Analysis of Cs-137 and Co-60 for a high Dose Rate Chemical Cleaning Tank - 17653

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Abstract

TMI/Exelon has requested that Canberra characterize the radiological contents of the CCT-1 (Chemical Cleaning Tank) located in the CCB (Chemical Cleaning Building). Central to the CCB is the EPICOR-II [1] system. The CCB was originally intended to be used in the chemical cleaning of the steam generators for TMI Units l and 2. It is a rectangular shaped building with dimensions of 48 feet wide by 60 feet long by 52 feet high. The foundation of the building and the walls up to a height of 13.5 feet above the basement floor are concrete and the upper walls and roof are of structural steel.

The EPICOR-II system was modified in the early 1980's to accommodate waste water processing from the March, 1979 TMI-2 accident, consists of the following components, all of which are located in the TMI chemical cleaning building: five processing pumps, a transfer pump, pre-filter/demineralizer (containing pre-coat material and cation bed resin), two demineralizers (one cation bed followed by a mixed bed), clean wastes (holding) receiver tank (CHRT; formerly the rinse hold tank; RHT or CCT-2), off-specification water (holding) receiving/batch tank (OHRT; formerly the chemical cleaning solution tank; CCT-1), chemical cleaning building sump pump, monorail hoist system, and ventilation filtration system.

TMI/Exelon required measurements on the tanks to that would meet Class A shipping requirements for LLW. The initial measurements on CCT-1 were performed applying the Generalized (Super) ISOCS templates in conjunction to a High Purity Germanium Detector. The measured activity values for ^{137}Cs and ^{60}Co will be discussed based on the models from Super ISOCS with uncertainty estimates from the - ISOCS Uncertainty estimator (IUE). Operational setup requirements will be described with the final activity values, based on model assumptions, from the measurements performed.

INTRODUCTION

TMI/Exelon has requested that Canberra characterize the radiological contents of the CCT-1 tank located in the CCB. Central to the CCB is the EPICOR-II [1] system. The CCB was originally intended to be used in the chemical cleaning of the steam generators for TMI Units l and 2. It is a rectangular shaped building with dimensions of 48 feet wide by 60 feet long by 52 feet high. The foundation of the building and the walls up to a height of 13.5 feet above the basement floor are concrete and the upper walls and roof are of structural steel.

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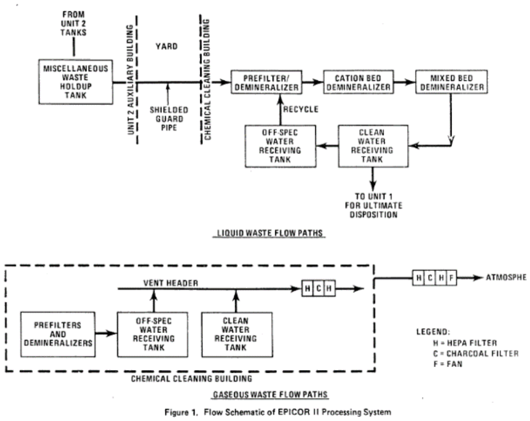


Figure 1 EPICOR-II system [1].

Aside from the waste water that was treated in the early 1980's from TMI-2, the normal waste water that is treated by EPICOR-II is called letdown. Letdown is water which is normally removed from the reactor coolant system for the purpose of controlling reactor coolant inventory and chemical and radioactivity content; it is depressurized and cooled prior to reaching the auxiliary building tanks, and, presumably the mixed waste holding tank (MWHT) for the TMI-2 era. In addition, normal leakage from system components in the auxiliary building has been a small but continuous source of waste water to the inventory which currently exists in all of the auxiliary building tanks (approximately 280,000 gallons). The level of contamination of the water in these tanks ranges from less than 0.1 to 35 uCi/ml of Cs-l37. Because of the relatively short half-life of I-131 (8.1 days) compared to that of Cs-l37 (30 years), Cs-l37 has become the dominant isotopic contributor.

Prior to processing in EPICOR-II, the water is analyzed for radioactivity and chemical content to provide estimates of activity buildup on the ion exchange resins and the need for required chemical addition for system optimization. The first processing pump is used to pump water from the auxiliary building tanks (and the mixed waste holding tank, MWHT, from the TMI-2 era) to the prefilter/demineralizer in the chemical cleaning building through the yard piping. The piping is enclosed in a shielded guard pipe, the open end of which terminates inside the chemical cleaning building. The prefilter/de mineralizer contains a precoat material which enables it to remove particulate radioactive wastes (e.g., activated corrosion products) and other suspended solids. The prefilter also contains cation bed resin which is highly efficient for the removal of cesium and other cationic radionuclides from the waste stream (removal efficiency greater than 90%). After passing through the prefilter/demineralizer, the water is circulated by the processing pumps through the two demineralizers arranged in series. The first demineralizer also contains a cation resin which also makes it highly efficient for removal of cesium and other cationic radionuclides from the waste stream (removal efficiency greater than 90%). The second de-mineralizer contains mixed resins (cation and anion) which are efficient for removal of both cationic and anionic radionuclides, including cesium and iodine (removal efficiency greater than 90%). After processing, the water is collected in the clean water receiving tank (CHRT) which has a capacity of 133,000 gallons. In the CHRT the water will be sampled and analyzed for nuclide identification. If the analysis shows that the processed waste contains concentration of radioactivity below predetermined limits, the water will then be transferred to the TMI Unit 1 or 2 liquid waste management system to be held for ultimate disposition. These predetermined limits are specified in the system operating procedures and in the plant radiological effluent technical specifications. Processed waste which is not suitable for transfer to TMI Unit 1 or 2 liquid waste management system will be pumped to the off-spec water receiving/batch tank (OHRT) which has a capacity of 95,000 gallons. Hater in this tank will be recycled through the EPICOR-II system for additional processing.

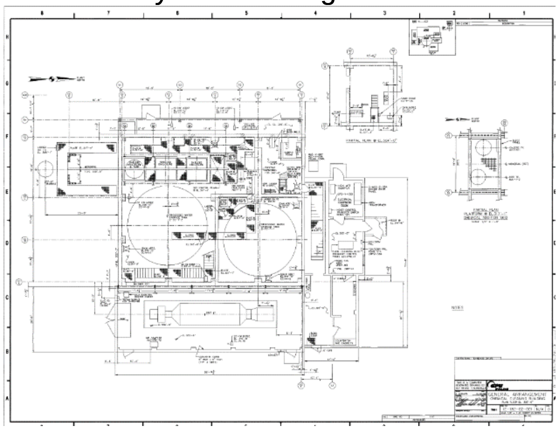


Figure 1 Overhead view of the CCB at TMI [3].

On overhead view of the CCB is shown in **Error! Reference source not found.**. The CCT-1 is a 95,000 gallon tank and is the smaller diameter tank to the lower right in **Error! Reference source not found.**. The RHT/CCT-2 is a larger 135,000 gallon tank to the left of CCT-1 in **Error! Reference source not found.**. A detailed side-view drawing of CCT-1 is depicted in **Error! Reference source not found.**. The CCT-1 is a capsule-shaped tank 38’ 6” in height with 10’ 11” radius hemispheres at the top and bottom.

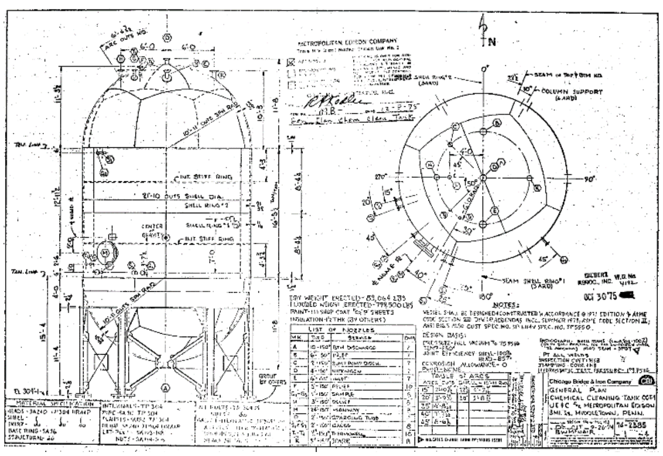
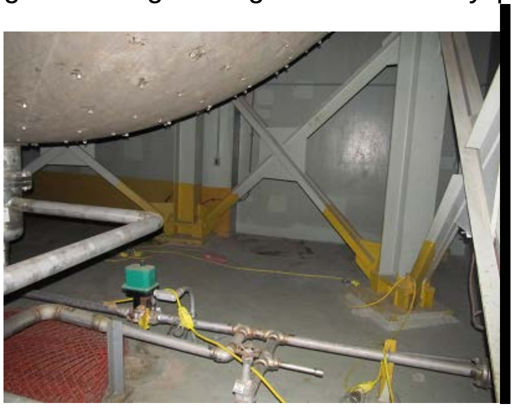


Figure 2 Engineering drawing of CCT-1 at TMI.

The CCT-1 is currently in service and the water fill height may change daily. Typical fill heights might be 30’ and sediment depths might be as high as 3’ [2] but more than likely the sediments are suspended due to pumps agitating the water within CCT-1 [3].

Figure 4 The bottom of the CCT-1 showing valves and pipes reducing workspace (view #1).

Volatile fission products such as Cs-137 and I-131 might be expected as well as Co-60 from activation of steel in the form of rust sediments that work their way to the tank. To investigate this, a two position survey, using a Canberra Inspector 1000 with NaI probe, was conducted by Canberra when visiting the TMI site on August 29th, 2016. The first survey was done just at the entrance of the CCB (see **Error! Reference source not found.**) and the survey spectrum is shown in 5. There was a somewhat significant Compton scattering continuum but no discernable peaks albeit the count time was relatively short. The second survey was conducted within 10' of the CCT-1, presumably near the bottom (see 4 and 5), and Cs-137 and Co-60 is evident, and abundant, as shown in 6. Note that I-131 was not detected and this is expected as the decay half-life is extremely short. Also note that the NaI probe is not collimated so it is not certain if the Cs-137 and/or Co-60 was actually emanating from the contents of the CCT-1 but might be originating from a nearby pipe of valve or even the RHT/CCT-2.



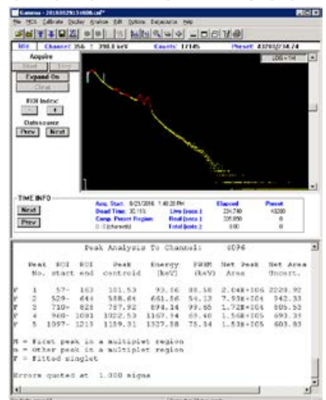


Figure 5 Area at bottom of CCT showing "open" area (view #2). (On the left)
Figure 6 Spectra acquired near (10 feet) of CCT-1. (On the right)

Objective

Canberra will *in situ* characterize the radiological contents of the CCT-1, in activity/unit, *e.g.*, uCi/ml and/or uCi/g, for nuclides that are detected, and identified, presumably, Cs-137 and Co-60. The characterization also includes minimal detectable activity per unit and total measurement uncertainty (TMU) for fiducial nuclide(s) that were identified. Canberra will not characterize any pipes, pumps or valves associated with, or connected to, the CCT-1. Certain assumptions will be made including:

- The radioactivity is suspended uniformly throughout the volume of water within the CCT-1. We assume this since the water is agitated [3].
- There is a sediment layer that potentially differs in density from that of water. The Chemistry Department at Exelon may provide the materials composition of the

sediments. The sediment layer may be of known depth; this depth can either be determined from AK provided by Exelon, densitometry measurements performed by Exelon, or by Exelon's gamma camera or Canberra's iPix gamma camera. These sediment assumptions were discussed with Exelon [2,3].

- It is understood that the contact dose with the bottom of the CCT-1 is +200 mr/hr. Canberra and Exelon must agree to minimize the dose acquired for Engineer #2 by developing a strategy so as to minimize exposure while adhering to ALARA goals. This might mean that some planned measurements in the basement of the CCB must be scrapped so the most important, and sensitive, measurements will be conducted first. The gamma camera scan is of most importance as the results from the scan will assist in developing the strategy. The second most important feature for strategizing is an assessment of the directional background radiation.

Equipment and Materials

- Canberra will use two Falcon 5000 portable/electrically cooled BEGe 2830 (18%) HPGe detectors onsite with associated platform materials and appropriate side collimation so as to mitigate the directional background. Canberra may also request to mobilize two of their Inspector 1000 units with NaI, LaBr and neutron probes (for survey purposes).
- Canberra used attenuators at the site to facilitate detector saturation conditions. These attenuators will be of Pb (lead) or W (tungsten) materials and approximately ¼"to 1" thick and of sheet form (smaller than 1'x1').
- Exelon provided 20 sealed/coated Pb bricks and mobilize to the basement of the CCB near the CCT-1.
- Canberra's iPix gamma camera was utilized for imaging the tank.
- Exelon provided QC check sources that were accessible during the measurement duration.

METHODS

Canberra has made simultaneous measurements on the roof of the CCB as well as the basement of the CCB using the two Falcon 5000 units and Canberra Engineers #1 and #2.

The CCB roof measurements were accomplished by Canberra Engineer #1 so that only the CCT-1 is viewed with a collimated Falcon 5000 pointing (vertically) down towards the roof as shown in Figure 7.

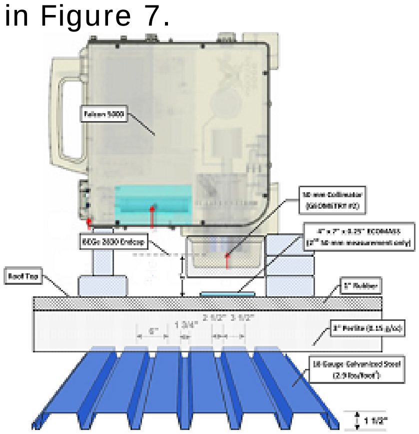
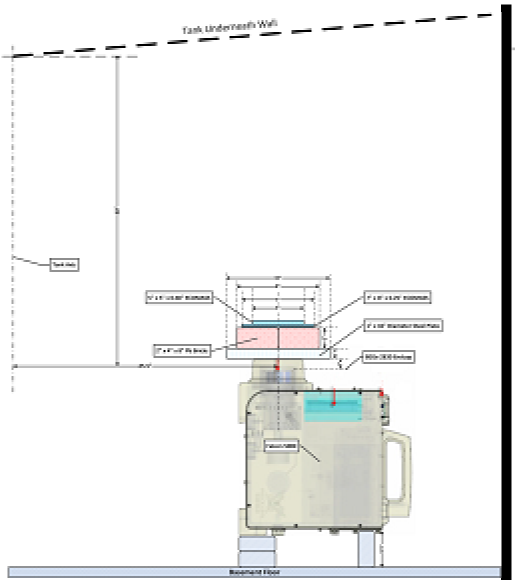


Figure 7 Falcon 5000 roof position for the 50 mm collimator shot (geometry #2).

Environmental directional background assessments were performed by making measurements, horizontally, in four 90 degree increments. The two collimator shots, the more open 100 mm and the narrower 50 mm, define two geometries; geometry #1 for the 100 mm collimator, shown in Figure 8, and geometry #2 for the 50 mm collimator, shown in Figure 9.



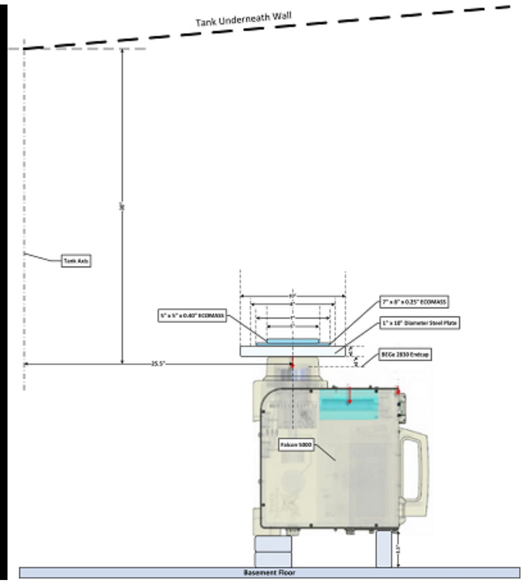
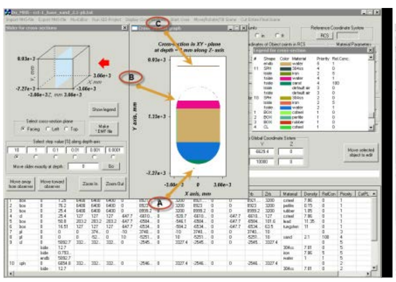
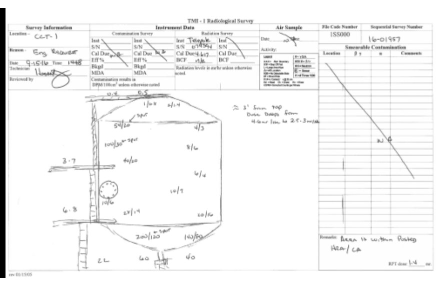


Figure 8 Falcon 5000 position in basement of CCB with steel disk, Pb and ECOMASS attenuators (geometry #3) (on the left).
Figure 9 Falcon 5000 position in basement of CCB with steel disk and ECOMASS attenuators (geometry #4) (on the right).

The CCB basement measurements were accomplished for two Falcon 500 positions, shown in **Error! Reference source not found.**, by Engineer #2 with only the open collimation (100 mm) so all of the bottom of CCT-1 could be viewed for the best sensitivity. Since the activity overwhelmed the BEGe 2830 detector, two attenuation levels were utilized; both levels included tungsten attenuation with one level including Pb brick attenuators. The attenuation level with the Pb bricks is defined as geometry #3 (**Error! Reference source not found.**) and that without the Pb bricks is defined as geometry #4 (**Error! Reference source not found.**).





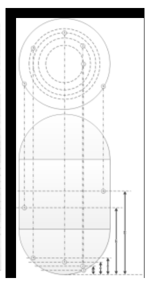


Figure 3 Super ISOCS composer showing the CCT-1 features using the *Display Cross-sections* selection. Feature A is the Falcon 5000 attenuator position for the CCB basement shots; feature B is the water fill height and feature C is the roof. (Left side)
Figure 4 Dose survey of CCT-1 conducted on 9/15/16. (Center)
Figure 5 6 Semi-random hotspot locations. (Right side)

The general positioning of the Falcon 5000 and associated dose for the CCB basement measurements is depicted in Figure 18.

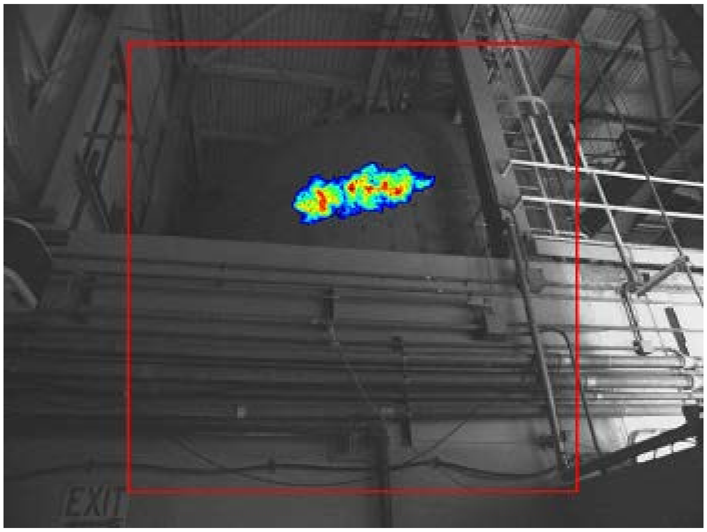


Figure 18 Hotspot iPix view of the top of the CCT-1 using the yellow mask (view I3).

GAMMA CAMMERA

Canberra made several views of the CCT-1 with the iPix camera in various regions of the CCB as shown in **Error! Reference source not found.**.

QUALITY CONTROL

Successful QC checks were accomplished at the start and completion of the project.

ANALYSIS

The analysis involves generating the Super ISOCS models, as shown in Figure 15, which ultimately produces detector efficiencies (cps/Bq). The efficiency is then applied to the count rate to produce an activity. This is accomplished for both the CCB roof and CCB basement measurements. The activity is then summed and divided by the volume of the CCT-1 (95,000 gallons) to produce the total measured activity concentration.

The models were designed so as to reflect the dose survey shown in Figure 16.

CCB ROOF MODEL

The roof measurement only samples the top hemisphere of the CCT-1 as shown in Figure 5. The model of the roof measurements involved a Super ISOCS model that assumed that nearly all of the activity was from plating on the inner sides of the CCT-1. This assumption was verified by placing a small tungsten attenuator in directly in front of the collimator so as to block out the view of the water but not the sides of the tank. We observed that the Cs-137 count rate did not change significantly implying that the activity was coming from the sides of the CCT-1. It was also assumed that the plating extended to 90% (34’ 9”) of the full height of the tank (38′ 6″) which defines an angle θ = 40° as shown in Figure 5. This defines a surface area of the top hemisphere of the tank of,

$$Top\ Hemisphere\ Surface\ Area = 2 \cdot \pi \cdot R^2 \cdot \int_0^{\theta=40^o} sin\theta\ d\theta$$

Using R = 10' 11" we have,

$$Top\ Hemisphere\ Surface\ Area = 2 \cdot \pi \cdot R^2 \cdot 0.24 = 179.7\ feet^2$$

We assume that all activity measured on the roof is spread, *i.e.*, plated, uniformly within this surface are. So the $Activity\ per\ Unit\ Area$ for the whole tank would be the measured activity from the roof shot divided by $Top\ Hemisphere\ Surface\ Area$. The remaining inner surface activity for the rest of the tank is the inner surface activity of the top hemisphere, main cylinder and the bottom hemisphere.

The surface are of the main cylinder is computed by,

$$Main\ Cylinder\ Surface\ Area = 2 \cdot \pi \cdot R \cdot H = 1{,}108.9\ feet^2$$

Where H = 16' 2" as shown in Figure 5.

By symmetry, we assume the same effective surface area as $Top\ Hemisphere\ Surface\ Area$ for the bottom hemisphere since the CCB basement measurements also see a fraction of this inner surface activity and since the intent is to add the CCB roof and CCB basement measured concentrations.

The total inner surface activity would then be computed as

$$Total\ Inner\ Surface\ Activity = Activity\ per\ Unit\ Area \cdot (Main\ Cylinder\ Surface\ Area + 2 \cdot Top\ Hemisphere\ Surface\ Area)$$

The activity concentration contribution from the inner surface of the CCT-1 would then be the $Total\ Inner\ Surface\ Activity$ divided by the volume of the entire vessel (95,000 gallons = 3.596E+08 ml).

CCB BASEMENT MODELS

3 basic Super ISOCS templates were created and efficiencies generated. The <u>first</u> Super ISOCS template contained 6 hotspots with 4 of the hotspots concentrated within the first six feet of the CCT-1 and the other two hotspots above that line up to the water fill line (approximately 31 feet). The <u>second</u> and <u>third</u> Super ISOCS templates assume a uniform deposition (plating) of the radioactivity up to the fill line with an additional 2' sandy/silt layer at the bottom of the CCT-1. The main difference between the <u>second</u> and <u>third</u> models was the density of the 2' sandy/silt layer, i.e., 1.1 g/cc and 2.1 g/cc.

Model #1

The main intention of this model was to assume that super-hot objects, such as resin beads, may have worked their way through to the filters and into the tanks. We assumed that the hotspots would be concentrated at the bottom since they are denser than water and that, according to dose survey, most of the contact dose was at the bottom. Based on these assumptions we placed, within the model, 6 hotspots within the tank close to the insides of the tank at 2’, 4’, 6’, 16’ and 20’ of elevation as shown in **Error! Reference source not found.**. This model is not applied to the roof since the fill height of the tank is several feet above the highest hotspot.

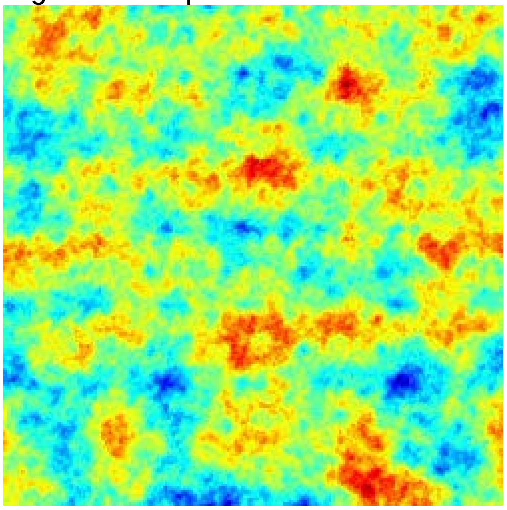


Figure 6 Gamma field iPix view showing CCT-1 through wall (view I2).

Model #2

This model assumes that there is a 24” silt/sandy layer at 2.1 g/cc at the bottom of the tank. Included in the model is a thin 1/32” iron layer all along the inner sides of CCT-1 shell. The model assumes that the relative concentration of the silt/sandy layer is 100%, the 1/32” iron layer is 5% and the water is 1% relative source strength.

Model #3

The third model is the same as the second model where the difference is that the 24” silt/sandy layer is 1.1 g/cc.

RESULTS

The results are separated into CCB roof and CCB basement measurements. These measurements are considered as being sensitive to different portions of the CCT-1.

The CCB roof measurements are sensitive to the radioactive material plated within the inner CCT-1 walls. We assumed that when the CCT-1 is cleaned that this material will be removed chemically and/or by power washing and mixed with the water within the volume of the CCT-1 for disposal.

The CCB basement measurements were sensitive to the volume within the bottom hemisphere of the CCT-1. We assume that there is a few feet of material at the bottom of the CCT-1, such as sand, at a density greater than that of water (1.0 g/cc) but less than sand (2.1 g/cc). We also assume that when the tank is cleaned that this material will be broken up and mixed within the volume of the CCT-1 for disposal.

Based on these assumptions, an activity concentration is computed for the plated activity and sedimentary activity and to total activity concentration is then the sum of the plated and sedimentary activity.

CCB ROOF

The results from the CCB roof Falcon 5000 100 mm measurement are shown in Table 1. The Total activity concentrations, shown in the table, are modeled as activities from materials plated within the inner sides of the CCT-1. It does not include the concentrations from the bottom of the CCT-1 which are assumed from the CCB basement measurements.

The plated activity for **Cs-137** is **5.84×10^{-4} uCi/ml** which is well below the class A limit of 1 uCi/ml. The average of both **Co-60** gamma lines (1173 keV and 1332 keV) is **4.80×10^{-3} uCi/ml** which is also much less than the class A limit of 700 uCi/ml.

The 2-σ Total Measurement Uncertainty (TMU) for all CCB roof measurements were estimated to be ± 50% with the counting statics contributing less than 5%.

Table 1 Activity computed from the roof measurement using the Falcon 5000 and the 100 mm collimator. This activity is assumed to be plated activity from the inner walls of the CCT-1.

Peak	Counts	Live	Branching	Super ISOCS Efficiency (cps/Bq)	uCi	Tank Capacity (Gallons)	Tank Capacity (ml)	Measurement Surface Area (foot^2)	Measurement Surface Activity per Surface Area (uCi/foot^2)	Main Cylindar Surface Area (foot^2)	Total Surface Activity (uCi)	Total Activity Concentration (uCi/ml)
662 keV	2485	3534.86	0.8512	8.68E-10	2.57E+04	95000	3.596E+08	179.7	1.43E+02	1,108.9	2.10E+05	5.84E-04
1173 keV	24277	3534.86	1	9.19E-10	2.02E+05	95000	3.596E+08	179.7	1.12E+03	1,108.9	1.65E+06	4.59E-03
1332 keV	26728	3534.86	1	9.27E-10	2.21E+05	95000	3.596E+08	179.7	1.23E+03	1,108.9	1.80E+06	5.01E-03

CCB BASEMENT

The results for Models #1 - #3 for geometries #3 and #4 are shown in the tables below.

The highest measured **Cs-137** activity concentration is **2.19x10-2 uCi/ml** (model #1; geometry #3; position F1) and the lowest is **1.58x10-4 uCi/ml** (model #1; geometry #4; position F1).

The highest measured **Co-60** activity concentration is **2.16x10-2 uCi/ml** (1173 keV; model #1; geometry #3; position F1) and the lowest is **9.69x10-5 uCi/ml** (1173 keV; model #1; geometry #4; position F1).

All of the other models fall in between these maxima and minima.

The 2-σ uncertainty for all CCB basement measurements are estimated to be ± 75% with the counting statics contributing less than 1%.

Model #1

Table 2 Activity concentration for CCB basement Falcon 5000 measurement computed for model #1 geometry #3 and Falcon 5000 position F1.

Peak	Counts	Live	Branching	Super ISOCS Efficiency (cps/Bq)	uCi	Tank Capacity (Gallons)	Tank Capacity (ml)	Activity Concentration (uCi/ml)
662 keV	12670	476.52	0.8512	1.07E-10	7.87E+06	95000	3.596E+08	2.19E-02
1173 keV	84273	476.52	1	6.15E-10	7.77E+06	95000	3.596E+08	2.16E-02
1332 keV	99796	476.52	1	8.44E-10	6.70E+06	95000	3.596E+08	1.86E-02

Table 3 Activity concentration for CCB basement Falcon 5000 measurement computed for model #1 geometry #3 and Falcon 5000 position F2.

Peak	Counts	Live	Branching	Super ISOCS Efficiency	uCi	Tank Capacity (Gallons)	Tank Capacity (ml)	Activity Concentration (uCi/ml)
662 keV	121158	6303.18	0.8512	1.07E-10	5.69E+06	95000	3.596E+08	1.58E-02
1173 keV	520052	6303.18	1	6.15E-10	3.63E+06	95000	3.596E+08	1.01E-02
1332 keV	604045	6303.18	1	8.44E-10	3.07E+06	95000	3.596E+08	8.53E-03

Table 4 Activity concentration for CCB basement Falcon 5000 measurement computed for model #1 geometry #4 and Falcon 5000 position F1.

Peak	Counts	Live	Branching	Super ISOCS Efficiency (cps/Bq)	uCi	Tank Capacity (Gallons)	Tank Capacity (ml)	Activity Concentration (uCi/ml)
662 keV	21790	156.74	0.8512	7.77E-08	5.68E+04	95000	3.596E+08	1.58E-04
1173 keV	29160	156.74	1	1.44E-07	3.48E+04	95000	3.596E+08	9.69E-05
1332 keV	32272	156.74	1	1.56E-07	3.56E+04	95000	3.596E+08	9.90E-05

Model #2

Table 5 Activity concentration for CCB basement Falcon 5000 measurement computed for model #2 geometry #3 and Falcon 5000 position F1.

Peak	Counts	Live	Branching	Super ISOCS Efficiency (cps/Bq)	uCi	Tank Capacity (Gallons)	Tank Capacity (ml)	Activity Concentration (uCi/ml)
662 keV	12670	476.52	0.8512	8.48E-10	9.96E+05	95000	3.596E+08	2.77E-03
1173 keV	84273	476.52	1	4.96E-09	9.63E+05	95000	3.596E+08	2.68E-03
1332 keV	99796	476.52	1	6.75E-09	8.39E+05	95000	3.596E+08	2.33E-03

Table 6 Activity concentration for CCB basement Falcon 5000 measurement computed for model #2 geometry #3 and Falcon 5000 position F2.

Peak	Counts	Live	Branching	Super ISOCS Efficiency (cps/Bq)	uCi	Tank Capacity (Gallons)	Tank Capacity (ml)	Activity Concentration (uCi/ml)
662 keV	121158	6303.18	0.8512	8.48E-10	7.20E+05	95000	3.596E+08	2.00E-03
1173 keV	520052	6303.18	1	4.96E-09	4.49E+05	95000	3.596E+08	1.25E-03
1332 keV	604045	6303.18	1	6.75E-09	3.84E+05	95000	3.596E+08	1.07E-03

Table 7 Activity concentration for CCB basement Falcon 5000 measurement computed for model #2 geometry #4 and Falcon 5000 position F1.

Peak	Counts	Live	Branching	Super ISOCS Efficiency (cps/Bq)	uCi	Tank Capacity (Gallons)	Tank Capacity (ml)	Activity Concentration (uCi/ml)
662 keV	21790	156.74	0.8512	2.49E-08	1.77E+05	95000	3.596E+08	4.92E-04
1173 keV	29160	156.74	1	6.36E-08	7.90E+04	95000	3.596E+08	2.20E-04
1332 keV	32272	156.74	1	7.33E-08	7.59E+04	95000	3.596E+08	2.11E-04

Model #3

Table 8 Activity concentration for CCB basement Falcon 5000 measurement computed for model #3 geometry #3 and Falcon 5000 position F1.

Peak	Counts	Live	Branching	Super ISOCS Efficiency (cps/Bq)	uCi	Tank Capacity (Gallons)	Tank Capacity (ml)	Activity Concentration (uCi/ml)
662 keV	12670	476.52	0.8512	6.78E-10	1.25E+06	95000	3.596E+08	3.47E-03
1173 keV	84273	476.52	1	3.96E-09	1.21E+06	95000	3.596E+08	3.35E-03
1332 keV	99796	476.52	1	5.39E-09	1.05E+06	95000	3.596E+08	2.92E-03

Table 9 Activity concentration for CCB basement Falcon 5000 measurement computed for model #3 geometry #3 and Falcon 5000 position F2.

Peak	Counts	Live	Branching	Super ISOCS Efficiency (cps/Bq)	uCi	Tank Capacity (Gallons)	Tank Capacity (ml)	Activity Concentration (uCi/ml)
662 keV	121158	6303.18	0.8512	6.78E-10	9.01E+05	95000	3.596E+08	2.51E-03
1173 keV	520052	6303.18	1	3.96E-09	5.63E+05	95000	3.596E+08	1.56E-03
1332 keV	604045	6303.18	1	5.39E-09	4.81E+05	95000	3.596E+08	1.34E-03

Table 10 Activity concentration for CCB basement Falcon 5000 measurement computed for model #3 geometry #4 and Falcon 5000 position F1.

Peak	Counts	Live	Branching	Super ISOCS Efficiency (cps/Bq)	uCi	Tank Capacity (Gallons)	Tank Capacity (ml)	Activity Concentration (uCi/ml)
662 keV	21790	156.74	0.8512	1.99E-08	2.22E+05	95000	3.596E+08	6.16E-04
1173 keV	29160	156.74	1	5.08E-08	9.90E+04	95000	3.596E+08	2.75E-04
1332 keV	32272	156.74	1	5.85E-08	9.52E+04	95000	3.596E+08	2.65E-04

IPIX VIEWS

The iPix views for the various positions depicted in **Error! Reference source not found.** and other views using the IPIX were applied. This figures were not supplied to keep the paper within the required limits. There are two basic data segments produced per view; a hotspot and a gamma field view. It appears that the iPix will always find hotspot and the gamma field view will eventually converge on the hotspot given enough acquisition time. We were hoping that the iPix would reveal the sedimentary layer but it looks like it either found a hotspot or the top of the sedimentary layer. The iPix really needed to be further back so as to get the whole CCT-1 in view but this was not possible.

The iPix data acquisition is event mode recorded and there might be a possibility to further analyze the event mode data in the future to see if it is truly possible to determine the depth of the sedimentary layer.

SUMMARY

The CCT-1 tank was characterized using two Falcon 5000 gamma spectral detectors and 4 Super ISOCS models. One of the Super ISOCS models was utilized for measurements made on the CCB roof (pointing down) and the other three models were for various configurations designated for the CCB basement (pointing up).

Two geometries were utilized for the CCB roof measurements and two geometries were utilized for the CCB basement measurements.

Activity concentrations for Cs-137 and Co-60 were compiled using the measured data and computed Super ISOCS efficiencies for the four models and four geometries.

The maximum **Cs-137** activity concentration measured from the CCB roof is **5.84x10-4 uCi/ml** and that for the CCB basement is **2.19x10-2 uCi/ml**. The total **Cs-137** activity concentration is the sum of these two values **2.25x10-2 uCi/ml** with a 2-σ Total Measurement Uncertainty (TMU) of 73%. This implies that the total **Cs-137** activity concentration is well less than the class A limit of 1 uCi/ml limit including a 2-σ TMU.

The maximum **Co-60** activity concentration measured from the CCB roof is **5.01x10-1 uCi/ml** and that for the CCB basement is **2.16x10-2 uCi/ml**. The total **Co-60** activity concentration is the sum of these two values **5.23x10-1 uCi/ml** with a 2-σ Total Measurement Uncertainty

(TMU) of 48%. This implies that the total **Cs-60** activity concentration is well less than the class A limit of 700 uCi/ml limit including a 2-σ TMU.

The maximum activity concentration results for both Cs-137 and Co-60 are listed in Table 11 below. These results were obtained by adding the maximum results from 3 models created the CCB basement Falcon 5000 measurements and using a single model for the CCB roof Falcon 5000 measurements.

Table 11 Final measured maximum activity concentration and associated 2-σ TMU.

Nuclide	Activity Concentration (uCi/ml)	2-σ TMU
Cs-137	2.25x10-2	73%
Co-60	5.23x10-1	48%

References

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