

PA-9 Design of Circular Concrete Manure Tanks using MWPS TR-9, dated November 1983

Purpose: NRCS is providing this generic, circular concrete, tank design guide as an option for sites requiring uneven backfill where the concrete contractor has not been selected or does not have their own set of drawings. The savings in design costs and review time will be partially offset by higher construction costs. Contractors and/or owners can choose to obtain a site specific design from an engineering consulting firm. These will require a review, prior to use with NRCS funded projects.

Background: NRCS reviewed and approved the use of this version of MWPS TR-9 dated November 1983 and determined it was valid for both even (+/-4 feet) and un-even backfill (wall height -3 feet) tank situations. This was issued in Bulletin PA 210-0-6 dated February 6, 1990. The review report dated June 7, 1989 stated that the excessive reinforcing in the horizontal and vertical reinforcing along with the strength of footing was judged as meeting our medium life criteria for an unequal backfill condition. An additional Bulletin PA 210-2-3, allowed for kicker walls up to 4 foot without allowing for the uneven condition. Also, a Pennsylvania Supplement labeled "Figure 2" dated November 1983 allowed for the footer and floor as a monolithic placement and gave a floor steel schedule.

MWPS TR-9 was updated in 1998 and it did not allow for uneven backfill. Using the newer 1998 MWPS TR-9, NRCS developed PA-064.1-2 for even backfill (+/- 4 ft.) with an allowance for kicker walls. NRCS also contracted a consultant to develop drawings for even backfill (+/- 4 ft.) tanks with a ramp. These are designated as PA-067r-1_1-6. Out of that same design package, drawings without a ramp were developed and designated as PA-083-r1_1-3. This package requires even backfill, does not include the ramp, does not allow for a kickerwall, and is more economical than PA-064.1-2. These can be found on the PA NRCS website under technical resources, Standard Pennsylvania Drawings.

NRCS has obtained clarification from MWPS (September 25, 2013) that they do not support the original 1983 document and therefore it is not liable for copyright infringement or some other release for its use.

A re-review of the 1983 version was done by PA NRCS engineering staff and it was determined that the steel schedule still meets the criteria for PA Standard 313 for even and uneven backfill.

Use of MWPS TR-9, Dated November 1983

1. The use of this design guide is "Concurred with by NRCS" for meeting Practice Standard 313. The final configuration must be site specific. Projects done under NRCS Engineering Job Approval will need appropriate review and final approval. All other users do so at their own risk and agree to indemnify, defend and hold harmless NRCS against any claims, liability, and expense arising from such use.
2. The use of these drawings for liquid manure storage requires approval by a PA Registered Engineer or an Engineer working under NRCS Engineering Job Approval to meet PA DEP regulatory requirements.
3. This design guide does not have a set of construction drawings. The designer must develop a set of drawings showing the selected wall and footer details along with a site

specific planview and sufficient construction notes. See Waste Storage Facility PA 313i, Instructions for use, Design and Check Data Requirements found in the section III of the FOTG for complete package development. These elements along with the appropriate specifications are required to develop a complete site specific engineering package for PA Registered Engineer approval. Final approval includes site inspection, foundation verification, "As-builts" and PA Registered Engineer Signature.

4. Tank sizing should be based on Nutrient Management Plan and an Engineering Inventory and Evaluation Report.
5. Table 2 shall be amended to require a minimum wall thickness of 8" for the 8' and 10' deep tanks. The 12' and 14' tanks require a 12" thick wall.
6. Figure 2, floor & footer joint detail can be replaced by attached Supplement to MWPS TR-9, Figure 2 revised 11/13 to allow for monolithic placement of floor and footer and also shows required As for floor. Steel placement is not changed.
7. Design documentation should include printing out the four pages and label with project name, show tank depth and diameter on Figure 1, floor joint on Figure 2 or use supplemental floor joint dated 11/13, circle steel from Table 2 and 3 for footer steel and appropriate wall steel from one of tables 4 thru 7. Selection of wall steel for intermittent diameters requires selecting the next higher diameter.
8. The maximal fill differential from one side of the tank to the other is the tank height minus 3 feet for frost protection except for sites with kicker walls. Then the maximum difference from one side to the other is 4 feet. See "Supplement to MWPS" for details on kicker wall.
9. Tank depths are 8, 10, 12, and 14'. Steel schedules provided at 30, 60, 90 and 120' diameters. Use next larger tank diameter for steel spacing, bar size, and wall thickness.
10. 12' and 14' high tanks require a double mat of steel and floor to wall dowels. These dowels can be changed to "L" bars that match the layout of the vertical wall steel in each mat. Set waterstop between dowels.
11. See floor steel requirements and floor, wall, footer detail. An engineer needs to approve the floor steel reduction, if adding geotextile.
12. The tank shall be surrounded by a chain link or woven wire fence (min. height of 5'). Include all appropriate signage as outlined in PA Standard 313.
13. Install appropriate safety signs, gates and safety stops at pushoff locations. See PA Standard Drawing PA-039-r1 and PA-002A-r1 for additional information.
14. Agitation and access points require a 12" thick stone pad over properly compacted fill for all locations. Sites with axle loads exceeding 8K can choose to add (6) extra horizontal #6 bars @4" o.c. starting at top of wall and extending 12' beyond opening on each side for single mat or add (3) extra horizontal #6 bars for double mat tanks.

This report is intended for engineers with an understanding of reinforced concrete design, applicable codes, and soil properties. Although it includes design criteria, adequate reinforcing for selected sections, and suggested footing and floor details, local conditions may dictate specific changes in the designs shown. Any changes should be approved by a professional engineer.

The designs are for tanks either above or below ground. They are in agreement with Ultimate Strength Design, ACI 318-77. The designs assume concrete compressive strength, $f'_c = 4,000$ psi, and steel tension yield point, $f_y = 60,000$ psi.

A design example explains the figures and tables.

Table 1. Tank capacities.

Dia ft	Depth ft	Capacity ft ³	gal
30	8	5,655	42,411
"	10	7,069	53,014
"	12	8,482	63,617
"	14	9,896	74,220
40	8	10,053	75,398
"	10	12,566	94,247
"	12	15,079	113,097
"	14	17,593	131,947
50	8	15,708	117,810
"	10	19,635	147,262
"	12	23,562	176,715
"	14	27,488	206,167
60	8	22,619	169,646
"	10	28,274	212,058
"	12	33,929	254,469
"	14	39,584	296,880
90	8	50,894	381,703
"	10	63,617	477,129
"	12	76,341	572,555
"	14	89,064	667,981
120	8	90,478	678,584
"	10	113,097	848,230
"	12	135,717	1,017,876
"	14	158,336	1,187,522

Design example

Problem: Design a manure tank with diameter $D = 90'$ and height $H = 12'$.

Solution:

- From Table 1, capacity is 76,341 ft³ or 572,555 gal.
- From Table 2, required wall thickness, t_w , is 12". The volume of concrete in the wall is:
 $\pi(46^2 - 45^2) \times 12 = 3,430.6$ ft³ (127 yd³)
- Wall reinforcement from Table 6, $D = 90'$, and from Fig 2.
Ring reinforcement (A_{sr}): #4, 5" o.c. in each wall face from bottom of wall to height of 5'; from 5' height to top of wall, #4, 4½" o.c. each face. Vertical reinforcement (A_{sv}): #4, 11" o.c. in each face. Because the hinged base reduces ring tension, less ring reinforcement is needed at the bottom of the wall than farther up.
Install two curtains of steel in 12' and 14' deep tanks. Place the full tabulated steel in each curtain.
- Footing dimensions and reinforcement, Table 3, with $H = 12'$ and $D = 90'$:
Width = 48"; thickness = 12"
14" outside of wall
Steel = #4, 9" o.c. both ways
- Fig 2 shows the joint between wall and footing.

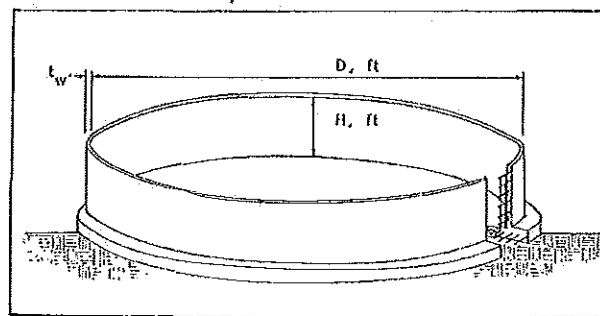


Fig 1. Round concrete manure tank.

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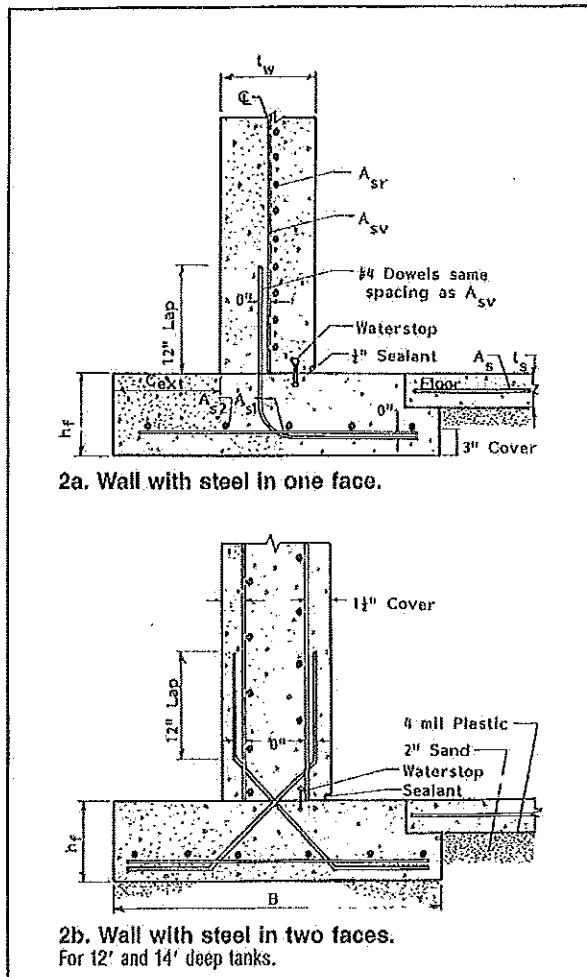


Fig 2. Wall to floor joints.

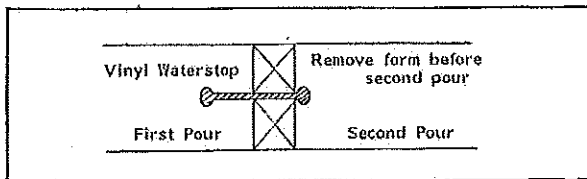


Fig 3. Floor joint.

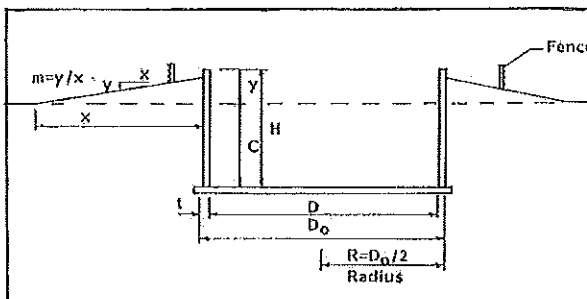


Fig 4. Backfill dimensions.

Table 2. Required wall thickness, t_w . ** -

H, ft	D, ft			
	30	60	90	120
8	6.0	6.0	6.0	8.0
10	6.0	6.0	7.0	9.5
12	12.0	12.0	12.0	12.0
14	12.0	12.0	12.0	14.0

**Minimum wall thickness shall be 8 in. -

Table 3. Ring foundations.

For tanks to 10' deep, allowable soil bearing must be at least 1 ksf. For tanks deeper than 10', allowable soil bearing must be at least 1.5 ksf.

Wall height H, ft	Tank diam D, ft	B in	h_i in	Mln C_{at} in	A_{11}	A_{12}
8	all	20	10	6	#4, 11"	#4, 11"
10	all	30	12	10	#4, 9"	#4, 9"
12	all	48	12	14	"	"
14 to 90	60	12	14	#4, 6"	"	"
14 to 90 up	60	12	15	"	"	"

Joints

Avoid wall joints if possible. Quantity of forming material or availability of concrete may make joints necessary. Vertical joints are easier to install and require less total length than horizontal joints.

In circular tanks, install temporary vertical bulkheads in the forms to divide the tank into more than one concrete pour. Extend reinforcing steel through the bulkhead at the end of the form so that ring tension is transferred from one wall section to the next. Extend the steel through the bulkhead far enough so that adequate lap splices are possible and so that all laps are not in a vertical line. Splices should conform to ACI 318, sections 12.2, 12.15, and 12.16.

Joints need to be watertight to prevent leakage and to protect the reinforcing steel. Position a commercially available water stop on the inside of the steel. Also put a $\frac{3}{4}$ " deep by $\frac{1}{2}$ " wide insert in the form next to the bulkhead to make a notch for caulking. A similar notch in the wall next to the floor is for caulking and is illustrated in Fig 2.

Both vertical and horizontal joints are constructed the same way, but vertical joints require less labor and material.

The procedure for making watertight floor joints is basically the same as for wall joints. Floor joints are control joints or contraction joints used to control cracking. Reinforcing steel is not extended through floor joints. See Fig 3.

Use floor joints for tank diameters 60' or larger. Joint along right angle diameters to form quadrants.

Choose caulking or joint sealant that resists chemical activity with the various manure components.

Table 4. Wall steel for 8' deep tanks.
Recommended bar size and spacing.

Height above floor, ft	Tank diameter, D ft							
	D = 30'		D = 60'		D = 90'		D = 120'	
	Asr	Asv	Asr	Asv	Asr	Asv	Asr	Asv
8	#4, 10"	#4, 10"	#4, 8"	#4, 10"	#4, 4"	#4, 10"	#5, 3.5"	#4, 8"
7	"	"	"	"	"	"	"	"
6	"	"	"	"	#4, 3.5"	"	#5, 4"	"
5	#4, 6"	"	#4, 4.5"	"	"	"	"	"
4	"	"	"	"	"	"	"	"
3	"	"	"	"	"	"	"	"
2	"	"	"	"	"	"	#5, 6"	"
1	"	"	"	"	"	"	"	"
0	"	"	"	"	"	"	"	"

Table 5. Wall steel for 10' deep tanks.
Recommended bar size and spacing.

Height above floor, ft	Tank diameter, D ft							
	D = 30'		D = 60'		D = 90'		D = 120'	
	Asr	Asv	Asr	Asv	Asr	Asv	Asr	Asv
10	#4, 10"	#4, 10"	#5, 9"	#4, 10"	#5, 5"	#4, 9.5"	#5, 3"	#4, 7"
9	"	"	"	"	"	"	"	"
8	"	"	"	"	"	"	"	"
7	"	"	#5, 6"	"	#5, 4"	"	#5, 3.5"	"
6	#4, 6"	"	"	"	"	"	"	"
5	"	"	#5, 5"	"	"	"	"	"
4	"	"	"	"	"	"	"	"
3	#4, 5"	"	"	"	"	"	"	"
2	"	"	"	"	#5, 5"	"	#5, 5"	"
1	"	"	"	"	"	"	"	"
0	"	"	"	"	"	"	"	"

Table 6. Wall steel for 12' deep tanks.
Recommended bar size and spacing. Place steel in two curtains, Fig 2b. Place the steel listed in each curtain.

Height above floor, ft	Tank diameter, D ft							
	D = 30'		D = 60'		D = 90'		D = 120'	
	Asr	Asv	Asr	Asv	Asr	Asv	Asr	Asv
12	#4, 11"	#4, 11"	#4, 8.5"	#4, 11"	#4, 4.5"	#4, 11"	#4, 3.5"	#4, 10"
11	"	"	"	"	"	"	"	"
10	"	"	"	"	"	"	"	"
9	"	"	#4, 5.5"	"	"	"	"	"
8	"	"	"	"	"	"	"	"
7	"	"	"	"	"	"	"	"
6	#4, 8.5"	"	"	"	"	"	"	"
5	"	"	"	"	"	"	"	"
4	"	"	"	"	#4, 5"	"	"	"
3	"	"	"	"	"	"	#4, 5"	"
2	"	"	"	"	"	"	"	"
1	"	"	"	"	"	"	"	"
0	"	"	"	"	"	"	"	"

Table 7. Wall steel for 14' deep tanks.
Recommended bar size and spacing. Place steel in two curtains, Fig 2b. Place the steel listed in each curtain.

Height above floor, ft	Tank diameter, D ft							
	D = 30'		D = 60'		D = 90'		D = 120'	
	Asr	Asv	Asr	Asv	Asr	Asv	Asr	Asv
14	#4, 11"	#4, 11"	#4, 11"	#4, 11"	#5, 9.5"	#4, 11"	#5, 5"	#4, 9.5"
13	"	"	"	"	"	"	"	"
12	"	"	#4, 8"	"	#5, 6"	"	"	"
11	"	"	"	"	"	"	"	"
10	"	"	#4, 5"	"	"	"	#5, 4.5"	"
9	#4, 8"	"	"	"	"	"	"	"
8	"	"	#4, 4"	"	#5, 5"	"	"	"
7	"	"	"	"	"	"	"	"
6	#4, 7"	"	"	"	"	#4, 8.5"	"	#4, 8"
5	"	"	"	"	"	"	#5, 5"	"
4	"	"	"	"	"	"	"	"
3	"	"	"	"	"	"	"	"
2	"	"	"	"	"	"	"	"
1	"	"	"	"	"	"	"	"
0	"	"	"	"	"	"	"	"

Concrete Quality

A 4,000 psi compressive strength was assumed in designing these tanks. The concrete used must also provide adequate durability under exposure to chemical attack and freeze-thaw cycles.

Use concrete with minimum 28-day compressive strength of 4,000 psi, minimum cement content of 564 lb/yd³, and maximum water-cement ratio of 0.49. Use Type I cement.

Use air-entrained concrete with the following minimum air content:

Maximum aggregate size and % air:

1" - 1½", 5%

¾" - 1", 6%

¾" - ¾", 7½%

Use the lowest slump (stiffest consistency) that is practical, because it will shrink less, reducing the potential for cracks. Suggested slumps are 4" with vibration, 6" without vibration.

Super plasticizer admixtures are available which greatly increase the slump for placing without the detrimental effects experienced by adding extra water. These admixtures should be specified by an experienced professional.

Placing

Place concrete in the forms in horizontal lifts of not over 2'. Consolidate each lift by vibrating or rodding. Pass the vibrator or rod through the lift being placed, so it penetrates the upper ¼ of the preceding lift so that no "cold" joints or "honeycombing" can remain. The time interval between lifts should not exceed 45 min so that each successive lift is continuous with the preceding one, as stated previously. For large tanks, it may be necessary to use two or more placing crews. If concrete cannot be supplied fast enough, reduce the lift depth. Casting the wall in sections reduces the number of workers needed and the demand for concrete. If concrete from the previous pour has set, wet the surface and brush on a cement paste just before placing more concrete.

Curing

Concrete gains strength by a chemical reaction (hydration) between cement and water. Curing reduces rapid evaporation of water in the concrete so that hydration can be complete. Curing is extremely important because it reduces shrinkage stresses, increases strength, and improves watertightness. Cure at air temperatures from 50-90 F.

Curing methods include a continual spray of water, a complete covering of polyethylene sheets, or a spray-on curing membrane. Continue curing for at least 3 days—7 days is preferred.

Backfilling

Exercise care in backfilling tanks in the ground, so soil load is uniform around the tank circumference. Place fill in lifts of about 12". Compact each lift to a density similar to the adjacent undisturbed

soil with a tamper or vibrator. Avoid backfill containing large rocks, hard soil chunks, or construction debris.

Unloading Station

Cast a 6" thick concrete slab adjacent to the tank for parking large tank wagons during emptying. The slab will reduce extra loads on the tank wall and prevent mud and erosion.

Safety

Open-top tanks built in the ground are a potential hazard for people and animals. Surround the tank with chain link or woven wire fencing and maintain it in good condition. Erect signs that state that the tank contains manure and is hazardous.

Optimum Excavation Depth

Concrete tanks are built either above or below ground depending on the application. The topography of the site and the tank use often determine the most desirable location and elevation. Other factors to consider are water table and bedrock depth.

Construction costs are lower for buried tanks if the excavated soil is backfilled against the tank wall. With this method, no soil needs to be trucked away and good drainage away from the tank is provided. The maximum depth of excavation "C" producing fill for earth berming is given by the equation:

$$m(R+x)^3 - mR^3 - 3R^2H = 0$$

$m = y/x = \text{slope of berm}$

$R_o = \text{outside tank radius} = \text{diameter}/2, \text{ ft}$

$D_o = \text{outside tank diameter, ft}$

$H = \text{tank depth}$

$x = \text{width of berm, ft}$

$= y/m = (H-C)/m$

$y = \text{height of berm, ft}$

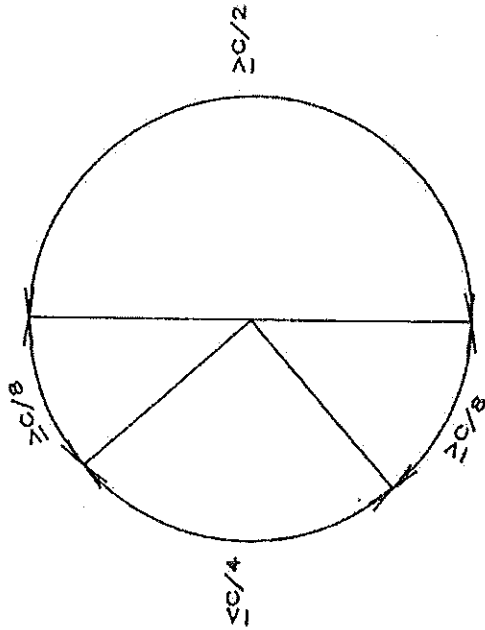
$C = \text{depth of tank below grade, ft}$

Table 8. Excavation depth for berm soil.

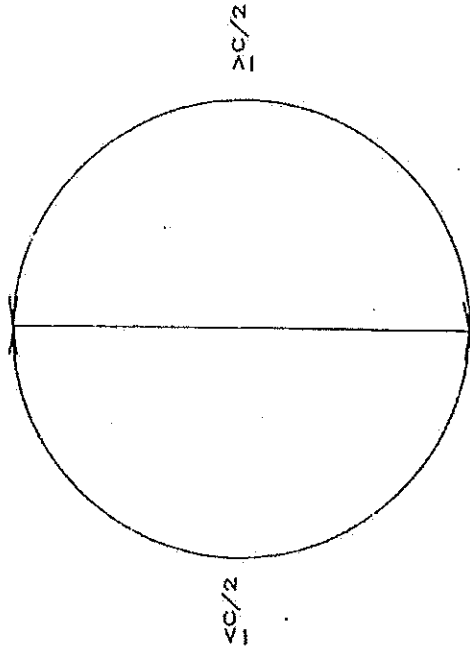
If the tank is installed to depth C tabulated, the excavation soil will form the berm.

H ft	D _o ft	Berm slope, m		
		¼	½	⅓
----- Depth C, ft -----				
8	31	4.4	5.5	6.1
"	61	3.4	4.4	5.4
"	91	2.8	3.8	4.8
"	121	2.4	3.4	4.4
10	31	5.9	7.0	7.9
"	61	4.6	5.9	7.0
"	91	3.9	5.2	6.4
"	121	3.4	4.7	5.9
12	32	7.4	8.7	9.7
"	62	6.0	7.4	8.7
"	92	5.0	6.6	8.0
"	122	4.4	6.0	7.5
14	32	9.0	10.4	11.5
"	62	7.3	9.0	10.5
"	92	6.3	8.1	9.7
"	122	5.5	7.4	9.1

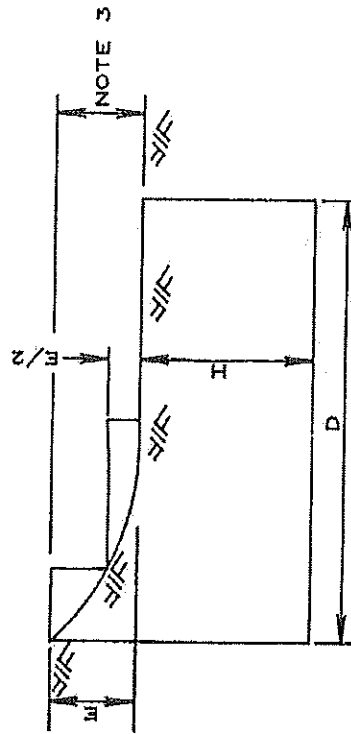
FOR $2' < E \leq 4'$



FOR $E \leq 2'$

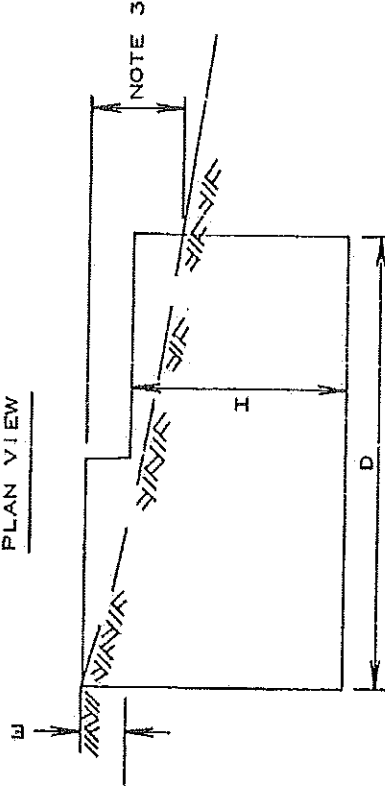


PLAN VIEW



ELEVATION

PLAN VIEW



ELEVATION

NOTES:

1. The dimensions shown represent the limitations for the use of "kicker walls" as per PA Bulletin No. PA 210-2-3.
2. The reinforcement steel on the extension height (E) is the same as that in the top section of the design height (H).
3. Maximum backfill differential is 4 feet.

C = CIRCUMFERENCE

D = DIAMETER

E = EXTENSION HEIGHT OF WALL

H = HEIGHT AT TOTAL DESIGN VOLUME (includes freeboard)

Not To Scale

SUPPLEMENT TO MAPS TR-9

Designed A. Wood Date 4/8/92

Drawn S. Dunn

Approved B. Borefs Sheet No 1 of 1

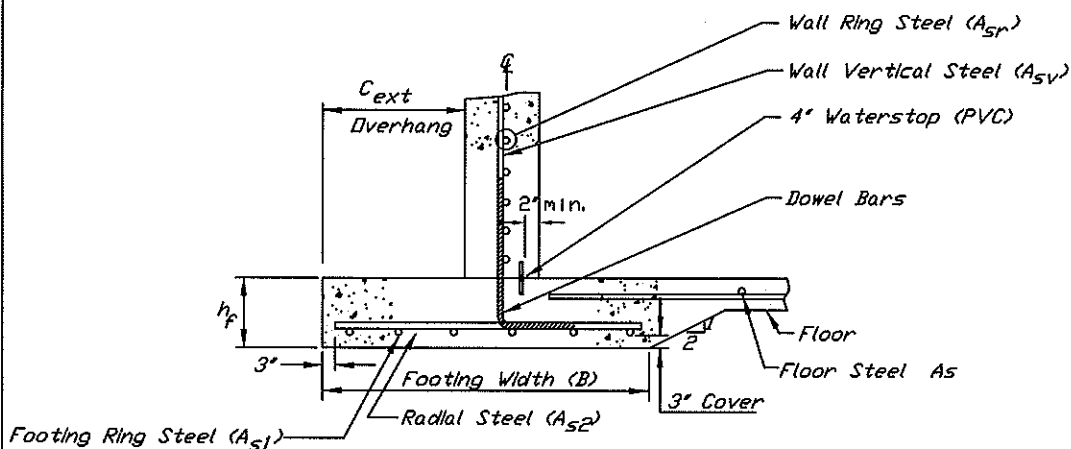


Figure 2 -MONOLITHIC FOOTING/FLOOR DETAIL

Note: Applies to both single and double mat tanks. Use of joints requires Design Engineer approval

FLOOR STEEL (A_s)

DISTANCE BETWEEN JOINTS *	FOR 5" THICK FLOOR	
	A_s	EXAMPLE
$\leq 30'$	.029	6X6-W1.4xW1.4 (10 ga.)
$>30' \leq 60'$	.058	6x6-W2.9xW2.9 (6 ga.)
$>60' \leq 90'$	.087	#3 @ 15"
$>90' \leq 120'$	.12	#4 @ 18"

This table is for floors on coarse granular or cohesive material. For floors on sand or pervious geotextile, A_s may be reduced 50% with PE approval.

Additional Notes:

- 1) Use this footing/floor detail. Use of joints requires Design Engineer approval.
- 2) 4" HD CPT footer drain required with free outlet.
- 3) Minimum of 3" of ASHTO #57 stone under floor. Also include 12" wide by 6" bands of stone under footer every 50'.
- 4) Minimum soil bearing shall be 2000 PSF. Additional site preparation will be needed for sites with poor bearing conditions and must be approved by PE.
- 5) NRCS Practice Standard 313 and Construction Specification 313 must be followed.

Approved By	_____	_____	_____
Title	_____	_____	_____

Designed	_____	_____	_____
Drawn	_____	_____	_____
Reviewed	_____	_____	_____
Checked	_____	_____	_____



TR-9, Figure 2 and Floor Steel Schedule

File Name	_____
Sheet	_____ of _____