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Comparison of Proposed BARCT Design for the Supplemental Treatment Demonstration Bulk Vitrification System (DBVS) with BARCT Design Accepted for the Waste Treatment Plant

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

Contractor for the U.S. Department of Energy
Office of River Protection under Contract DE-AC27-99RL14047

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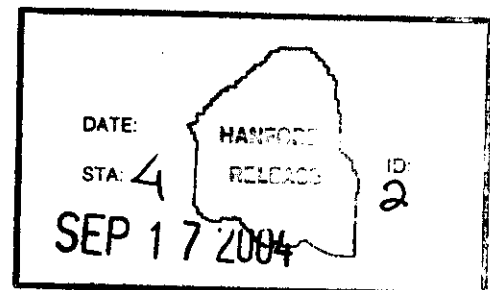
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**COMPARISON OF PROPOSED BARCT DESIGN FOR THE
SUPPLEMENTAL TREATMENT DEMONSTRATION BULK
VITRIFICATION SYSTEM (DBVS) WITH BARCT DESIGN
ACCEPTED FOR THE WASTE TREATMENT PLANT
(WTP)**

Prepared by
CH2M HILL Hanford Group, Inc.

July 2004

SUMMARY

The U.S. Department of Energy-Office of River Protection (ORP) has created aggressive initiatives to accelerate the closure of single-shell tanks (SSTs) containing mixed radioactive and dangerous waste at the Hanford Site. To meet the *Hanford Federal Facilities Agreement and Consent Order* milestones M-45-00 and M-62-00 for completing retrieval of SSTs by 2018 and completing tank waste treatment by 2028, ORP is evaluating optimizing the Hanford Site Waste Treatment Plant (WTP) high-level waste (HLW) and low-activity waste (LAW) vitrification in addition to treating waste using bulk vitrification as a supplemental technology. Further testing using Hanford tank waste is needed to provide data to support the bulk vitrification supplemental technology efforts.

The ORP is proposing to install and operate a Demonstration Bulk Vitrification System (DBVS) project under a Research, Development, and Demonstration permit application. The DBVS will process up to 1,355,500 L (300,000 gal) of LAW from Tank 241-S-109 located in the 200 West Area of the Hanford Site.

For all new construction of emission units, Best Available Radionuclide Control Technology (BARCT) shall be used in accordance with WAC 246-247, Radiation Protection – Air Emissions. It was noted in a Washington State Department of Health review of the *Radioactive Air Emissions Notice Of Construction For The Supplemental Treatment Test And Demonstration Facility* that a BARCT assessment is required considering the magnitude of the supplemental treatment project. However, the agency indicated the BARCT assessment already completed for the WTP can be used for similar abatement control equipment, but the WTP assessment conclusions have to support the DBVS project.

A comparison review of the proposed BARCT design for the DBVS project and the WTP BARCT assessment was completed as discussed herein. The conclusions reached from this comparison are:

- the DBVS and WTP radionuclide inventory to be processed are similar,
- the DBVS radionuclide inventory to be processed is less than 3% of the WTP radionuclide inventory,
- the DBVS and WTP airstream temperatures entering the melter to final stack discharge are similar during the vitrification process,
- the DBVS and WTP abatement control equipment's purpose and function are similar,
- the DBVS and WTP abatement design include two HEPA filters in series for control of particulates and aerosols,
- the WTP BARCT proposed no controls for emissions of radioactive gases <0.1 mrem/year,
- the WTP BARCT proposed using a caustic scrubber for control of radioactive gases >0.1 mrem/year (^{129}I),
- the DBVS radioactive gaseous emissions (^3H , ^{14}C , ^{106}Ru , ^{129}I) are <0.1 mrem/year,
- the DBVS and WTP abatement design protect the HEPA filters.

Based on this review, the selected abatement controls for the WTP and the proposed abatement controls for the DBVS project are similar in purpose and function. BARCT is being incorporated into the design of the DBVS project. The design of the DBVS and WTP offgas systems are similar with the exception of the equipment selected for airstream cooling. The WTP utilizes a submerged bed scrubber and the DBVS utilizes a quencher. It is requested that the Washington State Department of Health concur the proposed DBVS abatement controls meet the BARCT requirements.

PURPOSE

For all new construction of emission units, BARCT shall be used in accordance with WAC 246-247, Radiation Protection – Air Emissions. The purpose of this white paper is to compare the supplemental treatment DBVS proposed BARCT for emission unit STK-1 to the approved BARCT for WTP Emission Unit LV-S3. Both the DBVS and WTP emit radioactive air emissions resulting from vitrification of low activity waste (LAW). This comparison review will fulfill the requirement for a DBVS project BARCT assessment by utilizing the previous WTP BARCT assessment to ensure BARCT is incorporated into DBVS project design to control radioactive air emissions.

BACKGROUND

The ORP has created aggressive initiatives to accelerate the closure of single-shell tanks (SSTs) containing mixed radioactive and dangerous waste at the Hanford Site. To meet the *Hanford Federal Facilities Agreement and Consent Order* requirements for completing retrieval of SSTs by 2018 and completing tank waste treatment by 2028 (milestones M-45-00 and M-62-00), ORP is evaluating optimizing the Hanford Site WTP high-level waste (HLW) and LAW vitrification in addition to treating LAW using bulk vitrification as a supplemental technology.

Further testing using Hanford tank waste is needed to provide data for supporting bulk vitrification as a supplemental technology. ORP is proposing to install and operate the DBVS project for processing LAW from the saltcake inventory of Tank 241-S-109 located in the 200 West Area of the Hanford Site.

SCOPE

The scope of the BARCT comparison is limited to the radioactive air emissions from LAW processing as it relates to the WTP emission point, LV-S3, and the proposed DBVS emission point, STK-1. The BARCT assessment for the DBVS utilizes the prior BARCT assessment completed for the WTP and compares similarities in offgas air stream data and control equipment. This includes a comparison of the incoming radionuclide inventory to the melter for processing, as well as processing temperatures.

The vitrification process for both the DBVS and WTP use resistive heating to melt the waste. Process offgas from both the WTP and DBVS vitrification process is routed to their respective Offgas Treatment Systems (OGTS) where radioactive and non-radioactive contaminants are removed in order to minimize releases and subsequent effects to on-site workers and the public.

COMPARISON OF INVENTORY

Table 1 shows the Annual Possession Quantity (APQ) of radionuclides for WTP and DBVS. The APQ of radionuclides for WTP emission unit LV-S3 is based on processing all 177 single-shell and double-shell waste tanks. The APQ of radionuclides for DBVS emission unit STK-1 is based on the processing up to 1,355,500 L (300,000 gal) of saltcake solids and liquids (no sludge) from SST 241-S-109. Tank 241-S-109 radionuclide data was obtained from Hanford's Tank Waste Information Network System (TWINS) as reported in the Notice of Construction application, *Radioactive Air Emissions Notice of Construction For The Supplemental Treatment Test And Demonstration Facility* submitted to the Washington State Department of Health in February 2004. Radionuclide data used for the WTP APQ was obtained from Table B-1, *Best Available Radionuclide Control Technology Analysis for the WTP* (Curn 2002).

As shown in Table 1, the total APQ of radioactive analytes for the proposed DBVS is 81,200 curies and for the WTP is 3,170,000 curies. For all radionuclides of concern, the DBVS's APQ inventory is less than 3% of the WTP APQ. Although the analytes are similar, the DBVS APQ, for example, is significantly lower in ^{90}Sr and transuranics. However, the APQ of ^{137}Cs for the DBVS is greater.

COMPARISON OF DESIGN AIR STREAM TEMPERATURE DATA

A review of the OGTS airstream flow sheet data was performed to compare the WTP and DBVS. The following process flow diagrams as contained in the WTP BARCT analysis were reviewed: LAW Melter Feed (Figure 5-8), LAW Primary Offgas Treatment (Figure 5-9), LAW Secondary Offgas Treatment (Figure 5-10). The following process flow diagrams as contained in the Notice of Construction application for DBVS were reviewed: A-SK-003, Rev F (Sheet 1 of 2), and A-SK-004 Rev F (Sheet 2 of 2). These WTP and DBVS process flow diagrams show the gaseous airflow from the melter to final discharge to the atmosphere.

Figure 1 shows a comparison of the major unit operations for the WTP LAW OGTS and the proposed DBVS OGTS. Unit temperatures are given to demonstrate that the processing conditions are similar between the two facilities. Control of airstream temperature is of concern because of the need to protect HEPA filters and monitoring equipment. Although different control equipment may be used to cool the airflow such as a submerged bed scrubber used at WTP or a quencher used at the DBVS, the resultant exiting design airflow temperature from the equipment is similar.

SELECTED BARCT EQUIPMENT

Table 2 shows the comparison between the selected BARCT equipment for WTP and the proposed BARCT for the DBVS.

Radioactive Particulates/Aerosols - WTP

WTP LAW emission point #LV-S3 consists of offgas from vessel vents (Stream S53) that joins the airstream from the melter (Stream S_85). For control of particulates and aerosols in Stream S_85, BARCT consists of a submerged bed scrubber, and a wet electrostatic precipitator to cool the offgas and remove particulates and moisture, followed by two HEPA filters in series.

Radioactive Particulates/Aerosols - DBVS

The DBVS LAW emission point STK-1 consists of offgases from the Waste Receipt Tanks, Dryer, and melter. For control of particulates and aerosols in the airstream, proposed BARCT consists of one quencher to cool the offgas, one mist eliminator to remove moisture, one heater, and two stages of HEPA filters in series.

Radioactive Gasses - WTP

Because calculated unabated emissions of ^{129}I was >0.1 mrem/year to the maximally exposed individual (MEI), a caustic scrubber was selected as BARCT for control of ^{129}I radioactive gas. Although the ^{14}C calculated dose was also >0.1 mrem/year, no BARCT controls were proposed because the cost was considered unreasonable for the incremental gain in ^{14}C gas removal. Radioactive gas ^3H was not included in the BARCT analysis because the calculated unabated emissions were <0.1 mrem/year to the MEI.

Radioactive Gasses - DBVS

No BARCT controls are proposed for control of radioactive gases (^3H , ^{14}C , ^{106}Ru , ^{129}I) because the calculated unabated emissions are <0.1 mrem/year to the MEI. Although unabated emissions of ^{14}C were calculated to be approaching 0.1 mrem/year (0.075 mrem/yr), the unabated emission estimate was based on processing the maximum inventory of 300,000 gallons of saltcake in one calendar year when, in fact, no more than 200,000 gallons is planned be processed in a calendar year, based on a 70% facility availability. Because the amount of saltcake that is expected to be processed is only two-thirds of the 300,000 gallons bounding inventory in the NOC application, the estimated 0.075 mrem/year to the MEI is a conservative estimate. A more accurate estimate for a calendar year is $0.667 * 0.75$ mrem/yr = 0.50 mrem/yr. Therefore, no specific BARCT controls are being proposed for potential ^{14}C emissions.

The design temperature of the DBVS in-container melt is 1500°C ($2,730^\circ\text{F}$). This temperature exceeds the boiling point of ^{137}Cs ($670^\circ\text{C}/1,240^\circ\text{F}$). However, the temperature of the offgas leaving the melt is less than 500°C (930°F) and the quencher further reduces the airstream temperature to well below the boiling point of ^{137}Cs . Potential ^{137}Cs emissions are then captured as a particulate/aerosol by the HEPA filters. In-situ melter testing performed by the melter vendor is similar to the DBVS in-container vitrification process. Test results indicate that there is greater than 99% retention of ^{137}Cs in the vitrified glass (PNL-8281, *In Situ Vitrification of a Mixed-Waste Contaminated Soil Site: The 116-B-6A Crib at Hanford*; PNL-5240, *An In Situ Vitrification Pilot-Scale Radioactive Test*). Because of the quencher cooling and the expected retention of ^{137}Cs in the vitrified glass, the proposed BARCT control for ^{137}Cs emissions is the quencher, mist eliminator, heater, and two stages of HEPA filters in series. No additional BARCT controls are being proposed for ^{137}Cs emissions. For purposes of calculating an unabated dose to the MEI from potential ^{137}Cs emissions, a release fraction of $1.0\text{E}-02$ is used based upon vendor testing. This results in a more conservative estimate of ^{137}Cs emissions than use of the release fraction of $1.0\text{E}-03$ for particulates and aerosols in accordance with WAC-246-247-030(21)(a).

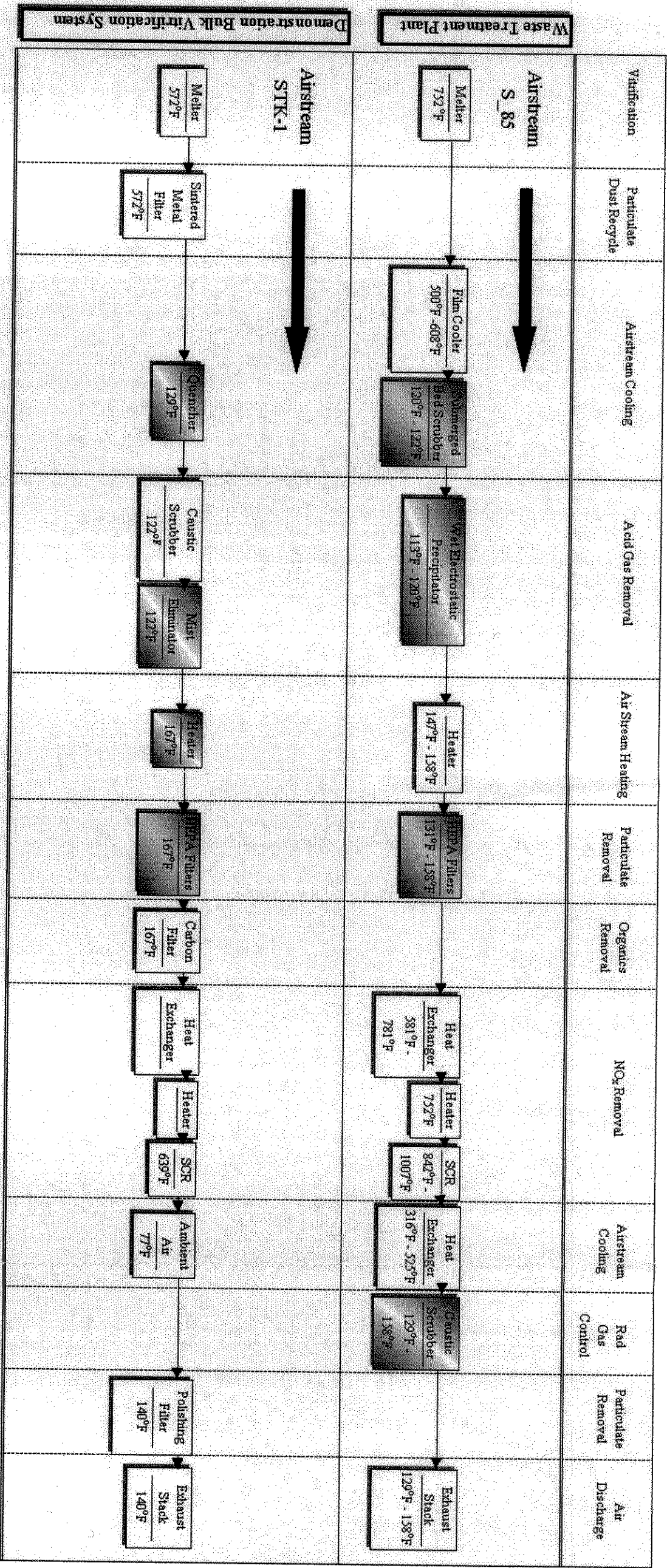
PURPOSE/FUNCTION OF BARCT EQUIPMENT

Table 3 shows the purpose and function of the selected BARCT equipment for the WTP and proposed BARCT equipment for the DBVS. All have similar purpose and function although different control equipment is being proposed as BARCT for airstream cooling. The WTP is using a Submerged Bed Scrubber and Wet Electrostatic Precipitator whereas the proposed BARCT for the DBVS is a quencher. In addition, the DBVS BARCT includes the heater to protect the HEPA filters from water condensation. Under either equipment control configuration, the airstream is controlled to a similar temperature and HEPAs are being protected from high heat off the melter and rapid particulate matter and moisture buildup.

Table 1. Annual Possession Quantity

Analyte Name	Analyte	WTP – LAW Melter Feed (Ci)	DBVS – LAW Melter Feed (Ci)
Tritium	3H	1.03E+03	1.09E+02
Carbon-14	14C	1.51E+02	3.76E+01
Nickel-59	59Ni	1.70E+01	4.20E+00
Cobalt-60	60Co	1.07E+03	2.10E+01
Nickel-63	63Ni	1.70E+03	3.89E+02
Selenium-79	79Se	7.77E+02	5.02E-01
Strontium-90	90Sr	1.17E+06	8.70E+03
Yttrium-90	90Y	1.17E+06	8.70E+03
Niobium-93 metastable	93mNb	4.53E+00	1.80E+01
Zirconium-93	93Zr	9.89E+00	2.46E+01
Technetium-99	99Tc	2.45E+03	1.80E+02
Ruthenium-106	106Ru	6.09E+05	7.24E-05
Cadmium-113 metastable	113mCd	9.59E+03	8.88E+01
Antimony-125	125Sb	4.91E+04	3.98E+01
Tin-126	126Sn	3.45E+03	3.04E+00
Iodine-129	129I	1.26E+01	3.47E-01
Cesium-134	134Cs	5.43E+00	2.09E-01
Cesium-137	137Cs	9.88E+02	2.36E+04
Barium-137 metastable	137mBa	9.98E+02	2.23E+04
Samarium-151	151Sm	1.32E+05	1.68E+04
Europium-152	152Eu	2.63E+02	3.96E+00
Europium-154	154Eu	3.70E+03	9.65E+01
Europium-155	155Eu	1.63E+03	7.95E+01
Radium-226	226Ra	1.39E+02	2.25E-04
Actinium-227	227Ac	8.56E+00	1.40E-03
Radium-228	228Ra	2.80E+00	6.78E-02
Thorium-229	229Th	4.14E+00	1.77E-03
Protactinium-231	231Pa	2.18E+00	6.25E-03
Thorium-232	232Th	3.34E-01	6.60E-03
Uranium-232	232U	9.20E-01	1.03E-02
Uranium-233	233U	3.75E+00	4.21E-02
Uranium-234	234U	5.59E+02	3.73E-02
Uranium-235	235U	1.22E+00	1.56E-03
Uranium-236	236U	8.49E-02	9.91E-04
Neptunium-237	237Np	4.01E+01	6.69E-01
Plutonium-238	238Pu	5.84E+01	1.48E-01
Uranium-238	238U	5.71E-01	3.54E-02
Plutonium-239	239Pu	6.32E+02	7.26E+00
Plutonium-240	240Pu	1.29E+02	1.11E+00
Americium-241	241Am	6.74E+03	4.82E+00
Plutonium-241	241Pu	6.58E+03	6.91E+00
Curium-242	242Cm	1.31E+01	9.18E-03
Plutonium-242	242Pu	3.21E-02	4.90E-05
Americium-243	243Am	5.31E-01	1.37E-04
Curium-243	243Cm	1.77E+00	7.16E-04
Curium-244	244Cm	4.33E+01	7.16E-03
Total Curies		3.17E+06	8.12E+04

Figure 1. Design Airstream Comparison



BARCT Control Equipment

References: 24590-WTP-RPT-ENV-01-004, Rev 1, Figures 5-8, 5-9, 5-10.
Process Flow Diagrams, Full DBVS, A-SK-003, Rev. F and A-SK-004, Rev. F

Table 3. Purpose/Function of BARCT Control Equipment

Control Equipment	Description	BARCT @ WTP	Proposed BARCT at DBVS
HEPA ¹	Removes and collects particulate matter	Yes	Yes
Submerged Bed Scrubber	Condenses water vapor, removes and collects particulate matter, and cools the melter offgas to about 50 °C (120°F). Protects HEPAs from rapid particulate matter buildup	Yes	No
Quencher	Provides scrubbing function and cools the melter offgas to about 25 °C (129°F)	No	Yes
Wet Electrostatic Precipitator	Provides for additional aerosol and particulate removal. Protects HEPAs from rapid particulate matter buildup	Yes	No
Mist Eliminator	Provides for additional aerosol and particulate removal. Protects HEPAs from rapid particulate matter and moisture buildup	No	Yes
Caustic Scrubber	Removes ¹²⁹ I	Yes	No
Heater	Reduces airstream relative humidity by increasing air temperature. Protects HEPAs from water condensation.	No	Yes

¹ WTP has noted that HEPA filters consistently attain a removal efficiency of 99.95%. The DBVS proposes using similar rated nuclear grade HEPAs

Table 2. Comparison of WTP BARCT and Proposed DBVS BARCT

Facility	Abated Emission Point	Airstream Number	Unabated Emission Sources	WTP BARCT Controls			
				Particulates and aerosols	Radioactive Gas		
LAW Vitrification	LV-S1		C3 Zone building air	HEPA (1 single stage)	¹²⁹ I	¹⁴ C	
	LV-S2	S52	C5 Zone building air	HEPA (2 in series)	NA	NA	NA
	LV-S3	S_85	LAW melter offgas	HEPA (2 in series) ³	NA	NA	NA
			Process vessel vent	Submerged Bed Scrubber Wet Electrostatic Precipitator	Caustic scrubber ¹	No Controls ²	
Proposed DBVS BARCT Controls							
Demonstration Bulk Vitrification System	STK-1	32	Waste Receipt Tanks Dryer offgas ICV melter offgas	Particulates and aerosols	Radioactive Gas ⁴		
				HEPA (2 in series) ³ Quencher Mist Eliminator Heater	¹²⁹ I	¹⁴ C	¹⁰⁶ Ru
				NucFils or equivalent	No Controls	No Controls	No Controls
			Storage Waste Container	Passive	No Controls	No Controls	No Controls

¹ Gas streams are scrubbed with a caustic solution (such as sodium hydroxide) to remove iodine and acidic gases including ¹⁴C.

² No additional controls were proposed for ¹⁴C because of unacceptable economic impact (i.e., cost is considered unreasonable for the incremental gain in ¹⁴C gas removal.

³ HEPAs are nuclear grade from the manufacturer and rated at 99.97% efficiency. The in-place leak test efficiency is 99.95% with a mono-dispersed aerosol.

⁴ Calculated emissions < 0.1 mrem/year and no BARCT controls are proposed in accordance with WAC 246-247(020)(2)(c).

[illegible]