{ feet}$$

$$W_b = L W D (\gamma_c - \gamma_w)$$

$$= 12 \text{ ft} \times 12 \text{ ft} \times 9 \text{ ft} \times (150 \text{ lb/ft}^3 - 62.4 \text{ lb/ft}^3) = 1296 \text{ ft}^3 \times 87.6 \text{ lb/ft}^3$$

$$W_b = 113,529.6 \text{ lb}$$

Determine factor of safety of assumed block size:

$$FS = \text{Factor of Safety} = 1.0$$

$$= W_b \div R_v = 113,529.6 \text{ lb} \div 101,952.93 \text{ lb}$$

$$FS = \underline{1.21} > 1.0 \therefore \underline{\text{O.K.}}$$

Determine size of reinforcing bars for strapping pipe to the block:

$$R_v = 101,952.93 \text{ lb}$$

Using grade 60 reinforcing bars, allowable tensile shear in reinforcement, $f_s = 24,000 \text{ psi}$

Required area of the reinforcing with 1.5 safety factor (FS)

$$A_{\text{required}} = FS \times (R \div f_s) = 1.5 \times (101,952.93 \text{ lb} \div 24,000 \text{ psi})$$

$$A_{\text{required}} = 6.38 \text{ in}^2$$

Using 4 #10 reinforcing bars as shown on Standard Detail B/1.7

$$A_{\text{provided}} = ((\# \text{ of bars}) \times 2 \text{ (each side of bar embedded in block)} A_{\text{bar}}) > A_{\text{required}}$$

$$= (4 \times 2 \times 1.27 \text{ in}^2) > 6.38 \text{ in}^2$$

$$A_{\text{provided}} = 10.16 \text{ in}^2 > 6.38 \text{ in}^2 \therefore \underline{\text{O.K.}}$$

Summary: The assumed block size is adequate. Adjust the size of the with the block configuration shown in Sketch "JJ". Provide a detail on the drawings typical to Sketch "JJ" and Standard Detail B/1.7.



g. Design Example: Lower Vertical Bend Concrete Thrust Blocks.

Determine size of a thrust block required for a 30"-1/8 (45°) LVB at Station 2 + 00

Ground surface elevation at the fitting = 134.4 Fitting invert elevation = 127.4.

HHG (High Hydraulic Grade) = 325 ft Surge pressure = 80 lb/in²

Pipe outside diameter (OD) = 32.00 inches (ANSI/AWWA C150/A21.50)

For obtaining HHG and surge pressure, see Part One, Section 5 (Total Internal and Transient Pressures).

Determine if special design is required.

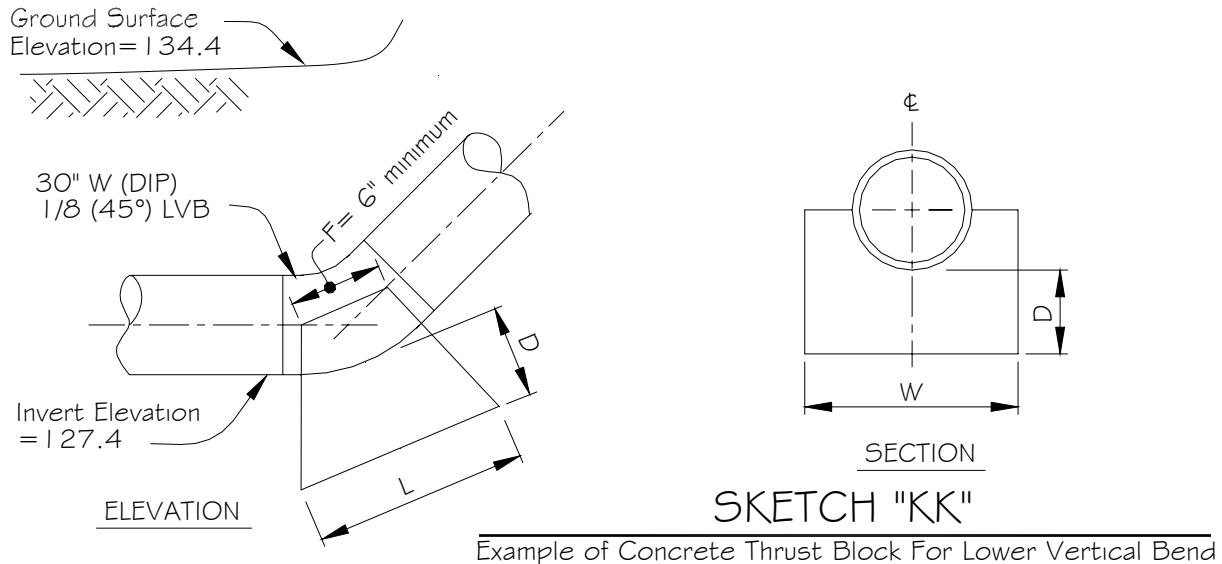
Standard Detail B/1.8 for lower vertical bend thrust blocks only includes up to 16-inch diameter water mains, therefore, this is a special design. Design the block using the same general block configuration as the standard detail and as shown on Sketch "KK". Determine minimum dimensions of the concrete block needed to offset the vertical component of the thrust generated by the 30"-1/8 (45°) LVB. If the assumptions and limitations indicated in the "notes" on the standard detail are consistent with the particular special design, then generally the special design dimensions can be indicated in a note on the contract drawings referencing Standard Detail B/1.8 without providing a detail of the block on the plans. This is true for this case, therefore, the special design dimensions are determined as follows:

Determine soil design parameters.

A soil boring located at the proposed fitting supports the following soil design parameters:

Silty Sand, High Groundwater.

For soil boring requirements, see Part Three, Section 20, (Geotechnical and Corrosion Submittals).

Determine design pressure:

P = design (total) pressure

$$= ((\text{HHG} - \text{pipe invert}) \times 0.433) + \text{surge} = ((325 - 127.4) \times 0.433) + 80$$

P = 165.63 lb/in²

Determine thrust force

R_v = thrust (resultant force)

Where: P = design (total) pressure

A = pipe cross sectional area

$$= (\pi \times (OD)^2) \div 4$$

Θ = 45° (for a 1/8 HB)

$$= (3.1415927 \times (32.00)^2) \div 4$$

$$A = 804.25 \text{ in}^2$$

$$R_v = 2 P A \sin(\Theta \div 2) = 2 \times (165.63 \text{ lb/in}^2) \times (804.25 \text{ in}^2) \times \sin(45^\circ \div 2)$$

$$R_v = 101,952.93 \text{ lb}$$

Using Sketch "KK", assume the following block dimensions:

$$L = 10 \text{ feet} \quad W = 7 \text{ feet} \quad D = 2 \text{ feet} \quad F = 6 \text{ inches (Minimum)}$$

Determine Area of Block:

$$A_b = L \times W$$

$$= 10 \text{ feet} \times 7 \text{ feet}$$

$$A_b = 70 \text{ ft}^2$$

Bearing Pressure - Check

$$P_b = R_v \div A_b$$

$$= 101,952.93 \text{ lb} \div 70 \text{ ft}^2$$

$$P_b = 1456 \text{ psf} < 2,000 \text{ psf} \quad \therefore \text{O.K.}$$

$$(\text{Allowable soil bearing pressure} = 2000 \text{ psf})$$

Summary:

The assumed block size is adequate, provide this note on the drawings, either on the "Blocking Notes" or the "General Notes". "Block 30"-1/8 LVB at Station 2+00 with concrete according to Standard Detail B/1.8 using the following block dimensions: L = 10'-0", W = 7'-0", D = 2'-0" and F = 6" (minimum).

h. Restrained Pipe Joints.

- 1) Concrete Thrust Blocks versus Restrained Pipe Joints. Always consider the use of concrete thrust blocks before the use of restrained pipe joints to resist the thrust forces acting on the pipe and fittings. However, there are some circumstances where restrained pipe joints may be the most practical method to prevent the separation of the pipe and fittings caused by the thrust forces. The use of restrained joint piping must be approved. Some common circumstances when the use of restrained joints may be appropriate are as follows:
 - a) There is not enough clearance between the proposed pipeline and nearby existing or proposed utilities or structures for a concrete thrust block. Clearance is not only the physical size of the block, but also the extent of the soil required to provide passive soil resistance for the block, see Passive Soil Pressure for Concrete Thrust Blocks, see this section.
 - b) Situation where many fittings are in close proximity.
 - c) Congested location, such as certain areas of the yard piping at a treatment plant where there are a large number of other pipelines in very close proximity, crossing each other, installed in common trenches at the same elevation or there is a very high probability that future pipes will be installed which would disturb the existing thrust blocks.
 - d) For pipe sizes larger than 24-inch diameter, see General in this Section, for additional design guidelines on the use of restrained joints versus thrust blocking.
- 2) Alternate Alignments. In many cases, it will be possible to modify the proposed alignment or adjust the fitting location to avoid the above described situations and to eliminate the need for restrained joints. Before restrained joints are specified, first investigate the possibility of changing the alignment or adjusting fitting locations to eliminate the need for restrained joints.



3) Design considerations.

- a) In the Specifications various types of restrained joints are specified. Different types of restrained joints are manufactured for different ranges of pipe sizes and design internal pressures. Verify the pressure rating during the selection of the type of restrained joint and specify the appropriate type of restrained joint for the particular application.
- b) Restrained joint systems. Resistance of thrust forces by the use of restrained joint pipe can be achieved using one of the following two methods;
- (1) Restrained joints only system. This method uses the friction between the soil and the specified length of restrained pipe to resist the thrust force. No passive soil resistance at the fitting and/or pipe shall be considered. The total friction force calculated shall be at least 1.5 times the full thrust force ($P \times A$), except for restraining reducers where the design thrust force is $P(A_1 - A_s)$ as defined in this section. When using polyethylene encasement for the purpose of corrosion protection, assume a lower friction coefficient between the soil and pipe. No soil cohesion term should be used in evaluating the soil-pipe friction. Use the following equation for determining the required restrained length.

$$L_{\text{required}} = (F \times S_f) \div ((2W_e + W_p + W_w) \times \tan \delta)$$

Where:

- L = minimum length of pipe to be restrained
(restrained length for each leg in the case of a bend)
- F = thrust force = $P \times A$
- P = design pressure
- A = cross sectional area of pipe
(using OD of pipe which equals the sealing diameter)
- S_f = safety factor (1.5)
- W_e = earth prism load (per foot length of pipe) *
- W_p = weight of pipe (per foot length of pipe) *
- W_w = weight of water in pipe (per foot length of pipe)
- δ = friction angle between dissimilar materials
(from NAVFAC DM-7.2, Table 1, May 1982, Foundations and Earth Structures)
- * Use effective (submerged) weight for below groundwater condition.

- (2) Combined restrained joint system. This method uses restrained joint pipe in combination with reinforced concrete thrust block(s). This system relies on the concrete thrust block to resist the thrust while the restrained joints transfer the thrust to the block(s) and prevent joint separation. One or both ends of the restrained pipe are anchored to a concrete thrust block(s). The concrete thrust block(s) are designed to resist the full thrust force ($P \times A$), except when restraining reducers, design for a thrust of $P(A_1 - A_s)$, as defined in this section under Design Thrust Force for Fittings.

4) Restrained joint information to be included on the drawings.

- a) Indicate on the profile the limits of the restrained joint length including the stations (to and from), and also provide a similar note in the Blocking Notes or General Notes. Typical note, "Restrained 12"W from the 12" plug/cap at station 0+00 to station 2+00".

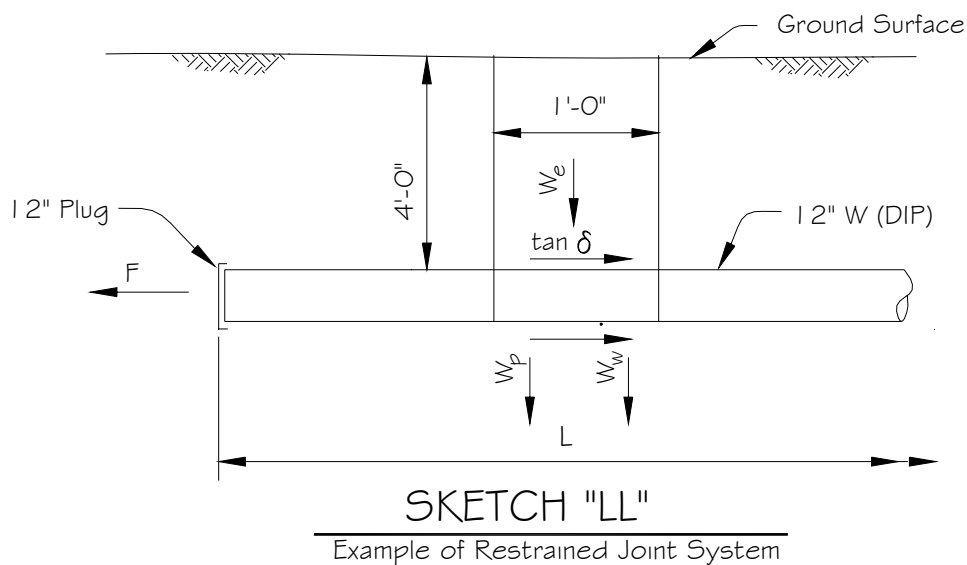


b) Special Design.

- (1) If the design requires the use of a specific type of restrained joint, then indicate the specific type of joint in the "Blocking Notes" or "General Notes" and on the pipe profile on the Drawings.
- (2) If the restrained joint type is not an approved joint in the Specifications, indicate the joint type in the "Blocking Notes" or "General Notes" and on the pipe profile on the Drawings. Obtain WSSC approval for the use of restrained joints which are not in the Specifications.

i. Design Example for Determining Required Length of Restrained Pipe.

Determine the length of restrained pipe necessary to restrain a 12" plug or cap on a 12" DIP, class 50, water pipeline.

Design parameters.

No fittings or valves located in the proposed restrained length.

Average depth of cover to the top of the pipe is 4 feet.

12" Plug invert elevation = 212.00 ft.

12" Plug at Station 3+61

Pipe outside diameter (OD) = 13.2 inches (ANSI/AWWA C150/A21.50)

Wall thickness of 12" DIP Class 50 = 0.31 inches. (ANSI/AWWA C150/A21.5, Table 50.5)

Pipe inside diameter (ID) = OD - (2 × wall thickness) = 12.58 inches.

HHG (High Hydraulic Grade) = 385 feet Surge pressure = 100 lb/in²

For obtaining HHG and surge pressure, see Part One, Section 5, (Total Internal and Transient Pressures).

Determine soil design parameters.

A nearby soil boring supports the following soil design parameters:

Fine sandy silt, No Groundwater

γ = soil unit weight = 120 lb/ft³ ϕ = soil friction angle = 25°

δ = pipe-soil friction angle = 11°



Determine design pressure:

$$\begin{aligned}
 P &= \text{design pressure} \\
 &= (\text{HHG} - \text{pipe invert elevation}) 0.433 + \text{surge} = (385 - 212.00) \times 0.433 + 100 \\
 P &= 174.90 \text{ lb/in}^2
 \end{aligned}$$

Determine thrust force:

$$\begin{aligned}
 F &= \text{thrust} = P (\text{design (total) pressure}) \times A (\text{pipe cross sectional area}) \\
 &= P \times ((\pi \times \text{OD}^2) \div 4) \\
 &= P \times ((3.1415927 \times (13.2)^2) \div 4) \\
 &= 174.90 \text{ lb/in}^2 \times 136.84 \text{ in}^2 \\
 F &= 23,933.32 \text{ lb}
 \end{aligned}$$

Determine weight of the earth:

$$\begin{aligned}
 W_e &= \text{weight of the earth} \\
 &= \text{OD (in feet)} \times \gamma \times \text{depth to top of pipe} \\
 &= (13.2 \text{ in} \div 12) \times 120 \text{ lb/ft}^3 \times 4 \text{ ft} \\
 W_e &= 528 \text{ lb/ft}
 \end{aligned}$$

Determine weight of pipe:

$$\begin{aligned}
 W_p &= \text{weight of the pipe} \\
 W_p &= 40.2 \text{ lb/ft} \quad (\text{ANSI/AWWA C151/A21.51, table 51.5, for mechanical joint (MJ) pipe. If using push-on type restrained joints or proprietary restrained joint pipe, obtain the pipe weight from the pipe manufacturer's information.})
 \end{aligned}$$

Determine weight of water:

$$\begin{aligned}
 W_w &= \text{weight of the water} \\
 &= \text{inside area of pipe (change to ft}^3) \times \text{unit weight of water} \\
 &= ((\text{ID}^2 \times \pi \div 4) \div 144) \times 62.4 \text{ lb/ft}^3 \\
 &= ((12.58 \text{ in})^2 \times 3.1415927 \div 4) \div 144) \times 62.4 \text{ lb/ft}^3 \\
 &= (124.29 \text{ in}^2 \div 144) \times 62.4 \text{ lb/ft}^3 \\
 W_w &= 53.86 \text{ lb/ft}
 \end{aligned}$$

Determine the minimum restrained length required:

$$\begin{aligned}
 L_{\text{required}} &= (F \times S_f) \div ((2W_e + W_p + W_w) \times \tan \delta) \\
 &= (23,933.32 \text{ lb} \times 1.5) \div (((2 \times 528 \text{ lb/ft}) + 40.2 \text{ lb/ft} + 53.86 \text{ lb/ft}) \times \tan 11^\circ) \\
 &= 35,899.98 \div ((1056 + 40.2 + 53.86) \times \tan 11^\circ) \\
 &= 35,899.98 \div (1149.86 \times \tan 11^\circ) \\
 &= 35,899.98 \div 223.51 \\
 L_{\text{required}} &= 160.61 \text{ ft}
 \end{aligned}$$

Summary:

Indicate on the drawings in the "Blocking Notes" or the General Notes the following: "Restrain 12" W from the 12" Plug/Cap at station 3+61 to station 2+00". Also, show the limits of the restrained length on the water main profile, indicating stations.



j. Thrust Blocks for Quick Connections to Existing Pipelines.1) Pre-poured thrust block.

- a) Generally used at a horizontal bend where a new pipe will tie into an existing pipe that has a limited shut down time for making the connection. Another use of the block is for a new tee when a new pipe is branched off from an existing pipe, the connection time is limited, and a TS&V cannot be used.
- b) The block consists of a pre-poured rectangular reinforced concrete block, a steel member between the bend or tee and the pre-poured block which is placed during the limited shutdown to transfer the thrust to the pre-poured block, and a final concrete block encasing the steel member poured after the main is pressurized. See Standard Detail B/3.2 for water pipelines 24" and smaller. Special Design is required for larger than 24-inch and all 90° (1/4) bends. If the total pressure (operating plus surge) is greater than 250 psi a special design is required.
- c) The special design consists of an initial concrete block, bearing rack assembly and final concrete. For all pipe sizes the initial concrete block consists of a rectangular pre-poured block. Determine the size of the block using one of the methods described in this section under Concrete Thrust Blocks, herein, for horizontal bends or tees. Indicate the special design dimensions and steel reinforcement requirements on the drawings. Locate the pre-poured block, such that the existing pipe can be removed and the new bend or tee can be installed without great difficulty.

2) Tie-rod thrust collar block.

- a) Consists of a pre-poured reinforced concrete collar block cast around an existing pipe with steel rods connected to one end of a new mechanical joint pipe or fitting. It is typically used on existing pipe where the thrust force in the direction of the pipe axis requires restraint. In some instances, it is also used in lieu of a welded-on thrust ring block on the new pipe where lead time to order the new pipe with the welded-on steel ring is insufficient.
- b) Do not design a tie-rod thrust collar block to be cast around Asbestos Cement Pipe (ACP) water mains.
- c) Design consists of the following:
 - (1) The thrust collar block is designed for thrust in one direction only.
 - (2) Indicate the type of existing pipe material and the Contract number of the existing pipe, which will have the concrete block cast around it.
 - (3) For pipe sizes 18-inch and smaller, the size of the block, reinforcing steel and details, are shown on Standard Details B/3.1 and B/3.1a. If the total pressure (operating plus surge) is greater than 250 psi, a special design is required
 - (4) Special Design, is required for pipeline sizes larger than 18-inch and total pressures for all sizes of pipelines greater than 250 psi. The special design consists of determining the size of the block using one of the methods described in Concrete Thrust Blocks for plugs, caps or tees. Provide a detail on the drawings indicating the special design block dimensions, steel reinforcement requirements, size and number of tie-rods, etc.



k. Welded-on Thrust Ring Blocks for New Pipe.

- 1) Generally used where the thrust force in the direction of the pipe axis requires restraint. However, due to the cost and the lead time required to order the pipe with a welded-on steel ring from the pipe manufacturer, a thrust ring block should only be used after the use of standard design blocking, as described in this section, has been ruled out. The most common circumstances where this block is used are as follows:
 - a) The required length of restrained joint pipe to resist the axial thrust is not available.
 - b) Analysis indicates that it will be more economical to use a short section of restrained joint pipe combined with a thrust ring block rather than to use the full required length of restrained joint pipe.
 - c) For a plug/cap at the end of the new pipeline where a future connection will be made. This block is used in lieu of a standard design block for caps or plugs as described in Concrete Thrust Blocks, in this section, to easily facilitate the future connection because the removal of the block is not required. It also minimizes service disruption during the future connection. This type of application should generally be considered for large diameter pipelines and for pipelines where the location of a valve is near the collar, which would also allow the collar to be used as a permanent restraint for the valve.
- 2) Design.
 - a) The thrust ring block consists of a steel ring factory welded to a new pipe and then cast into a reinforced concrete collar block. The thickness and the final outside diameter of the steel ring welded to the pipe are generally determined by the pipe manufacturer, see Thrust Rings below, for the design requirements and the information to be shown on the drawings.
 - b) Pipe sizes 18-inch and smaller, the size and details for welded-on thrust ring blocks for pipe sizes 18-inch and smaller can be referred to Standard Detail B/3.3.
 - c) Pipe sizes larger than 18-inch, determine the size of the reinforced concrete collar. Two sides of the block should extend at least one (1) foot beyond the sides of the trench into the undisturbed soil. Provide a special detail indicating the special design block dimensions, steel reinforcement requirements, etc. on the drawings.
- 3) Thrust rings.
 - a) Thrust rings are steel or iron rings welded onto the barrel of new DIP for the purpose of restraining thrusts. These rings are factory designed and welded by the pipe manufacturer or their fabricator.
 - b) Thrust rings are not covered by the AWWA standards, each pipe manufacturer has their own design. When specifying the rings on the drawings, care must be taken to design and detail the thrust transfer mechanism from the ring to the thrust restraint and provide correct and sufficient information to facilitate the contractor when ordering and installing the thrust rings.
 - c) In lieu of other rational designs, the following design considerations and methodology may be followed subject to each project's special requirements:



- (1) Thrust rings can be welded onto new pipe barrels only, not cast fittings or cast specials. Manufacturers' seep rings/collars, which are designed to prevent water penetration through a wall, typically called wall pipe or fittings, shall not be mistaken for thrust rings.
- (2) Some manufacturers have directional thrust rings. The drawings should clearly depict the direction/directions of the thrust. When thrust can act in either direction, design only bi-directional thrust rings and design concrete member (collar block or wall) accordingly.
- (3) If the thrust rings will be encased in concrete, clearly indicate the bearing face or faces and their location within the concrete. Thrust rings can be up to three (3") inches thick.
- (4) The following information will need to appear on the drawings either by notes or in a table:
 - (a) Thrust ring shall be designed for a thrust of ___ kips, acting in (indicate one or both directions. (Also show an arrow indicating the direction of the thrust on the detail.)
 - (b) The area of the thrust ring shall be proportioned such that the bearing stress on the concrete does not exceed one thousand (1000) psi.
 - (c) Locate the thrust ring two (2) feet minimum from the end of the pipe.
- (5) Thrust rings are designed by the manufacturer to bear on a uniform surface such as concrete. Point bearing such as provided by beam flanges or channel flanges on two or four sides should be avoided or contact the manufacturer for any special design requirements.
- (6) Design considerations when transferring the thrust ring load to a concrete wall or concrete thrust collar block:
 - (a) "d" for punching shear - from the thrust face of the ring to the centroid of the tension reinforcement.
 - (b) "d" for diagonal shear and for moment - from the compression face of the concrete to the centroid of the tensile reinforcement.
 - (c) Face of the support for diagonal shear and moment - tangent to the pipe surface.
 - (d) Reinforcing bars interrupted by the pipe penetration - accounted for by placing additional reinforcing around the pipe penetration.

1. When and How to Restrain Reducers.

- 1) Large end of reducer equal to or smaller than 14-inch diameter. No concrete thrust collar or restrained pipe is required for a reducer with the larger end diameter equal to or smaller than 14-inch, if the following conditions are met:
 - a) There are no bends or tunnels in front of the small end of the reducer within the minimum length as shown in Table "27". Provide a note on the drawings to "Fully home all pipe/fitting joints located within this distance".



TABLE "27"
Length of Straight Pipe Required in Front of Reducer¹

Reducer Size	Groundwater		Reducer Size	Groundwater	
	No	Yes		No	Yes
4"x 3"	10 feet	15 feet	12"x 4"	*	*
6"x 4"	50 feet	100 feet	12"x 6"	170 feet	*
8"x 4"	115 feet	*	12"x 8"	95 feet	200 feet
8"x 6"	45 feet	100 feet	12"x 10"	45 feet	90 feet
10"x 4"	195 feet	*	14"x 6"	*	*
10"x 6"	105 feet	215 feet	14"x 8"	155 feet	*
10"x 8"	45 feet	90 feet	14"x 10"	90 feet	195 feet
			14"x 12"	40 feet	90 feet

¹ The lengths were computed based upon the formula given in this section for Restrained Joint Systems and are based upon the following assumptions:

weight of soil	=	120 pcf	total pressure	=	250 psi
minimum earth cover	=	4 feet	weight of water	=	62.4 pcf
interface friction angle(pipe/earth)	=	19°	safety factor	=	1.5

* Pipe length required is too large. Will need other method to mitigate thrust force.

- b) Connecting to a smaller diameter line with a tee, valve and reducer with the block for the tee being designed for the full thrust of the large diameter end of the reducer, see Sketch "PP" for illustration. Provide a note on the drawings to "Fully home all pipe/fittings joints between the tee and the reducer".
 - c) The estimated total thrust force on the reducer is less than 30 kips.
 - d) If any one of the above conditions cannot be met, restrain or block the reducer according to Methods for reducer restraint, below.
- 2) Large end of reducer greater than 14-inch diameter. When the diameter of the large end of the reducer is greater than 14-inch, restrain the reducer with a concrete thrust collar block and/or restrained joints according to Methods for reducer restraint, below.
 - 3) Methods for reducer restraint. Use the most cost effective alternative for restraining the reducer and submit calculations. The following are several methods commonly used, with the first method being preferred.
 - a) Cast a reinforced concrete thrust collar block directly around the reducer, see Sketch "MM". Determine size of the concrete collar block and design thrust force, with the method described in this section for reducers in Concrete Thrust Blocks.
 - b) Cast a welded-on thrust ring block around the larger diameter pipe and restrain all joints between the block and the reducer, see Sketch "MM". Determine size of the collar block and the design thrust force, with the method described herein for reducers in Special Design Concrete Thrust Blocks.
 - c) Cast a welded-on thrust ring block around the smaller diameter pipe and fully home all the pipe joints between the block and the reducer, see Sketch "OO". Determine size of the collar block and the design thrust force, with the method described in this section for reducers in Special Design Concrete Thrust Blocks.



- d) Restrain the required length of the larger diameter pipe, refer to Restrained Pipe Joints in this section, for the method of determining the required restrained pipe length. The design thrust force (F) used for the design shall be $F = P(A_1 - A_s)$ as indicated under Design Thrust Force (F) for fittings, in this section.

m. When and How to Restrain Valves.

- 1) Direct buried valves 14-inch and smaller. Do not require restraint if the following conditions are met:
- There are no bends or tunnels on each side of the valve within the minimum length as shown in Table "28". Provide a note on the drawings to "Fully home all pipe/fitting joints located within this distance".
 - It is assumed that two consecutive valves will be closed during pipe break repairs.
 - When the conditions indicated above cannot be met, a concrete thrust collar block typical to Sketch "NN" or "OO" or the restrained joint method shall be used to restrain 14-inch and smaller size valves. Use the most cost effective alternative for restraining the valve and submit calculations.

TABLE "28"
Length of Straight Pipe Required in Front of Valves¹

Valve Size	Groundwater	
	No	Yes
4"	50 feet	105 feet
6"	70 feet	145 feet
8"	95 feet	190 feet
10"	110 feet	*
12"	150 feet	*
14"	160 feet	*

¹ The lengths were computed based upon the formula given in this section for Restrained Joint Systems and are based upon the following assumptions:

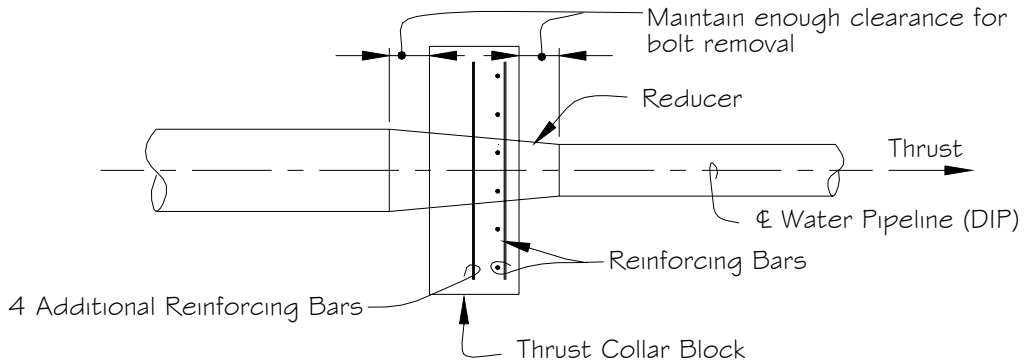
weight of soil	= 120 pcf	total pressure	= 250 psi
minimum earth cover	= 4 feet	weight of water	= 62.4 pcf
interface friction angle (pipe/earth)	= 19°	safety factor	= 1.5

* Pipe length required is too large. Will need other method to mitigate thrust force.

- 2) Valves 16-inch and larger. Install within vaults and restrain. There are two general methods of restraining large valves. One method is to use a thrust vault, see Sketch "QQ", which is a vault that takes the thrust generated from a closed valve and transfers it to the vault walls which in turn transfers it to the soil. The other method is to use concrete thrust collar blocks on each side of the valve, located away from the valve vault, see Sketch "RR".
- Determine size of the thrust vault, in accordance with passive earth pressure theory with consideration of the frictional forces acting along the sides as well as on the base of the vault. For structural design requirements, see Part Three, Section 16, (Design of Pipeline Structures).
 - When restraining a valve with concrete thrust collars, locate the collars so the vault is outside of the passive soil pressure zone of the collars, see Passive Soil Pressure for Concrete Thrust Blocks, in this section.

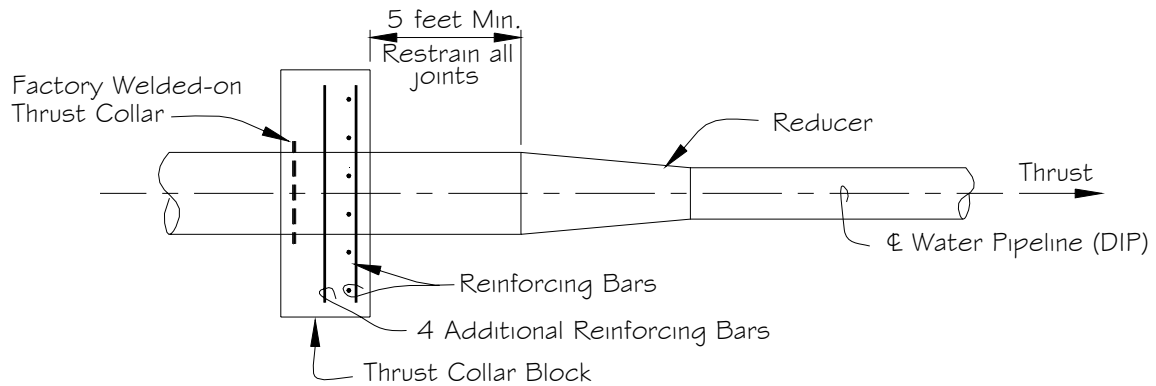


- 3) Line Stops. Temporary method for shut down of existing water pipelines. The line stop must be blocked to prevent the line stop from moving during closed condition. Submit method and special designs, see requirements under Special Design for Concrete Thrust Blocks in this section.



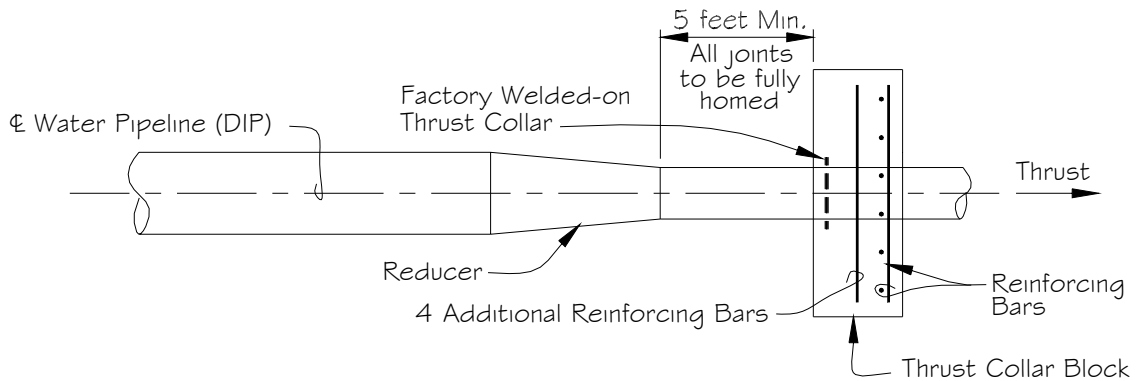
SKETCH "MM"

Thrust Block Cast Directly Around Reducer



SKETCH "NN"

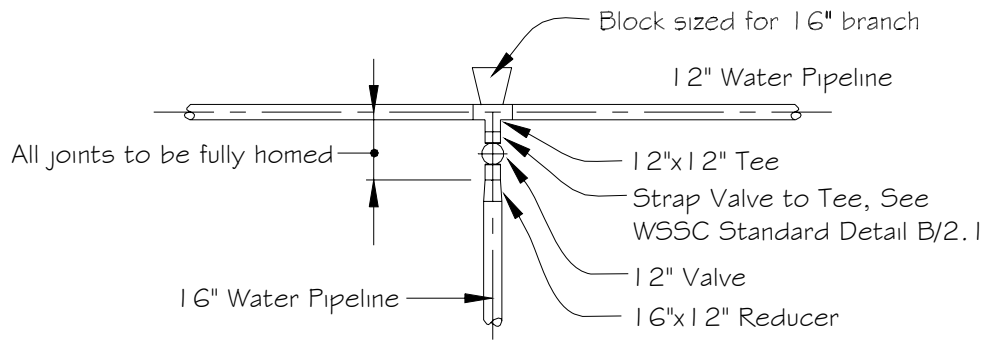
Welded-on Thrust Ring Block to Restrain Reducer (Large End)



SKETCH "OO"

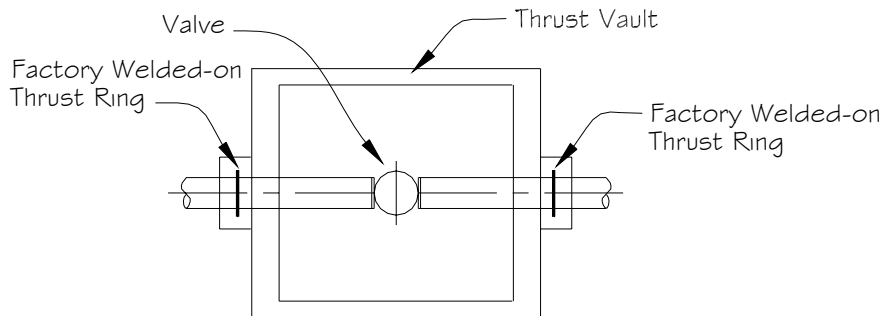
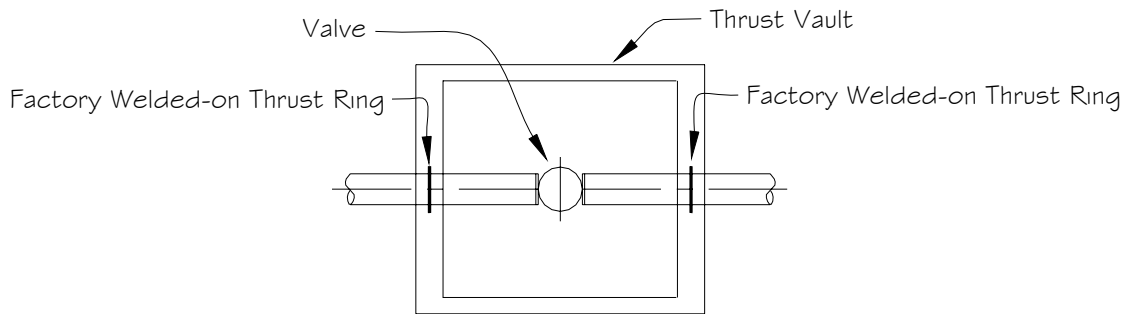
Welded-on Thrust Ring Block to Restrain Reducer (Small End)





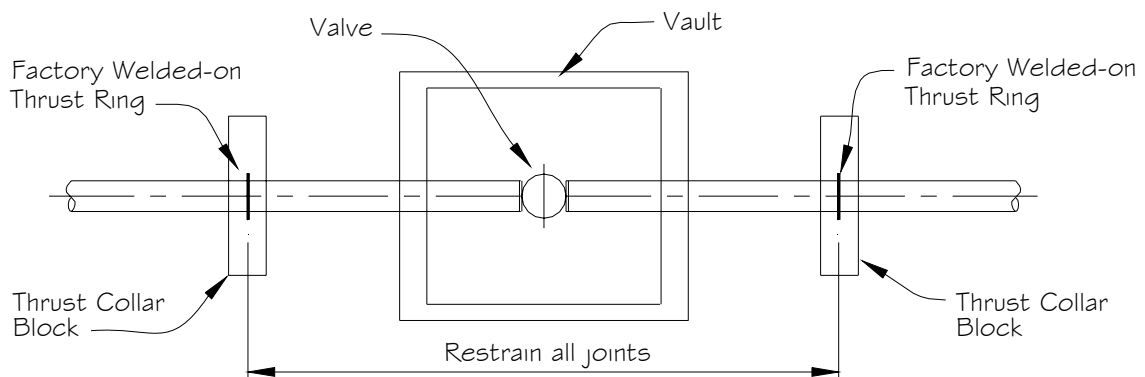
SKETCH "PP"

Blocking A Reducer When Reducing Down Into A Tee



SKETCH "QQ"

Schematic Examples of Thrust Vaults For 16" and Larger Valves



SKETCH "RR"

Valves 16" and Larger Restrained with Thrust Collar Blocking



n. Unbalanced Thrust at Connections to Existing Water Pipelines.

- 1) Take into account the potential unbalanced thrusts due to different pipe material and/or pipe deflections when making connections to existing or dissimilar pipelines. Provide pipe/joints restraints as necessary to balance these forces. This is especially true for large diameter water pipelines, where the thrust can be large.
- 2) Potential unbalanced thrusts - different pipe materials.
 - a) Check for unbalanced thrusts due to different pipe materials and different sealing diameters. The thrust generated is similar to that which occurs at reducers.
 - b) The sealing diameter is the internal diameter of the gasket at the bell joint, where the internal water pressure comes in contact. For DIP use the pipe OD and PCCP use the joint diameter at the gasket, see Table "29". For other pipe materials, verify the sealing diameter dimension, with the pipe manufacturer or the reference standards for the pipe.

TABLE "29"
DIP and PCCP Sealing Diameters

Pipe Sizes (inches)	Sealing Diameters (inches)		
	Ductile Iron Pipe (DIP) *	Lockjoint Prestressed Concrete Cylinder Pipe (PCCP) **	
		SP-5	SP-12
16	17.40	18.50	--
20	21.60	23.00	--
24	25.80	27.50	27.00
30	32.00	34.25	33.00
36	38.30	41.00	39.00
42	44.50	47.25	45.00
48	50.80	54.00	51.25
54	57.56	--	57.75
60	61.61	--	63.88

* from AWWA C151

** from Lockjoint Pipe Catalog

Example - Sealing diameters of different pipe material.

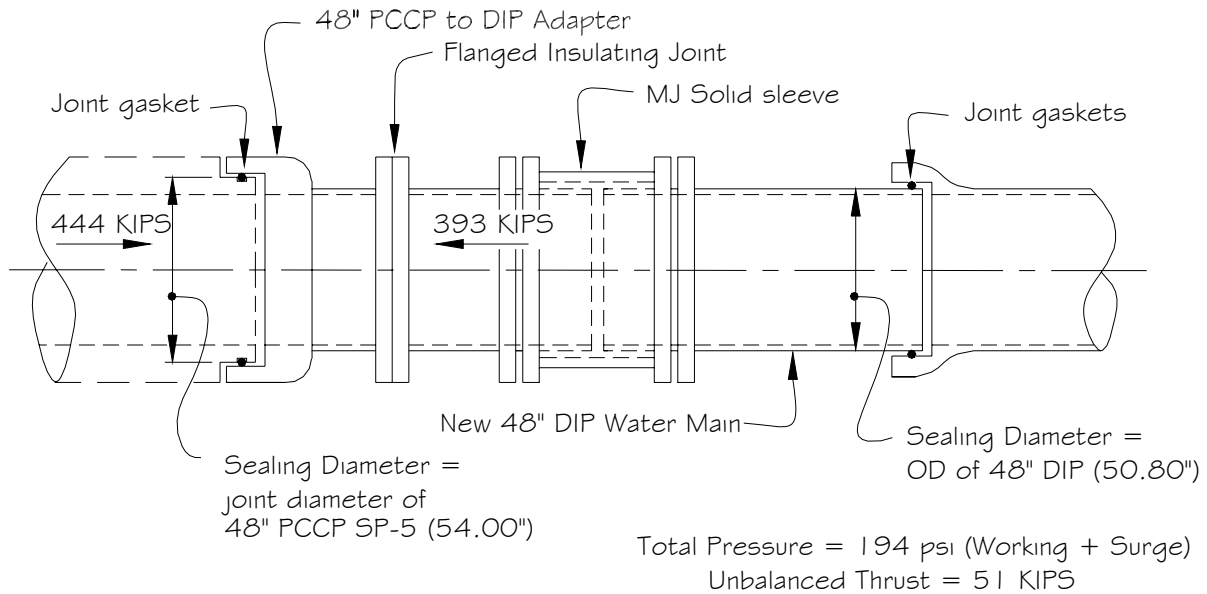
Existing 48" PCCP, SP-5 Water Main, Sealing diameter = 54.00 inches, see Table "29"

Proposed 48" DIP, Water Main, Sealing diameter = 50.80 inches, see Table "29"

Design Pressure: Working pressure = 124 psi Surge pressure = 70 psi

See Sketch "SS".





SKETCH "SS"

Connection PCCP to DIP Showing Unbalanced Thrusts

Determine the unbalanced thrust at the connection to the existing 48" PCCP water pipeline:

$$P = \text{design pressure} = \text{operating} + \text{surge}$$

$$= 124 + 70$$

$$P = 194.00 \text{ lb/in}^2$$

$$A_{\text{DIP}} = \text{pipe joint cross sectional area (sealing diameter)}$$

$$= \pi(\text{O.D.})^2/4$$

$$= \pi(50.80)^2/4, \text{ See Table 29}$$

$$A_{\text{DIP}} = 2026.89 \text{ in}^2$$

$$T_{\text{DIP}} = \text{Thrust for 48" DIP}$$

$$= A_{\text{DIP}} \times P$$

$$= (2026.89 \text{ in}^2)(194.00 \text{ lb/in}^2)$$

$$= 393,216.66$$

$$T_{\text{DIP}} = 393 \text{ KIPS}$$

$$A_{\text{PCCP}} = \text{pipe joint cross sectional area (sealing diameter)}$$

$$= \pi(\text{O.D.})^2/4$$

$$= \pi(54.00)^2/4, \text{ See Table 29}$$

$$A_{\text{PCCP}} = 2290.22 \text{ in}^2$$

$$T_{\text{PCCP}} = \text{Thrust for 48" PCCP}$$

$$= A_{\text{PCCP}} \times P$$

$$= (2290.22 \text{ in}^2)(194.00 \text{ lb/in}^2)$$

$$= 444,302.68$$

$$T_{\text{PCCP}} = 444 \text{ KIPS}$$

$$F = \text{Unbalanced Thrust} = P(A_{\text{PCCP}} - A_{\text{DIP}})$$

$$= (194.00 \text{ lb/in}^2)(2290.22 \text{ in}^2 - 2026.89 \text{ in}^2)$$

$$= (194.00 \text{ lb/in}^2)(263.33 \text{ in}^2)$$

$$= 51,086.02 \text{ lb}$$

$$F = 51 \text{ KIPS, Restrain or block the unbalanced thrust, see How to Restrain Reducers and Thrust Blocks for Quick Connections to Existing Pipelines, in this section.}$$

3) Potential Unbalanced Thrusts - Alignment deflections.

- a) Check alignment deflections for unbalanced thrust due to joint deflections, deflections in connecting pieces (PCCP bevel adapter), etc. The thrust generated is similar to that which occurs at bends. If possible, align the connection with no vertical/horizontal deflections.



- b) If the alignment has vertical/horizontal deflections, also account for the thrust restraints due to the alignment, see the example below.

Example - Unbalanced thrust due to an alignment deflection at the connection to existing pipelines:

Existing 48" PCCP, SP-5 Water Main,

Proposed 48" DIP, Water Main

Design Pressure: Working pressure = 124 psi Surge pressure = 70 psi

Connection requires Full Bevel Adapter (4°-15' deflection)

Determine the unbalanced thrust at the connection to the existing 48" PCCP water pipelines:

$$\begin{aligned}
 P &= \text{design pressure} & A_{\text{PCCP}} &= \text{pipe joint (sealing diameter) cross sectional area} \\
 &= \text{operating} + \text{surge} & &= \pi(\text{O.D.})^2/4 \\
 &= 124 + 70 & &= \pi(54.00)^2/4, \text{ see Table 29} \\
 P &= 194.00 \text{ lb/in}^2 & A_{\text{PCCP}} &= 290.22 \text{ in}^2
 \end{aligned}$$

$$\begin{aligned}
 R &= \text{resultant thrust at the bevel adapter} \\
 &= 2 P A \sin(\Theta \div 2) = 2 P A_{\text{PCCP}} \sin(4^\circ-15' \div 2) \\
 &= 2 (194.00 \text{ lb/in}^2) (290.22 \text{ in}^2) (\sin 2^\circ-07'-30'') \\
 &= (388.00 \text{ lb/in}^2) (290.22 \text{ in}^2) (0.0370797)
 \end{aligned}$$

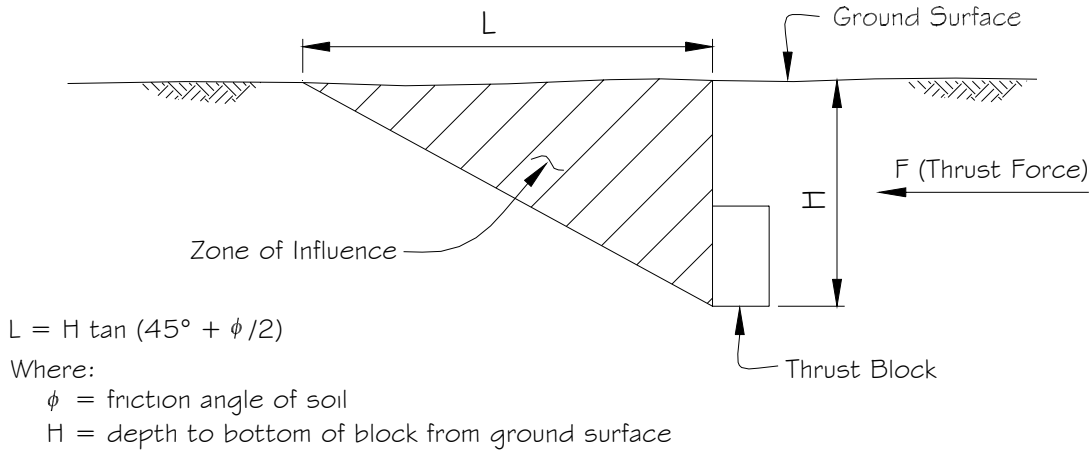
$$R = 32,949.26 \text{ lb.} \quad \text{The resultant thrust at the adapter may require concrete blocking, see Special Design Concrete Thrust Blocks, in this section.}$$

Also, take in consideration the unbalanced forces between the different pipe materials, see Example for "Sealing diameters of different pipe material", in this section.

o. Passive Soil Pressure for Concrete Thrust Blocks.

- 1) The function of concrete thrust blocks depends on the passive soil resistance. Sketch "TT" illustrates the approximate zone of influence and provides the equation to calculate the distance required behind a thrust block necessary for passive soil resistance. When determining if there is adequate passive soil resistance available for a proposed thrust block, consider the following items:
 - a) How likely are future excavations within the zone of influence?
 - b) Are there any utilities or structures within the proposed zone of influence for the block? Will the other utilities or structures be able to be excavated without the thrust block becoming unstable?
 - c) The passive earth pressures and active earth pressures shall not influence one another.
 - d) Take into account the slope of the ground in the calculations if it is ten (10°) degrees or more from the horizontal.
 - e) Are there any abnormal soil characteristics which may affect the passive resistance?





SKETCH "TT"

Zone of Influence for Passive Soil Resistance

p. Blocking Notes on the Drawings.

- 1) This section discusses where blocking notes should appear on the drawings and what information they should contain.
 - a) Location of Blocking Notes on the drawings.
 - (1) The notes should generally be placed on the first sheet, under "Blocking Notes". If these notes are not on the first sheet, there should be a note in the General Notes indicating which sheet they are on.
 - (2) Reference in the Blocking Notes, all standard and/or special details and restrained joints that are to be used for thrust restraint under the design contract.

Examples - Common Blocking Notes:

1. Strap fire hydrants to main, see Standard Detail B/2.1. Do not block fire hydrants or fire hydrant tees.
2. Block all horizontal bends with concrete, see Standard Detail B/1.0.
3. Block the 24"-1/8 HB at station 2+43 with concrete, see Standard Detail B/1.0, except use the following dimensions: $T = 5'-0"$, $H = 10'-0"$, $F = 1'-6"$, and $L = 12'-0"$.
4. Block 12"-1/8 HB at stations 0+00 and 3+87 at connections to existing 12" W according to Standard Detail B/3.2, see sheet 3 of 5 for details of the initial block.
5. Restrain all joints on 12" W from station 2+45 to station 3+25.

