Excerpt from

Recommended Practices for Installation of Underground Liquid Storage Systems

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APPENDIX A
FLOATOUT AND ANCHORAGE CALCULATIONS

A.1 Purpose. The purpose of the floatout and anchorage calculation is to determine the depth of burial from the top of the tank to finished grade necessary to prevent an underground tank from floating when empty and fully submerged. To do this, it is necessary that the total buoyant force be more than offset by the combined weight of the overburden (i.e., backfill material), paving over the tank, the weight of the empty tank, and associated equipment. In this appendix, the calculation for an empty, 8-foot nominal diameter, 10,000-gallon nominal capacity, double-walled, fiberglass-reinforced plastic (FRP) tank with the water table at grade is presented. These calculations are applicable to a single tank installation only.

A.2 Weight of Materials. The weight of material decreases when submerged. For our purposes, we have used the following submerged weights for common materials:

Material	Weight
Sand and pea gravel	60.0 pounds per cubic foot
Reinforced concrete	87.6 pounds per cubic foot
Tank and manways	5,000 pounds
Submersible pump and riser	300 pounds
Water	7.48 gallons per cubic foot
Water	62.4 pounds per cubic foot

A.3 Reflected-Tank Area. The reflected-tank area is the surface on which the overburden bears. In the case of cylindrical tanks, this is found by multiplying the actual tank diameter by its length. In the case of tanks with curved ends, the calculation is more complicated. The value we have used (231.42 square feet) was provided by the tank manufacturer:

Area of trapezoidal and circular-end segments	24.39	square feet
Cylindrical body	+ 207.03	square feet
Total	231.42	square feet

A.4 Tank Displacement. The buoyant force to be overcome is the total tank displacement, including the displacement of the structure and attached tank-top sumps. The following calculations illustrate two methods of calculating displacement. The method providing the larger value is more conservative and should be used.

Method #1. Calculate the total space occupied by the tank from data provided by the manufacturer.

Method #1	Cubic Feet	Gallons
Cylindrical tank body	1,290.67	9,654
Two curved ends	113.28	848
Two manways	5.08	38
	1,409.03	10,540

Method #2. Add the space occupied by the tank structure to the actual capacity of the tank, interstice, and manway.

Method #2	Cubic Feet	Gallons
Inner tank structure	15.18	114
Outer tank structure	15.75	118
Ribs (28)	9.42	70
Total tank structure	40.35	302
Tank capacity	1,300.80	9,730
Interstice capacity	82.89	620
Manway volume	5.08	38
	1,429.12	10,690

The alternative result, 1,429.12 cubic feet (10,690 gallons), should be used since it is more conservative. The tank manufacturers should provide information on their tank dimensions and capacity, on request.

A.5 Reinforced-Concrete Pad at Finished Grade. The 8-inch thick reinforced-concrete pad extends 2 feet beyond each end of the tank and extends 1 foot beyond each side of the tank. The paving will be 10' x 35', 350 square feet, 233.33 cubic feet. (350 square feet x 8 inches = 233.33 cubic feet.) Using the submerged weight of 87.6 pounds per cubic foot, the total weight of the paving is *20,440 pounds.*

A.6 Depth of Burial to Top of Tank. The depth of the overburden (backfill material) over the tank constitutes the greatest force for counteracting flotation. The burial depth must also be sufficient to allow piping to be sloped to the tank at least 1/8-inch per foot. Assuming that a total burial depth of 3'6" is sufficient for this purpose, we can make a trial calculation to determine if this combination of paving and burial depth will prevent floatout.

A.7 Volume and Weight of Overburden. To determine the depth of the overburden, it is necessary to deduct the thickness of the reinforced-concrete paving from the depth of burial to the top of the tank, (3'6" - 8" = 2'10" = 2.833 feet). We have assumed that pea gravel and sand

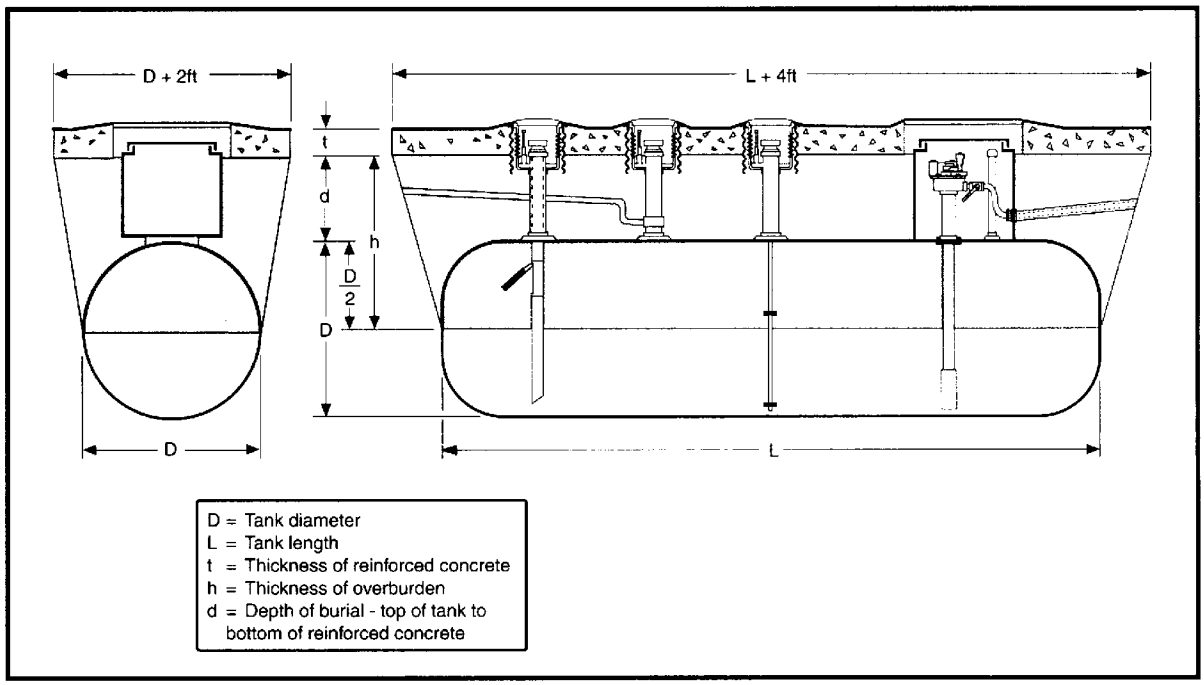

FIGURE A-1. ***Dimensions required for hold-down calculations.*** *The weight of overburden (shaded area) provides a great deal of the force available to offset buoyancy.*

have the same weight submerged, 60 pounds per cubic foot. The volume of the overburden can be calculated as follows:

$$[(h \div 3)\,(B1 + B2 + \sqrt{B1B2})] - [(V \div 2) + M]$$

Where:

D = Tank diameter, 7'11 1/4" (7.938 feet)

d = Depth of overburden, 2'10" (2.833 feet)

h = (D ÷ 2) + d = (7.938 ÷ 2) + 2.833
= 3.969 + 2.833 = 6.802 feet

B1 = Area of the concrete slab at grade,
350 square feet (See A.5)

B2 = Reflected-tank area,
231.42 square feet (See A.3)

V = Tank displacement, 10,690 gallons
(1429.12 cubic feet) (See A.4)

M = Void in overburden (4' x 4' tank-top sump),
41.85 cubic feet

Total volume of overburden

= [(h ÷ 3) (Bl + B2 + $\sqrt{B1B2}$)] - [(V ÷ 2) + M]

= [(6.802 ÷ 3) (350.00 + 231.42
+$\sqrt{350.00 \times 231.42}$)]
-[(1429.12 ÷ 2) + 41.85]

= 2.267 (581.42 + $\sqrt{80{,}997}$) - (714.56 + 41.85)

= 2.267 (581.42 + 284.60) - 756.41

= 2.267 (866.02) - 756.41

= 1963.27 - 756.41

= *1206.86 cubic feet of overburden*

Total weight of overburden

= 1206.86 cubic feet x weight of backfill material
(60 pounds per cubic foot)

= *72,412 pounds*

A.8 Adequacy of Restraining Forces. The adequacy of restraining forces is determined as follows:

Total restraining forces, in pounds	
Weight of overburden	72,412
Concrete paving at grade (See A.5)	20,440
Tank and manway weight, from manufacturer	5,000
Submersible pump and riser, from manufacturer	300
Total	98,152

Total buoyant force to be overcome, in pounds

Total displacement (A.4, Method #2)	
1,429.12 cubic feet at the weight of water (62.4 pounds per cubic foot)	89,177

Excess of restraining forces over buoyant forces, in pounds **8,975**

A.9 Calculation of Safety Factor. The safety factor in the example is 1.1 (98,152 ÷ 89,177). Because the density of backfill material varies, a safety factor of 1.2 is commonly used when calculating anchoring requirements. If a higher safety margin is desired, burial depth can be increased or supplemental restraints provided.

A.10 Effect of Adding 1 Foot to the Burial Depth. Adding 1 foot of burial depth adds significantly to the overburden. The addition of 17,371 pounds (89,783 –72,412) increases the total restraining force to 115,523 pounds and the safety factor to 1.3 (115,523 ÷ 89,177), as follows:

Where:
d = depth of overburden = 3'10" = 3.833 feet
h = (D ÷ 2) + d = (7.938 ÷ 2) + 3.833
= 3.969 + 3.833 = 7.802 feet
All other factors remain the same as A.7.

Total volume of overburden
= (7.802 ÷ 3) (866.02) - 756.14
= 2.601 (866.02) - 756.14
= 2252.52 - 756.14
= 1496.38 cubic foot of overburden

Total weight of additional overburden
= 1496.38 x 60 pounds per cubic foot
= 89,783 - 72,412 (See A.7)
= *17,371 pounds*

Total weight of restraining forces
= 98,152 (See A.8) + 17,371
= *115,523 pounds*

Comment

Adding to burial depth also provides room for pitching piping to the tank and protection from damage from traffic. When increasing burial depth, do not exceed the maximum allowable burial depth for the tank. (See Section 4.6.)

A.11 Applicability. Factors vary by geographic location, material supplier, and equipment manufacturer. Factors and calculations used in our example are not intended to represent good practice for a specific tank installation. They represent a frame of reference for specific calculations.

Manufacturers' instructions should always be followed. Contact the tank manufacturer if any doubt exists as to whether a specific installation requires additional burial depth or supplemental restraints.