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 District'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 District'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 or thrust-restraining pipe joints, provided that thrust restraint systems are designed by the Engineer of Work in accordance with the manufacturers' instructions. Engineer of Work must consider forces on joints upstream and downstream and restrain the necessary length of pipe in each direction.

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 03300 of the Specifications unless otherwise directed by District's Engineer. Concrete shall be placed

in accordance with the Standard Drawing W-20 and W-21 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, in-line valves, and dead-ends:

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

Where:

T = resultant thrust force (lb)
ρ = internal pressure $(\mathrm{lb/in^2})$
d = outside diameter of side (branch)outlet piping (for tees or wyes)or dead – end pipe (in)

B. Pipeline thrust at bends:

$$T = 0.50\pi\rho d^2 \sin\left(\Delta/2\right)$$

Where:

T = resultant thrust force (lb)
ρ = internal pressure $(\mathrm{lb/in^2})$
d = outside diameter of pipe adjacent to bend (in)
Δ = true angle of bend (degrees)

C. Pipeline thrust at reducers:

$$T = 0.25\pi\rho\left(D^2 - d^2\right)$$

Where:

T = resultant thrust force (lb)
ρ = internal pressure $(\mathrm{lb/in^2})$
D = outside diameter of pipe adjacent to the large end of the reducer (in)
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. Resultant Thrust Force Table for C900/C905 PVC:

The following table shows the thrust, in pounds, resulting from the required hydrostatic test pressure upon various fittings and types of pipe. Values in the following table is identical to those derived from the formulae shown above and are listed for convenience. Refer to AWWA M23, PVC Pipe Design and Installation for more detail. Thrust values for all other pipe materials shall be calculated by the Engineer of Work.

Table 5.2.1
Resultant Thrust Force

Pipe Size (in)	Outside Diameter (in)	Test Pressure (lb/in^2)	Tee, Valve & Dead End	90° Bend	45° Bend	22.5° Bend	11.25° Bend
				Thrust (lbs)			
AWWA C900, Class 305 PVC Pipe							
4	4.8	250	4,524	6,398	3,462	1,765	887
6	6.9	250	9,348	13,220	7,155	3,647	1,833
8	9.05	250	16,082	22,743	12,308	6,275	3,153
10	11.1	250	24,192	34,213	18,516	9,439	4,743
12	13.2	250	34,212	48,383	26,185	13,349	6,707
AWWA C905, Class 165 PVC Pipe							
14	15.3	215	39,529	55,902	30,254	15,423	7,749
16	17.4	215	51,124	72,301	39,129	19,948	10,022
18	19.5	215	64,209	90,806	49,144	25,053	12,587
20	21.6	215	78,784	111,417	60,298	30,740	15,444
24	25.8	215	112,400	158,958	86,028	43,856	22,034
AWWA C905, Class 235 PVC Pipe							
14	15.3	250	45,963	65,002	35,179	17,934	9,010
16	17.4	250	59,447	84,070	45,499	23,195	11,654
18	19.5	250	74,662	105,588	57,144	29,132	14,636
20	21.6	250	91,609	129,554	70,114	35,744	17,958
24	25.8	250	130,698	184,835	100,032	50,996	25,621

* The outside diameter is the same for both Class 165 and Class 235 PVC pipe.

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:

Table 5.2.2
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 District'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 (ft^2)
$T =$ resultant thrust force (lb)
$S_b =$ allowable soil bearing capacity (lb/ft^2), see Chart 1 for Values
$SF =$ 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 (ft^2)
$T =$ resultant thrust force (lb)
$SF =$ safety factor (use 1.5)
$\gamma =$ unit weight of soil (lb/ft^3), use appropriate soil value
$H_t =$ total depth to bottom of block (ft)
$N_d = \tan^2(45° + \emptyset/2)$
$\emptyset =$ soil internal friction angle (degrees), use appropriate soil value
$C_s =$ soil cohesion (lb/ft^2), 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 5.2.3. The engineer shall calculate thrust block sizes for this condition based upon each specific case. Refer to AWWA M23, PVC Pipe Design and Installation 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 District'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 District's Engineer prior to placing concrete. Thrust block excavations shall be keyed a minimum of twelve inches (12") into undisturbed soil.

Table 5.2.3
Thrust Block Bearing Area

Pipe Size (in)	Outside Diameter (in)	Test Pressure (lb/in^2)	Tee, Valve & Dead End	90° Bend	45° Bend	22.5° Bend	11.25° Bend
				Bearing Area (ft^2)			
AWWA C900, Class 305 PVC Pipe							
4	4.8	250	4.5	6.4	3.5	1.8	0.9
6	6.9	250	9.3	13.2	7.2	3.6	1.8
8	9.05	250	16.1	22.7	12.3	6.3	3.2
10	11.1	250	24.2	34.2	18.5	9.4	4.7
12	13.2	250	34.2	48.4	26.2	13.3	6.7
AWWA C905, Class 165 PVC Pipe							
14	15.3	215	39.5	55.9	30.3	15.4	7.7
16	17.4	215	51.1	72.3	39.1	19.9	10.0
18	19.5	215	64.2	90.8	49.1	25.1	12.6
20	21.6	215	78.8	111.4	60.3	30.7	15.4
24	25.8	215	112.4	159.0	86.0	43.9	22.0
AWWA C905, Class 235 PVC Pipe							
14	15.3	250	46.0	65.0	35.2	17.9	9.0
16	17.4	250	59.4	84.1	45.5	23.2	11.7
18	19.5	250	74.7	105.6	57.1	29.1	14.6
20	21.6	250	91.6	129.6	70.1	35.7	18.0
24	25.8	250	130.7	184.8	100.0	51.0	25.6

* The values in this table were obtained assuming an allowable soil bearing capacity of 1500 lb/ft2 for decomposed granite, 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 District'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 District Standard Drawing W-20.

5.2.8 ANCHOR BLOCKS

F. 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 District's Engineer to assure secure attachment to the vertical bend.

G. The required minimum volume, in cubic feet, of concrete anchor blocks shall be in accordance with the following formula:

$$Volume = \frac{T}{B}(SF) = \frac{2\rho A\left[\sin\left(\Delta/2\right)\right]}{B}(SF) = \frac{0.5\pi\rho d^2\left[\sin\left(\Delta/2\right)\right]}{B}(SF)$$

Where:

$T =$ total thrust (lb)
$\rho =$ internal pressure $(\mathrm{lb/in^2})$
$A =$ area of pipe using outside diameter $(\mathrm{in^2})$
$B =$ density of block material $(\mathrm{lb/ft^3})$, approximately 140 $\mathrm{lb/ft^3}$
$SF =$ safety factor (use 1.5)
$\Delta =$ 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 District'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 District'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 5.2.1 below:

THRUST/ANCHOR BLOCK TABLE							
Pipe Station	**Type/ Diameter of Pipe**	**Type of Block**	**Type of Appurtenance**	**Test Pressure**	**Total Thrust**	**Assumed Soil Capacity**	**Area or Volume of Block**
3+52.50	PVC/8"	Thrust	22.5° Hor Bend	250 lb/in^2	12,308 lb	1,500 lb/ft^2	12.3 ft^2
6+10.00	PVC/8"	Thrust	45° Hor Bend	250 lb/in^2	22,743 lb	1,500 lb/ft^2	22.7 ft^2
6+20.00	PVC/8"	Anchor	22.5° Vert Bend	250 lb/in^2	12,308 lb	*N/A	54.0 ft^3
6+30.00	PVC/8"	Anchor	45° Vert Bend	250 lb/in^2	22,743 lb	*N/A	105.5 ft^3

Figure 5.2.1
Sample Table for Plans

* 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 District'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 District'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 District's Engineer for review.

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 District's Engineer.

5.2.10 REFERENCES

Should the reader have any suggestions or questions concerning the material in this section, contact the District Engineer.

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. Valley Center Municipal Water District Standards:
    A. Design Guidelines
        i. Section 5.3, Line Valves
    B. Standard Drawings
        i. W-20 and W-21
    C. Technical Specifications
        i. Section 03000 Cast in Place Concrete
2. AWWA M23 - PVC Pipe Design and Installation
3. AWWA M11 Steel Pipe – A Guide for Design and Installation

END OF SECTION