Lot. (2) S

MAY 11 2000 **ENGINEERING DATA TRANSMITTAL**

1. EDT 628526

2. To: (Receiving Organization) Distribution	3. From: (Originating Organization) Process Engineering	4. Related EDT No.: N/A
5. Proj./Prog./Dept./Div.: Spent Nuclear Fuel Project	6. Design Authority/ Design Agent/Cog. Engr.: M. J. Klem	7. Purchase Order No.: N/A
8. Originator Remarks: For Release		9. Equip./Component No.: N/A 10. System/Bldg./Facility: CSB/212-H
11. Receiver Remarks:	11A. Design Baseline Document? [] Yes [X] No	12. Major Assm. Dwg. No.: N/A 13. Permit/Permit Application No.: N/A 14. Required Response Date: N/A

15. DATA TRANSMITTED

(A) Item No.	(B) Document/Drawing No.	(C) Sheet No.	(D) Rev. No.	(E) Title or Description of Data Transmitted	(F) Approval Designator	(G) Reason for Transmittal	(H) Originator Disposition	(I) Receiver Disposition
1	SNF-~~5471~~ 5741 JA 5-11-00		0	Spent Nuclear Fuel Project Canister Storage Building Process Flow Diagram Mass Balance Calculations	Q, N, S AR	2	1	1

16. KEY

Approval Designator (F)	Reason for Transmittal (G)		Disposition (H) & (I)	
E, S, Q, D or N/A (see WHC-CM-3-5, Sec.12.7)	1. Approval 2. Release 3. Information	4. Review 5. Post-Review 6. Dist. (Receipt Acknow. Required)	1. Approved 2. Approved w/comment 3. Disapproved w/comment	4. Reviewed no/comment 5. Reviewed w/comment 6. Receipt acknowledged

17. SIGNATURE/DISTRIBUTION
(See Approval Designator for required signatures)

(G) Reason	(H) Disp.	(J) Name (K) Signature (L) Date (M) MSIN	(G) Reason	(H) Disp.	(J) Name (K) Signature (L) Date (M) MSIN
		Design Authority	1	1	A.L. Pajunen *[signature]* 2/1/2000 R3-86
		Design Agent			
1	1	Cog.Eng. M. J. Klem *[signature]* 2/1/00 R3-86			
1	1	Cog. Mgr. J. R. Fredericksen *[signature]* 2/1/00 R3-86			
1	1	QA S.S. Moss *Stephen Scott Moss* 2-10-2000 R3-11			
1	2	Safety *[signature]* for R. Garrett 4/27/00 *[illegible]*			
		Env.			

18.	19.	20.	21. DOE APPROVAL (if required)
M. J. Klem *[signature]* 2/1/00 Signature of EDT Originator / Date	J.R. Frederickson *[signature]* 2/1/00 Authorized Representative for Receiving Organization / Date	J.R. Frederickson *[signature]* 2/9/00 Design Authority/ Cognizant Manager / Date	Ctrl. No. [] Approved [] Approved w/comments [] Disapproved w/comments

BD-7400-172-2 (05/96) GEF097

NS - This change can not be implemented into CSB design without a CSB Final SAR revision. *[initials]*

BD-7400-172-1

SNF-5741
Revision 0

Spent Nuclear Fuel Project Canister Storage Building Process Flow Diagram Mass Balance Calculations

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Project Hanford Management Contractor for the
U.S. Department of Energy under Contract DE-AC06-96RL13200

Fluor Hanford
P.O. Box 1000
Richland, Washington

SNF-5741
Revision 0
EDT 628526

Spent Nuclear Fuel Project Canister Storage Building Process Flow Diagram Mass Balance Calculations

M. J. Klem
Cogema Engineering Corporation

A. L. Pajunen
Fluor Hanford

Date Published
May 2000

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Project Hanford Management Contractor for the
U.S. Department of Energy under Contract DE-AC06-96RL13200

Fluor Hanford
P.O. Box 1000
Richland, Washington

5/11/00

Release Approval | Date

DATE:
HANFORD
STA: 4
RELEASE
ID: 2
MAY 11 2000

Release Stamp

Total Pages: 53

SNF-5741, rev 0

TABLE OF CONTENTS

LIST OF TABLES

LIST OF ACRONYMS

CSB	Canister Storage Building
CVD	Cold Vacuum Drying
CVDF	Cold Vacuum Drying Facility
HVAC	Heating, Ventilation Air Conditioning
LERF	Liquid Effluent Retention Facility
MCO	Multi-Canister Overpack
MHM	MCO Handling Machine
MTU	Metric Tons Uranium
OBSFD	Operation Block Sequence Flow Diagram
PFD	Process Flow Diagram
SNF	Spent Nuclear Fuel

1.0 PURPOSE AND OBJECTIVE

The purpose of these calculations is to develop the material balances for documentation of the Canister Storage Building (CSB) Process Flow Diagram (PFD) and future reference. The attached mass balances were prepared to support revision two of the PFD for the CSB. The calculations refer to diagram H-2-825869.

2.0 SUMMARY OF FINAL RESULTS AND CONCLUSIONS

See Appendix A for final results.

3.0 ASSUMPTIONS

See assumptions page in Appendix A.

4.0 SOFT WARE APPLICATIONS

No software applications were used.

5.0 COMPUTER MODEL

A Microsoft Excel spreadsheet was used to display material balances and verify hand calculations.

6.0 INPUT DATA

See Section 7.2 and Appendix A.

7.0 CALCULATIONS

7.1 Background

During the K Basin fuel removal process, the combined K Basins inventory of SNF from the N Reactor, which totals 2, 103 MTU (metric tons uranium) per Reilly (1998) is cleaned, re-racked, and loaded into 398 (Goldmann 2000) mechanically sealed multi-canister overpacks (MCOs), and transferred to the cold vacuum drying (CVD) Facility within individual casks. The CVD Facility drains and dries the SNF in place within each Cask/MCO assembly for transport from the 100 K Area to the CSB, where the MCOs are removed from their Transport Casks, staged for installation of welded closure caps, welded, and interim stored for up to 40 years. Following removal of an MCO from its Transport Cask, the empty cask is fitted with a new, empty MCO and returned to the K Basins, completing one process cycle.

The fuel conditioning processes (cleaning/re-racking at the K Basins and drying at the CVD Facility) are designed to produce MCOs that contain no more than 200 g of free water (i.e., not chemically bound as water of hydration) and not more than 1056 g of chemically bound water (1256 g total design basis value). Upon completion of the drying process, the Cask/MCO assembly is cooled by circulating chilled, deionized water through the Cask/MCO annulus for five hours, after which the MCO is backfilled with helium to 11 psig (9.5 psig to 12.5 psig worst case actual pressure range, after correction for calibration errors, etc.). The CVD Facility equipment is disconnected from the MCO process ports, the cooling water is drained from the Cask/MCO annulus, the annulus is dried by an instrument air purge, the top of the MCO shield plug is wiped dry, and the cover plates are installed on each MCO port. The cover plate seals and the shield plug's main seal are then helium leak tested to ensure that their total combined leakage path does not exceed 1×10^{-5} std cm^3/s, as defined by ANSI N14.5. Prior to installing the cask lid, the CVD Facility decontaminates and/or surveys all surfaces that will be exposed when the lid is removed at the CSB. Following installation of the cask lid, the CVD Facility decontaminates and (re)surveys all accessible surfaces of the cask and cask lid to comply with transport requirements and secures the cask for transport. The end product is a Cask/MCO assembly consisting of a thermally stable, helium inerted, mechanically sealed MCO (pressure relief is neither required nor provided) within a non-inerted, mechanically sealed Transport Cask.

The five hour pre-backfill cooling step and the 9.5 psig worst case minimum backfill pressure are designed to provide a minimum void space MCO (500L) with at least 31.0 gmol of helium. The minimum initial helium inventory is designed, in conjunction with the leak test acceptance criterion and associated helium loss calculations (Sherrell 1999), to support the oxygen gettering calculations of Duncan and Plys (1998), which assume that all MCOs will retain ~30 gmol of helium below their mechanically sealed shield plugs after 40 years of storage. The cool-down, backfill, and leak testing operations are more than adequate to ensure that all MCOs retain positive gage pressures (thus preventing ingress of air) at temperatures down to –31°C (Sherrell 1999), and also ensure that hydrogen concentrations within standard, vented CSB storage tubes containing two mechanically sealed MCOs will never exceed 1 vol%.

At the CSB, all 398 MCOs are welded, sealed closed, and interim stored until a decision on final disposition is reached and implemented. Argon is the cover gas and helium is the back gas during gas tungsten arc welding of the MCO cover cap assembly. Approximately six MCOs will undergo short term monitoring for a period of about two years before they are welded and sealed closed. Each monitored MCO is sampled a total of eight times during the two year operating period. After each sampling, the monitored MCO is reinerted with helium to replace the gas lost during sampling. The MCO sample cart is used to gas sample and reinert the monitored MCOs. The sample cart is purged with helium to remove air before MCO sampling and dilute the hydrogen after sampling for exhausting to the ventilation system.

Before welding of the monitored MCOs, the 100 psi pressure sending (located in the shield plug) is replaced with a 600 psi pressure sending unit. The monitored MCOs are vented through the internal filter and sample hood to atmospheric pressure, purged with helium during unit replacement, and then reinerted with helium to the same pressure. A 600 psi pressure readout unit is added to the cover cap of all 398 MCOs after welding.

Condensate liquid waste from the compressed air system and the heating, ventilation air conditioning (HVAC) system is collected and loaded into 55-gallon drums for disposal at the Liquid Effluent Retention Facility (LERF) or to the ground, in accordance with SNF process standards. Solid waste is collected and loaded into 55-gallon drums or burial boxes for disposal as low level waste.

The following stream calculations are presented on a project total basis and based on the best estimate case for an MCO containing one scrap basket and four Mk IV fuel baskets.

7.2 Discussion of Stream Calculations

7.2.1 IC-003 Vacuum Dried Fuel In MCO/Cask Delivered to CSB

This is an input stream originating from H-1-81168, Rev. 3 cask transport PFDs. The stream mass is listed below:

Table 7.2.1 IC-003 Stream

Stream Number	IC-003		Basic Notes
Description	MCOs to Vault		
Phase	S/G		
Number of Items	398		
Item Count Basis	MCO		
Volume, m^3	-		
Density, g/cc	-		
Pressure, Torr	1370		
Temperature, °C	61		
Components, kg			
Fuel	2.25E+06		
Uranium		2.09E+06	
Plutonium		4.10E+03	
Other		1.57E+05	
Sludge	2.73E+03		
$Al(OH)_3$		2.75E+02	
$Fe(OH)_3$		2.79E+01	
$UO_2(OH)_2$		9.63E+02	
UO_44H_2O		0.00E+00	
UO_42H_2O		9.60E+02	
UO_2		1.26E+02	
UH_3		3.78E+02	
Solids	0.00E+00		(1)
Stainless Steel		0.00E+00	
Aluminum		0.00E+00	
Other		0.00E+00	
Water	6.53E+01		
Air	0.00E+00		(1)
Other Gases	5.09E+01		(1)
Argon		0.00E+00	
Hydrogen		1.57E+00	
Helium		4.93E+01	
Total Mass, kg	2.25E+06		

(1) Material balance neglects air within the cask void space as well as the material of construction of the cask and MCO. The container is not part of the mass balance. Page J-11 of Duncan and Plys (1998) and Table 2-1 of Pajunen (2000) are the source of information for temperature, pressure, and composition of the MCO internal gas.

The initial hydrogen concentration of 6.0 vol % at time zero is based on Duncan and Plys (1998) An initial fill of 31.0 gmol He/MCO from Pajunen (2000) is used for this flowsheet (see Section 7.1).

The following calculations are part of the cask/transport PFD from Klem and Pajunen (2000). The helium, hydrogen, and gas pressure calculations are repeated for background since they are used in subsequent calculations. The oxygen is negligible due to the gettering reaction with uranium metal based on Duncan and Plys (1998).

Calculate masses at time zero:

0.06 H_2 = X gmol H_2/(X gmol H_2 + 31.0 gmol He) based on Duncan and Plys (1998) and Pajunen (2000)

Mass H_2 (X) = 0.06 x 31.0/0.94 = 1.978E+00 gmol H_2/MCO

Total H_2 mass at time zero = 1.978E+00 gmol/MCO x 2 g H_2/gmol x 398 MCOs x 0.001 kg/g = **1.57E+00 kg**

Mass water/MCO at time zero = <2.00E+02 g H_20 - 1.98E+00 gmol H_2 x 1 gmol H_2O/gmol H_2 x 18 g H_2O/gmol = 1.64E+02 g/MCO

Total water mass at time zero = 1.64E+02 g/MCO x 398 MCOs x 0.001 kg/g = **6.53E+01 kg**

Mass helium (based on initial fill) = 31.0 gmol/MCO x 4 g He/gmol x 398 MCOs x 0.001 kg/g = **4.93E+01 kg**

Time zero MCO gas pressure based on average temperature of fuel and 500L void volume = (1.98 gmol H_2 + 31.0 gmol He) x 0.0820 L atm/gmol K x 334 K/500L = 1.80 atm = 26.5 psia = **1370 torr**

Private communication with M. G. Plys of Fauske and Associates reports that the average fuel temperature is more representative of the MCO gas temperature than the scrap temperature used in Duncan and Plys (1998). Therefore, the average fuel temperature is used as the MCO gas temperature. The 500L void volume is based on the one scrap basket and best estimate case MCO.

7.2.2 IC-006 Empty MCO Loaded in Cask For Transport to K Basins

A total of 398 empty MCOs are transported to the K Basins for loading with fuel and scrap. Air within the empty containers and the containers themselves are not included in the material balance.

7.2.3 C-3 MCO/Cask in Cask Receiving Pit

The MCO and cask are moved from the transporter to the cask-receiving pit. No change of material balance. See Stream IC-003.

7.2.4 C-4 Empty Transporter

Decontaminate empty transporter as required before reassemble of shipping system. No material balance.

7.2.5 C-5 Remove MCO From Cask

There is no change in material balance. See Stream IC-003.

7.2.6 C-6 Move MCO From Transport Cask to Weld Station in MHM

The loaded MCO is moved from the transport cask to the weld station in the MCO handling machine (MHM). There is no change of material inside the MCO.

This is an input stream originating from cask transport Stream IC-003. The 392 MCOs go directly to welding. The six-monitored MCOs are deleted from this stream. The stream mass is listed below:

Table 7.2.2 Stream C-6

Stream Number		C-6	
Description		MCOs Direct to Welding	
Phase		S/G	
Number of Items		392	
Item Count Basis		MCO	
Volume, m^3		-	
Density, g/cc		-	
Pressure, Torr		1370	
Temperature, °C		61	
Components, kg			
Fuel		2.22E+06	
	Uranium		2.06E+06
	Plutonium		4.04E+03
	Other		1.55E+05
Sludge		2.69E+03	
	$Al(OH)_3$		2.71E+02
	Al_2O_3		0.00E+00
	$Fe(OH)_3$		2.75E+01
	$UO_2(OH)_2$		9.48E+02
	UO_44H_2O		0.00E+00
	UO_42H_2O		9.45E+02
	UO_2		1.24E+02
	UH_3		3.72E+02
	UO_3		0.00E+00
Solids			
	Stainless Steel		0.00E+00
	Aluminum		0.00E+00
	Other		0.00E+00
Water		6.43E+01	
Air		0.00E+00	
Other Gases		5.00E+01	
	Argon		0.00E+00
	Hydrogen		1.55E+00
	Helium		4.85E+01
Total Mass, kg		2.22E+06	

7.2.7 C-7 Move Short Term Monitored MCO to Vault in MHM

There are approximately six short term monitored MCOs over a two year period. The below material balance represents the six monitored MCOs at time zero.

Table 7.2.3 Stream C-7

Stream Number		C-7	
Description		Short Term Monitored MCO to Vault	
Phase		S/G	
Number of Items		6	
Item Count Basis		MCO	
Volume, m^3		-	
Density, g/cc		-	
Pressure, Torr		1370	
Temperature, °C		61	
Components, kg			
Fuel		3.39E+04	
	Uranium		3.15E+04
	Plutonium		6.18E+01
	Other		2.37E+03
Sludge		4.11E+01	
	$Al(OH)_3$		4.15E+00
	Al_2O_3		0.00E+00
	$Fe(OH)_3$		4.21E-01
	$UO_2(OH)_2$		1.45E+01
	$UO_4 4H_2O$		0.00E+00
	$UO_4 2H_2O$		1.45E+01
	UO_2		1.90E+00
	UH_3		5.70E+00
	UO_3		0.00E+00
Solids		0.00E+00	
	Stainless Steel		0.00E+00
	Aluminum		0.00E+00
	Other		0.00E+00
Water		9.84E-01	
Air		0.00E+00	
Other Gases		7.67E-01	
	Argon		0.00E+00
	Hydrogen		2.37E-02
	Helium		7.43E-01
Total Mass, kg		3.39E+04	

7.2.8 C-8 Short Term Monitored MCO in Storage Tube

Short term monitoring of the six preselected MCOs will have a small effect on the gas composition inside the MCOs. Four gas samples are taken from each monitored MCO/year at the sample/weld station over a two year period (private communication with G. D. Bazinet of Numatec Hanford Corporation). The lost helium and hydrogen is replaced with helium after each sampling (private communication with A. L. Pajunen of Fluor Hanford). See Stream C-7 for description of the six MCOs before monitoring and Stream C-12 for description of the six MCOs after two years of monitoring. The composition has been adjusted for radiolysis of hydrated oxides and refilling with helium to replace lost gas during sampling.

7.2.9 C-9 Cask Receiving Pit Containment Tent Offgas

The service pit containment tent is used for contamination control during recovery from off normal conditions such as high air pressure (> 3 psig) inside the transport cask annulus (Reed and Pajunen 1999), smearable radionuclide contamination on the MCO top, and/or the cask lid wall exceeds maximum permissible levels of smearable contamination. The exhaust flowrate of the service tent is established by the design capacity of the filter system. Filter EF-005 has a design capacity of 1,000 scfm (Ellis and Watts 1999). The containment tent ventilation system would be operated for approximately four hours during a recovery operation based on the operation block sequence flow diagram (OBSFD) (H-2-123400, Rev. H).

7.2.10 C-10 Cask Receiving Pit Containment Tent Replacement Filters

Filter system EF-005 consists of one prefilter and one HEPA filter. The prefilter is 24 in x 24 in x 2 in and the HEPA filter size is 24 in x 24 in x 11.5 in (Ellis and Watts 1999). Assume the prefilter weights 12 lb and the HEPA filter weighs 40 lb.

7.2.11 C-11 Spent Cask Receiving Pit HEPA Filters

Frequency of filter change is unknown at this time due to infrequent use of receiving pit containment tent.

7.2.12 C-12 Short Term Monitored MCOs From Sampling to Storage Tube

MCO composition has been adjusted to 2 years after receipt and backfilled with helium in order to replace estimated gas lost during gas sampling with the sample cart. Each of the six monitored MCOs is sampled a total of eight times over the two year monitoring period.

Table 7.2.4 Stream C-12 (Before 100 PSI Pressure Sending/Readout Unit Replacement)

Stream Number	C-12	
Description	Short Term Monitored MCO to Storage Tube	
Phase	S/G	
Number of Items	6	
Item Count Basis	MCO	
Volume, m^3	-	
Density, g/cc	-	
Pressure, Torr	1400	
Temperature, °C	60	
Components, kg		
Fuel	3.39E+04	
Uranium		3.15E+04
Plutonium		6.18E+01
Other		2.37E+03
Sludge	4.15E+01	
$Al(OH)_3$		4.13E+00
Al_2O_3		1.35E-02
$Fe(OH)_3$		4.21E-01
$UO_2(OH)_2$		1.36E+01
UO_44H_2O		0.00E+00
UO_42H_2O		1.45E+01
UO_2		2.34E+00
UH_3		5.70E+00
UO_3		8.18E-01
Solids	0.00E+00	
Stainless Steel		0.00E+00
Aluminum		0.00E+00
Other		0.00E+00
Water	9.66E-01	
Air	0.00E+00	
Other Gases	7.84E-01	
Argon		0.00E+00
Hydrogen		2.57E-02
Helium		7.58E-01
Total Mass	3.39E+04	

Table 7.2.5 Summary of Monitored MCO Sampling

Time Yr	Sample No[1]	Est MCO press psia	Est Temp °C	Est MCO H_2 Vol %	Est MCO He Vol %	Est DP MCO w sampling Psi	Est H_2 lost (sampling six MCOs) kg	Est He lost (sampling six MCOs) kg
0.0	-	26.5	61	6.0	94.0	-	-	-
0.25	1B	26.6	61	6.3	93.7	1.0	9.38E-04	2.79E-02
0.25	1A	26.6	61	6.2	93.8	-	-	-
0.5	2B	26.7	61	6.3	93.7	1.0	9.39E-04	2.79E-02
0.5	2A	26.7	61	6.1	93.9	-		
0.75	3B	26.8	61	6.3	93.7	1.0	9.39E-04	2.79E-02
0.75	3A	26.8	61	6.1	93.9	-		
1.0	4B	26.8	61	6.3	93.7	1.0	9.39E-04	2.79E-02
1.0	4A	26.8	61	6.1	93.9	-		
Subtotal							3.76E-03	1.11E-01
1.25	5B	26.8	60	6.4	93.6	1.0	9.42E-04	2.80E-02
1.25	5A	26.8	60	6.1	93.9	-		
1.5	6B	26.8	60	6.3	93.7	1.0	9.42E-04	2.80E-02
1.5	6A	26.8	60	6.1	93.9	-		
1.75	7B	27.0	60	6.4	93.6	1.0	9.56E-04	2.80E-02
1.75	7A	27.0	60	6.2	93.8	-		
2.0	8B	27.0	60	6.4	93.6	1.0	9.56E-04	2.80E-02
2.0	8A	27.0	60	6.3	93.7	-		
Subtotal	-	-	-	-	-	-	3.80E-03	1.12E-01
Grand Total	-	-	-	-	-	-	7.56E-03	2.23E-01

1. B= Before sampling, A= After sampling with He refill to replace lost H_2 and He

Table 7.2.6 Estimated Data from Best Estimate Single Scrap Basket Case[1]

Time Yr	Est. MCO press w/o sampling[2] psia	Est. Avg. Fuel Temp °C	Est. H_2 vol %	Est. He vol %
0.0	25.1	61	6.0	94.0
0.5	25.1	61	6.6	93.4
1.0	25.4	61	7.0	93.0
1.5	25.6	60	7.5	92.5
2.0	25.7	60	8.0	92.0

1. Based on Duncan and Plys (1998) Page J-11
2. Based on scrap temperature

Mass balance calculations are listed below for Table 7.2.5.

SAMPLE 1B

Determine mass of H_2 in six monitored MCOs at 0.25 yr and no sampling/refill of MCO

0.063 = X H_2/(XH_2 + 31.0 He) based on Duncan and Plys (1998) and Pajunen (2000)

X= 0.063 x 31.0/0.937 = 2.084 gmol H_2/MCO

Pressure of MCO before sampling based on initial He fill of 31.0 gmol/MCO = (2.084 gmol H_2 + 31.0 gmol He = 33.08 gmol/MCO) x 0.082 atm L/gmol K x 334 K/(500 L/MCO) = 1.81 atm = **26.6 psia**

MCO/sample cart pressure after pressurizing sample cart assuming no temperature effects = (P1V1 + P2V2)/(V1+V2) = (26.6 psia x 500 L MCO + 14.7 psia x 46.4 L sample cart)/(500 L + 46.4 L) = 25.6 psia

DP = 26.6 psia –25.6 psia = **1 psia**

Mass H_2 lost from six monitored MCOs after sampling at 0.25 yr = 6 x DP x V x 0.063 H_2/RT = 6 MCOs x 1.0 psia x 500 L/MCO x 0.063 H_2/(14.7 psia/atm x 0.0820 L atm/gmol K x 334 K) x 0.001 kg/g = 4.69E-04 kg mol = **9.38E-04 kg**

Mass He lost from six monitored MCOs after sampling at 0.25 yr = 6 MCOs x DP x V x 0.937 He/RT = 6 MCOs x 1.0 psia x 500 L/MCO x 0.937 He/(14.7 psia/atm x 0.0820 L atm/gmol K x 334 K) x 0.001 kg/g = 6.98E-03 kg mol = **2.79E-02 kg**

SAMPLE 1A

Mass H_2 remaining inside six monitored MCOs after sampling at 0.25 yr = 2.084 gmol/MCO x 6 MCOs x 0.001 kg/g – 4.69E-04 kg mol lost = 1.203E-02 kg mol =2.40E-02 kg

Mass He remaining inside six monitored MCOs after sampling at 0.25 yr and before refill = 3.10E-02 kg mol/MCO x 6 MCOs – 6.98E-03 kg mol lost = 1.790E-01 kg mol = 7.161E-01 kg

Pressure in reinerted/monitored MCOs at 0.25 yr = nRT/V = (1.203E-02 kg mole H_2 remaining + 4.69E-04 kg mol from H_2 lost + 6.985E-03 kg mol He lost +1.790E-01 kg mol He remaining = 1.985E-01) x 0.0820 atm L/ gmol K x 334 K) x 1000 g/kg/(500 L/MCO x 6 MCOs) = 1.81 atm = **26.6 psia**

Mass of He inside six monitored MCOs after reinert at 0.25 yr = 4.69E-04 kg mol H_2 lost + 6.985E-03 kg mol He lost + 1.790 E-01 kg mol remaining = 1.864E-01 kg mol

Concentration of H_2 in reinerted MCO after sampling at 0.25 yr = 1.203E-02 kg mol x 100/(1.864E-01 kg mol He + 1.203E-02 kg mol H_2 = 1.985E-01 kg mol) = **6.2 vol %**

Concentration of He in reinerted MCO after sampling at 0.25 yr = 100 – 6.2 = **93.8%**

SAMPLE 2B

Determine mass of H_2 in six monitored MCOs at 0.5 yr and no sampling/He reinerting

0.066 = X H_2/(XH_2 + 31.0 He) based on Duncan and Plys (1998) and Pajunen (2000)

X = 0.066 x 31.0/ 0.937 = 2.183E+00 gmol H_2 /MCO

Amount H_2 in six monitored MCOs before sampling at 0.5 yr (sampling and after reinert at 0.25 yr) = 2.183 gmol/MCO x 6 MCOs x 0.001 kg/g - 4.69E-04 kg mol lost at 0.25 yr = 1.263E-02 kg mol

Concentration of hydrogen at 0.5 yr before sampling = 1.263E-02 kg mol H_2 x 100/(1.263E-02 kg mol H_2 + 1.864E-01 kg mol He = 1.990E-01) = **6.3 %**

Concentration of He at 0.5 yr before sampling = 100 – 6.3 = **93.7 %**

MCO Pressure at 0.5 yr before sampling = 1.990E-01 kg mol x 0.0820 L atm/ gmol K x 334 K x 1000 g/kg /(500 L/MCO x 6 MCOs) = 1.817 atm = **26.7 psia**

MCO/sample cart pressure after pressurizing sample cart assuming no temperature effects = (P1V1 +P2V2)/(V1+V2) = (26.7 psia x 500 L + 14.7 psia x 46.4 L)/(500 L + 46.4 L) = 25.7 psia

DP = 26.7 psia – 25.7 psia = **1.0 psia**

Mass H_2 lost from six monitored MCOs after sampling at 0.5 yr = 6 MCOs x DP x V x 0.063 H_2/RT = 6 MCOs x 1.0 psia x 500 L/MCO x 0.063/(14.7 psia/atm x 0.0820 L atm/gmol K x 334 K) x 0.001 kg/g = 4.69E-04 kg mol = **9.39E-04 kg**

Mass He lost from six monitored MCOs after sampling at 0.5 yr = 6 MCOs x DP x V x 0.937 He/RT = 6 MCOs x 1.0 psia x 500 L/MCO x 0.937 He/(14.7 psia/atm x 0.0820 L atm/gmol K x 334 K) x 0.001 kg/g = 6.982E-03 kg mol = **2.79E-02 kg**

SAMPLE 2A

Mass H_2 remaining in six monitored MCOs after sampling at 0.5 yr = 1.263E-02 kg mol – 4.69E-04 kg mol lost at 0.5 yr = 1.216 E-02 kg mol = 2.43E-02 kg

Mass He remaining in six monitored MCOs after sampling at 0.5 yr = 1.864E-01 kg mol – 6.982E-03 kg mol lost at 0.5 yr = 1.794E-01 kg mol = 7.18E-01 kg

Pressure in reinerted/monitored MCOs at 0.5 yr = nRT/V = (1.216E-02 kg mol H_2 remaining + 4.69E-04 kg mol from H_2 lost + 6.98E-03 kg mol He lost + 1.794E-01 kg mol He remaining = 1.990E-01) x 0.0820 atm L/ gmol K x 334 K) x 1000 g/kg/(500 L/MCO x 6 MCOs) = 1.82 atm = **26.7 psia**

Mass of He in six monitored MCOs after reinert at 0.5 yr = 1.794E-01 kg mol remaining + 6.982E-03 kg mol He lost + 4.69E-04 kg mol H_2 lost= 1.868E-01 kg mol

Concentration of H_2 in MCO at 0.5 yr after reinert = 1.216E-02 kg mol H_2 x 100/(1.216E-02 kg mol H_2 + 1.868E-01 kg mol He = 1.990E-01) = **6.1 vol %**

Concentration of He = 100 – 6.1 = **93.9 vol %**

SAMPLE 3B

Determine mass of H_2 in six monitored MCOs at 0.75 yr and no sampling/He reinerting

0.068 H_2 = X H_2/(X H_2 + 31.0 He) based on Duncan and Plys (1998) and Pajunen (2000)

X = 0.068 x 31.0/ 0.932 = 2.262E+00 gmol H_2/MCO w/o sampling and reinerting

Amount H_2 remaining in six monitored MCOs before sampling at 0.75 yr (sampling and refill at 0.5 yr) = 2.262E-03 gmol/MCO x 6 MCOs x 0.001 kg/g - 4.69E-04 kg mol lost at 0.25 yr - 4.69E-04 kg mol at 0.5 yr = 1.263E-02 kg mol

Concentration of hydrogen at 0.75 yr before sampling = 1.263E-02 kg mol H_2 x 100/(1.263E-02 kg mol H_2 + 1.868E-01 kg mol He = 1.994E-01) = **6.3 %**

Concentration of He at 0.75 yr before sampling = 100 – 6.3 = **93.7 %**

MCO Pressure at 0.75 yr before sampling = 1.994E-01 kg mol x 0.0820 L atm/gmol K x 334 K x 1000 g/kg/(500 L/MCO x 6 MCOs) = 1.82 atm = **26.8 psia**

MCO/sample cart pressure after pressurizing sample cart assuming no temperature effects = (P1V1 +P2V2)/(V1+V2) = (26.8 psia x 500 L + 14.7 psia x 46.4 L)/(500 L + 46.4 L) = 25.8 psia

DP = 26.8 psia – 25.8 psia = **1.0 psia**

Mass H_2 lost from six monitored MCOs after sampling at 0.75 yr = 6 MCOs x DP x V x 0.063 H_2/RT = 6 MCOs x 1.0 psia x 500 L/MCO x 0.063/(14.7 psia/atm x 0.0820 L atm/gmol K x 334 K) x 0.001 kg/g = 4.69E-04 kg mol = **9.39E-04 kg**

Mass He lost from six monitored MCOs after sampling at 0.75 yr = 6 MCOs x DP x V x 0.937 He/RT = 6 MCOs x 1.0 psia x 500 L x 0.937 He/(14.7 psia/atm x 0.0820 L atm/gmol K x 334 K) x 0.001 kg/g = 6.98E-03 kg mol = **2.79E-02 kg**

SAMPLE 3A

Mass H_2 remaining in six monitored MCOs after sampling at 0.75 yr = 1.263E-02 kg mol – 4.69E-04 kg mol at 0.75 yr = 1.216 E-02 kg mol =2.43E-02 kg

Mass He remaining in six monitored MCOs after sampling at 0.75 yr and before reinerting = 1.868E-01 kg mol – 6.98E-03 kg mol = 1.798E-01 kg mol

Mass He in reinerted MCOs after sampling and reinert at 0.75 yr = 1.798 E-01 kg mol remaining + 6.98E-03 kg mol He lost + 4.69E-04 kg mol H_2 lost = 1.872E-01 kg mol

Concentration of H_2 in MCO at 0.75 yr after reinerting = 1.216E-02 kg mol H_2 x 100/(1.216E-02 kg mol H_2 + 1.872E-01 kg mol He) = **6.1 vol %**

Concentration of He = 100 – 6.1 = **93.9 vol %**

Pressure in refilled/monitored MCOs at 0.75 yr = nRT/V = (1.216E-02 kg mol H_2 + 1.872E-01 kg mol He = 1.993E-01) x 0.0820 atm L/gmol K x 334 K) x 1000 g/kg/(500 L/MCO x 6 MCOs) = 1.82 atm = **26.8 psia**

SAMPLE 4B

Determine mass of H_2 in six monitored MCOs at 1.0 yr and no sampling/He reinerting

0.070 H_2 = X H_2/(X H_2 + 31.0 He) based on Duncan and Plys (1998) and Pajunen (2000)

X = 0.070 x 31.0/0.930 = 2.333E+00 gmol H_2/MCO w/o sampling and reinerting

Amount H_2 remaining in six monitored MCOs before sampling at 1.0 yr (sampling and reinert at 0.75 yr) = 2.333 gmol/MCO x 6 MCOs x 0.001 kg/g - 4.69E-04 kg mol lost at 0.25 yr - 4.69E-04 kg mol lost at 0.5 yr - 4.69E-04 kg mol lost at 0.75 yr = 1.259E-02 kg mol

Concentration of hydrogen at 1.0 yr and before sampling = 1.259E-02 kg mol H_2 x 100/(1.259E-02 kg mol H_2 + 1.872E-01 kg mol He = 1.998E-01) = **6.3 %**

Concentration of He at 0.75 yr before sampling = 100 – 6.3= **93.7 %**

MCO pressure at 1.0 yr before sampling = 1.998E-01 kg mol x 0.0820 L atm/gmol K x 334 K x 1000 g/kg /(500 L/MCO x 6 MCOs) = 1.82 atm = **26.8 psia**

MCO/sample cart pressure after pressurizing sample cart = (P1V1 + P2V2)/(V1+V2) = (26.8 psia x 500 L + 14.7 psia x 46.4 L)/(500 L + 46.4 L) = 25.8 psia

DP = 26.8 psia – 25.8 psia = **1.0 psia**

Mass H_2 lost from six monitored MCOs after sampling at 1.0 yr = 6 MCOs x DP x V x 0.063 x H_2/RT = 6 MCOs x 1.0 psia x 500 L/MCO x 0.063/(14.7 psia/atm x 0.0820 L atm/gmol K x 334 K) x 0.001 kg/g = 4.69E-04 kg mol = **9.39E-04 kg**

Mass He lost from six monitored MCOs after sampling at 1.0 yr = 6 x DP x V x 0.937 He/RT = 6 MCOs x 1.0 psia x 500 L/MCO x 0.937 He/(14.7 psia/atm x 0.0820 L atm/gmol K x 334 K) x 0.001 kg/g = 6.98E-03 kg mol = **2.79E-02 kg**

SAMPLE 4A

Mass H_2 remaining in six monitored MCOs after sampling at 1.0 yr = 1.259E-02 kg mol – 4.69E-04 kg mol at 1.0 yr = 1.212E-02 kg mol =2.42E-02 kg

Mass He remaining in six monitored MCOs after sampling at 1.0 yr and before reinerting = 1.872E-01 kg mol – 6.98E-03 kg mol = 1.802E-01 kg mol

Mass He in reinerted MCOs after sampling and reinerting at 1.0 yr = 1.802E-01 kg mol *remaining + 6.98E-03 kg mol He lost + 4.69E-04 kg mol H_2 lost = 1.876E-01 kg mol*

Concentration of H_2 in MCO at 1.0 yr and after He reinerting = 1.212E-02 kg mol H_2 x 100/(1.212E-02 kg mol H_2 + 1.876E-01 kg mol He = 1.997E-01 kg mol) = **6.1 vol %**

Concentration of He in MCO at 1 yr and after He reinert = 100 – 6.1 = **93.9 vol %**

Pressure inside MCOs at 1.0 yr and after He reinert = 1.997E-01 kg mol x 0.0820 atm L/gmol K x 334 K) x 1000 g/kg /(500 L/MCO x 6 MCOs) = 1.82 atm = **26.8 psia**

SAMPLE 5B

Determine mass of H_2 in six monitored MCOs at 1.25 yr and no sampling/He reinerting

0.073 H_2 = X H_2/(X H_2 + 31.0 He) based on Duncan and Plys (1998) and Pajunen (2000)

X H_2 = 0.073 x 31.0/0.927 = 2.441E+00 gmol H_2/MCO w/o sampling and reinerting

Amount of H_2 in six monitored MCOs before sampling at 1.25 yr (sampling and reinerting at 1.0 yr) = 2.441 gmol/MCO x 6 MCOs x 0.001 kg/g – 4.69E-04 kg mol/sample event x 4 sample events = 1.277E-02 kg mol

Concentration of H_2 at 1.25 yr and before sampling = 1.277E-02 kg mol x 100/(1.277E-02 kg mol H_2 + 0.1876 kg mol He = 2.00E-01) = **6.4 vol %**

Concentration of He at 1.25 yr and before sampling = 100 – 6.4 = **93.7 vol %**

MCO pressure at 1.25 yr before sampling = 2.00E-01 x 0.0820 atm L/gmol K x 333 K) x 1000 g/kg/(500 L/MCO x 6 MCOs) = 1.82 atm = **26.8 psia**

MCO/sample cart pressure after pressurizing sample cart = (P1V1 + P2V2)/(V1+V2) = (26.8 psia x 500 L + 14.7 psia x 46.4 L)/(500 L + 46.4 L) = 25.8 psia

DP = 26.8 psia – 25.8 psia = **1 psia**

Mass H_2 lost from six monitored MCOs after sampling at 1.25 yr = 6 MCOs x DP x V x 0.064 H_2/RT = 6 MCOs x 1.0 psia x 500 L/MCO x 0.063 H_2/(14.7 psia/atm x 0.082 L atm/ gmol K x 333 K) x 0.001 kg/g = 4.71 E-04 kg mol = **9.42E-04 kg**

Mass He lost from six monitored MCOs after sampling at 1.25 yr = 6 MCOs x DP x V x 0.936 H_2/RT = 6 MCOs x 1.0 psia x 500 L/MCO x 0.937 H_2/(14.7 psia/atm x 0.082 L atm/ gmol K x 333 K) x 0.001 kg/g = 7.00E-03 kg mol = **2.80E-02 kg**

SAMPLE 5A

Mass H_2 remaining in six monitored MCOs after sampling at 1.25 yr = 1.277E-02 kg mol – 4.71E-04 kg mol = 1.23E-02 kg mol

Mass He remaining in six monitored MCOs after sampling at 1.25 yr and before reinerting = 0.1876 kg mol – 7.00E-03 kg mol lost = 1.806E-01 kg mol

Mass He in reinerted MCOs after sampling and reinerting at 1.25 yr = 1.806E-01 kg mol remaining + 7.00E-03 kg mol He lost + 4.71E-04 kg mol as H_2 lost = 1.881E-01 kg mol

Concentration of H_2 in MCO at 1.25 yr and after He reinerting = 1.23E-02 kg mol x 100/(1.23E-02 kg mol H_2 +1.881E-01 kg mol He = 2.00E-01) = **6.1 vol %**

Concentration of He = 100 – 6.1 = **93.9 vol %**

Pressure inside MCOs at 1.25 yr and after He reinerting = 2.00E-01 kg mol x 0.0820 atm L/gmol K x 333 K/(500 L/MCO x 6 MCOs) x 1000 g/kg = 1.82 atm = **26.8 psia**

SAMPLE 6B

Determine mass of H_2 in six monitored MCOs at 1.5 yr and no sampling/He reinerting

0.075 = X H_2/(X H_2 + 31.0 He) based on Duncan and Plys (1998) and Pajunen (2000)

X = 0.075 x 31.0/0.925 = 2.513 gmol/MCO without sampling and reinerting

Amount H_2 remaining in six monitored MCOs before sampling at 1.5 yr (sampling and reinerting at 1.25 yr) = 2.513 gmol/MCO x 6 MCOs x 0.001 kg/g – 4.69E-04 kg mol x 4 sampling events – 4.71E-04 kg mol at 1.25 yr = 1.273E-02 kg mol

Concentration of H_2 at 1.5 yr before sampling = 1.273E-02 kg mol x 100/(1.273E-02 kg mol H_2 + 1.881E-01 kg mol He = 2.00E-01) = **6.3 vol %**

Concentration of He = 100 – 6.3 = **93.7 vol %**

MCO pressure at 1.5 yr before sampling = 2.00E-01 kg mol x 0.082 L atm/gmol K x 333 K x 1000 g/gmol/(500 L/MCO x 6 MCOs) = 1.82 atm = **26.8 psia**

MCO/sample cart pressure after pressurizing sample cart assuming no temperature effects = (P1V1 + P2V2)/(V1+V2) = (26.8 psia x 500 L + 14.7 psia x 46.4 L)/(500 L + 46.4 L) = 25.8 psia

DP = 26.8 psia – 25.8 psia = **1 psia**

Mass H_2 lost from six monitored MCOs after sampling at 1.5 yr = 6 MCOs x DP x V x 0.063 H_2/RT = 6 MCOs x 1.0 psia x 500 L/MCO x 0.063 H_2/(14.7 psia/atm x 0.082 L atm/gmol K x 333 K) x 0.001 kg/g = 4.71E-04 kg mol = **9.42E-04 kg**

Mass He lost from six monitored MCOs after sampling at 1.5 yr = 6 MCOs x DP x V x 0.937H_2/RT = 6 MCOs x 1.0 psia x 500 L/MCO x 0.937 H_2/(14.7 psia/atm x 0.082 L atm/gmol K x 333 K) x 0.001 kg/g = 7.00E-03 kg mol = **2.80E-02 kg**

SAMPLE 6A

Mass H_2 remaining in six monitored MCOs after sampling at 1.5 yr and before reinerting = 1.273E-02 kg mol - 4.71E-04 kg mol lost = 1.226E-02 kg mol

Mass He remaining in six monitored MCOs after sampling at 1.5 yr and before reinerting = 1.881E-01 kg mol – 7.00E-03 kg mol lost = 1.811E-01 kg mol

Mass He in refill MCOs after sampling and reinerting at 1.5 yr = 1.811E-01 He remaining + 7.00E-03 kg mol He lost + 4.71E-04 kg mol lost as H_2 = 1.886E-01 kg mol

Concentration of H_2 in MCO at 1.5 yr and after He reinerting = 1.226E-02 kg mol x 100/(1.226E-02 kg mol H_2 + 1.886E-01 kg mol He = 2.00E-01) = **6.1 vol %**

Concentration of He = 100 – 6.1 = **93.9 vol %**

Pressure inside MCOs at 1.5 yr after reinerting = 2.00E-01 kg mol x 0.0820 L atm/gmol K x 333 K)/(500 L/MCO x 6 MCOs) x 1000 g/kg = 1.782 atm = **26.8 psia**

SAMPLE 7B

Determine mass of H_2 in six monitored MCOs at 1.75 yr and no sampling/He reinerting

0.078 = X H_2/(X H_2+31.0 He) based on Duncan and Plys (1998) and Pajunen (2000)

X = 0.078 x 31.0/0.922 = 2.622 gmol/MCO without sampling and reinerting

Amount H_2 remaining in six monitored MCOs before sampling at 1.75 yr (sampling and reinerting at 1.5 yr) = 2.622 gmol x 6 MCOs x 0.001 kg/g – 4.69E-04 kg mol x 4 sampling events – 4.71E-04 kg mol at 1.25 yr – 4.71E-04 kg mol at 1.5 yr = 1.291E-02 kg mol

Concentration of H_2 at 1.75 yr and before sampling = 1.291E-02 kg mol x 100/(1.291E-02 kg mol +1.886E-01 kg mol He = 2.015E-01) = **6.4 vol %**

Concentration of He at 1.75 yr and before sampling = 100 – 6.4 = **93.6 vol %**

MCO pressure at 1.75 yr before sampling = 2.015E-01 kg mol x 0.0820 L atm/gmol K x 333 K/(500 L/MCO x 6 MCOs x 1000 g/kg = 1.83 atm = **27.0 psia**

MCO/sample cart pressure after pressurizing sample cart assuming no temperature effects = (P1V1 + P2V2)/(V1+V2) = (27.0 psia x 500 L + 14.7 psia x 46.4 L)/(500 L + 46.4 L) = 26.0 psia

DP = 27.0 psia – 26.0 psia = **1 psia**

Mass H_2 lost from six monitored MCOs after sampling at 1.5 yr = 6 MCOs x DP x V x 0.064 H_2/RT = 6 MCOs x 1.0 psia x 500 L/MCO x 0.064 H_2/(14.7 psia/atm x 0.082 L atm/gmol K x 333 K) x 0.001 kg/g = 4.78E-04 kg mol = **9.56E-04 kg**

Mass He lost from six monitored MCOs after sampling at 1.5 yr = 6 MCOs x DP x V x 0.936H_2/RT = 6 MCOs x 1.0 psia x 500 L/MCO x 0.936 H_2/(14.7 psia/atm x 0.082 L atm/gmol K x 333 K) x 0.001 kg/g = 7.00E-03 kg mol = **2.80E-02 kg**

SAMPLE 7A

Mass H_2 remaining in six monitored MCOs after sampling at 1.75 yr and before reinerting = 1.291E-02 kg mol - 4.78E-04 kg mol lost = 1.243E-02 kg mol

Mass He remaining in six monitored MCOs after sampling at 1.75 yr and before reinerting = 1.886E-01 kg mol – 7.00E-03 kg mol lost = 1.816E-01 kg mol

Mass He in refill MCOs after sampling and reinerting at 1.75 yr = 1.816E-01 kg mol He remaining + 7.00E-03 kg mol He lost + 4.78E-04 kg mol lost as H_2 = 1.891E-01 kg mol

Concentration of H_2 in MCO at 1.75 yr and after He reinerting = 1.243E-02 kg mol x 100/(1.243E-02 kg mol H_2 + 1.891E-01 kg mol He = 2.015E-01) = **6.2 vol %**

Concentration of He at 1.75 yr and after He fill = 100 – 6.2 = **93.8 vol %**

Pressure inside MCO at 1.75 yr and after He refill = 2.015E-01 kg mol x 0.082 L atm/gmol K x 333 K x 1000 g/kg/(500 L/MCO x 6 MCOs) = 1.83 atm = **27.0 psia**

SAMPLE 8B

Determine mass of H_2 in six monitored MCOs at 2.0 yr and no sampling/He reinerting

0.080 = X H_2/(X H_2+31.0 He) based on Duncan and Plys (1998) and Pajunen (2000)

X = 0.080 x 31.0/0.920 = 2.696 gmol H_2/MCO without sampling and reinerting

Amount H_2 remaining in six monitored MCOs before sampling at 2.0 yr (sampling and reinerting at 1.5 yr) = 2.696 gmol x 6 MCOs x 0.001 kg/g – 4.69E-04 kg mol x 4 sampling events – 4.71E-04 kg mol at 1.25 yr – 4.71E-04 kg mol at 1.5 yr – 4.78E-04 kg mol at 1.75 yr = 1.288E-02 kg mol

Concentration of H_2 at 2.0 yr and before sampling = 1.288E-02 kg mol x 100/(1.288E-02 kg mol +1.891E-01 kg mol He = 2.02E-01) = **6.4 vol %**

Concentration of He at 2.0 yr and before sampling = 100 – 6.4 = 93.6 vol % He

MCO pressure at 2.0 yr before sampling = 2.02E-01 kg mol x 0.0820 L atm/gmol K x 333 K/(500 L/MCO x 6 MCOs x 1000 g/kg = 1.84 atm = **27.0 psia**

MCO/sample cart pressure after pressurizing sample cart assuming no temperature effects = (P1V1 + P2V2)/(V1+V2) = (27.0 psia x 500 L + 14.7 psia x 46.4 L)/(500 L + 46.4 L) = 26.0 psia

DP = 27.0 psia – 26.0 psia = **1 psia**

Mass H_2 lost from six monitored MCOs after sampling at 2.0 yr = 6 MCOs x DP x V x 0.064 H_2/RT = 6 MCOs x 1.0 psia x 500 L/MCO x 0.063 H_2/(14.7 psia/atm x 0.082 L atm/gmol K x 333 K) x 0.001 kg/g = 4.71E-04 kg mol = **9.56E-04 kg**

Mass He lost from six monitored MCOs after sampling at 2.0 yr = 6 MCOs x DP x V x 0.936 H_2/RT = 6 MCOs x 1.0 psia x 500 L/MCO x 0.936 H_2/(14.7 psia/atm x 0.082 L atm/gmol K x 333 K) x 0.001 kg/g = 7.00E-03 kg mol = **2.80E-02 kg**

SAMPLE 8A

Mass H_2 remaining in six monitored MCOs after sampling at 2.0 yr and before reinerting = 1.288E-02 kg mol - 4.71E-04 kg mol lost = 1.283E-02 kg mol = 2.57E-02 kg

Mass He remaining in six monitored MCOs after sampling at 2.0 yr and before reinerting = 1.891E-01 kg mol – 7.00E-03 kg mol lost = 1.821E-01 kg mol

Mass He in reinerted MCOs after sampling and reinerting at 2.0 yr = 1.821 E-01 kg mol He remaining + 7.00E-03 kg mol He lost + 4.71E-04 kg mol lost as H_2 = 1.896E-01 kg mol = 7.58E-01 kg

Concentration of H_2 in MCO at 2.0 yr and after He reinerting = 1.283E-02 kg mol x 100/(1.283E-02 kg mol H_2 + 1.896E-01 kg mol He = 2.024E-01) = **6.3 vol %**

Concentration of He at 2.0 yr and after He reinerting = 100 – 6.3 = **93.7 vol %**

Pressure inside MCO at 2.0 yr and after He reinerting = 2.024E-01 kg mol x 0.082 L atm/gmol K x 333 K x 1000 g/kg/(500 L /MCO x 6 MCOs) = 1.84 atm = **27.0 psia** = **1400** torr

Determine Estimated Hydrated Oxide Radiolysis and Remaining Amount of Free Water in Monitored MCOs at 2 Years

Based on adjusted approximations from sections 5.5.1 and 5.5.2 of Duncan and Plys (1998), assume 0.005 % of $Al(OH)_3$ and 6.0 % of $UO_2(OH)_2$ are decomposed by radiation to Al_2O_3, UO_3, and hydrogen during the two years of MCO monitoring (private communication with A. L. Pajunen of Fluor Hanford). This approximation gives a larger free water inside the MCO since a small amount of hydrogen is produced by radiolysis of the bound (hydrated oxide) water. The oxygen is gettered by reaction with uranium metal to form additional UO_2.

Determine amount of Al_2O_3, UO_2, and hydrogen produced by radiolytic decomposition of $Al(OH)_3$ in six monitored MCOs (hydrogen included in above estimates as part of overall hydrogen generation from modeling in Duncan and Plys (1998)):

$2Al(OH)_3 \rightarrow Al_2O_3 + 3H_2O \rightarrow Al_2O_3 + 3H_2 + 1.5O_2$

$1.5\ O_2 + 1.5U \rightarrow 1.5UO_2$ (gettering)

4.15 kg $Al(OH)_3$/78 g/gmol → 0.995 x 4.15 kg $Al(OH)_3$ + 0.005 x 4.15 kg $Al(OH)_3$/(78 g/gmol) x 1 gmol Al_2O_3/2 gmol $Al(OH)_3$ x 102 g Al_2O_3/gmol (kg Al_2O_3) + 0.005 x 4.15 kg $Al(OH)_3$/(78 g/gmol) x 3 gmol H_2/2 gmol x 2g H_2/gmol (kg H_2) + 1.5 gmol O_2 or UO_2/2 gmol $Al(OH)_3$ x 0.005 x 4.15 kg $Al(OH)_3$/(78 g/gmol)

Remaining $Al(OH)_3$ = 0.995 x 4.15 kg = **4.13 kg** or 6.88E-01 kg/MCO

Amount Al_2O_3 produced = 0.005 x 4.15 kg $Al(OH)_3$/(78 g/gmol) x 1 gmol Al_2O_3/2 gmol $Al(OH)_3$ x 102 g Al_2O_3/gmol = **1.35E-02 kg** or 2.26E-03 kg/MCO

Amount hydrogen produced = 0.005 x 4.15 kg $Al(OH)_3$ /(78 g/gmol) x 3 gmol H_2/ 2 gmol $Al(OH)_3$ x 2 g H_2/gmol = **7.98E-04 kg H_2** or 1.33E-04 kg H_2/MCO

Amount of new UO_2 produced = 0.005 x 4.15 kg $Al(OH)_3$/(78 g/gmol) x 1.5 gmol UO_2/2 gmol $Al(OH)_3$ x 270 g UO_2/gmol = **5.39E-02 kg UO_2** or 8.98E-03 kg/MCO

Determine amount of UO_3, UO_2, and hydrogen produced at two years by radiolytic decomposition of $UO_2(OH)_2$ in six monitored MCOs (hydrogen included in above estimates as part of overall hydrogen generation from modeling in Duncan and Plys (1998)):

$UO_2(OH)_2 \rightarrow UO_3 + H_2O \rightarrow UO_3 + H_2 + 0.5\ O_2$

$O_2 + U \rightarrow UO_2$

14.5 kg $UO_2(OH)_2$/304 g/gmol → 0.94 x 14.5 kg $UO_2(OH)_2$ + 0.06 x 14.5 kg $UO_2(OH)_2$/304 g/gmol x 1 gmol UO_3/gmol $UO_2(OH)_2$ x 286 g UO_3/gmol (kg UO_3) + 0.06 x 14.5 kg $UO_2(OH)_2$/304 g/gmol x 1 gmol H_2/gmol $UO_2(OH)_2$ x 2 g H_2/gmol (kg H_2) + 0.06 x 14.5 kg $UO_2(OH)_2$/304 g/gmol x 0.5 gmol O_2/gmol $UO_2(OH)_2$ x 1 gmol UO_2/gmol O_2 x 270 g UO_2/gmol

Remaining $UO_2(OH)_2$ = 0.94 x 14.5 kg = **1.36E+01 kg** or 2.27E+00 kg/MCO

Amount UO_3 produced = 0.06 x 14.5 kg $UO_2(OH)_2$/304 g/gmol x 1 gmol UO_3/gmol $UO_2(OH)_2$ x 286 g/gmol UO_3 = **8.18E-01 kg** or 1.36E-01 kg/MCO

Amount of UO_2 produced = 0.06 x 14.5 kg $UO_2(OH)_2$/304 g/gmol x 0.5 gmol O_2/gmol $UO_2(OH)_2$ x 1 gmol UO_2/gmol O_2 x 270 g UO_2/gmol = **3.86E-01 kg** or 6.44E-02 kg/MCO

Total UO_2 in 6 monitored MCOs = 1.90E+00 kg (C-7) + 5.4E-02 kg + 3.86E-01 kg = 2.34E+00 kg or 3.90E-01 kg/MCO

Amount hydrogen produced = 0.06 x 14.5 kg $UO_2(OH)_2$/304 g/gmol x 1 gmol H_2/gmol $UO_2(OH)_2$ x 2 g H_2/gmol = **5.72E-03 kg**

Total hydrogen produced from radiolysis of $Al(OH)_3$ and $UO_2(OH)_2$ in six monitored MCOs = 7.98E-04 kg + 5.72E-03 kg = **6.51E-03 kg** = 3.26E-03 kg mol

Total hydrogen produced/monitored MCO from radiolysis of $Al(OH)_3$ and $UO_2(OH)_2$ = 6.51E-03 kg/6 MCOs = 1.09E-03 kg = **5.43E-04 kg mol**

Determine hydrated oxide water resulting from decomposition of $Al(OH)_3$ and $UO_2(OH)_2$

Free water/MCO at time zero based on 6.0 vol % H_2 = 1.64E+02 g = 9.11E+00 gmol (see Stream IC 003)

Amount of H_2/MCO at time zero = **1.978E+00** gmol H_2/MCO (See Stream IC-003)

Amount of H_2/MCO at two yr w/o sampling (assume the same amount H_2 produced with sampling) = **2.696E+00** gmol H_2/MCO (See 8B)

Change of H_2 from time zero to two yr with correction for decomposition of hydrated oxides = 2.696E+00 –1.978E+00 – 5.43E-01 gmol = **1.75E-01 gmol H_2/MCO**

Determine amount of free water equivalent to change of H_2 value

$H_20 \rightarrow H_2 + 0.5O_2$

1.75E-01 gmol H_2 x 1 gmol H_20/gmol H_2 x 18 g H_20/gmol = **3.15E+00** g H_2O/MCO

Water remaining/monitored MCO at 2 yr = 1.64E+02 – **3.15E+00** = 1.61E+02 g

Water remaining in six monitored MCOs = 1.61E+02 g/MCO x 6 MCOs = 9.66E+02 g = **9.66E-01 kg**

7.2.13 C-13 Monitored MCOs to Welding

Assume same composition and number of MCOs as Stream C-12. See Stream C-52 for composition after venting, 100 psi pressure unit replacement, and helium reinerting.

7.2.14 C-14 MCOs to Welding

Sum of Stream C-6 for the 392 MCOs going directly to welding and Stream C-52 for the six monitored MCOs at 2 yr.

7.2.15 C-15 MCOs to Canister Cover Cap Welding

Optional leak test results in no change of MCO composition. MCO composition same as Stream C-14.

7.2.16 C-16 Argon Welding Gas Supply

Argon is supplied from cylinders as the cover gas for welding of the MCO cover caps and cover plate welds. Assume the following conditions:

- four weld passes per MCO for the cover cap weld and two weld passes per MCO for the cover plate weld(private communication with T. A. Delucchi of COGEMA)
- an argon cover gas usage rate of 40 standard ft^3/hr for each cover cap weld and 20 standard ft^3/hr for each cover plate weld (private communication with T. A. Delucchi of COGEMA)
- a 0.5 hr/pass welding rate for both the cover cap and cover plate (private communication with T. A. Delucchi of COGEMA)
- 1 ½% of MCOs (0.015 x 398 = 6 MCOs) experience a cover cap weld test failure and no MCOs experience a cover plate weld test failure based on dye penetrant test (private communication with T. A. Delucchi of COGEMA)
- failed cover cap rewelding is 2.5 cm (1 in)/weld failed MCO (private communication with T. A. Delucchi of COGEMA)

Volume of argon gas = (40 ft^3/hr x 0.5 hr/pass x 4 passes/MCO cover cap + 20 ft^3/h x 0.5 hr/pass x 2 passes/MCO cover plate) x 398 MCOs = 3.98E+04 std ft^3 = **1.13E+03 std m^3**

Mass of argon gas = 3.98E+04 ft^3 x 28.3 L/ft^3 x 273 K/288 K x gmol/22.4 L x 39.94 g/gmol = **1.90E+03 kg**

7.2.17 C-17 Deleted

7.2.18 C-18 Deleted

7.2.19 C-19 MCO Welding/Grinding Waste

Assume the following:

- mass of welding waste (beads and wire fragments) is 0.2 g/weld (private communication with T. A. Delucchi of COGEMA)
- one spool of weld wire [4 in dia x 2.0 in high, 2.0 lb initial total wt, and 0.35 lb final weight (2.0-1.65 lb = 160 g weld wire)] is used per MCO cover cap weld (private communication with T. A. Delucchi of COGEMA)
- 4.5 weld rods (1/16 in dia x 36 in long) are used for each cover plate weld; 6 in lengths of weld rod (2.33 g/rod) result as waste (private communication with T. A. Delucchi of COGEMA)
- 1 ½% of MCOs (6 total) have a failed weld section (1 in long) based on dye penetrant test and require grinding and rewelding; grinding and rewelding waste = 4.0 g per failed MCO weld (private communication with T. A. Delucchi of COGEMA)
- Welding beads, weld wire, weld rod, and weld grinding waste is steel with a density of 7.89 g/cc. Spool is fabricated from plastic (private communication with T. A. Delucchi of COGEMA)
- The Port # 2 cover plate (5.5 in dia x 1.0 in) and 4 bolts (2.9 in long x 0.49 in dia) of the MCO shield plug are removed before welding of the cover cap in order to allow future access to the sample valve (Smith 1999, H-2-828048, Rev. 3, and private conversation with L. H. Goldmann of Fluor Hanford). Assume cover plate and bolts discarded to waste.
- The 100 psi pressure sending unit (3 in dia x 2 in high and 2.5 lb) and readout unit (2.75 in dia x 1 in high and 0.5 lb) in Port #1 of shield plug of monitored MCOs is replaced with a 600 psi sending unit before welding cover cap. The 100 psi pressure units are discarded to solid waste. Pressure unit size is based on private communication with D. G. Douglas of Vista Research Inc.

Mass of welding waste = 0.2 g/weld x 6 welds/MCO x 398 MCOs = **478 g**
Mass of weld wire/rod waste = (160 g unused wire + 10 g unused weld rod/MCO) x 398 MCOs = 6.77E+05 g = **6.77E+01 kg**
Mass weld spool waste = 60 g plastic spool/MCO x 398 MCOs = **2.39E+01 kg**
Volume of weld spool waste = (4 in dia x 2 in high = 412 cc/MCO) x 398 MCOs = 1.64E+05 cc = **1.64E-01 m^3**.
Volume unused weld rod = 1/16 in dia x 6.0 in long x 4.5 rods/MCO x 398 MCOs = 33 in^3 = **5.43E-04 m^3**
Volume of cover plate = 5.5 in dia x 1 in x 398 MCOs = 9.45+03 in^3 = **1.55E-01 m^3**
Volume of bolts = 0.49 in dia x 2.9 in long x 4 bolts/MCO x 398 MCOs = 8.70E+02 in^3 = **1.43E-02 m^3**
Volume of 100 psi pressure sending units = 3 in dia x 2 in high/MCO x 6 MCOs = 85 in^3 = 1.39E-03 m^3
Grinding and reweld waste mass = 4.0 g/failed MCO weld x 6 failed MCO welds = **24 g**
Mass of cover plate = 7.0 lb/MCO x 398 MCOs x 454 g/lb x 0.001 kg/g = **1.26E+03 kg**
Mass of cover plate bolts = 1.29E-01 lb/bolt x 4 bolts/MCO x 398 MCOs x 454 g/lb x 0.001 kg/g = **9.32E+01 kg**

Volume of 100 psi pressure readout units = 2.75 in dia x 1 in high x 6 MCOs = 36 in^3 = 5.84E-04m^3
Mass of 100 psi pressure sending units = 2.5 lb/MCO x 6 MCOs x 4545/lb x .001 kg/g = 6.81 kg
Mass of 100 psi readout units = 0.5 lb/MCO x 6 MCOs = 3.0 lb = 1.4 kg
Welding waste mass steel = 0.48 kg + 67.7 kg + 0.024 kg = **6.82E+01 kg**
Mass MCO cover plate/bolts = 1.26E+03 kg + 9.32E+01 kg = **1.35E+03 kg**
Mass plastic weld spool = **2.39E+01 kg**
Waste mass total = 68.2 kg + 1.35E+03 + 23.9 kg +6.8 kg + 1.4 kg = **1.45E+03 kg**
Waste volume = 1.64E-01 m^3 + 5.43E-04 m^3 + 1.55E-01 m^3 + 1.43E-02 m^3 + 1.39E-03 m^3 + 5.84E-04m^3= **3.35E-01 m^3**
Average density = 1.45E+03 kg/3.35E-01m^3 = 4.33E+03 kg/m^3 = 4.33 g/cc

7.2.20 C-20 MCO Weld Preparation and Examination Waste

Assume 2 kg/MCO of solid waste from weld preparation and examination. Assume there will be no liquid. Solid waste density is assumed as 0.6 g/cc before and after use.

Total solid mass = 2 kg/MCO x 398 MCOs = **796 kg**
Total solid volume = 796 kg/0.6E03 kg/m^3 = **1.33 m^3**

7.2.21 C-21 Welded MCO to Interim Storage

There is no change within the MCOs during welding. Before removal of the weld sealed MCO from the weld station, a magnetic pressure readout unit is installed in the cover cap of all 398 MCOs. The sludge content of the 392 MCOs from direct welding and six monitored MCOs has been adjusted to two yr of interim storage. This adjustment is based on radiolysis of the hydrated oxide (See Stream C-12 for description of radiolysis) and helium reinerting. The below calculations are for the 392 MCOs going directly to welding. Total for Stream C-21 is sum of Stream C-52 for six monitored MCOs and below calculations for 392 direct welded MCOs.

Remaining $Al(OH)_3$ = 0.995 x 271 kg = **269.5 kg** or 6.88E-01 kg/MCO

Amount Al_2O_3 produced = 0.005 x 271 kg $Al(OH)_3$/(78 g/gmol) x 1 gmol Al_2O_3/2 gmol $Al(OH)_3$ x 102 g Al_2O_3/gmol = **8.86E-01 kg** or 2.26E-03 kg/MCO

Amount hydrogen produced = 0.005 x 271 kg $Al(OH)_3$/(78 g/gmol) x 3 gmol H_2/2 gmol $Al(OH)_3$ x 2 g H_2/gmol = **5.21E-02 kg H_2** or 1.33E-04 kg H_2/MCO

Amount of new UO_2 produced = .005 x 271 kg $Al(OH)_3$/(78 g/gmol) x 1.5 gmol UO_2/2 gmol $Al(OH)_3$ x 270 g UO_2/gmol = **3.52E+00 kg UO_2** or 8.98E-03 kg/MCO

Remaining $UO_2(OH)_2$ = 0.94 x 948 kg = **8.91E+02 kg** or 2.27E+00 kg/MCO

Amount UO_3 produced = 0.06 x 948 kg $UO_2(OH)_2$/304 g/gmol x 1 gmol UO_3/gmol $UO_2(OH)_2$ x 286 g/gmol UO_3 = **5.31E+01 kg** or 1.36E-01 kg/MCO

$Fe(OH)_3$	=	2.75E+01 kg	same as Stream C-6
UH_3	=	3.72E+02 kg	same as Stream C-6
$UO_4{\cdot}4H_2O$	=	0.00E+00 kg	same as Stream C-6
$UO_4{\cdot}2H_2O$	=	9.45E+02 kg	same as Stream C-6

Amount of new UO_2 produced = 0.06 x 948 kg $UO_2(OH)_2$/304 g/gmol x 0.5 gmol O_2/gmol $UO_2(OH)_2$ x 1 gmol UO_2/gmol O_2 x 270 g UO_2/gmol = **2.52E+01 kg** or 6.44E-02 kg/MCO

Total UO_2 in 392 MCOs = 1.24E+02 kg (C-6) + 3.5E+00 kg + 2.52E+01 kg = **1.53E+02 kg** or 3.90E+01 kg/MCO

Amount hydrogen produced = 0.06 x 948 kg $UO_2(OH)_2$/304 g/gmol x 1 gmol H_2/gmol $UO_2(OH)_2$ x 2 g H_2/gmol = **3.74E-01 kg**

Total hydrogen produced from radiolysis of $Al(OH)_3$ and $UO_2(OH)_2$ in 392 direct welded MCOs = 5.21E-02 kg + 3.74E-01 kg = **4.26E-01 kg** = 2.13E-01 kg mol

Total hydrogen produced/direct welded MCO from radiolysis of $Al(OH)_3$ and $UO_2(OH)_2$ = 4.26E-01 kg/392 MCOs = 1.09E-03 kg = **5.43E-04 kg mol**

Determine hydrated oxide water resulting from decomposition of $Al(OH)_3$ and $UO_2(OH)_2$

Free water/MCO at time zero based on 6.0 vol % H_2 = 1.64E+02 g = 9.11E+00 gmol (see Stream IC-003)

Amount of H_2/MCO at time zero = **1.978E+00** gmol H_2/MCO (See Stream IC-003)

Amount of H_2/MCO at two yr = 0.08 x 31.0/0.92 = **2.696E+00** gmol H_2/MCO based on Duncan and Plys (1998) and Pajunen (2000)

Change of H_2 from time zero to two years with correction for decomposition of hydrated oxides = 2.696E+00 gmol–1.978E+00 gmol – 5.43E-01 gmol= **1.75E-01 gmol H_2**/MCO

Determine amount of free water equivalent to change of H_2 value

1.75E-01 gmol H_2 x 1 gmol H_20/gmol H_2 x 18 g H_20/gmol = **3.15E+00** g H_2O/MCO

Water remaining/direct welded MCO at 2 yr = 1.64E+02 – **3.15E+00** = 1.61E+02 g

Water remaining in 392 direct welded MCOs = 1.61E+02 g/MCO x 392 MCOs = 6.31E+04 g = **6.31E+01 kg**

Amount of hydrogen at two yr in 392 MCOs = 2.696 gmol/MCO x 392 MCOs x 2 g/gmol x 0.001 kg/g = 2.11E+00 kg

Pressure of welded MCOs = nRT/V = (2.696 gmol H_2 + 31.0 gmol He) x 0.082 L atm/gmol K x 333 K/500 L = 1.84 atm = 27.0 psia = 1400 torr

7.2.22 C-22 He Gas Supply

Helium gas is supplied for the following operations: back gas during welding, weld testing, sample cart equipment/hose purging, sample cart pressure decay test, dilution of the MCO internal gas when released to the exhaust system, MCO reinerting (sampling and pressure unit replacement for monitored MCOs), and inerting of the MCO over pack storage tube(s). Assume the following:

- Piping from He supply source to sample/weld station, purge cart station and receiving pit has been initially charged with He to required pressures
- He is supplied at 10 standard ft^3/hr as back gas during the 4 passes for cap welding and 1 of 2 passes for plate cover welding (0.5 hr/pass for each weld - private communication with T. A. Delucchi of COGEMA)
  - He = 10 ft^3/hr x 5 weld passes/MCO x 0.5 hr/weld pass x 398 MCOs = **9,500 std ft^3**
- He is supplied at 10 ft^3/hr for weld testing of the cap and plate cover (private communication with T. A. Delucchi of COGEMA); cover cap void space is estimated at 3.4 ft^3
  - He = 3.4 ft^3/MCO x 4 circumference weld tests/MCO x 398 MCOs = **5,400 std ft^3**
- He is supplied for purging and pressure testing of the MCO sample cart piping, dilution of MCO gas before discharge to the ventilation system (dilute the H_2 to 2.0 vol. % (< 25 % of 8.7 vol. % flammability limit of H_2 in Table B-4 of Piepho and Rittmann (1999)) in order to meet NFPA 69 requirements), reinerting of the monitored MCOs (FDI 1999, FH 1999) and reinerting of monitored MCOs after replacement of the 100 psig pressure sending units. Allow 6,000 std ft^3 of helium per MCO sampled (8 times) and pressure unit replacement. This results in a total predicted helium usage of 36,000 std ft^3 for the monitored MCO operations.
- Estimated total He usage for normal operations = 9,500 + 5,400 + 36,000 = 50,900 std ft^3 ~ **51,000 std ft^3 = 1.44E+03 m^3**
- He is supplied for inerting the over pack storage tube; the inerting of an overpack storage tube is an off normal event and is not included in this PFD calculation.
- The total mass of supply helium is calculated below:
  - Mass of He used = 1.44E+03 std m^3 x 1000 L/m^3 x 273 K/288 K x gmol/22.4 L x 4 g/gmol x 0.001 kg/g = **244 kg**

7.2.23 C-23 Monitored MCO Exhaust Gas

The internal gas of the six monitored MCOs will be sampled eight times during a two-year period. After sampling and before welding, the 100 psi pressure sending and readout units of the monitored MCOs are replaced with a 600 psi pressure sending unit. The MCO gas is exhausted through the sample cart and diluted with helium before entering the building ventilation system. There are no predicted gas constituents at this time except helium and hydrogen. Allow 36,000 std ft^3 of helium for sampling six monitored MCOs eight times and pressure unit replacement. Off normal MCO sampling is recovery action and is not included in this estimate.

- Estimated volume MCO internal gas loss to exhaust system:
  - sampling (based on Stream C-12) = [(7.56E-03 kg H_2/(2 g/gmol) + 2.23E-01 kg He/(4 g/gmol) = 5.95E-02 kg mol] x 1000 g/kg x 22.4 L/gmol x m^3/1000 L x 288 K/273 K= 1.41E+01 std m^3 = 50 std ft^3
  - Pressure unit replacement

$$\frac{(27.0-14.7\,psia)(500L/MCO)\,x\,6\,MCOs}{(0.082\,Latm/gmol\,x\,14.7\,psia/atm\,x\,333K)}\,x\,\frac{22.4L}{gmol}\,x\,\frac{288K}{273K}\,x\,\frac{ft^3}{28.3L}=80\,std\,ft^3$$

  - Total MCO internal gas loss = 50 std ft^3 + 80 std ft^3 = 130 std ft^3
- Mass of He exhausted in MCO internal gas from sampling and pressure unit replacement:
  - MCO sampling (see C-12) = 2.23E-01 kg
  - Pressure sending unit replacement

$$\frac{(27.0-14.7\;psia)(500\;L/MCO)\;x\;6\;MCOs\;x\;0.937\;He}{(0.082\;L\;atm/gmol\;K\;x\;14.7\;psia/atm\;x\;333\;K)}\;x\;4\;g/mol\;x\;0.001\;kg/g=3.44E-01\;kg$$

  - Internal MCO helium exhausted = 2.23E-01 kg + 3.44E-01 kg = 5.67E-01 kg
- Mass of hydrogen exhausted in MCO internal gas:
  - MCO sampling (see Stream C-12) = **7.56E-03** kg
  - Pressure sending unit replacement

$$\frac{(27.0-14.7\;psia)\,x\;500L/MCO\;x\;0.063\;H_2\;x\;6\;MCOs\;x\;2\;g/gmol\;x\;0.001\;kg/g}{(0.082\;Latm/gmolK\;x\;14.7\;psia/atm\;x\;333K)}=\mathbf{1.16E0\text{-}02\;kg}$$

  - Internal MCO hydrogen exhausted = 7.56E-03 kg + 1.16E-02 kg = 1.92E-02 kg
- Total He exhausted during MCO gas sampling and pressure unit replacement = 36,000 std ft^3 = 1.02 std m^3 = 1.72+01 kg

7.2.24 C-24 Deleted

7.2.25 C-25 Annex Room Air to Weld Station Exhaust

Annex room air will be the total airflow through the filter system AH-006. Capacity of the AH-006 filter is 500 scfm based on FDI (1999a) and H-2-127455, Rev. 2A. Based on 290 min of weld station usage/MCO (block flow diagram steps 3-16, 3-17, 3-18, 3-24, 3-25, 3-36, 3-40, 3-41, and 3-42 of H-2-123400, Rev. H)) 160 min/MCO for sampling (steps 12-1 through 12-9 of H-2-123400, Rev. H), and 60 min/MCO pressure unit replacement, the weld station exhaust is:

- Weld station exhaust volume = 500 scfm x (290 min/MCO x 398 MCOs + 160 min/MCO x 48 MCOs + 60 min/MCO x 6 MCOs) = 6.17E+07 std ft^3 (1.74E+06 m^3).
  - Annex room air volume = 6.17E+07 ft^3 – 36,000 ft^3 He (Stream C-23) – 39,800 ft^3 Ar (Stream C-16) = 6.16E+07 ft^3 **(1.74E+06 m^3)**
  - Annex room exhaust air mass = 6.16E+07 ft^3 x 273 K/288 K x 28.3 L/ft^3 x gmol/22.4 L x 28.97 g/gmol x 0.001 kg/g = **2.14E+06 kg**

7.2.26 C-26 Filtered Weld Station Offgas

The weld station offgas is composed of the annex room air, helium, and argon welding gases. The total volume is determined by the filter capacity of 500 scfm based on FDI (1999a) and H-2-129455, Rev. 2A, and usage times of 290 min/MCO for welding and 160 min/MCO for sampling (H-2-123400, Rev. H).

- The weld station exhaust volume = 6.16E+07 std ft^3 (1.74E+06 m^3) based on Stream C-25.
- Mass helium exhausted from sampling, pressure unit replacement, and welding = 1.72 E+02 kg (Stream C-23 sampling and pressure unit replacement) + [(9500 + 5400 std ft^3 from Stream C-22 welding supply)] x 273 K/288 K x 28.3 L/ft^3 x gmol/22.4 L x 4 g/gmol x 0.001 kg/g = **2.44E+02 kg**

The total mass is the sum of the air, helium, hydrogen, and argon gases.

- The weld station exhaust mass = 2.14E+06 kg air (Stream C-25) +2.44E+02 kg He + 7.56E-03 kg H_2 (Stream C-12) + 1.16E-02 kg H_2 (Stream C-23) + 1.90E+03 kg Ar (Stream C-16) = **2.14E+06 kg**

7.2.27 C-27 Weld Station Spent HEPA Filter Waste

Weld station filter Stream C-27 contains the AH-006 prefilter and HEPA filter. The dimensions are 12 in x 24 in x 2 in for the prefilter and 12 in x 24 in x12 in for the HEPA filter based on FDI (1999a). Assume the prefilter weight is 6 lb. and the HEPA filter weight is 25 lb. The spent filters are assumed to weigh the same as the original filters. At this time there is no information available on change out frequency of the exhaust filter.

7.2.28 C-28 Replacement Filters for Weld Station

See Stream C-27 for description.

7.2.29 C-29 Clean Empty Cask

The clean empty transport cask is ready to receive a new empty MCO. No mass balance required.

7.2.30 C-30 Cask Decontamination Material

Assume decon material of 2 kg/MCO and density of 0.6 kg/L. The amount of the decon material for 398 MCOs is listed below.

- Mass of cask decon material = 2 kg/MCO x 398 MCO = **796 kg**
- Volume of cask decon material = 796 kg/0.6 kg/L = 1326 L (**1.33 m^3**)

7.2.31 C-31 Empty Transport Cask

The empty transport cask is surveyed for contamination before loading with a new, empty MCO. No mass balance required.

7.2.32 C-32 Cask Decontamination Waste

Assume there is no change in volume and weights of decon material after use. See Stream C-30 for description.

7.2.33 C-33 Miscellaneous Decontamination Material

Assume the 6 monitored MCOs require decontamination material during the 2-year monitoring period and pressure unit replacement. Based on a decon material weight of 2 kg/MCO and density of 0.6 kg/L, the amount of miscellaneous decon material for the monitored MCOs is listed below.

- Mass of monitored MCO decon material = 2 kg/MCO x 48 (6 x 8) MCO monitoring events + 2 kg/MCO x 6 pressure unit replacements = 108 kg
- Volume of monitored MCO decon material = 108 kg/0.6 kg/L = 180 L (**0.18 m^3**)

7.2.34 C-34 Miscellaneous Decontamination Waste

Assume there is no change in volume and weights of decon material after use. See Stream C-33 for description.

7.2.35 C-35 Accumulated Solid Waste

Accumulated solid waste is listed in Table 7.2.7

Table 7.2.7 Accumulated Solid Waste

Stream	Mass, kg	Volume, m^3	Waste Container
C-19	1,445[2]	0.33	55 gal drum
C-20	796	1.33	55 gal drum
C-32	796	1.33	55 gal drum
C-34	108	0.18	55 gal drum
C-51[1]	0	0	55 gal drum
Total	**3,145**	**3.17**	

1. Information on replacement and disposal of this filter is not available at this time. Filter replacement depended on pressure drop and radiation dose rate.
2. Amount includes 20 kg of plastic weld spool waste.

7.2.36 C-36 Packaged Solid Waste

The solid waste will be packaged into 55-gallon drums or burial boxes. See Stream C-37 for number of drums and Stream C-49 for number of burial boxes. The filled drums and burial boxes are transported to solid waste disposal.

7.2.37 C-37 Solid Waste Drums

Table 7.2.8 is based on information in Stream C-35

Table 7.2.8 Solid Waste Disposed in Drums

Stream	Volume, m^3
C-19	0.33
C-20	1.33
C-32	1.33
C-34	0.18
C-51	0
Total	3.17

Assume the 55-gallon drums are filled to an 80 % maximum capacity (0.17 m^3).

- Minimum number of empty 55-gallon waste drums = **3.17 m^3**/(0.17 m^3/drum) = **19**

7.2.38 C-38 Cask Service System and Weld Station Exhaust

The capacity of the cask service offgas system (Stream C-47) is 5 scfm based on design capacity of HEPA exhaust filter FH-2. The design capacity of the weld station exhaust system (Stream C-26) is 500 scfm. The offgas flowrate is equivalent to Stream C-26 because Stream C-47 is used for off normal conditions. The Stream C-26 information is summarized below.

Table 7.2.9 Cask Service System and Weld Station Exhaust

Stream	C-47	C-26	Total
Air, kg	0	2.14E+06	**2.14E+06**
Helium, kg	0	2.44E+02	**2.44E+02**
Hydrogen, kg	0	1.92E-02	**1.92E-02**
Argon., kg	0	1.90E+03	**1.90E+03**
Total, kg	0	2.06E+06	**2.14E+06**

7.2.39 C-39 MHM Ventilation Exhaust

The air flowrate of the MHM extract system is 800 scfm based on the capacity of MHM exhaust fan (private communication with C. E. Swenson of Fluor Hanford). The design capacity of prefilter PF-1 and HEPA exhaust filter HF-1 is 1,000 scfm. The MHM ventilation system is operated during movement of the MCOs. The following times are required for loading, transfer, and unloading of the MCOs by MHM.

- 4.0 hr to transfer each monitored MCO (6 total) from transport cask to standard storage tube (steps 2-22 thru 2-27 and 4-1 thru 4-6 of H-2-123400, Rev. H)
  - MHM extract system air volume = 4.0 hr/MCO x 60 min/hr x 800 scfm x 6 MCOs = 1.15E+06 std ft^3 **(3.25 E+04 m^3)**
- 3.2 hr to transfer each MCO (392 total) from transport cask to sample/weld station (steps 2-22 thru 2-27 and 3-1 thru 3-4 of H-2-123400, Rev. H)
  - MHM extract system air volume = 3.2 hr/MCO x 60 min/hr x 800 scfm x 392 MCOs =6.02E+07 std ft^3 **(1.70 E+06 m^3)**
- 3.8 hr to transfer each MCO (392 + 6 x 8 = 440) from sample weld station to standard storage tube (steps 12-15 thru 12-19 and 13-1 thru 13-6 of H-2-123400, Rev. H)
  - 3.8 hr x 60 min/hr x 800 scfm x 440 MCOs = 8.03 E+07 std ft^3 **(2.27 E+06 m^3)**
- 3.6 hr to transfer each monitored MCO (6 x 8 = 48) from standard storage tube to sample weld/station for sampling and welding after 8^{th} sample (steps 14-3 thru 14-10 and 3-1 thru 3-4 of H-2-123400, Rev. H)
  - 3.6 hr/MCO x 60 min/hr x 800 scfm x 48 MCOs = 8.29 E+06 std ft^3 **(2.34E+05 m^3)**
- 5.25 hr to transfer and place each intermediate impact absorber in the standard storage tubes (steps 9-3 thru 9-18 of H-2-123400, Rev. H)
  - 5.25 hr/MCO x 60 min/hr x 800 scfm x 198 intermediate impact absorbers = 4.99E+07 std ft^3 **(1.41E+06 m^3)**
- Total volume air exhausted by MHM extract system during MCO transfers = **1.99E+08 std ft^3 (5.62E+06 m^3)**
- Total mass air exhausted by MHM extract system during MCO transfers = 1.99E+08 std ft^3 x 28.3L/ft^3 x 273 K/288 K x gmol/22.4 L x 28.9 g/gmol x 0.001 kg/g = **6.89E+06 kg**

7.2.40 C-40 Replacement Filters for MHM

The MHM extract filter system PF-1/HF-1 consists of one prefilter and one high efficiency filter. The PF-1 filter is 12 in x 24 in x 2 in and weighs and estimated 6 lb. The HF-1 filter is 12 in x 24 in x 11.5 in and weighs 40 lb (private communication with C. E. Swenson of Fluor Hanford). There is no information available at this time on change out frequency of the MHM filters.

7.2.41 C-41 Spent Filters From MHM

There are no changes in the filter mass and volume of the MHM extract system filters. See Stream C-40 for description.

7.2.42 C-42 Operating Area Ventilation Exhaust

The total volume of gas exhausted to the stack is determined by the design capacity of the PF-001/002 filters. Each filter has a capacity of 9,000 scfm (Flanders 1997 and H-2-129580, Rev. 3). Based on a two year-operating period, the amount of gas exhausted to the environment is listed below.

Table 7.2.10 Ventilation System Exhaust

Stream	C-38	C-39	Other	Total
Air, kg	2.14E+06	6.89E+06	**3.18E+08**	**3.27E+08**
He, kg	2.44E+02	0	0	2.44E+02
H_2, kg	1.92E-02	0	0	1.92E-02
Ar, kg	1.90E+03	0	0	1.90E+03
Total	2.14E+06	**6.89E+06**	**3.18E+08**	**3.27E+08**

- Volume gas discharged to environment based on 2 yr operation = 9,000 scfm x 2 yr x 365 day/yr x 24 hr/day x 60 min/hr = 9.46E+09 std ft^3 air (2.68E+08 m^3)
- Mass of gas discharged to environment based on 2 yr operation = 9.46E09 std ft^3 air x 28.3 L/ft^3 x 273 K/288 K gmol/22.4 L x 28.9 g/gmol x 0.001 kg/g = **3.27E+08 kg**
- Mass of other air from operating area and support building based on 2 yr operation = 3.27E+08 kg – 2.14E+06 - 6.89E+06 kg = **3.18E+08 kg**

7.2.43 C-43 Spent HEPA Filter From Operating Area

There is no change in mass or volume of the operating vault filters. See Stream C-44 for description.

7.2.44 C-44 Replacement HEPA Filter for Operating Area

Filter system PF-001/002 each consists of nine prefilters and nine HEPA filters based on Flanders (1997). The size of the prefilters is 24 in x 24 in x 2 in. The size of the HEPA filters is 24 in x 24 in x 11.5 in. Assume prefilters weigh 12 lb each and HEPA filters weigh 40 lb each. The design capacity is 9500 scfm and normal operation is 9,000 scfm. There is no information available at this time on change frequency out of the operating vault filters.

7.2.45 C-45 Spent HEPA Filters From Support Building

There is no information available at this time on change out of these filters. See Stream C-46 for description.

7.2.46 C-46 Replacement HEPA Filters for Support Building

Filter system AH-004 consists of one prefilter and one HEPA filter. The prefilter is 24 in x 24 in x 2 in and the HEPA filter is 24 in x 24 in x 11.5 in based on DE&S (1997). Assume the prefilter weighs 12 lb and the HEPA filter weighs 40 lb. The filter design capacity is 920 scfm (H-2-129587, Rev. 3).

7.2.47 C-47 Cask Service Exhaust System

Cask servicing is an off normal condition and there is no predicted exhaust air or waste. The FH-2 HEPA filter design capacity is 5 scfm. The filter weights 66 lb and measures 28 in flange to flange based on Fairey (1999a).

7.2.48 C-48 Solid Waste Burial Boxes

The waste boxes are used for disposal of the filters from Streams C-11, C-27, C-41, C-43 and C-45. Information on replacement of these filters, size of the disposal boxes, and number of burial boxes is not available at this time. See Stream C-49.

7.2.49 C-49 Accumulated Filter Waste

Information on replacement of the exhaust filters for these streams is not available at this time. Filter replacement depended on pressure drop and radiation dose rate.

Table 7.2.11. Burial Box Waste

Stream	Mass, kg	Volume, m^3	Waste Container
C-11	0	0	Burial box
C-27	0	0	Burial box
C-41	0	0	Burial box
C-43	0	0	Burial Box
C-45	0	0	Burial box
Total	0	0	

7.2.50 C-50 Replacement Sample HEPA Filter

The FH-9 sample HEPA filter for MCO gas sampling is 6.6 in outside diameter by 12 in long and weights an estimated 29 lb based on Fairey (1999). There is no information available at this time on change out frequency of this filter. The design capacity is 33 scfm.

7.2.51 C-51 Spent HEPA Filter from Sample Hood

There are no changes in the filter mass and volume of the sample HEPA filter. See Stream C-50 for description.

7.2.52 C-52 Helium Reinerted Monitored MCOs to Welding

The monitored MCOs are vented, purged with helium, low range pressure sending unit replaced, reinerted with helium to the same pressure, and leak checked before welding. The MCO gas is diluted with helium and vented to the sample hood exhaust through the sample cart.

Table 7.2.12 Stream C-52 (After Pressure Sending/Readout Unit Replacement)

Stream Number	C-52	
Description	Helium Reinerted Monitored MCO to Welding	
Phase	S/G	
Number of Items	6	
Item Count Basis	MCO	
Volume, m^3	-	
Density, g/cc	-	
Pressure, Torr	1400	
Temperature, °C	60	
Components, kg		
Fuel	3.39E+04	
Uranium		3.15E+04
Plutonium		6.18E+01
Other		2.37E+03
Sludge	4.15E+01	
$Al(OH)_3$		4.13E+00
Al_2O_3		1.35E-02
$Fe(OH)_3$		4.21E-01
$UO_2(OH)_2$		1.36E+01
UO_44H_2O		0.00E+00
UO_42H_2O		1.45E+01
UO_2		2.34E+00
UH_3		5.70E+00
UO_3		8.18E-01
Solids	0.00E+00	
Stainless Steel		0.00E+00
Aluminum		0.00E+00
Other		0.00E+00
Water	9.66E-01	
Air	0.00E+00	
Other Gases	7.94E-01	
Argon		0.00E+00
Hydrogen		1.38E-02
Helium		7.80E-01
Total Mass, kg	3.39E+04	

Mass H_2 and He inside monitored MCOs after venting for pressure unit replacement:

$$H_2\ mass = \frac{1\ atm\ x\ 500L/MCO\ x\ 6\ MCOs\ x\ 0.063\ H_2}{(0.082\ Latm/gmol\ K\ x\ 333K)} = 6.92E+00\ gmol = 1.38E-02\ kg$$

$$He\ mass = \frac{1\ atm\ x\ 500L/MCO\ x\ 6MCOs\ x\ 0.937\ He}{(0.082\ Latm/gmol\ K\ x\ 333\ K)} = 1.03E+02\ gmol$$

Mass He inside monitored MCOs after He reinerting for pressure unit replacement:

$$27.0\ psia = \frac{(1.10E+02\ gmol\ H_2\ \&\ He + He\ added)\ x\ 0.082\ Latm/gmol\ K\ x\ 333\ K}{(500\ L/MOCO\ x\ 6\ MCOs\ x\ atm/14.7 psia)}$$

Mass He added for reinerting = 9.18E+01 gmol
Total He mass = 1.03E+02 gmol + 9.18E+01 gmol = 1.95E+02 gmol = 7.8E-01 kg

7.2.53 C-53 MCO Pressure Units

A supply of 600 psi pressure sending units for the monitored MCOs and 600 psi pressure readout units for all welded MCOs will be stored at the warehouse and delivered to the CSB by truck. There is no change of material balance inside the MCO. Pressure unit size and weight are based on Douglas and Ohl (1999) and private communication with D. G. Douglas of Vista Research, Inc.

- 600 psi sending units for six monitored MCOs
  - Approximate Volume = 6 MCOs x (3.0 dia x 2.0 in h)/unit x 1 unit/MCO = 8.48E+01 in^3
  - Weight = 6 MCOs x 2.19 lb/unit x 1 unit/MCO = 1.31E+01 lb

- 600 psi readout units for all 398 MCOs
  - Approximate Volume = 398 MCOs x (2.7 in dia x 0.937 in h)/unit x 1 unit/MCO = 2.13E+03 in^3
  - Weight = 398 MCOs x 0.38 lb/unit x 1 unit/MCO = 1.51E+02 lb

Total volume = 8.48E+01 in^3 + 2.13E+03 in^3 = 2.21E+03 in^3 = 3.63E-02 m^3
Total weight = 1.31E+01 lb + 1.51E+02 lb = 1.64E+02 lb = 7.44E+01 kg

7.2.54 IC-083 Filtered and Monitored Exhaust From CSB

See Stream C-42 for description

7.2.55 IC-085 CSB Support Solid Waste

See Stream C-36 for description.

7.2.56 IC-087 New MCO Shell for Cask Loading

A small supply of new, empty MCOs in shipping crates will be delivered by truck from the warehouse to CSB. These MCOs will be unpacked and stored at the CSB until loaded into an empty transport cask and transported to the K Basins. The empty shipping crates are returned to the vendor. Size and weight of the new, empty MCOs are based on Drawing H-2-828041, Rev. 4, and private communication with L. H. Goldmann of Fluor Hanford.

Approximate (storage) volume = 24 in dia x 157.4 in h = 7.12E+04 in^3
Average measured weight = 1942 lb

Total volume = 398 MCOs x 1.72E+04 in^3/MCO = 2.83E+07 in^3 = 4.64E+02 m^3

Total weight = 398 MCOs x 1942lb/MCO = 7.73E+05 lb = 3.50E+05 kg

7.2.57 IC-129 Liquid Effluents

Condensate from the compressed air and ventilation systems is collected in the SU-1 and SU-2 sump and loaded into a 55 gallon drum for sampling and disposal. Contaminated condensate is transported to the LERF for disposal. Non contaminated condensate is discharged to the ground in accordance with SNF Project Process Standard 409 for maintenance type discharges.

The AH-001 and AH-002 fans remain in operation continuously for operating area return air temperatures (TE-265) between 63°F and 82°F. When the return air temperature increases to 82°F, condensing unit CU-001 (evaporator temperature = 52°F) will start and remain in operation. If the return air temperature increases to 85°F, condensing unit CU-002 (evaporator temperature = 52°F) will start and remain in operation in order to hold the return air temperature constant. As the cooling load decreases, the operation of CU-002 and CU-001 ceases (Notes on H-2-129582, Rev. 3). Table 7.2.13 lists the monthly average psychrometric data between 1950 and 1997 (Hoitink and Burk 1998). The months of July and August have the highest dry and wet bulb temperatures. The monthly average dew point temperatures are less than the 52°F evaporator temperature of CU-001 and CU-002. Therefore, no HVAC condensate is anticipated based on monthly average data.

Table 7.2.13 Monthly Average Psychrometric Data

Category	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Dry bulb	30.9	37.4	45.1	53.2	62.2	69.9	77.2	75.6	66.4	53.0	40.0	32.4	53.6°F
Wet bulb	28	34	38	44	50	55	58	58	53	45	36	30	44°F
Rel. hum.	77.3	70.5	56.6	47.3	42.8	39.6	33.3	35.6	42.2	56.4	73.6	80.3	54.6 %
Dew Point	24.2	27.6	28.8	31.6	36.9	41.5	43.6	43.9	40.4	36.1	31.3	26.5	34.4°F

Additional data for extremes of monthly average psychrometric data show the highest dry bulb temperatures were 83.3°F in July 1985 and 82.5°F in August 1967. The highest wet bulb temperatures were 62°F in July 1985 and 61°F in August 1991.

Based on July 1985 extreme averages and an air handler evaporator temperature of 52°F, cooling of the operating area air would increase the relative humidity from a value of about 31% to near 100%. The moisture in the air would remain at about 0.008 lb water/lb dry air producing very little HVAC condensate at the extreme average conditions.

Information on compressed air requirements and resulting condensate is based on an average flowrate of 40 scfm (FDI 1996) and monthly average psychrometric data. The results are summarized in Table 7.2.14.

Table 7.2.14 Estimated Compressed Air Condensate

Category	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Dry bulb	30.9	37.4	45.1	53.2	62.2	69.9	77.2	75.6	66.4	53.0	40.0	32.4	53.6°F
Dry air vol. ft^3/lb	12.4	12.6	12.7	13.0	13.2	13.4	13.6	13.5	13.3	13.0	12.6	12.4	-
Dew Point	24.2	27.6	28.8	31.6	36.9	41.5	43.6	43.9	40.4	36.1	31.3	26.5	34.4°F
lb H_2O/lb dry air 10^{-3}	2.64	3.11	3.28	3.72	4.61	5.53	6.45	6.06	5.13	4.43	3.67	2.94	-
Avg H_2O 10^{-4} lb/ft^3	2.13	2.47	2.58	2.86	3.49	4.12	4.74	4.49	3.86	3.41	2.91	2.37	-
H_20 into compressor 10^2 lb	3.80	3.98	4.60	4.94	6.23	7.12	8.46	8.02	6.67	6.08	5.03	4.23	74.19

Dry air volume = V/n =RT/P ft^3/lb

Lb H_2O/lb dry air is estimated from thermodynamic properties of moist air at standard atmospheric pressure (Perry 1984) and the dew point temperature.

Average H_2O lb/ft^3 = lb H_2O/lb dry air/dry air volume ft^3/lb

H_2O into compressor/month (lb) = average H_2O lb/ft^3 x 40 scfm x 60 min/hr x 24 hr/day x no. days/month

Annual average condensate from air compressor operation is estimated as 7.42E+03 lb/yr.

Mass of condensate based on 2 yr of CSB operation = 2 yr x 7.42E+03 lb/yr = 1.48E+04 lb = **6.74E+03 kg**

Volume of condensate 6.74E+04 kg/0.998 kg/L x 0.001 m^3/L = **6.75E+00 m^3**
Number of 55 gallon drums at 80 % capacity = 6.75 m^3/(55 gal x 0.8 x 3.78 L/gal) x 1000 L/m^3 = **41**

7.2.58 IC-233 MCO Cover Cap, Plug, and Plate

A supply of cover caps, test plugs, and cover plates will be stored at the warehouse and delivered to the CSB by truck. The addition of these components do not change the material balance inside the MCO. Size and weight of the components are based on Drawing H-2-828042, Rev. 4, and private communication with L. H. Goldmann of Fluor Hanford.

- Canister Cover Cap
  - Approximate (storage) volume = 25.3 in dia x 9.0 in h = 4.52E+03 in^3
  - Average measured weight = 500 lb
- Cover Plate
  - Approximate volume = 4.0 in dia x 0.38 in h = 4.8E+00 in^3
  - Average measured weight = 1.0 lb

- Test Plug
  - Approximate volume = 2.38 in dia x 2.75 in h = 1.22E+01 in^3
  - Average measured weight = 2.0 lb

Total Volume = 398 MCOs x (4.52E+03 in^3 + 4.8E+00 in^3 + 1.22E+01 in^3) = 1.81E+06 in^3
= 2.96E01 m^3

Total Weight = 398 MCOs x (500 lb + 1.0 lb + 2.0 lb) = 2.00E+05 lb = 9.08E+04 kg

8.0 RESULTS

Results of the calculations are shown in Appendix A and drawing H-2-825869, Rev. 2.

9.0 CONCLUSIONS

Drawing H-2-825869, Rev. 2 reflects the average design capacity and current processing strategy.

10.0 REFERENCES

DE&S, 1997, Contract No. KH-5511-W-379, Canister Storage Building Government Furnished Equipment Data Transmittal, letter MCC-5511-1262, Duke Engineering & Services Hanford, Inc., Richland, Washington.

Douglas, D. G. and P.C. Ohl, 1999, *Magnetically Coupled Pressure Gauge: Definitive Design*, TM-FO21-99-05, Vista Research, Inc., Richland, Washington.

Duncan, D. R., and M. G. Plys*, 1998, *MCO Internal Gas Composition and Pressure During Interim Storage*, HNF-SD-SD-TI-040, Rev. 3, Duke Engineering and Services Hanford Inc., Richland, Washington and *Fauske and Associates, Burr Ridge, Illinois.

Ellis and Watts, 1999, *Installation Operation and Maintenance Manual for Exhaust Unit CSB-EF-005*, K0797-08, Rev. 0, Ellis and Watts, Batavia, Ohio.

Fairey, 1999, *DE&S Hanford Data Book*, MO98666, Fairey Microfiltrex, Fareham, England.

Fairey, 1999a, *DE&S Hanford Data Book*, MO98678, Fairey Microfiltrex, Fareham, England.

FDI, 1999, *System Design Description, MCO Sampling/Welding (MSW) System*, Fluor Daniel Inc., Richland, Washington.

FDI, 1999a, *MCO Sampling/Weld Station Exhaust Unit*, W-379-C-CSB-15835, Fluor Daniel Inc., Richland, Washington.

FDI 1996, *Condensate from Instrument Air Compressor* (process note to file), Fluor Daniel Inc, Richland, Washington.

FH 1999, *Spent Nuclear Fuel Project Final Safety Analysis Report Annex A "Canister Storage Building Final Safety Analysis Report*" HNF-3353, Rev. 0, Fluor Hanford, Richland, Washington.

Flanders, 1997, *Technical Manual*, Purchase Order MBS-SDX-A18981, Job 96508, Flanders/Charcoal Service Corporation, Bath, North Carolina.

Goldmann, L. H., 2000, *Performance Specification for the Spent Nuclear Fuel Multi-Canister Overpack*, HNF-S-0426, Rev. 6, fluor Hanford, Richland, Washington.

Hoitink, D. J. and K. W. Burk, 1998, *Hanford Site Climatological Data Summary 1997, With Historical Data*, PNNL-17794, Pacific Northwest National Laboratory, Richland, Washington.

Klem, M. J.*, and A. L. Pajunen, 2000, *Spent Nuclear Fuel Project Cask/Transportation Process Flow Diagram Mass Balance Calculation*, SNF-5046, Rev. 0, Fluor Hanford, *Cogema Engineering Corporation, Richland, Washington.

NFPA 69,1997, *Standard for Explosion Prevention Systems*, National Fire Protection Association, Quincy, Massachusetts.

Piepho, M. R and P. R. Rittmann, 1999, C*old Vacuum Drying Facility Design Basis Accident Analysis Documentation*, HNF-2770, Rev. 3, Fluor Daniel Northwest Inc, Richland, Washington.

Reed, A. V and A. L. Pajunen*, 1999, *Evaluation of Canister Storage Building Cask Receipt Pressure*, HNF-4509, Rev. 0, COGEMA Engineering Corporation Richland, Washington and *Numatec Hanford Corporation Richland, Washington.

Rielly, M. A, 1998, *Spent Nuclear Project Technical Data Book,* HNF-SD-SNF-TI-015, Rev. 6, Duke Engineering and Services Hanford Inc., Richland, Washington.

Pajunen, A. L., 2000, *Spent Nuclear Fuel Project Product Specification*, HNF-SD-SNF-OCD-001, Rev. 4, Fluor Hanford, Richland, Washington.

Perry, R. H. and D. W. Green, 1984 "*Perry's Chemical Engineer's Handbook*" Sixth Edition, R. H. Perry and D. W. Green, editors McGraw Hill Inc., New York, New York.

Sherrell, D. L, 1999, *Multi-canister Overpack Combustible Gas Management Leak Detection Criteria*, HNF-2155, Rev. 1 Fluor Hanford, Richland, Washington.

Smith, K. E., 1999, *MCO Design Report*, HNF-SD-SNF-DR-003, Rev. 2, Fluor Daniel Hanford Inc., Richland, Washington.

SNF Standard 409, 2000, *Discharges to Ground SNF Project Process Standards*, Rev. 1, Fluor Hanford, Richland, Washington.

H-2-123400, Rev. H, Operational Sequence Block Flow Diagram.

H-2-129582, Rev. 3, P & ID HVAC Operating Area CSB-AH-001.

H-1-81168, Rev. 3, SNF Project Cask/Transportation Level 1 Process Flow Diagram.

H-2-825869, Rev. 2, SNF Project Canister Storage Building Level 1 PFD.

H-2-828041, Rev. 4, Multi-Canister Overpack Assembly

H-2-828042, Rev. 4, MCO Mechanical Closure

H-2-828048, Rev. 3 MCO Process Port Cover Plates.

H-2-129455, Rev. 2A, HVAC MCO Sampling/Weld Station Flow Diagrams.

H-2-129580, Rev. 3, HVAC Composite Diagram

H-2-129587, Rev. 3, P&ID HVAC Support Area Equipment

APPENDIX A

MS Excel Spreadsheet Calculations
For Development
Of Drawing H-2-825869, Rev. 2

STREAM NUMBER	IC-003	IC-006	IC-083	IC-085	IC-087	IC-129	IC-233	C-3	C-4	C-5	C-6	C-7	C-8
DESCRIPTION	VACUUM DRIED FUEL IN MCO/CASK DELIVERED TO CSB	EMPTY MCO LOADED IN CASK FOR TRANSPORT TO BASINS	FILTERED AND MONITORED EXHAUST FROM CSB	CSB SUPPORT SOLID WASTE	NEW MCO SHELL FOR CASK LOADING	CSB VENTILATION CONDENSATE	CANISTER COVER CAP ASSEMBLY	MCO/CASK IN CASK RECEIVING PIT	EMPTY TRANSPORT	CASK LID REMOVAL	MCO FROM TRANSPORT TO WELD STATION WITH MHM	MOVE SHORT TERM MONITORING MCO TO VAULT	SHORT TERM MONITORED MCO IN STORAGE TUBE
TRANSFER TYPE	BATCH	BATCH	CONTINUOUS	BATCH	BATCH	BATCH	BATCH	BATCH	BATCH	BATCH	BATCH	BATCH	BATCH
PHASE (NOTE 2)	S/G	S	G	S	S	L	S	S	S	S	S	S	S
NUMBER OF ITEMS	398	398	-		398	41	398	398	398	398	392	6	6
ITEM COUNT BASIS	MCO	MCO	-	55 GAL DRUM/BOX	MCO	55 GAL DRUM	MCO	MCO	EMPTY TRANSPORT	MCO	MCO	MCO	MCO
VOLUME, m^3	-	-	2.67E+08	3.17E+00	4.64E+02	6.75E+00	2.96E+01	-	-	-		-	-
DENSITY, g/cc	-	-	1.22E-03	-	-	0.998	-	-	-	-	-	-	-
PRESSURE, TORR	1370	-	7.60E+02	-	-	-	-	1370	-	1370	1370	1370	1400
TEMPERATURE, Deg C	61	AMBIENT	1.50E+01	AMBIENT	AMBIENT	AMBIENT	AMBIENT	61	AMBIENT	61	61	61	60
COMPONENTS, Kg (NOTE 3)				0									
FUEL	2.25E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.25E+06	0.00E+00	2.25E+06	2.22E+06	3.39E+04	3.39E+04
URANIUM	2.09E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.09E+06	0.00E+00	2.09E+06	2.06E+06	3.15E+04	3.15E+04
PLUTONIUM	4.10E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.10E+03	0.00E+00	4.10E+03	4.04E+03	6.18E+01	6.18E+01
OTHER	1.57E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.57E+05	0.00E+00	1.57E+05	1.55E+05	2.37E+03	2.37E+03
SLUDGE	2.73E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.73E+03	0.00E+00	2.73E+03	2.69E+03	4.11E+01	4.14E+01
$Al(OH)_3$	2.75E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.75E+02	0.00E+00	2.75E+02	2.71E+02	4.15E+00	4.13E+00
Al_2O_3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.35E-02
$Fe(OH)_3$	2.79E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.79E+01	0.00E+00	2.79E+01	2.75E+01	4.21E-01	4.21E-01
$UO_2(OH)_2$	9.63E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.63E+02	0.00E+00	9.63E+02	9.48E+02	1.45E+01	1.36E+01
UO_4-$4H_2O$	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
UO_4-$2H_2O$	9.60E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.60E+02	0.00E+00	9.60E+02	9.45E+02	1.45E+01	1.45E+01
UO_2	1.26E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.26E+02	0.00E+00	1.26E+02	1.24E+02	1.90E+00	2.34E+00
UH_3	3.78E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.78E+02	0.00E+00	3.78E+02	3.72E+02	5.70E+00	5.70E+00
UO_3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.18E-01
SOLIDS	0.00E+00	0.00E+00	0.00E+00	3.14E+03	3.50E+05	0.00E+00	9.08E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
STAINLESS STEEL	0.00E+00	0.00E+00	0.00E+00	1.42E+03	3.50E+05	0.00E+00	9.08E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ALUMINUM	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
OTHER	0.00E+00	0.00E+00	0.00E+00	1.72E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
WATER	6.53E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.74E+03	0.00F+00	6.53E+01	0.00E+00	6.53E+01	6.43E+01	9.84E-01	9.66E-01
AIR	0.00E+00	0.00E+00	3.27E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
OTHER GASES	5.09E+01	0.00E+00	2.14E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.09E+01	0.00E+00	5.09E+01	5.01E+01	7.67E-01	7.84E-01
ARGON	0.00E+00	0.00E+00	1.90E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
HYDROGEN	1.57E+00	0.00E+00	1.92E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.57E+00	0.00E+00	1.57E+00	1.55E+00	2.37E-02	2.57E-02
HELIUM	4.93E+01	0.00E+00	2.42E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.93E+01	0.00E+00	4.93E+01	4.86E+01	7.43E-01	7.58E-01
TOTAL MASS KG	2.25E+06	0.00E+00	3.27E+08	3.14E+03	3.50E+05	6.74E+03	9.08E+04	2.25E+06	0.00E+00	2.25E+06	2.22E+06	3.39E+04	3.39E+04

ASSUMPTIONS:
1. ASSUME ONE SCRAP AND FOUR FUEL BASKETS PER MCO AND TWO YR OF CSB OPERATION (AVERAGE DESIGN CAPACITY)
2. MATERIAL BALANCE NEGLECTS MCO, MCO COMPONENTS, CASK, WASTE DRUM, AND WASTEBOX COMPOSITION AND WEIGHT
3. ASSUME DECON MATERIALS = 2.0 Kg OF SOLIDS (RAGS)/MCO
4. ASSUME DECON MATERIAL DENSITY = 0.6 Kg/L BEFORE AND AFTER USE
5. ASSUME THAT THE GAS IN THE TRANSPORT CASK ANNULUS IS AIR
6. ASSUME ARGON WILL BE USED FOR THE FRONT GAS DURING WELDING
7. ASSUME HELIUM WILL BE USED FOR THE BACK GAS DURING WELDING, PURGING & REINERTING OF MONITORED MCOs
8. ASSUME THERE ARE 4 WELD PASSES/MCO FOR CANISTER COVER CAP, 2 WELD PASSES/MCO FOR COVER PLATE, AND 0.5 hr/WELD
9. ASSUME 11/2 % OF CANISTER COVER CAP WELDS REQUIRE GRINDING AND REWELDING
10. ASSUME WELDING WASTE (BEADS & FRAGMENTS) IS 0.2 g/WELD
11. ASSUME ONE SPOOL WELD WIRE/MCO IS USED FOR COVER CAP WELDING; WEIGHT OF UNUSED WIRE AND SPOOL IS 160 G
12. ASSUME 4.5 WELD RODS/MCO ARE USED FOR COVER PLATE WELDING; UNUSED PORTION IS 6 IN AND WEIGH 2.33 G/ROD
13 ASSUME PORT # 2 COVER (3180 G) AND 4 BOLTS (235 G) OF MCO SHIELD PLUG ARE DISCARDED TO WASTE
14. ASSUME MASS OF GRINDING AND REWELD WASTE IS 4.0g/FAILED MCO
15 ASSUME SIX MONITORED MCOs; EACH MONITORED MCO IS SAMPLE 8 TIMES DURING 2 YR PERIOD
16. ASSUME MONITORED MCOs ARE REINERTED WITH HELIUM TO REPLACE GAS LOST AFTER EACH SAMPLE AND AFTER REPLACEMENT OF 100 PSI PRESSURE SENDING/READOUT UNITS IN SHIELD PLUG
17. ASSUME PRESSURE SENDING UNIT, PRESSURE READOUT UNIT, AND TEMPERATURE READOUT UNIT ARE INSTALLED IN MCO SHIELD PLUG OF SNF LOADED MCO BEFORE TRANSPORT TO CSB.
18. ASSUME PRESSURE SENDING AND READOUT UNIT OF MONITORED MCOs ARE REPLACED BEFORE WELDING. WEIGHT OF 100 PSI SENDING UNIT IS 1140 G. WEIGHT OF 100 PSI READOUT UNIT IS 230 G. WEIGHT OF 600 PSI SENDING UNIT IS 993 G.
19. ASSUME 600 PSI READOUT UNIT (172 G) INSTALLED IN CANISTER COVER CAP OF ALL WELDED MCOs AFTER WELDING IS COMPLETED.
20 ASSUME MONITORED MCO's REQUIRE USE OF DECONTAMINATION MATERIAL
21 ASSUME MCO GAS IN SAMPLE CART IS DILUTED TO 25 % OF LFL WITH HELIUM BEFORE DISCHARGE TO EXHAUST SYSTEM
22. ASSUME 80% MAX FILL FOR WASTE DRUMS
23. ASSUME NO HEPA FILTER REPLACEMENTS AND WASTE BOXES BASED ON 2 YR OPERATING PERIOD
24. ASSUME NO CHANGE IN HEPA FILTERS BEFORE AND AFTER USE
25. ASSUME COMPRESSED AIR REQUIREMENT OF 40 scfm
26. MATERIAL BALANCE OF WELDED AND INTERIM STORED MCOs BASED ON 2 YR TIME PERIOD
27. ASSUME 0.5 wt % $Al(OH)_3$ and 6.0 wt % $UO_2(OH)_2$ ARE DECOMPOSED BY RADIATION TO Al_2O_3, UO_3 AND HYDROGEN. OXYGEN GETTERING BY U METAL TO FORM UO_2.
28. ASSUME MINIMUM MCO VOID OF 500 L AND MINIMUM INITIAL HELIUM FILL OF 31.0 GMOL/MCO
29. ASSUME AVERAGE FUEL TEMPERATURE REPRESENTS MCO GAS TEMPERATURE
30. ASSUME ULTRASONIC TEST OF CANISTER COVER CAP WELD NOT REQUIRED

NOTE:
1. BASIS FOR OVERALL MASS BALANCE BASED ON NUMBER OF MCOs
DOES NOT INCLUDE CAPACITY ALLOCATION FOR SYSTEM OPERATING EFFICIENCIES
2. S = SOLID, L = LIQUID, G = GAS, AND MIXTURES INDICATED AS
S/L = SOLID/LIQUID MIXTURE
3. FUEL CONSISTS OF TOTAL MASS OF FUEL COMPONENTS, INCLUDING FUEL AND CLADDING. SLUDGE MASS IS REPORTED ON A WET BASIS. OTHER SOLIDS CONSIST OF A VARIETY OF MATERIAL, PRIMARILY METALS, EXCLUDING CONTAINER MATERIALS LIKE THE MCO, CASK AND SOLID WASTE PACKAGING DRUMS/BOXES. AIR IN STANDARD STORAGE TUBE.

STREAM NUMBER	C-9	C-10	C-11	C-12	C-13	C-14	C-15	C-16	C-17	C-18	C-19	C-20	C-21
DESCRIPTION	CASK RECEIVING PIT OFFGAS	CASK RECEIVING PIT REPLACEMENT HEPA FILTERS	SPENT CASK RECEIVING PIT HEPA FILTERS	SHORT TERM MONITORED MCO TO STORAGE TUBE	MONITORED MCOs TO WELDING	MCOs TO WELDING	MCOs TO CANISTER COVER CAP WELDING	ARGON WELDING GAS SUPPLY	DELETED	DELETED	MCO WELDING/GRINDING WASTE	MCO WELDING EXAMINATION WASTE	WELDED MCO TO INTERIM STORAGE
TRANSFER TYPE	BATCH	BATCH	BATCH	BATCH	BATCH	BATCH	BATCH	BATCH			BATCH	BATCH	BATCH
PHASE (NOTE 2)	G	S	S	S	S	S	S	G			S	S	S
NUMBER OF ITEMS	0	-	-	6	6	398	398	398			398	398	398
ITEM COUNT BASIS	MCO	TOTAL	TOTAL	MCO	MCO	MCO	MCO	MCO			MCO	MCO	MCO
VOLUME, m^3	0.00E+00	0.00E+00	0.00E+00	-	-	-	-	1.13E+03			3.35E-01	1.33E+00	-
DENSITY, g/cc	0.00E+00	0.00E+00	0.00E+00	-	-	-	-	1.68E-03			4.33	0.6	-
PRESSURE, TORR	760	-	-	1400	1400	1370	1370	-			-	-	1400
TEMPERATURE, Deg C	AMBIENT	AMBIENT	AMBIENT	60	60	61	61	15			25	25	60
COMPONENTS, Kg (NOTE 3)													
FUEL	0.00E+00	0.00E+00	0.00E+00	3.39E+04	3.39E+04	2.25E+06	2.25E+06	0.00E+00			0.00E+00	0.00E+00	2.25E+06
URANIUM	0.00E+00	0.00E+00	0.00E+00	3.15E+04	3.15E+04	2.09E+06	2.09E+06	0.00E+00			0.00E+00	0.00E+00	2.09E+06
PLUTONIUM	0.00E+00	0.00E+00	0.00E+00	6.18E+01	6.18E+01	4.10E+03	4.10E+03	0.00E+00			0.00E+00	0.00E+00	4.10E+03
OTHER	0.00E+00	0.00E+00	0.00E+00	2.37E+03	2.37E+03	1.57E+05	1.57E+05	0.00E+00			0.00E+00	0.00E+00	1.57E+05
SLUDGE	0.00E+00	0.00E+00	0.00E+00	4.14E+01	4.14E+01	2.73E+03	2.73E+03	0.00E+00			0.00E+00	0.00E+00	2.75E+03
$Al(OH)_3$	0.00E+00	0.00E+00	0.00E+00	4.13E+00	4.13E+00	2.75E+02	2.75E+02	0.00E+00			0.00E+00	0.00E+00	2.74E+02
Al_2O_3	0.00E+00	0.00E+00	0.00E+00	1.35E-02	1.35E-02	1.35E-02	1.35E-02				0.00E+00	0.00E+00	9.00E-01
$Fe(OH)_3$	0.00E+00	0.00E+00	0.00E+00	4.21E-01	4.21E-01	2.79E+01	2.79E+01	0.00E+00			0.00E+00	0.00E+00	2.79E+01
$UO_2(OH)_2$	0.00E+00	0.00E+00	0.00E+00	1.36E+01	1.36E+01	9.62E+02	9.61E+02	0.00E+00			0.00E+00	0.00E+00	9.05E+02
UO_4-$4H_2O$	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00			0.00E+00	0.00E+00	0.00E+00
UO_4-$2H_2O$	0.00E+00	0.00E+00	0.00E+00	1.45E+01	1.45E+01	9.60E+02	9.60E+02	0.00E+00			0.00E+00	0.00E+00	9.60E+02
UO_2	0.00E+00	0.00E+00	0.00E+00	2.34E+00	2.34E+00	1.26E+02	1.26E+02	0.00E+00			0.00E+00	0.00E+00	1.55E+02
UH_3	0.00E+00	0.00E+00	0.00E+00	5.70E+00	5.70E+00	3.78E+02	3.78E+02	0.00E+00			0.00E+00	0.00E+00	3.78E+02
UO_3	0.00E+00	0.00E+00	0.00E+00	8.18E-01	8.18E-01	8.18E-01	8.18E-01	0.00E+00			0.00E+00	0.00E+00	5.39E+01
SOLIDS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00			1.45E+03	7.96E+02	0.00E+00
STAINLESS STEEL	0.00E+00	5.60E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00			1.43E+03	0.00E+00	0.00E+00
ALUMINUM	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00			0.00E+00	0.00E+00	0.00E+00
OTHER	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00			2.39E+01	7.96E+02	0.00E+00
WATER	0.00E+00	0.00E+00	0.00E+00	9.66E-01	9.66E-01	6.52E+01	6.52E+01	0.00E+00			0.00E+00	0.00E+00	6.40E+01
AIR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00			0.00E+00	0.00E+00	0.00E+00
OTHER GASES	0.00E+00	0.00E+00	0.00E+00	7.84E-01	7.84E-01	5.10E+01	5.10E+01	1.90E+03			0.00E+00	0.00E+00	5.15E+01
ARGON	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.90E+03			0.00E+00	0.00E+00	0.00E+00
HYDROGEN	0.00E+00	0.00E+00	0.00E+00	2.57E-02	2.57E-02	1.56E+00	1.56E+00	0.00E+00			0.00E+00	0.00E+00	2.12E+00
HELIUM	0.00E+00	0.00E+00	0.00E+00	7.58E-01	7.58E-01	4.94E+01	4.94E+01	0.00E+00			0.00E+00	0.00E+00	4.94E+01
TOTAL MASS KG	0.00E+00	0.00E+00	0.00E+00	3.39E+04	3.39E+04	2.25E+06	2.25E+06	1.90E+03			1.45E+03	7.96E+02	2.25E+06

STREAM NUMBER	C-22	C-23	C-24	C-25	C-26	C-27	C-28	C-29	C-30	C-31	C-32	C-33	C-34	C-35
DESCRIPTION	HE GAS SUPPLY	MONITORED MCO GAS EXHAUST	DELETED	ANNEX ROOM AIR GOING TO WELD STATION	FILTER WELD STATION OFFGAS	WELD STATION SPENT HEPA FILTER WASTE	REPLACEMENT HEPA FILTERS FOR WELD STATION	CLEAN EMPTY CASK	CASK DECON MATERIAL	EMPTY CASK	CASK DECON WASTE	MISC DECON MATERIALS	MISC DECON WASTE	ACCUMULATED SOLID WASTE
TRANSFER TYPE	BATCH	BATCH		BATCH	BATCH	BATCH	BATCH	BATCH	BATCH	BATCH	BATCH	BATCH	BATCH	BATCH
PHASE (NOTE 2)	G	G		G	G	S	S	S	S	S	S	S	S	S
NUMBER OF ITEMS	398	6		398	398	-	-	398	398	398	-	6	6	19
ITEM COUNT BASIS	MCO	MCO		MCO	MCO	TOTAL	TOTAL	CASK TRANSFER	-	CASK TRANSFER	-	MCO		55 GAL DRUM
VOLUME, m^3	1.44E+03	1.02E+03		1.74E+06	1.74E+06	-	-	-	1.33E+00	-	1.33E+00	1.80E-01	1.80E-01	3.17E+00
DENSITY, g/cc	1.69E-04	-		1.22E-03	1.22E-03	-	-	-	0.6	-	0.6	0.6	0.6	1.00E+00
PRESSURE, TORR	760	760		760	760	-	-	-	-	-	-	-	-	-
TEMPERATURE, Deg C	15	15		15	15	AMBIENT	AMBIENT	AMBIENT	AMBIENT	AMBIENT	AMBIENT	AMBIENT	AMBIENT	AMBIENT
COMPONENTS, kg (NOTE 3)														
FUEL	0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
URANIUM	0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PLUTONIUM	0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
OTHER	0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SLUDGE	0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
$Al(OH)_3$	0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Al_2O_3	0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
$Fe(OH)_3$	0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
$UO_2(OH)_2$	0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
$UO_4\text{-}4H_2O$	0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
$UO_4\text{-}2H_2O$	0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
UO_2	0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
UH_3	0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
UO_3	0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SOLIDS	0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.96E+02	0.00E+00	7.96E+02	1.08E+02	1.08E+02	3.14E+03
STAINLESS STEEL	0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.42E+03
ALUMINUM	0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
OTHER	0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.96E+02	0.00E+00	7.96E+02	1.08E+02	1.08E+01	1.72E+03
WATER	0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
AIR	0.00E+00	0.00E+00		2.14E+06	2.14E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
OTHER GASES	2.44E+02	1.72E+02		0.00E+00	2.14E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ARGON	0.00E+00	0.00E+00		0.00E+00	1.90E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
HYDROGEN	0.00E+00	1.92E-02		0.00E+00	1.92E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
HELIUM	2.44E+02	1.72E+02		0.00E+00	2.44E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TOTAL MASS KG	2.44E+02	1.72E+02		2.14E+06	2.14E+06	0.00E+00	0.00E+00	0.00E+00	7.96E+02	0.00E+00	7.96E+02	1.08E+02	1.08E+02	3.14E+03

STREAM NUMBER	C-36	C-37	C-38	C-39	C-40	C-41	C-42	C-43	C-44	C-45	C-46	C-47
DESCRIPTION	PACKAGED SOLID WASTE	SOLID WASTE DRUMS	SERVICE SYSTEM EXHAUST AND WELD STATION OFFGAS	MHM VENTILATION EXHAUST	REPLACEMENT HEPA FILTER MHM	SPENT HEPA FILTER MHM	OPERATING AREA VENTILATION EXHAUST	SPENT HEPA FILTER OPERATING AREA	REPLACEMENT HEPA FILTER OPERATING AREA	SPENT HEPA FILTER SUPPORT BUILDING	REPLACEMENT HEPA FILTER SUPPORT BUILDING	CASK SERVICE SYSTEM EXHAUST
TRANSFER TYPE	BATCH	BATCH	BATCH	BATCH	BATCH	BATCH	CONTINUOUS	BATCH	BATCH	BATCH	BATCH	BATCH
PHASE (NOTE 2)	S	S	G	G	S	S	G	S	S	S	S	G
NUMBER OF ITEMS	-	19	-	-	-	-	-	-	-	-	-	-
ITEM COUNT BASIS	DRUM/BOX	55 GAL DRUM	-	-	TOTAL	TOTAL	-	TOTAL	TOTAL	TOTAL	TOTAL	-
VOLUME, m^3	3.17-	-	1.74E+06	5.62E+06	-	-	2.67E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0
DENSITY, g/cc	-	-	1.22E-03	1.22E-03	-	-	1.22E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	-
PRESSURE, TORR	-	-	760	760	-	-	760	-	-	-	-	-
TEMPERATURE, Deg C	AMBIENT	AMBIENT	15	15	AMBIENT	AMBIENT	15	AMBIENT	AMBIENT	AMBIENT	AMBIENT	-
COMPONENTS, Kg (NOTE 3)												
FUEL	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
URANIUM	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PLUTONIUM	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
OTHER	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SLUDGE	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
$Al(OH)_3$	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Al_2O_3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
$Fe(OH)_3$	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
$UO_2(OH)_2$	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
UO_4-$4H_2O$	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
UO_4-$2H_2O$	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
UO_2	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
UH_3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
UO_3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SOLIDS	3.14E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
STAINLESS STEEL	1.42E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ALUMINUM	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
OTHER	1.72E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
WATER	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
AIR	0.00E+00	0.00E+00	2.14E+06	6.89E+06	0.00E+00	0.00E+00	3.27E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
OTHER GASES	0.00E+00	0.00E+00	2.14E+03	0.00E+00	0.00E+00	0.00E+00	2.14E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ARGON	0.00E+00	0.00E+00	1.90E+03	0.00E+00	0.00E+00	0.00E+00	1.90E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
HYDROGEN	0.00E+00	0.00E+00	1.92E-02	0.00E+00	0.00E+00	0.00E+00	1.92E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
HELIUM	0.00E+00	0.00E+00	2.44E+02	0.00E+00	0.00E+00	0.00E+00	2.44E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TOTAL MASS KG	3.14E+03	0.00E+00	2.14E+06	6.89E+06	0.00E+00	0.00E+00	3.27E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

STREAM NUMBER	C-48	C-49	C-50	C-51	C-52	C-53
DESCRIPTION	SOLID WASTE BOXES	ACCUMULATED FILTER WASTE	REPLACEMENT SAMPLE HEPA FILTER	SPENT HEPA FILTER FROM SAMPLE HOOD	HELIUM REINERTED MONITORED MCOs TO WELDING	PRESSURE SENDING AND READOUT UNITS
TRANSFER TYPE	BATCH	BATCH	BATCH	BATCH	BATCH	BATCH
PHASE (NOTE 2)	S	S	S	S	S/G	S
NUMBER OF ITEMS	-	-	-	-	6	398
ITEM COUNT BASIS	BURIAL BOX	BURIAL BOX	TOTAL	TOTAL	MCO	MCO
VOLUME, m^3	-	-	-	-	-	3.63E-02
DENSITY, g/cc	-	-	-	-	-	-
PRESSURE, TORR	-	-	-	-	1400	-
TEMPERATURE, Deg C	AMBIENT	AMBIENT	AMBIENT	AMBIENT	60	AMBIENT
COMPONENTS, kg (NOTE 3)						
FUEL	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.39E+04	0.00E+00
URANIUM	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.15E+04	0.00E+00
PLUTONIUM	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.18E+01	0.00E+00
OTHER	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.37E+03	0.00E+00
SLUDGE	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.14E+01	0.00E+00
$Al(OH)_3$	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.13E+00	0.00E+00
Al_2O_3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.35E-02	0.00E+00
$Fe(OH)_3$	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.21E-01	0.00E+00
$UO_2(OH)_2$	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.36E+01	0.00E+00
UO_4-$4H_2O$	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
UO_4-$2H_2O$	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.45E+01	0.00E+00
UO_2	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.34E+00	0.00E+00
UH_3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.70E+00	0.00E+00
UO_3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.18E-01	0.00E+00
SOLIDS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.44E+01
STAINLESS STEEL	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.44E+01
ALUMINUM	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
OTHER	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
WATER	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.66E-01	0.00E+00
AIR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
OTHER GASES	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.94E-01	0.00E+00
ARGON	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
HYDROGEN	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.38E-02	0.00E+00
HELIUM	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.80E-01	0.00E+00
TOTAL MASS KG	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.39E+04	7.44E+01

REVIEW CHECKLIST

Document Reviewed:
SNF-5741, SNF Project Canister Storage Building PFD Mass Balance Calculations
Rev0

Scope of Review:
Technical Review of Mass Balance Calculations

Yes	No	NA		
⊗	○	○	*	Previous reviews complete and cover analysis, up to scope of this review, with no gaps.
⊗	○	○		Problem completely defined.
○	○	⊗		Accident scenarios developed in a clear and logical manner.
⊗	○	○		Necessary assumptions explicitly stated and supported.
○	○	⊗		Computer codes and data files documented.
⊗	○	○		Data used in calculations explicitly stated in document.
⊗	○	○		Data checked for consistency with original source information as applicable.
⊗	○	○		Mathematical derivation checked including dimensional consistency of results.
○	○	⊗		Models appropriate and used within range of validity or use outside range of established validity justified.
⊗	○	○		Hand calculations checked for errors. Spreadsheet results should be treated exactly the same as hand calculations.
○	○	⊗		Software input correct and consistent with document reviewed.
○	○	⊗		Software output consistent with input and with results reported in document reviewed.
⊗	○	○		Limits/criteria/guidelines applied to analysis results are appropriate and referenced. Limits/criteria/guidelines checked against references.
⊗	○	○		Safety margins consistent with good engineering practices.
⊗	○	○		Conclusions consistent with analytical results and applicable limits.
⊗	○	○		Results and conclusions address all points required in the problem statement.
○	○	⊗		Format consistent with appropriate NRC Regulatory Guide or other standards.
○	○	⊗	*	Review calculations, comments, and/or notes are attached.
⊗	○	○		**Document approved.**

Richard A. Sexton [signature] 1/25/00
Reviewer (Printed Name and Signature) Date

*Any calculations, comments, or notes generated as part of this review should be signed, dated and attached to this checklist. Such material should be labeled and recorded in such a manner as to be intelligible to a technically qualified third party.

PAGINATION SHEET

Document: SNF-5741

Page 1 of 1

Number of Originals:

Halftone

Recto	Verso
DIST	-
EDT	-
Cover	-
Cover	disclaimer
i	ii
iii	[redacted]
[redacted]	[redacted]
1	2
↓	↓
39	40
41	—
A-1	—
A-2	▲
3	
4	↓
5	
A-6	—
Chlist	—

Foldout

Recto	Verso

Reduction

Recto	Verso

DISTRIBUTION SHEET

To	From	Page 1 of 1
Distribution	Process Engineering	Date 2/2/00
Project Title/Work Order		EDT No. 628526
Spent Nuclear Fuel Project Canister Storage Building Process Flow Diagram Mass Balance Calculations		ECN No. N/A

Name	MSIN	Text With All Attach.	Text Only	Attach./ Appendix Only	EDT/ECN Only
<u>Spent Nuclear Fuel Project</u>					
G. D. Bazinet	S8-06	X			
D. M. Black	R3-86	X			
S. B. Carter	S8-05	X			
D. L. Cooley	R3-86	X			
J. R. Frederickson	R3-86	X			
R. L. Garrett	R3-26	X			
M. J. Klem	R3-86	X			
S. A. Krieg	S8-06	X			
F. W. Moore	R3-86	X			
S. S. Moss	R3-11	X			
A. L. Pajunen	R3-86	X			
O. M. Serrano	S2-44	X			
R. A. Sexton	R3-86	X			
V. D. Zarasua	S2-44	X			
SNF Project Files	R3-11	X			
SNF Project Procedures	X3-86				X
SNF Project Training	S2-45				X