Chapter 2. Secondary Containment Facility

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Secondary containment refers to structures built around pesticide storage, fertilizer storage, rinsate storage, and areas used for mixing or loading. Secondary containment structures are used to contain pesticides and fertilizers (liquid or dry) that have escaped from the primary storage due to leaks, spills, fire, impacts, vandalism, or ruptured tanks and to prevent them from moving into the environment. Secondary containment systems are designed to provide adequate time for site operators to capture and clean up spills, secure the contaminated materials, and repair damage to the primary storage containers. Secondary containment systems are not designed to hold liquid for long periods.

Proper storage management, that is, preventing or minimizing leaks, spills, and other incidents, is the first and foremost defense against environmental contamination. When an accident occurs, however, the secondary containment is intended to be the safety net. Proper design and construction of a secondary containment are essential. Subsequent routine inspection and maintenance are imperative if a secondary containment system is to function as intended. Worker safety, state, and federal regulations must be taken into account in facility design.

Functional Secondary Containment Design

Fertilizer and pesticide secondary containment structures must be designed as separate and segregated areas. The main functional areas of secondary containment structures are typically identified as:

- Fertilizer Storage
- Pesticide Storage
- Rinsate Storage
- Sludge Storage

Separation and segregation of fertilizer and pesticide secondary containment structures allows the pesticide or fertilizer to be recovered and used as it was intended. This prevents the recovered mixture from potentially becoming a hazardous waste. Storage of bulk pesticide and bulk fertilizer in a common secondary containment structure is not recommended but is allowed if the secondary containment structure is in a fully enclosed building.

A mixing and loading pad can be considered a secondary containment structure for bulk pesticides, bulk fertilizer, and rinsate storage tanks. It must meet the largest storage capacity to meet either a secondary containment capacity or a mixing and loading pad capacity. Multiple product storage and uses of a single area (such as a mixing loading pad) can create management problems. Mixtures of fertilizer, pesticide, and rinsate and other possible wastes may be more difficult to use or dispose of properly.

Provide additional and separate containment pans around valves, pumps, and mixing tanks to catch small leaks and spills that occur regularly in these areas. This confines the released product to a smaller area making it easier to recover and preventing contamination of the larger secondary containment structure. It also minimizes the volume of recovered rinsate that will have to be handled. Precipitation falling in an open contaminated secondary containment structure increases the volume of rinsate that will have to be recovered and handled properly.

Design details

Slope secondary containment floors 2 percent to a single sump so contaminated precipitation (rinsate) can be easily recovered and pumped out. Sump pumps transfer the rinsate into storage tanks within a secondary containment structure. Equip sump pumps with automatic cutoff switches to prevent overfilling the storage tanks. Unless you know for certain what the rinsate liquid contains, it should be tested before deciding how the rinsate can be used appropriately.

Roofs adjacent to a secondary containment structure should be guttered to prevent clean rainwater from draining into the secondary containment structure. It is best to keep clean water clean rather than dealing with a large volume of contaminated rinsate from the secondary containment structure. Any recovered rinsate should be handled in an appropriate manner. This may be as simple as using the rinsate as make-up water for spray solutions. **NOTE:** Never let precipitation accumulate in an open secondary containment structure for more than one or two days. Accumulated liquid within the secondary containment reduces the capacity of the secondary containment to hold the required volumes of the primary storage tanks if they were to rupture. Another reason not to allow precipitation to accumulate in a secondary containment is that secondary containment structures are not designed to be completely watertight under a constant hydrostatic pressure.

Storage tank seats

It is beneficial to elevate steel storage tanks a few inches above the secondary containment floor to keep the tank bottom dry, to prevent corrosion, and to allow the manager to check for leaks. One method of elevating tanks is to place them on a bed of smooth, rounded stones as illustrated in Figure 2.1a. This method also allows the tank to be easily leveled on containment floors that slope to a sump. Another method is to lay preservative treated 2 × 6 boards flat on the floor spaced a few inches apart with the boards oriented parallel to the slope of the floor. Set the storage tank on the boards, Figure 2.1b. Another approach is to place an additional 4- to 6-inch thick concrete pad on top of the structural floor to elevate the tanks, Figure 2.1c. Extend the tank pads about 2 feet beyond the edges of the tank. If storage tanks are in a secondary containment incorporating a synthetic liner and felt pad, place 6 inches of smooth stone under the tank, Figure 2.2.

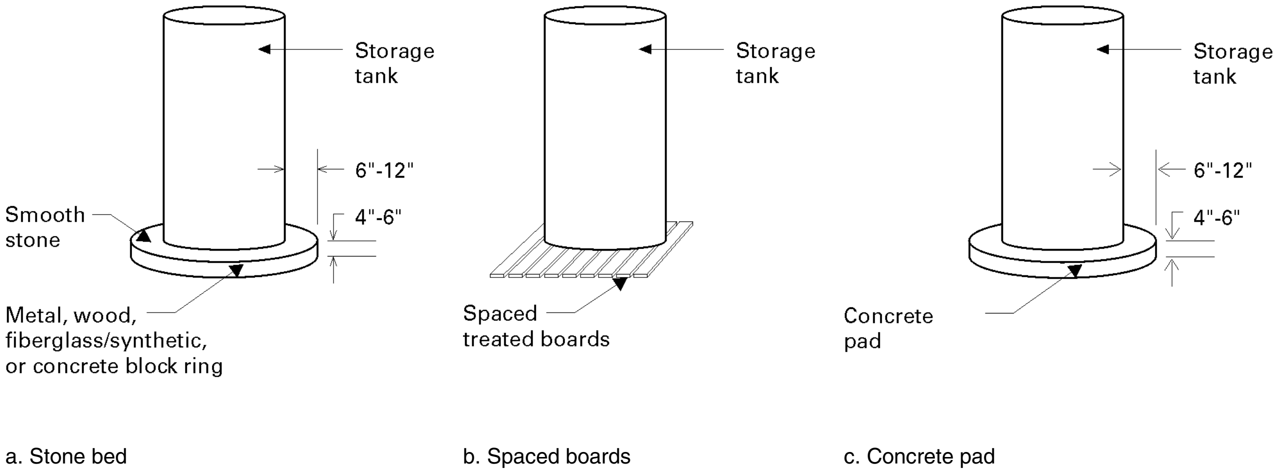


Figure 2.1. Elevated storage tank on stone bed (a), spaced boards (b), concrete pad (c).

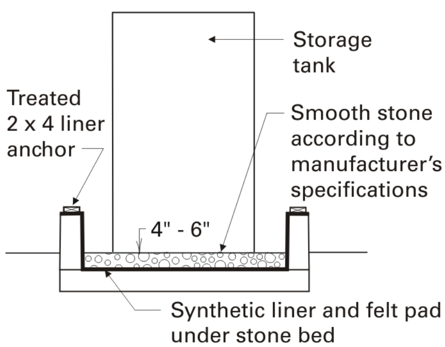
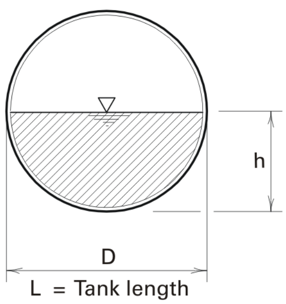


Figure 2.2 Synthetic liner under stone bed.

Sizing Secondary Containments

Secondary containment facilities must be large enough to hold all bulk pesticide or fertilizer that could leak from the largest storage tank, plus any other items that occupy volume within the secondary containment structure, such as other storage tanks, pumps, mixing equipment, concrete anchor blocks, and precipitation that falls within the containment structure.

Secondary containment is designed to hold at least 125 percent (110 percent if tanks are indoors) of the volume of the largest tank plus the displaced volumes of other tanks and equipment in the secondary containment (for example, the amount of liquid displaced by the portion of tanks below the height of the secondary containment wall). Figures 2.3a, 2.3b, and 2.3c and Tables 2.1 through 2.3 show how to calculate the volumes of horizontal, cylindrical, vertical, and cone-bottom tanks.



Horizontal cylindrical tank fluid volume (center section of tank):

$$V_1 = \left[\frac{\pi}{8} D^2 - \frac{D^2}{4}\sin^{-1}\left(1 - \frac{2h}{D}\right) - \left(\frac{D}{2} - h\right)\left(Dh - h^2\right)^{0.5}\right](L)$$

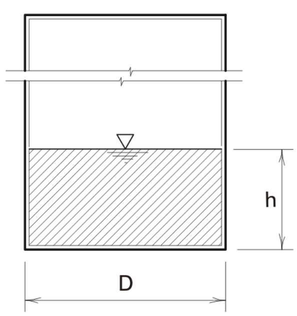
Spherical tank fluid volume (end sections of tank):

$$V_2 = \frac{\pi}{3} h^2 (1.5D - h)$$

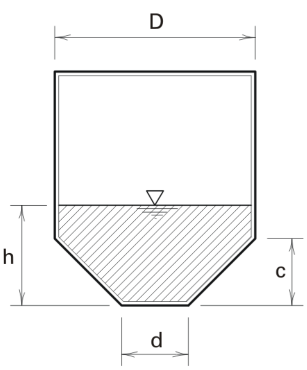
Total tank fluid volume:

$$V = V_1 + V_2$$

a. Horizontal



$$V = \frac{\pi}{4} D^2 h$$



Fluid level above cone:

$$V = \frac{\pi}{3} h\left(D^2 + d^2 + Dd\right) + \frac{\pi}{4} D^2 (h - c)$$

Fluid level within cone:

$$V = \frac{\pi}{3} h\left(K^2 + d^2 + Kd\right)$$

Where:

$$K = \frac{h}{cD} + d\left(1 - \frac{h}{c}\right)$$

b. Vertical tanks

c. Cone bottom tanks

Figure 2.3. Equations for tank volumes.

Table 2.1. Volume of vertical cylindrical tanks.

	Volume (ft^3)		Volume (gal)	
Diameter (ft)	Per foot of height	Per inch of height	Per foot of height	Per inch of height
4	12.57	1.05	94.00	7.83
5	19.63	1.64	146.87	12.24
6	28.27	2.36	211.49	17.62
7	38.48	3.21	287.86	23.99
8	50.27	4.19	375.99	31.33
9	63.62	5.30	475.86	39.65
10	78.54	6.54	587.48	48.96
11	95.03	7.92	710.85	59.24
12	113.10	9.42	845.97	70.50
13	132.73	11.06	992.84	82.74
14	153.94	12.83	1151.46	95.95
15	176.71	14.73	1321.83	110.15
16	201.06	16.76	1503.94	125.33
17	226.98	18.92	1697.81	141.48
18	254.47	21.21	1903.43	158.62
19	283.53	23.63	2120.79	176.73
20	314.16	26.18	2349.91	195.83

Table 2.2. Volume of horizontal cylindrical tanks, cu. ft.

Fluid level, ft	Diameter, ft						
	4	6	8	10	12	14	16
0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.5	0.91	1.13	1.31	1.47	1.61	1.74	1.87
1.0	2.46	3.10	3.63	4.09	4.50	4.88	5.23
1.5	4.30	5.53	6.52	7.39	8.16	8.86	9.52
2.0	6.28	8.25	9.83	11.18	12.39	13.49	14.51
2.5	8.26	11.15	13.42	15.35	17.07	18.63	20.06
3.0	10.11	14.14	17.22	19.82	22.11	24.19	26.10
3.5	11.66	17.12	21.14	24.50	27.44	30.10	32.53
4.0	12.57	20.02	25.13	29.34	33.00	36.29	39.31
4.5		22.75	29.12	34.28	38.74	42.73	46.37
5.0		25.18	33.05	39.27	44.60	49.35	53.68
5.5		27.15	36.85	44.26	50.56	56.13	61.19
6.0		28.27	40.44	49.20	56.55	63.02	68.87
6.5			43.74	54.04	62.54	69.97	76.67
7.0			46.64	58.72	68.49	76.97	84.57
7.5			48.96	63.19	74.36	83.96	92.54
8.0			50.27	67.36	80.10	90.92	100.53
8.5				71.15	85.66	97.81	108.53
9.0				74.45	90.99	104.58	116.49
9.5				77.07	96.03	111.21	124.39
10.0				78.54	100.71	117.65	132.19
10.5					104.94	123.84	139.87
11.0					108.60	129.75	147.38
11.5					111.48	135.31	154.69
12.0					113.10	140.45	161.75
12.5						145.07	168.53
13.0						149.06	174.96
13.5						152.19	181.00
14.0						153.94	186.56
14.5							191.54
15.0							195.83
15.5							199.19
16.0							201.06

Table 2.3. Volume of horizontal cylindrical tanks, gallons.

Fluid level, ft	Diameter, ft						
	4	**6**	**8**	**10**	**12**	**14**	**16**
0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.5	6.78	8.42	9.78	10.98	12.06	13.05	13.97
1.0	18.38	23.17	27.13	30.57	33.67	36.51	39.14
1.5	32.20	41.35	48.80	55.26	61.03	66.31	71.19
2.0	47.00	61.71	73.51	83.64	92.68	100.90	108.50
2.5	61.80	83.41	100.38	114.85	127.68	139.33	150.08
3.0	75.62	105.75	128.78	148.23	165.39	180.92	195.21
3.5	87.21	128.08	158.15	183.25	205.26	225.11	243.34
4.0	94.00	149.78	187.99	219.44	246.85	271.47	294.02
4.5		170.15	217.83	256.40	289.76	319.61	346.87
5.0		188.32	247.20	293.74	333.64	369.17	401.53
5.5		203.07	275.60	331.08	378.16	419.86	457.72
6.0		211.49	302.48	368.04	422.98	471.37	515.13
6.5			327.18	404.23	467.81	523.41	573.51
7.0			348.86	439.25	512.33	575.73	632.60
7.5			366.20	472.63	556.21	628.04	692.17
8.0			375.99	503.83	599.12	680.09	751.97
8.5				532.22	640.71	731.60	811.77
9.0				556.90	680.58	782.28	871.34
9.5				576.50	718.28	831.85	930.43
10.0				587.48	753.29	879.99	988.81
10.5					784.93	926.35	1046.23
11.0					812.30	970.54	1102.41
11.5					833.91	1012.12	1157.08
12.0					845.97	1050.55	1209.92
12.5						1085.15	1260.60
13.0						1114.95	1308.73
13.5						1138.41	1353.86
14.0						1151.46	1395.44
14.5							1432.75
15.0							1464.81
15.5							1489.97
16.0							1503.94

Secondary containment wall height

The maximum allowable containment wall height is 4 feet. Higher walls are expensive to construct to withstand the full hydrostatic head of liquid and increase tank anchoring requirements and the risk of pipe ruptures due to tank flotation. In general, a 4-foot containment wall height is safer, more practical, and more functional than a higher wall. If a higher wall is selected, wide steps or stairs with handrails on both sides of the wall at gates in the security fence may be an adequate solution for worker safety, comfort, and convenience. However, steps over walls present a continual safety problem for workers, especially in icy conditions.

Secondary containment floor area

Additional floor area may be necessary to allow adequate floor space for present and future tanks plus mixing and transfer equipment in the secondary containment structure. Space also may be needed for replacing small existing tanks with larger diameter tanks in the future. Workers also need space to move between tanks and move over containment walls without undue risk or hazards. If possible, orient tank weld seams toward the interior of the containment structure, and orient tank outlet valves toward the center of the containment structure in case there is a plumbing or weld failure. Having the welds and outlet valves toward the interior of the containment structure could possibly prevent a leak from squirting over the secondary containment wall.

Provide at least the required 2 feet between tanks and 2 feet between a tank and a containment wall to allow visual inspection of the tanks. More space may be needed between some of the tanks to allow room for pipes, pumps, and valves, Figure 2.4. The 2-foot distance between a tank and a secondary containment wall may not be adequate to contain spurting (jetting) leaks from tall tanks. Workers should not have to climb over piping to get between tanks. Usually, the guidelines for spacing tanks, rather than the calculated required volume, control the dimensions for floor areas in secondary containments.

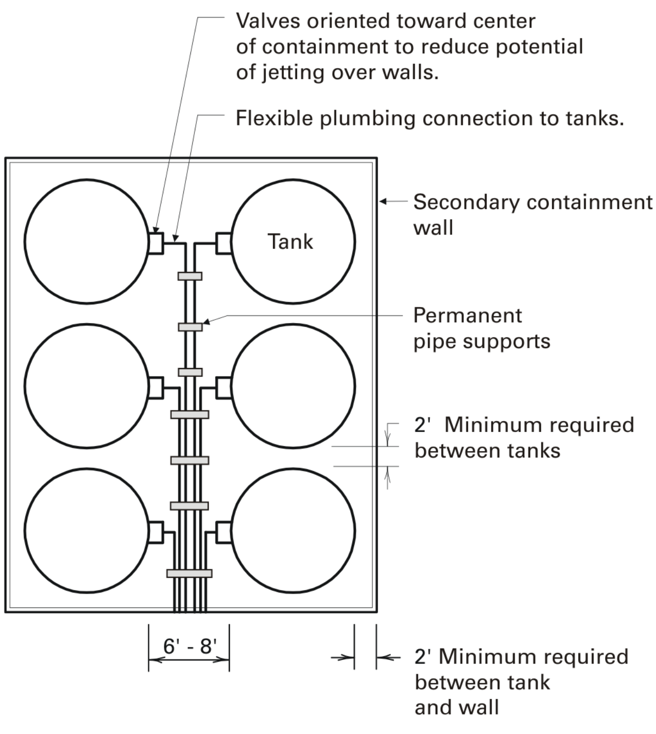


Figure 2.4. Tank spacing in secondary containment.

Figure 2.5 shows the minimum secondary containment floor area (MSCFA) required to provide space for the tanks and the required 2 feet between each tank and the 2 feet between a tank and walls for several common layouts with all vertical tanks of the same diameter. MSCFA is calculated based on inside dimensions of the secondary containment walls. Plan for the future when designing the secondary containment capacity. Even though an operation presently has 8-foot and 12-foot diameter tanks, it may prefer all 12-foot diameter tanks in the future. It is best to design a containment structure for the largest tanks to allow flexibility for changes in the facility.

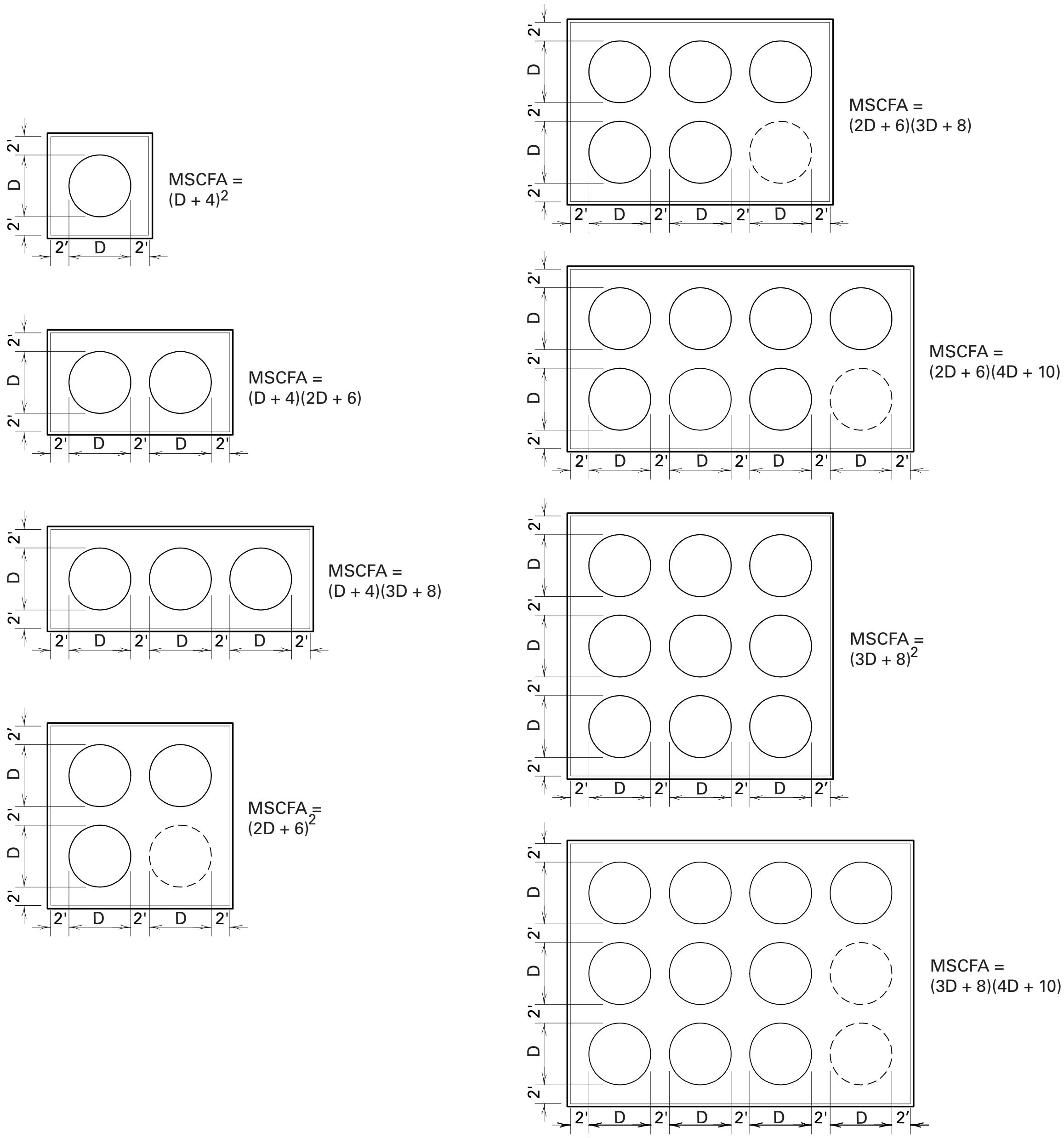


Figure 2.5 The minimum secondary containment floor area (MSCFA) required to provide space for the tanks and the required 2 feet between each tank and the 2 feet between a tank and walls for several common layouts with all vertical tanks of the same diameter.

Secondary containment sizing for vertical tanks only

For vertical storage tanks, which are not elevated above the containment floor, calculate the required secondary containment floor area (SCFA) dimensions inside containment walls by:

$$SCFA = \frac{(LTV)(FF)}{SCVD} + TBA$$

Where:

SCFA = Containment floor area, sq. ft. Use inside wall dimensions of secondary containment walls. For vertical tanks only.

LTV = Largest tank volume, cu. ft. A full tank is assumed. 1 cu. ft. = 7.48 gallons.

FF = Freeboard factor, 1.1 for 110% of largest tank (inside storage), 1.25 for 125% of largest tank. (outside storage)

SCVD = Secondary containment depth, ft.

TBA = Sum of the tank base areas, sq. ft. Do **not** include the tank base area of the largest tank because it is included in LTV. Values for individual tank base areas are in Table 2.1 (use the cu. ft/ft of height values).

A tank sitting on a solid base, such as rocks or boards, is not considered elevated because the base support takes up volume. These calculations do not allow for volume taken up by these supports or other equipment in the containment structure. If the volume of equipment is significant, add additional area. Note that the containment floor area required may be larger than that calculated based on the 2-foot required clearance space between tanks and required 2-foot clearance between tanks and walls. Tables 2.4 through 2.6 give SCFA values for containments with vertical storage tanks of the same diameter. It is estimated that the available secondary containment volume in a stone or gravel bed is approximately $L \times W \times D/2$.

Table 2.4. Secondary containment floor area (SCFA) for vertical tanks, FF=1.0.

Tank diameter, ft	Tank height, ft	Single tank area, ft^2	Single tank volume, ft^3	Single tank volume, gal.	Cont. depth, ft	Number of tanks							
						1	2	3	4	5	6	7	8
						SCFA, ft^2							
15	20	177	3534	26437	1	3534	3711	3888	4064	4241	4418	4595	4771
					2	1767	1944	2121	2297	2474	2651	2827	3004
					3	1178	1355	1532	1708	1885	2062	2299*	2520*
					4	884	1060	1237	1414	1653*	1908*	2299*	2520*
14	20	154	3079	23029	1	3079	3233	3387	3541	3695	3848	4002	4156
					2	1539	1693	1847	2001	2155	2309	2463	2617
					3	1026	1180	1334	1488	1642	1796	2052*	2244*
					4	770	924	1078	1232	1476*	1700*	2052*	2244*
13	20	133	2655	19857	1	2655	2787	2920	3053	3186	3318	3451	3584
					2	1327	1460	1593	1726	1858	1991	2124	2256
					3	885	1018	1150	1283	1416	1549	1819*	1984*
					4	664	796	929	1062	1309*	1504*	1819*	1984*
12	20	113	2262	16919	1	2262	2375	2488	2601	2714	2827	2941	3054
					2	1131	1244	1357	1470	1583	1696	1810	1923
					3	754	867	980	1093	1206	1320*	1600*	1740*
					4	565	679	792	905	1152*	1320*	1600*	1740*
11	20	95	1901	14217	1	1901	1996	2091	2186	2281	2376	2471	2566
					2	950	1045	1140	1235	1330	1425	1521	1616
					3	634	729	824	919	1014	1148*	1395*	1512*
					4	475	570	665	784*	1005*	1148*	1395*	1512*
10	20	79	1571	11750	1	1571	1649	1728	1806	1885	1963	2042	2121
					2	785	864	942	1021	1100	1178	1257	1335
					3	524	602	681	759	868*	988*	1204*	1300*
					4	393	471	550	676*	868*	988*	1204*	1300*
9	18	64	1145	8565	1	1145	1209	1272	1336	1400	1463	1527	1590
					2	573	636	700	763	827	891	1027*	1104*
					3	382	445	509	576*	741*	840*	1027*	1104*
					4	286	350	455*	576*	741*	840*	1027*	1104*
8	16	50	804	6016	1	804	855	905	955	1005	1056	1106	1156
					2	402	452	503	553	624*	704*	864*	924*
					3	268	318	384*	484*	624*	704*	864*	924*
					4	201	264*	384*	484*	624*	704*	864*	924*
7	14	38	539	4030	1	539	577	616	654	693	731	770	808
					2	269	308	346	400*	517*	580*	715*	760*
					3	180	220*	319*	400*	517*	580*	715*	760*
					4	135	220*	319*	400*	517*	580*	715*	760*
6	12	28	339	2538	1	339	368	396	424	452	481	580*	612*
					2	170	198	260*	324*	420*	468*	580*	612*
					3	113	180*	260*	324*	420*	468*	580*	612*
					4	85	180*	260*	324*	420*	468*	580*	612*
5	10	20	196	1469	1	196	216	236	256*	333*	368*	459*	480*
					2	98	144*	207*	256*	333*	368*	459*	480*
					3	81*	144*	207*	256*	333*	368*	459*	480*
					4	81*	144*	207*	256*	333*	368*	459*	480*

***MSCFA controls secondary containment floor area. See Figure 2.5**

Table 2.4 continued

	Number of tanks									
	1	2	3	4	5	Alt. 5	6	7	Alt. 7	8
Tank diameter, ft	MSCA, ft^2									
15	361	684	1007	1296	1908	1653	1908	2520	2299	2520
14	324	612	900	1156	1700	1476	1700	2244	2052	2244
13	289	544	799	1024	1504	1309	1504	1984	1819	1984
12	256	480	704	900	1320	1152	1320	1740	1600	1740
11	225	420	615	784	1148	1005	1148	1512	1395	1512
10	196	364	532	676	988	868	988	1300	1204	1300
9	169	312	455	576	840	741	840	1104	1027	1104
8	144	264	384	484	704	624	704	924	864	924
7	121	220	319	400	580	517	580	760	715	760
6	100	180	260	324	468	420	468	612	580	612
5	81	144	207	256	368	333	368	480	459	480

Table 2.5. Secondary containment floor area (SCFA) for vertical tanks, FF=1.10.

This table is for containment with all tank diameters the same and no space provided for additional equipment. Additional volume may be needed for precipitation.

Tank diameter, ft	Tank height, ft	Single tank area, ft^2	Single tank volume, ft^3	Single tank volume, gal.	Cont. depth, ft	Number of tanks: 1 (SCFA, ft^2)	2	3	4	5	6	7	8
15	20	177	3534	26437	1	3888	4064	4241	4418	4595	4771	4948	5125
					2	1944	2121	2297	2474	2651	2827	3004	3181
					3	1296	1473	1649	1826	2003	2179	2356	2533
					4	972	1149	1325	1502	1679	1908*	2299*	2520*
14	20	154	3079	23029	1	3387	3541	3695	3848	4002	4156	4310	4464
					2	1693	1847	2001	2155	2309	2463	2617	2771
					3	1129	1283	1437	1591	1745	1899	2053	2244*
					4	847	1001	1155	1308	1476*	1700*	2052*	2244*
13	20	133	2655	19857	1	2920	3053	3186	3318	3451	3584	3717	3849
					2	1460	1593	1726	1858	1991	2124	2256	2389
					3	973	1106	1239	1372	1504	1637	1819*	1984*
					4	730	863	995	1128	1309*	1504*	1819*	1984*
12	20	113	2262	16919	1	2488	2601	2714	2827	2941	3054	3167	3280
					2	1244	1357	1470	1583	1696	1810	1923	2036
					3	829	942	1056	1169	1282	1395	1600*	1740*
					4	622	735	848	961	1152*	1320*	1600*	1740*
11	20	95	1901	14217	1	2091	2186	2281	2376	2471	2566	2661	2756
					2	1045	1140	1235	1330	1425	1521	1616	1711
					3	697	792	887	982	1077	1172	1395*	1512*
					4	523	618	713	808	1005*	1148*	1395*	1512*
10	20	79	1571	11750	1	1728	1806	1885	1963	2042	2121	2199	2278
					2	864	942	1021	1100	1178	1257	1335	1414
					3	576	654	733	812	890	988*	1204*	1300*
					4	432	511	589	676*	868*	988*	1204*	1300*
9	18	64	1145	8565	1	1260	1323	1387	1450	1514	1578	1641	1705
					2	630	693	757	821	884	948	1027*	1104*
					3	420	483	547	611	741*	840*	1027*	1104*
					4	315	379	455*	576*	741*	840*	1027*	1104*
8	16	50	804	6016	1	885	935	985	1035	1086	1136	1186	1237
					2	442	493	543	593	643	694	864*	924*
					3	295	345	395	484*	624*	704*	864*	924*
					4	221	271	384*	484*	624*	704*	864*	924*
7	14	38	539	4030	1	593	631	670	708	747	785	824	862
					2	296	335	373	412	517*	580*	715*	760*
					3	198	236	319*	400*	517*	580*	715*	760*
					4	148	220*	319*	400*	517*	580*	715*	760*
6	12	28	339	2538	1	373	401	430	458	486	515	580*	612*
					2	187	215	260*	324*	420*	468*	580*	612*
					3	124	180*	260*	324*	420*	468*	580*	612*
					4	93	180*	260*	324*	420*	468*	580*	612*
5	10	20	196	1469	1	216	236	255	275	333*	368*	459*	480*
					2	108	144*	207*	256*	333*	368*	459*	480*
					3	72	144*	207*	256*	333*	368*	459*	480*
					4	54	144*	207*	256*	333*	368*	459*	480*

***MSCFA controls secondary containment floor area. See Figure 2.5.**

Table 2.5 continued

Tank diameter, ft	Number of tanks									
	1	2	3	4	5	Alt 5	6	7	Alt 7	8
	MSCFA, ft^2									
15	361	684	1007	1296	1908	1653	1908	2520	2299	2520
14	324	612	900	1156	1700	1476	1700	2244	2052	2244
13	289	544	799	1024	1504	1309	1504	1984	1819	1984
12	256	480	704	900	1320	1152	1320	1740	1600	1740
11	225	420	615	784	1148	1005	1148	1512	1395	1512
10	196	364	532	676	988	868	988	1300	1204	1300
9	169	312	455	576	840	741	840	1104	1027	1104
8	144	264	384	484	704	624	704	924	864	924
7	121	220	319	400	580	517	580	760	715	760
6	100	180	260	324	468	420	468	612	580	612
5	81	144	207	256	368	333	368	480	459	480

Table 2.6. Secondary containment floor area (SCFA) for vertical tanks, FF=1.25.
This table is for containment with all tank diameters the same and no space provided for additional equipment. Additional volume may be needed for precipitation.

Tank diameter, ft	Tank height, ft	Single tank area, ft^2	Single tank volume, ft^3	Single tank volume, gal.	Cont. depth, ft	Number of tanks							
						1	2	3	4	5	6	7	8
						SCFA, ft^2							
15	20	177	3534	26437	1	4418	4595	4771	4948	5125	5301	5478	5655
					2	2209	2386	2562	2739	2916	3093	3269	3446
					3	1473	1649	1826	2003	2179	2356	2533	2710
					4	1104	1281	1458	1635	1811	1988	2299*	2520*
14	20	154	3079	23029	1	3848	4002	4156	4310	4464	4618	4772	4926
					2	1924	2078	2232	2386	2540	2694	2848	3002
					3	1283	1437	1591	1745	1899	2053	2206	2360
					4	962	1116	1270	1424	1578	1732	2052*	2244*
13	20	133	2655	19857	1	3318	3451	3584	3717	3849	3982	4115	4247
					2	1659	1792	1925	2057	2190	2323	2456	2588
					3	1106	1239	1372	1504	1637	1770	1902	2035
					4	830	962	1095	1228	1361	1504*	1819*	1984*
12	20	113	2262	16919	1	2827	2941	3054	3167	3280	3393	3506	3619
					2	1414	1527	1640	1753	1866	1979	2092	2205
					3	942	1056	1169	1282	1395	1508	1621	1740*
					4	707	820	933	1046	1159	1320*	1600*	1740*
11	20	95	1901	14217	1	2376	2471	2566	2661	2756	2851	2946	3041
					2	1188	1283	1378	1473	1568	1663	1758	1853
					3	792	887	982	1077	1172	1267	1395*	1512*
					4	594	689	784	879	1005*	1148*	1395*	1512*
10	20	79	1571	11750	1	1963	2042	2121	2199	2278	2356	2435	2513
					2	982	1060	1139	1217	1296	1374	1453	1532
					3	654	733	812	890	969	1047	1204*	1300*
					4	491	569	648	726	868*	988*	1204*	1300*
9	18	64	1145	8565	1	1431	1495	1559	1622	1686	1749	1813	1877
					2	716	779	843	907	970	1034	1097	1161
					3	477	541	604	668	741*	840*	1027*	1104*
					4	358	421	485	576*	741*	840*	1027*	1104*
8	16	50	804	6016	1	1005	1056	1106	1156	1206	1257	1307	1357
					2	503	553	603	653	704	754	864*	924*
					3	335	385	436	486	624*	704*	864*	924*
					4	251	302	384*	484*	624*	704*	864*	924*
7	14	38	539	4030	1	673	712	750	789	827	866	904	943
					2	337	375	414	452	517*	580*	715*	760*
					3	224	263	319*	400*	517*	580*	715*	760*
					4	168	220*	319*	400*	517*	580*	715*	760*
6	12	28	339	2538	1	424	452	481	509	537	565	594	622
					2	212	240	269	324*	420*	468*	580*	612*
					3	141	180*	260*	324*	420*	468*	580*	612*
					4	106	180*	260*	324*	420*	468*	580*	612*
5	10	20	196	1469	1	245	265	285	304	333*	368*	459*	480*
					2	123	144*	207*	256*	333*	368*	459*	480*
					3	82	144*	207*	256*	333*	368*	459*	480*
					4	61	144*	207*	256*	333*	368*	459*	480*

*** MSCFA controls secondary containment floor area. See Figure 2.5**

Table 2.6 continued.

Tank diameter, ft	Number of tanks									
	1	2	3	4	5	Alt 5	6	7	Alt 7	8
	MSCFA, ft^2									
15	361	684	1007	1296	1908	1653	1908	2520	2299	2520
14	324	612	900	1156	1700	1476	1700	2244	2052	2244
13	289	544	799	1024	1504	1309	1504	1984	1819	1984
12	256	480	704	900	1320	1152	1320	1740	1600	1740
11	225	420	615	784	1148	1005	1148	1512	1395	1512
10	196	364	532	676	988	868	988	1300	1204	1300
9	169	312	455	576	840	741	840	1104	1027	1104
8	144	264	384	484	704	624	704	924	864	924
7	121	220	319	400	580	517	580	760	715	760
6	100	180	260	324	468	420	468	612	580	612
5	81	144	207	256	368	333	368	480	459	480

Secondary containment sizing for non-vertical or elevated tanks

For containments that have tanks other than all vertical tanks or containments in which some of the tanks are elevated, calculate secondary containment floor area (SCFA) by:

$$SCFA = \frac{(LTV)(FF) + TBV)}{SCVD}$$

Where:

TBV = Sum of the tank base volumes, cu. ft. Do **not** include the base volume of the largest tank because it is included in LTV.

= BV1 + BV2 + … + BVn

BV = Base volume of an individual tank, cu. ft.

To determine BV:

For vertical tanks:

BV = (VPF) (SCVD - TBE)

Where:

VPF = Volume/unit of depth, cu. ft./ft of depth. Determine from Table 2.1 or the equation in Figure 2.3.

TBE = Tank base elevation, ft. For tanks setting on the floor or a solid base (e.g. stones), TBE = 0.

For horizontal tanks:

BV = The tank volume given in Table 2.2 or calculated from the equation in 2.3 at a fluid level of (SCVD - TBE).

For vertical tanks with cone bottoms:

BV = The tank volume calculated from the equation in Figure 2.3 at a fluid level of (SCVD - TBE).

Example: Calculating secondary containment volume

A liquid fertilizer dealer has two, 12-foot diameter × 20-foot high, three, 10-foot diameter × 15-foot high, and two, 9-foot diameter × 15-foot high vertical storage tanks. The dealer is trying to decide between a 3-foot and a 4-foot secondary containment wall height. An additional 25% of the largest tank is required for freeboard because the secondary containment structure is not roofed (FF =1.25).

From Table 2.1, the largest tank volume LTV = 113.1 cu. ft/ft of depth × 20' = 2,262 cu. ft.

Now determine the area of the bases of the other tanks in the containment structure, TBA:

TBA = 113.1 + 3 × 78.54 + 2 x 63.62 = 476 sq. ft.

Next, calculate the secondary containment floor area, SCFA, for each of the two containment depths.

For 3-foot depth:

$$SCFA = \frac{(LTV)(FF)}{SCVD} + TBA$$

= 2,262 × 1.25 / 3 + 476

= 1,419 sq. ft.

For 4-foot depth:

SCFA = 2,262 × 1.25 / 2 + 476

= 1,890 sq. ft.

The volume displaced by transfer pumps and plumbing is assumed insignificant and is ignored in this example. If large mixing tanks, transfer tanks, or concrete tank supports are to be placed in the containment structure, their displacement area and volume below the level of the containment wall must be included.

As shown in Figure 2.6, the containment structure has to be at least 27 feet wide to allow enough space for the tanks and 2-foot access around tanks. A 27-foot × 53-foot area provides the computed area for the 3-foot depth, but the area needs to be at least 27 feet × 54 feet for all the tanks to fit. For the 2-foot depth, a 27-foot × 70-foot area is required for the tanks and to allow the tanks to fit in the area with adequate clearance.

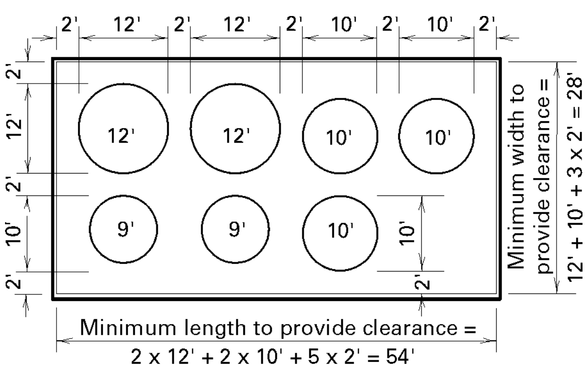


Figure 2.6. Scaled site plan for the secondary containment in the example.

If a tank were to be placed in the empty corner by the 10-foot diameter tanks in the future, its displacement volume would have to be included in the SCFA calculation now. It would be best to design the containment structure for eight, 12-foot diameter tanks, because it would allow more flexibility in future facility changes. From Table 2.6, a 30-foot × 58-foot (1,740 sq. ft. / 30 feet = 58 feet) containment structure would be required for a 3-foot high wall.

NOTE: *To make sure all the tanks and equipment will fit into the containment structure with sufficient clearance, it is extremely important to make a scale drawing of the structure with the tanks drawn to scale in position. The 3-foot wall plan contains more floor slab area than the 4-foot wall plan does, but this is offset by the additional wall area the 4-foot wall plan requires. Savings in concrete should be a secondary consideration after function and safety for secondary containments.*

Curbed Areas

Secondary containment of small storage tank volumes of pesticide or fertilizer can be accomplished by constructing a small curb. Table 2.7 shows secondary containment floor area required to store minibulk containers or drums. Curbs also can be used to provide secondary containment for mixing and loading pads and for pesticide warehouse or storage rooms. Using curbs is an excellent method for containing bottles, jugs, drums, and small minibulk storage tanks.

The curb must surround the complete storage area and must be high enough to have sufficient volume to contain any potential spillage from a primary storage tank. To provide secondary containment for bulk pesticides or pesticide rinsate, the curb must be at least 4 inches high. If the curbed area is not roofed, it should also be designed with any required freeboard. Using small rounded or ramped curbs (less than 6 inches in height) and more area that is horizontal provides the secondary containment capacity required but also allows movement of tanks within the secondary containment structure and more easily accommodates foot traffic between the functional areas. Figure 2.7 shows an example of a curb placed on a mixing and loading pad. Small pesticide packages can be moved easily with hand trucks. Workers also can move more easily without having to climb steps or climb over walls.

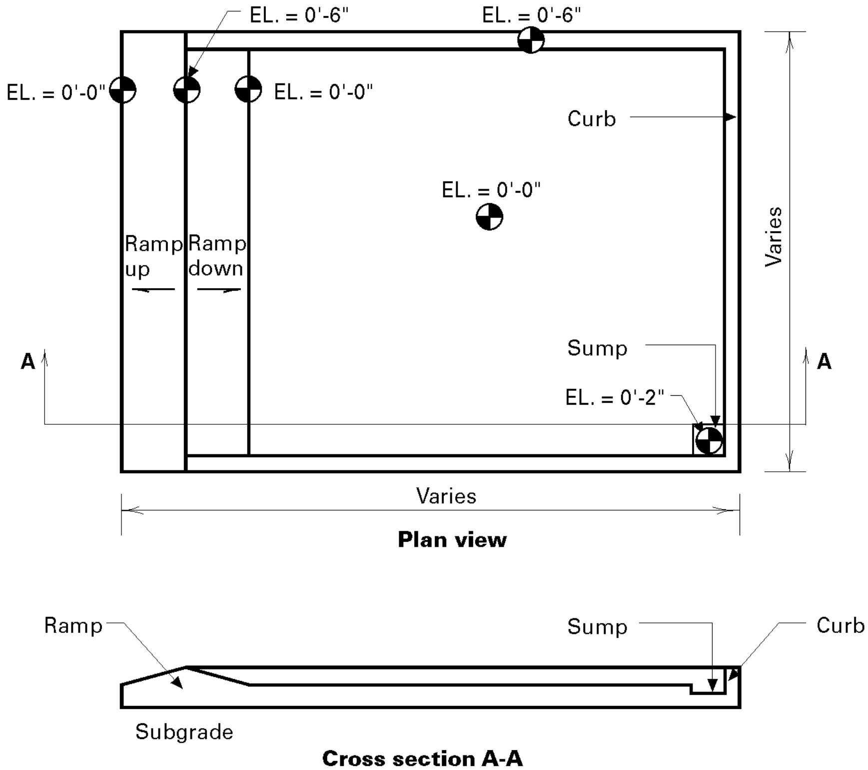


Figure 2.7. Curbed and ramped secondary containment.

Table 2.7. Floor area for curbed secondary containment.
Assuming a 6" curbed area.

Minibulk container size, gal	Containment area per minibulk, ft^2
60	16
110	30
150	41
200	54
250	67
300	81

Concrete Wall and Floor Containment

As the tank size increases, secondary containment volume usually requires an increase in the curb (wall) height to provide the needed volume. A reinforced concrete wall can be designed to withstand the horizontal loads. The concrete wall is usually placed on top of a floating slab to provide an impermeable or liquid tight joint and to create a relatively liquid impermeable system for secondary containment. This is usually called a secondary containment dike.

Synthetic Liners with Concrete Walls

In Wisconsin, synthetic liners (e.g. synthetic rubber, EPDM, polyurea) can be used as secondary containment for bulk fertilizers, but not for bulk pesticides. These synthetic liners can be used to repair concrete containments with cracks or other support walls used to support the horizontal load, Figure 2.8. Flexible liners have factory- or field-bonded seams to form a single continuous barrier that lines the entire secondary containment facility. To be effective, synthetic liners must be extremely durable and chemically resistant to the stored products. Install synthetic liners as recommended by the manufacturer to prevent punctures and tears. Properly designed and installed liners, if protected from puncturing, are superior to concrete liners as a barrier to liquid flow.

Some facilities use a layer of sand or smooth gravel to protect a synthetic liner used on the floor of a containment facility. This practice is acceptable, but if the protective granular cover becomes contaminated, any precipitation in the containment structure also is contaminated. Large (1-inch to 1.5-inch diameter) smooth gravel may be decontaminated by flushing it with a large amount of water, but the flush water would then have to be treated as contaminated. To prevent this situation from occurring, use small pans under pumps, valves, and plumbing connections to minimize contamination of the granular material. Otherwise, the granular fill must be replaced and the contaminated material disposed of properly. Additionally, removing the gravel without damaging the synthetic liner is difficult.

Most manufacturers of synthetic liner materials will guarantee the lifespan of the liner regardless of UV exposure, provided the liner is installed as recommended and is protected from the tank and equipment stresses. It is possible to leave the liner exposed. This would minimize the problems created by contaminated granular material and make the system easier to inspect for damage and clean up after a release.

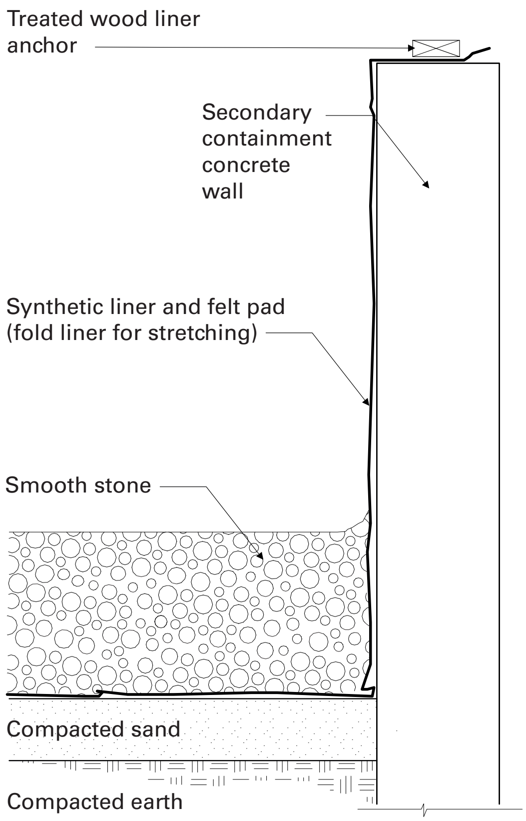


Figure 2.8. Synthetic liner with concrete wall for secondary containment.

Storage Tank Plumbing

Use flexible hoses at the pipe-to-tank connection to allow some flexing of plumbing lines due to thermal expansion and to prevent potential plumbing rupture if one tank floats or shifts. It is possible to have a catastrophic failure of multiple tanks if rigid steel plumbing between multiple storage tanks is used and a rupture of one tank occurs. In the case of multiple tank failures, the secondary containment could overflow.

Elevated pipes are easier to maintain. They must be supported by permanent supports. Do not exceed dimensions for intervals specified in Table 2.8. Run rigid steel pipe to a deck for loading and unloading of pesticides and fertilizers. Do not place rigid pipe near traffic lanes where it is subject to damage by vehicles. Protect rigid pipe from vehicles with steel posts or high curbs. Use flexible hose connections from rigid plumbing or manifolds to vehicles. Permanent plumbing is preferred to eliminate drips that occur when hoses are switched from tank to tank. Do not install pesticide and fertilizer plumbing lines, sump pump lines, or drain lines under secondary containment floors or mixing and loading pads or in inaccessible areas.

Plumbing cannot penetrate through secondary containment walls: plumbing pipes must be run over containment walls rather than through them. It is difficult to seal around pipes that go through walls and very difficult to ensure the integrity of a seal throughout a facility's life.

Table 2.8. Maximum pipe span between supports.

Pipe material	Nominal diameter, in.	Maximum span, ft
Mild steel	2	10
	2.5	11
	3	12
	3.5	13
	4	14
	5	15
	6	17
PVC, Schedule 40	2	4
	3	5
	4	6
	5	8
	6	10

Electrical Systems

If possible, elevate electrical items (motors, wiring, controls, etc.) off the containment floor so they do not become submerged. Ideally, place all electrical components above the top of the secondary containment wall (highest liquid level) so they do not become submerged during a spill. Use Ground Fault Circuit Interrupters (GFCI) on all electric circuits within secondary containment and other parts of pesticide and fertilizer handling facilities as specified by the National Fire Protection Association (NFPA) and the National Electric Code (NEC).

Security Fencing

Vandalism and theft can be major problems for pesticide and fertilizer storage facilities. Use fences or buildings to prevent unauthorized entry to the secondary containment and to protect children, pets, and other animals from accidental entry. Fencing is required to provide security for all storage tanks, mixing and loading equipment, and empty pesticide containers held for disposal unless the entire facility is enclosed inside a secured building. If possible, place all valves, pipes, and pumps inside a fence or building. Otherwise, lock valves when they are not supervised.

Select security fencing that is a minimum of 5 feet high and constructed of 12-gauge hardened steel wire mesh with 3-inch x 3-inch diagonal openings. Ideally, the fencing would be installed independent of the secondary containment structures. If fencing is installed on top of secondary containment walls, the fencing must be installed by attaching the fence posts to brackets bolted to the containment wall as shown in figures 2.9 and 2.10. Use fence gates of a rigid steel frame and wire fence mesh with maximum openings of 1 or 2 inches between the fence posts and gate and the concrete. Do not place fence posts into the top of a concrete wall as this creates a weak section that causes cracks in the concrete.

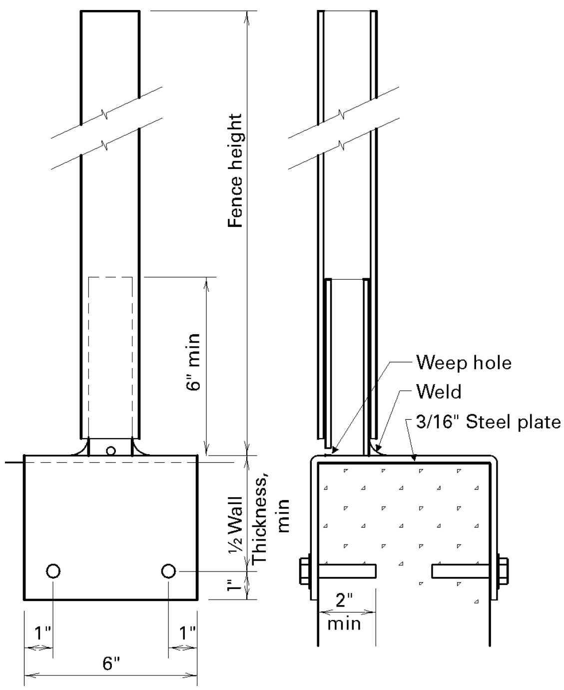


Figure 2.9. Metal saddle support for fence post.

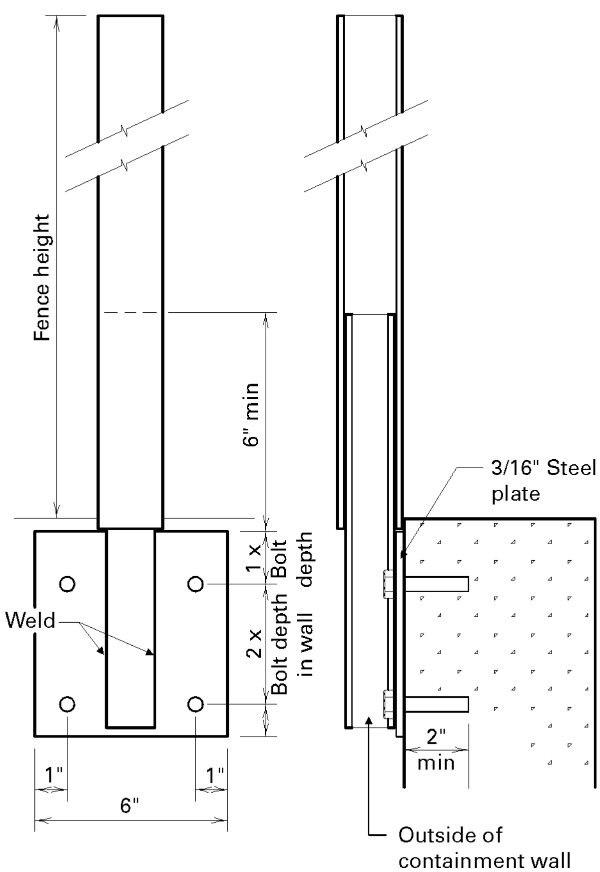


Figure 2.10. Wall plate support for fence post.

Loads from tank anchors

Tanks within a secondary containment must be anchored to prevent floating or tipping due to loading from vertical buoyancy and horizontal wind forces. Tanks are anchored to prevent flotation when fluid levels rise within the secondary containment structure. If tanks are not anchored, one tank failure could raise the liquid level in the secondary containment structure and cause other tanks within the structure to float and possibly tip, resulting in additional tank failures. Since secondary containment is not designed to hold the volume of all the tanks within it, the additional liquid from other failed tanks would overflow the secondary containment causing a spill. Tank anchors and connections must be adequate to resist the calculated loads.

Upward forces due to flotation are equal to the weight of the fluid displaced by the empty portion of the tank that is below the fluid level minus the empty tank weight. Flotation force can be calculated by:

FF = FD x VD - TW

Where:

FF = Flotation force, lb

FD = Fluid density of fertilizer, typically 70-85 lb/cu. ft.

VD = Volume of fluid displaced by the tank, cu. ft. Table 2.1 – 2.3

TW = Empty tank weight, lb

When calculating flotation force, assume the worst conditions. Assume one tank is empty when another tank leaks, and assume that the secondary containment will be completely filled to the height of the wall. Flotation forces can be reduced by elevating the tank and/or using cone-bottom tanks because less fluid volume is displaced. Elevated cone-bottom tanks are popular for handling many products because they have fewer flotation problems, and all of the product can be easily removed from the tank.

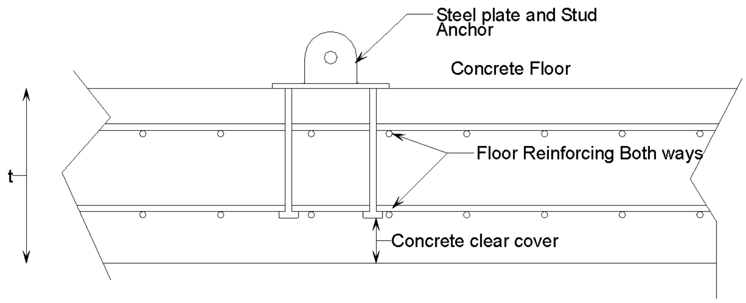
Horizontal wind loads will vary depending on the type of tank, tank width, and tank height. Wind loads place repetitive loads from many directions on the tanks and anchor points over the life of the structure. It is beyond the scope of this discussion to determine loads applied to tanks and the resulting anchor design needs due to wind forces. A professional engineering analysis is needed to determine the loads and the design of the anchors. It is important to consider the loads on both the tank and the secondary containment structure.

It is recommended that if possible tanks should be anchored outside of the secondary containment walls to eliminate the additional load on the wall. Tank anchors can be integrated into the secondary containment floor if the structure is designed to withstand the additional loads due to the loading causes by tank anchors. Anchoring tanks to the secondary containment walls is not allowed.

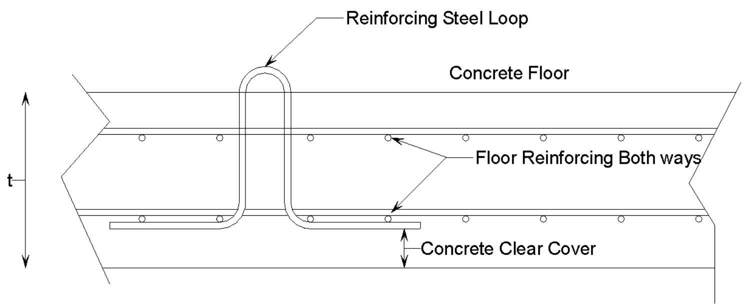
Options for tank anchors

If the design for the tank anchor system is incorporated into the secondary containment floor, the additional tank loads must be accounted for in the secondary containment floor and reinforcing steel design.

Figure 2.11 shows two methods of incorporating anchors into the secondary containment floor. An engineered anchor system design shall be provided for each tank and the secondary containment concrete floor.



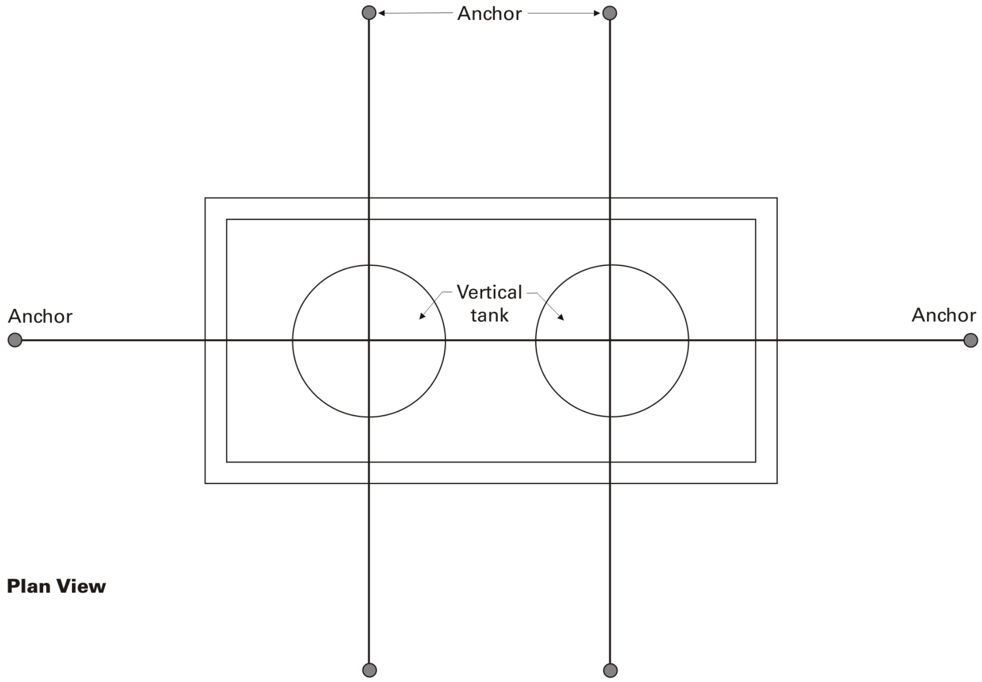
a. Tank floor plate anchor



b. Tank floor reinforcing bar anchor

Figure 2.11. Anchors incorporated into the tank floor.

Tanks can also be anchored to the soil or concrete anchors located outside the secondary containment structure. Acceptable anchor designs for this option can be found in Figures 2.12 and 2.13. This option eliminates the need for designing the secondary containment floor to support the additional tank loads and minimizes the potential for cracks in the floor due to the point loads from the tank anchors.



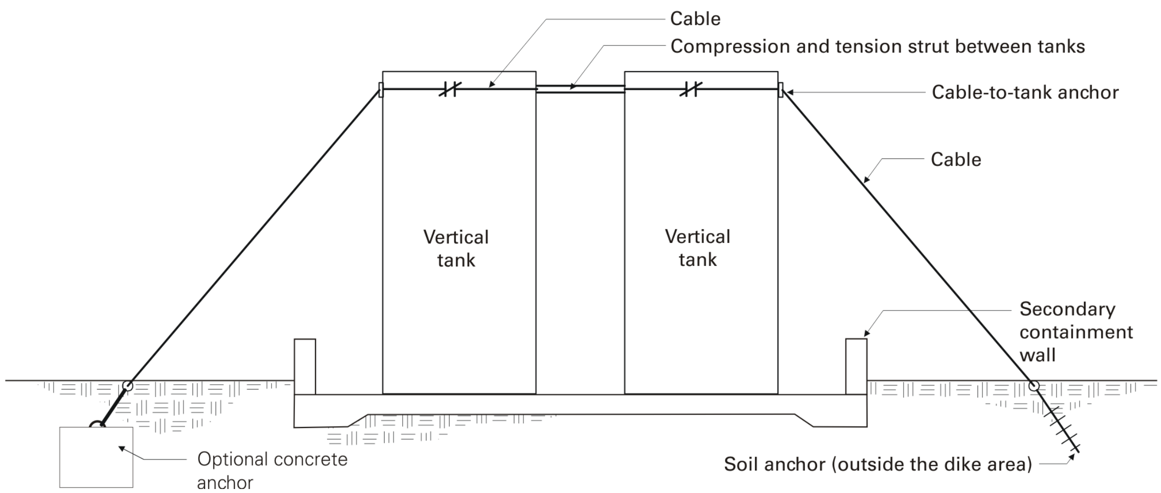


Figure 2.12. Cable anchors located outside the secondary containment structure for vertical tanks.

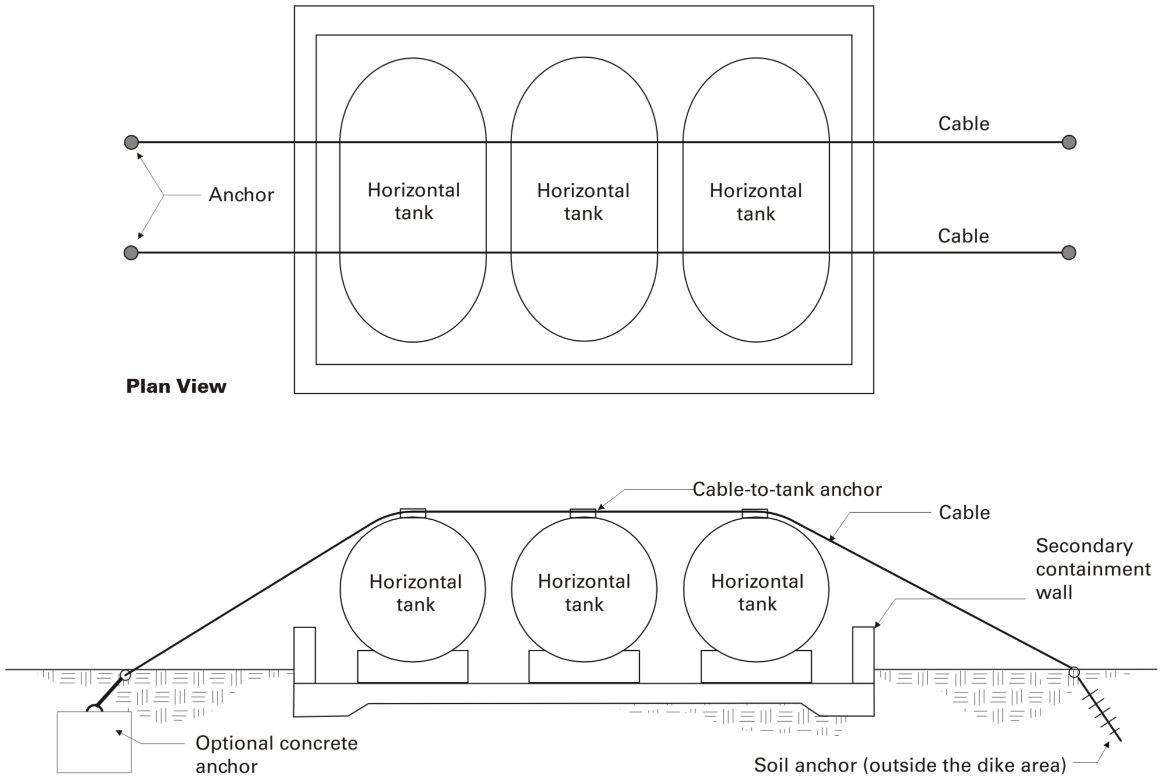


Figure 2.13. Cable anchors located outside the secondary containment structure for horizontal tanks.

Use cables to tie down vertical tanks in at least three equally spaced locations (e.g., 120 degrees apart around the tank's circumference) to prevent the tank from shifting. The cable and the connections of the cable to the tank and the ground anchor need to be strong enough to resist flotation and wind forces. Use cable strength specifications provided by the cable supplier.

Tank anchoring also can be accomplished by providing dead weights such as concrete blocks that sit on the secondary containment floor, Figure 2.14, or outside the secondary containment structure. See Table 2.9 for designs of concrete weights. In all cases, cables must be kept tight so tanks cannot shift.

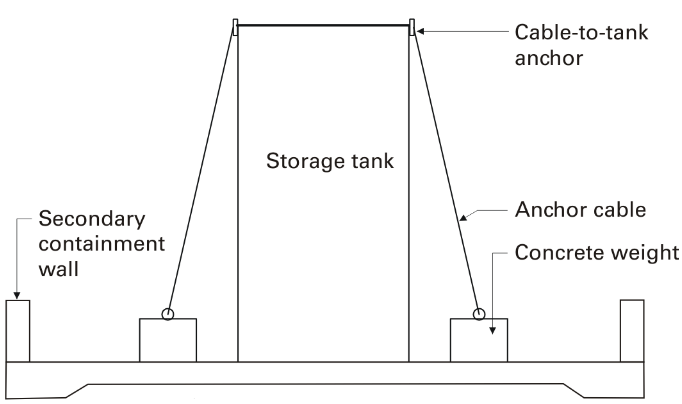


Figure 2.14. Tank anchoring system using concrete weights.

Table 2.9. Concrete weight design.
Use 60 grade steel and make bending diameter at least six times bar diameter.

		Restraint provided, lb Fluid level around block[b]		
Cube dimension, ft[a]	Rebar size	None (R_0)	Submerged (R_s) (100 lb/ft^3)	Submerged (R_s) (70 lb/ft^3)
1	#3	150	50	80
1.5	#3	505	165	270
2	#3	1,200	400	640
2.5	#3	2,340	780	1,250
3	#3	4,050	1,350	2,160
3.5	#4	6,430	2,140	3,425
4	#5	9,600	3,200	5,120
4.5	#6	13,665	4,555	7,290
5	#6	18,750	6,250	10,000
5.5	#7	24,955	8,315	13,300
6	#8	32,400	10,800	17,280

[a]Cubed dimension (a) in figure above.
[b]If the blocks are in the containment area, the spilled fluid will tend to float the block. Submerged values are based on a fluid density of 100 lb/ft^3 and 70 lb/ft^3. Use linear interpolation to determine restraint if fluid level is part way up the block as follows:

$$R_h = R_o - \left[(a-h) + a \times (R_o - R_s)\right]$$

Where:

R_h = Restraint with fluid level at h, lb
R_o = Restraint with no fluid, lb
R_s = Restraint when block submerged, lb
a = Block dimension, ft
h = Fluid level from block bottom, ft