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Secondary Waste Considerations for Vitrification of Sodium-Bearing Waste at the Idaho Nuclear Technology and Engineering Center FY-2001 Status Report

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Bechtel BWXT Idaho, LLC

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ABSTRACT

The Idaho Nuclear Technology and Engineering Center (INTEC) is considering vitrification to process liquid sodium-bearing waste. Preliminary studies were completed to evaluate the potential secondary wastes from the melter off-gas clean up systems. Projected secondary wastes comprise acidic and caustic scrubber solutions, HEPA filters, activated carbon, and ion exchange media. Possible treatment methods, waste forms, and disposal sites are evaluated from radiological and mercury contamination estimates.

SUMMARY

The High-Level Waste Program is considering vitrification of the liquid sodium-bearing waste stored at the Idaho Nuclear Technology and Engineering Center which is part of the Idaho National Engineering and Environmental Laboratory. Several secondary wastes are anticipated from the melter off-gas clean up system, such as acidic and caustic scrubber solutions, HEPA filters, activated carbon, and ion exchange media. These wastes are expected to be designated as mixed low-level wastes. Initial scoping studies were completed to evaluate possible disposal paths for these wastes. The radiological and land disposal regulations as well as the individual site waste acceptance criteria were considered to anticipate treatment methods, waste forms, and disposal sites for each waste stream.

In general, the radiological content of the secondary wastes can be managed and a disposal site found. Hanford Site accepts Category 1 and 3 mixed low-level wastes. The Nevada Test Site is seeking a mixed waste license for both Class A and Class C wastes. Additionally, Envirocare of Utah will accept Class A mixed low-level waste.

The land disposal regulations may present more of a challenge for secondary waste disposal. It is well known that in the vitrification process nearly all mercury exits the melter and enters the off-gas system; thus, the mercury in the sodium-bearing waste will find its way to the secondary wastes. Under the baseline flowsheet, both the scrubber grout and the activated carbon may exceed 260 mg/kg value for high mercury. Mercury collection and treatment methods for these secondary waste must demonstrate leach resistance and amalgamation equivalency agreements may be needed to allow land disposal.

NOMENCLATURE

Alkaline Grout	A grout formulation where the waste is rendered basic (pH > 12) and mixed with a 9:1 blend of blast furnace slag and portland cement.
Blast Furnace Slag	A finely ground non-metallic waste produce developed in the manufacture of pig iron, consisting basically of a mixture of lime, silica, and alumina, the same oxides that make up portland cement, but not in the same proportions or forms.
Calcination	The process of converting a liquid to a solid product called calcine.
Cement	Refers to type I/II portland cement.
CsIX	A proposed process to treat sodium-bearing waste by cesium removal via ion exchange, then grouting and shipment to the Waste Isolation Pilot Plant.
Denitration	Thermal process to destroy the nitrate content of the waste.
Fly Ash	A pozzolan of finely divided residue that results from the combustion of ground or powdered coal. Class C fly ash may contain 10% lime, has cementitious properties, and reacts with water to form a solid. Class F fly ash does not use water and aids in grout flow.
GAC	Granulated activated carbon.
Grout	A mixture of portland cement, other powdered additives, waste, and water. It may contain fine-grained sand and does not include large aggregate material. For this study, grouting is the process of solidifying and stabilizing low-level waste in cement based materials.
HEPA Filter	High efficiency particulate air filter.
Leaching	The process whereby a liquid agent will dissolve hazardous materials within a waste mass and transport these materials through the mass and beyond. The most widely used laboratory leaching test is the TCLP (Toxic Characteristic Leaching Procedure) specified by the EPA in several regulations. For many treated and untreated wastes, the results of this test determine whether the EPA considers the material toxic or not.

Low-Activity Waste — Low-level waste derived from the solvent extraction, ion exchange, and chemical extraction separation processes on the tank farm sodium-bearing waste and on the dissolved calcines.

NGLW — Newly generated liquid waste -- low-level waste projected to be produced that is not part of the existing tank farm inventory. Sources are the process equipment waste system, decontamination solutions, and filter leach solutions.

Portland Cement — The product obtained by pulverizing clinker consisting essentially of hydraulic calcium silicates.

Pozzolan — A siliceous or siliceous and aluminous material that reacts with liquid calcium hydroxide in the cement gel to form compounds possessing cementitious properties.

Solidification — The process of producing from liquid, sludge, or loose solids a more or less monolithic structure having some integrity. Occasionally, solidification may refer to the process that results in a soil-like material rather than a monolithic structure. Solidification does not necessarily reduce leaching of hazardous materials. However, when a waste is solidified, its mass and structure are altered, decreasing migration of solutions within the mass.

Stabilization — Generally refers to a purposeful chemical reaction that has carried out to make waste constituents less leachable. This is accomplished by chemically immobilizing hazardous materials or reducing their solubility by a chemical reaction.

Waste Form — The final product for long-term storage. This includes the solidified/stabilized waste as well as the container. The waste form must pass extensive qualification testing prior to release for storage.

Waste Loading — The mass weight percent of the waste in the total mass of the final waste form.

Vitrification — The process of placing waste material in a glass form. This is a thermal process where the waste material is placed in a melter with glass beads or frit, then heated together, poured into a storage container, and cooled to a solid form.

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SECONDARY WASTE CONSIDERATIONS FOR VITRIFICATION OF SODIUM-BEARING WASTE AT THE IDAHO NUCLEAR TECHNOLOGY AND ENGINEERING CENTER FY-2001 STATUS REPORT

1. INTRODUCTION

The Idaho Nuclear Technology and Engineering Center (INTEC) High-Level Waste Program is to prepare the liquid sodium-bearing waste and calcined solids for eventual disposal. Several alternative disposal processes have been explored for these wastes. During fiscal year 2001, the direct vitrification of sodium-bearing waste was studied. The specific task covered in this report is the potential secondary wastes resulting from the off-gas cleanup operations during vitrification of sodium-bearing waste.

The vitrification process uses a glass melter to immobilize the sodium-bearing waste (SBW). As part of this process, an off-gas cleanup system is required which utilizes liquid scrubbers, high efficiency filters, and activated carbon to clean the off-gas air prior to release to the environment (Figure 1). These clean up actions result in secondary waste production and subsequent need for their treatment and disposal. Initial scoping studies evaluated the feasibility of treatment and disposal of scrubber blowdown solutions, ion exchange media, filters, and activated carbon. It is expected that these wastes will be designated as mixed low-level wastes.

A SBW vitrification baseline flowsheet and mass balance were submitted to the Department of Energy and form the basis for this secondary waste evaluation.[1] It is anticipated that 522 m^3 of grouted scrubber waste, 6.3 m^3 of spent filters, 54 m^3 of activated carbon, and 5.4 m^3 ion exchange media will be produced as secondary wastes.

1.1 Off-Gas System Description

Following the melter the off-gas is cooled in a film cooler at a flowrate of 1910 m^3/hr plus 150 m^3/hr of pressure control air. The off-gas is then rinsed by an acidic scrubber solution followed by a high efficiency mist eliminator to remove the bulk of particulate carryover from the melter. At this point the off-gas flowrate is expected to be 2060 m^3/hr. The scrubber is followed by a set of high efficiency particulate air (HEPA) filters. Next, any oxides of nitrogen are destroyed in the Noxidizer $_{TM}$ unit and the flowrate goes up to 3440 m^3/hr. The off-gas is again rinsed by a caustic scrubber to remove most of the acidic gases. This is followed by a demister and a bed of granulated activated carbon to polish/clean the off-gas and remove any remaining mercury. Finally, the off-gas passes through another set of HEPA filters prior to release to the atmosphere at 3450 m^3/hr.

Since the acidic scrubber solution may be very contaminated, it is planned to recycle most of this solution back to the melter. The current flowsheet predicts 19.6 L/hr to be recycled to the melter and about 1.3 L/hr to be waste blowdown solution. The blowdown will the undergo cesium removal (CsIX) utilizing ion exchange media such as crystalline silicotitanate (CST) to reduce the gamma radiation levels of the solution. The acid scrubber blowdown will then be combined with the caustic scrubber blowdown (22.5 L/hr) to yield about 24 L/hr to be grouted. The combined solution is expected to be caustic and should be directly grouted with minimal pretreatment.

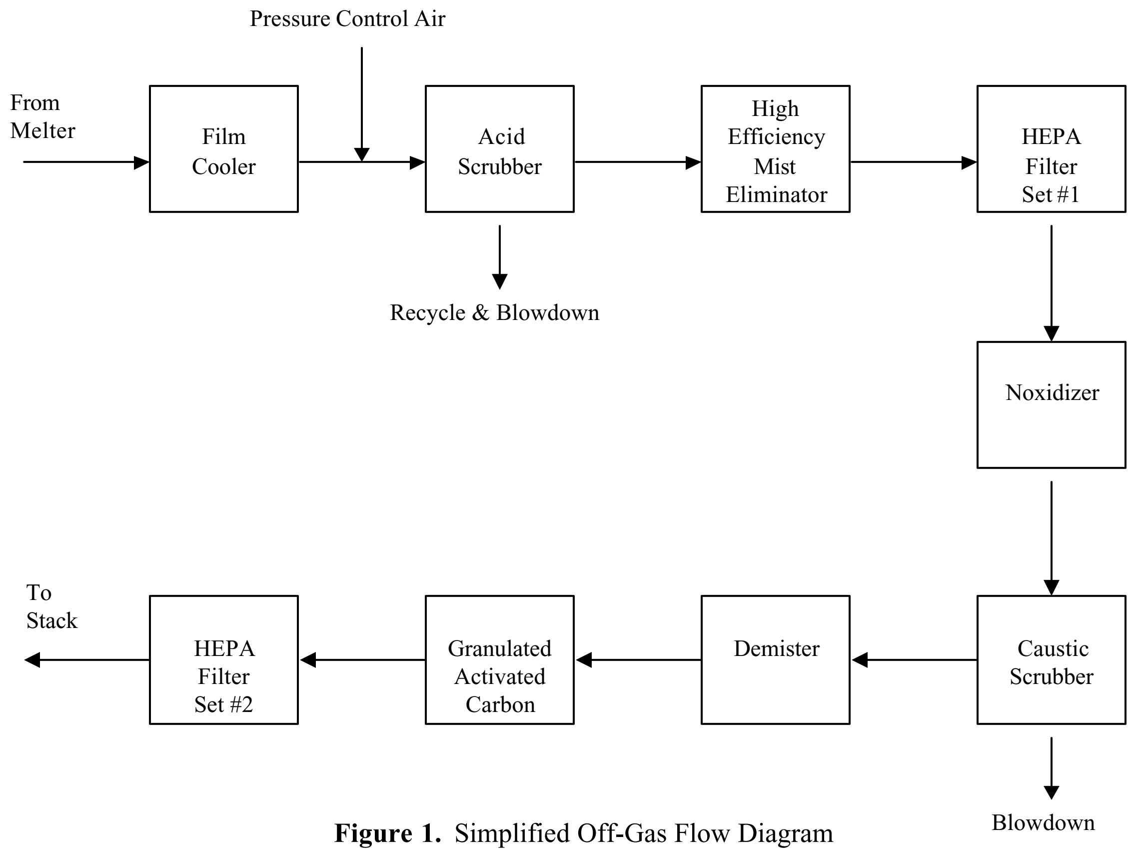

Figure 1. Simplified Off-Gas Flow Diagram

The HEPA filter set #1, following the acid scrubber is expected to be changed out every 6 months during the 2 year campaign. The carbon bed and ion exchange media should last the 2 years. For the final HEPA filter set #2, it is planned to change out the prefilters every 6 months and the main HEPA filters in these banks should remain in place for the 2 years.

1.2 Potential Disposal Sites

Four disposal sites are available to the INEEL for disposal of secondary waste. These are Hanford Site, Nevada Test Site, Envirocare of Utah, and the Radioactive Waste Management Complex (RWMC) at the INEEL. The RWMC is not considered a potential site since it is not designated as a long term mixed waste disposal site. The Hanford Site has been designated as DOE's mixed waste disposal site and is now receiving waste, although little from out of state at the present. The Nevada Test Site (NTS) at the present will accept only low-level waste; however, NTS has applied for a mixed waste license which should be approved in 2002. Envirocare of Utah will accept mixed low-level Class A waste, but decided to withdraw their application for Class C waste.

The radioactive content of the waste must be provided to all sites. The concentration of each specific radionuclide cannot exceed its specified disposal limit. In addition, all sites have a sum of fractions rule that must be met for the combination of all radionuclides. This rule requires the concentration of each radionuclide be divided by the concentration limit to yield a fraction, then all these fractions are summed. The total sum of fractions must be less than 1.0. This prevents excessive radiation in the waste by having several radionuclides near their concentration limits. The sum of fractions rule is used as a determining factor as to the category or class of the waste.

Concerning the SBW listed waste codes (F001, F002, F003, and U134), Envirocare will accept all of these codes, whereas, Hanford and NTS do not accept the hydrofluoric acid (U134) listed code. As such, any waste going to Hanford or NTS will need a waiver or acceptance agreement.

For the RCRA metals, Envirocare and the NTS will accept the standard toxicity characteristic leaching procedure (TCLP). Hanford, on the other hand, utilizes the concentration of the metals in the waste and not in a leachate solution (the exact values/limits need to be determined). For these secondary wastes, it is anticipated that the wastes will be high for mercury (greater than 260 mg/kg). This will require that the mercury pass TCLP and a best available technology (BDAT) equivalency be established with the disposal site.

All of the sites impose the no free liquid rule. Further, none of the sites have specific physical strength requirements for grouted waste or other solids. All sites accept the standard 55 gallon waste drum for most waste classes. For high radiation wastes, Hanford requires a high integrity container (HIC) be used.

1.3 Assumptions

Assumptions used in developing the secondary waste flowsheets are:

- Acidic and caustic combined scrub density is 1300 g/L.
- Combined scrub grout density is 1800 kg/m^3 at 35 wt% waste loading.
- The HEPA filter media density is 110 kg/m^3.
- The HEPA filter density with the frames is 1000 kg/m^3.
- The HEPA filter volume is based on 4 banks of a 24" X 24" X 6" prefilter followed 2 filters 24" X 24" X 12". This calculates to 1.13 m^3.
- Interim filters are changed out 4 times during the 2 years of operations.
- For the final filters, the prefilters will be changed out 4 times during the 2 years of operation and the HEPA filters behind the prefilters will remain in place during the 2 years of operation.
- Since the final filter bank prefilters are changed out 4 times, it is assumed that 99% of the contamination is on the 16 prefilters and 1% on the final 8 HEPAs.
- No compaction of filters is assumed in contamination concentrations.
- Sulfur impregnated activated carbon is used and remains in place for the 2 years of operations.
- The activated carbon bed density is 550 kg/m^3.
- Ion exchange media remains in place during the 2 years.
- Ion exchange media density is 640 kg/m^3.
- Operations are based on 24 hours per day, 200 days per year, for 2 years.

2. METHODOLOGY

The SBW vitrification flowsheet and mass balance dated August 6, 2001, for the “Total” waste was used to evaluate the secondary waste concentrations. The “Total” concentration mass balance is the projected blended combination of all wastes collected until 2012 from both the SBW and Newly Generated Liquid Waste (NGLW). These concentrations were compared against the waste acceptance criteria (WAC) for the various disposal sites. Detailed WAC summaries for each secondary waste are found in Appendix A. The calculations include the individual radionuclides compared to the WAC limit, the transuranic (TRU) content, and the sum of fractions. These resulting values are presented for the Hanford WAC Category 1 and 3, Nevada Test Site WAC using the Nuclear Regulatory Commission (NRC) WAC Class A and C, and Envirocare of Utah WAC. In most cases the mass balance presents the radionuclide concentration in Curies per cubic meter (Ci/m^3). The grout density is used to calculate the TRU concentration in nano-Curies per gram (nCi/g) and the Envirocare concentration in pico-Curies per gram (pCi/g).

The mass balance spreadsheet reported the combined scrubber grout radionuclide concentrations directly. For the other secondary wastes the difference between the inlet unit operation and the outlet unit operation were subtracted from each other and multiplied by the flow rate and total time of operation to obtain the concentration build up. This was done for the interim HEPA filters between the High Efficiency Mist Eliminatory (HEME) outlet and the noxidizer inlet. For the HEPA set #1 filters, the concentrations were divided by 4 to allow for the 4 change outs during operations. The final HEPA set #2 filter radionuclide concentration was obtained by using the outlet concentrations from the activated carbon and the stack release values. The buildup on the activated carbon bed was determined by subtracting the concentrations at the outlet of the demister and the carbon bed outlet and then multiplying by the off-gas flowrate at that point and the total operating time. The cesium concentration on the ion exchange media was found in a likewise manner.

For these scoping studies, only a limited number of radionuclides were used as noted in Appendix A. The nine radionuclides were found to be the major contributors to the sum of fractions and TRU content. However, when the waste is disposed, all radionuclides must be accounted for in the sum. Thus, if the preliminary sum is 0.9, the final sum may exceed the limit of 1.0 due to the addition of the all the other radionuclide fractions.

In order to estimate the radiation dose from the radioactive contamination levels for each secondary waste, the projected curie concentration for the nine radionuclides were entered into MicroShield. For the scrubber grout, ion exchange media, and activated carbon, a 55 gallon drum was used as the disposal container. The HEPA filters were grouped together in a rectangular volume with an iron/steel container. The estimated dose results were on contact at 1 cm from the container. At this time, the results are only preliminary. No independent verification of the results have been completed to date.

The mercury concentration in the various secondary wastes was calculated from the mass balance spreadsheet using calculations similar to the above with the additional calculation for particulate and gaseous mercury whenever noted in the “Total” mass balance. In all cases the mercury concentration was calculated in terms of milligrams of mercury per kilogram of secondary waste (mg/kg) to match the regulatory units. Appendix C is a spreadsheet showing the mercury concentrations for each secondary waste.

3. RESULTS AND CONCLUSIONS

Table 1 presents the resulting sum of fractions, TRU content, and mercury concentration for the various waste streams for the baseline off-gas flowsheet, specifically the noxidizer flowsheet. Again, to meet a specific waste classification, the sum of fractions must be less than 1. Further, the regulatory limit between low and high mercury is 260 mg/kg. The results for each secondary waste stream are discussed in individual sections below.

Table 1. SBW Vitrification Flowsheet Secondary Waste Results.

	Sum of Fractions							
	Hanford		NRC			Major	TRU	Mercury
Secondary Waste	Cat 1	Cat 3	Class A	Class C	Envirocare	Nuclide	nCi/g	mg/kg
Combined Scrub Grout with CsIX	19.6	0.0	7.8	0.0	15.7	Sr	< 1	450
Ion Exchange Media	72500	0.3	399	0.1	10400	Cs	< 1	< 1
HEPA Filter Set #1	1230	0.0	24.5	0.5	143	Cs,Sr,I	2.5	2560
Activated Carbon	0.0	0.0	0.0	0.0	0.0	None	< 1	93800
HEPA Filter Set #2	0.0	0.0	0.0	0.0	0.0	None	< 1	< 1

3.1 Scrubber Blowdown Grout Disposal

From a radioactive standpoint, recycling the majority of the acid scrubber blowdown and combining a small amount with the caustic scrubber solution greatly improves the waste disposal possibilities for the scrubber grout. As can be seen from Table 1, the scrubber grout easily meets the Hanford Category 3 and NRC Class C low-level waste limits for the sum of the fractions rule. The grouted waste would not meet the waste acceptance criteria (WAC) for Envirocare, Hanford Category 1, or NRC Class A due to the presence of strontium-90. With the cesium removed the contact radiation dose from a 55 gallon drum is expected to be less than 1 mR/hr (Appendix B). Therefore, the grout may be contact handled, but would be Category 3 / Class C waste due to the remaining strontium-90.

The mercury level in the grout calculates to 450 mg/kg. In the combined scrub solution prior to grouting the mercury level is 1280 mg/kg. Since these values are over the high mercury limit, a equivalency agreement will be needed with the disposal sites. The grout projected formulation uses blast furnace slag which has been shown to retain mercury due to sulfur in the slag. Prior tests with newly generated liquid wastes have shown that whenever blast furnace slag is used the mercury will pass leach tests (TCLP) even at mercury levels as high as 4260 mg/kg in the simulated waste and 1910 mg/kg in the grout.[2] Amalgamation is the required treatment process for high mercury; therefore, grouting will need to be demonstrated/accepted as a process with equivalent results.

3.2 Ion Exchange Media Disposal

There are two options for disposal of the ion exchange media. First, there is the option of placing the media in a high integrity container for disposal as remote handled material at Hanford as Category 3 material. The cesium in the media is 30% of the cesium limit for Category 3. This media would be extremely radioactive with about 400 Curies of cesium per cubic meter. If this material was placed in a 55 gallon drum, the contact radiation dose would be about 230 rem per hour (R/hr). For comparison purposes, the 400 Ci/m^3 is about one-fifth the cesium curie content of the high-level calcine.

The second possible method of disposal of the ion exchange media is to recycle the media to the melter. If a media such as crystalline silicotitanate is used the aluminum and silicon based media could readily be incorporated with glass forming materials. It is planned that after the sodium-bearing waste liquid is vitrified that any remaining tank waste solids would be washed from the tanks and subsequently vitrified. The ion exchange media could be added to the melter along with the tank solids. This latter disposal method would avoid the need for a separate waste stream.

There have been questions as to the need for ion exchange. For example, even though the cesium is removed the remaining strontium-90 keeps the waste at a Category 3 / Class C waste as noted in Table 1. If the cesium were left in the waste, the waste form would be Category 3 / Class C. The real answer to this issue is in the grouting process as to whether the process will be contact handled or remote handled. By removing the cesium the radiation dose from a drum of grout is reduced from over 900 millirem per hour (mR/hr) to less than 1 millirem per hour (Appendix B). The trade off is then the requirement to add shielding to the grouting process for remote handling of 900 mR/hr as opposed to no shielding for contact handled. It is thought that the expense of an ion exchange system is less expensive than a remote handled, shielded grout mixing system. There is another alternative to improve the waste classification as noted in the next paragraph.

In the baseline process, the current flowsheet runs CsIX on the acidic scrubber solution prior to combining with the caustic scrub. Cesium can be removed from an acidic solution via ion exchange, but a successful strontium ion exchange media has not been found for acidic solutions. However, both cesium and strontium can be removed from alkaline solutions by ion exchange. The feasibility study on the vitrification of calcine[3] proposes to run the ion exchange after the acidic and caustic scrubber solutions are combined. In this case the ion exchange takes place in an alkaline environment which is normal operations at most other sites. In the alkaline case, both cesium and strontium can be removed. Thus, if over 99% of the strontium could be removed, as well as cesium, the waste could be contact handled and be Category 1 / Class A waste. This should be a simple change to the flowsheet and accomplish more for the same unit operation.

3.3 HEPA Filter Disposal

HEPA filter set #1 is the unit following the acidic scrubber and before the noxidizer. As noted in Table 1, these filters would be highly contaminated both by radioactivity and mercury. With the 4 change outs, based on the sum of fractions rule, the filters would qualify as Category 3 / Class C waste. In the set are 4 prefilters and 8 HEPA filters. If these filters were stacked together, the unit size would be 122 cm X 122 cm X 76 cm (4' X 4' X 2.5'). At the projected contamination levels, this package would be about 8 R/hr on contact and would need remote handling (Appendix B).

The mercury is over 2500 mg/kg for HEPA filter set #1. Without further treatment, there is nothing in the filters to retard mercury from leaching out. Without a successful TCLP test, the disposal sites will most likely reject the waste. The high levels of mercury present a significant problem, if not impossible, for direct disposal of the filter set #1.

There are two possible solutions to resolve the high radiation and mercury, other than frequent, excessive change outs. First, the use of washable ceramic filters could be utilized and second, the mercury could be driven to the acidic scrubber solution.

In-situ washable HEPA filters offer the best option for this unit operation (HEPA set #1). The wash water or acid could be added to the acidic scrubber solution and recycled to the melter. This would avoid another secondary waste stream. The filters would not need to be changed out. Savannah River Site has been experimenting with washable ceramic HEPA filters.[4, 5] Further studies on these filters would need to be checked for flow capacity, amount of rinse solution produced, and plugging problems with the acidic scrubber off-gas.

The second option could resolve the mercury issue, but not the radiation. In this case an oxidant is added to the off-gas stream prior to the acidic scrubber. The oxidant, such as hydrogen peroxide, would oxidize the gaseous mercury such that the mercury is scrubbed by the acidic solution. At the present, the majority of the mercury is collected on the activated carbon. With the use of an oxidant, it is possible to drive the mercury to a different secondary waste stream. The long term disposal agreements for high mercury may drive the direction of mercury to the grout or activated carbon.

For the final HEPA filters, set #2, it has been proposed to change out the prefilters every 6 months to avoid plugging problems following the caustic scrubber. The main filters in the banks would remain in the system for the entire 2 years. Appendix A shows the detailed sum of fractions for both the prefilters and the main filters. In both cases, these final filters are low-level Category 1 and Class A waste as shown in Table 1. Additionally, the levels are low enough that the filters could be disposed at Envirocare of Utah which could be the most cost effective disposal site for the filters. Since HEPA set #2 follows the activated carbon beds, the mercury levels are of no concern.

In addition to the process off-gas filters, there are the facility heating, ventilation, air conditioning (HVAC) filters. The vitrification feasibility study shows 28 inlet filter banks and 17 outlet filter banks.[6] The inlet filters are single banks of 16 HEPA filters and 16 prefilters. The planned outlet filters are double banks of 32 HEPA filters and 16 prefilters. This totals 448 inlet HEPAs and 448 prefilters that should be "cold" for disposal. The outlet filters will total 544 HEPAs and 272 prefilters that could be potentially "hot" filters for disposal. Thus, there are a significant number of filters to be checked and appropriately disposed at facility closure.

3.4 Activated Carbon Disposal

As a result of the two scrubber operations, the activated carbon presents no radiological disposal problems. The carbon could be disposed at any of the sites. However, the main problem for the activated carbon is the very high mercury level at 93800 mg/kg. The current plan is to utilize sulfur impregnated granulated activated carbon, such as Mersorb supplied by Selective Adsorptions Associates. This material can absorb up to 20 weight percent (wt%) mercury. In other words, 100 kg Mersorb can adsorb 20 kg of mercury and pass TCLP leach tests. Unsubstantiated user claims state that the loading should be limited to 15 wt%. In the current flowsheet, over 96% of the total mercury in the SBW ends up on the activated carbon. For the 54 m^3 of activated carbon, the mercury loading would be about 9 wt%.

Leach tests are needed to verify the mercury loading levels on Mersorb with the projected off-gas. The mercury that chemically reacts with the sulfur should not leach. However, it may be possible that mercury trapped in the carbon matrix could leach out. Since the loading is about half the theoretical loading, the trapped mercury may also chemically react over time. These issues will need to be investigated.

Again, if the activated carbon can be shown to pass the leach test (TCLP), amalgamation equivalency agreements will be needed with the disposal site and regulators.

Due to the high mercury concentration in the secondary waste streams, it may also be possible to collect all the mercury as elemental mercury. It is estimated that less than two 55-gallon drums would be needed (weight limits not withstanding!) if all the mercury in the SBW were collected. Utilizing the oxidant method, all the mercury could be driven into the acidic scrub solution. A mercury removal system could then be added to the acidic scrubber blowdown stream prior to recycle and grouting. Additional cleanup steps, such as triple distilling, may be needed to render the mercury free of radioactive contamination for recovery and other uses or amalgamation and disposal.

4. RECOMMENDATIONS

1. The composition of mercury and long-lived radionuclides must be carefully followed throughout the process and a disposal "home" determined. All possible process flowsheets must require secondary waste disposal as a major issue to process selection.
2. Washable ceramic filters are recommended for HEPA set #1 in the off-gas system due to high radioactivity and mercury buildup. This would avoid several change outs and eliminate a remote handled waste.
3. The ion exchange take place after combining the acidic and caustic scrubber solutions to allow removal of both cesium and strontium.
4. The ion exchange media should be sent to the melter, as such the media should be compatible with the melter glass former materials.
5. Mercury leach testing is needed to verify retention by the activated carbon.
6. Mercury amalgamation equivalency must be pursued with regulators and potential disposal sites for both the grout and activated carbon waste streams.
7. Mercury collection and removal should be evaluated.

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APPENDIX A

WASTE ACCEPTANCE CRITERIA SUMMARIES

WASTE ACCEPTANCE CRITERIA SUMMARY

Major Radionuclide Contributors

Assumptions:
1800 kg/m^3 grout density
35% waste loading

Revised:
8/6/2001

Combined Scrubber Blowdown Grout with CsIX

Specific Isotopes	Combined Scrub Ci/L	Combined Scrub Grout Ci/m^3	Hanford WAC: Cat. 1 Limit Ci/m^3	Cat. 1 Fraction	Cat. 3 Limit Ci/m^3	Cat. 3 Fraction	NRC WAC: Scrub Grout nCi/g	Class A Limit Ci/m^3	Class A Fraction	Class C Limit Ci/m^3	Class C Fraction
Sr-90	7.08E-04	3.1E-01	1.6E-02	19.57	5.4E+04	0.00		0.04	7.83	7000	0.00
Tc-99	5.29E-11	2.3E-08	2.3E-02	0.00	5.0E+00	0.00		0.3	0.00	3	0.00
I-129	1.27E-07	5.6E-05	8.5E-03	0.01	1.8E+00	0.00		0.008	0.01	0.08	0.00
Cs-137	9.00E-07	4.0E-04	5.5E-03	0.07	1.2E+04	0.00		1	0.00	4600	0.00
Pu-241	1.86E-11	8.2E-09	6.1E-02	0.00	2.5E+01	0.00		350	0.00	3500	0.00
								nCi/g		nCi/g	
Pu-238	8.08E-11	3.6E-08	4.7E-03	0.00	2.4E+01	0.00	0.0	10	0.00	100	0.00
Pu-239	1.15E-11	5.1E-09	1.9E-03	0.00	4.2E-01	0.00	0.0	10	0.00	100	0.00
Pu-240	9.85E-13	4.4E-10	1.9E-03	0.00	4.3E-01	0.00	0.0	10	0.00	100	0.00
Am-241	8.92E-12	3.9E-09	2.1E-03	0.00	8.5E-01	0.00	0.0	10	0.00	100	0.00
		Sum of Fractions =		19.65		0.00			7.83		0.00

Envirocare WAC

Specific Isotopes	Ci/L	pCi/g	Limit pCi/g	Fraction
Sr-90	7.08E-04	3.93E+05	2.5E+04	15.73
Tc-99	5.29E-11	2.94E-02	1.9E+05	0.00
I-129	1.27E-07	7.04E+01	3.1E+03	0.02
Cs-137	9.00E-07	5.00E+02	6.0E+04	0.01
Pu-241	1.86E-11	1.04E-02	3.5E+05	0.00
Pu-238	8.08E-11	4.49E-02	1.0E+04	0.00
Pu-239	1.15E-11	6.39E-03	1.0E+04	0.00
Pu-240	9.85E-13	5.47E-04	1.0E+04	0.00
Am-241	8.92E-12	4.96E-03	1.0E+04	0.00
		Sum of Fractions =		15.76

WASTE ACCEPTANCE CRITERIA SUMMARY

Major Radionuclide Contributors

Assumptions:
1800 kg/m^3 grout density
35% waste loading

Revised: 8/6/2001

Combined Scrubber Blowdown Grout without CsIX

Specific Isotopes	Combined Scrub Ci/L	Combined Scrub Grout Ci/m^3	Hanford WAC: Cat. 1 Limit Ci/m^3	Cat. 1 Fraction	Cat. 3 Limit Ci/m^3	Cat. 3 Fraction	Scrub Grout nCi/g	NRC WAC: Class A Limit Ci/m^3	Class A Fraction	Class C Limit Ci/m^3	Class C Fraction
Sr-90	7.08E-04	3.1E-01	1.6E-02	19.57	5.4E+04	0.00		0.04	7.83	7000	0.00
Tc-99	5.29E-11	2.3E-08	2.3E-02	0.00	5.0E+00	0.00		0.3	0.00	3	0.00
I-129	1.27E-07	5.6E-05	8.5E-03	0.01	1.8E+00	0.00		0.008	0.01	0.08	0.00
Cs-137	9.00E-03	4.0E+00	5.5E-03	723.53	1.2E+04	0.00		1	3.98	4600	0.00
Pu-241	1.86E-11	8.2E-09	6.1E-02	0.00	2.5E+01	0.00		350	0.00	3500	0.00
								nCi/g		nCi/g	
Pu-238	8.08E-11	3.6E-08	4.7E-03	0.00	2.4E+01	0.00	0.0	10	0.00	100	0.00
Pu-239	1.15E-11	5.1E-09	1.9E-03	0.00	4.2E-01	0.00	0.0	10	0.00	100	0.00
Pu-240	9.85E-13	4.4E-10	1.9E-03	0.00	4.3E-01	0.00	0.0	10	0.00	100	0.00
Am-241	8.92E-12	3.9E-09	2.1E-03	0.00	8.5E-01	0.00	0.0	10	0.00	100	0.00
			Sum of Fractions =	743.11		0.00			11.81		0.00

Envirocare WAC

Specific Isotopes	Ci/L	pCi/g	Limit pCi/g	Fraction
Sr-90	7.08E-04	3.93E+05	2.5E+04	15.73
Tc-99	5.29E-11	2.94E-02	1.9E+05	0.00
I-129	1.27E-07	7.04E+01	3.1E+03	0.02
Cs-137	9.00E-03	5.00E+06	6.0E+04	83.31
Pu-241	1.86E-11	1.04E-02	3.5E+05	0.00
Pu-238	8.08E-11	4.49E-02	1.0E+04	0.00
Pu-239	1.15E-11	6.39E-03	1.0E+04	0.00
Pu-240	9.85E-13	5.47E-04	1.0E+04	0.00
Am-241	8.92E-12	4.96E-03	1.0E+04	0.00
			Sum of Fractions =	99.06

WASTE ACCEPTANCE CRITERIA SUMMARY

Major Radionuclide Contributors

Assumptions:
640 kg/m^3 IX media density
5.2 m^3 total IX media volume

Revised: 8/6/2001

Ion Exchange Media

			Hanford WAC					NRC WAC			
Specific Isotopes	IX Media Ci/L	IX Media Ci/m^3	Cat. 1 Limit Ci/m^3	Cat. 1 Fraction	Cat. 3 Limit Ci/m^3	Cat. 3 Fraction	IX Media with chg out nCi/g	Class A Limit Ci/m^3	Class A Fraction	Class C Limit Ci/m^3	Class C Fraction
Sr-90			1.6E-02	0.00	5.4E+04	0.00		0.04	0.00	7000	0.00
Tc-99			2.3E-02	0.00	5.0E+00	0.00		0.3	0.00	3	0.00
I-129			8.5E-03	0.00	1.8E+00	0.00		0.008	0.00	0.08	0.00
Cs-137	3.99E-01	3.99E+02	5.5E-03	72462.06	1.2E+04	0.03		1	398.54	4600	0.09
Pu-241			6.1E-02	0.00	2.5E+01	0.00		350	0.00	3500	0.00
								nCi/g		nCi/g	
Pu-238			4.7E-03	0.00	2.4E+01	0.00	0.0	10	0.00	100	0.00
Pu-239			1.9E-03	0.00	4.2E-01	0.00	0.0	10	0.00	100	0.00
Pu-240			1.9E-03	0.00	4.3E-01	0.00	0.0	10	0.00	100	0.00
Am-241			2.1E-03	0.00	8.5E-01	0.00	0.0	10	0.00	100	0.00
			Sum of Fractions =	72462.06		0.03			398.54		0.09

Envirocare WAC

Specific Isotopes	IX Media Ci/L	IX Media pCi/g	Limit pCi/g	Fraction
Sr-90			2.5E+04	0.00
Tc-99			1.9E+05	0.00
I-129			3.1E+03	0.00
Cs-137	3.99E-01	6.23E+08	6.0E+04	10378.68
Pu-241			3.5E+05	0.00
Pu-238			1.0E+04	0.00
Pu-239			1.0E+04	0.00
Pu-240			1.0E+04	0.00
Am-241			1.0E+04	0.00
			Sum of Fractions =	10378.68

WASTE ACCEPTANCE CRITERIA SUMMARY

Major Radionuclide Contributors

Assumptions:

1000 kg/m^3 filter density

1.13 m^3 total filter volume

4 number of change outs

Revised: 8/6/2001

HEPA Filter Set #1 Disposal

with change outs

Specific Isotopes	Filter Ci/m^3	Filter with 4 chg out Ci/m^3	Hanford WAC Cat. 1 Limit Ci/m^3	Cat. 1 Fraction	Cat. 3 Limit Ci/m^3	Cat. 3 Fraction	Filter with chg out nCi/g	NRC WAC Class A Limit Ci/m^3	Class A Fraction	Class C Limit Ci/m^3	Class C Fraction
Sr-90	2.07E+00	5.17E-01	1.6E-02	32.34	5.4E+04	0.00		0.04	12.94	7000	0.00
Tc-99	4.90E-03	1.23E-03	2.3E-02	0.05	5.0E+00	0.00		0.3	0.00	3	0.00
I-129	1.52E-01	3.80E-02	8.5E-03	4.47	1.8E+00	0.02		0.008	4.75	0.08	0.47
Cs-137	2.63E+01	6.58E+00	5.5E-03	1195.71	1.2E+04	0.00		1	6.58	4600	0.00
Pu-241	1.03E-05	2.58E-06	6.1E-02	0.00	2.5E+01	0.00		350	0.00	3500	0.00
								nCi/g		nCi/g	
Pu-238	7.49E-03	1.87E-03	4.7E-03	0.40	2.4E+01	0.00	1.9	10	0.19	100	0.02
Pu-239	1.07E-03	2.67E-04	1.9E-03	0.14	4.2E-01	0.00	0.3	10	0.03	100	0.00
Pu-240	9.14E-05	2.29E-05	1.9E-03	0.01	4.3E-01	0.00	0.0	10	0.00	100	0.00
Am-241	8.28E-04	2.07E-04	2.1E-03	0.10	8.5E-01	0.00	0.2	10	0.02	100	0.00
		Sum of Fractions =		1233.22		0.02			24.50		0.50

Envirocare WAC

with change outs

Specific Isotopes	Ci/m^3	pCi/g	Limit pCi/g	Fraction
Sr-90	5.17E-01	5.17E+05	2.5E+04	20.70
Tc-99	1.23E-03	1.23E+03	1.9E+05	0.01
I-129	3.80E-02	3.80E+04	3.1E+03	12.25
Cs-137	6.58E+00	6.58E+06	6.0E+04	109.61
Pu-241	2.58E-06	2.58E+00	3.5E+05	0.00
Pu-238	1.87E-03	1.87E+03	1.0E+04	0.19
Pu-239	2.67E-04	2.67E+02	1.0E+04	0.03
Pu-240	2.29E-05	2.29E+01	1.0E+04	0.00
Am-241	2.07E-04	2.07E+02	1.0E+04	0.02
		Sum of Fractions =		142.80

WASTE ACCEPTANCE CRITERIA SUMMARY
Major Radionuclide Contributors

Revised: 8/6/2001

Assumptions:
1000 kg/m^3 filter density
0.23 m^3 total filter volume
4 number of change outs
99% contamination on prefilters

Prefilter from HEPA Set #2 Disposal
with change outs

Specific Isotopes	Filter Ci/m³	Filter with 4 chg out Ci/m³	Hanford WAC Cat. 1 Limit Ci/m³	Cat. 1 Fraction	Cat. 3 Limit Ci/m³	Cat. 3 Fraction	Filter with chg out nCi/g	NRC WAC Class A Limit Ci/m³	Class A Fraction	Class C Limit Ci/m³	Class C Fraction
Sr-90	2.06E-09	5.15E-10	1.6E-02	0.00	5.4E+04	0.00		0.04	0.00	7000	0.00
Tc-99	4.88E-12	1.22E-12	2.3E-02	0.00	5.0E+00	0.00		0.3	0.00	3	0.00
I-129	1.91E-07	4.78E-08	8.5E-03	0.00	1.8E+00	0.00		0.008	0.00	0.08	0.00
Cs-137	2.62E-08	6.54E-09	5.5E-03	0.00	1.2E+04	0.00		1	0.00	4600	0.00
Pu-241	1.72E-12	4.30E-13	6.1E-02	0.00	2.5E+01	0.00		350	0.00	3500	0.00
								nCi/g		nCi/g	
Pu-238	7.45E-12	1.86E-12	4.7E-03	0.00	2.4E+01	0.00	0.0	10	0.00	100	0.00
Pu-239	1.06E-12	2.65E-13	1.9E-03	0.00	4.2E-01	0.00	0.0	10	0.00	100	0.00
Pu-240	9.09E-14	2.27E-14	1.9E-03	0.00	4.3E-01	0.00	0.0	10	0.00	100	0.00
Am-241	8.23E-13	2.06E-13	2.1E-03	0.00	8.5E-01	0.00	0.0	10	0.00	100	0.00
			Sum of Fractions =	0.00		0.00			0.00		0.00

Envirocare WAC
with change outs

Specific Isotopes	Ci/m³	pCi/g	Limit pCi/g	Fraction
Sr-90	5.15E-10	5.15E-04	2.5E+04	0.00
Tc-99	1.22E-12	1.22E-06	1.9E+05	0.00
I-129	4.78E-08	4.78E-02	3.1E+03	0.00
Cs-137	6.54E-09	6.54E-03	6.0E+04	0.00
Pu-241	4.30E-13	4.30E-07	3.5E+05	0.00
Pu-238	1.86E-12	1.86E-06	1.0E+04	0.00
Pu-239	2.65E-13	2.65E-07	1.0E+04	0.00
Pu-240	2.27E-14	2.27E-08	1.0E+04	0.00
Am-241	2.06E-13	2.06E-07	1.0E+04	0.00
			Sum of Fractions =	0.00

WASTE ACCEPTANCE CRITERIA SUMMARY
Major Radionuclide Contributors

Assumptions:
1000 kg/m^3 filter density
0.91 m^3 total filter volume
0 number of change outs
1% contamination on filters

Final Filters from HEPA Set #2 Disposal
with no change outs

Specific Isotopes	Final Filters Ci/m^3	Final Filters Ci/m^3	Hanford WAC: Cat. 1 Limit Ci/m^3	Cat. 1 Fraction	Cat. 3 Limit Ci/m^3	Cat. 3 Fraction	NRC WAC: Final Filters nCi/g	Class A Limit Ci/m^3	Class A Fraction	Class C Limit Ci/m^3	Class C Fraction
Sr-90	5.28E-12	5.28E-12	1.6E-02	0.00	5.4E+04	0.00		0.04	0.00	7000	0.00
Tc-99	1.25E-14	1.25E-14	2.3E-02	0.00	5.0E+00	0.00		0.3	0.00	3	0.00
I-129	4.90E-10	4.90E-10	8.5E-03	0.00	1.8E+00	0.00		0.008	0.00	0.08	0.00
Cs-137	6.71E-11	6.71E-11	5.5E-03	0.00	1.2E+04	0.00		1	0.00	4600	0.00
Pu-241	4.41E-15	4.41E-15	6.1E-02	0.00	2.5E+01	0.00		350	0.00	3500	0.00
								nCi/g		nCi/g	
Pu-238	1.91E-14	1.91E-14	4.7E-03	0.00	2.4E+01	0.00	0.0	10	0.00	100	0.00
Pu-239	2.72E-15	2.72E-15	1.9E-03	0.00	4.2E-01	0.00	0.0	10	0.00	100	0.00
Pu-240	2.33E-16	2.33E-16	1.9E-03	0.00	4.3E-01	0.00	0.0	10	0.00	100	0.00
Am-241	2.11E-15	2.11E-15	2.1E-03	0.00	8.5E-01	0.00	0.0	10	0.00	100	0.00
			Sum of Fractions =	0.00		0.00			0.00		0.00

Envirocare WAC

Specific Isotopes	Ci/m^3	pCi/g	Limit pCi/g	Fraction
Sr-90	5.28E-12	5.28E-06	2.5E+04	0.00
Tc-99	1.25E-14	1.25E-08	1.9E+05	0.00
I-129	4.90E-10	4.90E-04	3.1E+03	0.00
Cs-137	6.71E-11	6.71E-05	6.0E+04	0.00
Pu-241	4.41E-15	4.41E-09	3.5E+05	0.00
Pu-238	1.91E-14	1.91E-08	1.0E+04	0.00
Pu-239	2.72E-15	2.72E-09	1.0E+04	0.00
Pu-240	2.33E-16	2.33E-10	1.0E+04	0.00
Am-241	2.11E-15	2.11E-09	1.0E+04	0.00
			Sum of Fractions =	0.00

Assumptions:
550 kg/m^3 GAC density
54.0 m^3 total GAC volume

Revised:
8/6/2001

Vit. Process Off-Gas Activated Carbon Disposal

			Hanford WAC				GAC	NRC WAC			
			Cat. 1		Cat. 3		with	Class A		Class C	
Specific	GAC	GAC	Limit	Cat. 1	Limit	Cat. 3	chg out	Limit	Class A	Limit	Class C
Isotopes	Ci/L	Ci/m^3	Ci/m^3	Fraction	Ci/m^3	Fraction	nCi/g	Ci/m^3	Fraction	Ci/m^3	Fraction
Sr-90	8.86E-15	8.86E-12	1.6E-02	0.00	5.4E+04	0.00		0.04	0.00	7000	0.00
Tc-99	2.10E-17	2.10E-14	2.3E-02	0.00	5.0E+00	0.00		0.3	0.00	3	0.00
I-129	8.15E-11	8.15E-08	8.5E-03	0.00	1.8E+00	0.00		0.008	0.00	0.08	0.00
Cs-137	1.13E-13	1.13E-10	5.5E-03	0.00	1.2E+04	0.00		1	0.00	4600	0.00
Pu-241	7.40E-18	7.40E-15	6.1E-02	0.00	2.5E+01	0.00		350	0.00	3500	0.00
								nCi/g		nCi/g	
Pu-238	3.21E-17	3.21E-14	4.7E-03	0.00	2.4E+01	0.00	0.0	10	0.00	100	0.00
Pu-239	4.57E-18	4.57E-15	1.9E-03	0.00	4.2E-01	0.00	0.0	10	0.00	100	0.00
Pu-240	3.91E-19	3.91E-16	1.9E-03	0.00	4.3E-01	0.00	0.0	10	0.00	100	0.00
Am-241	3.54E-18	3.54E-15	2.1E-03	0.00	8.5E-01	0.00	0.0	10	0.00	100	0.00
		Sum of Fractions =		0.00		0.00			0.00		0.00

Envirocare WAC

Specific	GAC	GAC	Limit	
Isotopes	Ci/L	pCi/g	pCi/g	Fraction
Sr-90	8.86E-15	1.61E-05	2.5E+04	0.00
Tc-99	2.10E-17	3.82E-08	1.9E+05	0.00
I-129	8.15E-11	1.48E-01	3.1E+03	0.00
Cs-137	1.13E-13	2.05E-04	6.0E+04	0.00
Pu-241	7.40E-18	1.35E-08	3.5E+05	0.00
Pu-238	3.21E-17	5.83E-08	1.0E+04	0.00
Pu-239	4.57E-18	8.30E-09	1.0E+04	0.00
Pu-240	3.91E-19	7.11E-10	1.0E+04	0.00
Am-241	3.54E-18	6.44E-09	1.0E+04	0.00
		Sum of Fractions =		0.00

APPENDIX B

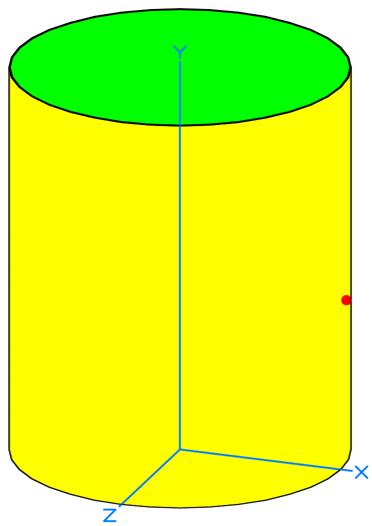
RADIOLOGICAL ESTIMATES

MicroShield v5.05 (5.05-00310)
BECHTEL - BBWI

Page : 1
DOS File : VITSCB.MS5
Run Date : August 6, 2001
Run Time: 15:26:47
Duration : 00:00:40

File Ref: ___________
Date: ___________
By: ___________
Checked: ___________

Case Title: Combined Scrub Drum
Description: Combined Scrub with CsIX -- 8/6/01
Geometry: 7 - Cylinder Volume - Side Shields



Source Dimensions

Height	69.84 cm	2 ft 3.5 in
Radius	29.21 cm	11.5 in

Dose Points

	X	Y	Z
# 1	30.37 cm	31.04 cm	0 cm
	12.0 in	1 ft 0.2 in	0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	1.87e+05 cm³	Mixed ->	1.9
		Concrete	1.8
		Water	0.1
Shield 1	.16 cm	Iron	7.86
Transition	1.0 cm	Air	0.00122
Air Gap		Air	0.00122

Source Input
Grouping Method : Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Excluded
Library : ICRP-38

Nuclide	curies	becquerels	μCi/cm³	Bq/cm³
Am-241	7.3946e-010	2.7360e+001	3.9500e-009	1.4615e-004
Ba-137m	6.8143e-005	2.5213e+006	3.6400e-004	1.3468e+001
C-14	1.0577e-003	3.9135e+007	5.6500e-003	2.0905e+002
Co-60	5.8221e-011	2.1542e+000	3.1100e-010	1.1507e-005
Cs-134	7.9188e-010	2.9299e+001	4.2300e-009	1.5651e-004
Cs-135	1.7092e-009	6.3240e+001	9.1300e-009	3.3781e-004
Cs-137	7.4508e-005	2.7568e+006	3.9800e-004	1.4726e+001
Eu-154	5.0920e-010	1.8840e+001	2.7200e-009	1.0064e-004
Eu-155	1.3048e-010	4.8278e+000	6.9700e-010	2.5789e-005
H-3	6.1778e-003	2.2858e+008	3.3000e-002	1.2210e+003
I-129	7.9188e-010	2.9299e+001	4.2300e-009	1.5651e-004
Ni-63	3.3697e-010	1.2468e+001	1.8000e-009	6.6600e-005
Pa-233	2.3588e-011	8.7275e-001	1.2600e-010	4.6620e-006
Pm-147	4.4742e-011	1.6555e+000	2.3900e-010	8.8430e-006
Pu-238	6.6832e-009	2.4728e+002	3.5700e-008	1.3209e-003
Pu-239	9.5287e-010	3.5256e+001	5.0900e-009	1.8833e-004
Pu-240	8.1621e-011	3.0200e+000	4.3600e-010	1.6132e-005
Pu-241	1.5444e-009	5.7144e+001	8.2500e-009	3.0525e-004
Se-79	3.9126e-011	1.4477e+000	2.0900e-010	7.7330e-006
Sm-151	2.4898e-009	9.2124e+001	1.3300e-008	4.9210e-004

DOS File : VITSCB.MS5
Run Date : August 6, 2001
Run Time: 15:26:47
Duration : 00:00:40

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Sr-90	5.8595e-002	2.1680e+009	3.1300e-001	1.1581e+004
Tc-99	4.3806e-009	1.6208e+002	2.3400e-008	8.6580e-004
U-232	5.1481e-008	1.9048e+003	2.7500e-007	1.0175e-002
U-234	9.1918e-012	3.4010e-001	4.9100e-011	1.8167e-006
Y-90	5.8595e-002	2.1680e+009	3.1300e-001	1.1581e+004

Buildup
The material reference is : Source

Integration Parameters

Radial	26
Circumferential	26
Y Direction (axial)	26

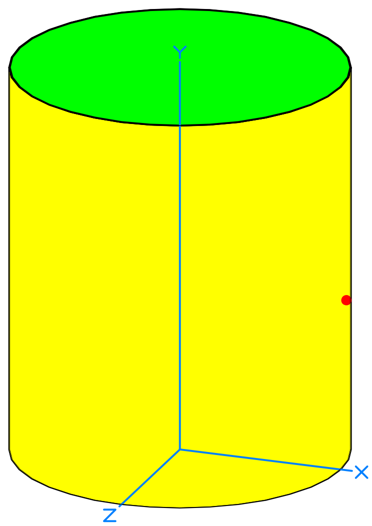
Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	1.913e+05	1.080e-37	3.454e-27	9.266e-39	2.963e-28
0.02	3.609e+04	1.336e-19	3.288e-19	4.628e-21	1.139e-20
0.03	1.527e+05	2.777e-08	1.424e-07	2.752e-10	1.412e-09
0.04	3.628e+04	7.498e-06	6.540e-05	3.316e-08	2.893e-07
0.05	1.314e+00	6.016e-09	6.822e-08	1.602e-11	1.817e-10
0.06	1.384e+01	3.313e-07	3.953e-06	6.581e-10	7.851e-09
0.08	1.644e+00	2.064e-07	2.157e-06	3.266e-10	3.414e-09
0.1	9.226e+00	2.602e-06	2.285e-05	3.980e-09	3.496e-08
0.15	1.459e+00	1.077e-06	6.915e-06	1.773e-09	1.139e-08
0.2	1.302e+00	1.598e-06	8.335e-06	2.821e-09	1.471e-08
0.3	5.900e-01	1.371e-06	5.607e-06	2.601e-09	1.064e-08
0.4	1.825e-01	6.568e-07	2.307e-06	1.280e-09	4.495e-09
0.5	5.124e-01	2.586e-06	8.121e-06	5.077e-09	1.594e-08
0.6	2.264e+06	1.507e+01	4.341e+01	2.941e-02	8.473e-02
0.8	3.467e+01	3.582e-04	9.080e-04	6.814e-07	1.727e-06
1.0	8.829e+00	1.286e-04	2.988e-04	2.370e-07	5.509e-07
1.5	1.042e+01	2.839e-04	5.687e-04	4.776e-07	9.569e-07
2.0	3.447e-04	1.454e-08	2.672e-08	2.248e-11	4.132e-11
3.0	7.755e-08	5.941e-12	9.779e-12	8.061e-15	1.327e-14
TOTALS:	2.680e+06	1.507e+01	4.341e+01	2.941e-02	8.474e-02

Page : 1
DOS File : VITSCB2.MS5
Run Date : August 6, 2001
Run Time: 15:39:43
Duration : 00:00:39

File Ref: ____________
Date: ____________
By: ____________
Checked: ____________

Case Title: Combined Scrub Drum
Description: Combined Scrub without CsIX -- 8/6/01
Geometry: 7 - Cylinder Volume - Side Shields



Source Dimensions

Height	69.84 cm	2 ft 3.5 in
Radius	29.21 cm	11.5 in

Dose Points

	X	Y	Z
# 1	30.37 cm	31.04 cm	0 cm
	12.0 in	1 ft 0.2 in	0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	1.87e+05 cm³	Mixed ->	1.9
		Concrete	1.8
		Water	0.1
Shield 1	.16 cm	Iron	7.86
Transition	1.0 cm	Air	0.00122
Air Gap		Air	0.00122

Source Input
Grouping Method : Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Excluded
Library : ICRP-38

Nuclide	curies	becquerels	μCi/cm³	Bq/cm³
Am-241	7.3946e-010	2.7360e+001	3.9500e-009	1.4615e-004
Ba-137m	7.4508e-001	2.7568e+010	3.9800e+000	1.4726e+005
C-14	1.0577e-003	3.9135e+007	5.6500e-003	2.0905e+002
Co-60	5.8221e-011	2.1542e+000	3.1100e-010	1.1507e-005
Cs-134	7.9188e-006	2.9299e+005	4.2300e-005	1.5651e+000
Cs-135	1.7092e-005	6.3240e+005	9.1300e-005	3.3781e+000
Cs-137	7.4508e-001	2.7568e+010	3.9800e+000	1.4726e+005
Eu-154	5.0920e-010	1.8840e+001	2.7200e-009	1.0064e-004
Eu-155	1.3048e-010	4.8278e+000	6.9700e-010	2.5789e-005
H-3	6.1778e-003	2.2858e+008	3.3000e-002	1.2210e+003
I-129	7.9188e-010	2.9299e+001	4.2300e-009	1.5651e-004
Ni-63	3.3697e-010	1.2468e+001	1.8000e-009	6.6600e-005
Pa-233	2.3588e-011	8.7275e-001	1.2600e-010	4.6620e-006
Pm-147	4.4742e-011	1.6555e+000	2.3900e-010	8.8430e-006
Pu-238	6.6832e-009	2.4728e+002	3.5700e-008	1.3209e-003
Pu-239	9.5287e-010	3.5256e+001	5.0900e-009	1.8833e-004
Pu-240	8.1621e-011	3.0200e+000	4.3600e-010	1.6132e-005
Pu-241	1.5444e-009	5.7144e+001	8.2500e-009	3.0525e-004
Se-79	3.9126e-011	1.4477e+000	2.0900e-010	7.7330e-006
Sm-151	2.4898e-009	9.2124e+001	1.3300e-008	4.9210e-004

Nuclide	curies	becquerels	μCi/cm³	Bq/cm³
Sr-90	5.8595e-002	2.1680e+009	3.1300e-001	1.1581e+004
Tc-99	4.3806e-009	1.6208e+002	2.3400e-008	8.6580e-004
U-232	5.1481e-008	1.9048e+003	2.7500e-007	1.0175e-002
U-234	9.1918e-012	3.4010e-001	4.9100e-011	1.8167e-006
Y-90	5.8595e-002	2.1680e+009	3.1300e-001	1.1581e+004

Buildup
The material reference is : Source

Integration Parameters

Radial	26
Circumferential	26
Y Direction (axial)	26

Results

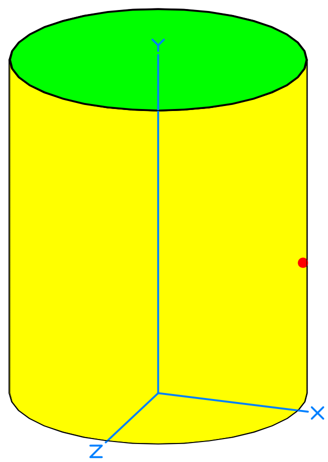
Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	1.913e+05	1.080e-37	3.454e-27	9.266e-39	2.963e-28
0.02	3.609e+04	1.336e-19	3.288e-19	4.628e-21	1.139e-20
0.03	1.669e+09	3.036e-04	1.557e-03	3.009e-06	1.543e-05
0.04	3.966e+08	8.197e-02	7.150e-01	3.625e-04	3.162e-03
0.05	1.314e+00	6.016e-09	6.822e-08	1.602e-11	1.817e-10
0.06	1.384e+01	3.313e-07	3.953e-06	6.581e-10	7.851e-09
0.08	1.644e+00	2.064e-07	2.157e-06	3.266e-10	3.414e-09
0.1	9.226e+00	2.602e-06	2.285e-05	3.980e-09	3.496e-08
0.15	1.459e+00	1.077e-06	6.915e-06	1.773e-09	1.139e-08
0.2	6.283e+01	7.710e-05	4.020e-04	1.361e-07	7.096e-07
0.3	4.278e+01	9.942e-05	4.065e-04	1.886e-07	7.711e-07
0.4	1.825e-01	6.568e-07	2.307e-06	1.280e-09	4.495e-09
0.5	4.278e+03	2.159e-02	6.780e-02	4.238e-05	1.331e-04
0.6	2.475e+10	1.648e+05	4.747e+05	3.216e+02	9.265e+02
0.8	2.758e+05	2.850e+00	7.223e+00	5.420e-03	1.374e-02
1.0	8.212e+03	1.196e-01	2.780e-01	2.205e-04	5.124e-04
1.5	8.917e+03	2.429e-01	4.866e-01	4.086e-04	8.187e-04
2.0	3.447e-04	1.454e-08	2.672e-08	2.248e-11	4.132e-11
3.0	7.755e-08	5.941e-12	9.779e-12	8.061e-15	1.327e-14
TOTALS:	2.682e+10	1.648e+05	4.747e+05	3.216e+02	9.265e+02

MicroShield v5.05 (5.05-00310)
BECHTEL - BBWI

Page : 1
DOS File : VIT-CSIX.MS5
Run Date : August 28, 2001
Run Time: 12:42:10
Duration : 00:00:18

File Ref: ____________
Date: ____________
By: ____________
Checked: ____________

Case Title: IX Media Drum
Description: Ion Exchange with Cesium
Geometry: 7 - Cylinder Volume - Side Shields



Source Dimensions

Height	69.84 cm	2 ft 3.5 in
Radius	29.21 cm	11.5 in

Dose Points

	X	Y	Z
# 1	30.37 cm	31.04 cm	0 cm
	12.0 in	1 ft 0.2 in	0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	1.87e+05 cm³	Carbon	0.64
Shield 1	.16 cm	Iron	7.86
Transition	1.0 cm	Air	0.00122
Air Gap		Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels	μCi/cm³	Bq/cm³
Ba-137m	7.4695e+001	2.7637e+012	3.9900e+002	1.4763e+007
Cs-137	7.4695e+001	2.7637e+012	3.9900e+002	1.4763e+007

Buildup
The material reference is : Source

Integration Parameters

Radial	26
Circumferential	26
Y Direction (axial)	26

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0315	7.440e+06	6.579e-05	3.472e-03	5.669e-07	2.991e-05
0.0318	5.889e+10	7.248e-01	3.925e+01	6.038e-03	3.269e-01
0.0322	1.085e+11	1.852e+00	1.028e+02	1.490e-02	8.277e-01
0.0363	1.087e+10	3.176e+00	2.163e+02	1.818e-02	1.238e+00
0.0364	2.104e+10	6.409e+00	4.375e+02	3.648e-02	2.490e+00
0.0367	2.646e+08	9.370e-02	6.452e+00	5.224e-04	3.597e-02
0.0373	7.592e+09	3.732e+00	2.615e+02	1.987e-02	1.392e+00
0.6616	2.481e+12	4.943e+07	1.182e+08	9.584e+04	2.292e+05

DOS File : VIT-CSIX.MS5
Run Date : August 28, 2001
Run Time: 12:42:10
Duration : 00:00:18

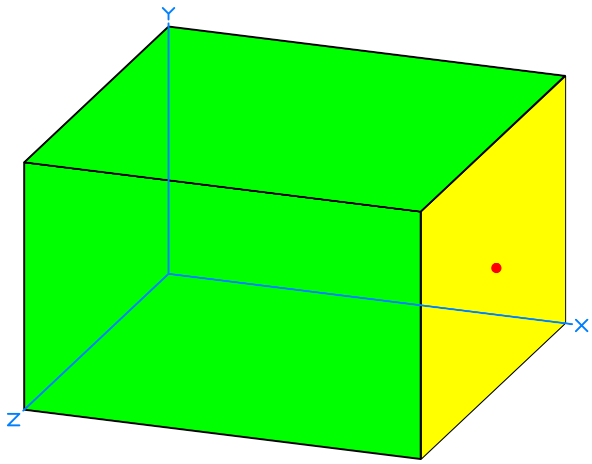
Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
TOTALS:	2.688e+12	4.943e+07	1.182e+08	9.584e+04	2.292e+05

MicroShield v5.05 (5.05-00310)
BECHTEL - BBWI

Page : 1
DOS File : PREFILTR.MS5
Run Date : September 13, 2001
Run Time: 09:19:39
Duration : 00:00:14

File Ref: ____________
Date: ____________
By: ____________
Checked: ____________

Case Title: HEPA Filter Set #1
Description: Vit. Process Off-Gas Filter Set #1 - 4 Change Outs -- 8/6/01
Geometry: 13 - Rectangular Volume



Source Dimensions

Length	122.0 cm	4 ft 0.0 in
Width	122.0 cm	4 ft 0.0 in
Height	76.0 cm	2 ft 5.9 in

Dose Points

	X	Y	Z
# 1	123.16 cm	38 cm	61 cm
	4 ft 0.5 in	1 ft 3.0 in	2 ft 0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	1.13e+06 cm³	Air	0.00122
Shield 1	.16 cm	Iron	7.86
Air Gap		Air	0.00122

Source Input
Grouping Method : Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Excluded
Library : ICRP-38

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Am-241	2.3416e-004	8.6639e+006	2.0700e-004	7.6592e+000
Ba-137m	7.4432e+000	2.7540e+011	6.5800e+000	2.4346e+005
Cs-137	7.4432e+000	2.7540e+011	6.5800e+000	2.4346e+005
I-129	4.2985e-002	1.5904e+009	3.8000e-002	1.4060e+003
Pu-238	2.1153e-003	7.8267e+007	1.8700e-003	6.9190e+001
Pu-239	3.0203e-004	1.1175e+007	2.6700e-004	9.8790e+000
Pu-240	2.5904e-005	9.5845e+005	2.2900e-005	8.4730e-001
Pu-241	2.9185e-006	1.0798e+005	2.5800e-006	9.5460e-002
Sr-90	5.8482e-001	2.1638e+010	5.1700e-001	1.9129e+004
Tc-99	1.3914e-003	5.1480e+007	1.2300e-003	4.5510e+001
U-234				
Y-90	5.8482e-001	2.1638e+010	5.1700e-001	1.9129e+004

Buildup
The material reference is : Source

Integration Parameters

X Direction	20
Y Direction	20
Z Direction	20

Results

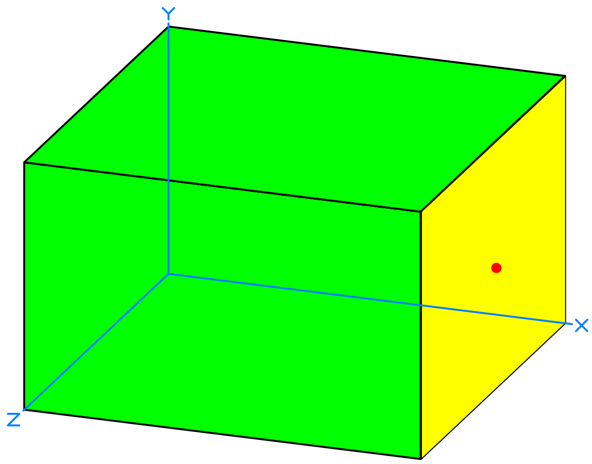
Page : 2
DOS File : PREFILTR.MS5
Run Date : September 13, 2001
Run Time: 09:19:39
Duration : 00:00:14

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	7.424e+06	1.146e-32	5.325e-26	9.827e-34	4.568e-27
0.02	3.972e+06	2.054e-15	7.521e-15	7.115e-17	2.605e-16
0.03	1.779e+10	1.066e-01	9.778e-01	1.057e-03	9.691e-03
0.04	4.082e+09	1.563e+01	2.204e+02	6.913e-02	9.747e-01
0.05	2.837e+03	1.484e-04	1.976e-03	3.954e-07	5.265e-06
0.06	3.097e+06	6.049e-01	6.081e+00	1.201e-03	1.208e-02
0.08	2.163e+03	1.515e-03	7.828e-03	2.397e-06	1.239e-05
0.1	1.127e+04	1.463e-02	4.742e-02	2.239e-05	7.254e-05
0.15	1.983e+03	5.388e-03	1.063e-02	8.873e-06	1.750e-05
0.2	1.875e+02	7.521e-04	1.195e-03	1.327e-06	2.110e-06
0.3	2.663e+02	1.731e-03	2.391e-03	3.283e-06	4.535e-06
0.4	5.861e+02	5.267e-03	6.816e-03	1.026e-05	1.328e-05
0.5	3.179e+01	3.656e-04	4.547e-04	7.177e-07	8.925e-07
0.6	2.472e+11	3.473e+06	4.205e+06	6.779e+03	8.208e+03
0.8	6.494e+01	1.248e-03	1.457e-03	2.374e-06	2.771e-06
1.0	2.943e+00	7.206e-05	8.229e-05	1.328e-07	1.517e-07
TOTALS:	2.691e+11	3.473e+06	4.206e+06	6.779e+03	8.209e+03

Page : 1
DOS File : FINPREFL.MS5
Run Date : August 29, 2001
Run Time: 11:29:58
Duration : 00:00:14

File Ref: ____________
Date: ____________
By: ____________
Checked: ____________

Case Title: Prefilters Set #2
Description: Vit. Process Off-Gas Final Prefilters -- 8/6/01
Geometry: 13 - Rectangular Volume



Source Dimensions

Length	122.0 cm	4 ft 0.0 in
Width	122.0 cm	4 ft 0.0 in
Height	76.0 cm	2 ft 5.9 in

Dose Points

	X	Y	Z
# 1	123.16 cm	38 cm	61 cm
	4 ft 0.5 in	1 ft 3.0 in	2 ft 0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	1.13e+06 cm³	Air	0.00122
Shield 1	.16 cm	Iron	7.86
Air Gap		Air	0.00122

Source Input
Grouping Method : Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Excluded
Library : ICRP-38

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Am-241	2.3302e-013	8.6219e-003	2.0600e-013	7.6220e-009
Ba-137m	7.3979e-009	2.7372e+002	6.5400e-009	2.4198e-004
Cs-137	7.3979e-009	2.7372e+002	6.5400e-009	2.4198e-004
I-129	5.4071e-008	2.0006e+003	4.7800e-008	1.7686e-003
Pu-238	2.1040e-012	7.7848e-002	1.8600e-012	6.8820e-008
Sr-90	5.8256e-010	2.1555e+001	5.1500e-010	1.9055e-005
Tc-99	1.3800e-012	5.1062e-002	1.2200e-012	4.5140e-008
U-234				
Y-90	5.8256e-010	2.1555e+001	5.1500e-010	1.9055e-005

Buildup
The material reference is : Source

Integration Parameters

X Direction	20
Y Direction	20
Z Direction	20

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	7.099e-03	1.096e-41	5.092e-35	9.397e-43	4.368e-36

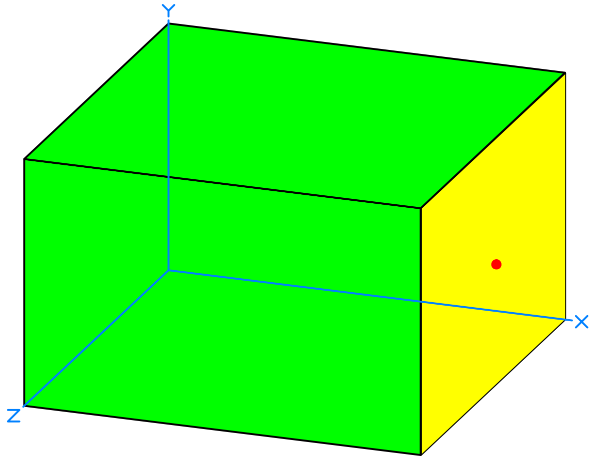
Page : 2
DOS File : FINPREFL.MS5
Run Date : August 29, 2001
Run Time: 11:29:58
Duration : 00:00:14

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.02	3.887e-03	2.010e-24	7.360e-24	6.962e-26	2.549e-25
0.03	1.418e+03	8.500e-09	7.793e-08	8.424e-11	7.723e-10
0.04	1.543e+02	5.906e-07	8.328e-06	2.612e-09	3.683e-08
0.05	2.244e-09	1.174e-16	1.563e-15	3.128e-19	4.165e-18
0.06	3.082e-03	6.019e-10	6.051e-09	1.196e-12	1.202e-11
0.08	2.080e-06	1.456e-12	7.525e-12	2.304e-15	1.191e-14
0.1	9.909e-06	1.286e-11	4.167e-11	1.968e-14	6.375e-14
0.15	1.196e-06	3.249e-12	6.407e-12	5.350e-15	1.055e-14
0.2	8.620e-08	3.458e-13	5.496e-13	6.102e-16	9.700e-16
0.3	8.360e-08	5.433e-13	7.506e-13	1.031e-15	1.424e-15
0.4	4.440e-08	3.990e-13	5.163e-13	7.774e-16	1.006e-15
0.5	9.169e-09	1.055e-13	1.312e-13	2.070e-16	2.574e-16
0.6	2.457e+02	3.452e-03	4.180e-03	6.738e-06	8.158e-06
0.8	6.197e-08	1.191e-12	1.390e-12	2.265e-15	2.644e-15
1.0	2.904e-09	7.109e-14	8.119e-14	1.310e-16	1.497e-16
TOTALS:	1.818e+03	3.453e-03	4.188e-03	6.741e-06	8.196e-06

DOS File : FINFILTR.MS5
Run Date : August 29, 2001
Run Time: 11:31:57
Duration : 00:00:14

File Ref: ____________
Date: ____________
By: ____________
Checked: ____________

Case Title: Final Filter Set #2
Description: Vit. Process Off-Gas Final HEPA Filters -- 8/6/01
Geometry: 13 - Rectangular Volume



Source Dimensions

Length	122.0 cm	4 ft 0.0 in
Width	122.0 cm	4 ft 0.0 in
Height	76.0 cm	2 ft 5.9 in

Dose Points

	X	Y	Z
# 1	123.16 cm	38 cm	61 cm
	4 ft 0.5 in	1 ft 3.0 in	2 ft 0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	1.13e+06 cm^3	Air	0.00122
Shield 1	.16 cm	Iron	7.86
Air Gap		Air	0.00122

Source Input
Grouping Method : Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Excluded
Library : ICRP-38

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Am-241	2.3868e-015	8.8312e-005	2.1100e-015	7.8070e-011
Ba-137m	7.5902e-011	2.8084e+000	6.7100e-011	2.4827e-006
Cs-137	7.5902e-011	2.8084e+000	6.7100e-011	2.4827e-006
I-129	5.5428e-010	2.0508e+001	4.9000e-010	1.8130e-005
Pu-238	2.1606e-014	7.9941e-004	1.9100e-014	7.0670e-010
Sr-90	5.9727e-012	2.2099e-001	5.2800e-012	1.9536e-007
Tc-99	1.4140e-014	5.2317e-004	1.2500e-014	4.6250e-010
U-234				
Y-90	5.9727e-012	2.2099e-001	5.2800e-012	1.9536e-007

Buildup
The material reference is : Source

Integration Parameters

X Direction	20
Y Direction	20
Z Direction	20

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	7.285e-05	1.124e-43	5.225e-37	9.643e-45	4.482e-38

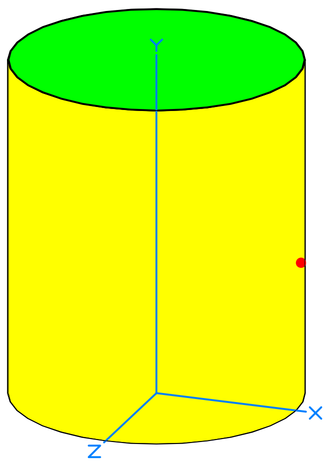
DOS File : FINFILTR.MS5
Run Date : August 29, 2001
Run Time: 11:31:57
Duration : 00:00:14

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.02	3.985e-05	2.060e-26	7.544e-26	7.136e-28	2.613e-27
0.03	1.453e+01	8.713e-11	7.989e-10	8.635e-13	7.917e-12
0.04	1.581e+00	6.055e-09	8.537e-08	2.678e-11	3.776e-10
0.05	2.299e-11	1.203e-18	1.601e-17	3.204e-21	4.266e-20
0.06	3.156e-05	6.165e-12	6.198e-11	1.225e-14	1.231e-13
0.08	2.130e-08	1.492e-14	7.707e-14	2.360e-17	1.220e-16
0.1	1.016e-07	1.319e-13	4.275e-13	2.019e-16	6.540e-16
0.15	1.227e-08	3.333e-14	6.574e-14	5.489e-17	1.082e-16
0.2	8.830e-10	3.542e-15	5.630e-15	6.251e-18	9.936e-18
0.3	8.563e-10	5.565e-15	7.688e-15	1.056e-17	1.458e-17
0.4	4.548e-10	4.087e-15	5.289e-15	7.962e-18	1.030e-17
0.5	9.391e-11	1.080e-15	1.343e-15	2.120e-18	2.637e-18
0.6	2.521e+00	3.542e-05	4.288e-05	6.913e-08	8.370e-08
0.8	6.358e-10	1.222e-14	1.426e-14	2.324e-17	2.712e-17
1.0	2.982e-11	7.300e-16	8.337e-16	1.346e-18	1.537e-18
TOTALS:	1.864e+01	3.542e-05	4.297e-05	6.916e-08	8.409e-08

MicroShield v5.05 (5.05-00310)
BECHTEL - BBWI

Page : 1	File Ref: ____________
DOS File : GAC-8-6.MS5	Date: ____________
Run Date : August 29, 2001	By: ____________
Run Time: 11:13:05	Checked: ____________
Duration : 00:00:33	

Case Title: GAC Disposal
Description: Activated Carbon in Drum -- 8/6/01
Geometry: 7 - Cylinder Volume - Side Shields



Source Dimensions

Height	69.84 cm	2 ft 3.5 in
Radius	29.21 cm	11.5 in

Dose Points

	X	Y	Z
# 1	30.37 cm	31.04 cm	0 cm
	12.0 in	1 ft 0.2 in	0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	1.87e+05 cm³	Carbon	0.55
Shield 1	.16 cm	Iron	7.86
Transition	1.0 cm	Air	0.00122
Air Gap		Air	0.00122

Source Input
Grouping Method : Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Excluded
Library : ICRP-38

Nuclide	curies	becquerels	μCi/cm³	Bq/cm³
Am-241	6.6271e-016	2.4520e-005	3.5400e-015	1.3098e-010
Ba-137m	2.1154e-011	7.8270e-001	1.1300e-010	4.1810e-006
Cs-137	2.1154e-011	7.8270e-001	1.1300e-010	4.1810e-006
I-129	1.5257e-008	5.6452e+002	8.1500e-008	3.0155e-003
Pu-238	6.0093e-015	2.2234e-004	3.2100e-014	1.1877e-009
Sr-90	1.6586e-012	6.1370e-002	8.8600e-012	3.2782e-007
Tc-99	3.9313e-015	1.4546e-004	2.1000e-014	7.7700e-010
U-234				
Y-90	1.6586e-012	6.1370e-002	8.8600e-012	3.2782e-007

Buildup
The material reference is : Source

Integration Parameters

Radial	26
Circumferential	26
Y Direction (axial)	26

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	2.025e-05	4.021e-45	9.683e-37	3.449e-46	8.306e-38

Page : 2
DOS File : GAC-8-6.MS5
Run Date : August 29, 2001
Run Time: 11:13:05
Duration : 00:00:33

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.02	1.107e-05	1.389e-27	2.061e-26	4.811e-29	7.140e-28
0.03	3.955e+02	9.415e-10	4.442e-08	9.331e-12	4.402e-10
0.04	4.243e+01	8.286e-08	6.039e-06	3.664e-10	2.671e-08
0.05	6.383e-12	2.001e-19	1.261e-17	5.330e-22	3.359e-20
0.06	8.764e-06	1.144e-12	5.296e-11	2.272e-15	1.052e-13
0.08	5.914e-09	3.159e-15	7.992e-14	4.999e-18	1.265e-16
0.1	2.825e-08	3.025e-14	4.818e-13	4.629e-17	7.370e-16
0.15	3.411e-09	8.591e-15	6.806e-14	1.415e-17	1.121e-16
0.2	2.452e-10	9.876e-16	5.470e-15	1.743e-18	9.653e-18
0.3	2.378e-10	1.738e-15	6.617e-15	3.297e-18	1.255e-17
0.4	1.263e-10	1.386e-15	4.230e-15	2.701e-18	8.242e-18
0.5	2.607e-11	3.909e-16	1.032e-15	7.673e-19	2.026e-18
0.6	7.027e-01	1.357e-05	3.244e-05	2.648e-08	6.332e-08
0.8	1.767e-10	5.070e-15	1.024e-14	9.643e-18	1.949e-17
1.0	8.293e-12	3.227e-16	5.901e-16	5.949e-19	1.088e-18
TOTALS:	4.386e+02	1.365e-05	3.852e-05	2.685e-08	9.047e-08

APPENDIX C

MERCURY CONCENTRATIONS

Mercury Concentrations in Secondary Waste Streams

Combined Scrub & Grout

Hg = 7.67E-03 Molar
Flow = 24.00 L/hr
Density = 1.20 kg/L (assumed value)
Waste Loading = 35% (assumed value)

Hg Concentration in Scrub = 1281.74 mg Hg / kg scrub
Hg Concentration in Grout = 448.61 mg Hg / kg grout

HEPA Filter Set #1

Particulate Mercury

Hg in off-gas before filters = 2.58E-04 g/m^3 = 2.58E-01 mg Hg / m^3 off gas
Hg in off-gas after filters = 1.02E-12 g/m^3 = 1.02E-09 mg Hg / m^3 off gas

Gaseous Mercury

Hg in off-gas before filters = 1.48E-05 mole fraction = 142.47 mg Hg / m^3 off gas
Hg in off-gas after filters = 1.48E-05 mole fraction = 142.47 mg Hg / m^3 off gas

Total Hg collected = 0.26 mg Hg / m^3 off gas

Filter volume = 1.13 m^3
Flow at filters = 2,057 m^3/hr
Filter density = 110 kg/m^3

Hg collected on filters during entire process = 4.50E+06 mg Hg / m^3 filter = 4.09E+04 mg Hg / kg filter media
Hg collected with change outs = 4 1.13E+06 mg Hg / m^3 filter = 2.56E+03 mg Hg / kg filter media

Mercury Concentrations in Secondary Waste Streams

Granulated Activated Carbon (GAC)

Particulate Mercury

Hg in off-gas before GAC =	6.28E-14 g/m^3	=	6.28E-11 mg Hg / m^3 off gas
Hg in off-gas after GAC =	6.28E-16 g/m^3	=	6.28E-13 mg Hg / m^3 off gas

Gaseous Mercury

Hg in off-gas before GAC =	8.84E-06 mole fraction	=	84.93 mg Hg / m^3 off gas
Hg in off-gas after GAC =	8.84E-08 mole fraction	=	0.85 mg Hg / m^3 off gas

Hg collected = 84.08 mg Hg / m^3 off gas

GAC volume = 54.0 m^3
Flow at GAC = 3,451 m^3/hr
GAC density = 550 kg/m^3

Hg collected on GAC during entire process = 5.16E+07 mg Hg / m^3 filter = 9.38E+04 mg Hg / kg filter media

Allowable Hg loading on GAC at 15 wt% = 1.50E+05 mg Hg / kg filter media

Mercury Concentrations in Secondary Waste Streams

HEPA Filter Set #2 (Final Filters)

Particulate Mercury

Hg in off-gas before filters =	6.28E-16 g/m^3 =	6.28E-13	mg Hg / m^3 off gas
Hg in off-gas after filters =	2.48E-24 g/m^3 =	2.48E-21	mg Hg / m^3 off gas

Gaseous Mercury

Hg in off-gas before filters =	8.84E-08 mole fraction =	0.85	mg Hg / m^3 off gas
Hg in off-gas after filters =	8.84E-08 mole fraction =	0.85	mg Hg / m^3 off gas
	Hg collected =	0.00	mg Hg / m^3 off gas

Prefilters volume =	0.92	m^3	HEPA volume =	0.91	m^3
Flow at prefilters =	3,451	m^3/hr	Flow at filters =	3,451	m^3/hr
Prefilter density =	110	kg/m^3	HEPA density =	110	kg/m^3
Contamination level =	99%		Contamination level =	1%	
Change outs =	4		Change outs =	0	

Total Hg out stack = 2.81E+07 mg Hg

Hg collected on prefilters during process =	2.24E-05 mg Hg / m^3 filter =	2.03E-07	mg Hg / kg filter media
Hg collected on HEPAs during process =	2.30E-07 mg Hg / m^3 filter =	2.09E-09	mg Hg / kg filter media

Mercury Concentrations in Secondary Waste Streams

Mercury Mass Balance

Hg in SBW = 3.79E-03 molar
SBW Flowrate = 3.79E+02 L/hr
Total Hg in system = 2.76E+09 mg Hg

	Media Volume m^3	Volume Conc. mg / m^3	Total Hg mg	Total Hg %	
Glass =	6.18E+02	9.39E+04	5.80E+07	2.0%	*
Combined Scrub Grout =	5.21E+02	4.49E+02	2.34E+05	0.0%	
Interim HEPA =	4.52E+00	1.13E+06	5.09E+06	0.2%	
GAC =	5.40E+01	5.16E+07	2.79E+09	96.8%	
Final Prefilters =	9.20E-01	2.24E-05	2.06E-05	0.0%	
Final HEPAs =	9.06E-01	2.30E-07	2.08E-07	0.0%	
Stack Gas =	3.31E+07	8.49E-01	2.81E+07	1.0%	
			2.88E+09	100.0%	

Error = 3.9%

* Assumes 2% mercury stays in glass as in baseline flowsheet.