Response to the U.S. Nuclear Regulatory Commission Request for Additional Information on the Draft Waste-Incidental-to-Reprocessing Evaluation for the West Valley Demonstration Project Concentrator Feed Makeup Tank and Melter Feed Hold Tank

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ACRONYMS, ABBREVIATIONS, AND UNITS

Acronyms and Abbreviations

ALARA	as low as reasonably achievable
CFMT	Concentrator Feed Makeup Tank
DOE	Department of Energy
LLW	low-level waste
MEP	maximum extent practical
MFHT	Melter Feed Hold Tank
NRC	Nuclear Regulatory Commission
RAI	request for additional information
WIR	waste incidental to reprocessing
WVDP	West Valley Demonstration Project
WVES	West Valley Environmental Services
WVNSCO	West Valley Nuclear Services Company

Units

cc	cubic centimeter
Ci	curie
cm	centimeter
cm^2	centimeter squared
cm^3	centimeter cubed
g	gram [mass]
h	hour
mR	milliroentgen
µCi	0.000001 curie
nCi	0.000000001 curie
R	roentgen

INTRODUCTION

The U.S. Department of Energy (DOE) is consulting with the U.S. Nuclear Regulatory Commission (NRC) on the draft waste-incidental-to-reprocessing (WIR) evaluation for the West Valley Demonstration Project (WVDP) Concentrator Feed Makeup Tank (CFMT) and the Melter Feed Hold Tank (MFHT) (DOE-WV 2012b), which was prepared in accordance with DOE Manual 435.1-1, *Radioactive Waste Management Manual*. To this end, DOE submitted the draft evaluation to the NRC for review on June 29, 2012.

In connection with its review, NRC provided a request for additional information (RAI, NRC 2012b) on August 21, 2012 with six comments.

DOE is providing responses to the RAI comments and making some related changes to the WIR evaluation prior to finalizing it to ensure that management and disposal of the two vessels is protective of human health and safety and the environment. The DOE responses are provided in the following format:

Number: The NRC number is specified.

Subject: The subject as identified by NRC is listed.

Basis: The basis for the comment as described by NRC is reproduced in its entirety.

Path forward: The recommended path forward provided by NRC is reproduced in its entirety.

DOE response: The DOE response addresses the comment, providing explanatory information on the basis for the response.

Conclusions: This section discusses the conclusions from consideration of the NRC comment and the related DOE response.

Changes to the draft evaluation: This section describes changes to be made to the draft evaluation.

References are cited where appropriate, with a reference list provided at the end of the responses. An attachment containing portions of vessel drawings is provided to supplement information in the responses.

Number: IN-1

Comment: Uncertainty accounted for in the calculation of the waste inventory presented in Tables 2-2 and 2-4 is difficult to interpret.

Basis: NUREG-1854, Section 3.1, states that NRC should verify that analytical uncertainties are either propagated into calculations of waste inventory or have been adequately bounded (NRC 2007). Cs-137 concentrations are based on the dose conversion factor multiplied by the average of dose readings. Other radionuclide concentrations are determined through the use of an average scaling factor. The values in Table 2-2 seem to reflect this approach. The DOE concludes that the uncertainty associated with the radionuclide estimates is bounded by a +/-20% concentration range. As page 23 of the draft evaluation states, "*To account for uncertainties in the radionuclide activity estimates, the NNSS waste profile radiological technical basis document (CHBWV 2011) identifies high and low activity ranges that are plus 20 percent and minus 20 percent, respectively, of the final waste form activity concentrations, which are based on the estimates in the characterization report (WMG 2011) and shown in Table 2-2.*" This statement seems to imply that Table 2-2 reflects the upper bound of uncertainty, which does not seem to be the case.

Path Forward: Describe if the values in Table 2-2 or Table 2-4 reflect the average values or the upper 20% uncertainty bound. If the table reflects the average and not the upper 20% uncertainty, provide a basis for why the average adequately considers the uncertainty in the data, discussing impacts of uncertainty on removal to the maximum extent practical and the waste classification.

DOE response: Changes are being made to the Draft Evaluation as discussed below to ensure that it is clear that analytical uncertainties that could impact the vessel waste inventories are adequately bounded.

Table 2-2 and Table 2-4 Values

The values in Tables 2-2 and 2-4 of the Draft Evaluation are best estimates from the characterization report (WMG 2011) that were made using the average dose rates and the geometric means of the analytical data used to calculate scaling factors. These estimates do not reflect the upper 20 percent uncertainty bound.

As with the WVDP vitrification melter characterization (DOE-WV 2012a), uncertainties in the sample analytical data were not used in calculating the activity scaling factors because multiple results were available and they were consistent. Instead, geometric averaging was used to calculate the scaling factors because geometric averaging of scaling factors is a common practice throughout the commercial nuclear power industry in cases where more than one representative sample is available. This practice is incorporated into the RADMAN™ software used at West Valley, which has been reviewed and approved by the NRC (NRC 2012a).

This practice is also consistent with NUREG/CR-6567/PNNL-11659, *Low-Level Waste Classification, Characterization, and Assessment: Waste Streams and Neutron-Activated Metals* (NRC 2000), which states that it "is important that waste generators utilize the most accurate scaling factors possible, so that reliable estimates of these nuclides [ones for which activity scaling actors are used] can be made."

Since best estimates based on geometric mean values were used in the characterization of the vessels, the impacts of the use of bounding estimates on removal of key radionuclides to the maximum extent technically and economically practical and on waste classification were also considered as discussed below.

Consideration of Data Uncertainty

The use of best estimates for the vessel radionuclide inventories based on average values of dose rates and geometrical means of analytical data does not take into account uncertainties in the data. However, data variability and results uncertainty are discussed in Sections 2.5.5 and 2.6.5 of the draft evaluation with the conclusion that the uncertainty in the analytical data is bounded by the ±20 percent concentration range estimates included in the Nevada National Security Site waste profile (CHBWV 2011). The uncertainties in individual sample analytical measurements are typically less than 20 percent as can be seen in Table 2-3 for the CFMT (maximum of 15 percent) and Table 2-5 for the MFHT (maximum of six percent) using representative data. Analysis showed that analytical data uncertainties have a negligible impact on radionuclide scaling factors and the inventory estimates (Kurasch 2012).

Impacts of Data Uncertainty on Removal to the Maximum Extent Technically and Economically Practical

Regarding impacts of uncertainty on the analyses related to removal of key radionuclides to the maximum extent technically and economically practical, the decontamination reduction factors in Table 4-4 would decrease slightly if 20 percent upper bound values were used for the vessel “after all flushes” inventories. Note that Table 4-4 is being revised to make use of decontamination factors instead of percent reduction factors to make comparisons easier. The revised table appears on page 24 below. Notes (3) and (5) for the revised table show the impacts of using bounding estimates on the decontamination factors.

Figure 4-5 of the draft evaluation illustrates vessel flushing effectiveness in terms of Cs-137 residual activity before and after flushing and changes in dose rates before and after flushing. Use of the upper bound Cs-137 concentrations would have an insignificant impact on the figure given the scale used for estimated residual Cs-137 activity.

Use of the upper bound residual radionuclide estimates would not change DOE conclusions on removal of key radionuclides to the maximum extent technically and economically practical.

Impacts of Analytical Data Uncertainty on Waste Classification

Regarding impacts of uncertainty on the waste classification of the vessel waste packages, the percent of Class C limit values in Table 6-1 (Vessel Waste Classification Results With Respect to Class C limits) would increase by 20 percent if the upper bound inventory estimates were to be used. Table 6-1 is being revised to show the increases in the sums of fractions from using bounding estimates as discussed below. The resulting sums of fractions with bounding estimates remain well below 1.0.

Conclusions: The use of average values without regard for uncertainty in the analytical data to develop activity scaling factors is consistent with accepted practice. However, DOE agrees that it is prudent to ensure that uncertainties related to the average values are adequately bounded.

Changes to the draft evaluation: The following changes to this end and to improve clarify will be made to the draft evaluation:

Note (1) to Table 2-2 (Concentrator Feed Makeup Tank Total Activity Estimate) will be changed to add the statement: “These are best estimates based on the average of measured dose rates and geometric mean values of sample analytical data being used to estimate radionuclide scaling factors.”

The text at the bottom of page 25 will be changed as follows, with the changes highlighted: “Given the approach used in the characterization, and the negligible impact of analytical data uncertainty on the

inventory estimates (Kurasch 2012), DOE concludes that uncertainty associated with the radionuclide estimates is ~~likely~~ bounded . . .”

Similar changes will be made to the similar text for the MFHT on page 29.

Note (1) to Table 2-4 (Melter Feed Hold Tank Total Activity Estimate) will be changed like Note (1) to Table 2-2.

Table 4-4 (Vessel Flushing Effectiveness in Terms of Estimated Cs-137 Removal) will be changed as described in the response to Comment MEP-1 to show the impacts of using bounding estimates on decontamination factors.

Table 6-1 of the Draft Evaluation (Vessel Waste Classification Results With Respect to Class C Limits) will be changed as described in the response to Comment IN-2 to show the impacts of using bounding estimates on waste classification.

Please see the response to Comment IN-3 for minor changes to be made in the inventory estimates for the CFMT.

Number: IN-2

Comment: The radionuclides listed in the inventory for the CFMT differ from those in the MFHT.

Basis: NUREG-1854, Section 3.1, advises that the NRC evaluate inventory estimates and verify the technical bases (NRC 2007).

Path forward: Please explain why certain radionuclides appear in the inventory [for the] MFHT but not in inventory for [the] CFMT given that the same material was sent through both tanks.

DOE response: Table 1 lists radionuclides for which estimates were provided for the two vessels and the vitrification melter to show the differences in radionuclides considered in the inventory estimates.

Table 1. Radionuclide Differences

Nuclide	CFMT(1)	MFHT(2)	Melter(3)	Remarks
C-14		√	√	Analyte only for glass shard samples.
K-40		√	√	Analyte only for glass shard samples.
Mn-54		√	√	Analyte only for glass shard samples.
Co-60	√	√	√	
Ni-63		√	√	Analyte only for glass shard samples.
Sr-90	√	√	√	
Zr-95		√	√	Analyte only for glass shard samples.
Tc-99	√	√	√	
I-129			√	I-129 insignificant in glass shard samples.
Cs-137	√	√	√	
Eu-154	√	√	√	
Th-228		√	√	Analyte only for glass shard samples.
Th-229			√	Th-229 insignificant in glass shard samples.
Th-230		√	√	Analyte only for glass shard samples.
Th-232	√	√	√	
U-232	√	√	√	
U-233	√	√	√	
U-234	√	√	√	
U-235		√	√	Analyte only for glass shard samples.
U-236		√	√	Analyte only for glass shard samples.
U-238	√	√	√	
Np-237	√	√	√	
Pu-238	√	√	√	
Pu-239	√	√	√	
Pu-240	√	√	√	

Table 1. Radionuclide Differences

Nuclide	CFMT[1]	MFHT[2]	Melter[3]	Remarks
Pu-241	√	√	√	
Pu-242			√	Estimated for the melter by an alternate process.[4]
Am-241	√	√	√	
Am-242m			√	Estimated for the melter by an alternate process.[4]
Am-243	√	√	√	
Cm-242	√	√	√	
Cm-243	√	√	√	
Cm-244	√	√	√	
Cm-245			√	Estimated for the melter by an alternate process.[4]
Cm-246			√	Estimated for the melter by an alternate process.[4]

NOTES: (1) From WMG 2011, page 29 labeled "Analysis of Multiple Sample Data Sets (SCAL), CFMT."
(2) From WMG 2011, page 33 labeled "Analysis of Multiple Sample Data Sets (SCAL), MFHT."
(3) From Table 2-2 of the vitrification melter waste-incidental-to-reprocessing evaluation (DOE-WV-2012a).
(4) See Section 2.5.3 of DOE-WV-2012a.

Reasons for Differences

The reason why C-14, K-40, Mn-54, Ni-63, Zr-95, Th-228, Th-230, U-235, and U-236 do not appear in the analytical data for the CFMT is because these radionuclides were not analytes for the samples used to characterize the CFMT. Table 2 shows the characterization samples for the two vessels. Analytical data from the glass shard samples collected from the evacuated canisters were used only for characterization of the MFHT.

Table 2. Vessel Characterization Samples

Vessel	Sample Source[1]						
CFMT	Batch 72 Slurry 1	Batch 72 Slurry 2	Batch 74 Slurry	Batch 75 Slurry	CFMT Liquid 1	CFMT Liquid 2	CFMT Liquid 3
MFHT	Batch 72 Slurry 1	Batch 72 Slurry 2	Batch 74 Slurry	Batch 75 Slurry	Glass Shards 1	Glass Shards 2	---

NOTES: (1) From WMG 2011.

The characterization report (WMG 2011) shows that C-14, K-40, Mn-54, Ni-63, Zr-95, Th-228, Th-230, U-235, and U-236 were used for characterization of the MFHT in tables of scaling factors (Sample Report, page 21) and radionuclide activity estimates (Package Characterization Report, page 25).

In regard to the statement in the path forward about both vessels seeing the same materials, there was one exception: the CFMT liquid never went to the MFHT.

Residual Radioactivity Estimates Based on Melter Scaling Factors

The site contractor considered the samples selected for characterization purposes to be representative of the residual radioactivity in each vessel when the data were provided to WMG in 2004. Records describing the basis for the selected samples are not available and the site characterization personnel

involved are no longer at the project. However, factors leading to selection of the specified characterization samples likely included:

- With minor exceptions, slurry batches prior to Batch 72 were not analyzed for a full suite of radionuclides,
- Radionuclide concentrations in batches 73 and 74 were similar so using both would not have been useful,
- Batches 76 and 77 consisted of flush solutions and thus would not have been representative of residual contamination in the vessels,
- The liquid samples were collected from the last material contained in the CFMT, and
- The glass shard samples represented the last material contained in the MFHT.

However, it could also be reasonable to conclude that the radionuclide distributions in these vessels are the same as those in the vitrification melter. To determine whether use of the scaling factors developed for the vitrification melter could produce significantly different results, the residual radioactivity in each vessel was recalculated using the vitrification melter scaling factors and same Cs-137 estimates used in the WMG characterization report (WMG 2011).

These estimates are shown in Table 3 and are based on Cs-137 activities of 95.3 curies for the CFMT and 97.1 curies for the MFHT from WMG 2011 and scaling factors for the melter from Exhibit 1 in the melter characterization report (WMG 2004), with data corrected for decay and ingrowth to October 1, 2004 for comparison purposes. The total estimates compare with the WMG estimates as follows: (1) the CFMT estimate is 102 curies compared to 99.4 curies for the revised WMG estimate discussed in the DOE response to comment IN-3. The MFHT estimate was approximately 103 curies in both cases.

Table 3. Total Activity Estimates in Curies Using Melter Scaling Factors

Nuclide	CFMT(1)	MFHT(2)	Nuclide	CFMT(1)	MFHT(2)
C-14	4.61E-04	4.70E-04	U-235	8.18E-06	8.33E-06
K-40	1.78E-03	1.82E-03	U-236	2.45E-05	2.50E-05
Mn-54	3.26E-03	3.32E-03	U-238	4.89E-05	4.98E-05
Co-60	1.98E-03	2.02E-03	Np-237	1.34E-04	1.37E-04
Ni-63	2.20E-02	2.24E-02	Pu-238	1.50E-02	1.52E-02
Sr-90	5.46E+00	5.56E+00	Pu-239	3.44E-03	3.51E-03
Zr-95	5.49E-01	5.59E-01	Pu-240	2.63E-03	2.68E-03
Tc-99	2.40E-04	2.45E-04	Pu-241	7.01E-02	7.15E-02
I-129	Note (3)	Note (3)	Pu-242	Note (3)	Note (3)
Cs-137	9.53E+01	9.71E+01	Am-241	6.52E-02	6.64E-02
Eu-154	2.78E-02	2.84E-02	Am-242m	Note (3)	Note (3)
Th-228	1.14E-03	1.17E-03	Am-243	7.60E-04	7.75E-04
Th-229	Note (3)	Note (3)	Cm-242	4.65E-03	4.74E-03
Th-230	7.93E-06	8.08E-06	Cm-243	3.72E-04	3.79E-04
Th-232	8.72E-06	8.88E-06	Cm-244	9.72E-03	9.90E-03
U-232	1.10E-03	1.12E-03	Cm-245	Note (3)	Note (3)
U-233	4.49E-04	4.57E-04	Cm-246	Note (3)	Note (3)

Table 3. Total Activity Estimates in Curies Using Melter Scaling Factors

Nuclide	CFMT(1)	MFHT(2)	Nuclide	CFMT(1)	MFHT(2)
U-234	2.13E-04	2.18E-04			

NOTES: (1) Based on a Cs-137 activity of 95.3 Ci from WMG 2011 and scaling factors for the melter from Exhibit 1 in the melter characterization report (WMG 2004), with data corrected for decay and ingrowth to October 1, 2004 for comparison purposes.

(2) Based on a Cs-137 activity of 97.1 curies from WMG 2011 and scaling factors for the melter from Exhibit 1 in the melter characterization report (WMG 2004), with data corrected for decay and ingrowth to October 1, 2004 for comparison purposes.

(3) No scaling factors were available for these radionuclides, which are not significant for waste characterization and classification purposes.

Conclusions: Estimates for C-14, K-40, Mn-54, Ni-63, Zr-95, Th-228, Th-230, U-235, and U-236 were included for the MFHT because analytical data for these radionuclides were available for the MFHT but not the CFMT. Different sample analytical data sets were used in characterizing the two vessels based on the judgment of the site contractor when the vessels were characterized in 2004. However, it would also be reasonable to use scaling factors developed for the vitrification melter for characterization of the two vessels.

Changes to the draft evaluation: The following changes will be made to the draft evaluation. Please note that these changes are linked to additional changes described in the DOE response to RAI comment IN-3.

The information in Table 3 above will be incorporated into two new tables for the WIR evaluation, one for the CFMT and one for the MFHT. These tables will be included in Sections 2.5.5 and 2.6.5, respectively, with additions to the text similar to the following:

"**Comparison Using Vitrification Melter Scaling Factors**

As shown in the characterization report (WMG 2011), scaling factors for the concentrator feed makeup tank and melter feed hold tank were developed from different sample analytical data. This factor accounts for scaling factors for certain radionuclides (C-14, K-40, Mn-54, Ni-63, Zr-95, Th-228, Th-230, U-235, and U-236[1]) used for the melter feed hold tank not being used for the concentrator feed makeup tank.

Both vessel data sets were different from the data set used to develop the scaling factors for the vitrification melter, which made use of data from the glass shard samples from the two evacuated canisters. For information and perspective, estimates for the residual radioactivity in the concentrator feed makeup tank were developed using the melter scaling factors. Table 2-4 shows the results.

New Table 2-4 based on Table 3 above to appear here.

The total estimated residual activity in the vessel using the vitrification melter scaling factors is 102 curies compared to the estimate of 99.4 curies shown in Table 2-2."

The additions to Section 2.6.5 will be similar.

In addition, Table 6-1 and the related text will be changed as follows:

[1] Cs-134, Eu-152, Eu-155, Pu-236, and Pu-242 were analytes for the melter feed hold tank samples but did not exceed the minimum detectable concentrations. Likewise, Th-228, Th-230, U-235, and U-236 were analytes for the concentrator feed makeup tank samples but concentrations did not exceed the minimum detectable and these radionuclides were thus considered to be negligible.

"Radiological characterization of the subject vessels before packaging was as described in Section 2.5.3. Table 6-1 shows the results of the waste classification calculations, which show that the vessel waste packages do not exceed Class C limits even in the bounding cases. For perspective, the sums of fractions were calculated in three ways:

- Using average dose rates and geometric mean values of analytical data as described in the characterization report (WMG 2011) and the related analysis (Kurasch 2012);
- Using the radionuclide scaling factors used in characterization of the vitrification melter (WMG 2004); and
- Using the vitrification melter scaling factors and the 20 percent upper bound on Cs-137 activity described in the Nevada National Security Site waste profile sheet (CHBWV 2012)[2].

Table 6-1. Vessel Waste Classification Results With Respect to Class C limits

Vessel	Fraction of Class C Limit					
	Table 1			Table 2		
	WMG(1)	With MSF(2)	Upper Bound(3)	WMG(1)	With MSF(2)	Upper Bound(3)
CFMT	0.065	0.12	0.14(4)	0.020	0.021	0.024
MFHT	0.063	0.092	0.11	0.016	0.016	0.019

LEGEND: CFMT = concentrator feed makeup tank, MFHT = melter feed hold tank, MSF = melter scaling factors

NOTES: (1) Calculated using information in WMG 2011 considering the minor changes to the WMG estimates described in the related analysis (Kurasch 2012).

(2) Calculated using scaling factors used for the vitrification melter characterization (WMG 2004).

(3) Calculated using scaling factors used for the vitrification melter characterization (WMG 2004) with a +20 percent upper bound for the Cs-137 activity as used in the Nevada National Security Site waste profile sheet (CHBWV 2012). The +20 percent values bound the uncertainties in analytical data.

(4) Each calculation was based on the average of nine dose rate measurements taken along the side of each vessel. Even if the maximum measured dose rates were to be used instead of the averages, the maximum sum of fractions would still be much less than 1.0 indicating that the radionuclide concentrations are well within Class C limits.

Table 6-1 shows all sums of fractions to be well below 1.0, demonstrating that the vessel waste packages do not exceed concentration limits for Class C LLW.

For conservatism, the calculations were performed using only the weight and size of the vessels themselves. Neither the grout nor the shipping container was considered (WMG 2011) in the calculations even though the mass of the grout – which was necessary for stabilization purposes and to encapsulate surface contamination – could have been considered in accordance with applicable concentration averaging guidance (NRC 1995)."

[2] As discussed in the response to comment IN-3, the waste profile technical basis document is to be revised.

Number: IN-3

Comment: There is ambiguity surrounding the approach used in characterizing inventory values for the MFHT and CFMT.

Basis: NUREG-1854, Section 3.1, advises that the NRC evaluate the statistical metric of radionuclide concentrations used to calculate inventories in the waste determination (e.g., mean, 95-percent upper confidence limit) to ensure that the technical basis for the selection is adequate and the metric is properly calculated (NRC 2007). The draft evaluation states that the characterization for the CFMT is based on the average of five analytical samples (page 23), four of which are from batches, and one of which is from residual liquid in the vessel following vitrification. The Attachment to CHBWV (2011), which lists the concentrations of these samples, includes four batch samples (microcurie/gram) and three liquid samples (microcurie/cubic centimeter). The values shown for each of the batch samples represents the arithmetic average of the nine analyses for each sample. The attachment also shows a last column labeled "*Average Value All Data Sets,*" which is a geometric average of the four batch samples and the three analyses for the single liquid sample.

The draft evaluation states that the analytical data used in characterization of the MFHT came from "*four of the samples used in characterization of the concentrator feed makeup tank – two samples of batch 72 taken at different times, one sample from batch 74, one sample from batch 77 – along with two glass shard samples taken from the two evacuated canisters used to remove molten glass from the vitrification melter (WMG 2011). The batch samples were the same ones used in the concentrator feed makeup tank characterization*." However, the CFMT used a sample from batch 75, not from batch 77 and the attachment listing the sample data shows batch 75. DOE should confirm if this is a typo.

Path Forward: Verify that the last batch sample used for the MFHT is batch 75 and not batch 77. Explain why the liquid sample for CFMT was treated as three separate samples in the calculation of the geometric mean and describe any impacts on overall conclusions if this liquid sample had been treated as one sample instead of three.

DOE response: The last batch sample used for the MFHT was Batch 75.

The analytical data supplied by the WVDP contractor were used in the characterization as they were provided. However, it would have been more appropriate in determining the geometric means of the analytical data for the CFMT to avoid treating the results of three analyses of the same liquid sample as separate analysis results when the slurry sample concentrations were averages of multiple analysis results.

Review of the characterization report (WMG 2011) in connection with evaluation of this comment showed that assumption 5 on page 1 of report (the density of the WVNSCO supplied waste samples in Reference 1 is 1 g/cc) was incorrect. The density of the CFMT liquid sample was 1.15 g/cm^3, which is relevant in converting the sample concentrations to consistent units in calculation of the scaling factors.

Table 5 shows the original version of the CFMT inventory and a revised version based on treating the each replicate sample as a discrete data point and using the actual liquid sample density in converting the sample concentrations to consistent units. Both sets of estimates are as of October 1, 2004.

Table 5. Original and Revised Concentrator Feed Makeup Tank Activity Estimates

Nuclide	Activity (Ci)		Nuclide	Activity (Ci)	
	Original[1]	Revised[2]		Original[1]	Revised[2]
C-14	NA	NA	U-238	6.39E-06	4.80E-06
K-40	NA	NA	Np-237	6.66E-05	5.69E-05
Mn-54	NA	NA	Pu-238	5.19E-03	6.99E-03
Co-60	1.85E-03	4.14E-03	Pu-239	1.40E-03	1.59E-03
Sr-90	1.12E+00	3.94E+00	Pu-240	1.07E-03	1.59E-03
Zr-95	NA	NA	Pu-241	1.54E-02	1.40E-02
Tc-99	4.17E-03	1.80E-03	Pu-242	NA	NA
Cs-137	9.53E+01	9.53E+01	Am-241	2.48E-02	3.77E-02
Eu-154	5.17E-02	5.66E-02	Am-242m	NA	NA
Th-228	NA	NA	Am-243	2.55E-04	3.33E-04
Th-230	NA	NA	Cm-242	9.78E-05	3.91E-04
Th-232	2.53E-06	1.90E-06	Cm-243	1.55E-04	3.25E-03
U-232	1.41E-04	1.06E-04	Cm-244	4.02E-03	3.25E-03
U-233	5.84E-05	3.25E-05	Cm-245	NA	NA
U-234	2.79E-05	3.25E-05	Cm-246	NA	NA
U-235	NA	NA			

LEGEND: NA = not available.

NOTES: (1) From WMG 2011.

(2) From Kurasch 2012, using data on which the original estimate (WMG 2011) was based, but treating each replicate sample as a discrete data point and using the liquid sample density (1.15 g/cm^3) in converting the analytical data to consistent units. These estimates, like the WMG estimates, made use of geometric mean scaling factors.

The total activity in the revised estimates of Table 5 is 99.4 curies compared to the original estimate of 96.5 curies, a difference of approximately three percent. The revised estimate for total alpha-emitting transuranic radionuclides is 0.0510 curie (Kurasch 2012), compared to the original estimate of 0.0371 curie (WMG 2011).

Conclusions: Consideration of the three separate liquid sample results along with the slurry samples results, which were based on the averages of multiple analyses, affected the WMG characterization results for the CFMT as reported in Table 2-2 of the Draft Evaluation, as did not taking into account the sample density differences, which are relevant because the liquid samples results were expressed in units of μCi/cc and slurry samples as μCi/g. However, accounting for these factors produces only minor changes in the inventory estimates that do not affect DOE's conclusions about removal of key radionuclides to the maximum extent technically and economically practical or the vessel waste classification.

The characterization report results for the MFHT as described in Table 2-4 of the Draft Evaluation were not affected by these considerations because liquid samples were not used and all concentration values were expressed in consistent units of μCi/g.

Changes to the draft evaluation: The Draft Evaluation will be corrected by changing Batch 77 to Batch 75 on page 28.

Table 2-2 in the Draft Evaluation will be changed to make use of the revised estimates shown in Table 5 above. The revised Table 2-2 and the related text will read as follows, with changes from the Draft Evaluation highlighted in yellow. Note that the Nevada National Security Site waste profile sheet technical basis document will be revised to reflect the revised estimates (hence the new CHBWV 2012 reference).

2.5.3 Characterization

"Details of the waste package characterization appear in the waste profile prepared for disposal at the Nevada National Security Site (CHBWV 2012), the associated characterization report (WMG 2011), and calculations that made minor changes to the characterization report estimates (Kurasch 2012). The characterization process made use of sample analytical data and the average measured dose rate of collimated readings taken with a shielded radiation probe one foot from the sides of the installed vessel (1.62 R/h).

A QAD[3] geometry model was used to calculate a dose-to-curie conversion factor for cesium 137, the amount of cesium 137 estimated from the measured dose rate, and the amounts of other radionuclides estimated using radionuclide scaling factors based on sample analytical data. The RADMAN™[13] and Megashield™[13] computer codes were used in the calculations.

Table 2-2 shows the estimated residual radioactivity in the concentrator feed makeup tank, which totaled 99.4 Ci as of October 1, 2004.

Table 2-2. Concentrator Feed Makeup Tank Total Activity Estimate(1)

Nuclide	Activity (Ci)	Nuclide	Activity (Ci)
C-14	NA	U-238	4.80E-06
K-40	NA	Np-237	5.69E-05
Mn-54	NA	Pu-238	6.99E-03
Co-60	4.14E-03	Pu-239	1.59E-03
Sr-90	3.94E+00	Pu-240	1.59E-03
Zr-95	NA	Pu-241	1.40E-02
Tc-99	1.80E-03	Pu-242	NA
Cs-137	9.53E+01	Am-241	3.77E-02
Eu-154	5.66E-02	Am-242m	NA
Th-228	NA	Am-243	3.33E-04
Th-230	NA	Cm-242	3.91E-04
Th-232	1.90E-06	Cm-243	3.25E-03
U-232	1.06E-04	Cm-244	3.25E-03
U-233	3.25E-05	Cm-245	NA
U-234	3.25E-05	Cm-246	NA

[3] The QAD, RADMAN™ and Megashield™ software are computer codes commonly used in evaluation of radioactive waste packages and associated shielding.

Table 2-2. Concentrator Feed Makeup Tank Total Activity Estimate(1)

Nuclide	Activity (Ci)	Nuclide	Activity (Ci)
U-235	NA		

LEGEND: NA = not available.

NOTES: (1) From WMG 2011 as of October 1, 2004 as revised (1) to treat the each replicate sample as a discrete data point to normalize the analytical data used to calculate radionuclide scaling factors and (2) to convert the concentrator feed makeup tank liquid sample results to the same unit as the other samples using the measured density of the liquid sample (Kurasch 2012)."

Please note that the "Comparison Using Vitrification Melter Scaling Factors" changes described in the response to RAI comment IN-2 will follow the revised Table 2-2.

Number: IN-4

Comment: Please provide additional explanation as to the number and location of dose rate measurements taken and used in the MFHT and CFMT characterization.

Basis: NUREG-1854, Section 3.1, advises that NRC staff verify that the number of required samples provided in the sampling plan is based on accurate assumptions about the heterogeneity of the waste. NRC staff should also assess the technical basis for any identified limitations in the number or locations of samples (e.g., limited number of sampling ports or internal obstructions in tanks, difficulties in sampling specific phases of waste, significant worker hazards), and confirm that the resulting uncertainties in total inventory have been adequately represented or bounded. Prior to decontamination, the waste was not expected to be uniformly distributed around the interior of the vessel. Page 40 of the draft evaluation describes that the vessels were expected to have residual HLW slurry in the upper third of the vessel, as well as in dead spaces in the CFMT nozzles and on the MFHT. This could imply that after decontamination, the residual material would also be in the upper one-third of the vessel. The draft evaluation does not draw a connection between the location of the dose rate measurements taken and the expected distribution of the waste within the vessel prior to and after decontamination.

The draft evaluation is also not clear regarding the number of samples that were taken versus the number that were used in the calculation. Page 23 of the draft evaluation states, "…*the characterization made use of the average value of 10 dose rate measurements to calculate the amount of Cs-137 present in the [CFMT] vessel*." Page 24 of the draft evaluation states that "*…the use of the average value of the nine measurements taken in various locations on the concentrator feed makeup tank (WVNSCO, 2004c) minimizes the uncertainty in the Cs-137 activity estimate*." The diagrams in the reference WNVSCO (2004c) shows 12 dose measurements for the MFHT and 10 dose measurements for the CFMT. The QAD® computer model outputs1 for each tank show 9 dose rate measurements, and utilize the average of these nine.

Path forward: Provide a technical basis for the number and location of dose rate measurements. Describe how the number and location of required samples are based on assumptions about the heterogeneity of the residual waste within the tanks after cleaning. Explain why the number of measurements shown in the diagrams differs for the MFHT and CFMT. Explain why the QAD® computer output sheets seem to indicate that only nine of the measurements for each vessel were utilized in the calculation.

DOE response: The following information is provided to address the four requests in the path forward. The information provided is taken primarily from Radiation and Contamination Survey Report 123427 of February 4, 2004 (WVNSCO 2004a, WVNSCO 2004c in the Draft Evaluation) and the vessel characterization report (WMG 2011).

Basis for Number and Location of Measurements

Engineering direction for the dose rate surveys called for shielded probe readings down the side and over the top of each vessel in locations specified in the survey plans, which consisted mainly of sketches showing the measurement locations (WVNSCO 2004a). The survey plans provided for nine measurements along the side of each vessel at intervals of approximately one foot, along with four measurements on the top of each vessel (if possible). These measurements were considered to be sufficient for radiation protection purposes and for modeling to determine the residual Cs-137 activity.

Assumptions About Homogeneity

In establishing the numbers and locations of the dose rate measurements, it was assumed that the post-flushing residual contamination was uniformly distributed on the vessel interior surfaces. This assumption was based on the results of visual inspections which showed that essentially no visible deposits remained, with the visibility sufficient to discern fabrication weld beads and threads on bolts. Consideration was given to the simplifying assumption discussed in the response to comment MEP-1 below about the residual material covering only the upper one-third of the vessels prior to flushing. However, it is reasonable to expect that some contamination was present on the lower two-thirds of the vessels before flushing and that some lessor amount would remain after flushing.

The assumption of a uniform distribution of residual contamination in the vessels after flushing was borne out by the consistency of the dose rates measured on the sides of the vessels as shown in the survey record (WVNSCO 2004a).

Why Measurements on the Two Vessels Differ

Nine measurements were taken on the side of each vessel as planned. Due to limited accessibility, presumably caused by interferences which prevented placement of the detector probe in certain quadrants over the tops of the vessels[4], one measurement was taken on the top of the CFMT and three measurements were taken on the top of the MFHT. That is, a total of 10 measurements were taken on the CFMT and 12 on the MFHT.

Basis for Use of Nine Measurements

The QAD geometry models were set up with the source geometry represented by a cylinder covering the vessel inside diameter and dose rates located one foot from the side of each vessel. Therefore, measurements at the tops of the vessels were not used in the modeling. The characterization subcontractor confirmed that this process was used (WMG 2012).

Conclusions: The use of the nine dose rate measurements taken along the side of each vessel to determine the residual Cs-137 activity was appropriate.

Changes to the draft evaluation The Draft Evaluation will be corrected to show that nine dose rate measurements were used for this purpose for each vessel.

[4]The survey record (WVNSCO 2004a) does not state why certain dose rate measurements at the tops of the vessel were not taken.

Number: MEP-1

Comment: The assessment of the amount of radioactivity present prior to the flushing of the CFMT and MFHT is unclear.

Basis: NUREG-1854, Section 3.3.2, states that the reviewer should verify that reported removal efficiencies are reasonably reliable. The amount of Cs-137 in the vessels prior to flushing assumed an average 0.25 inch thickness in the upper one-third of the vessels and the Cs-137 concentration in the material was assumed to be the same as that in the last batch of slurry sent to the concentrator feed makeup tank before the vitrification system flushing (batch 75), which had the second highest Cs-137 concentration (1.16x104 µCi/cm3) among the feed material (Kurasch, 2011). However, little detail is provided on why the upper one-third is assumed to be covered in residual material as opposed to some other proportion. There is also not sufficient detail about the volume, and surface area assumptions to reproduce the estimates before flushing provided in Table 4-4. In addition, it should be noted that in using the second highest Cs-137 concentration, DOE may be biased towards overestimating the amount of Cs-137 in the vessels prior to flushing. Since the material remaining in the melter is characterized by using batches 72, 74 and 75, it would be more intuitive to also use this combination of samples to characterize what was in the vessel prior to flushing. Overestimating the amount of activity (curies) before flushing could artificially inflate the reduction factor and is therefore not a conservative approach.

Path forward: Please provide additional support for the activity estimates (curies) before flushing provided in Table 4-4 including the surface area and volume assumptions, further justification for assuming the upper third of the vessels is coated, and a technical basis for assuming the concentration of batch 75 only. Please also discuss the impacts of assumptions on overall conclusions regarding removal to the maximum extent practical.

DOE response: The following information is provided to address each of the four requests in the path forward.

Basis for Estimated Cs-137 Activity in the Vessels Before Flushing

The vessel inside dimensions are as follows:

Vessel	Diameter	Height
CFMT	3.1 m	4.2 m
MFHT	3.1 m	3.05 m

These values are based on drawings included in Attachment 1.

The CFMT surface area of interest considering the top (7.55 m^2) and the upper one-third of the sides (13.24 m^2) is approximately 20.79 m^2 or approximately 2.0E+05 cm^2. The MFHT surface area of interest considering the top (7.35 m^2) and the upper one-third of the sides (9.64 m^2) is approximately 17 m^2 or approximately 1.7E+05 cm^2.

The residual material (dried slurry) thickness is assumed to be 0.25 inch or 0.635 cm. The Batch 75 Cs-137 concentration was 1.16E+04 $\mu Ci/cm^3$ as given in the characterization report (WMG 2011). Multiplying the surface area of interest by the assumed residual material thickness by the Batch 75 Cs-137 concentration yields 1.47E+09 µCi (about 1,500 curies) for the CFMT and 1.25E+09 µCi (about 1,200 curies) for the smaller MFHT, assuming a density of 1.0 g/cm^3.

However, the Batch 75 Cs-137 concentration was measured and reported as 1.16E+04 µCi/g. The specific gravity of the Batch 75 samples was 1.33. This means that the Batch 75 Cs-137 concentration on a volume basis was 1.54E+04 $\mu Ci/cm^3$. Taking this factor into account would result in increasing the

estimates based on the Batch 75 Cs-137 concentration by a factor of 1.33, yielding approximately 2,000 curies for the CFMT and approximately 1,600 curies for the MFHT.

Basis for Assuming Residual Material Covers the Upper One-Third of Each Vessel

The assumption that residual material coated the upper one-third of each vessel was a simplifying approximation based in part on physical and operational attributes associated with the two vessels. The following discussion regarding the basis for this assumption focusses on the CFMT; however, the MFHT situation is analogous.

Figure 4-4 of the Draft Evaluation shows the height of liquid in the CFMT – as indicated by the in-tank instrumentation and recorded on the transfer process data sheets at the time the transfers were made – versus time for some representative example batches. All batches processed in this vessel followed this general pattern. Volumes in the CFMT and MFHT were monitored and controlled during operations to avoid overflow.

The liquid levels were generally limited to the nominal lower two-thirds of both the CFMT and MFHT. During operation, liquid levels were monitored and managed. For the CFMT, three bubblers were used to measure the liquid height above the bubbler location. With a high level alarm limit for this vessel of 115 inches (i.e., when the bubbler indicated 115 inches the alarm was activated in the control room), this translates to about 126 inches from the bottom outside of the CFMT. The tank is nominally 156 inches long from the outside bottom to the top flat flange to which the agitator assembly was attached. Thus the high level alarm limit was established to be 30 inches below the top of the tank, indicating that the static liquid height (i.e., the liquid height without the mixer blades running) was not allowed to be in direct contact with the upper 30 inches of the tank. See the maximum operating liquid level as depicted on Figure 1-2 on page 33.

Operationally, tank levels were likely kept lower to avoid tripping the high level alarm and disrupting production operations. As Figure 4-4 shows, at least for batches 76 and 77, tank level was no higher than nominally 120-122 inches. (This is interpreted here to be a reasonable estimate of operating margin to avoid tripping a level alarm and interrupting production operations.) This would indicate that peak levels during operation were likely to be nominally 36 inches below the top of the tank. The data in Figure 4-4 indicate that levels did not remain at this elevation for a long time. Inspection of Figure 4-4 indicates that evaporation was reasonably efficient in lowering the tank level, followed by a level measurement, and then followed by more waste material input, followed by evaporation, etc.

In principal, the agitator blades in the CFMT ran all the time unless a liquid level was to be taken. When the blades were started, the surface of the liquid would have been expected to have bubbled and roiled until equilibrium was reached, eventually forming a swirling mass with a cone-shaped top surface where liquid was higher on the outside of the swirling mass than on the inside. If the liquid was near the top of the vessel, the formation of this upper cone shape would tend to splash liquid waste material upward unto the upper tank surfaces that did not otherwise normally be exposed to this liquid waste material. The shape and mixing was also influenced by the four equally spaced vertical baffle plates. These baffle plates extended radially inward about 13 inches from the CFMT's inside diameter, with a one-inch gap between the plate and the inside wall of the vessel nominally for the full operating height. The swirling liquid mass would move around these plates and the top surface would certainly be disrupted as the material swirled around them.

As the heating coils evaporated this liquid and the level dropped, this swirling cone-topped mass would be reduced in height. As the intermediate set of mixing blades were exposed, the conical surface of the swirling liquid mass propelled by the lower mixing blades could potentially be impacted by the middle

level whirling mixing blades, potentially splashing additional material around the inside of the vessel. Such splashing is expected to have occurred generally in the lower two-thirds of the vessel, which was subsequently rewetted with the addition of more transferred liquid waste material.

The upper portion of the CFMT was thus periodically impacted by the liquid waste material when the liquid level was high due to the combination of liquid waste transfer input splashing and mixer blade induced movements creating a swirling liquid pool. As the swirling liquid pool level dropped as a result of evaporation, any splashing phenomena (caused by the mixing blades or the entry of the next transfer of liquid waste material) dropped with it. Filling the vessel back up with additional transfer material raised the splashing level to again potentially impact the upper head area.

These phenomena were judged to be reasonably represented by the simple two-thirds to one-third split.

Basis for the Assumed 0.25-Inch Material Thickness

Photographs showing conditions in the upper portions of the vessels form the basis for the assumed material thickness. Figure 4-2 in the Draft Evaluation shows representative before-flushing images on the interior of both vessels. Figure 1 shows an enlarged view of one of the images in Figure 4-2 of the Draft Evaluation that shows a substantial buildup of dried slurry.

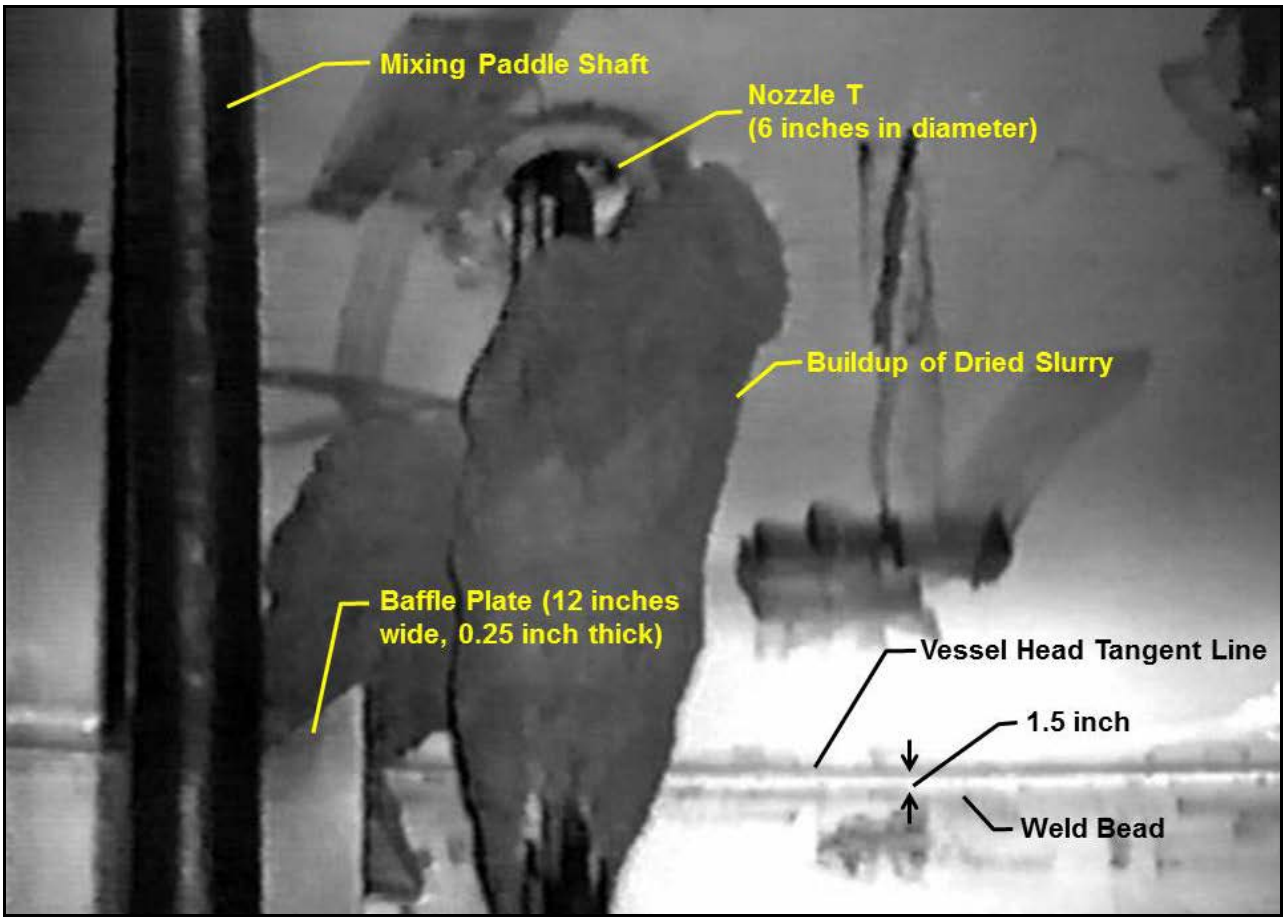

Figure 1. CMFT Head Before Flushing

Figure 2 shows another image of the inside of the MFHT before it was flushed. This image shows buildup of residual material adjacent to the head stiffeners

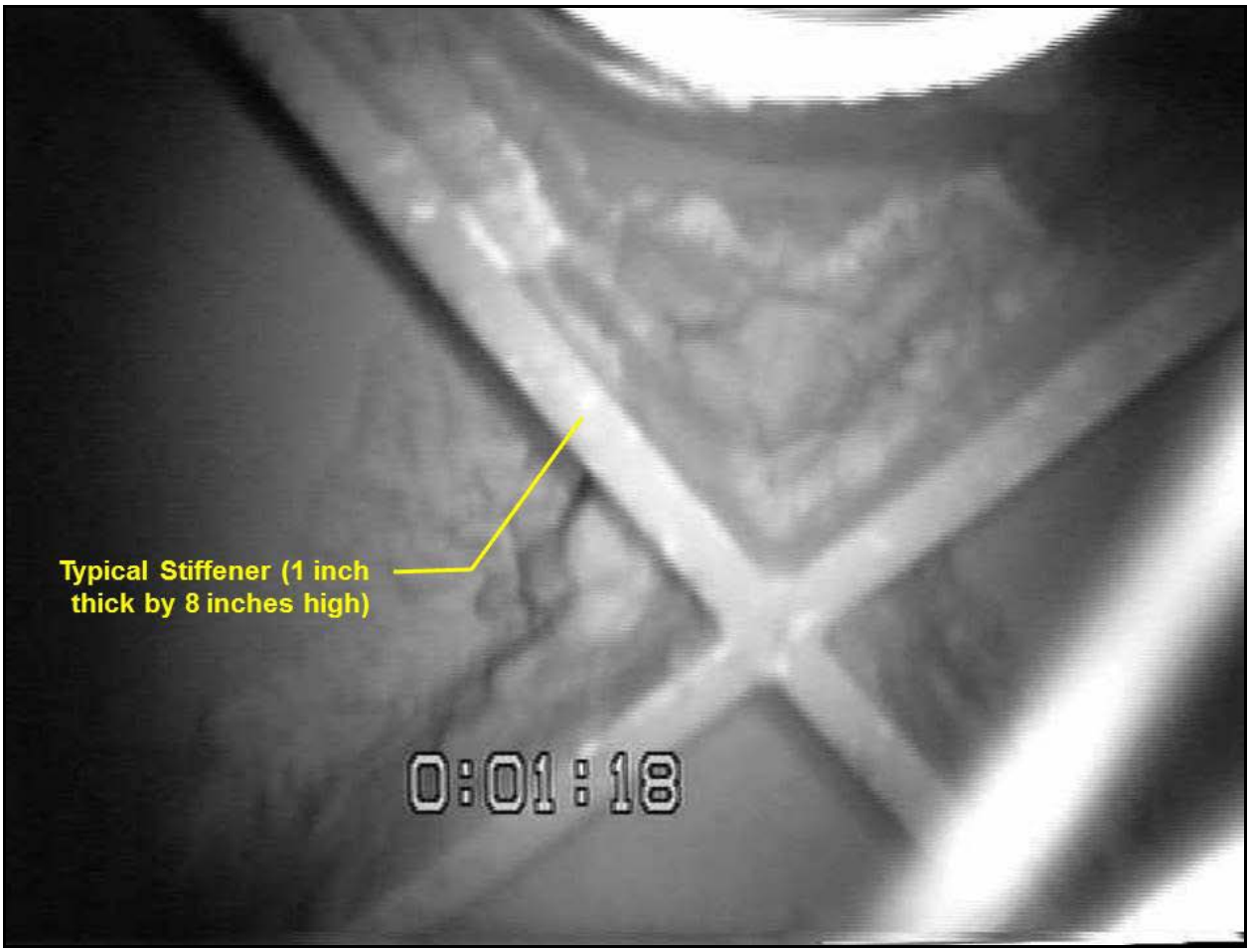

Figure 2. MFHT Head Before Flushing (Photo 6 of WVNSCO 2002b)

Additional images of conditions inside the vessels before flushing could not be located. However, while the original estimate of an average 0.25 inch-thick coating of dried slurry on the upper one-third of each vessel may be reasonable, it cannot be verified based on available photographic evidence.

Use of Batch 75 Data

The Batch 75 data were used because these data were considered to be reasonably representative of the radioactivity in the residual material on the vessel interior surfaces before the vessels were flushed. However, it is agreed that use of the Batch 75 Cs-137 concentration would not be conservative.

Given that the material adhering to the upper surfaces of the vessels likely accumulated over time, another approach would be to assume a Cs-137 concentration more representative of the average over time. The geometric mean of Cs-137 concentrations for all batches is 4.68E+03 µCi/g or approximately 6.5E+03 µCi/cm^3. The all-batches geometric mean value is likely to better approximate the radionuclide concentrations in the material that adhered to the insides of the vessels before they were flushed and the geometric mean concentration has therefore been used to revise Table 4-4 as described below.

A third approach would be to use data from Batches 72, 74, and 75 to estimate the amounts of Cs-137 that were present prior to flushing the vessels. Table 6 shows the results of using this approach, which would make use of data used for characterization of the vessels.

Table 6. Cs-137 Estimates Based on Batch 72, 74, and 75 Data

Vessel	Using Average of Data		Using Geometric Mean of Data	
	Cs-137 μCi/cm^3	Activity (Ci)	Cs-137 μCi/cm^3	Activity (Ci)
CFMT	6.515E+03(1)	8.1E+02(2)	3.416E+03(1)	4.3E+02(2)
MFHT	6.843E+03(1)	7.3E+00(3)	3.346E+03(1)	3.6E+02(3)

NOTES: (1) From Kurasch 2012.
(2) Based on 2.0E+05 cm^2 area with an average 0.625 cm material thickness.
(3) Based on 1.7E+05 cm^2 area with an average 0.625 cm material thickness.

Both sets of estimates in Table 3 are smaller than those from use of the Batch 75 Cs-137 concentration or the geometric mean of Cs-137 concentrations measured over time.

Impacts of Assumptions (Use of Batch 75 Data)

Use of the geometric mean of Cs-137 concentrations over time or a combination of the Batch 72, 74, and 75 data would produce lower decontamination factors as shown in the revised Table 4-4 below.

However, the estimated reductions in residual activity inside the vessels formed only one of three measures of removal of key radionuclides to the extent technically and economically practical. The visual inspection results clearly demonstrated the effectiveness of the high-pressure waste spray in removing residual material and key radionuclides from inside of the vessels as can be seen in Figure 4-2 of the Draft Evaluation. Before and after dose rate measurements described on page 43 of the Draft Evaluation show much higher decontamination factors – 89 for the CFMT and 105 for the MFHT – than the estimates based on the Cs-137 concentrations in Batch 75 or the average Cs-137 concentrations in the analytical data used for characterization of the vessels.

Conclusions: The lower decontamination factors produced by use of the average Cs-137 concentrations in the characterization data sets do not change the conclusion that key radionuclides have been removed from the vessels to the maximum extent technically and economically practical. The two other measures of key radionuclide removal – the amounts of residual material before and after flushing based on visual inspections and decontamination factors based on dose rate reductions – support this conclusion.

Changes to the draft evaluation: The following changes will be made to the Draft Evaluation in light of the NRC comments and the additional information provided above.

The text on page 43 of the Draft Evaluation will be changed as follows, with revised or new information highlighted in yellow. Note that the final amounts of Cs-137 in the two vessels were corrected as discussed in the response to comment IN-1.

"**Dose Rate Reduction**

Radiation detectors positioned using special fixtures to monitor decontamination progress showed that flushing reduced dose rates, although the amount of dose rate reduction was masked to some degree by other radiation sources in the cell, which included filled HLW canisters. Dose rates measured near the head of the concentrator feed makeup tank dropped from 200 to 8 R/h. Dose rates near the melter feed hold tank dropped from 250 to 22 R/h[5].

[5]The pre-flush dose rates were recorded on May 1, 2002 (WVNSCO 2002b). The post-flush dose rates were recorded on July 15, 2002 after all of the high-pressure spray flushing had been completed (WVNSCO 2002d).

Additional dose rate measurements made in February 2004 (WVNSCO 2004c) showed lower levels, with a maximum of 2.25 R/h on the concentrator feed makeup tank and a maximum of 2.39 R/h on the melter feed hold tank. The 2004 data, which were used in vessel characterization (WMG 2011), are indicative of a decontamination factor for the flushing of 89 for the concentrator feed makeup tank and 105 for the melter feed hold tank. (For the concentrator feed makeup tank, the decontamination factor is based on the initial measurement of 200 R/h divided by the final measurement of 2.25 R/h and, for the melter feed hold tank, the initial measurement of 250 R/h was divided by the final 2.39 R/h.)

The large differences in vessel dose rates before and after flushing demonstrate that the two vessels were effectively decontaminated and are consistent with the visual inspection results.

Reduction in Residual Radioactivity

An estimate of the flushing effectiveness can also be made by comparing the estimated residual activity in each vessel before flushing and after all of the flushing was completed. This comparison involves estimating the volume of visible dry slurry present in each vessel before flushing, converting these volumes to Cs-137 activity using a representative Cs-137 concentration, and comparing these results with the estimated residual radioactivity after completion of flushing.

Table 4-4 shows estimated residual cesium 137 in the two vessels before flushing and after completion of flushing, when the vessels were drained to the extent practical.

"**Table 4-4. Vessel Flushing Effectiveness in Terms of Estimated Cs-137 Removal**

Condition	CFMT Remaining Inventory (Ci)	CFMT Decontamination Factor	MFHT Remaining Inventory (Ci)	MFHT Decontamination Factor
Before Flushing(1)(2)	630	NA	540	NA
After All Flushes	95.3(3)	6.6(4)	97.1(5)	5.6(6)

LEGEND: CFMT = concentrator feed makeup tank, MFHT = melter feed hold tank, NA = not applicable

NOTES: (1) The activity in each vessel before flushing began was estimated in the following manner: (a) the residual material (dried slurry) coating observed on the vessel interior surfaces before flushing was assumed to average 0.250-inch thickness over the upper one-third of the vessels, based on pre-flush visual inspection results; and (b) the Cs-137 concentration in this material was assumed to be a representative, decay corrected concentration of 5.0E+03 μCi/cm^3.

(2) An alternate approach would be to use the arithmetic averages or geometric means of the Cs-137 concentrations in a combination of Batch 72, Batch 74, and Batch 75 as before-flushing reference points. This approach would yield somewhat lower estimates (Kurasch 2012).

(3) From Table 2-2 above.

(4) This decontamination factor is based on the best estimate Cs-137 activity. If a 20 percent greater upper bound estimate were to be used, the decontamination factor would be 5.5 rather than 6.6.

(5) From Table 2-3 above. [Table number to change.]

(6) This decontamination factor is based on the best estimate Cs-137 activity. If a 20 percent greater upper bound estimate were to be used, the decontamination factor would be 4.6 rather than 5.6."

The estimates in Table 4-4 should be considered to be order-of-magnitude estimates. As can be seen in Figure 4-2, the residual material buildup in some areas was much greater than 0.250 inch. The area values used in the estimates did not include the areas of the internal baffles. These factors suggest that the before-flushing estimates in Table 4-4 are low.

Conclusions About Flushing Effectiveness

Visual inspections show that the flushing removed essentially all of the visible residual material. Consideration of the before and after dose rates indicates that flushing removed around 99 percent of the residual Cs-137 inside the vessels. That is, the decontamination factor for the flushing performed – the "direct" flushes using the high-pressure spray apparatus and the "indirect" flushes associated with other vitrification flush solutions passing through the two vessels – was around 100 based on the reduction in measured dose rates.

The flushing Plan (WVNSCO 2002a) identified the expected conditions after the flushes for both vessels as "*Dried slurry deposits are expected to be removed from the surfaces accessible to the spray head, with some removal from protected areas*."[6] The significant differences between the before and after surface conditions inside the vessels combined with the dose rate reductions demonstrate that these objectives were achieved and that the flushes were effective in removing key radionuclides to the maximum extent technically and economically practical.

DOE considers the visual inspection results to be the best measure of flushing effectiveness because they provide direct evidence of the extent to which the vessels were decontaminated. The dose rate reductions also provide a meaningful measure of flushing effectiveness. However, consideration of the estimated amounts of Cs-137 present before and after flushing produces counterintuitive results, with much lower decontamination factors than those calculated from reductions in measured dose rates, likely because of difficulties in estimating the amounts of residual materials present before flushing. The decontamination factors in the Table 4-4 are therefore considered to be less reliable indicators of flushing effectiveness.

Additional information on the overall effectiveness of the various flushes in reducing residual radioactivity in the concentrator feed makeup tank and the melter feed hold tank is provided in Section 4.3 below, including a table that summarizes all of the flushes performed – the direct flushes using the high-pressure spray, the indirect flushes associated with other vitrification facility flush solutions that passed through the vessels, and additional flushes that were performed prior to removal of the vessels in 2004."

[6]No numerical goals for flushing effectiveness were established in planning for the flushes.

Number: MEP-2

Comment: Please provide additional information regarding the impracticality of chemical decontamination.

Basis: NUREG-1854, Section 3.3.2, states that the reviewer should identify any removal goals DOE established before radionuclide removal began, and also to consider whether DOE considered modifications to the removal process to improve removal if termination is based on declining removal efficiency (NRC 2007). Section 4.2.4 of the draft evaluation states chemical decontamination was shown to be effective in testing, but that it was deemed impractical because the chemicals were incompatible with the requirements for an acceptable glass mixture. Since the resulting flush solutions would have been feed to the Melter and transferred to the evacuated canisters, this made the chemical decontamination approach unacceptable due to technical impracticality (WVNSCO 2001). Later however, the draft evaluation states that sodium hydroxide solution was added to the CFMT in December 2003 after the vitrification system had been shut down. In this case, since the resulting fluids were sent to Tank 8D-4 instead of the vitrification system, the chemical approach was no longer technically disadvantaged for the CFMT at that point in time.

Path forward: Please discuss if DOE considered the practicality of a chemical flush for the MFHT after the vitrification system had been shut down. If application of such technology would have been infeasible or impractical for the MFHT, please describe the reasons.

DOE response: Available records do not indicate that a chemical flush of the MFHT after shutdown of the vitrification system was considered[7]. While such a chemical flush would have been technically practical in theory, it would not have been economically practical as discussed below.

The *Report on Deployment of Miscellaneous Tank and Piping Cleaning Equipment and Methodology* (WVNSCO 2002b) describes how the vessel was effectively flushed with nitric acid and water prior to shutdown of the vitrification system and demonstrated the effectiveness of this flushing with before and after photographs of the vessel interior and before and after dose rates. This report states that:

> "The video inspections conducted of the CFMT and MFHT internal surfaces showed a dramatic improvement in the degree of cleanliness. The internal surfaces of these tanks were essentially free of any visible deposits and it was noted that even the fabrication weld beads and polishing marks could be identified."

Because both vessels had been effectively decontaminated based on before and after visual inspections and dose rate measurements, there was no need for further decontamination of either vessel by chemical flushing.

As noted in Table 4-5 of the Draft Evaluation, sodium hydroxide was added to CFMT in December 2003 and removed about one month later. This sodium hydroxide addition was not intended for vessel

[7] The flushing of the CFMT and MFHT was performed in accordance with the *HLW Processing Systems Flushing Operations Run Plan* (WVNSCO 2002a). This flushing plan noted in Section 5.1 that that "The flushing of HLW systems and components will result in mobilized HLW which will be vitrified." Section 5.1 also stated that "In order to avoid generation of non-standard HLW canisters, all flushing media beyond currently accepted (e.g. water and nitric acid) shall be reviewed and approved for its suitability and acceptance of the resulting glass." It is therefore evident that system flushing with nitric acid and water was only considered viable while the melter was operating in order to vitrify the secondary waste stream thus created and use of chemicals other than nitric acid in flushes could have complicated or compromised the production of a fully compliant waste glass. In any case, the direct and indirect flushes actually performed effectively and removed key radionuclides from the two vessels to the maximum extent technically and economically practical.

decontamination purposes but rather as a means of sending this chemical to Tank 8D-4 to raise the pH of the liquid in Tank 8D-4, according to the individual who was the tank farm manager at the time (Meess 2012). While this process may have served to "chemically flush" the CFMT to a minor extent, this was a side effect of the sodium hydroxide transfer.

In January 2004, the work package for preparing the vitrification vessels for removal (WVNSCO 2004b) was issued. It provided for rinsing both the CFMT and the MFHT with utility water but not chemically flushing them

It is evident that a chemical flush of the MFHT after shutdown of the vitrification system would have been technically practical. Such a flush would not been economically practical considering the limited potential benefits and the costs that would have been involved.

The potential benefits from chemical flushing would have been negligible for the following reasons:

- The vessel had been effectively decontaminated by the high-pressure flushes as evidenced by visual inspections of the vessel interior;
- Comparison between before and after dose rates confirmed that the vessel had been effectively decontaminated;

In addition, the radionuclide concentrations in the vessel waste package are well below Class C limits[8] and the dose rates on the sides of the waste package reach a maximum of only 5 mR/h on contact. The vessel waste package meets requirements for disposal as low-level waste at the Nevada National Security Site and would be expected to meet requirements for disposal as low-level waste at the Waste Control Specialists facility in Texas. Moreover, the potential impacts to members of the public from disposal of the vessel without additional decontamination will be negligible.

A potential benefit of chemical flushing would likely have been use of less shielding (slightly thinner wall thickness) in the disposal package, which could have produced a small one-time material cost saving.

The costs of additional decontamination by chemical flushing likely would have been significant considering development of procedures and work packages, performing the actual flushing, and managing the resulting wastes.

Consideration of the expected costs and potential benefits leads to the conclusion that the costs would have outweighed any minimal benefits that might have been achieved. Therefore undertaking further removal of key radionuclides in this case by chemical flushing would not have been sensible or useful in light of the negligible potential benefits to human health and the environment, and would have been inconsistent with DOE as low as reasonably achievable (ALARA) requirements.

Conclusions: Although chemical flushing of the MFHT after vitrification system shutdown would have been technically practical, it would not have been economically practical. Given the purpose of the sodium hydroxide addition to the CFMT and the small volume that was added to the vessel, it would be better to not take credit for this caustic material addition as a flush of the CFMT.

Changes to the draft evaluation: The following changes will be made to the Draft Evaluation:

(1) The footnote on page 45 about flushing the CFMT with sodium hydroxide solution will be deleted.

[8]Achieving Class C concentration limits should not be viewed as an indicator, or exclusive indicator, of removal of key radionuclides to the maximum extent technical and economically practical. However, waste that meets Class C concentration limits is suitable for disposal as LLW and not highly radioactive.

(2) Table 4-5 on page 46 will be changed to delete reference to the sodium hydroxide addition.

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[9] As indicated previously, the radiological technical basis document attached to the Nevada National Security Site waste profile sheet will be revised to reflect minor changes in the CFMT inventory estimate.

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Attachment 1
Vessel Drawings

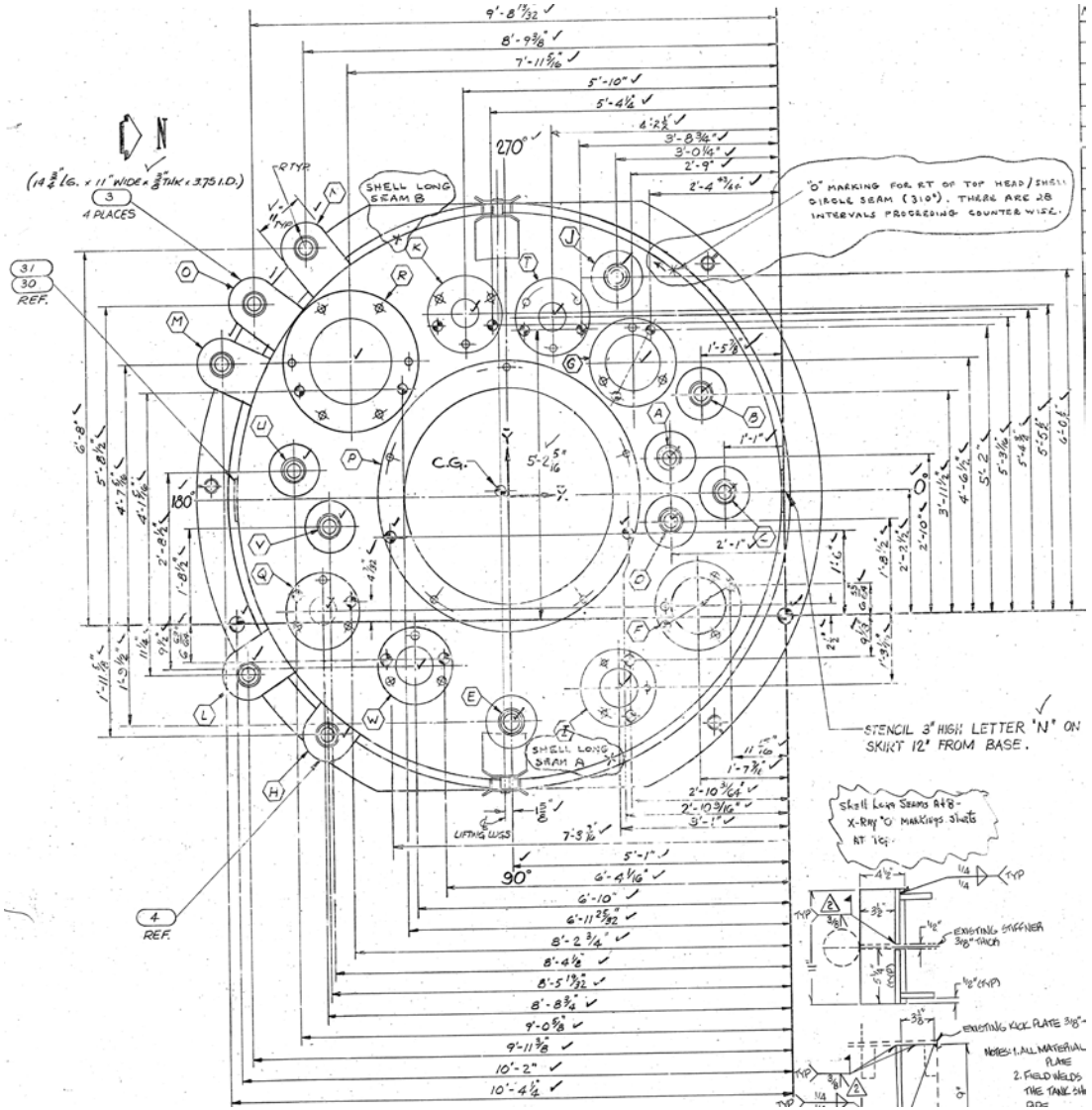

Figure 1-1. CFMT Plan View (From Drawing 58-5221-5-662, Rev. 2, Sheet 1 of 3)

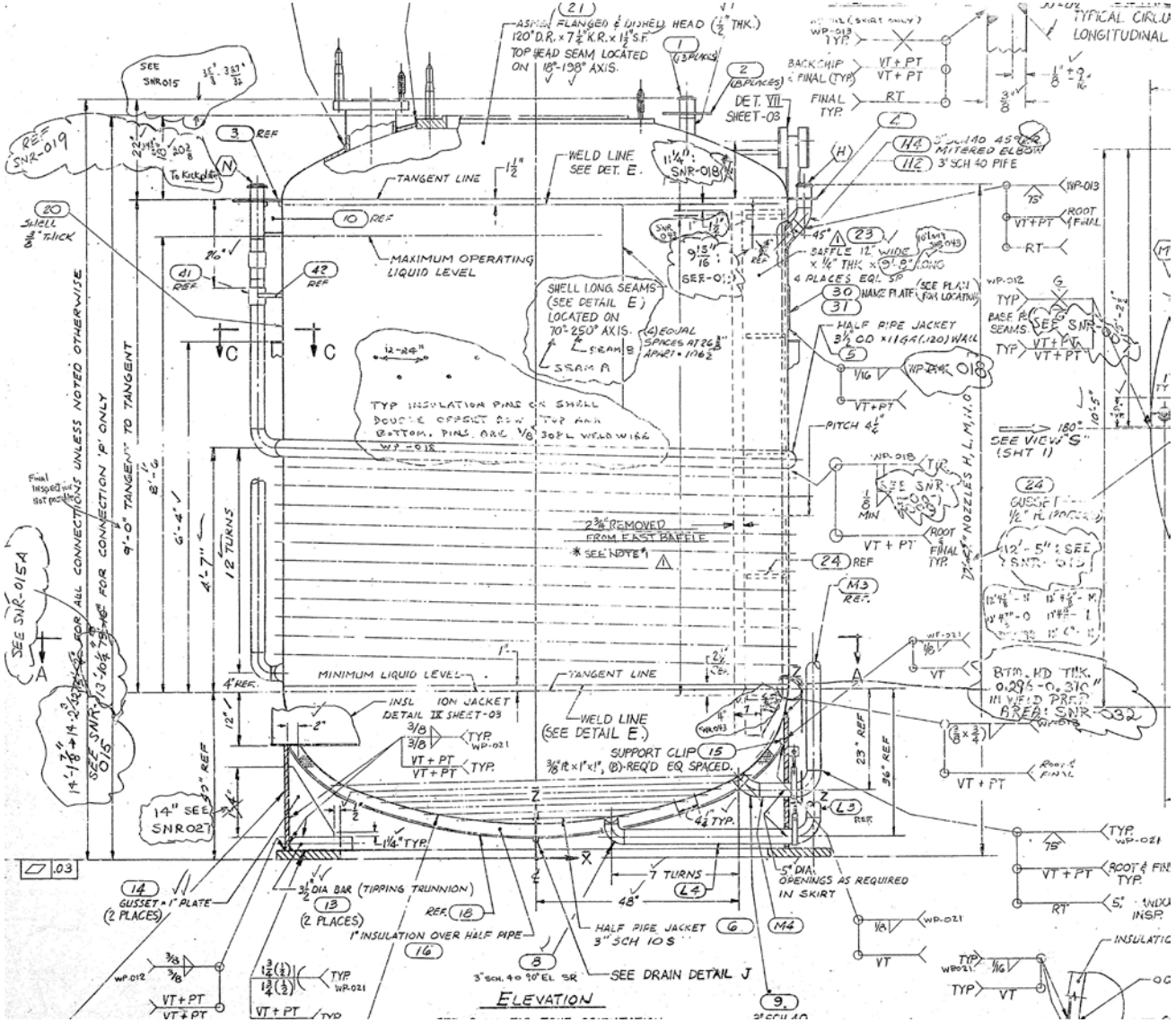

Figure 1-2. CFMT Elevation View (From Drawing 58-5221-5-662, Rev. 2, Sheet 2 of 3)

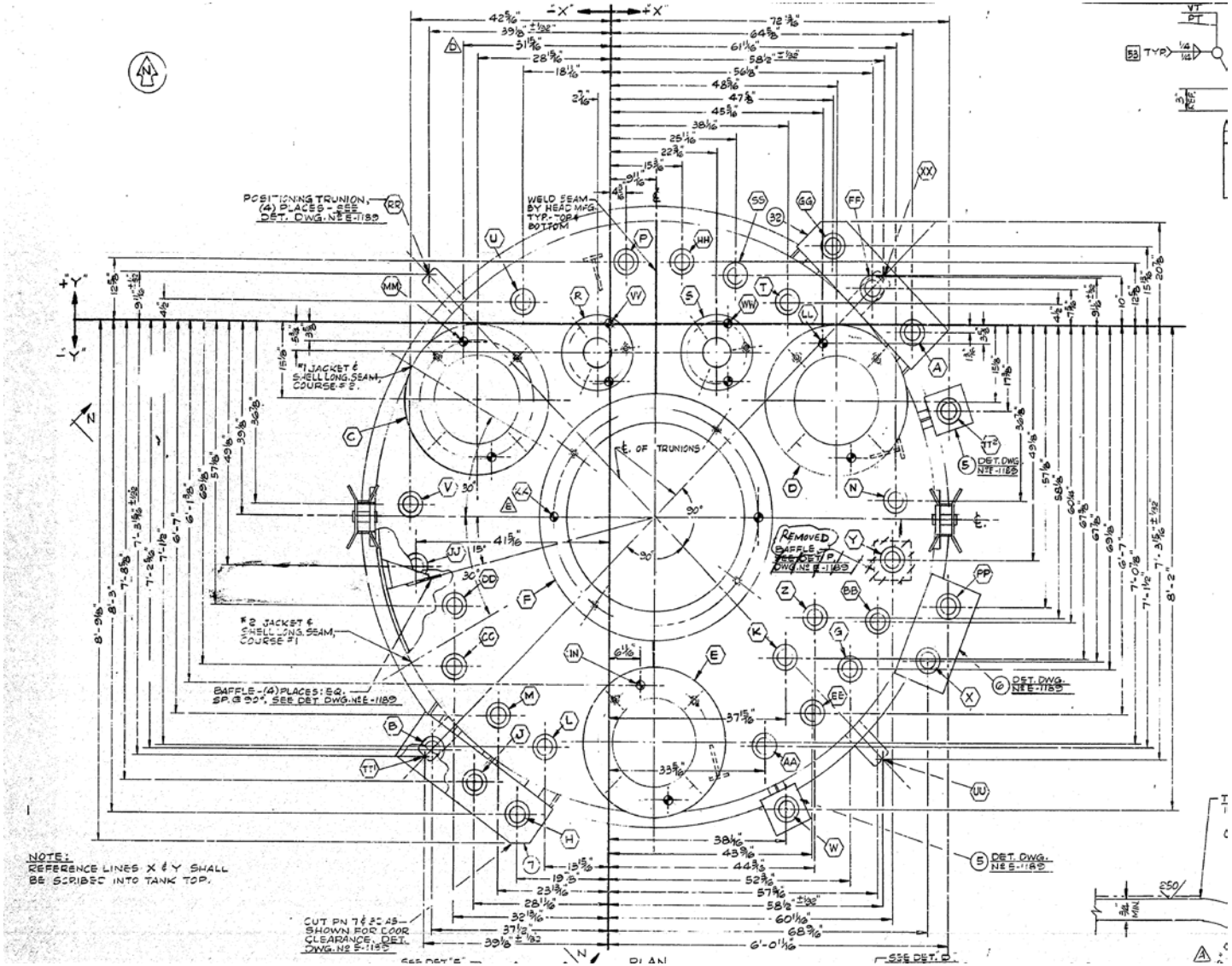

Figure 1-3. MFHT Plan View (From Drawing E-1188 Rev. 1)

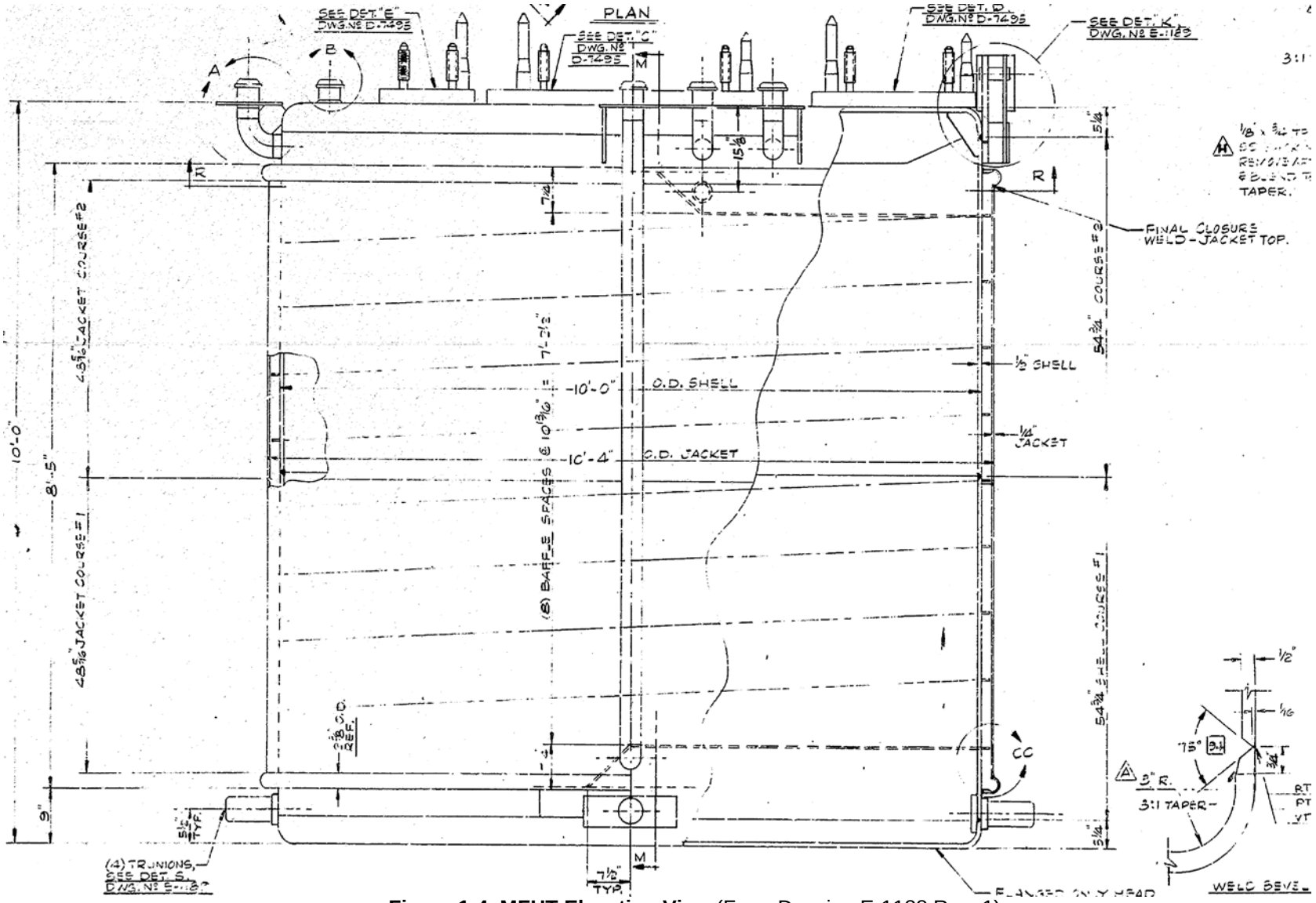

Figure 1-4. MFHT Elevation View (From Drawing E-1188 Rev. 1)