

WATER AGENCIES' STANDARDS

Design Guidelines for Water and Sewer Facilities

SECTION 5.2 THRUST RESTRAINT AND ANCHOR BLOCKS

5.2.1 PURPOSE

The purpose of this section is to provide guidelines for the design of thrust blocks and anchor blocks for underground pressure pipelines. In general, thrust blocks and anchor blocks are required to provide thrust restraint to counteract forces created by the contents of underground pressure pipelines. For design specific to steel pipelines the reader should also refer to AWWA M-11.

5.2.2 STANDARD TERMS AND DEFINITIONS

Wherever technical terms or pronouns are used in these guidelines or in related documents, the intent and meaning shall be interpreted as described in industry accepted nomenclature and reference materials.

5.2.3 GENERAL

It is the responsibility of the user of these documents to refer to and utilize industry standards not directly referenced within this document as necessary. The Engineer of Work may not deviate from the criteria presented in this section without prior written approval of the Agency's Engineer.

5.2.4 GUIDELINE

Thrust blocks and anchor blocks are not required on steel pipe with welded joints where, in the opinion of the Agency's Engineer, pipe design provides adequate thrust restraint. In addition, thrust blocks and anchor blocks are not required on steel or ductile-iron pipe with flanged joints if sufficient thrust restraint has been achieved by the restraint system. For design of collar, wrapper and crotch plates for steel pipe refer to AWWA M-11.

Thrust blocks and anchor blocks may also be eliminated in locations where thrust-restraining fittings (including flanged fittings) are utilized along with thrust-restraining pipe joints, provided that thrust restraint systems are designed by the Engineer of Work in accordance with the manufacturers' instructions, are approved by the Agency's Engineer, and are shown on the Approved Plans.

The design and sizing of thrust blocks and anchor blocks shall conform to the following guidelines:

- A. Thrust blocks or anchor blocks are required on all unrestrained pressure pipelines at locations where thrust forces caused by internal pressures act upon the sides or ends of pipelines.
 1. Thrust blocks are required at all unrestrained tees, wyes, reducers, horizontal bends, ascending vertical bends, and dead-ends. Since the act of closing an in-line valve creates a dead-end, valves not connected to other fittings also require thrust blocks.

2. Anchor blocks are required at all unrestrained descending vertical bends.
- B. Thrust blocks and anchor blocks shall be formed from concrete poured against wetted, undisturbed soil. Concrete materials shall be in accordance with Section 03000 of the WAS Specifications unless otherwise directed by Agency's Engineer. Concrete shall be placed in accordance with the WAS Standard Drawing WT-01 and such that fittings and valves are accessible for repairs or replacement.

5.2.5 THRUST CALCULATIONS

Pipeline thrust shall be calculated using the following formulae. Calculations below use standard American units.

- A. Pipeline thrust at tees, wyes, in-line valves, and dead-ends:

$$T = 0.25\pi p d^2$$

Where: T = resultant thrust force (lb),
 p = internal pressure (lb/in²), and
 d = outside diameter of side (branch) outlet piping (for tees or wyes) or dead-end pipe (in).

- B. Pipeline thrust at bends:

$$T = 0.50\pi p d^2 (\sin \Delta / 2)$$

Where: T = resultant thrust force (lb),
 p = internal pressure (lb/in²),
 d = outside diameter of pipe adjacent to bend (in), and
 Δ = true angle of bend (degrees).

- C. Pipeline thrust at reducers:

$$T = 0.25\pi p (D^2 - d^2)$$

Where: T = resultant thrust force (lb),
 p = internal pressure (lb/in²),
 D = outside diameter of pipe adjacent to the large end of the reducer (in), and
 d = outside diameter of pipe adjacent to the small end of the reducer (in).

- D. Pipeline thrust at crosses:

For the most conservative approach and due to the fact that valves can be placed at crosses on any leg and the valve then closed the designer should use the approach above in Item B. for pipeline thrust at bends. The only difference is the angle at a cross will always be 90°.

E. Thrust Table for C900/C905 PVC:

The following tables show the thrust, in pounds, resulting from the installation of the noted fittings per 100 lb/in² of hydrostatic pressure applied to C900 and C905 PVC Pipe. For instance, if the required design pressure is 235 lb/in², multiply the values in the table by 2.35. Note that the design pressure is the class of pipe. The safety factor in conjunction with using the class of pipe as the design pressure provides sufficient redundancy for hydro-test conditions and minor surges for both thrust and anchor blocks. Values in the following tables are identical to those derived from the formulae shown above and are listed for convenience. Refer to AWWA M23 Manual of Water Supply Practices for more detail. Thrust values for all other pipe materials shall be calculated by the Engineer of Work.

Table 1 – Sample Table Thrust for AWWA C900 PVC Pipe (lb)								
Nominal Pipe Size (in)	Average Outside Diameter (in)	Pressure (lb/in ²)	Tees, Wyes, Valves, and Dead Ends	90° Bend	45° Bend	22.5° Bend	11.25° Bend	Class
4	4.80	100	1,810	2,559	1,385	706	355	200
6	6.90	100	3,739	5,288	2,862	1,459	733	200
8	9.05	100	6,433	9,097	4,923	2,510	1,261	200
10	11.10	100	9,677	13,685	7,406	3,776	1,897	200
12	13.20	100	13,685	19,353	10,474	5,340	2,683	200

Table 2 – Sample Table Thrust for AWWA C905 PVC Pipe (lb)								
Nominal Pipe Size (in)	*Outside Diameter (in)	Pressure (lb/in ²)	Tees, Wyes, Valves, and Dead Ends	90°	45°	22.5°	11.25°	Class
14	15.30	100	18,385	26,001	14,072	7,174	3,604	165/235
16	17.40	100	23,779	33,628	18,199	9,278	4,661	165/235
18	19.50	100	29,865	42,235	22,858	11,653	5,855	165/235
20	21.60	100	36,644	51,822	28,046	14,298	7,183	165/235
24	25.80	100	52,279	73,934	40,013	20,398	10,249	165/235

* The outside diameter is the same for both Class 165 and Class 235 PVC pipe. The thrust values are per 100 lb/in².

5.2.6 ALLOWABLE SOIL BEARING CAPACITY

Calculations to determine the size of thrust blocks or valve support blocks shall use the results of soil bearing capacity tests performed by a qualified geotechnical engineer when such test results are available. In the absence of such test results, allowable soil bearing capacity shall be determined by using the following table:

Chart 1 – Estimated Bearing Strength (Undisturbed Soil)	
Type of Soil	Allowable Soil Bearing Capacity
Muck, peat, etc.*	0 lb/ft ²
Soft Clay	500 lb/ft ²
Fine Sand	1,000 lb/ft ²
Decomposed Granite (D.G.)	1,500 lb/ft ²
Sandy Gravel	2,000 lb/ft ²
Cemented Sandy Gravel	4,000 lb/ft ²
Hard Shale	5,000 lb/ft ²
Granite	10,000 lb/ft ²

*In muck, peat or other incompetent soils, resistance shall be achieved by removal and replacement with ballast of sufficient stability to resist the intended thrusts. Design of thrust restraint systems in such cases shall be prepared by a qualified geotechnical engineer and shall be approved by the Agency's Engineer.

5.2.7 THRUST BLOCKS

- A. Thrust blocks shall be installed on unrestrained pressure pipelines at all tees, wyes, reducers, horizontal bends, ascending vertical bends, and dead-ends, and shall bear directly against fittings and firm, wetted, undisturbed soil. Thrust blocks shall be located so that bearing areas on both fittings and soil are centered along the direction of thrust. For tees and wyes, the direction of thrust is along a line directly opposite the side outlet. For bends, the direction of thrust is along a line bisecting the outside angle formed by the adjacent pipe segments. For reducers, the direction of thrust is along the pipeline from the large end to the small end of the reducer. For dead-ends, including in-line valves, the direction of thrust is along the pipeline.
- B. The required minimum area, in square feet, that a concrete thrust block must bear against undisturbed soil shall be in accordance with the following formula:

$$A = \frac{T}{S_b}(SF)$$

Where: A = area of thrust block (ft²),
 T = resultant thrust force (lb),
 S_b = allowable soil bearing capacity (lb/ft²), see Chart 1 for values,
and
 SF = safety factor (Use 1.5)

A passive resistance thrust block design is required if the height of the thrust block is greater than 0.5 times the depth from finish grade to the bottom of the designed thrust block. The required thrust block area using this method can be calculated as follows:

$$A = \frac{T(SF)}{\gamma H_t N_d + 2C_s \sqrt{N_d}}$$

Where: A = area of thrust block (ft²),
 T = resultant thrust force (lb),
 SF = safety factor (Use 1.5),
 γ = unit weight of soil (lb/ft³), use appropriate soil value,
 H_t = total depth to bottom of block (ft),

$$N_d = \tan^2 (45^\circ + \phi/2),$$

ϕ = soil internal friction angle (degrees), use appropriate soil value,

C_s = soil cohesion (lb/ft²), use appropriate soil value

Note: The thrust block area using the passive resistance thrust block design is generally larger than what is shown in Table 3. The engineer shall calculate thrust block sizes for this condition based upon each specific case. Refer to AWWA M23 Manual of Water Supply Practices for more detail.

The formulas above do not consider the weight of pipe and fittings. The Engineer of Work may alternately supply thrust block calculations that include the weight of the pipe and fittings to be restrained. Such alternate calculations shall be submitted to the Agency's Engineer for review and approval.

An undisturbed section of trench wall adjacent to the fitting and centered in the direction of thrust shall be excavated to dimensions providing the minimum bearing area calculated from the formula given above. In general, the bearing area shall be as close to square as is possible given actual field conditions. The shape and location of all thrust block excavations shall be approved by the Agency's Engineer prior to placing concrete. Thrust block excavations shall be keyed a minimum of twelve inches (12") into undisturbed soil.

Table 3 – Sample Table Thrust Block Size for PVC Pipe (ft²) Design Pressure = Class of Pipe; S_b=1,500 lb/ft²; SF=1.5							
Nominal Pipe Size (in)	Average Outside Diameter (in)	Tees, Wyes Valves, and Dead Ends	90° Bend	45° Bend	22.5° Bend	11.25° Bend	Class
4	4.80	3.6	5.1	2.8	2.0	2.0	200
6	6.90	7.5	10.6	5.7	2.9	2.0	200
8	9.05	12.9	18.2	9.8	5.0	2.5	200
10	11.10	19.4	27.4	14.8	7.6	3.8	200
12	13.20	27.4	38.7	20.9	10.7	5.4	200
14	15.30	30.3	42.9	23.2	11.8	5.9	165
16	17.40	39.2	55.5	30.0	15.3	7.7	165
18	19.50	49.3	69.7	37.7	19.2	9.7	165
20	21.60	60.5	85.5	46.3	23.6	11.9	165
24	25.80	86.3	122.0	66.0	33.7	16.9	165
14	15.30	43.2	61.1	33.1	16.9	8.5	235
16	17.40	55.9	79.0	42.8	21.8	11.0	235
18	19.50	70.2	99.3	53.7	27.4	13.8	235
20	21.60	86.1	121.8	65.9	33.6	16.9	235
24	25.80	122.9	173.7	94.0	47.9	24.1	235

* The values in this table were obtained assuming an allowable soil bearing capacity of 1500 lb/ft² for decomposed granite and per 100 lb/in². Differing soil conditions may apply.

- C. Thrust blocks are required for in-line valves not located adjacent to pipe fittings. Dead-end thrust is created when such valves are closed for repair or maintenance. Thrust blocks for in-line valves not located adjacent to pipe fittings shall be designed by the Engineer of Work for the approval of the Agency's Engineer and shall be detailed on the Approved Plans. Concrete valve support blocks as described in Section 5.3 are not intended to provide thrust restraint, and cannot be substituted for concrete thrust blocks.
- D. Concrete support blocks are required for all valves and fittings.
- E. Thrust blocks are to be placed in accordance with WAS Standard Drawing WT-01.

5.2.8 ANCHOR BLOCKS

- A. Anchor blocks shall be located at all unrestrained descending vertical bends. Thrust blocks are not suited for such applications because excavation necessarily disturbs soil in the direction of thrust. Anchor blocks rely on the weight of the concrete used to restrain thrust. Anchor blocks must include as a minimum two (2) number four (#4) steel reinforcing bars with 2-inch minimum concrete embedment as directed by the Agency's Engineer to assure secure attachment to the vertical bend.
- B. The required minimum volume, in cubic feet, of concrete anchor blocks shall be in accordance with the following formula:

$$Volume = \frac{T}{B}(SF) = \frac{2pA \sin \frac{\Delta}{2}}{B}(SF) = \frac{0.5\pi p d^2 \left(\sin \frac{\Delta}{2} \right)}{B}(SF)$$

- Where:
- T = total thrust (lb),
 - p = internal pressure (lb/in²),
 - A = area of pipe using outside diameter (in²)
 - B = density of block material, lb/ft³ (approximately 140 lb/ft³),
 - SF = Safety Factor (suggest 1.5)
 - Δ = true angle of bend (degrees).

The formula above does not consider the weight of pipe and fittings. The Engineer of Work may alternately supply anchor block calculations that include the weight of the pipe and fittings to be restrained. Such alternate calculations shall be submitted to the Agency's Engineer for review and approval. In addition, the buoyant density of the thrust block material must be used if it is anticipated that the soil could become saturated or if the water table is above the thrust block elevation.

The shape and location of all anchor blocks shall be approved by the Agency's Engineer prior to placing concrete.

5.2.9 NOTATIONS ON PLANS

- A. The Engineer of Work shall show the results of calculations for all thrust blocks and anchor blocks on the Approved Plans.

- B. Results of calculations for all thrust blocks and anchor blocks may be individually noted in plan drawings at the location(s) required, or may be presented in the form of a clear and complete "Thrust/Anchor Block Table." Thrust block and anchor block information shall include pipe station, type of block (Thrust or Anchor), test pressure, total thrust, assumed or tested soil capacity, and area or volume of block(s) required. If Thrust/Anchor Block Table(s) are used, they shall be shown on the same plan sheet as the fittings for which the thrust block(s) or anchor block(s) are required. An example of a typical Thrust/Anchor Block Table is shown in Figure A below:

**FIGURE A
Sample Table**

THRUST/ANCHOR BLOCK TABLE							
Pipe Sta.	Type/ Dia, of Pipe	Type of Block	Type of Appurtenance	Design Pressure	Total Thrust	Assumed Soil Capacity	Area or Volume of Block
3+52.50	PVC/8"	Thrust	22.5° Hor Bend	200 lb/in ²	5,020 lb	1,500 lb/ft ²	5.0 ft ²
6+10.00	PVC/8"	Thrust	45° Hor Bend	200 lb/in ²	9,847 lb	1,500 lb/ft ²	10.0 ft ²
6+20.00	PVC/8"	Anchor	22.5° Vert Bend	200 lb/in ²	5,020 lb	*N/A	54.0 ft ³
6+30.00	PVC/8"	Anchor	45° Vert Bend	200 lb/in ²	9,847 lb	*N/A	105.5 ft ³

* The specific weight of concrete is 140lb/ft³.

The example table shown above is intended to be representative only. Any similar format that conveys all information required to size thrust blocks and anchor blocks is acceptable.

Calculated areas or volumes shown in Thrust/Anchor Block tables shall be rounded up to the next ½ ft² or ½ ft³. In the example above, an assumed soil capacity of 1,500 lb/ft² is used. If soil bearing capacities are assumed, and, in the opinion of the Agency's Engineer, soils actually encountered on-site are not equal to or better than those assumed, the Engineer of Work shall promptly recalculate thrust block sizes based on observed soil conditions or on soil capacity tests and transmit such recalculations to the Agency's Engineer. If thrust block calculations rely upon the results of soils capacity tests, the appropriate column shall be labeled "Tested Soil Capacity" and the soils tests shall be submitted to the Agency's Engineer for review.

- C. In locations where thrust-restraining fittings (including flanged fittings) and thrust-restraining pipe joints are used in lieu of concrete thrust blocks, the length of the required thrust-restraining pipe system shall be clearly delineated and noted on the pipeline profile drawing(s). Thrust restraining systems shall not be used in conjunction with thrust blocks. The Engineer of Work shall submit calculations confirming the adequacy of the thrust restraint design detailed in the drawing(s) for the review and approval of the Agency's Engineer.

5.2.10 REFERENCES

- A. Should the reader have any suggestions or questions concerning the material in this section, contact one of the member agencies listed.

- B. The publications listed below form a part of this section to the extent referenced and are referred to in the text by the basic designation only. Reference shall be made to the latest edition of said publications unless otherwise called for. The following list of publications, as directly referenced within the body of this document, has been provided for convenience. It is the responsibility of the user of these documents to make reference to and/or utilize industry standards not otherwise directly referenced within this document.
1. Water Agencies' Standards (WAS)
 - a. Design Guidelines:
 1. Section 5.3, Line Valves
 - b. Standard Specifications:
 1. Section 03000 Cast in Place Concrete
 - c. Standard Drawings:
 1. WT-01
 2. AWWA M23 PVC – Design and Installation
 3. AWWA M11 Steel Pipe – A Guide for Design and Installation

END OF SECTION