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ENGINEERING CHANGE NOTICE

Page 1 of 2

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Operating Specification	☐	Interface Control Drawing	☐	Spares Multiple Unit Listing	☐
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Radiation Work Permit	☐	Essential Material Specification	☐	Purchase Requisition	☐
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EXPERIENCE WITH AEROSOL GENERATION DURING ROTARY MODE CORE SAMPLING IN THE HANFORD SINGLE-SHELL WASTE TANKS

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Abstract: This document provides data on aerosol concentrations in tank headspaces, total mass of aerosols in the tank headspace, and mass of aerosols sent to the exhauster during rotary mode core sampling from November 1994 through June 1999. A decontamination factor for the RMCS exhauster filter housing is calculated based upon operational data and non-destructive assay.

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EXPERIENCE WITH AEROSOL GENERATION DURING ROTARY MODE CORE SAMPLING IN THE HANFORD SINGLE-SHELL WASTE TANKS

March 2001

John Schofield
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Richland, Washington

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TERMS

CGM	combustible gas meter
HEPA	high-efficiency particulate air
NDA	nondestructive assay
NOC	Notice of Construction
PMCS	push mode core sampling
RMCS	rotary mode core sampling
SST	single-shell tank

DEFINITIONS

Changeout. The replacement of air in a tank headspace with a volume of air equal to the headspace volume.

Core. A top-to-bottom (or until sampling is halted) collection of segments taken from the waste in a tank. As applied in this document, all segments taken with the sampling truck in the same position, and without changing the drill string insertion location through a tank riser are part of the same core.

Exhauster. The exhauster used during RMCS on a tank.

Headspace. The volume of air above the waste surface in a tank.

Housing. The main body of the exhauster containing the filter media.

Record sample. Stack samples taken during RMCS to measure the radionuclides released to the atmosphere.

RMCS core. A core taken from a tank with one or more segments taken in RMCS mode.

Segment. An individual 19-in.-long sample, or a group of samples that equals 19 in. in length. Segments are obtained through a drill string inserted into a tank riser.

Specific activity. The concentration of a radionuclide in the waste on a mass basis, normally in μCi/g or mCi/g.

Weighted average. An average that is weighted based upon a given parameter; in this document, weighted averages are based upon the number of RMCS segments.

EXPERIENCE WITH AEROSOL GENERATION DURING ROTARY MODE CORE SAMPLING IN THE HANFORD SINGLE-SHELL WASTE TANKS

1.0 SUMMARY

This document presents information on aerosol formation in tank headspaces during rotary mode core sampling (RMCS) in single-shell tanks (SSTs) at the Hanford Site. RMCS, using a nitrogen purge gas to cool the bit and provide hydrostatic head pressure, was performed periodically in SSTs between November 1994 and June 1999. All the available data relevant to aerosol formation during RMCS in SSTs was used for this study.

The mass of aerosols generated during RMCS was very small. The average mass of suspended waste solids present in an SST headspace during RMCS was less than 0.1 g. The mass of suspended solids sent to an exhauster averaged less than 0.1 g per RMCS segment and less than 0.5 g per RMCS core. The results are three orders of magnitude less than assumed in current accident analyses and environmental permit applications. The measured decontamination factor for the RMCS exhauster housing exceeded 70,000.

2.0 PURPOSE

The purpose of this document is to present estimates, based upon RMCS operating experience, of the concentration and total mass of waste aerosols present in SST headspaces during RMCS, and estimates of the mass of aerosols sent to the exhauster used on the tank. This document also evaluates the performance of the RMCS exhausters and provides an estimate of the filter housing decontamination factor. This document is not an evaluation of aerosol formation processes, aerosol dispersion patterns within the tank headspace, aerosol settling rates, or factors affecting removal of particulates from tanks. When using the values given in this document to estimate maximum potential quantities released to an exhauster, or to account for peak concentrations in a tank headspace when evaluating potential accident scenarios, engineering judgment should be used as deemed necessary to adjust the values given in this document for conservatism.

Revision 2 is an editorial update to Revision 1. This revision updates the document to a standard format and corrects several minor errors. No technical changes were made from Revision 1.

3.0 INTRODUCTION

Core sampling is used to obtain 19-inch-long samples of radioactive waste in the Hanford Site single-shell waste tanks. A 19-inch core sample is a segment. A core is made up of all the

segments taken as the drill bit passes through the waste. A sample may be taken in push mode or in rotary mode. A segment taken in rotary mode with purge gas flowing is designated an RMCS segment, and a core in which any RMCS segment is taken is designated an RMCS core. RMCS is used for tanks in which the waste may be too hard to sample using other methods.

Before 1994, core sampling was performed using a variety of different liquids to cool the drill bit during RMCS and provide a hydrostatic head in the drill string during both RMCS and push-mode core sampling (PMCS). RMCS sampling was halted in 1990 because of safety concerns with flammable gases and organic nitrates in the waste tanks. The RMCS equipment was redesigned to use nitrogen gas to cool the cutting bit. The nitrogen flow rate is approximately 30 to 40 standard ft^3/min (0.85 to 1.1 m^3/min) while the drill string is rotating. The nitrogen passes through holes in the bit, up through the waste, and is released to the tank headspace. Tank headspace volumes are in the range of 50,000 to 100,000 ft^3 (1,400 to 2,800 m^3). Since the nitrogen purge gas flow could slightly pressurize a passively ventilated tank headspace, an exhauster was included with the redesigned RMCS equipment. RMCS using the nitrogen-purge process was performed from November 1994 to January 1995, July 1995 to October 1995, and December 1997 to June 1999. From December 1997 to July 1998, RMCS was performed in the SX Tank Farm with the SX tank exhauster providing the ventilation. During 1994 and 1995, and from May 1998 through June 1999, RMCS was performed in the BY, S, U, and TX Tank Farms using an RMCS exhauster.

An estimate of the mass of aerosols sent to an exhauster during RMCS is needed as a basis for the potential-to-emit estimate that is included in environmental permits for the exhausters employed during RMCS. Estimates of tank headspace mass concentrations and total suspended solids during RMCS also are used in certain accident analyses related to RMCS. Since the bit rotation and gas sparging nature of RMCS have a higher potential for aerosol generation than many in-tank activities, aerosols generated during RMCS may provide an estimate of the upper limit for the concentration of aerosols to be found in a tank headspace during these activities.

As of March 2001 there are two Notices of Construction (NOCs) approved by the Washington Department of Health for exhauster use during RMCS. One Washington Department of Health permit (NOC-3) is for exhauster systems 3 and 4 (referred to as exhauster B and exhauster C in this document) during RMCS in a tank that is normally passively ventilated. The second Washington Department of Health permit (NOC-4) is for RMCS in the SX Tank Farm using the SX exhauster. The U.S. Environmental Protection Agency also has granted approval for RMCS exhauster use in a tank that is normally passively ventilated (NOC-5) and for RMCS in the SX Tank Farm with the SX exhauster (NOC-6).

Very conservative assumptions were made in estimating RMCS aerosol quantities for the existing NOCs and safety basis accident analyses because no operational data were available on aerosol levels when most of these NOCs and accident analyses were prepared. WHC-SD-WM-ES-225, *Aerosol Study for the Rotary Mode Exhauster*, provided the initial estimate of aerosols sent to the exhauster during RMCS. Based upon assumptions in WHC-SD-WM-ES-225, a value of 1 kg of waste sent to the exhauster per RMCS core was used as the basis for the first two RMCS NOCs (NOC-1 and NOC-2). This number was based upon drilling tests in drums of extremely hard, dry simulated saltcake. The hard simulant was

intended to present a limiting case for RMCS drill bit testing and was not physically representative of actual tank wastes. The estimate of 1 kg of waste per RMCS core was modified to 77 g of waste per RMCS segment when using the RMCS exhauster (NOC-3 and NOC-5) and 35 g of waste per segment for RMCS in the SX Tank Farm (NOC-4 and NOC-6).

A value of 600 g of waste in the tank headspace was assumed for certain RMCS accident analyses in WHC-SD-WM-SAD-035, *A Safety Assessment of Rotary Mode Core Sampling in Flammable Gas Single Shell Tanks: Hanford Site, Richland, Washington*. This number was based upon earlier conservative assumptions regarding particulates generated during a large gas release event in Tank 241-101-SY. A value of 100 g of waste in the headspace was used in an update of the RMCS accident analysis submitted to the U.S. Department of Energy for approval (Hanson 1998).

After nitrogen-purged RMCS operations commenced in November 1994, it became obvious that the estimates of aerosol generation rates in WHC-SD-WM-ES-225 were very conservative. This was evident from in-tank videos that showed very little dust formation and from the lack of any dose rate buildup on the in-tank prefilter (when used) or the exhauster high-efficiency particulate air (HEPA) filters. An evaluation was begun in 1997 to use data obtained during or following RMCS operations to estimate actual aerosol generation rates and exhauster filter performance. This document provides the results of that evaluation.

4.0 AEROSOL ESTIMATION METHODS

Dedicated particulate sampling methods such as employing sticky tapes or specially designed samplers to capture aerosols for microscopic evaluation were not used for this evaluation. Funding and personnel were not available for an in-depth study, nor was such a study necessary. Aerosol quantities were estimated using the best data available from existing sources associated with RMCS (filter housing dose rates, combustible-gas meter [CGM] filter papers, stack record samples), or easily obtained additional data (nondestructive assay [NDA] of housing). Three separate methods were used to provide estimates of the aerosols present in the tank headspace or sent to the exhauster. The first method used NDA of RMCS exhauster filter housings to estimate particulates captured on the filters. The second method used the RMCS exhauster HEPA filter dose rates following completion of a core to estimate the mass of waste on the filters. The third method estimated the tank headspace aerosol concentration based upon analytical data from filter papers located upstream of CGMs employed during RMCS. A CGM draws air out of a tank headspace at a constant flow rate during RMCS to monitor for flammable gases.

It was not possible to utilize any single method of estimating aerosol quantities for all RMCS sampling events. For some sampling events, not all data types were available or, if available, were not useful. Data may not have been not useful because no RMCS segments were taken during the time period evaluated, because analytical data were below background levels, because the analytical variance was greater than ±100%, or (for the SX Tank Farm) because other tanks were exhausted in parallel or series with the tank being core sampled. All calculations conservatively assumed that the background radionuclide concentration in a tank headspace was

zero and that all radionuclides detected by one of these methods were due solely to RMCS activities.

Table 1 lists the RMCS sampling events that provided the data for this document, the exhauster that was in service, the aerosol estimation methods used for the event, and the number of RMCS cores and segments obtained using the sampling method. The data in this document were obtained during RMCS in 11 separate tanks. Twenty-three RMCS cores containing 115 RMCS segments were obtained. The aerosol estimation methods are summarized below.

Table 1. Summary of Aerosol Estimation Methods Used. (2 sheets)

Tank and date sampled	Sample riser	Exhauster used	Exhauster operating period[a]	Aerosol estimation methods used			RMCS exhauster housing DF	Number of RMCS cores and RMCS segments taken[b]
				NDA	HEPA dose rate	CGM filter paper	NDA and RMCS stack record samples	
BY-106 – 1994	10B	A	1		X			1/8
BY-106 – 1995	10B	A						1/3
BY-110 – 1995	12B	A						2/11
	7							1/2
	12B							0/0
	4							0/0
BY-108 – 1995	12A[c]	B	2		X			0/0
	7[c]							0/0
BY-105 – 1995	12A	B						1/3
SX-101 – 1997-98	19	SX	3			X		1/5
	4					X		1/4
SX-103 – 1998	7					X		1/2
	11					X		1/4
SX-105 – 1998	6					X		1/1
	14					X		1/5
SX-102 – 1998	8					X[d]		0/0
	4							1/2
S-110 – 1998	6	C	4	X	X	X	X	1/2
	14					X		1/8
U-107 – 1998	7	C				X[d]		1/3
	2							1/7
BY-105 – 1998	7	C[e]				X		1/9
	11B	C[e]				X		1/9
TX-113 – 1998-99	3	C				X		1/12
TX-113 – 1998-99	3[c]	B	5	X	X			0/0
	5	B				X		1/6
TX-118 – 1999	12B	C	6	X	X			1/5
	9B							1/4

Table 1. Summary of Aerosol Estimation Methods Used. (2 sheets)

Tank and date sampled	Sample riser	Exhauster used	Exhauster operating period[a]	Aerosol estimation methods used			RMCS exhauster housing DF	Number of RMCS cores and RMCS segments taken[b]
				NDA	HEPA dose rate	CGM filter paper	NDA and RMCS stack record samples	
Number of RMCS cores and segments obtained during data collection period[b]				10/65	16/92	15/79	10/65	23/115[f]

[a]See Appendix F for explanation of exhauster operating periods.

[b]Includes RMCS cores and segments only. Push-mode core sampling cores and segments obtained during exhauster operation are not included.

[c]No RMCS segments were taken from 241-BY-108 or from 241-TX-113, Riser 3, using exhauster B. Any material retained on the filters during these operating times was assumed to come from next RMCS sampling event with the same exhauster.

[d]One CGM filter paper was used for both cores in 241-SX-102 and for both cores in 241-U-107.

[e]Tank 241-BY-105 in 1998 is shown as two separate exhauster installations since stack record samples were pulled after each riser was sampled.

[f]A total of 23 RMCS cores and 115 RMCS segments was taken between November 1994 and June 1999. The sum of cores and segments is less than the number of cores and segments obtained by summing the data collection period numbers at left because more than one aerosol estimation method was used for some sampling periods.

CGM = combustible-gas meter.
DF = decontamination factor.
HEPA = high-efficiency particulate air (filter).
NDA = nondestructive assay.
RMCS = rotary mode core sampling.

4.1 ROTARY MODE CORE SAMPLING EXHAUSTER HOUSING NONDESTRUCTIVE ASSAY

Appendix A describes the NDA of RMCS exhauster housings after they were used during RMCS operations from May 1998 through June 1999. Gamma assays of the housings were performed to measure the ^{137}Cs on the prefilter, primary HEPA filter, and secondary HEPA filter. The quantity of ^{137}Cs present on each was estimated by comparison with the ^{137}Cs count rate from a known standard measured in an equivalent geometry. The quantity on all three filters was summed to estimate the total in the housing. The mass of particulates was obtained by dividing the quantity of ^{137}Cs present by a weighted average of the ^{137}Cs concentration of the wastes in the tanks being exhausted. With this data, average tank headspace mass concentrations were calculated as well as the mass per core and per segment sent to the exhauster. The mass of waste in a tank headspace was calculated by multiplying the tank headspace concentration by the tank headspace volume. A summary of the results is given in Table 2. The detailed results are given in Appendix A, Table A-3.

Table 2. Summary of Rotary Mode Core Sampling Aerosol Data.

Aerosol estimation method / Result	NDA of exhauster filter housing	Dose rate increase on RMCS exhauster filter housing	Combustible gas meter filter paper data	Weighted average*	NDA and stack record sample data
Average tank headspace mass concentration during RMCS (g waste/m^3)	7.7 E-06	2.2 E-05	4.0 E-05	**2.4 E-05**	
Average mass of suspended solids in tank headspace during RMCS (g waste)	1.8 E-02	4.7 E-02	9.7 E-02	**5.6 E-02**	
Average mass per RMCS core to exhauster (g waste)	5.2 E-01	5.9 E-01	1.8 E-01	**4.2 E-01**	
Average mass per RMCS segment to exhauster (g waste)	6.3 E-02	1.0 E-01	3.4 E-02	**6.9 E-02**	
Filter housing decontamination factor					**72,600**

*Weighted average based upon number of RMCS segments taken with each method.

NDA = nondestructive assay.
RMCS = rotary mode core sampling.

4.2 ROTARY MODE CORE SAMPLING EXHAUSTER FILTER DOSE RATE DATA

Appendix B describes using RMCS exhauster dose rate data to estimate aerosol quantities. Dose rates were taken at the side of the RMCS exhauster housing during and after all sampling events in which the RMCS exhauster was used. The dose rate at the edge of the HEPA filter housing is used to estimate a quantity of ^{137}Cs on the filter. Dividing the quantity of ^{137}Cs on the filter by a weighted average of the ^{137}Cs concentration in the wastes of the tanks being exhausted provides the waste mass on the filters. With the waste mass known, tank headspace mass concentrations can be calculated as well as the mass per core or per segment sent to the exhauster. The mass of waste in a tank headspace was calculated by multiplying the tank headspace concentration by the tank headspace volume. A summary of the results is given in Table 2. The detailed results are given in Appendix B, Table B-3. The minimum detection ability of the dose rate instruments used is 0.5 mR/h. Most RMCS exhauster dose rates obtained after an RMCS core was taken were less than detectable. An exhauster housing registered slightly above the minimum detectable limit at 0.7 mR/h after core sampling on Tanks 241-S-110, 241-U-107, 241-BY-105, and 241-TX-113. The housing with the same filters in place read 0.8 mR/h after completion of sampling on the next tank, 241-TX-118.

4.3 COMBUSTIBLE-GAS METER FILTER PAPER ANALYSES

Appendix C describes using CGM filter paper analytical data to estimate aerosol quantities. The filter papers are inserted in-line in front of a CGM where they catch the radionuclides in the tank vapors drawn into the CGM. These filter papers were removed and analyzed starting in 1997. For conservatism, only sample results with a variance greater than 100% were used. These analytical data were divided by the specific activity of the radionuclides present on the filter paper for the tank on which the CGM was being operated. This provides an estimate of the aerosol mass concentration in the tank headspace because a particulate sample is drawn directly from the tank headspace during RMCS. With this data, the mass of waste in the headspace and the mass per core and per segment sent to the exhauster can be calculated. The mass of waste in a tank headspace was calculated by multiplying the tank headspace concentration by the tank headspace volume. A summary of the results is given in Table 2. The detailed results are given in Appendix C, Table C-4.

5.0 ROTARY MODE CORE SAMPLING EXHAUSTER DECONTAMINATION FACTOR ESTIMATION METHOD

The RMCS exhauster filter housing decontamination factor was calculated by comparing stack record sampler data with the housing NDA data to calculate an efficiency for the housing. The housing contains a prefilter and two HEPA filters in series. Table 1 lists the RMCS sampling events that provided the data for estimating the decontamination factor.

5.1 HOUSING NONDESTRUCTIVE ASSAY AND RECORD SAMPLE DATA COMPARISON

Appendix D uses RMCS exhauster stack record sample data to estimate stack ^{137}Cs emissions for the time periods during which NDA data were obtained. The stack emissions were used with the NDA data to calculate a filter housing decontamination factor. The only radionuclide shown as present by the NDA was ^{137}Cs. No stack record samples showed ^{137}Cs present above detection limits. However, total beta results above minimum detection limits were available for seven of the nine stack record samples taken during the time periods for which NDA data were obtained. For the remaining two samples, conservative assumptions were made as to the stack's total beta concentration. Stack total beta emissions were converted to ^{137}Cs emissions using the ^{137}Cs-to-total-beta ratio for the waste in the tank being sampled. The filter housing input was calculated by adding this calculated ^{137}Cs emission to the quantity shown by NDA to be in the housing. Dividing the emissions by the input provided the penetration efficiency. Results of the housing efficiency and decontamination factor calculations are provided in Appendix D, Table D-1.

6.0 DISCUSSION OF RESULTS

All calculations were based upon radionuclides measured on the exhauster filters, in the tank headspace air, or in the exhauster stack. These radionuclide quantities were divided by the specific activity of waste in the tank to provide mass quantities in the air, on the filters, or in the exhaust stream. Appendix E provides the waste-specific activities used in this document, along with limitations and potential errors associated with using them.

The calculated average mass concentration in a tank headspace during RMCS ranged from a low of 7.7 E-06 g/m^3, based upon exhauster housing NDA data, to a high of 4.0 E-05 g/m^3, based upon CGM filter paper data. The weighted average of all methods was 2.4 E-05 g/m^3. Weighted averages used in this document were based upon numbers of RMCS segments obtained during application of that particular method.

The average mass concentration is not the peak concentration, as illustrated by Figure 1. Figure 1 is a representation of relative concentrations only, not a plot of measured concentrations during a specific sampling event. Lines A and B represent aerosol concentrations at points near the drill string and at the tank outlet to the exhauster. Line C represents the calculated average concentration in the tank headspace. The peak concentration in the air to the exhauster will exceed the average tank headspace concentration for short periods of time. It is beyond the scope of this document to provide a detailed spatial- and time-dependent analysis of tank aerosol concentrations. The methods used in this document provide an estimate of an average tank headspace mass concentration only.

The average mass of suspended solids in a tank headspace was estimated by multiplying the average headspace mass concentration by the tank headspace volume. The calculated average mass of suspended solids in a tank headspace during RMCS ranged from a low of 1.8 E-02 g, based upon exhauster housing NDA data, to a high of 9.7 E-02 g, based upon CGM filter paper data. The weighted average of all methods was 5.6 E-02 g. Comparing 5.6 E-02 g to the 600 g and 100 g used in accident analysis assumptions, it is evident that the accident analyses used peak tank headspace mass levels three to four orders of magnitude greater than the average mass level in a tank headspace during RMCS.

Multiplying an average concentration by the tank headspace volume to estimate the mass of suspended solids in the tank headspace at a given time makes the simplifying assumption that the tank headspace concentration is constant with time and uniform within the headspace during RMCS. As illustrated by Figure 1, the tank headspace concentration is not constant with time or uniform within the headspace. When determining a maximum value for mass of solids in a tank headspace, engineering judgment needs to be applied that evaluates all the parameters involved that could increase or decrease the average mass value provided in this document. With all other variables being equal, the mass concentration and mass of suspended solids in a tank headspace also will be affected by the volume of the headspace and the exhaust flow rate. The headspace volumes of the tanks sampled to date are typical of SSTs. The exhauster flow rate is not expected to change for the RMCS exhauster. If additional samples are taken in 241-SX tanks where the exhauster flow rate is higher than in the four 241-SX tanks that have already been sampled, the mass present in the tank headspace can be expected to be reduced.

Figure 1. Relative Waste Aerosol Concentrations in Tank Headspace.

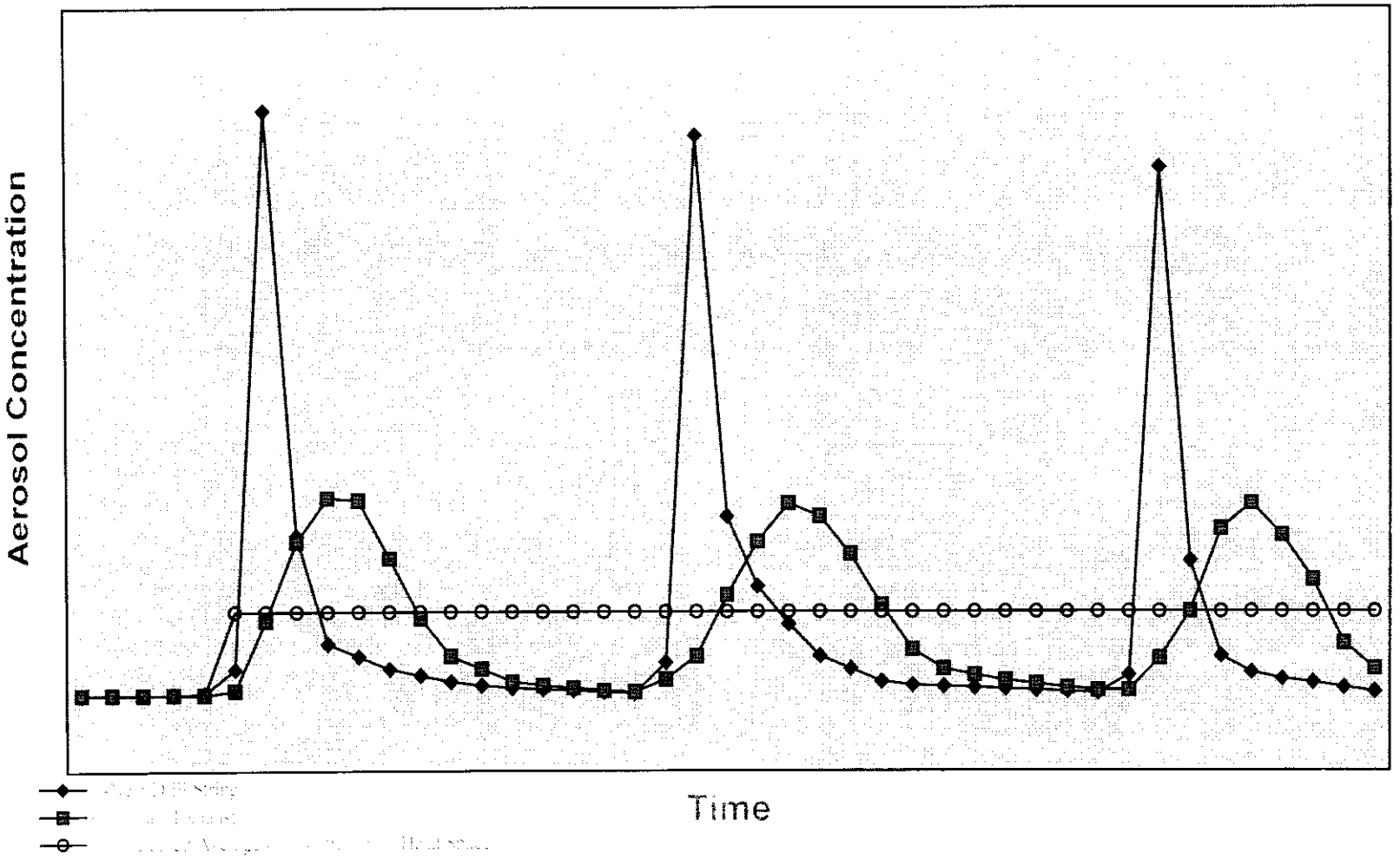

Figure is conceptual model only showing relative concentrations in tank head space, not actual measurements

The calculated mass of waste sent to an exhauster ranged from lows of 1.8 E-01 g per RMCS core and 3.4 E-02 g per RMCS segment, based upon CGM filter paper data, to highs of 5.9 E-01 g per RMCS core and 1.0 E-01 g per RMCS segment, based upon exhauster housing dose rate data. The weighted average of all methods was 4.2 E-01 g per RMCS core and 6.9 E-02 g per RMCS segment. Comparing the average with the 1 kg per RMCS core and 35 to 77 g per RMCS segment numbers used for the potential-to-emit estimates, it is evident that the potential-to-emit estimates are conservative by at least three orders of magnitude.

Results given in this document based upon total beta or ^{137}Cs data are likely more valid than alpha-based results because of the higher concentrations of beta-gamma radionuclides in the waste and their greater ease of measurement when compared to alpha emitters. Equal weight is given to all results regardless of whether based upon total alpha, total beta, or ^{137}Cs data. This provides conservative results since the aerosol values based on total beta or ^{137}Cs were normally lower than those based upon total alpha results.

The mass-per-segment numbers should be a better indicator of RMCS aerosol emissions from the tank than the mass-per-core numbers. This is because the quantity of aerosols generated in a tank should be proportional to the time of purge-gas flow and bit rotation. The time of purge-gas flow and bit rotation should be proportional to the number of RMCS segments taken. Thus, the mass of RMCS-generated aerosols sent to an exhauster on a given tank should be roughly proportional to the number of RMCS segments obtained from the tank. The number of RMCS segments in a core can vary. To date the range has been from 1 to 12 RMCS segments per RMCS core. The average has been 5 RMCS segments per RMCS core.

The results for mass-per-core or mass-per-segment based on NDA and housing dose rate data have a firmer basis than results based upon CGM filter paper data. This is because the RMCS exhauster housing NDA and dose rate methods are a direct physical measurement of essentially all the ^{137}Cs released to the exhaust stream during RMCS. Aerosol measurements based upon HEPA dose rate are conservative as the filters showed no detectable dose rate for three of the five periods evaluated, and barely perceptible readings after the other two.

For tank headspace concentrations and mass of waste in a tank headspace during RMCS, the results based on CGM filter paper data have a firmer basis than results based on housing NDA or dose rate. This is because the CGM filter paper data are a direct measurement of the concentration in the air in a tank headspace during the time aerosols are being generated. The CGM filter paper data should provide a higher tank headspace mass concentration than that calculated by filter housing NDA or dose rate. This is because aerosols are only generated during times when the CGM is operating, and the CGM operates for less time than the exhauster does. Since the concentration is based upon dividing a filter quantity by the volume of gas passing through the filter, the volume of gas in proportion to the material on the filter will be less for the CGM filter paper than for an exhauster filter, resulting in a higher concentration based on CGM filter paper data. A factor is included in the CGM-based concentration to account for radionuclides in the dome space that have not settled out or been removed by the exhauster when the CGM is shut off.

The average results for all methods are within reasonable agreement with each other considering all the variables and assumptions involved. The filter housing decontamination factor is in good agreement with expected values.

This document contains seven appendices. Appendices A through C provide particulate results based upon RMCS exhauster housing NDA, RMCS exhauster housing dose rates, and CGM filter paper data. Appendix D provides an RMCS exhauster filter housing decontamination factor based on housing NDA and stack record sample data. Appendix E provides waste specific activities, and Appendix F provides the raw data used in Appendices A through D.

7.0 CONCLUSIONS

The results in this document are based upon RMCS operating experience from the start of nitrogen-purged RMCS in November 1994 through June 1999. Table 2 summarizes the information presented in the appendices. Based upon this information and the lack of any significant aerosol formation seen in in-tank videos, it can be concluded that past estimates of aerosol concentrations used for regulatory permits and accident analyses were conservative by a nominal three orders of magnitude.

In order to estimate mass releases for regulatory permits, the overall emissions with time are needed. For future permits the mass-per-core or mass-per-segment values in Table 2 can be used directly, with conservatism added if deemed appropriate for the tanks to be sampled. When estimating maximum concentrations or maximum mass quantities in the tank headspace for use in accident analyses, additional conservatism needs to be added to the average concentration and mass values in Table 2.

8.0 REFERENCES

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APPENDIX A

ESTIMATION OF AEROSOLS GENERATED DURING ROTARY MODE CORE SAMPLING BASED UPON ROTARY MODE CORE SAMPLING EXHAUSTER HOUSING NONDESTRUCTIVE ASSAY

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APPENDIX A

ESTIMATION OF AEROSOLS GENERATED DURING ROTARY MODE CORE SAMPLING BASED UPON ROTARY MODE CORE SAMPLING EXHAUSTER HOUSING NONDESTRUCTIVE ASSAY

A.1 SUMMARY OF METHOD

This method of estimating rotary mode core sampling (RMCS) aerosol quantities uses nondestructive assay (NDA) of the exhauster housing to determine the ^{137}Cs activity (in curies) on the filters inside. This ^{137}Cs activity is then divided by the ^{137}Cs specific activity (Ci/g) in the waste for the tanks on which the exhauster and the filters were operating during sampling. The resulting mass on the filters divided by the volume of air flowing through the exhauster provides an estimate of the average aerosol mass concentration in the air entering the exhauster. This value is multiplied by the tank headspace volume to obtain the average mass of particulates present in the tank headspace during RMCS. The mass of waste on the filters divided by the number of rotary cores or segments taken provides the mass per core or per segment sent to the exhauster.

A.2 DESCRIPTION

One prefilter and two high-efficiency particulate air (HEPA) filters are arranged in series for each RMCS exhauster. Particulates captured on the filters contain radionuclides, with ^{137}Cs being the predominant gamma emitter. By performing an NDA of the exhauster housing filters, the quantity of ^{137}Cs in the housing can be estimated. This ^{137}Cs value is then used to back-calculate to a waste mass on the filters using the ^{137}Cs concentration in the tank waste. This filter waste mass is used to calculate the concentration of particulates in the tank exhaust stream, the total suspended solids in the tank headspace, and the mass of waste sent to the exhauster for each RMCS core or segment taken.

Exhauster operations have been divided into six operating periods for evaluation in this document. These operating periods are discussed in Appendix F and shown in Table F-1. NDA data were obtained for exhauster operating periods 4, 5, and 6. Relevant information for these periods also is listed in Table A-1.

Period 4 covers use of exhauster C during RMCS for both cores taken in Tanks 241-S-110, 241-U-107, 241-BY-105, and the first core taken in Tank 241-TX-113. The filters and housing were new before RMCS began in Tank 241-S-110. No filter changeouts were made during this period; the accumulated particulates from these RMCS events were retained on the housing prefilter, primary HEPA filter, and secondary HEPA filter.

Period 5 covers use of exhauster B during RMCS for the second core taken in Tank 241-TX-113. The filters and housing were new before RMCS began in Tank 241-TX-113. No filter changeouts were made during this period. Exhauster B also ran for a short time during sampling

for the first core in Tank 241-TX-113, but no RMCS segments were taken when the exhauster was operating. Stack record samples (see Appendix D) indicate small levels of aerosols were present in the stack exhaust during this time period. Any material collected on the filters during this time period was counted as part of the aerosols generated during the second RMCS core.

Period 6 covers use of exhauster C during RMCS for both cores taken in Tank 241-TX-118. During period 6 the filters also contained the waste particles from period 4. No filter changeouts were made during this period. The aerosol mass generated during RMCS in Tank 241-TX-118 was determined from the increase in ^{137}Cs on the filters between period 4 and period 6.

A description of the sampling method used for the NDA obtained following period 4 is provided in Greager (1999). The same method was used for the NDA following periods 5 and 6. The NDA consisted of a gamma energy analysis of the exhauster housing performed at points adjacent to the prefilter, first HEPA filter, and second HEPA filter. The detector was mounted outside the housing and inside a lead collimator. The collimator was used to minimize the background count rate and contribution from adjacent filters. The only radionuclide reported as present was ^{137}Cs. The NDA compared the count rates from the exhauster housing with the count rate from a National Institute of Standards and Technology traceable ^{137}Cs source located in the middle of a filter in a geometry equivalent to that of the RMCS exhauster housing. The count rates from housing filter readings were divided by the count rate for the source to give a reported quantity of ^{137}Cs on the filters. Section A.2.1 summarizes the NDA data. Two correction factors were applied to the reported filter ^{137}Cs values for use in this document. These are discussed in Sections A.2.2.

A.2.1 Reported Nondestructive Assay Data

The NDA results for period 4 are provided in Greager (1999). The only radionuclide reported as present on the filters was ^{137}Cs. The results are restated in Table A-2. The NDA results for periods 5 and 6 are provided in Schofield (2001). The only radionuclide reported as present on the filters was ^{137}Cs. The results are restated in Table A-2.

A.2.2 Adjusted Nondestructive Assay Data

The reported results are based upon comparing the count rate for a reference point source located in the middle of a mock-up assembly that is equivalent to the exhauster housing, with the count rate from the same detector inside a lead collimator placed outside the actual exhauster housing. Limitations with this method include comparison of a point source with a distributed matrix and the inability of the detector to see the entire filter because of the presence of the collimator. Correction factors were used to adjust the reported values to account for these two limitations.

The first correction factor accounts for the differences in comparing a distributed source and a point source standard. The reported results were calculated based upon a point source standard because there are no readily available filter standards for a distributed source. The material in the filter housing should be fairly evenly distributed through the filter media, however, so comparing count rates for the filter housing and the point source standard will result in some

error. To correct for this error, shielding calculations were performed on an exhauster housing filter assuming the ^{137}Cs was evenly distributed throughout the filter media, and then again assuming the activity was a point source in the middle of the filter. The results of these dose rate calculations are reported in Schofield (2001). Schofield (2000) and Schofield (2001) show that the dose rate at the NDA detector location would be about 0.625 mR/h/mCi of ^{137}Cs for a point source and 0.73 mR/h/mCi of ^{137}Cs for a distributed source. To adjust the reported non-destructive assay results to what they would have been if a ^{137}Cs distributed standard source were available, the values reported in Schofield (2001) need to be multiplied by a factor calculated as follows:

$$0.625 \text{ mR/h/mCi} \div 0.73 \text{ mR/h/mCi} = 0.86 .$$

The second correction factor accounts for the inability of the detector to see the contents of the entire filter because of the detector's location inside the lead collimator. Using basic geometry, Schofield (2000) estimated that the detector had about a 100% view of 60.8% of a HEPA filter, about a 50% view of 26.4% of the filter, and was shielded from the remaining 12.8%. The detector count rate was thus estimated to be approximately 74.1% of what it would be if the detector were not collimated. To correct the reported results to what they would have been if an uncollimated detector had been used, the reported values need to be multiplied by the following factor:

$$1 \div 0.741 = 1.35 .$$

Combining the two correction factors gives the following single adjustment factor:

$$0.86 \times 1.35 = 1.16 .$$

According to Table A-2, the total quantity of ^{137}Cs reported present in the housing for period 4 was 0.430 mCi. This quantity was multiplied by 1.16 to give 0.50 mCi of ^{137}Cs. The reported results for periods 5 and 6 were revised in the same manner to give 0.032 mCi of ^{137}Cs and 0.64 mCi of ^{137}Cs, respectively. To determine the net increase in ^{137}Cs for the housing during period 6, the value from period 4 was subtracted from the total:

$$0.64 \text{ mCi} - 0.50 \text{ mCi} = 0.14 \text{ mCi of } ^{137}Cs.$$

A.3 CALCULATION OF MASS QUANTITY ON FILTERS

Calculation of the mass of waste on the filters requires knowledge of the specific activity of the waste on the filters. The specific activities used for each exhauster operating period are given in Table A-1. The paragraphs below provide a derivation of the specific activities used.

The specific activity values for the waste in each tank sampled are given in Appendix E, Table E-1. RMCS was performed on more than one tank during period 4, so a weighted-average specific activity was used to calculate the waste mass on the filters during this period. The weighted-average specific activity was calculated based upon the number of RMCS segments taken from each tank sampled. The number of RMCS segments obtained during each period for

which NDA measurements were made is listed in Table A-1. These values were obtained from Appendix F, Table F-1. A weighted-average specific activity for the waste on the filters in period 4 was obtained by using the following formula:

$$[(0.227\ \text{mCi/g})(10\ \text{seg}) + (0.121\text{mCi/g})(10\ \text{seg}) + (0.225\ \text{mCi/g})(18\ \text{seg}) + (0.130\ \text{mCi/g})(12\ \text{seg})] \div (50\ \text{segments}) = 0.182\ \text{mCi of } ^{137}\text{Cs/g}\ .$$

Calculating a weighted average based upon the number of segments assumes that aerosol generation is roughly the same per segment and that the specific activity of a radionuclide is constant throughout a tank. These assumptions are adequate for the purpose of this document. Aerosol generation can vary with water content, waste hardness, depth of sample taken, nitrogen flow rate, and porosity of the waste. An in-depth evaluation of these parameters is beyond the scope of this document. The impact of these variables is assumed to average out over all the RMCS segments taken. The specific activities used do not vary greatly from tank to tank, so any variations will not have a significant impact on the final aerosol results. See Appendix E for further discussion of the limitations on specific activities used in this document.

The filters were new at the start of period 5 and the only tank sampled with the exhauster was Tank 241-TX-113. Therefore, the specific activity of ^{137}Cs for Tank 241-TX-113, 0.130 mCi/g, was used.

The same exhauster and filters used for period 4 were used for period 6. The net increase in ^{137}Cs for period 6 was determined by subtracting the period 4 ^{137}Cs from the total. Since this net increase was only attributable to Tank 241-TX-118, the specific activity of ^{137}Cs for Tank 241-TX-118, 0.130 mCi/g, was used for the waste added to the filters during period 6. (Note it is only a coincidence that Tanks 241-TX-113 and 241-TX-118 have the same nominal ^{137}Cs concentration.)

The total mass of waste caught on the exhauster filters during period 4 was calculated as follows:

$$0.50\ \text{mCi} \div 0.182\ \text{mCi/g waste} = 2.75\ \text{g waste on the filters.}$$

The mass of waste caught on the exhauster filters during period 5 was calculated as follows:

$$0.032\ \text{mCi} \div 0.130\ \text{mCi/g waste} = 0.25\ \text{g waste on the filters.}$$

The mass of waste caught on the exhauster filters during period 6 was calculated as follows:

$$(0.64\ \text{mCi} - 0.50\ \text{mCi}) \div 0.130\ \text{mCi/g waste} = 1.1\ \text{g waste on the filters.}$$

A.4 AEROSOL CALCULATIONS

The tank headspace particulate concentration was estimated by dividing the mass of waste caught on the exhauster filters by the volume of air sent to the exhauster. The volume of air to the exhauster was obtained by multiplying the exhauster flow rate by the exhauster run times from Appendix F, Table F-1, for each tank.

For the RMCS exhausters, the recorded exhauster flow rate is reported in standard cubic feet per minute. The RMCS exhauster flow rate is controlled to a nominal 200 standard ft^3/min. The exhauster flow rate was corrected to actual cubic feet per minute before calculating the tank headspace aerosol concentration. Appendix F, Table F-1, includes the actual cubic feet per minute flow rates.

The calculated flow rates during RMCS for the tanks sampled during period 4 were 207 actual ft^3/min (241-S-110), 206 actual ft^3/min (241-U-107), 208 and 209 actual ft^3/min (241-BY-105) and 203 actual ft^3/min (241-TX-113). The total volume of tank air through the exhauster during period 4 was calculated as follows:

$$[(207\ ft^3/min)(159.78\ h) + (206\ ft^3/min)(273.85\ h) + (208\ ft^3/min)(135.77\ h) + (209\ ft^3/min)(307.92\ h) + (203\ ft^3/min)(302.30\ h)]\ (60\ min/h) = 1.46\ E{+}07\ ft^3\ .$$

The average tank headspace mass concentration during period 4 was calculated as follows:

$(2.75\ g \div 1.46\ E{+}07\ ft^3) \times (35.315\ ft^3/m^3) = 6.64\ E{-}06$ grams of waste per cubic meter in the exhauster inlet.

The gas flow rates and average tank headspace mass concentrations during RMCS for periods 5 and 6 were calculated in a similar manner.

The average mass of waste in a tank headspace during RMCS was calculated by multiplying the tank headspace mass concentration for the exhauster operating period by the individual tank headspace volume from Appendix F, Table F-2, as shown below for Tank 241-S-110:

$(2.75\ g \div 1.46\ E{+}07\ ft^3) \times (8.91\ E{+}04\ ft^3) = 1.67\ E{-}02$ g waste in Tank 241-S-110 headspace.

The particulate quantities in the other tank headspaces were calculated in a similar manner. The weighted-average mass in a tank headspace shown in Table A-3 for period 4 was based upon the number of segments taken in each tank during period 4.

The mass sent to the exhauster per RMCS core or per RMCS segment was obtained by dividing the mass of waste caught on the exhauster filters during each period by the numbers of RMCS cores or RMCS segments obtained during the period. The average mass of waste sent to the exhauster during period 4 is calculated as follows:

$2.75\ g\ waste \div 7\ rotary\ cores = 3.9\ E{-}01$ g waste per rotary core

and

$2.75\ g\ waste \div 50\ rotary\ segments = 5.5\ E{-}02$ g waste per rotary segment.

The mass of waste to the exhauster per RMCS core and RMCS segment for periods 5 and 6 were calculated in a similar manner.

All data were input to a spreadsheet to perform the calculations. Results are provided in Table A-3.

A.5 SUMMARY OF CALCULATIONS

NDA was performed on the RMCS exhauster filter housings used during three separate exhauster operating periods during which 10 RMCS cores and 65 RMCS segments were obtained from five tanks. Weighted averages of the average tank headspace mass concentration, average mass of suspended solids in a tank headspace, and average mass sent to the exhauster per RMCS core or segment for the three periods combined were calculated based upon the number of RMCS segments taken during each period. Based upon RMCS exhauster housing NDA data, the results are as follows.:

- The average tank headspace mass concentration during RMCS was 7.7 E-06 g waste/m^3.
- The average mass of suspended solids in a tank headspace during RMCS was 1.8 E-02 g waste.
- The average mass sent to the exhauster during RMCS was 5.2 E-01 g waste per core.
- The average mass sent to the exhauster during RMCS was 6.3 E-02 g waste per segment.

A.6 REFERENCES

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Schofield, J. S., 2001, *Compilation of Miscellaneous References Used in RPP-4826, Revision 1, Experience with Aerosol Generation During Rotary Mode Core Sampling in Hanford Single Shell Waste Tanks* (Letter 7KN00-01-003 to File, March 1), CH2M HILL Hanford Group, Inc., Richland, Washington.

Table A-1. Exhauster Operating Periods and Data Used for Aerosol Estimates Based upon Nondestructive Assay.

Exhauster operating period	Dates of exhauster operation	Exhauster used	Tanks sampled	Number of RMCS cores/segments obtained	Specific activity used for waste on filter (μCi ^{137}Cs/g waste)
4	5/19/98 to 2/12/99	C (4)	S-110, U-107, BY-105, TX-113	7 cores / 50 segments	182
5	4/12/99 to 4/29/99	B (3)	TX-113	1 core / 6 segments	130
6	5/6/99 to 6/2/99	C (4)	TX-118	2 cores / 9 segments	130

RMCS = rotary mode core sampling.

Table A-2. Nondestructive Assay Data.

Location	Exhauster operating period 4 (mCi of ^{137}Cs)	Exhauster operating period 5 (mCi of ^{137}Cs)	Exhauster operating period 6 (mCi of ^{137}Cs)
Prefilter	1.34 E-01	1.38 E-02	1.32 E-01
First HEPA filter	2.81 E-01	1.31 E-02	4.18 E-01
Second HEPA filter	1.5 E-02	5.83 E-04	3.84 E-03
Total reported	4.3 E-01	2.75 E-02	5.53 E-01
Quantity assumed present (Total reported times 1.16 adjustment factor*)	5.0 E-01	3.2 E-02	6.4 E-01
Net increase in ^{137}Cs content of housing	5.0 E-01	3.2 E-02	1.4 E-01

*Adjustment factor to correct for point source standard versus material distributed on filter and to correct for portion of filter housing not seen by collimated detector (see text for value basis).

HEPA = high-efficiency particulate air (filter).

Table A-3. Concentrations and Aerosol Mass Quantities During Rotary Mode Core Sampling Based upon Nondestructive Assay Data.

Exhauster operating period	Tank and risers sampled	Average aerosol concentration in air to exhauster (g waste/m^3)	Average mass of particulates in tank headspace during RMCS (g waste)		g waste/RMCS core	g waste/RMCS segment
4	S-110 – R6, R14	6.6 E-06	1.7 E-02	weighted average = 1.4 E-02	3.9 E-01	5.5 E-02
	U-107 – R7, R2		1.1 E-02			
	BY-105 – R7, R11B 1998		1.5 E-02			
	TX-113 – R3		1.3 E-02			
5	TX-113 – R5	6.4 E-06	1.3 E-02		2.5 E-01	4.1 E-02
6	TX-118 – R12B, 9B	1.5 E-05	4.3 E-02		1.1 E+00	1.2 E-01
Weighted average*		**7.7 E-06**	**1.8 E-02**		**5.2 E-01**	**6.3 E-02**

*The weighted-average tank headspace concentration and weighted-average mass of waste in a tank headspace are weighted averages of the three individual periods based upon the number of segments taken in that period. The weighted average for grams per core or grams per segment is the sum of the total grams of waste added to the filters for all three periods divided by the sum of the cores or segments taken during the three periods.

RMCS = rotary mode core sampling.

APPENDIX B

ESTIMATION OF AEROSOLS GENERATED DURING ROTARY MODE CORE SAMPLING BASED UPON ROTARY MODE CORE SAMPLING EXHAUSTER HIGH-EFFICIENCY PARTICULATE AIR FILTER DOSE RATES

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APPENDIX B

ESTIMATION OF AEROSOLS GENERATED DURING ROTARY MODE CORE SAMPLING BASED UPON ROTARY MODE CORE SAMPLING EXHAUSTER HIGH-EFFICIENCY PARTICULATE AIR FILTER DOSE RATES

B.1 SUMMARY OF METHOD

This method of estimating rotary mode core sampling (RMCS) aerosol quantities divides the dose rate increase (mR/h) at the side of the RMCS high-efficiency particulate air (HEPA) filter housing by a calculated dose conversion factor (mR/h/mCi of ^{137}Cs) to obtain an approximation of the radionuclide activity in the housing. This radionuclide activity is divided by the waste-specific activity (mCi/g) to determine the mass of waste on the HEPA filter. Dividing the HEPA filter waste mass by the volume of air passing through the filter provides an estimate of the average tank headspace particulate concentration during RMCS. Multiplying the average tank headspace particulate concentration by the tank headspace volume gives an estimate of the average mass of suspended particulates in the tank headspace during RMCS. Dividing the HEPA filter waste mass by the number of RMCS cores or RMCS segments provides the mass per RMCS core or per RMCS segment sent to the exhauster.

B.2 DESCRIPTION

Particulates in the exhaust stream are removed by the HEPA filters upstream of the exhaust fan. The captured particulates contain radionuclides, with ^{137}Cs being the predominant gamma emitter. As the particulate quantity on the HEPA filter increases, the dose rate at the side of the filter housing will increase proportionately. By monitoring the HEPA dose rate at the side of the filter housing, the quantity of ^{137}Cs on the HEPA filter can be estimated. This ^{137}Cs value is then used to back-calculate to a waste mass quantity on the filter using the ^{137}Cs concentration in the tank waste. This filter waste mass quantity is used to calculate the concentration of particulates in the tank exhaust stream, the total suspended solids in the tank headspace, and the mass of waste sent to the exhauster for each RMCS core or segment taken. Although radionuclides will be trapped on both the prefilter and the primary HEPA filter, with a very small amount on the secondary HEPA filter, calculations in this section were based upon the simplifying assumption that all the activity was on the primary HEPA filter. This is adequate for the purposes of this document. To date, the only detectable radiation level on the one housing that indicates a dose rate above background is adjacent to the primary HEPA filter. NDA data provided in Appendix A, Table A-2 indicates 50 to 75 percent of the ^{137}Cs in the exhauster housing is on the primary HEPA filter, with the majority of the rest coming from the prefilter. The prefilter is located close to the primary HEPA filter and it is probable that some of the radiation showing as coming from the prefilter actually came from the primary HEPA filter despite the collimated detector used for the NDA.

During RMCS exhauster operation, the dose rate, in milliroentgen per hour, at the side of the HEPA filter housing is periodically measured with a dose rate detector, in accordance with procedures, to indicate when radioactive particulates are building up on the filter. The limit of detection of the standard dose rate detector used is 0.5 mR/h.

Exhauster operations were divided into six operating periods for evaluation in this document. These periods are discussed in Appendix F and shown in Table F-1. Housing dose rate data were obtained for exhauster operating periods 1, 2, 4, 5, and 6. Relevant information for these periods also is listed in Table B-1. Dose rate data are available and were used for all tanks on which an RMCS exhauster was present and RMCS samples were taken. This includes Tanks 241-BY-106, 241-BY-105 (1995), 241-BY-110, 241-S-110, 241-U-107, 241-BY-105 (1998), 241-TX-113, and 241-TX-118. The dose rate at the end of a period was used as the basis for calculating radionuclides on the filters.

The only operating period for which dose rate data were not used for estimating filter radionuclide content was period 3. Period 3 covered RMCS in the SX Tank Farm using the SX exhauster. The dose rate at the side of the SX exhauster HEPA filter housing was measured during RMCS of SX Tank Farm tanks (for sampling of Tanks 241-SX-101, 241-SX-102, 241-SX-103, and 241-SX-105), but the data are not useful for estimation of aerosol quantities because the SX exhauster draws on 13 tanks in parallel or in series with the tank being core sampled. Many of the tanks have a much higher off-gas flow rate than the sampled tank. In addition, background radiation in the area of the SX exhauster filter housing makes any increase in the housing dose rate during RMCS difficult to detect.

B.3 DOSE RATE DATA

The dose rate data for each period are listed in Table B-2. No dose rates above minimum detectable limits were evident at the sides of any RMCS exhauster during periods 1, 2 and 5. Dose rate measurements were less than detectable for period 4 during sampling of Tanks 241-S-110 and 241-U-107. When sampling on Tank 241-BY-105, a few readings of 0.7 mR/h occurred but most were still less than 0.5 mR/h. This variation in readings is to be expected as the specific instrument, person using the instrument, and location at which the dose rate is checked can vary with time. The final recorded dose rate when sampling was complete on Tank 241-BY-105 was less than 0.5 mR/h. At the end of period 4 following completion of the first core in Tank 241-TX-113, exhauster C was listed as having a 0.7 mR/h dose rate. Period 6 used exhauster C again, with the same housing and filters as at the end of period 4. The final dose rate for period 6 was 0.8 mR/h.

Periods 1, 2, 4, and 5 all began with a new housing and new filters. For periods 1, 2, and 5, the final dose rate was conservatively assumed to be 0.5 mR/h, giving an increase of 0.5 mR/h for each of these periods. For period 4 the dose rate increase was 0.7 mR/h. Since period 6 used the same housing and filters as period 4, the increase for period 6 was 0.8 mR/h - 0.7 mR/h = 0.1 mR/h.

The dose rate increase was converted into a ^{137}Cs content on the primary filter for each period. Schofield (2001) provides various dose rates for an RMCS exhauster housing assuming even

dispersal of 1 mCi of ^{137}Cs on the first HEPA filter. According to Schofield (2000), the estimated dose rate conversion factor is 1.6 mR/h/mCi of ^{137}Cs at the detector location for the dose rate meter. The assumption that radionuclides are evenly distributed on the HEPA filter is a reasonable assumption based upon the exhauster design and the method used to measure the radiation dose rate.

Gamma-emitting ^{137}Cs is the predominant radionuclide contributor to filter dose rates. Beta-emitting ^{90}Sr may contribute to the dose rate because of bremsstrahlung radiation, and other nuclides may provide some small additional dose, but the major penetrating dose rate contributor in aged single-shell tank waste is ^{137}Cs. Ignoring the presence of all radionuclides (including ^{90}Sr) except ^{137}Cs in calculating a HEPA filter waste mass will provide a conservative result. This is because assuming all radiation present is due to ^{137}Cs will result in overestimating the ^{137}Cs content of the filter housing, which in turn will result in overestimating the waste mass on the HEPA filter.

Dividing the HEPA filter dose rate increase for each exhauster installation by the dose conversion factor of 1.6 mR/h/mCi results in an increase of 0.31 mCi of ^{137}Cs on the RMCS exhauster filters for periods 1, 2, and 5, an increase of 0.44 mCi for period 4, and an increase of 0.063 mCi for period 6.

B.4 CALCULATION OF MASS QUANTITY ON FILTERS

Dividing the ^{137}Cs content of the filters by the specific activity of ^{137}Cs in the waste gives the estimated mass of waste sent to the exhauster. The specific activity value used for the waste in each tank sampled is given in Appendix E, Table E-1. Since RMCS was performed on more than one tank during periods 1 and 4, a weighted-average specific activity was used for these periods. The weighted-average specific activity was calculated based upon the number of RMCS segments taken from each tank sampled during that period. The number of RMCS segments obtained during each period is listed in Table B-1. These data were obtained from the individual tank data in Appendix F, Table F-1. Calculations to estimate the specific activity of waste mixtures were performed in the same manner as shown in Appendix A. For periods 2, 5, and 6, RMCS samples were taken in only one tank. The waste specific activity used for these periods was the specific activity of the tank sampled. The specific activities used for each exhauster operating period are given in Table B-1.

The mass of waste on the HEPA filter for period 1 was calculated as follows:

(0.31 mCi) (1,000 μCi/mCi) = 310 μCi of ^{137}Cs on the HEPA filter

(310 μCi of ^{137}Cs on the HEPA filter) ÷ (177 μCi of ^{137}Cs/g waste) = 1.77 g waste on HEPA filter.

For all exhauster installations except in Tank 241-BY-106 in 1994 and 1995, the RMCS exhausters were hooked directly to the waste tank. When sampling Tank 241-BY-106, a prefilter was installed in the tank riser between the tank and the exhauster. The prefilter was not used for Tank 241-BY-110 during period 1 or for any other tank in any other period. Thus, for periods 2,

4, 5, and 6, the mass of waste on the HEPA filter was assumed equal to the mass of waste leaving the tank risers. For period 1, the mass of waste on the HEPA filter had to be adjusted for the Tank 241-BY-106 prefilter decontamination factor to estimate the combined mass of waste leaving the Tank 241-BY-106 and Tank 241-BY-110 tank risers.

A decontamination factor of 5 was conservatively used to account for radionuclide removal by the Tank 241-BY-106 prefilter (see Appendix D for the basis of the prefilter decontamination factor), although there was no smearable contamination on the prefilter when removed from the tank (see Appendix F, Sections F.1.1 and F.1.2). There were 11 RMCS segments taken from Tank 241-BY-106 and 13 from Tank 241-BY-110. The total mass of waste assumed to exit the tank risers was therefore calculated as follows:

$$(1.77 \text{ g waste})\ (11 + 13) \div [(11/5) + 13] = 2.8 \text{ g waste from tank risers.}$$

The decontamination factor of 5 to account for the prefilter is only applicable to the RMCS of Tank 241-BY-106 in 1994 and 1995; for all other exhauster periods the mass of waste on the HEPA filter was equal to the mass of waste sent to the exhauster riser.

The mass of waste sent to the exhauster for period 2 was calculated as follows:

$$(0.31 \text{ mCi})\ (1{,}000\ \mu\text{Ci/mCi}) = 310\ \mu\text{Ci of } ^{137}\text{Cs on the HEPA filter}$$

$$(310\ \mu\text{Ci of } ^{137}\text{Cs on HEPA filter}) \div (225\ \mu\text{Ci of } ^{137}\text{Cs/g waste}) = 1.39 \text{ g waste from tank.}$$

Using the same formula, the mass of waste sent to the exhauster from periods 4 and 5 was 2.41 g and 2.40 g, respectively, and the increase in waste on the filters for period 6 was 0.48 g.

B.5 AEROSOL CALCULATIONS

The tank headspace particulate concentration was obtained by dividing the mass of waste leaving the riser by the volume of gas sent to the exhauster. This volume of gas sent to the exhauster was obtained by multiplying the exhauster flow rate by the exhauster run time from Appendix F, Table F-1. The calculations for aerosols generated based upon HEPA filter dose rates use actual cubic feet per minute while the exhauster flow is recorded in standard cubic feet per minute, so the actual cubic feet per minute flow rates in Appendix F, Table F-1, were used.

The average mass of aerosols in the tank headspace was obtained by multiplying the average tank headspace particulate concentration by the tank headspace volume from Appendix F, Table F-2.

The mass sent to the exhauster per RMCS core or per RMCS segment was obtained by dividing the mass of waste leaving the risers by the number of RMCS cores or RMCS segments obtained during the exhauster operating period.

The following is an example of how the average tank headspace mass concentration, average mass of aerosols in the tank headspace, and mass sent to the exhauster per RMCS core or RMCS

segment were calculated for period 1. The data used are from Appendix E, Table E-1, and from Appendix F, Tables F-1 and F-2.

(200 standard ft^3/min) (29.92 in. Hg @ STP ÷ 29.16 in. Hg) [(84°F)(1°R/°F) + 459°R] ÷ 528°R = 211 actual ft^3/min to the exhauster from Tank 241-BY-106 in the period November 1994 to December 1994.

Using the same formula results in 210 actual ft^3/min for Tank 241-BY-106 in January 1995 and 209 actual ft^3/min for Tank 241-BY-110.

(2.8 g waste to exhauster for period 1) ÷ {[(211 actual ft^3/min)(48.78 h) + (210 actual ft^3/min)(18.67 h) + (209 actual ft^3/min)(112.5 h)] (60 min/h)} = 1.2 E-06 g waste/ft^3 to risers

(1.2 E-06 g/ft^3) (35.315 ft^3/m^3) = 4.3 E-05 g waste/m^3 to exhauster riser

(1.2 E-06 g/ft^3) (5.3 E+04 ft^3 in Tank 241-BY-106 headspace) = 6.6 E-01 g waste in Tank 241-BY-106 headspace during RMCS

(1.2 E-06 g/ft^3) (9.2 E+04 ft^3 in Tank 241-BY-110 headspace) = 1.1 E-01 g waste in Tank 241-BY-110 headspace during RMCS

(2.8 g waste) ÷ (5 RMCS cores) = 5.6 E-01 g waste per core to exhauster riser

(2.8 g waste) ÷ (24 RMCS segments) = 1.2 E-01 g waste per segment to exhauster riser.

All data were input to a spreadsheet and the average tank headspace mass concentration, average mass of aerosols in the tank headspace, mass to exhauster per RMCS core, and mass to exhauster per RMCS segment were calculated for each of the RMCS exhauster operating periods in the same manner as shown above. Results are given in Table B-3.

B.6 SUMMARY OF CALCULATIONS

RMCS exhauster operations were segregated into five operating periods (the sixth RMCS operating period used the SX exhauster). The exhauster B data for Tank 241-BY-108 and Tank 241-TX-113, riser 3, were not used in these calculations as no RMCS was performed when the exhauster was operating. Exhausters were operated in seven tanks during which 16 RMCS cores and 92 RMCS segments were obtained. Based on RMCS filter housing dose rate data, the results indicate the following.

- The average tank headspace mass concentration during RMCS was 2.2 E-05 g waste/m^3.
- The average mass of suspended solids in the tank headspace during RMCS was 4.7 E-02 g waste.
- The average mass sent to the exhauster during RMCS was 5.9 E-01 g waste per RMCS core.

- The average mass sent to the exhauster during RMCS was 1.0 E-01 g waste per RMCS segment.

These values are conservative as the assumed dose rate at the end of RMCS for periods 1, 2, and 5 was assumed to be 0.5 mR/h. In addition, using a decontamination factor of 5 for the Tank 241-BY-106 prefilter skews the results high. The in-tank prefilters used in both sampling events in Tank 241-BY-106 showed no detectable contamination.

Operating periods 4 and 6 were the only periods showing detectable exhauster housing dose rates. The increase on the filters of 0.44 mCi of ^{137}Cs and 0.063 mCi of ^{137}Cs for these two periods, based upon dose rate data, corresponds reasonably well to the increase on the filters of 0.50 mCi of ^{137}Cs and 0.14 mCi of ^{137}Cs for these two periods shown by the NDA data (see Appendix A). The period 5 dose rate of 0.31 mCi of ^{137}Cs is an order of magnitude above the 0.032 mCi of ^{137}Cs for the same period as determined by the NDA. This is the result of assuming the housing dose rate is equal to the minimum detectable 0.5 mR/h.

B.7 REFERENCES

Schofield, J. S., 2000, *Use of Microshield Calculations for RMCS Exhauster Housing for Estimating Radionuclide Quantities on the Filters Using NDA and Dose Rate Measurements* (Letter 74910-00-002 to File, January 6), CH2M HILL Hanford Group, Inc., Richland, Washington.

Schofield, J. S., 2001, *Compilation of Miscellaneous References Used in RPP-4826, Revision 1, Experience with Aerosol Generation During Rotary Mode Core Sampling in Hanford Single Shell Waste Tanks* (Letter 7KN00-01-003 to File, March 1), CH2M HILL Hanford Group, Inc., Richland, Washington.

Table B-1. Rotary Mode Core Sampling Exhauster Operating Periods Used for Filter Housing Dose Rate Aerosol Estimates.

Exhauster operating period	Dates of exhauster operation	Exhauster used	Tanks sampled	Number of cores and segments	Specific activity used for waste on filter (μCi ^{137}Cs/g waste)
1	11/17/94 to 10/20/95	A (2)	BY-106, BY-110	5 cores / 24 segments	177
2	7/24/95 to 9/15/95	B (3)	BY-108*, BY-105	1 core / 3 segments	225*
4	5/19/98 to 2/12/99	C (4)	S-110, U-107, BY-105, TX-113	7 cores / 50 segments	182
5	9/22/98 to 4/29/99	B (3)	TX-113	1 core / 6 segments	130
6	5/6/99 to 6/2/99	C (4)	TX-118	2 cores / 9 segments	130

*No rotary mode core sampling was performed in Tank 241-BY-108 so the specific activity for operating period 2 is equal to the Tank 241-BY-105 specific activity.

Table B-2. Dose Rate Data and Filter Cesium-137 Content.

	Exhauster operating period 1	Exhauster operating period 2	Exhauster operating period 4	Exhauster operating period 5	Exhauster operating period 6
Dose rate at end of period (mR/h)	<0.5	<0.5	0.7	<0.5	0.8
Conversion factor (mR/h/mCi of ^{137}Cs)	1.6	1.6	1.6	1.6	1.6
^{137}Cs on filters (mCi)	0.31	0.31	0.44	0.31	0.50
Net increase in ^{137}Cs for period (mCi)	0.31	0.31	0.44	0.31	0.06

Table B-3. Concentrations and Aerosol Mass Quantities During Rotary Mode Core Sampling Based Upon High-Efficiency Particulate Air Filter Dose Rate at Side of Rotary Mode Core Sampling Exhauster.

Exhauster operating period	Tank and risers sampled	Average tank headspace concentration (g waste/m^3)	Average mass of suspended solids in tank headspace (g waste)		Mass per RMCS core to exhauster (g waste)	Mass per RMCS segment to exhauster (g waste)
1	BY-106 – Riser 10B	4.3 E-05	6.6 E-02	9.1 E-02	5.6 E-01	1.2 E-01
	BY-110 – R12B, R7, R4		1.1 E-01			
2	BY-105 – R12A	8.8 E-05	2.0 E-01		1.4 E+00	4.6 E-01
4	S-110 – R6, R14	5.8 E-06	1.5 E-02	weighted average = 1.3 E-02	3.4 E-01	4.8 E-02
	U-107 – R7, R2		9.8 E-03			
	BY-105 – R7, R11B		1.4 E-02			
	TX-113 – R12		1.2 E-03			
5	TX-113 – R6	6.3 E-05	1.3 E-01		2.4 E+00	4.0 E-01
6	TX-118 – R9	6.4 E-06	1.9 E-02		2.4 E-01	5.3 E-02
Weighted Average*		**2.2 E-05**	**4.7 E-02**		**5.9 E-01**	**1.0 E-01**

*The weighted-average tank headspace concentration and weighted-average mass of waste in a tank headspace are weighted average of the three individual periods based upon the number of segments taken in that period. The weighted average for grams per core or grams per segment is the sum of the total grams of waste added to the filters for all three periods divided by the sum of the cores or segments taken during the three periods.

RMCS = rotary mode core sampling.

APPENDIX C

ESTIMATION OF AEROSOLS GENERATED DURING ROTARY MODE CORE SAMPLING BASED UPON COMBUSTIBLE GAS METER IN-LINE FILTER PAPER ANALYSES

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APPENDIX C

ESTIMATION OF AEROSOLS GENERATED DURING ROTARY MODE CORE SAMPLING BASED UPON COMBUSTIBLE GAS METER IN-LINE FILTER PAPER ANALYSES

C.1 SUMMARY OF METHOD

This method of estimating rotary mode core sampling (RMCS) aerosol quantities uses radionuclide assay data from in-line filter papers located upstream of continuous gas meters (CGMs) that sample the tank air for flammable gases during RMCS. The radionuclide activity on the filter paper is divided by the waste radionuclide specific activity and the air flow through the CGM to obtain an estimate of the average mass concentration in the tank headspace during the time the CGM is operating. Multiplying the estimated average tank headspace mass concentration by the tank headspace volume gives an estimate of the average mass of particulates in the tank headspace during RMCS. To obtain the mass per RMCS core or per RMCS segment sent to the exhauster, the tank headspace average mass concentration is multiplied by the volume of gas sent to the exhauster during the time the CGM was operating, then multiplied by a correction factor to account for particulates in the headspace removed by the exhauster when the CGM is not operating, and divided by the number of RMCS cores or RMCS segments.

C.2 DESCRIPTION

During most tank waste-intrusive activities performed since 1996, an intrinsically safe CGM located above ground has been used to continually monitor the tank air for flammable gases during in-tank activities. During RMCS the CGM sampling line draws air directly from the tank headspace. The riser used for the CGM sampling line is located between the sampling riser and the exhaust riser if practical. A pump in the CGM draws tank air up through the line at 0.5 L/min for measurement of the lower flammability limit by the CGM. A filter paper is installed in the sampling line upstream of the CGM to protect the unit from internal contamination.

Following CGM use, the CGM filter papers normally are discarded after they are monitored in the field for contamination. To help estimate the tank headspace particulate levels during RMCS, these filter papers were retained and analyzed in the 222-S Laboratory following removal from all tanks in which RMCS was performed from the fall of 1997 through April 1999. Data were collected for the four tanks in the SX Tank Farm in which RMCS was performed and for the next four tanks on which the RMCS exhauster was deployed. These tanks are listed in Table C-1.

C.3 REPORTED COMBUSTIBLE GAS METER DATA

The CGM operational data used to estimate aerosol levels during RMCS include CGM operating times, CGM flow rates, and filter paper analytical data. A summary report containing the laboratory data and all the field operating data sheets for CGM usage was prepared following completion of sampling on each tank except Tank 241-TX-113 (Langlois 1998a through 1998g). For Tank 241-TX-113, a separate report was prepared following each core (Langlois 1999a and 1999b). The CGM data from these reports are provided in Table C-2.

CGM filter papers from 14 CGM installations that operated during RMCS were collected and analyzed. Quantities of ^{137}Cs, total alpha, and total beta were measured on the filter papers for each of these installations, resulting in 42 data points. Eight of the measurement results were very low and had errors of more than ±100%. These values were not used, resulting in a net of 34 data points for calculating average headspace mass concentrations based upon CGM data.

C.4 CALCULATED TANK HEADSPACE RADIONUCLIDE CONCENTRATIONS

To calculate the average tank headspace radionuclide concentrations during RMCS, the filter paper radionuclide quantities were first divided by a sampling efficiency factor. This adjusted radionuclide value was divided by the volume of tank air passing through the paper to give the average tank headspace radionuclide concentration.

The efficiency used for most stack samplers onsite is 73% (see Appendix D). Estimates attached to the summary reports (Langlois 1998a through 1998g, 1999a, 1999b) indicate the CGM filter paper sampling method used should have a sampling efficiency exceeding 73%. For conservatism, a sampling efficiency of 50% was assumed in this document for the CGM filter paper method.

The estimated ^{137}Cs, total alpha, and total beta concentrations in the tank vapor space were calculated by dividing the radionuclide quantity on the filter paper (see Table C-2) by the assumed CGM sampling efficiency of 0.5 and the volume of gas going to the CGM. The volume of gas going to the CGM was calculated by multiplying the time of CGM operation (see Table C-2) by the CGM flow rate of 500 mL/min. For example, the Tank 241-SX-101 headspace concentration of ^{137}Cs based upon analysis of the CGM filter papers used during RMCS of riser 19 is calculated as follows:

$$(2.6\text{ E-04 }\mu\text{Ci} \div 0.5) \div [(1{,}755\text{ min})(500\text{ mL/min})] = 5.9\text{ E-10}\mu\text{Ci/ml}\ .$$

All radionuclide concentrations were calculated in a similar fashion. Results are given in Table C-3. Table C-3 lists the radionuclide concentrations for all 42 data points. The eight radionuclide concentrations not used for estimating mass concentrations are noted. Table C-3 also contains the calculated number of tank headspace changeouts by the tank exhauster during CGM operation. Tank headspace changeouts were calculated by multiplying the exhauster flow rates (in actual cubic feet per minute) from Appendix F, Table F-1, by the CGM run times from Table C-2 and dividing by the tank headspace volumes from Appendix F, Table F-2.
The number of tank headspace changeouts during CGM operation was used when estimating the

waste mass sent to the exhauster. See Section C.5, "Aerosol Calculations," below for explanation.

C.5 AEROSOL CALCULATIONS

Average tank headspace mass concentrations based upon CGM filter paper data were calculated by dividing the headspace radionuclide concentrations from Table C-3 by the waste-specific activities for each tank sampled. The waste-specific activities used came from Appendix E, Table E-1, and are listed again in Table C-1. The average of the mass concentrations based upon radionuclide data for each tank was used as the average headspace mass concentration for that tank. For example, the Tank 241-SX-101 headspace mass concentration analysis from the CGM filter papers used during RMCS of riser 19 is calculated as follows:

(5.9 E-10 μCi ^{137}Cs/mL ÷ 112 μCi ^{137}Cs/g waste) (28,317 mL/ft^3) = 1.5 E-07 g waste/ft^3 based upon ^{137}Cs

(1.7 E-11 μCi TA/mL ÷ 5.04 E-01 μCi TA/g waste) (28,317 mL/ft^3) = 9.4 E-07 g waste/ft^3 based upon total alpha

(4.3 E-09 μCi total beta/mL ÷ 357 μCi total beta/g waste) (28,317 mL/ft^3] = 3.4 E-07 g waste/ft^3 based upon total beta

[(1.5 E-07 g waste/ft^3 + 9.4 E-07 g waste/ft^3 + 3.4 E-07 g waste/ft^3) ÷ 3] = 4.8 E-07 g waste/ft^3

(4.8 E-07 g waste/ft^3) (35.31467 ft^3/m^3) = 1.7 E-05 g waste/m^3 .

All tank headspace mass concentrations were calculated in the same manner. The results are presented in Table C-4. The weighted-average tank headspace mass concentration during RMCS was based upon the number of RMCS segments taken for each data point.

The average aerosol mass in the headspace during RMCS was calculated by multiplying the average tank headspace mass concentration by the tank headspace volume from Appendix F, Table F-2. Using the same data point as above:

(4.8 E-07 g waste/ ft^3) (1.15 E+05 ft^3) = 5.5 E-02 g waste in the Tank 241-SX-101 headspace during RMCS.

All average mass quantities present in the tank headspace during RMCS were calculated in the same manner using a spreadsheet. The results are provided in Table C-4. The weighted-average mass of waste in a tank headspace shown in Table C-4 was calculated based upon the number of segments obtained for each data point.

Estimation of the mass of waste sent to the exhauster per RMCS core or segment requires calculation of the total mass of waste sent to the exhauster. Multiplying the average headspace concentration during RMCS by the exhauster flow rate (in actual cubic feet per minute) and the

time of CGM operation will give the mass of waste sent to the exhauster during the CGM time frame only. A large majority of the mass of waste aerosols will have exited the tank or resettled by the time the CGM is shut off, but some residual suspended particles may remain. These would eventually pass to the exhauster or settle out. An adjustment factor was used as described in the following paragraphs to account for particles that may exit to the exhauster following shutdown of the CGM.

Particulates are generated by RMCS when purge gas is blowing out the drill string and the bit is rotating under the waste surface. This averages about 6 minutes per segment. Multiplying the number of RMCS segments per core by 6 minutes per segment and dividing by the number of minutes of CGM operation shows the creation of particulates will only occur during a nominal 3% to 4% of the time the CGM is operating. During RMCS, the normal practice is to install the CGM, turn it on when personnel enter a tank farm, and keep the unit in constant operation for the remainder of the shift. When the portable RMCS exhauster is used, the exhauster normally is started at least 1 hour before RMCS is initiated, and it is kept in operation until it is time to halt operations for the week. The SX exhauster is kept in constant operation. Comparing exhauster operating times from Appendix F, Table F-1, with CGM operating times from Table C-1, it can be seen the CGMs are in operation about 3% to 15% of the time the RMCS exhauster is operating on a tank. This time comparison was not made for the SX exhauster because the SX exhauster is in constant operation.

The CGM operates over a much longer time period than the time period during which particulates could be generated. Therefore the majority of particulates generated by RMCS should have settled or been exhausted during the CGM operating period. Table C-3 shows a range of 0.84 to 6.3 tank headspace changeouts made by the exhauster during CGM operating periods. The average was 2.4 headspace changeouts. With the CGMs operating 25 to 33 times longer than the aerosol generation periods, and an average of more than two tank headspace changeouts during CGM operation, most of the aerosols generated during RMCS will have settled out or been removed by the exhauster by the time the CGM is shut off. To account for particulates remaining in the tank headspace that could subsequently be removed by an exhauster after the CGM was turned off, it was conservatively assumed that 20% of the total mass of particles generated during RMCS were not removed from the tank headspace during the CGM operating period. Therefore, the product of the tank headspace concentration and the volume of air sent to the exhauster during the time of CGM operation was multiplied by a factor of 1.25 (100/80) to estimate the total mass of waste sent to the exhauster as a result of RMCS. This is shown below for the same Tank 241-SX-101 riser 19 data point used in the above calculations:

$$(4.8\ \text{E-07 g/ft}^3)\ (100\ \text{ft}^3/\text{min})\ (1{,}755\ \text{min})\ (1.25) = 1.1\ \text{E-01 g waste to exhauster.}$$

This value was divided by the number of RMCS cores and RMCS segments from Table C-1 to provide the grams per core and grams per segment in Table C-4:

(1.1 E-01 g waste to exhauster) ÷ (1 core) = 1.1 E-01 g waste per RMCS core to exhauster

and

(1.1 E-01 g waste to exhauster] ÷ (5 segments) = 2.1 E-02 g waste per RMCS segment to exhauster.

All mass-per-core and mass-per-segment values were calculated in the same manner using a spreadsheet. The results are provided in Table C-4. The weighted-average mass per core and mass per segment in Table C-4 were calculated based upon the number of cores or segments obtained for each data point.

C.6 SUMMARY OF CALCULATIONS

There were 34 valid CGM filter paper data points from 14 RMCS CGM sampling periods in eight tanks during which 15 RMCS cores and 79 RMCS segments were obtained. Based upon CGM filter paper data, the results indicate the following.

- The average tank headspace mass concentration during RMCS was 4.0 E-05 g waste/m^3.
- The average mass of suspended solids in the tank headspace during RMCS was 9.7 E-02 g waste.
- The average mass sent to the exhauster during RMCS was 1.8 E-01 g waste per RMCS core.
- The average mass sent to the exhauster during RMCS was 3.4 E-02 g waste per RMCS segment.

Ignoring all CGM filter paper analytical data points with variances greater than 100% will result in conservative results. These data points indicate negligible radioactivity was present. If a value of zero were assigned to each data point with an analytical error of more than 100% rather than ignoring it, the weighted-average particulate quantities in Table C-4 would be reduced by about 12%.

The average tank headspace mass concentrations based upon CGM data will be higher than the average tank headspace mass concentrations based upon filter housing NDA or dose rate. The RMCS exhauster received tank air during the shifts when sampling was performed and during some of the off-shifts when no sampling was done. The CGMs were only operated during the shifts when sampling was performed. The aerosol concentration in the air drawn into the CGM and the RMCS exhauster should be roughly the same during operating shifts. The aerosol concentration in the air to the exhauster will be somewhat less during the off-shifts when no sampling is being performed and the CGM is shut off. Therefore, the tank headspace concentration will be higher when based upon CGM data. This does not impact the mass of waste sent to the exhauster per core or per segment.

C.7 REFERENCES

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Table C-1. Operating Data for Tanks on Which Combustible Gas Meter Filter Paper Data Were Used for Rotary Mode Core Sampling Aerosol Calculations.

		SX-101*	SX-101*	SX-103	SX-103	SX-105*	SX-105	SX-102	S-110	S-110	U-107	BY-105	BY-105	TX-113	TX-113
Riser sampled		R19	R4	R7	R11	R6	R14	R8, R4	R6	R14	R7, R2	R7	R11B	R3	R5
Exhauster used		SX	SX	SX	SX	SX	SX	SX	C	C	C	C	C	C	B
Number of RMCS cores/segments obtained		1/5	1/4	1/2	1/4	1/1	1/5	1/2	1/2	1/8	2/10	1/9	1/9	1/12	1/6
Specific activity used for waste on filter paper (μCi/g)	^{137}Cs	112		238		251		224	227		121	225		130	
	Total alpha	0.504		0.175		0.229		0.215	0.338		0.129	0.139		0.0748	
	Total beta	357		675		645		684	791		308	759		242	

*Two filter papers used for these cores.

RMCS = rotary mode core sampling.

Table C-2. Combustible Gas Meter Operational and Filter Paper Analysis Data.

	SX-101*	**SX-101***	**SX-103**	**SX-103**	**SX-105***	**SX-105**	**SX-102**	**S-110**	**S-110**	**U-107**	**BY-105**	**BY-105**	**TX-113**	**TX-113**
Riser sampled	R19	R4	R7	R11	R6	R14	R8, R 4	R6	R14	R7, R2	R7	R11B	R3	R5
Number of CGM filter papers used	2	2	1	1	2	1	1	1	1	1	1	1	1	1
CGM operating time (min)	1,755 (952+803)	2,185 (415+1,770)	790	1,280	2,760 (1,900+860)	1,100	873	590	615	1,300	1,200	593	2,166	1,495
CGM flow rate (Lpm)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
^{137}Cs on filter paper (μCi)	2.60 E-04 ±10.0% (3.09 E-05 +2.29 E-04)	1.67 E-04 ±19.8% (1.89 E-05 +1.48 E-04)	2.50 E-03 ±1.78%	5.65 E-03 ±1.41%	1.00 E-04 ±12.6% (0 +1.00 E 04)	7.69 E-03 ±1.19%	4.85 E-04 ±6.56%	4.11 E-05 ±25.6%	1.12 E-03 ±2.72%	2.03 E-03 ±2.01%	2.06 E-03 ±1.97%	1.16 E-02 ±0.76%	6.57 E-05 ±16.5%	7.56 E-05 ±28.1%
Total alpha on filter paper (μCi)	7.39 E-06 ±48.6% (4.52 E-07 +6.94 E-06)	3.89 E-05 ±13.1% (4.34 E-07 +3.85 E-05)	3.36 E-07 ±113%	3.81 E-07 ±96.5%	4.80 E-07 ±168% (3.04 E-07 +1.76 E-07)	4.13 E-07 ±367%	1.28 E-05 ±13.4%	4.1 E-07 ±500%	4.1 E-07 ±500%	3.51 E-07 ±500%	3.40 E-07 ±180%	7.46 E-07 ±71.4%	6.12 E-07 ±72.3%	3.40 E-07 ±500%
Total beta on filter paper (μCi)	1.87 E-03 ±2.35% (3.09 E-05 +1.84 E-03)	1.06 E-03 ±1.27% (4.21 E-06 +1.06 E-03)	2.13 E-03 ±0.81%	4.36 E-03 ±0.53%	1.21 E-04 ±5.25% (3.00 E-05 +9.07 E-05)	5.55 E-03 ±0.46%	4.17 E-04 ±1.83%	3.47 E-05 ±7.42%	1.46 E-03 ±0.95%	1.42 E-03 ±1.61%	1.45 E-03 ±0.90%	9.70 E-03 ±0.35%	6.92 E-05 ±4.54%	1.24 E-04 ±3.30%

*Sample error for combined filter papers is estimated as follows: $Error_{sum} = [(Conc_1)(Error_1) + (Conc_2)(Error_2)] \div Conc_{sum}$.

Table C-3. Tank Headspace Radionuclide Concentrations Based Upon Combustible Gas Meter Filter Paper Data.

	SX-101 R19	SX-101 R4	SX-103 R7	SX-103 R11	SX-105 R6	SX-105 R14	SX-102 R8, 4	S-110 R6	S-110 R14	U-107 R7, 2	BY-105 R7	BY-105 R11B	TX-113 R3	TX-113 R5
Assumed sampling efficiency	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
^{137}Cs concentration in headspace (μCi/ml)	5.9 E-10	3.1 E-10	1.3 E-08	1.8 E-08	1.5 E-10	2.8 E-08	2.2 E-09	2.8 E-10	7.3 E-09	6.3 E-09	6.9 E-09	7.8 E-08	1.2 E-10	2.0 E-10
Total alpha concentration in headspace (μCi/ml)	1.7 E-11	7.1 E-11	1.7 E-12*	1.2 E-12	7.0 E-13*	1.5 E-12*	5.9 E-11	2.8 E-12*	2.7 E-12*	1.1 E-12*	1.1 E-12*	5.0 E-12	1.1 E-12	9.1 E-13*
Total beta concentration in headspace (μCi/ml)	4.3 E-09	2.0 E-09	1.1 E-08	1.4 E-08	1.8 E-10	2.0 E-08	1.9 E-09	2.4 E-10	9.5 E-09	4.4 E-09	4.9 E-09	6.5 E-08	1.3 E-10	3.3 E-10
Tank headspace changeouts by exhauster during CGM operation	1.5	1.9	0.89	1.4	3.2	1.3	0.84	1.4	1.4	4.5	3.1	1.5	6.3	4.0

*These values not used for calculation of aerosol concentrations; error range for data point was >100%

CGM = combustible gas meter.

Table C-4. Aerosol Mass Concentrations and Quantities During Rotary Mode Core Sampling Based Upon Combustible Gas Meter Filter Paper Data.

		SX-101 R19	SX-101 R4	SX-103 R7	SX-103 R11	SX-105 R6	SX-105 R14	SX-102 R8&4	S-110 R6	S-110 R14	U-107 R2&7	BY-105 R7	BY-105 R11B	TX-113 R3	TX-113 R5	Weighted Average
Nuclide basis for mass concentration	^{137}Cs*	5.3 E-06	2.7 E-06	5.3 E-05	7.4 E-05	5.8 E-07	1.1 E-04	9.9 E-06	1.2 E-06	3.2 E-05	5.2 E-05	3.1 E-05	3.5 E-04	9.3 E-07	1.6 E-06	
	Total alpha*	3.3 E-05	1.4 E-04	-	6.8 E-06	-	-	2.7 E-04	-	-	-	-	3.6 E-05	1.5 E-05	-	
	Total beta*	1.2 E-05	5.5 E-06	1.6 E-05	2.0 E-05	2.7 E-07	3.1 E-05	2.8 E-06	3.0 E-07	1.2 E-05	1.4 E-05	6.4 E-06	8.6 E-05	5.3 E-07	1.4 E-06	
	Average mass concentration*	1.7 E-05	5.0 E-05	3.5 E-05	3.4 E-05	4.2 E-07	7.1 E-05	9.5 E-05	7.6 E-07	2.2 E-05	3.3 E-05	1.8 E-05	1.6 E-04	5.5 E-06	1.5 E-06	**4.0 E-05**
	Average mass of waste in tank headspace during RMCS (g)	5.5 E-02	1.6 E-01	8.7 E-02	8.5 E-02	1.1 E-03	1.8 E-01	2.8 E-01	1.9 E-03	5.6 E-02	5.5 E-02	4.3 E-02	3.6 E-01	1.1 E-02	2.9 E-03	**9.7 E-02**
	Mass per RMCS core sent to exhauster (g/core)	1.1 E-01	3.9 E-01	9.7 E-02	1.5 E-01	4.2 E-03	2.8 E-01	2.9 E-01	3.3 E-03	9.9 E-02	1.6 E-01	1.6 E-01	6.9 E-01	8.7 E-02	1.5 E-02	**1.8 E-01**
	Mass per RMCS segment sent to exhauster (g/segment)	2.1 E-02	9.6 E-02	4.8 E-02	3.8 E-02	4.2 E-02	5.6 E-02	1.5 E-01	1.7 E-03	1.2 E-02	3.1 E-02	1.8 E-02	7.6 E-02	7.3 E-03	2.5 E-03	**3.4 E-02**

*All values in grams of waste per cubic meter.

RMCS = rotary mode core sampling.

APPENDIX D

ESTIMATION OF ROTARY MODE CORE SAMPLING EXHAUSTER HOUSING DECONTAMINATION FACTOR

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APPENDIX D

ESTIMATION OF ROTARY MODE CORE SAMPLING EXHAUSTER HOUSING DECONTAMINATION FACTOR

D.1 SUMMARY OF METHOD

This appendix estimates a decontamination factor for the rotary mode core sampling (RMCS) exhausters using data from the nondestructive assay (NDA) of the exhauster housing and applicable stack record sample data. The amount of ^{137}Cs in the exhauster effluent is divided by the amount of ^{137}Cs in the exhauster inlet to provide a penetration efficiency. The reciprocal of the penetration efficiency is the decontamination factor.

D.2 DESCRIPTION

Each RMCS exhauster has an isokinetic sampler located on the stack downstream of the blower and high-efficiency particulate air (HEPA) filters. A small pump pulls air from the exhaust stack into a filter paper at a rate proportional to the exhaust flow. Radionuclides in the exhaust stream passing through the sample line are caught on the filter paper. The stack operating time and flow rate are recorded. When the record sample filter paper is removed, the filter paper is analyzed in a laboratory for radionuclides. The radionuclide concentration in the stack effluent stream is calculated by dividing the quantity of material on the filter paper by the volume of air through the sampler, and then dividing again by a factor to compensate for stack sampler and filter paper efficiency.

The ^{137}Cs in the exhauster effluent was estimated from the effluent total beta concentration as described in Section D.5. The ^{137}Cs on the filters, determined by NDA of the housing (see Appendix A), is added to the ^{137}Cs emissions to give the total ^{137}Cs input to the filter housing. Dividing the emissions by the input gives the filter housing penetration efficiency. Subtracting the penetration efficiency from 1.0 gives the filter housing efficiency. Dividing 1.0 by the penetration efficiency gives the decontamination factor.

D.3 ROTARY MODE CORE SAMPLING STACK RECORD SAMPLE DATA

RMCS exhauster stack record samples are taken after completion of each sampling event on a tank. Normally the samples are taken after all cores on that tank have been obtained, but in 1998, record samples for Tank 241-BY-105 were taken following each core. Record samples also are taken at the end of each year. All samples are analyzed for total alpha and total beta. At the end of each year, all the filter papers for that year are composited and analyzed for individual radionuclides. Sample results are entered into the Automated Bar Coding of Air Samples at Hanford and Environmental Release Summary databases. Several of the filter papers from 1998 were reanalyzed using a longer count time to bring the error rate down.

Schofield (2000) compiled and evaluated all available RMCS exhauster stack record sample data, filtered out the unusable data, provided derivation for the stack sampling efficiency factor, and summarized the results. Most of the data points were so low as to be unusable because the results were either negative or had error variances greater than 100%.

Column 5 of Table D-1 provides the stack effluent concentrations used for calculation of the filter housing decontamination factor. The stack effluent data in Table D-1 come from Schofield (2000). These values include a 0.73 sampling efficiency factor.

D.4 CALCULATION OF ROTARY MODE CORE SAMPLING FILTER HOUSING DECONTAMINATION FACTOR BASED UPON HOUSING INLET AND OUTLET DATA

The RMCS exhauster housing NDA and stack record sample data available for exhauster operating periods 4, 5, and 6 were used to estimate an actual decontamination factor for the RMCS exhauster housings. No NDA measurements were taken following periods 1, 2 or 3. The housing NDA data were for ^{137}Cs, but there were no usable ^{137}Cs concentrations for the RMCS exhauster outlet. The RMCS exhauster stack ^{137}Cs concentrations were either negative, had a variance greater than 100%, or were not available. Total beta analyses were available, however, so the stack effluent ^{137}Cs concentrations were estimated by multiplying the total beta concentration by the ratio of ^{137}Cs to total beta in the tank waste.

Column 4 of Table D-1 lists the stack exhaust volume for each stack record sample period. The stack exhaust volume for the exhauster installation on Tank 241-S-110 is calculated as follows:

$$(200 \text{ standard ft}^3/\text{min})\ (159.78 \text{ h})\ (60 \text{ min/h}) = 1.99 \text{ E+06 standard ft}^3 .$$

All other stack volumes in Table D-1 were calculated the same way. Unlike the practice used in Appendices A, B, and C, no adjustment was made to change the 200 standard ft^3/min to actual cubic feet per minute. This is because the RMCS stack record sample concentrations from Schofield (2000) are based upon a 200 standard ft^3/min flow rate rather than the actual flow rate. Since the concentrations are on the same basis as the flow rate, there is no need to correct to actual cubic feet per minute.

The total beta emissions for the RMCS exhauster stack were calculated by multiplying the volume by the concentration. For the same Tank 241-S-110 data point, the total beta emissions are calculated as follows:

$$(1.99 \text{ E+06 ft}^3)\ (1.8 \text{ E-15 } \mu\text{Ci/mL})\ (28{,}317 \text{ mL/ft}^3)\ (\text{mCi}/1.0 \text{ E+03 } \mu\text{Ci})$$
$$= 1.0 \text{ E-07 mCi total beta} .$$

All other total beta emissions in Table D-1 were calculated the same way.

The ratio of ^{137}Cs to total beta was calculated from data in Appendix E, Table E-1. For the same Tank 241-S-110 data point, the ratio is calculated as follows:

3.260 E+05 Ci ^{137}Cs ÷ 1.14 E+06 Ci total beta = 2.9 E-01 Ci ^{137}Cs/Ci total beta
= 2.9 E-01 mCi ^{137}Cs/mCi total beta .

The ^{137}Cs emission for the same Tank 241-S-110 data point was estimated as follows:

(1.0 E-07 mCi total beta) (2.9 E-01 mCi ^{137}Cs/mCi total beta) = 2.9 E-08 mCi ^{137}Cs .

All ^{137}Cs emissions in Table D-1 were calculated in the same manner.

Column 2 of Table D-1 lists the increase in ^{137}Cs on the filters for each operating period, as determined by NDA. This data was obtained from Appendix A, Table A-2. The penetration efficiency for each operating period was calculated by dividing the ^{137}Cs quantity from the exhauster outlet by the ^{137}Cs quantity to the filter inlet. The quantity of ^{137}Cs to the filter inlet is equal to the quantity caught on the filters plus the quantity leaving the exhauster. The following example is for operating period 4:

(8.1 E-06 mCi) ÷ (5.0 E-01 + 8.1 E-06 mCi) = 1.6 E-05
= 1.6 E-03% filter penetration efficiency.

The filter housing efficiency for operating period 4 is then calculated as follows:

1 - 1.6 E-05 = 0.999984
= 99.9984% filter housing efficiency.

The decontamination factor for operating period 4 is then calculated as follows:

1 ÷ 1.6 E-05 = 6.2 E+04.

The overall filter penetration efficiency, filter housing efficiency, and decontamination factor for periods 4, 5, and 6 were calculated by dividing the effluent from all three periods by the total filter input:

(9.5 E-06 mCi) ÷ (6.7 E-01 + 9.5 E-06 mCi) = 1.4 E-05
= 1.4 E-03% filter penetration efficiency.

1 - 1.4 E-05 = 0.999986
= 99.9986% filter housing efficiency.

1 ÷ 1.4 E-05
= 7.3 E+04 decontamination factor.

D.5 ESTIMATION OF HOUSING DECONTAMINATION FACTOR BASED UPON GENERAL PERFORMANCE DATA

HEPA filters are tested by the manufacturer to a minimum 99.97% efficiency using a 0.3-μm monodisperse aerosol. After installation, HEPA filters are tested in-place in accordance with ASME N510, *Testing of Nuclear Air Treatment Systems*. The HEPA filters are tested to a

minimum 99.95% efficiency using a polydisperse aerosol with an approximate droplet size distribution that is 99% less than 3.0 μm, 50% less than 0.7 μm, and 10% less than 0.4 μm. The RMCS exhauster housing is tested in accordance with ASME N510 and is thus required to have a minimum removal efficiency of 99.95% for an aerosol with this approximate size distribution. The particle size distribution of the waste aerosols generated by RMCS is unknown, but it is assumed that the removal efficiency for RMCS-generated aerosols is the same as the removal efficiency for the test aerosol.

A 99.95% efficiency is equivalent to a decontamination factor of 2 E+03, while a 99.97% efficiency is equivalent to a decontamination factor of 3.3 E+03. The actual decontamination factor for the RMCS exhauster housing is higher than either of these. The exhauster has two HEPA filters in series, even though the minimum efficiency specified in the Notices of Construction for the RMCS exhausters is only equivalent to one HEPA filter. ERDA 76-21, *Nuclear Air Cleaning Handbook*, recommends using a decontamination factor of $3{,}000^n$ for a filter bank, where *n* is the number of HEPA filters in series. This would result in a decontamination factor of 9 E+06 for the RMCS exhauster housing. This is unrealistic. Using a decontamination factor of 9 E+06 in the calculations would result in quantities of ^{137}Cs on the HEPA filters that are orders of magnitude above what has been shown to be there based upon the measured dose rates and NDA. A decontamination factor of 9 E+06 would mean the dose rate would have to be almost 100 mR/h at the side of the exhauster housing instead of the 0.5 to 0.8 mR/h dose rates encountered. Waste particles entering the second HEPA filter will not have the same particle size distribution as those entering the first HEPA filter. The majority of the waste particles will be captured on the first HEPA filter, and although the decontamination factor for each HEPA filter if tested individually using the ASME N510 aerosol test method may be 3 E+03 (or higher), the overall decontamination factor for the two filters in series will not be $3{,}000^2$. This is because the size distribution of the particles entering the second HEPA filter would have a greater percentage of smaller particles than would be found in the size distribution of the particles entering the first HEPA filter.

Davis and Barnett (1995) included an evaluation of a number of different facility stacks at the Hanford Site in which the HEPA filter upstream air concentrations were estimated using several different methods. This report concluded that back-calculation using a value of $3{,}000^n$ overestimated the upstream radionuclide concentration by three to four orders of magnitude when compared with filter NDA data for the nine stacks for which NDA data were obtained, and by three orders of magnitude for the two stacks for which upstream air sample data were available. Back-calculation using a value of $3{,}000^n$ was shown to be high by four orders of magnitude for the single stack for which a powder release estimate was available. Based upon this information, the RMCS exhauster dual-filter-in-series housings would have a decontamination factor of at least three, and maybe four, orders of magnitude less than 9 E+06, or in the 1 E+03 to 1 E+04 range. A decontamination factor of 1 E+03 would be less than the minimum permissible under the Notice of Construction. After comparing the older stack data and design with the newer RMCS exhauster design, the minimum decontamination factor is expected to be at least 1 E+04.

Table D-2 provides the available RMCS exhauster aerosol test data. This information was obtained from Waldo (1999). Before 1998, testing was conducted to determine the efficiency of

the RMCS exhauster primary HEPA filter and either the efficiency of the secondary HEPA filter or the overall efficiency for both filters. Starting in 1998, the efficiency of the primary and secondary HEPA filters was measured separately. The overall efficiency of the two filters in series was only measured three times in 11 setups. Two times the overall penetration efficiency of the two filters in series was less than 0.002% and the remaining time the only information that could be found was a value of less than 0.05%. Most individual filters had a penetration efficiency of 0.002%. This appears to be about the limit of the detection equipment. Based upon data in Table D2, a penetration efficiency of 0.002% (99.998% efficiency) is normal for a single HEPA filter and thus a minimum for an RMCS exhauster housing. Assuming a 0.002% penetration efficiency for the two filters combined results in a decontamination factor of 5 E+04 (equal to 1 ÷ 0.00002) for the RMCS exhauster housing.

In summary, the measured decontamination factor for the RMCS exhauster housings based on stack effluent and filter housing NDA data over the period from May 1998 through June 1999 was about 7.3 E+04. RMCS aerosol testing prior to use indicates a decontamination factor of about 5.0 E+04 for each of the filters separately, but their overall efficiency is not measured. Referenced data based on older stacks at the Hanford Site indicate that the RMCS exhauster housing with two HEPA filters would likely have a decontamination factor of at least 1 E+04.

D.6 ESTIMATED AEROSOL LEVELS DURING ROTARY MODE CORE SAMPLING BASED UPON ROTARY MODE CORE SAMPLING STACK RECORD SAMPLE DATA

Revision 0 of this document used the positive record sample results with variance less than 100% to estimate aerosol concentrations in the exhauster inlet using an assumed exhauster housing decontamination factor of 5.0 E+04. This method of estimating aerosols was eliminated from Revision 1 and Revision 2 because the stack concentrations were either too low, too scattered, or too questionable to provide reliable results. One hundred twelve RMCS stack record sample data points were evaluated in Schofield (2000). Excluding the sample results for total beta that were used for estimating the housing decontamination factor, only 10 data points had positive values and variances less than 100%; the remaining data points were either negative, had a variance greater than 100%, or the results were not available.

For comparison purposes only, Schofield (2000) applied the decontamination factor of 7.3 E+04 calculated in this document to the data points not used to calculate the exhauster housing decontamination factor to estimate aerosol concentrations upstream of the filters. The results showed aerosol levels approximately the same as those estimated using NDA, dose rate, or CGM filter paper data when a value of zero was used for negative sample results or those with a variance greater than 100%. When only the 10 positive results with a variance of less than 100% were used, the aerosol levels calculated were two to five times higher than those estimated using NDA, dose rate, or CGM filter paper data. Because of the variability of the data resulting from the extremely low record sample concentrations, and the few useable data points, estimation of aerosol levels using record sample data was not included in Revision 1 or Revision 2. See Schofield (2000) for further discussion of the use of record sample data to estimate aerosol levels.

D.7 SUMMARY OF CALCULATIONS

A total of nine RMCS exhauster stack record sample data points were used with exhauster housing NDA data for the same operating periods to estimate the RMCS exhauster filter housing decontamination factor. These data points were obtained when sampling on five tanks during which 10 RMCS cores and 65 RMCS segments were obtained. The overall decontamination factor was 7.3 E+04.

Estimation of aerosol generation quantities based upon RMCS stack record sample data and a nominal decontamination factor of 7 E+04 is possible. However, results will likely be skewed high if record sample data points that show nondetectable levels of radionuclides present are ignored rather than being represented by a value of zero.

D.8 REFERENCES

ANSI/ASME N510, 1989, *Testing of Nuclear Air Treatment System*, American Society of Mechanical Engineers, New York, New York.

ERDA 76-21, 1976, *Nuclear Air Cleaning Handbook*, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Davis, W. E., and Barnett, J. M., 1995, "Potential Radionuclide Emissions from Stacks on the Hanford Site, Part 1: Dose Assessment," *Proceedings of the Twenty-third DOE/NRC Nuclear Air Cleaning Conference*, July 25-28, 1994.

Schofield, J. S., 2000, *RMCS Exhauster Stack Record Sample Data* (Letter 74910-00-003, Rev. 1 to File, January 20), CH2M HILL Hanford Group, Inc., Richland, Washington.

Waldo, E. J., 1999, *RMCS Exhauster Aerosol Test Data* (Letter 74910-99-009 to J. S. Schofield, June 22) , CH2M HILL Hanford Group, Inc., Richland, Washington.

Table D-1. Stack Effluent Data for Calculation of Rotary Mode Core Sampling Exhauster Filter Housing Decontamination Factor.

Operating period	^{137}Cs on filters[a] (mCi)	Tanks on which exhauster was used[a]	Stack exhaust volume[b] (standard ft^3)	Total beta effluent concentration used for estimating housing DF[c] (µCi/ml)	Total beta out stack (mCi)	^{137}Cs to total beta ratio[d]	^{137}Cs out stack (mCi)	Penetration efficiency	Filter housing efficiency	DF
4	5.0 E-01	S-110 – R6, R14	1.99 E+06	1.8 E-15	1.0 E-07	0.29	2.9 E-08	**1.6 E-03 %**	**99.9984%**	**6.2 E+04**
		U-107 – R7, R2	3.39 E+06	2.1 E-15	2.0 E-07	0.39	7.8 E-08			
		BY-105 – R7	1.69 E+06	4.6 E-15	2.2 E-07	0.30	6.4 E-08			
		BY-105 – R11B	3.86 E+06	4.0 E-15	4.3 E-07	0.30	1.3 E-07			
		TX-113 – R3	6.81 E+05	8.9 E-15	1.7 E-07	0.54	9.2 E-08			
		TX-113 – R3	3.68 E+06	1.4 E-13	1.4 E-05	0.54	7.7 E-06			
		Subtotal					8.06 E-06			
5	3.2 E-02	TX-113 – R3	1.08 E+06	8.9 E-15	2.7 E-07	0.54	1.5 E-07	**5.6 E-04 %**	**99.9995%**	**1.8 E+05**
		TX-113 – R5	1.35 E+06	1.6 E-15	6.1 E-08	0.54	3.3 E-08			
		Subtotal					1.79 E-07			
6	1.4 E-01	TX-118 – R9B, R12B	2.64 E+06	2.5 E-14	1.8 E-06	0.66	1.2 E-06	**8.5 E-04 %**	**99.9992%**	**1.2 E+05**
Overall	6.7 E-01						9.5 E-06	**1.4 E-03 %**	**99.9986%**	**7.3 E+04**

[a]From Appendix A, Table A-2.

[b]Calculated from flow rate and operating time data in Appendix F, Table F-1 (see text).

[c]From Schofield, J. S., 2000, *RMCS Exhauster Stack Record Sample Data* (Letter 74910-00-003, Rev. 1, to File, January 20), CH2M HILL Hanford Group, Inc., Richland, Washington.

[d]From ^{137}Cs and total beta data in Appendix E, Table E-1.

DF = decontamination factor.

Table D-2. Rotary Mode Core Sampling Exhauster High-Efficiency Particulate Air Filter Aerosol Test Data.

Measured elements	BY-106 1994-1995	BY-110 1995	BY-108 1995	BY-105 1995	S-110 1998	U-107 1998	BY-105 1998	TX-113 (B) 1998	TX-113 (C) 1998-1999	TX-113 (B) 1999	TX-118 1999
Primary HEPA filter %	0.002*	0.002	0.002	Not available	0.002	0.003	0.002	0.002	0.004	0.002	0.002
Secondary HEPA filter %	Not measured	0.002	0.002	Not available	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Overall %	0.002*	0.002	Not measured	<0.05	Not measured	Not measured	Not measured	Not measured	Not measured	Not measured	Not measured

*Data are from February 1995 after exhauster was removed from Tank 241-BY-106. The only data available for November 1994 prior to initial use of exhauster show greater than 99.95% efficiency (less than 0.05% penetration).

HEPA = high-efficiency particulate air (filter).

APPENDIX E

TANK WASTE RADIONUCLIDE CONCENTRATIONS USED FOR AEROSOL CALCULATIONS

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APPENDIX E

TANK WASTE RADIONUCLIDE CONCENTRATIONS USED FOR AEROSOL CALCULATIONS

The rotary mode core sampling (RMCS) exhauster nondestructive assay (NDA) data, high-efficiency particulate air (HEPA) filter dose rate data, combustible-gas meter (CGM) filter paper data, and stack record sample data provide information on the quantity of radionuclides on the exhauster filters, in the tank headspace, or in the exhauster stack during RMCS. The radionuclide activity recorded in these data needs to be divided by the radionuclide concentration specific activity of the waste to determine the mass of waste in the tank headspace and in the tank gases sent to the exhauster.

The mass quantities in this document were calculated using dry basis radionuclide concentrations. Waste particles carried into the tank headspace by the purge gas could be wet or dry. If wet, some of the non-chemically bound water will start to evaporate immediately providing the relative humidity in the tank is less than 100%. The water present in a waste particle may be chemically bound as a hydrate, or it may be free. The chemically bound water will not readily evaporate; therefore even a "dry" particle may have some water associated with it. It is impractical to measure the actual water content of the waste particulates caught on the CGM filter paper, the exhauster HEPA filters, or the stack record sample paper. Since the quantity of water in the waste particulates is unknown, particulate levels were calculated using dry basis radionuclide concentrations. Thus, all particulate values given in this document are stated on a dry basis.

The waste radionuclide concentrations, on a dry basis, were calculated from data available in the Tank Waste Information Network System in December 1999 (TWINS 1999). No corrections were made for decay for this document. The Best Basis Inventory/Best Basis Summary numbers from the TWINS (1999) database were used. These values are the consensus estimates to use for Hanford waste tank contents, but they do not include water. The information was downloaded from the TWINS (1999) database into a spreadsheet. The total chemical, total beta, and total alpha quantities were summed in the spreadsheet for all the tanks that were sampled, and concentrations for ^{137}Cs, ^{90}Sr, total beta, and total alpha were automatically calculated in microcuries per gram. These concentrations are provided in Table E-1. Because laboratory techniques for measuring gross beta levels only detect beta particles with a minimum decay energy above 150 to 200 keV, only radionuclides with a beta decay energy greater than ~200 keV were included in the total beta numbers.

The CGM filter paper and stack record sample data indicate the measured radionuclide values are not always in the same ratio to each other as they are in the TWINS (1999) database, nor are all the radionuclides detected that the database indicates are present. Radionuclides can be distributed unevenly in a tank. Soluble fission products (primarily ^{137}Cs) are found in the liquid, saltcake, and sludges. Insoluble fission products and actinides are found largely in sludges as these are primarily chemical precipitates. Sludge could be mixed with saltcake, be present in a

distinct layer at the bottom of a tank, or be in several layers in the tank depending upon how waste was transferred into a tank. Waste particles would likely not have the same specific activity on a microscopic scale as they would have on a macroscopic scale were the tank contents homogenized. During RMCS, a top-to-bottom core sample is attempted, resulting in the drill bit and purge gas (which causes aerosols to form) passing through most of the waste matrix. Assuming the aerosol generation rate is approximately constant during drilling, the specific activity of a radionuclide in the suspended solids should be roughly the same as the average specific activity of the same radionuclide in the tank waste. The waste specific activity is probably not homogeneous from top to bottom in a tank, and the aerosol generation rate will likely also vary. It is beyond the scope of this document to provide an in-depth analysis of all the factors affecting aerosol radionuclide concentration. Although sample radionuclide data were not always in the same ratio as was provided by TWINS (1999), the simplifying assumption was made in this document that the average tank specific activity is adequate to provide an approximation of the specific activity of the suspended solids. Average specific activities for individual radionuclides in the tanks were used in the preparation of the Notices of Construction for the RMCS exhausters.

The aerosol calculations presented in this document are only as accurate as the TWINS (1999) data. The combined radionuclide content of all Hanford Site waste tanks is known fairly well since the overall content can be estimated from reactor production records, $^{137}Cs/^{90}Sr$ recovery data, and processing plant discharges. Thus, TWINS (1999) data for all tanks combined should be reasonable. There are undoubtedly differences between TWINS (1999) data and the actual contents of a specific tank. While the specific tank radionuclide data used in this document may not be exact, deviations from the actual concentrations are assumed to balance out over the number of tanks sampled.

E.2 REFERENCES

TWINS, 1999, *Tank Waste Information Network System*, available at http://twins.pnl.gov:8001/htbin/TCD/getTableList.exe, accessed in December 1999.

Table E-1. Tank Contents from *Tank Waste Information Network System* Best Inventory Database and Calculated Specific Activities.

Contents	BY-105	BY-106	BY-108	BY-110	S-110	SX-101	SX-102	SX-103	SX-105	TX-113	TX-118	U-107
Mass (kg)	2.32 E+06	2.94 E+06	8.47 E+05	1.58 E+06	1.44 E+06	2.18 E+06	2.01 E+06	2.38 E+06	2.45 E+06	2.38 E+06	1.43 E+06	1.73 E+06
^{137}Cs (Ci)	5.22 E+05	7.04 E+05	3.51 E+05	1.95 E+05	3.26 E+05	2.43 E+05	4.51 E+05	5.66 E+05	6.14 E+05	3.09 E+05	1.86 E+05	2.10 E+05
^{90}Sr (Ci)	6.20 E+05	4.96 E+05	1.95 E+05	2.63 E+05	4.05 E+05	2.66 E+05	4.60 E+05	5.19 E+05	4.80 E+05	1.33 E+05	4.84 E+04	1.60 E+05
$^{239+240}$Pu (Ci)	1.22 E+02	6.14 E+01	5.97 E+01	6.94 E+01	4.06 E+02	8.73 E+02	2.60 E+02	1.97 E+02	2.70 E+02	1.05 E+02	4.55 E+03	1.91 E+02
^{241}Am (Ci)	1.43 E+02	1.23 E+02	2.47 E+01	3.55 E+01	6.39 E+01	2.05 E+02	1.44 E+02	1.92 E+02	2.64 E+02	6.77 E+01	3.81 E+03	2.58 E+01
Total beta (Ci)*	1.76 E+06	1.70 E+06	7.41 E+05	7.22 E+05	1.14 E+06	7.76 E+05	1.37 E+06	1.61 E+06	1.58 E+06	5.76 E+05	2.83 E+05	5.32 E+05
Total alpha (Ci)	3.23 E+02	1.96 E+02	1.84 E+02	1.63 E+02	4.87 E+02	1.10 E+03	4.33 E+02	4.17 E+02	5.62 E+02	1.78 E+02	8.36 E+03	2.22 E+02
^{137}Cs (μCi/g)	2.25 E+02	2.40 E+02	4.14 E+02	1.23 E+02	2.27 E+02	1.12 E+02	2.24 E+02	2.38 E+02	2.51 E+02	1.30 E+02	1.30 E+02	1.21 E+02
^{90}Sr (μCi/g)	2.67 E+02	1.69 E+02	2.30 E+02	1.66 E+02	2.82 E+02	1.22 E+02	2.29 E+02	2.18 E+02	1.96 E+02	5.60 E+01	3.38 E+01	9.30 E+01
$^{239+240}$Pu (μCi/g)	5.24 E-02	2.09 E-02	7.04 E-02	4.39 E-02	2.82 E-01	4.01 E-01	1.29 E-01	8.28 E-02	1.10 E-01	4.42 E-02	3.18 E+00	1.11 E-01
^{241}Am (μCi/g)	6.15 E-02	4.19 E-02	2.92 E-02	2.24 E-02	4.44 E-02	9.42 E-02	7.16 E-02	8.06 E-02	1.08 E-01	2.84 E-02	2.66 E+00	1.49 E-02
Total beta (μCi/g)*	7.59 E+02	5.78 E+02	8.75 E+02	4.56 E+02	7.91 E+02	3.57 E+02	6.84 E+02	6.75 E+02	6.45 E+02	2.42 E+02	1.98 E+02	3.08 E+02
Total alpha (μCi/g)	1.39 E-01	6.65 E-02	2.17 E-01	1.03 E-01	3.38 E-01	5.04 E-01	2.15 E-01	1.75 E-01	2.29 E-01	7.48 E-02	5.84 E+00	1.29 E-01

Note: The *Tank Waste Information Network System* is available on the Internet at http://twins.pnl.gov:8001/tcd/main.html. Information in this table is from the database as accessed in December 1999.

*Total beta only includes radionuclides with a beta decay energy greater than approximately 200 keV.

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APPENDIX F

ROTARY MODE CORE SAMPLING EXHAUSTER AND CORE SAMPLE DATA

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APPENDIX F

ROTARY MODE CORE SAMPLING EXHAUSTER AND CORE SAMPLE DATA

This appendix provides the basic data obtained during rotary mode core sampling (RMCS) operations that were used in preparation of this document.

F.1 BASIC OPERATIONAL DATA

Three RMCS exhausters and three RMCS sampling trucks have been deployed since startup of nitrogen-purged RMCS in November 1994. The exhausters are formally designated 296-P-32, 296-P-33, and 296-P-34. These were originally referred to as parts of RMCS Systems 2, 3, and 4, respectively, in the Notices of Construction for these units. The exhauster designations were changed for routine field use in 1996 to exhausters A, B, and C to avoid confusion with core sampling trucks 2, 3, and 4 because any exhauster could be used with any RMCS truck. Exhauster A (2) and RMCS truck 2 have not been used for RMCS since 1995 and are no longer in service for core sampling.

RMCS has been conducted in four general time frames since 1994. These time frames were separated by down time for equipment modifications or resolution of environmental permitting and safety concerns. For ease of analysis in this document, exhauster operations were organized into six distinct operating periods. Periods 1 to 6 were grouped based upon times when the same exhauster and same set of high-efficiency particulate air (HEPA) filters were being used. These periods thus overlap with the four general operating time frames:

1. The first time frame lasted from November 1994 to January 1995. RMCS truck 2 and exhauster 2 (A) were used on Tank 241-BY-106 along with an in-tank prefilter. This tank provided the location for initial deployment and testing of the nitrogen-purged equipment in a waste tank. During this period, radiation dose rates were taken at the side of the exhauster housing. Stack record samples were taken in December 1994 and January 1995.

2. The second time frame lasted from July 1995 through October 1995. RMCS trucks 2 and 4 were used with exhausters 2 and 3 (A and B) on Tanks 241-BY-105, 241-BY-108, and 241-BY-110. During this period, radiation dose rates were taken at the sides of the exhauster housings. Stack record samples were taken after completion of sampling on each tank. No RMCS samples were taken from Tank 241-BY-108; all samples were taken in push mode for this tank.

3. The third time frame began when RMCS was restarted in December 1997 and ended in July 1998. Trucks 3 and 4 were used for sampling Tanks 241-SX-101, 241-SX-103, 241-SX-105, and 241-SX-102 with the SX Tank Farm exhauster providing ventilation. The RMCS exhausters were not used. During this period radiation dose rates were taken at the sides of the SX exhauster housing as part of routine surveys by health physics

technicians. The SX Tank Farm exhauster stack record samples were taken when required by normal operating procedures. The SX Tank Farm record sampler and filter housing dose rate data were not evaluated for this document. It would not be practical using filter dose rate or stack record sample data to estimate the RMCS aerosol addition, if any, to the SX Tank Farm ventilation system. The background radiation around the SX Tank Farm filter housing makes measurement of any small increase in dose rate difficult to detect. The number of tanks being ventilated, and the involved off-gas header routings (the exhauster is pulling on 13 tanks in series or in parallel with the tank being sampled), and any concurrent in-tank activities in the SX Tank Farm tanks not being sampled would make it impractical to assess which aerosols resulted from RMCS. Beginning with RMCS in the SX Tank Farm, radionuclide analyses were performed on the filter papers protecting the combustible-gas meters (CGMs), which draw air out of the tank vapor space for flammable gas detection.

4. The fourth time frame began in May 1998. Between October 1995 and May 1998, exhausters B and C were extensively modified with new filter housings and other equipment to meet new requirements in the Notice of Construction. Trucks 3 and 4 were used with exhausters B and C (3 and 4) on Tanks 241-S-110, 241-U-107, 241-BY-105, 241-TX-113, and 241-TX-118. This period marked the first use of the RMCS trucks and RMCS exhausters together following resolution of flammable gas concerns and modifications to the exhausters. New housings and filters were installed. Radiation dose rates were taken at the sides of the exhauster housings. Stack record samples were taken after completion of sampling for each exhauster installation. Radionuclide analyses were performed on the CGM filter papers for all tanks except Tank 241-TX-118.
A nondestructive assay (NDA) was performed on the exhauster C housing following completion of the first core on Tank 241-TX-113. The housing filters, when assayed, contained aerosols captured by the exhauster following RMCS in Tanks 241-S-110, 241-U-107, 241-BY-105 (during 1998) and the first core of Tank 241-TX-113. Another NDA was performed on exhauster C following completion of both cores in Tank 241-TX-118. An NDA was performed following sampling of the second core in Tank 241-TX-113 using exhauster B. The time frame ran through early June 1999. No RMCS samples have been taken since June 1999. RMCS sampling is planned to begin again in 2001.

For the purposes of evaluating aerosol formation based upon RMCS exhauster housing NDA and dose rate data, the exhauster operations were grouped into six operating periods. These periods are shown in Table F-1, and restated in Appendix A, Table A-1, and Appendix B, Table B-1. All tanks sampled during periods 1, 2, 4, 5, and 6 were exhausted by one exhauster with the same housing and filters present during that period. During period 3 the SX exhauster was used during RMCS in the SX Tank Farm.

A brief description of each RMCS tank sampling operation is provided below.

F.1.1 Tank 241-BY-106, November 1994 to December 1994 (Operating Period 1)

RMCS using the nitrogen purge gas system with an exhauster was formally begun on November 17, 1994, on Tank 241-BY-106, riser 10B. Exhauster 2 (A) and truck 2 were used.

A sintered metal prefilter was inserted in the riser between the tank and the exhauster. Eight segments were taken in rotary mode and five segments in push mode until sampling was halted on December 21, 1994. One RMCS core was obtained. The total exhauster run time was 48.78 hours. The stack record sample was removed and analyzed following this run period. Dose rates taken at the side of the exhauster housing during RMCS were all less than 0.5 mR/h. The in-tank prefilter was smeared for contamination when removed from the tank; the smears showed less than detectable levels of radionuclides present (Waldo 1999). The prefilter had been washed with an installed spray system before it was removed from the tank, but subsequent testing showed the water flow and pressure were too low to have been effective at removing contamination.

F.1.2 Tank 241-BY-106, January 1995 (Operating Period 1)

Following some process modifications, RMCS in Tank 241-BY-106, riser 10B, resumed on January 18, 1995. Exhauster 2 (A) and truck 2 were used. The sintered metal prefilter was inserted in the riser between the tank and the exhauster. RMCS was halted on January 24, 1995, because of authorization basis and equipment operability issues for RMCS. Three segments were taken in rotary mode and 11 segments in push mode. One RMCS core was obtained. The total exhauster run time was 18.67 hours. The stack record sample was removed and analyzed following this run period. Dose rates taken at the side of the exhauster housing during RMCS were all less than 0.5 mR/h. The in-tank prefilter was smeared for contamination when removed from the tank, and the smears showed less than detectable levels of radionuclides present (Waldo 1999). The prefilter was not washed this time.

F.1.3 Tank 241-BY-110, July 1995 to October 1995 (Operating Period 1)

Following resolution of RMCS authorization basis and equipment issues and completion of the fabrication and testing of trucks 3 and 4, RMCS was begun in Tank 241-BY-110 on July 11, 1995. Exhauster 2 (A) and truck 2 were used. Samples were taken from risers 12B, 7, 12B again, and 4. There was no in-tank prefilter used in this or any subsequent RMCS periods. Sampling was performed until October 25, 1995, when RMCS was halted because of flammable gas issues. Thirteen RMCS segments and 56 push-mode core sampling (PMCS) segments were taken. Three RMCS cores were obtained. The total exhauster run time was 112.5 hours. The stack record sample was removed and analyzed following this run period. Dose rates taken at the side of the exhauster housing during RMCS were all less than 0.5 mR/h.

F.1.4 Tank 241-BY-108, July 1995 to August 1995 (Operating Period 2)

Core sampling was begun in Tank 241-BY-108 on July 25, 1995. Exhauster 3 (B) and truck 4 were used. Sampling was done in risers 12A and 7. The tank material proved soft enough that no RMCS segments were required. All segments were obtained in push mode although the exhauster was operated during part of the time sampling was performed. Sampling was completed August 18, 1995. Sixteen PMCS segments were taken. The total exhauster run time was 66.17 hours. The stack record sample was removed and analyzed following this run period. Dose rates taken at the side of the exhauster housing during RMCS were all less than 0.5 mR/h.

F.1.5 Tank 241-BY-105, August 1995 to October 1995 (Operating Period 2)

RMCS was begun in Tank 241-BY-105, riser 12A, on August 30, 1995. Exhauster 3 (B) and truck 4 were used. This tank has a concrete layer about 12 to 18 in. thick on top of the waste that had to be drilled through. Part way through sampling, questions arose as to the flammable gas status of the tank and RMCS was halted on October 6, 1995. Three RMCS and seven PMCS segments were taken. One RMCS core was obtained. The total exhauster run time was 44.13 hours. The stack record sample was removed and analyzed following this run period. Dose rates taken at the side of the exhauster housing during RMCS were all less than 0.5 mR/h.

F.1.6 Tank 241-SX-101, December 1997 to February 1998 (Operating Period 3)

Following resolution of extensive regulatory and authorization basis issues and installation of equipment modifications, RMCS started in Tank 241-SX-101 with truck 4 on December 4, 1997. An RMCS exhauster was not used because all SX tank farm tanks that were rotary mode core sampled are ventilated with the SX exhauster. Sampling was performed in risers 19 and 4 and was completed on February 10, 1998. Nine RMCS and six PMCS segments were taken. Two RMCS cores were obtained. SX exhauster stack record samples and filter housing dose rates were obtained as part of routine operations for the SX exhauster, not as part of the RMCS process. Filter papers used in the suction line for the CGM were saved and analyzed in the laboratory to estimate the airborne radionuclide concentration in the tank headspace. Two CGM filter papers were needed for each core, as moisture in the tank vapors condensed on the papers in the cold weather and began to restrict tank gas flow to the CGM.

F.1.7 Tank 241-SX-103, April 1998 to May 1998 (Operating Period 3)

RMCS started in Tank 241-SX-103 with truck 4 on April 27, 1998. The SX exhauster was used for ventilation (see Section F.1.6). Sampling was performed in risers 7 and 11 and was completed on May 11, 1998. Six RMCS and 18 PMCS segments were taken. Two RMCS cores were obtained. During sampling, filter papers used in the suction line for the CGM were saved and analyzed in the laboratory to estimate the airborne radionuclide concentration in the tank headspace. One CGM filter paper was used during each core. SX exhauster stack record samples and filter housing dose rates were obtained as part of routine operations for the SX exhauster, not as part of the RMCS process.

F.1.8 Tank 241-SX-105, February 1998 to May 1998 (Operating Period 3)

RMCS started in Tank 241-SX-105 with truck 3 on February 25, 1998. The SX exhauster was used for ventilation (see Section F.1.6). Sampling was performed in risers 6 and 14 and was completed on May 15, 1998. Six RMCS and 20 PMCS segments were taken. Two RMCS cores were obtained. During sampling, filter papers used in the suction line for the CGM were saved and analyzed in the laboratory to estimate the airborne radionuclide concentration in the tank headspace. Two filter papers were needed for the first core, as moisture in the tank vapors condensed on the papers in the cold weather and began to restrict tank gas flow to the CGM. One filter paper was used for the second core. SX exhauster stack record samples and filter

housing dose rates were obtained as part of routine operations for the SX exhauster, not as part of the RMCS process.

F.1.9 Tank 241-SX-102, June 1998 to July 1998 (Operating Period 3)

RMCS started in Tank 241-SX-102 with truck 4 on June 17, 1998. The SX exhauster was used for ventilation (see Section F.1.6). Sampling was performed in risers 8 and 4 and was completed on July 7, 1998. Two RMCS and 18 PMCS segments were taken. Two RMCS cores were obtained. During sampling, filter papers used in the suction line for the CGM were saved and analyzed in the laboratory to estimate the airborne radionuclide concentration in the tank headspace. One filter paper was used for each core. SX exhauster stack record samples and filter housing dose rates were obtained as part of routine operations for the SX exhauster, not as part of the RMCS process

F.1.10 Tank 241-S-110, May 1998 to June 1998 (Operating Period 4)

RMCS was begun in Tank 241-S-110 on May 18, 1998. Exhauster C (4) and truck 3 were used. This tank marked the first use of an RMCS exhauster since 1995. Sampling was completed on June 4, 1998. Risers 6 and 14 were sampled. Ten RMCS and 8 PMCS segments were taken. Two RMCS cores were obtained. The total exhauster run time was 159.78 hours. The stack record sample was removed and analyzed following this run period. Dose rates taken at the side of the exhauster housing during RMCS were all less than 0.5 mR/h. During sampling, filter papers used in the suction line for the CGM were saved and analyzed in the laboratory to estimate the airborne radionuclide concentration in the tank headspace. One filter paper was used for each core. Waste particles retained on the exhauster housing filters were part of the inventory measured by NDA after the first core was obtained in Tank 241-TX-113.

F.1.11 Tank 241-U-107, June 1998 to July 1998 (Operating Period 4)

RMCS was begun in Tank 241-U-107 on June 10, 1998. Exhauster C and trucks 3 and 4 were used. Sampling was completed on July 15, 1998. Risers 7 and 2 were sampled. Ten RMCS and 19 PMCS segments were taken. Two RMCS cores were obtained. The total exhauster run time was 273.85 hours. The stack record sample was removed and analyzed following this run period. Dose rates taken at the side of the exhauster housing during RMCS were all less than 0.5 mR/h. During sampling, filter papers used in the suction line for the CGM were saved and analyzed in the laboratory to estimate the airborne radionuclide concentration in the tank headspace. One filter paper was used for each core. Waste particles retained on the exhauster housing filters were part of the inventory measured by NDA after the first core was obtained in Tank 241-TX-113.

F.1.12 Tank 241-BY-105, July 1998 to August 1998 (Operating Period 4)

RMCS was begun in Tank 241-BY-105 again on July 22, 1998. Exhauster C and trucks 3 and 4 were used. Sampling was completed on August 25, 1998. Risers 7 and 11B were sampled. A total of 18 RMCS and 18 PMCS segments were taken. The material was hard enough to

require rotary mode sampling all the way to the bottom of the waste, but it resulted in negligible recovery. After RMCS was performed to the waste bottom, a PMCS core was taken in the same hole to recover material. Two RMCS cores were obtained. The exhauster run time was 135.77 hours for the first RMCS core and 307.92 hours for the second RMCS core. Stack record sample information in the Automated Bar Coding of Air Samples at Hanford database shows 305.58 hours operation for the second core, but the sampler data sheet shows the time counter was mistakenly reset 2.34 hours into the run. No correction was made in this document for the record sample concentration of the second core from Tank 241-BY-105 since the error is conservative and results in only slightly higher (<1%) record sample radionuclide concentrations for this core. A stack record sample was removed and analyzed following each core, which provided two record samples for Tank 241-BY-105 in 1998. Dose rates taken at the side of the exhauster housing during RMCS were almost all less than 0.5 mR/h, but a few readings indicated 0.7 mR/h. This variation was assumed to be due to personnel reading the instrument differently or to the fact that the exhauster had been used on enough tanks to result in sufficient activity on the filters to cause readings approximately at the background detection level. The final reading when both cores were completed was less than 0.5 mR/h. During sampling, filter papers used in the suction line for the CGM were saved and analyzed in the laboratory to estimate the airborne radionuclide concentration in the tank headspace. One filter paper was used for each core. Waste particles retained on the exhauster housing filters were part of the inventory measured by NDA after the first core was obtained in Tank 241-TX-113.

F.1.13 Tank 241-TX-113, September 1998 to May 1999 (Operating Periods 4 and 5)

Core sampling began in Tank 241-TX-113, riser 3, on September 22, 1998. Exhauster B (3) and truck 4 were used at the start. This was the first use of exhauster B since it was modified. Exhauster B ran for a total of 87.38 hours before being disconnected on October 23, 1998. During this time no RMCS segments were obtained but two PMCS segments were taken. Exhauster C was installed and operated for 55.98 hours from December 10, 1998, to December 28, 1998. No RMCS or PMCS sampling was performed during this time frame. No RMCS segments were taken until February 1999. Exhauster C ran for 302.30 hours between December 28, 1998, and February 12, 1999. Sampling was completed on the core from riser 3 on February 12, 1999. Twelve RMCS segments were obtained during the time exhauster C was operating. The exhauster flow rate for both exhausters was a nominal 200 standard ft^3/min. Stack record samples were taken following removal of exhauster B, at the end of 1998 for exhauster C, and after obtaining the first core with exhauster C in use. Aerosol calculations were based on only the 302.30 hours run time for exhauster C in 1999 because this was the time period during which RMCS segments were obtained. Dose rates taken at the side of the exhauster housing during the short PMCS period with exhauster B were all less than 0.5 mR/h. Dose rates with exhauster C varied from less than 0.5 mR/h to 0.7 mR/h. The final reading on exhauster C after the first core was obtained was 0.7 mR/h. During sampling, filter papers used in the suction line for the CGM were saved and analyzed in the laboratory to estimate the airborne radionuclide concentration in the tank headspace. One filter paper was used for the core. Waste particles retained on the exhauster housing filters were part of the inventory measured by NDA after this core was obtained.

Sampling in riser 5 began on April 12, 1999, using exhauster B and truck 3. Six RMCS segments and one PMCS segment were taken for this core before sampling was halted on

April 28, 1999. The total exhauster run time for this core was 117.12 hours. Problems with high vacuum in the tank required the exhauster flow rate to be reduced to 190 standard ft^3/min to keep the system within pressure limits. The stack record sample for the second core was removed and analyzed following the run period. Dose rates taken at the side of the exhauster housing during sampling for the second core were all less than 0.5 mR/h. During sampling, filter papers used in the suction line for the CGM were saved and analyzed in the laboratory to estimate the airborne radionuclide concentration in the tank headspace. One filter paper was used. An NDA was performed on the exhauster housing after this core was obtained. The only radionuclides present in the housing were those from this core plus what was removed from the tank headspace during the non-RMCS sampling activities in riser 3 that occurred in this tank from September 22, 1998, to October 23, 1998. For conservatism, all radionuclides in the housing were assumed to come from the RMCS sampling in riser 5.

Some clarification may be needed to explain use of the exhauster operating times and NDA, dose rate, and record sample data obtained during core sampling on Tank 241-TX-113 during operating periods 4 and 5. In September 1998, core sampling was set up for sampling riser 3 on Tank 241-TX-113 using exhauster B. Exhauster B operated for a total of 87.38 hours between September 22, 1998, and October 22, 1998. The stack record sample was removed at the end of this period. The Environmental Release Summary database incorrectly shows the exhauster operated between November 16, 1998, and November 19, 1998. The Automated Bar Coding of Air Samples at Hanford database shows the stack record sample was removed on November 19, 1998. The stack record sample showed effluent concentrations during this time period with variances greater than 100%. No RMCS samples were taken during this period, so the data and time were not included when calculating RMCS aerosol numbers. Exhauster B was removed and exhauster C installed in late November to early December. Operating period 4 included the use of exhauster C during the subsequent RMCS sampling of riser 3. Exhauster C was operated for a total of 55.59 hours between December 10, 1998, and December 23, 1998. The stack record sample was removed on December 28, 1998. No sampling was performed during this period, so the data and time were not included when calculating RMCS aerosol numbers. Exhauster C was operated for a total of 302.18 hours between December 28, 1998, and February 8, 1999. All the RMCS segments from riser 3 were taken during this time period so only the data and time for this period were included when calculating RMCS aerosol numbers. Operating period 5 was for exhauster B use during sampling of riser 5. Exhauster B operated for a total of 117.12 hours between April 12, 1999, and April 28, 1999. For completeness, Table F-1 includes the operating information for exhauster B in September and October of 1998 during the sampling of riser 3 as part of operating period 5. No RMCS samples were taken during this period.

F.1.14 Tank 241-TX-118, May 1999 to June 1999 (Operating Period 6)

RMCS began in Tank 241-TX-118 on May 6, 1999. Exhauster C (4) and truck 4 were used. Sampling was completed on June 2, 1998. Risers 9B and 12B were sampled. Nine RMCS segments were taken and no PMCS segments. Two RMCS cores were obtained. The total exhauster run time was 212.47 hours. The stack record sample was removed and analyzed following this run period. The maximum dose rate taken at the side of the exhauster housing following RMCS was 0.8 mR/h. CGM filter papers were not analyzed. An NDA was performed on the exhauster housing after the two cores were obtained. The exhauster housing contained the

same nuclides as for the first NDA (Tanks 241-S-110, 241-U-107, 241-BY-105, and 241-TX-113, first core) plus those from Tank 241-TX-118.

F.2 OPERATIONAL DATA

The basic core sampling operational data used in this document include the number of RMCS cores and segments, the exhauster run times and flow rates, the RMCS exhauster HEPA filter dose rates, and tank vapor space temperatures. Table F-1 lists the basic operational data. This information, excluding tank vapor space temperature data, was obtained from procedural data sheets in the sampling work packages (WP-1 to WP-23).

Tank temperature data for the tanks ventilated with the RMCS exhausters were obtained from the Tank Waste Information Network System database (TWINS 1999). Plots for each tank were prepared for the time periods during with RMCS was conducted, and the average value of the highest thermocouple located in the tank (the lowest temperature reading) was estimated and used as the average tank headspace temperature during the RMCS period.

The SX exhauster flow rates listed in Table F-1 are estimates only. The combined flow rate for Tanks 241-SX-101 through 241-SX-106, plus Tank 241-SX-109 (seven tanks) averaged 440 ft^3/min during calendar year 1996 (Schofield 2001) for an average of 63 ft^3/min per tank. According to inlet flow measurements at the tank inlet HEPA filters (Schofield 2001), the flow through each individual tank (Tanks 241-SX-101 through 241-SX-106 plus 241-SX-109) was less than 55 ft^3/min at the breather filter. Assuming an exhaust flow of 100 ft^3/min for each SX Tank Farm tank sampled is therefore conservative.

F.3 CALCULATED DATA

Calculated data include the tank headspace volumes, conversion of the RMCS exhauster flow rate from standard cubic feet per minute to actual cubic feet per minute, and the number of tank headspace changeouts made by an exhauster during RMCS.

Tank headspace volume includes the dome space volume above the top of the sidewall plus the void space between the waste surface and the top of the sidewall. The following formula was used to calculate tank headspace volumes:

$$\text{Headspace volume in cubic feet} = \{DS_v + [(H_{sw})\,(12) + H_k + H_b - H_w]\,(V_{in})\} \div 7.48$$

where

DS_v = dome space volume, gal
H_{sw} = height of tank body sidewall above knuckle, ft
H_k = height of tank knuckle area, in.
H_b = height of tank bottom below knuckle, in.
H_w = height of waste in tank, in.
V_{in} = 2,755.5 gal/in of waste in 241-SX Tank Farm tanks; 2,754 gal/in. in all others.

The tank dome space volumes, height of tank sidewall above the knuckle, height of tank knuckle area, and height of tank bottom below the knuckle were obtained from Schofield (2001). The height of waste in each tank at the time of core sampling was obtained from the Tank Waste Information Network System database (TWINS 1999). Tank dimensions and waste level data are given in Table F-2 along with the calculated tank headspace volumes.

Aerosol calculations for Appendices A, B, and C require exhauster flow rates in actual cubic feet per minute. The RMCS exhauster flow rate is controlled and recorded in standard cubic feet per minute. The mass flow rate of the exhauster air is measured and internal logic in the exhauster controller calculates what the volumetric flow rate would be if the temperature and pressure in the exhauster inlet were at standard conditions. The standard conditions used in the logic controller are 29.921 in. Hg (760 mm Hg) and 69 °F (21 °C).

A correction factor is built into the exhauster control logic that assumes an atmospheric pressure of 29.27 in. Hg, the average atmospheric pressure at the Hanford Site. The RMCS exhauster will operate at about 1 to 2 in. H_2O negative pressure, resulting in about a 29.16 in. Hg pressure in a waste tank when the RMCS exhauster is operating. To revise the indicated RMCS exhauster reading from standard cubic feet per minute to actual cubic feet per minute, the following formula was used:

$$(29.92/29.16)\ (T + 459)/528$$

where T is the tank headspace temperature in degrees Fahrenheit. The tank headspace temperatures in Table F-1 were input to the spreadsheet file used for aerosol calculations and converted to actual cubic feet per minute. The flow rates in actual cubic feet per minute are included in Table F-1.

The number of tank headspace changeouts when using the RMCS exhauster was calculated by multiplying the exhauster flow rate in actual cubic feet per minute by the time of exhauster operation and dividing the result by the tank headspace volume. Tank headspace changeouts are listed in Table F-2.

F.4 REFERENCES

Schofield, J. S., 2001, *Compilation of Miscellaneous References Used in RPP-4826, Revision 1, Experience with Aerosol Generation During Rotary Mode Core Sampling in Hanford Single Shell Waste Tanks* (Letter 7KN00-01-003 to File, March 1), CH2M HILL Hanford Group, Inc., Richland, Washington.

TWINS, 1999, *Tank Waste Information Network System*, available at http://twins.pnl.gov:8001/htbin/TCD/getTableList.exe, accessed in June, August and October 1999.

Waldo, E. J., 1999, *RMCS Exhauster Aerosol Test Data* (Letter 74910-99-009 to J. S. Schofield, June 22),

WP-1, Work Package ES-94-00808, "241-BY-106 Perform Rotary Core Sample [Riser 10B]."

WP-2, Work Package ES-95-00258, "241-BY-110 Rotary Core Sample [Risers 12B, 7, 12B, 4]."

WP-3, Work Package ES-95-00045, "241-BY-108 Obtain Rotary Core Sample [Risers 12A & 7]."

WP-4, Work Package ES-95-00434, "241-BY-105 Rotary Mode Core Sample [Riser 12A]."

WP-5, Work Package WS-97-00173, "241-SX-101 Rotary Mode Core Sample Riser 19."

WP-6, Work Package WS-97-00174, "241-SX-101 Rotary Mode Core Sample Riser 4."

WP-7, Work Package WS-97-00143, "241-SX-103 Rotary Mode Core Sample Riser 7."

WP-8, Work Package WS-97-00144, "241-SX-103 Rotary Mode Core Sample Riser 11."

WP-9, Work Package WS-97-00207, "241-SX-105 RMCST Obtain Core Sample Riser 6."

WP-11, Work Package WS-97-00208, "241-SX-105 RMCST Core Sample Riser 14."

WP-12, Work Package WS-98-00049, "241-SX-102 Rotary Mode Core Sample Riser 8."

WP-13, Work Package WS-97-00050, "241-SX-102 Rotary Mode Core Sample Riser 4."

WP-14, Work Package WS-97-00224, "241-S-110 RMCST Obtain Core Sample Riser 6."

WP-15, Work Package WS-97-00225, "241-S-110 RMCST Obtain Core Sample Riser 14."

WP-16, Work Package WS-97-00230, "241-U-107 RMCST Core Sample Riser 7."

WP-17, Work Package WS-97-00231, "241-U-107 RMCST Core Sample Riser 2."

WP-18, Work Package ES-97-00452, "241-BY-105 RMCST Core Sample Riser 7."

WP-19, Work Package ES-97-00453, "241-BY-105 RMCST Core Sample Riser 11B."

WP-20, Work Package WS-98-00072, "241-TX-113 Rotary Core Sample Riser 3."

WP-21, Work Package WS-98-00073, "241-TX-113 RMCST Core Sample Riser 5."

WP-22, Work Package WS-98-00067, "241-TX-118 RMCST Core Sample Riser 9B."

WP-23, Work Package WS-98-00068, "241-TX-118 RMCST Core Sample Riser 12B."

Table F-1. Basic Rotary Mode Core Sampling and Exhauster Operational Data.

	BY-106[a]	BY-106[a]	BY-110	BY-108	BY-105	SX-101[b]	SX-103[b]	SX-105[b]	SX-102	S-110[b]	U-107	BY-105[c]	BY-105[c]	TX-113	TX-113	TX-113	TX-118
Exhauster operating periods for NDA and dose rate calculations	Period 1			Period 2		Period 3				Period 4						Period 5	Period 6
Sampling period	11/17/94 to 12/21/94	1/20/95 to 1/24/95	7/7/95 to 10/20/95	7/24/95 to 8/18/95	9/5/95 to 9/15/95	12/4/97 to 2/10/98	4/27/98 to 5/11/98	2/25/98 to 5/15/98	6/17/98 to 7/7/98	5/19/98 to 6/4/98	6/10/98 to 7/15/98	7/21/98 to 7/31/98	8/17/98 to 9/4/98	12/10 to 12/23 1998	12/28 to 2/8 1999	9/22 to 10/22 1998	4/12/99 to 4/29/99	5/6/99 to 6/2/99
Riser sampled	10B	10B	12B. 7. 12B. 4	12A, 7	12A	19 4	7 11	6 14	8. 4	6 14	7. 2	7	11B	3		3	5	9B. 12B
Number of RMCS cores	1	1	3	0	1	1 1	1 1	1 1	1	1 1	2	1	1	0	1	0	1	2
Number of RMCS segments	8	3	13	0	3	5 4	2 4	1 5	2	2 8	10	9	9	0	12	0	6	9
Exhauster used	2 (A)		2 (A)	3 (B)	3 (B)	SX	SX	SX	SX	C (4)	C (4)	C (4)	C (4)	C (4)		B (3)	B (3)	C (4)
Exhauster run time (hours)	48.78	18.67	112.5	66.17	44.13	-	-	-	-	159.78	273.85	135.77	307.92[d]	55.98	302.3	87.38	117.12	212.47
Tank vapor temperature (°F)	84	81	80	81	85	-	-	-	-	74	72	76	78	63	63	63	61	73
Exhauster flow (scfm)	200	200	200	200	200	-	-	-	-	200	200	200	200	200	200	200	190	200
Exhauster flow (acfm)	211	210	209	210	211	100[e]	100[e]	100[e]	100[e]	207	206	208	209	203	203	206	192	207
HEPA dose rate at end of sampling (mR/h)	<0.5	<0.5	<0.5	<0.5	<0.5	N/A	N/A	N/A	N/A	<0.5	<0.5	<0.5	<0.5	<0.5	0.7	<0.5	<0.5	0.8

Note: Shaded columns indicate that no RMCS samples were taken.

[a]Two columns shown for Tank 241-BY-106 in 1994 and 1995 because separate stack record samples were taken for each core.

[b]Separate columns shown for number of RMCS cores and number of RMCS segments where separate combustible gas meter filter papers were used for each core.

[c]Two columns shown for Tank 241-BY-105 (1998) because separate stack record samples were taken and separate combustible gas meter filter papers were used for each core .

[d]Stack record sample information in Automated Bar Coding of Air Samples at Hanford indicates 305.58 hours, but the exhauster run counter was mistakenly reset 2.34 hours into run. A value of 307.92 hours was used in this document. See sampling description for Tank 241-BY-105 (1998).

[e]Assumed flow rate (see text).

HEPA = high-efficiency particulate air (filter).
NDA = nondestructive assay.
RMCS = rotary mode core sampling.

Table F-2. Tank Dimensional Data, Headspace Volumes and Headspace Changeouts during Rotary Mode Core Sampling.

	BY-106	BY-106	BY-110	BY-108	BY-105	SX-101	SX-103	SX-105	SX-102	S-110	U-107	BY-105	BY-105	TX-113	TX-113	TX-118
Riser sampled	10B	10B	12B, 7, 12B, 4	12A, 7	12A	19,4	7,11	6,14	8, 4	6,14	7, 2	7	11B	3	5	9B,12B
Nominal waste level (in.)	244	244	140	87.3	167	166.5	236.5	240.5	193.5	148.7	156.5	168	168	197	197	111.5
Height of sidewall above knuckle (ft)	19.95	19.95	19.95	19.95	19.95	31.08	31.08	31.08	31.08	20.01	14.01	19.95	19.95	19.95	19.95	19.95
Height of knuckle (in.)	48	48	48	48	48	0	0	0	0	48	48	48	48	48	48	48
Height below knuckle (in.)	12	12	12	12	12	14.875	14.875	14.875	14.875	12	12	12	12	12	12	12
Dome space volume (gal)	2.49 E+04	2.49 E+04	2.49 E+04	2.49 E+04	2.49 E+04	2.47 E+04	2.47 E+04	2.47 E+04	2.47 E+04	2.49 E+04	2.47 E+04	2.49 E+04	2.49 E+04	2.49 E+04	2.49 E+04	2.49 E+04
Tank headspace volume (ft^3)	5.37 E+04	5.37 E+04	9.20 E+04	1.11 E+05	8.21 E+04	1.15 E+05	8.87 E+04	8.73 E+04	1.05 E+05	8.91 E+04	5.94 E+04	8.17 E+04	8.17 E+04	7.10 E+04	7.10 E+04	1.03 E+05
Tank headspace changeouts during exhauster operation	11.5	4.4	15.4	N/A	6.8	>25*	>25*	>25*	>25*	22.3	57.1	20.7	47.2	51.8	19.0	25.7

*Number of headspace changeouts in SX Tank Farm shown as more than 25 because SX exhauster operated constantly during exhauster operating period 3.