• OSR 45-24 (Rev 8-21-2006)

Calculation Cover Sheet H.W. 4/17/07

Project	Calculation Number	Project Number
Navigator	M-CLC-H-02820	N/A
Title Volume and Surface Area Percentages of the Cooling Coils in Type III and Type IIIA Tanks	Functional Classification SC	Sheet 1 of 13
	Discipline Mechanical	
Calc Level [X] Type 1 Type 2	Type 1 Calc Status Preliminary [X] Confirmed	
Computer Program No. NA	Version/Release No.	
Purpose and Objective The purpose of the calculation is to provide an estimate of the cooling coil to tank volume and surface area ratios for Type III and IIIA waste tanks. The data is to be used for developing assumptions and scenarios as input to the Tank Closure Performance Assessment Model.	DC/RO Date _____	

Summary of Conclusion
Type III Tanks:
Volume Percentage of Cooling Coils = 0.11%
Surface Area Percentage of Cooling Coils = 26.6%

Type IIIA Tanks:
Volume Percentage of Cooling Coils = 0.27%
Surface Area Percentage of Cooling Coils = 65.6%

Revisions

Rev No.	Revision Description
0	Initial Issue

Sign Off

Rev No.	Originator (Print) Sign/Date	Verification/Checking Method	Verifier/Checker (Print) Sign/Date	Manager (Print) Sign/Date
0	Henry Wong Henry Wong 4/17/07	Document review	Choi Chin choi chin 4/17/07	Greg C Arthur 4/17/07

Additional Reviewer (Print)	Signature	Date
Design Authority - (Print) Brannen J Adkins	Signature Brannen J. Adkins	Date 4/17/07
Release to Outside Agency - (Print) N/A	Signature	Date

Security Classification of the Calculation
UNCLASSIFIED

Calculation Continuation Sheet

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OPEN ITEMS -------- NONE

RECORD OF REVISION				
Rev. No.	**Pages Superseded**	**Pages Added**	**Pages Revised**	**Description of Revisions**
0				New issue.

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1.0 PURPOSE

The purpose of the document is to provide an estimate of the total cooling coil volume to waste tank interior volume percentage and total cooling coil surface area to waste tank interior surface area percentage for Type III and Type IIIA waste tanks. The data is to be used for developing assumptions and scenarios as input to the Tank Closure Performance Assessment Model.

2.0 INPUT AND ASSUMPTIONS

Various cooling coils and waste tank dimensions are obtained from the SRS drawings and calculations listed in Section 6.0.

Assumptions:
1. Tank wall bottom curvature is relatively small (1' radius) and is neglected. Angle between wall and floor is calculated as 90º for simplicity.
2. Maximum fill levels for Type III and Type IIIA tanks are 378.6" and 378" respectively (see Attachment 2 and Ref. 25). These operating fill limits will be used to calculate the cooling coil / tank surface area percentage, whereas the cooling coil / tank volume percentage will be calculated with full capacity (see Attachment 1).

3.0 ANALYTICAL METHODS AND COMPUTATIONS

Cooling coil piping in Type III and Type IIIA tanks are vastly different. Type III tank cooling coils are insertable, deployable coolers that were installed into riser B-1 through B-10 after the tank was completed. Type IIIA tanks have permanently mounted U-shape cooling coils installed prior to completion of the tanks. Both types have grooved channels in the concrete beneath the tank to provide bottom cooling.

This calculation will compute the overall length of cooling coils in the tank. The volumes and surface areas of the cooling coils will then be determined with the diameters and overall length of the piping. The data will be compared with the internal volumes and maximum fill surface areas of the tanks. Data from the six Type III tanks that have variable numbers of insertable coolers will be calculated individually to obtain a more accurate average number. Tank 35 is a Type IIIA tank, but has insertable coolers and is included in the Type III tank calculation. Data from Tank 48, 49, and 50 will be used to obtain an average number to represent Type IIIA tanks.

3.1 TYPE III TANKS CALCULATION

There are three types of cooling coils installed in Type III tanks (29-32, 33, 34) and tank 35:
1. Consolidated Bundle - consists of closely spaced cooling piping (2" sch 40 pipes)
2. Conical - consists of 11 double-pipe elements (2"& 1¼" sch 40 pipes) in a conical configuration with a base that deploy at the bottom to a diameter of 24 feet.
3. Cylindrical - consists of 20 single-pipe elements (2" sch 40 pipes) that deploy at the top and bottom to a diameter of 16 feet.

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1. Consolidated Bundle Coolers can be subdivided into 30 sections of long spans, 10 sections of short spans, 23 pieces of long radius U-bends (LR), and 16 pieces of short radius U-bends (SR) (Ref. 12, 13, 14 & 21).

Estimated cooling coil length per bundle (full length) = 30 long sections*(31'1" - 6") + 10 short sections*(29'6" - 4") + 23 LR bends*π*3" + 16 SR bends*π*2"
= 1236 ft

Estimated cooling coil length per bundle (up to fill limit) = 30 long sections*(31'1" - 6"-15.4") + 9 LR bends*π*3" + 10 short sections*(29'6" - 4") + 16 SR bends*π*2"
= 1186 ft

Estimated cooling coil volume per bundle (full length) =pipe cross sectional area*full pipe length
= $(\pi/4)*(2.375/12)^2*1236$ = 38 cu. ft

Estimated cooling coil surface area per bundle (up to fill limit) = pipe circumference*fill limit pipe length
= π*(2.375/12)*1186 = 737 sq. ft

2. Conical Deployable Cooler has 11 double pipe loops and 2 inlet/outlet loops. Each loop is fabricated of a section of 2" sch 40 pipe with a U-bend, and a section of 1¼" sch 40 pipe with a smaller U-bend (Ref. 5, 6, & 7). The two sections are joined by a reducer. When inserted into the tank, the top of the cooling coil U-bends are well below the fill limit level.

Estimated cooling coil length per cooler = 13 double-pipes*[(2*11'3½") large pipes + π*3" large pipe bends + (2*9') extensions] + 13 double-pipes*(2*10'1½") small pipes + 10*π*1.875"small pipe bends
= 538' large pipe length + 268' small pipe length
= 806 ft

Estimated cooling coil volume per cooler = (large pipe cross sectional area*large pipe length) + (small pipe cross sectional area*small pipe length)
= $(\pi/4)*(2.375/12)^2*538 + (\pi/4)*(1.66/12)^2*268$
= 21 cu. ft

Estimated cooling coil surface area per cooler = (large pipe circumference*large pipe length) + (small pipe circumference*small pipe length)
= π*(2.375/12)*538 + π*(1.66/12)*268
= 451 sq. ft

3. Cylindrical Deployable Cooler has 10 loops interconnected to outline a cylinder (Ref. 8, 9, 10, 11 & 24). Similar to the Conical Deployable Cooler, the top of the cooling coil U-bends remain well below the fill limit level when installed.

Estimated cooling coil length per cooler = 20 single-pipes*[19' + 9'7" + π*3"] + 4 inlet/outlet pipes*[29' + π*3"] = 707 ft

Estimated cooling coil volume per cooler = pipe cross sectional area*pipe length
= $(\pi/4)*(2.375/12)^2*707$ = 22 cu. ft

Estimated cooling coil surface area per cooler = pipe circumference*pipe length
= π*(2.375/12)*707 = 440 sq. ft

The six Type III tanks and Tank 35 have different numbers and types of insertable coolers installed in risers B1 through B10 as tabulated below:

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Table 1 – Type III Tank Cooling Coil Numbers and Types

Tank Number	Cooler Number & Types
29	4 Cylindrical & 5 Bundle
30	5 Cylindrical
31	5 Bundle & 3 Cylindrical
32	5 Bundle
33	4 Conical & 4 Cylindrical
34	7 Conical & 3 Cylindrical
35	5 Bundle

Based on Table 1 and the volume of each type of cooling coils estimated, the volumes of cooling coils that take up in each Type III tank are tabulated below:

Table 2 – Type III Tank Cooling Coil Volumes

Tank Number	Cooler Volume, cu. ft.
29	278
30	110
31	256
32	190
33	172
34	213
35	190

Average volume of cooling coils in Type III tanks = (278 + 110 + 256 + 190 + 172 + 213 + 190) / 7
= 201 cu. ft

Primary tank volume = 183,588 cu. ft. (Ref. 20)

Average Volume Percentage of Cooling Coils in Type III Tanks = 201 / 183588
= 0.11%

Based on Table 1 and the surface area (up to the fill limit) of each type of cooling coils estimated, the surface areas of cooling coils that take up in each Type III tank are tabulated below:

Table 3 – Type III Tank Cooling Coil Surface Areas

Tank Number	Cooler Surface Area, sq. ft.
29	5445
30	2200
31	5005
32	3685
33	3564
34	4477
35	3685

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Average surface area of cooling coils in Type III tanks (up to the fill limit)
= (5445 + 2200 + 5005 + 3685 + 3564 + 4477 + 3685) / 7
= 4009 sq. ft

Modeling the tank as a cylinder, the wall area, floor area and center column area (up to the fill limit) are computed as follows:

Primary tank wall area = Area of vertical wall + Area of top curvature (up to the fill limit)
= π*Diameter of Tank*Wall Height + Area of submerged wall curvature
= π*85'*(33' - 4') + ¼*π*2*4*π*85*[90 - $\cos^{-1}$(2.55/4)]º / 90º (Ref . 1)
= 7744.03 + 738.35
= 8482 sq. ft

Primary tank floor area = π*(Diameter of Tank)² / 4
= π*(85)² / 4
= 5675 sq. ft

Tank center column area = Surface area of cylindrical column + Surface area of submerged frustum
= π*6.75'*24.75' + π*9.615'*(10.175' + 3.375') (Ref.1, 23)
= 934 sq. ft

Primary tank surface area (up to the fill limit) = (8482 +5675 + 934) sq. ft
= 15091 sq. ft

Average Surface Area Percentage of Cooling Coils in Type III Tanks = 4009 / 15091
= 26.6%

For comparison purpose, Volume and Surface Area Percentages of Cooling Coils for Tanks 29-35 are listed in the following Table:

Table 4 – Volume and Surface Area Percentages of Type III Tanks (29-35)

Tank Number	Volume % of Cooling Coils	Surface Area % of Cooling Coils
29	0.15%	36.1%
30	0.06%	14.6%
31	0.14%	33.2%
32	0.10%	24.4%
33	0.09%	23.6%
34	0.12%	29.7%
35	0.10%	24.4%

3.2 TYPE IIIA TANKS CALCULATION

Type IIIA tanks (25-28, 36-51) have permanently mounted U-shape vertical cooling coils supported from tank bottom. Each tank has around 250 loops of 2" sch 40 pipes. Each loop is also supported by a loop

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guide attached to the tank roof, so that the top of each U-bend is about 3 ft from the roof and well below the maximum tank fill level.

Three ITP tanks (Tank 48, 49, 50) data are used here to estimate the average Type IIIA cooling coil volume and surface area percentage. Tank 50 and Tank 51 have identical data. Other Type IIIA tanks drawings were reviewed and their configurations are found to be similar.

There are four types of upper loop (straight section and U-bends) and two types of bottom U-bend dimension (Ref. 3 & 4). The pipe length of each type is multiplied by the quantity to get the total length of pipe for that type. The total length of each type is totaled to get the overall length of the cooling coil in the tank. This length will then be used as input to compute the total volume and surface area of the cooling coil and compare them to the tank volume and surface area. The results are tabulated as follows:

Table 5 and 6 list the calculated pipe length of upper loops and bottom U-bends for Tanks 48, 49, and 50. For dimensions Z, X, Details A-A through F-F, Details A through L, see drawing W708852 (Ref. 3).

Table 5 – Type IIIA Tank Cooling Coil Data (Upper Loops)

Section Detail	Z , ft	Section Length, ft	Quantity of Section, Tank 48	Total Length, ft Tank 48	Quantity of Section, Tank 49	Total Length, ft Tank 49	Quantity of Section, Tank 50	Total Length, ft Tank 50
A-A	--	55.71	220	12256	222	12368	217	12089
B-B	0.802	56.51	6	339	5	283	6	339
C-C	0.354	56.06	8	448	7	392	10	561
D-D	1.068	48.28	2	97	2	97	2	97
E-E	--	47.21	19	897	19	897	19	897
F-F	0.208	55.92	2	112	2	112	2	112

Table 6 – Type IIIA Tank Cooling Coil Data (Bottom U-Bends)

Section Detail	X , ft	Section Length, ft	Quantity of Section, Tank 48	Total Length, ft Tank 48	Quantity of Section, Tank 49	Total Length, ft Tank 49	Quantity of Section, Tank 50	Total Length, ft Tank 50
A	--	6.21	249	1546	248	1540	252	1565
B	0.354	6.56	13	85	12	79	9	59
C	2.406	8.62	1	9	2	17	1	9
D	5.078	11.29	1	11	1	11	1	11
E	3.333	9.54	1	10	1	10	1	10
F	0.802	7.01	7	49	8	56	7	49
G	1.813	8.02	2	16	2	16	2	16
H	3.188	9.40	2	19	2	19	2	19
J	1.021	7.23	1	7	1	7	1	7
K	3.500	9.71	1	10	1	10	1	10
L	1.240	7.45	2	15	2	15	2	15

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Combining total length of cooling coils from Table 5 and 6:

Total length of cooling coils in Tank 48 = 15926 ft

Total length of cooling coils in Tank 49 = 15929 ft

Total length of cooling coils in Tank 50 = 15865 ft

Average length of cooling coils in Tank 48, 49, and 50 = (15926 + 15929 + 15865) / 3
= 15907 ft

Average Volume of Cooling Coils in Type IIIA Tank = Pipe cross sectional area*pipe length
= $(\pi/4)*(2.375/12)^2*15907$
= 489 cu. ft

Primary tank volume = 183,588 cu. ft. (Ref. 20)

Average Volume Percentage of Cooling Coils in Type IIIA Tanks = 489 / 183588
= 0.27%

Average Surface Area of Cooling Coils in Type IIIA Tank = Pipe perimeter*pipe length
= $\pi*(2.375/12)*15907$
= 9891 sq. ft

Primary tank wall area = Area of vertical wall + Area of top curvature (up to the fill limit)
= π*Diameter of Tank*Wall Height + Area of submerged curvature
= $\pi*85'*(33' - 4') + ¼*\pi*2*4*\pi*85*[90 - \cos^{-1}(2.5/4)]^o / 90^o$ (Ref. 1)
= 7744.03 + 721.14
= 8465 sq. ft

Primary tank floor area = $\pi*(\text{Diameter of Tank})^2 / 4$
= $\pi*(85)^2 / 4$
= 5675 sq. ft

Tank center column area = Surface area of cylindrical column + Surface area of submerged frustum
= $\pi*6.75'*24.75' + \pi*9.545'*(10.125' + 3.375')$
= 930 sq. ft

Primary tank surface area (up to the fill limit) = (8465 +5675 + 930) sq. ft
= 15070 sq. ft

Average Surface Area Percentage of Cooling Coils in Type IIIA Tanks = 9891 / 15070
= 65.6%

For comparison purpose, Volume and Surface Area Percentages of Cooling Coils for each ITP Tanks are listed in the following Table:

Table 7 – Volume and Surface Area Percentages of Individual Type IIIA Tanks (48-50)

Tank Number	Total Length of Cooling Coils, ft	Volume % of Cooling Coils	Surface Area % of Cooling Coils
48	15926	0.27%	65.7%
49	15929	0.27%	65.7%
50	15865	0.27%	65.5%

4.0 RESULTS

Type III Tanks:

Volume Percentage of Cooling Coils = 0.11%
Surface Area Percentage of Cooling Coils = 26.6%

Type IIIA Tanks:

Volume Percentage of Cooling Coils = 0.27%
Surface Area Percentage of Cooling Coils = 65.6%

5.0 CONCLUSIONS

Type I, II, III, and IIIA tanks' cooling coil to tank volume and surface area percentage data are requested by Liquid Waste Operations Engineering as part of the modeling input for project 'Navigator'.

The results of this calculation provides input data of Type III and IIIA tanks to be used for developing assumptions and scenarios as input to the Tank Closure Performance Assessment Model. Type I and II tanks will be covered by calculation C-CLC-G-00364.

6.0 REFERENCES

1. W236562, "HLW Storage Fac. General Arrangement and Const. Details, Concrete"
2. W700853, "Tanks 38 thru 43 Additional Waste Storage Tanks, Primary Liner Plans and Details"
3. W708852, "Waste storage Fac. FY78, Cooling Coil Elev. T48 – T51, Process Piping Arrgt., Process"
4. W707625, "Waste storage Fac. FY78, Cooling Coil Plan T48, Process Piping Arrg't, Process"
5. S5-2-7852, "Waste Tank Conical Deployable Cooling Coil Assembly"
6. S5-2-7863, "Waste Tank Conical Deployable Cooling Coil, Piping Weldment"
7. S5-2-7865, "Waste Tank Conical Deployable Cooling Coil, Detail Sheet No. 9"
8. S5-2-8325,"Waste Tank Cylindrical Deployable Cooling Coil, No.1, Assembly"
9. S5-2-8333, "Waste Tank Cylindrical Deployable Cooling Coil, Detail Sheet 7"
10. S5-2-8334, "Waste Tank Cylindrical Deployable Cooling Coil, Detail Sheet 8"
11. S5-2-8337, "Waste Tank Cylindrical Deployable Cooling Coil, Detail Sheet 10"
12. W237191, "Bldg 241-H&F Additional HLW Storage, Wst. Tk. Cooler Arrg't, Process"

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13. D139577, “WST Tk Cooler Details”
14. S4-2-613, “Waste Tanks 29, 30, 31 and 32 Bayonet Cooler Support, Arrangement and Detail”
15. S5-2-6335, “Waste Tank 75 Ft Dia and 85 Ft Dia., 2 Ft Dia Riser Cooling Coil Unit, Details”
16. S5-2-6337, “Waste Tank 75 Ft Dia, 2 Ft Dia Riser Cooling Coil Unit, Arrangement”
17. S5-2-6338, “Waste Tank 75 Ft Dia, 2 Ft Dia Riser Cooling Coil Unit, Details”
18. S5-2-6333, “Waste Tank 85 Ft Dia, 2 Ft Dia Riser Cooling Coil Unit, Arrangement”
19. M-M6-G-0669, “H & F Area HLWT Cooling Coil Status & Configuration Piping Diagram”
20. U-CLC-G-00001, “Total Fill Volumes of High Level Waste Tanks”
21. T-CLC-H-00629, “Tank 32 Cooling Coil Stress Analysis for Salt Adhesion”
22. C-CLC-G-00355, “Carbon steel Components in Type I and Type II Tanks and Annuli”
23. Mark’s Standard Handbook for Mechanical Engineers, Ninth Edition Page 2-10.
24. S5-2-8332, “Tanks 38 thru 43 Additional Waste Storage Tanks, Secondary Liner Plans and Details”
25. WG17\WCS1.5 PROD\WCS1.5, *Waste Characterization System*

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7.0 ATTACHMENTS

ATTACHMENT 1

Email from Bruce Martin (Tank Closure Planning):

Bruce Martin/WSRC/Srs
03/01/2007 12:41 PM

To:
cc: Brannen Adkins/WSRC/Srs@Srs, Henry Wong/WSRC/Srs@Srs, John-J Phillips/WSRC/Srs@Srs, Jeffry Newman/WSRC/Srs@Srs
Subject: Calculation

Henry asked that I send an e-mail to clarify what was needed from a tank closure perspective:

1) The volume section of the calc. should calculate the volume of the cooling coils for comparison with the total volume of the entire tank internal space that will be filled with grout at closure (up to the roof).

2) The surface area section of the calc. should calculate the surface area of the cooling coils, tank support columns, floor, and walls up to the highest waste level (per tank type) ever allowed in each type tank.

Please call if you have any other questions, and thanks very much for helping tank closure with these calculations.

Bruce 8-2902/15472

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ATTACHMENT 2

Email from Hilary Bui (Tank Farm Process Engineering):

Hilary Bui/WSRC/Srs
03/01/2007 12:42 PM

To: Bruce Martin/WSRC/Srs@Srs
cc: Henry Wong/WSRC/Srs@Srs, John-J Phillips/WSRC/Srs@Srs
Subject: Re: Max operating limits for HLW tanks

These are the overflow limits, set at the level of the lowest penetration into the tank:

Type I tanks: 280.3"
Type II: 316.2
Type III: 378.6
Type IIIA: 378
Type IV: 393.3

Thanks,
Hilary Bui
8-8184