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Subject: Review of the Technical Basis for REFCON: ASDRUM, DRROOM, and VROOM Performance Assessment Analysis Parameters with Comparison to the Currently Emplaced Steel Surface Area per Unit Volume in the WIPP Repository[1]

Current Parameter Summary

The technical basis for REFCON:ASDRUM was established as an estimated $A_d = 6\ m^2$ of steel surface area per equivalent drum of waste, which accounted for steels used to fabricate the waste containers (drums and boxes) and steels contained in the waste (Brush 1991). The parameter accounted for both inner and outer surfaces of the containers, but the reference provides no details on how the steel surface area of the waste was estimated.

The technical basis for REFCON:DRROOM was established by determining the ideal packing of 55-gallon drums and/or Standard Waste Boxes in a generic storage room that measured 33 ft. (10.06 m) wide by 300 ft. (91.44 m) long by 13 ft. (3.96 m) high, where the bounding configuration was a 3-high stack of 7-packs of drums that were hexagonally nested in an area that spanned 54 rows by 6 columns (Sandia WIPP Project 1992). Thus, the ideal number of waste drums in a room, n_d, was established as follows:

$$n_d = \left[(7\times3)\frac{\text{drums}}{\text{stack}}\right]\left[(54\times6)\frac{\text{stacks}}{\text{room}}\right] = 6{,}804\ \frac{\text{drums}}{\text{room}}$$

The technical basis for REFCON:VROOM consistently utilized the generic storage room dimensions listed above to determine the repository room volume, V_R, that contained the 6,804 drums as follows (Screiber 1991):

$$V_R = \left[(33\ \text{ft})(300\ \text{ft})(13\ \text{ft})\right]\left[\frac{1\ \text{m}^3}{35.31467\ \text{ft}^3}\right] = 3{,}644.378\ \text{m}^3$$

[1] Supports response to CRA 2014 EPA Comment 4-C-4.

WIPP:4.2.1:PA:QA-L:RECERT:543151

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The resulting steel surface area per unit volume coefficient, D_s, utilized in the PA analysis is implemented as a bounding coefficient as follows (Compliance Recertification Application (CRA) 2014 Appendix PA equation PA.75):

$$D_s = \frac{A_d n_d}{V_R} = \frac{\left(6\frac{m^2}{drum}\right)\left(6{,}804\frac{drums}{room}\right)}{3644.378\,m^3} = 11.2\frac{m^2}{m^3}\,\text{per room}$$

Average Room Size and Waste Drums per Room Assessment

To examine the adequacy of the D_s coefficient, which is proportional to the gas generation rate and used as an input to PA gas generation calculations, and to determine the appropriateness of the parameters used exclusively to calculate the coefficient, the DRROOM and VROOM parameter values are compared to those obtained for an average room based on known repository panel dimensions and the idealized CH-TRU waste emplacement scenario illustrated in Figure DATA-B-11, Attachment B, of CRA 2014 Appendix DATA-2014. Figure DATA-B-11 identifies the number of available one-level container positions per panel as 3,636. With each container position, or stack, accommodating a 3-high stack of 7-packs of drums, an idealized average number of waste drums in a room, n_d', is calculated as follows:

$$n_d' = \frac{\left[(7\times3)\frac{drums}{stack}\right]\left[3{,}636\frac{stacks}{panel}\right]}{\left[7\frac{rooms}{panel}\right]} = 10{,}908\frac{drums}{room}$$

The corresponding average room volume for standard panels 1 through 8, V_R', is calculated from the panel volume as follows (Screiber 1991):

$$V_R' = \left[\frac{1{,}627{,}923\frac{ft^3}{panel}}{7\frac{rooms}{panel}}\right]\left[\frac{1\,m^3}{35.31467\,ft^3}\right] = 6{,}585\frac{m^3}{room}$$

The drum to volume ratio for an idealized average room (10,908/6,585 = 1.66) is lower than that for the generalized room (6,804/3644.378 = 1.87) such that the currently implemented DRROOM and VROOM parameters are conservative inputs to the determination of the D_s coefficient. However, the detailed basis of the ASDRUM parameter, particularly the surface area of steel representing the waste, is not well understood and requires further evaluation. The purpose of the evaluation is to determine whether the ASDRUM parameter value of 6 m^2 is also a conservative value that is exclusively used in PA to determine the D_s coefficient.

Surface Area of Container Types and Average Iron-based Metal Waste

A query of the WIPP Waste Data System (WDS) was undertaken and data summarized in Table 1 provides the number, type, and tare weight of emplaced waste and dunnage containers in

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addition to the average iron-based metal content of emplaced waste for each container type as of December 31, 2014 (Offner 2015). The iron-based metal waste weight listed in Table 1 includes all iron-based metal in the waste in addition to iron-based metal in internal containers or liners for direct load cases. For cases involving the overpacking of other authorized payload container types, the overpacked containers are not considered in the average iron-based metal waste weight. The direct load vs. overpack case distinction is made to allow the direct calculation of overpacked payload container steel surface areas based on known container geometries rather than treating the overpacked payload containers as waste.

The inner and outer steel surface area of each emplaced container is conservatively obtained by doubling the surface area determined from the bounding external payload container dimensions provided in Section DATA-B-1.3, Attachment B, of CRA 2014 Appendix DATA-2014. The container inside and outside surface area, A_c, is calculated for each container geometry as follows, depending upon whether the bounding geometry is cylinder (d = outside diameter, h = outside height) or a rectangular prism (l = outside length, w = outside width, h = outside height):

$$A_c = \begin{cases} \pi\left(d^2+2dh\right) & \text{for a cylinder} \\ 4\left(lw+wh+lh\right) & \text{for a rectangular prism} \end{cases}$$

As applicable, the inside and outside surface areas of all authorized containers shipped in an overpacked configuration, n_{op}, are summed to determine the total payload container surface area that includes the surface area of the outer and all overpacked inner payload containers, A_{ct}, as follows:

$$A_{ct} = A_c + \sum_{i=1}^{n_{op}} A_{c,i}$$

Both the overpacked and direct load configurations employ two comparative methods to estimate the surface area of the iron-based metal waste contents. An estimate of the average iron-based metal waste surface area per container is required because only the weight of iron-based metal waste is explicitly known whereas the steel surface area of containers can be calculated directly. The first method uses a spherical waste surrogate assumption to determine the total surface area, A_{wsph}, of the number of 1 cm spheres required to achieve the average iron-based metal waste weight, W_{wstl}, for each container type. The second method uses a sheet waste surrogate assumption to determine the total steel surface area of the waste, A_{wsht}, as the product of the waste weight and the payload container's surface area to tare weight, W_{tare}, ratio. Equations used to calculate the surface area of iron-based metal waste are provided below:

$$A_{wsph} = \frac{W_{wstl}}{\left(\frac{1}{6}\right)(0.01\,\text{m})\left(7{,}817\,\frac{\text{kgf}}{\text{m}^3}\right)}$$

$$A_{wsht} = W_{wstl}\left(\frac{A_{ct}}{W_{tare}}\right)$$

Table 2 summarizes the container dimensions, the calculated container total steel surface area (including overpacked containers, as applicable), and the iron-based metal waste surface area for both the spherical and sheet surrogate waste assumptions.

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The total steel surface area, A_t, is a summation of the container steel and iron-based metal waste surface areas established for the two waste surrogate assumptions as follows:

$$A_t = \begin{cases} A_{ct} + A_{wsph} & \text{for spherical surrogate} \\ A_{ct} + A_{wsht} & \text{for sheet surrogate} \end{cases}$$

In order to compare the total steel surface area results for the various container types, it is necessary to normalize the individual container results to a common volumetric standard. One approach is to normalize the surface area by the ratio of the number of containers in a single waste stack to the number of 55-gallon drums in a single waste stack. The theoretical number of containers per waste stack is geometrically limited by the standard payload container assembly configurations and the dimensions of the standard waste stack defined by a hexagonal prism with a circumradius of 36 inches and a height equal to the room height. The normalization of total steel surface area to a 55-gallon drum standard is given by the following equation:

$$A_{55std} = A_t \left(\frac{n_{cs}}{n_{cs,55std}} \right)$$

Table 3 summarizes the total steel surface area normalized to a 55-gallon drum standard for all container types for both waste steel surrogate assumptions. The average normalized steel surface area of all container types for the spherical and sheet waste surrogates is 6.00 m^2 and 6.31 m^2, respectively. Remote-handled payload containers not emplaced on the repository floor are not evaluated in the normalization process. The average results compare well against the currently implemented ASDRUM parameter, but a number of payload container types have a normalized total steel surface area that is greater than the ASDRUM parameter. As such, an evaluation of the actual numbers of payload containers emplaced within the repository is desired to determine the steel surface area to volume coefficient for all emplaced waste within the WIPP repository.

Currently Emplaced Repository Steel Surface Area to Volume Coefficient

Utilizing the WDS emplacement data for the total number of emplaced containers, $n_{emplaced}$, of each type given in Table 1, along with the total steel surface area for each waste surrogate assumption given in Table 3, allows a determination of the total steel surface area associated with all currently emplaced containers. Additionally, WDS information identifies that waste is emplaced in a total of 40 rooms (n_{rooms}) such that the average repository room steel surface area to volume coefficient, D_s', for all emplaced container types, n_{types}, is calculated as follows:

$$D_s' = \frac{1}{n_{rooms} V_R'} \sum_{i=1}^{n_{types}} n_{emplaced,i} A_{t,i}$$

For conservatism and to simplify the calculation, the volume associated with the remote-handled canisters is ignored in the above equation, but the surface area of the canister and applicable overpack containers and waste is included along with the surface area of the shield plug (1.829 m in height by 0.737 meters in diameter) associated with each emplaced canister. The overall repository average room steel surface area to volume coefficient determination is summarized in Table 4. For both the spherical and sheet waste surrogate assumptions, the overall average room steel surface area to volume coefficients of 9.06 m^2/m^3 and 10.15 m^2/m^3 are conservatively

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below the currently utilized PA analysis value of 11.2 m^2/m^3. This conservatism results in a predicted PA gas generation rate that is 10% to 24% higher than would be predicted by a D_s coefficient based on the currently emplaced waste.

From a waste emplacement perspective, a total of 40 rooms of emplaced waste is associated with an average number of waste stacks per room of 458 and an equivalent number of 55-gallon drums per room of 9,616. Thus, the current fill factor of rooms, on average, is 9,616/10,908 = 88% of the theoretically achievable fill factor for waste located on the repository floor.

Conclusions

It is concluded that the currently implemented generic drum-based parameters for REFCON: ASDRUM, DRROOM, and VROOM are appropriately bounding of the current repository conditions and adequately account for both variations in the composition of currently authorized container types and quantity of iron-based metals in the waste.

The Excel spreadsheet utilized to facilitate the calculations in this memo is provided electronically and in Appendix A.

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Table 1: Waste Data System Query of Waste Emplacements as of December 31, 2014

Container Type	Number of Emplaced Containers plus Dunnage $n_{emplaced}$ (#)	Average Iron-Based Metal Waste Weight per Container Type W_{wstl} (kgf)	Container Tare Weight W_{tare} (kgf)
55-gallon drum (DL)	96,494	6.41	28.60
12-in. Standard Pipe Overpack (DL)	25,626	2.00	110.30
S100 Pipe Overpack (DL)	814	0.00	70.50
S300 Pipe Overpack (DL)	45	0.00	109.80
85-gallon drum (OP one drum)	5	27.76	37.00
100-gallon drum (DL of compacted pucks)	34,255	170.59	56.70
Standard Waste Box (DL)	6,807	234.36	290.30
Standard Waste Box (OP four drums)	6,054	17.90	290.30
Standard Large Box 2 (DL)	228	492.13	1,224.49
Ten Drum Overpack (DL)	24	928.91	770.98
Ten Drum Overpack (OP ten drums)	6,023	22.87	770.98
Shielded Container (OP one drum)	9	16.40	782.77
RH FL Waste Canister (DL)	18	2.20	799.09
RH RL Waste Canister (DL)	1	0.00	517.01
RH RL Waste Canister (OP 3 drums)	700	31.84	517.01

Notes:

DL = direct load
OP = overpack
RH FL = remote-handled fixed-lid
RH RL = remote-handled removable-lid

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Table 2: Container Dimensions, Steel Surface Area, and Average Iron-Based Metal Waste Surface Areas

Container Type	h (m)	d / w (m)	l (m)	A_{ct} (m^2)	A_{wsph} (m^2)	A_{wsht} (m^2)
55-gallon drum (DL)	0.889	0.610		4.58	0.49	1.03
12-in. Standard Pipe Overpack (DL)	0.699	0.325		6.34	0.15	0.11
S100 Pipe Overpack (DL)	0.699	0.325		6.34	0.00	0.00
S300 Pipe Overpack (DL)	0.699	0.325		6.34	0.00	0.00
85-gallon drum (OP one drum)	1.022	0.728		10.92	2.13	8.19
100-gallon drum (DL of compacted pucks)	0.889	0.813		6.62	13.09	19.91
Standard Waste Box (DL)	0.937	1.384	1.803	21.93	17.99	17.70
Standard Waste Box (OP four drums)	0.937	1.384	1.803	40.23	1.37	2.48
Standard Large Box 2 (DL)	1.854	1.753	2.743	52.58	37.77	21.13
Ten Drum Overpack (DL)	1.858	1.810		31.42	71.30	37.86
Ten Drum Overpack (OP ten drums)	1.858	1.810		77.19	1.76	2.29
Shielded Container (OP one drum)	0.908	0.584		8.98	1.26	0.19
RH FL Waste Canister (DL)	3.061	0.660		14.06	0.17	0.04
RH RL Waste Canister (DL)	3.061	0.660		14.06	0.00	0.00
RH RL Waste Canister (OP 3 drums)	3.061	0.660		27.79	2.44	1.71

Notes:

A_{ct} = inside and outside surface area of container, including overpacked containers, as applicable

A_{wsph} = surface area of iron-based metal waste using spherical surrogate

A_{wsht} = surface area of iron-based metal waste using container sheet metal surrogate

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Table 3: Normalized Total Steel Surface Area per Container Type

Container Type	n_{cs} (#)	Spherical Surrogate A_{55std} (m^2)	Sheet Surrogate A_{55std} (m^2)
55-gallon drum (DL)	21	5.07	5.60
12-in. Standard Pipe Overpack (DL)	21	6.49	6.45
S100 Pipe Overpack (DL)	21	6.34	6.34
S300 Pipe Overpack (DL)	21	6.34	6.34
85-gallon drum (OP one drum)	12	7.46	10.92
100-gallon drum (DL of compacted pucks)	9	8.45	11.37
Standard Waste Box (DL)	3	5.70	5.66
Standard Waste Box (OP four drums)	3	5.94	6.10
Standard Large Box 2 (DL)	0.678	2.92	2.38
Ten Drum Overpack (DL)	1.5	7.34	4.95
Ten Drum Overpack (OP ten drums)	1.5	5.64	5.68
Shielded Container (OP one drum)	9	4.39	3.93
RH FL Waste Canister (DL)			
RH RL Waste Canister (DL)			
RH RL Waste Canister (OP 3 drums)			
Average		6.00	6.31

Notes:

A_{55std} = container surface area normalized to a 55-gallon drum standard based on the number of equivalent containers in a waste stack

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Table 4: Total Emplaced Steel Surface Area and Room Average Steel Surface Area to Disposal Volume Coefficients

Container Type	Spherical Surrogate		Sheet Surrogate	
	Total Steel Surface Area $n_{emplaced} \times A_t$ (m^2)	Room Average Surface Area to Volume Coefficient D_s' (m^2/m^3)	Total Steel Surface Area $n_{emplaced} \times A_t$ (m^2)	Room Average Surface Area to Volume Coefficient D_s' (m^2/m^3)
55-gallon drum (DL)	489,033	1.86	540,499	2.05
12-in. Standard Pipe Overpack (DL)	166,289	0.63	165,299	0.63
S100 Pipe Overpack (DL)	5,157	0.02	5,157	0.02
S300 Pipe Overpack (DL)	285	0.00	285	0.00
85-gallon drum (OP one drum)	65	0.00	96	0.00
100-gallon drum (DL of compacted pucks)	675,205	2.56	908,700	3.45
Standard Waste Box (DL)	271,701	1.03	269,745	1.02
Standard Waste Box (OP four drums)	251,881	0.96	258,583	0.98
Standard Large Box 2 (DL)	20,600	0.08	16,805	0.06
Ten Drum Overpack (DL)	2,465	0.01	1,663	0.01
Ten Drum Overpack (OP ten drums)	475,461	1.80	478,679	1.82
Shielded Container (OP one drum)	92	0.00	83	0.00
RH FL Waste Canister (DL)	256	0.00	254	0.00
RH RL Waste Canister (DL)	14	0.00	14	0.00
RH RL Waste Canister (OP 3 drums)	21,164	0.08	20,652	0.08
Canister Shield Plug	7,317	0.03	7,317	0.03
Total		9.06		10.15

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Screiber, J. 1991. *Analyst Calculation: Screiber, 7/26/91, Updated Waste Storage Volumes.* ERMS 237713. Carlsbad, NM: Sandia National Laboratories.

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Appendix A:

Calculations:

Current Analysis Baseline:

ASDRUM (m^2)	6
DRROOM (drums/room)	6804
VROOM (m^3)	3644.378
A/V ratio	11.2

Hexagonal Prism (Stack):

Room Height (m)	4.572	Payload Positions per Panel	3636
Circumdiameter (m)	1.829	Average Payload (Stack) Positions per Room	519
Footprint Area (m^2)	2.173	Average Stack Volume per Room (m^3)	5160
Stack Volume (m^3)	9.934	Average Theoretical Number of Drums per Room	10908

Figure DATA-B-11 CH-TRU Waste Emplacement CRA14:

J. Screiber Paper (7/29/91):

Panel Volume (m^3)	46098
Average Room Volume (m^3)	6585

Spherical Surrogate Waste A/V/W Relationship:

Sphere Diameter (m)	0.010
Sphere Area (m^2)	3.142E-04
Sphere Volume (m^3)	5.236E-07
Sphere Weight (kgf)	4.093E-03

WDS Data as of 12/31/2014:

Total Rooms with Emplaced Containers	40
Average Stacks per Room	458
Average Stack Volume Per Room (m^3)	4549
Equivalent 55-gal drums per Room	9616

Calculation of Emplaced Container A/V Ratio Based on Payload Container Type Comparing Two Waste Surrogates (spherical surrogate as 1" cm spheres, sheet surrogate scaled by the waste to payload container weight fraction)

	Container Dimensions and Weight				WDS Emplacement Data		Container + Waste Steel Surface Area			Waste Stack Metrics		Spherical Waste Surrogate			Sheet Waste Surrogate		
Container Type	Height (m)	Diameter or Width (m)	Length (m)	Tare Weight (kgf)	No. of Waste and Dunnage Containers Emplaced (#)	Average Steel Waste Weight per Container (kgf)	Outer and Overpacked Container(s) (m^2)	Spherical Surrogate Waste Equivalent (m^2)	Sheet Surrogate Waste Equivalent (m^2)	No. of Containers per Stack (#)	No. of Equivalent Stacks (#)	Total Steel Surface Area (m^2)	Steel Surface Area Normalized to 55GD Stack Equivalent	Room Average A/V ratio (m^2/m^3)	Total Steel Surface Area(m^2)	Steel Surface Area Normalized to 55GD Stack Equivalent	Room Average A/V ratio (m^2/m^3)
55GD	0.889	0.610		29	96,494	6.41	4.58	0.49	1.03	21	4,595	489,033	5.07	1.86	540,499	5.60	2.05
POP 12-in	0.699	0.325		110	25,626	2.00	6.34	0.15	0.11	21	1,220	166,289	6.49	0.63	165,299	6.45	0.63
POP S100	0.699	0.325		71	814	0.00	6.34	0.00	0.00	21	39	5,157	6.34	0.02	5,157	6.34	0.02
POP S300	0.699	0.325		110	45	0.00	6.34	0.00	0.00	21	2	285	6.34	0.00	285	6.34	0.00
85GD OP	1.022	0.728		37	5	27.76	10.92	2.13	8.19	12	0	65	7.46	0.00	96	10.92	0.00
100GD	0.889	0.813		57	34,255	170.59	6.62	13.09	19.91	9	3,806	675,205	8.45	2.56	908,700	11.37	3.45
SWB DL	0.937	1.384	1.803	290	6,807	234.36	21.93	17.99	17.70	3	2,269	271,701	5.70	1.03	269,745	5.66	1.02
SWB OP	0.937	1.384	1.803	290	6,054	17.90	40.23	1.37	2.48	3	2,018	251,881	5.94	0.96	258,583	6.10	0.98
SLB2	1.854	1.753	2.743	1224	228	492.13	52.58	37.77	21.13	0.678	336	20,600	2.92	0.08	16,805	2.38	0.06
TDOP DL	1.858	1.810		771	24	928.91	31.42	71.30	37.86	1.5	16	2,465	7.34	0.01	1,663	4.95	0.01
TDOP OP	1.858	1.810		771	6,023	22.87	77.19	1.76	2.29	1.5	4,015	475,461	5.64	1.80	478,679	5.68	1.82
SCA	0.908	0.584		783	9	16.40	8.98	1.26	0.19	9	1	92	4.39	0.00	83	3.93	0.00
FLC DL	3.061	0.660		799	18	2.20	14.06	0.17	0.04			256		0.00	254		0.00
RLC DL	3.061	0.660		517	1	0.00	14.06	0.00	0.00			14		0.00	14		0.00
RLC OP	3.061	0.660		517	700	31.84	27.79	2.44	1.71			21,164		0.08	20,652		0.08
SHIELD PLUG	1.829	0.737			719		10.18					7,317		0.03	7,317		0.03
Total or Average											18,317	2,386,986	6.00	9.06	2,673,828	6.31	10.15

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Calculations:

Current Analysis Baseline:

ASDRUM (m^2)	6
DRROOM (drums/room)	6304
VROOM (m^3)	3644.378
A/V ratio	=B25*B26/B27

Hexagonal Prism (Stack):

Room Height (m)	4.572
Circumdiameter (m)	1.829
Footprint Area (m^2)	=(3*SQRT(3)/2)*(B32/2)^2
Stack Volume (m^3)	=B33*B31

Figure DATA-B-11 CH-TRU Waste Emplacement CRA14:

Payload Positions per Panel	=543+5*546+363
Average Payload (Stack) Positions per Room	=H31/7
Average Stack Volume per Room (m^3)	=H32*B34
Average Theoretical Number of Drums per Room	=H32*9.48

J. Screiber Paper (7/29/91):

Panel Volume (m^3)	=25510.647+20189.855+163.529+233.614
Average Room Volume (m^3)	=M31/7

Spherical Surrogate Waste A/V/W Relationship:

Sphere Diameter (m)	0.01
Sphere Area (m^2)	=4*PI()*(B38/2)^2
Sphere Volume (m^3)	=(4/3)*PI()*(B38/2)^3
Sphere Weight (kgf)	=B40*7817

WDS Data

Total Rooms with Emplaced Containers	40
Average Stacks per Room	=L64/H38
Average Stack Volume Per Room (m^3)	=H39*$B$34
Equivalent 55-gal drums per Room	=$B$9*9.48

Calculation of Emplaced Container A/V Ratio Basec

	Container Dimensions and Weight				WDS Emplacement Data		Container + Waste Steel Surface Area			Waste Stack Metrics		Spherical Waste Surrogate			Sheet Waste Surrogate		
Container Type	Height (m)	Diameter or Width (m)	Length (m)	Tare Weight (kgf)	No. of Waste and Dunnage Containers Emplaced (#)	Average Steel Waste Weight per Container (kgf)	Outer and Overpacked Container(s) (m^2)	Spherical Surrogate Waste Equivalent (m^2)	Sheet Surrogate Waste Equivalent (m^2)	No. of Containers per Stack (#)	No. of Equivalent Stacks (#	Total Steel Surface Area (m^2)	Steel Surface Area Normalized to 55GD Stack Equivalent	Room Average A/V ratio (m^2/m^3)	Total Steel Surface Area(m^2)	Steel Surface Area Normalized to 55GD Stack Equivalent	Room Average A/V ratio (m^2/m^3)
55GD	0.889	0.61		28.6	96494	6.406326610986099	=4*PI()*((B48*(C48/2)+(C48/2)^2))	=(G48/$B$41)*$B$39	=(G48/E48)*H48	21	=ROUND(F48/K48,0)	=F48*(H48+I48)	=K48*(H48+I48)/$K$48	=M48/($H$38*$M$32)	=F48*(H48+I48)	=K48*(H48+I48)/$K$48	=P48/($H$38*$M$32)
POP 12-in	0.699	0.325		110.3	25626	2.00064114571139	=4*PI()*((B49*(C49/2)+(C49/2)^2))+5*H48	=(G49/$B$41)*$B$39	=(G49/E49)*H49	21	=ROUND(F49/K49,0)	=F49*(H49+I49)	=K49*(H49+I49)/$K$48	=M49/($H$38*$M$32)	=F49*(H49+I49)	=K49*(H49+I49)/$K$48	=P49/($H$38*$M$32)
POP S100	0.699	0.325		70.5	814	0	=4*PI()*((B50*(C50/2)+(C50/2)^2))+5*H48	=(G50/$B$41)*$B$39	=(G50/E50)*H50	21	=ROUND(F50/K50,0)	=F50*(H50+I50)	=K50*(H50+I50)/$K$48	=M50/($H$38*$M$32)	=F50*(H50+I50)	=K50*(H50+I50)/$K$48	=P50/($H$38*$M$32)
POP S300	0.699	0.325		109.8	45	0	=4*PI()*((B51*(C51/2)+(C51/2)^2))+5*H48	=(G51/$B$41)*$B$39	=(G51/E51)*H51	21	=ROUND(F51/K51,0)	=F51*(H51+I51)	=K51*(H51+I51)/$K$48	=M51/($H$38*$M$32)	=F51*(H51+I51)	=K51*(H51+I51)/$K$48	=P51/($H$38*$M$32)
85GD OP	1.022	0.728		37	5	27.764	=4*PI()*((B52*(C52/2)+(C52/2)^2))+5*H48	=(G52/$B$41)*$B$39	=(G52/E52)*H52	12	=ROUND(F52/K52,0)	=F52*(H52+I52)	=K52*(H52+I52)/$K$48	=M52/($H$38*$M$32)	=F52*(H52+I52)	=K52*(H52+I52)/$K$48	=P52/($H$38*$M$32)
100GD	0.889	0.813		56.7	34255	170.5854126404 9	=4*PI()*((B53*(C53/2)+(C53/2)^2))	=(G53/$B$41)*$B$39	=(G53/E53)*H53	9	=ROUND(F53/K53,0)	=F53*(H53+I53)	=K53*(H53+I53)/$K$48	=M53/($H$38*$M$32)	=F53*(H53+I53)	=K53*(H53+I53)/$K$48	=P53/($H$38*$M$32)
SWB DL	0.937	1.384	1.803	290.3	6807	234.3613970912 3	=4*(B54*C54+C54*D54+B54*D54)	=(G54/$B$41)*$B$39	=(G54/E54)*H54	3	=ROUND(F54/K54,0)	=F54*(H54+I54)	=K54*(H54+I54)/$K$48	=M54/($H$38*$M$32)	=F54*(H54+I54)	=K54*(H54+I54)/$K$48	=P54/($H$38*$M$32)
SWB OP	0.937	1.384	1.803	290.3	6054	17.90395606210 77	=4*(B55*C55+C55*D55+B55*D55)+4*$H$48	=(G55/$B$41)*$B$39	=(G55/E55)*H55	3	=ROUND(F55/K55,0)	=F55*(H55+I55)	=K55*(H55+I55)/$K$48	=M55/($H$38*$M$32)	=F55*(H55+I55)	=K55*(H55+I55)/$K$48	=P55/($H$38*$M$32)
SLB2	1.854	1.753	2.743	1224.49	228	492.1307017543 86	=4*(B56*C56+C56*D56+B56*D56)	=(G56/$B$41)*$B$39	=(G56/E56)*H56	=($B$33/(C56*D56))*1.5	=ROUND(F56/K56,0)	=F56*(H56+I56)	=K56*(H56+I56)/$K$48	=M56/($H$38*$M$32)	=F56*(H56+I56)	=K56*(H56+I56)/$K$48	=P56/($H$38*$M$32)
TDOP DL	1.858	1.81		770.98	24	928.9083333333 33	=4*PI()*((B57*(C57/2)+(C57/2)^2))	=(G57/$B$41)*$B$39	=(G57/E57)*H57	1.5	=ROUND(F57/K57,0)	=F57*(H57+I57)	=K57*(H57+I57)/$K$48	=M57/($H$38*$M$32)	=F57*(H57+I57)	=K57*(H57+I57)/$K$48	=P57/($H$38*$M$32)
TDOP OP	1.858	1.81		770.98	6023	22.87246222812 55	=4*PI()*((B58*(C58/2)+(C58/2)^2))+10*$H$48	=(G58/$B$41)*$B$39	=(G58/E58)*H58	1.5	=ROUND(F58/K58,0)	=F58*(H58+I58)	=K58*(H58+I58)/$K$48	=M58/($H$38*$M$32)	=F58*(H58+I58)	=K58*(H58+I58)/$K$48	=P58/($H$38*$M$32)
SCA	0.908	0.584		782.77	9	16.4	=4*PI()*((B59*(C59/2)+(C59/2)^2))+5*H48	=(G59/$B$41)*$B$39	=(G59/E59)*H59	9	=ROUND(F59/K59,0)	=F59*(H59+I59)	=K59*(H59+I59)/$K$48	=M59/($H$38*$M$32)	=F59*(H59+I59)	=K59*(H59+I59)/$K$48	=P59/($H$38*$M$32)
FLC DL	3.061	0.66		799.09	18	2.2	=4*PI()*((B60*(C60/2)+(C60/2)^2))	=(G60/$B$41)*$B$39	=(G60/E60)*H60			=F60*(H60+I60)		=M60/($H$38*$M$32)	=F60*(H60+I60)		=P60/($H$38*$M$32)
RLC DL	3.061	0.66		517.01	1	0	=4*PI()*((B61*(C61/2)+(C61/2)^2))	=(G61/$B$41)*$B$39	=(G61/E61)*H61			=F61*(H61+I61)		=M61/($H$38*$M$32)	=F61*(H61+I61)		=P61/($H$38*$M$32)
RLC OP	3.061	0.66		517.01	700	31.84	=4*PI()*((B62*(C62/2)+(C62/2)^2))+3*$H$48	=(G62/$B$41)*$B$39	=(G62/E62)*H62			=F62*(H62+I62)		=M62/($H$38*$M$32)	=F62*(H62+I62)		=P62/($H$38*$M$32)
SHIELD PLUG	1.829	0.737			=SUM(F60:F62)		=4*PI()*((B63*(C63/2)+(C63/2)^2))					=F63*(H63)		=M63/($H$38*$M$32)	=F63*(H63)		=P63/($H$38*$M$32)
Total or Average											=SUM(L48:L63)	=SUM(M48:M63)	=AVERAGE(N48:N59)	=SUM(O48:O63)	=SUM(P48:P63)	=AVERAGE(Q48:Q63)	=SUM(R48:R63)

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