Criteria & Toxics Air Emissions Notice of Construction for the Operation of the 241-AP, 241-SY, and 241-AY/AZ Tank Farm Ventilation System Upgrades

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EXECUTIVE SUMMARY

This document serves as a notice of construction pursuant to the requirements of *Washington Administrative Code* 173-400, "General Regulations for Air Pollution Sources," and *Washington Administrative Code* 173-460, "Controls for New Sources of Toxic Air Pollutants," for operation of new ventilation systems in the 241-SY Tank Farm, 241-AP Tank Farm, and 241-AY/AZ Tank Farms. The new ventilation systems include replacing the existing exhaust trains with two new parallel exhaust trains with the 241-SY ventilation system capable of a 2,500 standard cubic feet per minute flow rate and each the 241-AP and the 241-AY/AZ ventilation systems capable of a 3,000 standard cubic feet per minute flow rate. Operation of the new ventilation systems will be for the storage, treatment, retrieval, sampling, transfers, mixing and disposal of the waste in the tanks. The new exhausters are being upgraded with increased flow rates to accommodate the increased heat from mixer pumps that are added to mix the tanks for waste feed delivery to the Waste Treatment and Immobilization Plant.

The combined emissions from all three exhausters for the criteria pollutants nitrogen oxides and volatile organics were found to be above the criteria for exemption in accordance with *Washington Administrative Code* 173-400. Emissions of toxic air pollutants for all three exhausters were analyzed and 91 toxics were found to potentially be emitted. Of the 91 toxics identified 44 were found to be above the *Washington Administrative Code* 173-460 de minimis screening levels and 32 were found to be above the small quantity emission rate. Only dimethyl mercury was found to be above the acceptable source impact level. A second tier health impacts analysis will be submitted separately to analyze the impact of emissions on public health.

A best available control technology for toxics evaluation was performed for each exhauster in this notice of construction application. The technologies considered were eliminated due to technical infeasibilities or because the costs exceeded the amounts the Washington Department of Ecology considers to be economically justifiable. The best available control technology for toxics was determined to be a de-entrainer, heater, pre-filter, and two banks of nuclear grade high efficiency particulate air filters in series.

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LIST OF TERMS

AEA	Atomic Energy Act
AERMOD	American Meteorological Society/U.S. Environmental Protection Agency Regulatory Model
AMCA	Air Movement Control Association
ANSI	American National Standard Institute
ARRA	American Recovery and Reinvestment Act
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
AOP	air operating permit
ASIL	acceptable source impact level
ASME	American Society of Mechanical Engineers
BACT	Best Available Control Technology
CAS	Chemical Abstracts Service
CFR	Code of Federal Regulations
DOE	U.S. Department of Energy
DST	double-shell tank
Ecology	State of Washington, Department of Ecology
USEPA	United States Environmental Protection Agency
EIS	environmental impact statement
HMS	Hanford Meteorology Station
HEPA	high-efficiency particulate air
HIA	Health Impact Analysis
HPS	Health Physics Society
NEPA	National Environmental Policy Act of 1969
NOC	notice of construction
ORP	U.S. Department of Energy, Office of River Protection
RCRA	Resource Conservation and Recovery Act
RCW	Revised Code of Washington
SEPA	State Environmental Policy Act
SQER	small quantity emission rate
TAP	toxic air pollutant
tBACT	*Best Available Control Technology for Toxics*
TWINS	Tank Waste Information Network System
TWRS	Tank Waste Remediation System
VOC	volatile organic compounds
WAC	Washington Administrative Code
WFD	waste feed delivery
WTP	Waste Treatment and Immobilization Plant

UNITS

g/s	grams per second
gal	gallons
lb/yr	pound(s) per year
m	meter
scfm	standard cubic feet per minute
$\mu g/m^3$	microgram per cubic meter

METRIC CONVERSION CHART

Into metric units			Out of metric units		
U.S. Customary Units	**Multiply by**	**To get**	**U.S. Customary Units**	**Multiply by**	**To get**
Length			**Length**		
Inches	25.40	Millimeters	millimeters	0.0393	inches
Inches	2.54	Centimeters	centimeters	0.393	inches
Feet	0.3048	Meters	meters	3.2808	feet
Yards	0.914	Meters	meters	1.09	yards
Miles	1.609	Kilometers	kilometers	0.62	miles
Area			**Area**		
square inches	6.4516	Square centimeters	square centimeters	0.155	square inches
square feet	0.092	square meters	square meters	10.7639	square feet
square yards	0.836	square meters	square meters	1.20	square yards
square miles	2.59	Square kilometers	square kilometers	0.39	square miles
Acres	0.404	Hectares	hectares	2.471	acres
Mass (weight)			**Mass (weight)**		
Ounces	28.35	Grams	grams	0.0352	ounces
Pounds	0.453	Kilograms	kilograms	2.2046	pounds
short ton	0.907	metric ton	metric ton	1.10	short ton
Volume			**Volume**		
fluid ounces	29.57	Milliliters	milliliters	0.03	fluid ounces
Quarts	0.95	Liters	liters	1.057	quarts
Gallons	3.79	Liters	liters	0.26	Gallons
cubic feet	0.03	cubic meters	cubic meters	35.3147	cubic feet
cubic yards	0.76456	cubic meters	cubic meters	1.308	cubic yards
Temperature			**Temperature**		
Fahrenheit	subtract 32 then multiply by 5/9ths	Celsius	Celsius	multiply by 9/5ths, then add 32	Fahrenheit
Energy			**Energy**		
kilowatt hour	3,412	British thermal unit	British thermal unit	0.000293	kilowatt hour
Kilowatt	0.948	British thermal unit per second	British thermal unit per second	1.055	kilowatt
Force/Pressure			**Force/Pressure**		
pounds per square inch	6.895	Kilopascals	kilopascals	0.14504	pounds per square inch

Source: *Engineering Unit Conversions*, M. R. Lindeburg, PE., Second Ed., 1990, Professional Publications, Inc., Belmont, California.

1.0 INTRODUCTION

This Notice of Construction (NOC) application is being submitted for approval in accordance with *Washington Administrative Code* (WAC) 173-400, "General Regulations for Air Pollution Sources," and WAC 173-460, "Controls for New Sources of Toxic Air Pollutants." This NOC application describes the operation of the new ventilation systems in the 241-SY, 241-AP, 241-AY/AZ Tank Farms located in the 200 West and 200 East Areas of the Hanford Site. Operation of these new ventilation systems will be for the storage, treatment, retrieval, sampling, and transfer of liquid/slurry wastes contained in the 200 West and East Area tanks in support of future tank operation activities and waste feed delivery (WFD) to Hanford's Waste Treatment and Immobilization Plant (WTP). This project is an American Recovery and Reinvestment Act (ARRA) project deemed essential in supporting WFD to Hanford's WTP.

The new ventilation systems will have increased flow rates to support WFD operations. During WFD, two mixer pumps will be added to up to two tanks in each farm to make the waste homogeneous for sampling and processing at WTP. The heat generated during mixing and by the pumps will be removed from the tanks via the new ventilation systems. The new ventilation systems are designed to have increased flow capabilities to maintain the tanks within their operating temperature parameters.

Emissions of all criteria air pollutants and toxic air pollutants (TAPs) were estimated based upon tank concentration headspace data from the Tank Waste Information Network (TWINS) database. Due to uncertainties in waste transfers between tanks over the life of these projects, a conservative approach was taken to estimate emissions. Emissions were estimated based upon the highest per tank emission rate of each pollutant for all the tanks in both the 200 West and 200 East Areas. All of the tanks in each tank farm were then assumed to have the highest per tank emission rate for each pollutant. Finally, it was assumed that two tanks would be mixed at any given time and a factor of 10 will be applied to their emissions to simulate the increased emission from mixing. The estimated emissions are very conservative and assume that only two tanks are being mixed in each tank farm for the entire year. Mixing is anticipated to take approximately two weeks and be performed periodically as needed.

The emissions for criteria pollutants were estimated to be below the regulatory exemption levels with the exception of nitrogen oxides (NO_x) and total volatile organic compounds (VOCs) as shown in Appendix A. Estimated NO_x emissions are 7,630 lbs/year and the estimated VOC emissions are 20,132 lbs/year. Both of these levels exceed the 4,000 lb/year exemption level in WAC 173-400-110(5)(d).

Emissions of all TAPs as defined in WAC 173-460-150 were estimated applying the same methodology used for the criteria pollutants using the TWINS database. A total of 91 TAPS were found but only 44 were above the de minimis emission screening level, while 32 were above the small quantity emission rate (SQER), and one was above the acceptable source impact level (ASIL). Dimethyl mercury was found to be above the ASIL and a second tier petition Health Impacts Analysis (HIA), as required in WAC 173-460-090, will be submitted separately.

Appendix B contains a copy of RPP-ENV-46679, *Evaluation of Best Available Control Technology for Toxics (tBACT) Double shell Tank Farms Primary Ventilation Systems Supporting Waste Transfer Operations.* The technologies considered were eliminated due to

technical infeasibilities or because the costs exceeded the amounts the Washington Department of Ecology (Ecology) and the U.S. Environmental Protection Agency (EPA) considers to be economically justifiable. Based on the results of the tBACT evaluation, the proposed tBACT control technology for the double shell tank (DST) primary ventilation systems consists of a moisture de-entrainer, pre-heater, prefilters, and two banks of nuclear grade high efficiency particulate air (HEPA) filters in series.

2.0 FACILITY IDENTIFICATION AND LOCATION

The DST farms are located at:

U.S. Department of Energy, Office of River Protection
Hanford Site
200 East and West Area Tank Farms
Richland, WA 99352

The DSTs are located in the 200 East and West Areas of the Hanford Site (See Figure 1). A brief description of each tank farm follows. Table 1 lists the locations of the tank farms.

241-SY Tank Farm: The 241-SY Tank Farm consists of three buried DSTs in the 200 West Area. The tanks each have a capacity of 1.16 million gallons (gal). The 241-SY Tank Farm is the only DST in the West Area and is the transfer point between the West Area and the East Area, where waste will be treated. The 241-SY Tank Farm was placed into service in 1977. Figure 2 shows a map of the 241-SY Tank Farm and Figure 3 is an aerial photograph of the farm. The three tanks are numbered 241-SY-101, 241-SY-102, and 241-SY-103.

Current 241-SY exhausters are assigned stack numbers 296-S-25 ("A" Train) and 296-P-23 ("B" Train) and operate alternately. They are listed in the *Hanford Site Air Operating Permit* (AOP) Number 00-05-006 under emission points S-296S025-001 (296-S-25) and P-296SY-001 (296-P-23). The new assigned 241-SY exhauster stack numbers are 296-S-026 ("A" Train) and 296-S-027 ("B" Train) and will operate as one exhauster being primary and the other secondary, only one exhauster will operate at a time. At the completion of testing the old exhausters will be disconnected, power disconnected, and removed at a later date.

241-AP Tank Farm: The AP Tank Farm consists of eight buried DSTs in the 200 East Area. The tanks each have a capacity of 1.16 million gal. The AP Tank Farm will be the transfer point for low activity waste from the 200 East Area to the WTP. The AP Tank Farm was placed into service in 1986. Figure 4 shows a map of the AP Tank Farm and Figure 5 is an aerial picture of the AP Tank Farm. The tanks are numbered 241-AP-101 through 241-AP-108.

The current 241-AP exhauster is assigned stack number 296-A-40 and consists of two exhaust trains that operate alternately with a shared stack. The existing stack is listed in the AOP Number 00-05-006 under emission point P-296AP-001 (296-A-40). The new assigned 241-AP exhauster stack numbers are 296-A-048 ("A" Train) and 296-A-049 ("B" Train) and will operate as one exhauster being primary and the other secondary, only one exhauster will operate at a time. At the completion of testing the old exhausters will be disconnected, power disconnected, and removed at a later date.

241-AY and 241-AZ Tank Farms: The 241-AY Tank Farm and the 241-AZ Tank Farm each have two buried DSTs in the 200 East Area. The AY and AZ Tank Farms were placed into service in 1971 and 1977 respectively. A map of the AY and AZ Tank Farms is shown in Figure 6. Due to the proximity of the two tank farms, it is possible to use one exhauster system to ventilate both farms. Figure 7 shows an aerial photo of the 241-AY, 241-AZ and nearby 241-AX Tank Farms.

The current 241-AY/AZ exhauster system consists of two exhaust trains. The stack is assigned number 296-A-42, and is listed in the AOP Number 00-05-006 under emission points P-296A042-001 (296-A-42). The newly installed and assigned 241-AY/AZ exhauster stack numbers are 296-A-050 (“A” Train) and 296-A-051 (“B” Train) and will operate as one exhauster being primary and the other secondary, only one exhauster will operate at a time. At the completion of testing the old exhausters will be disconnected, power disconnected, and removed at a later date.

Figure 1. The Hanford Site.

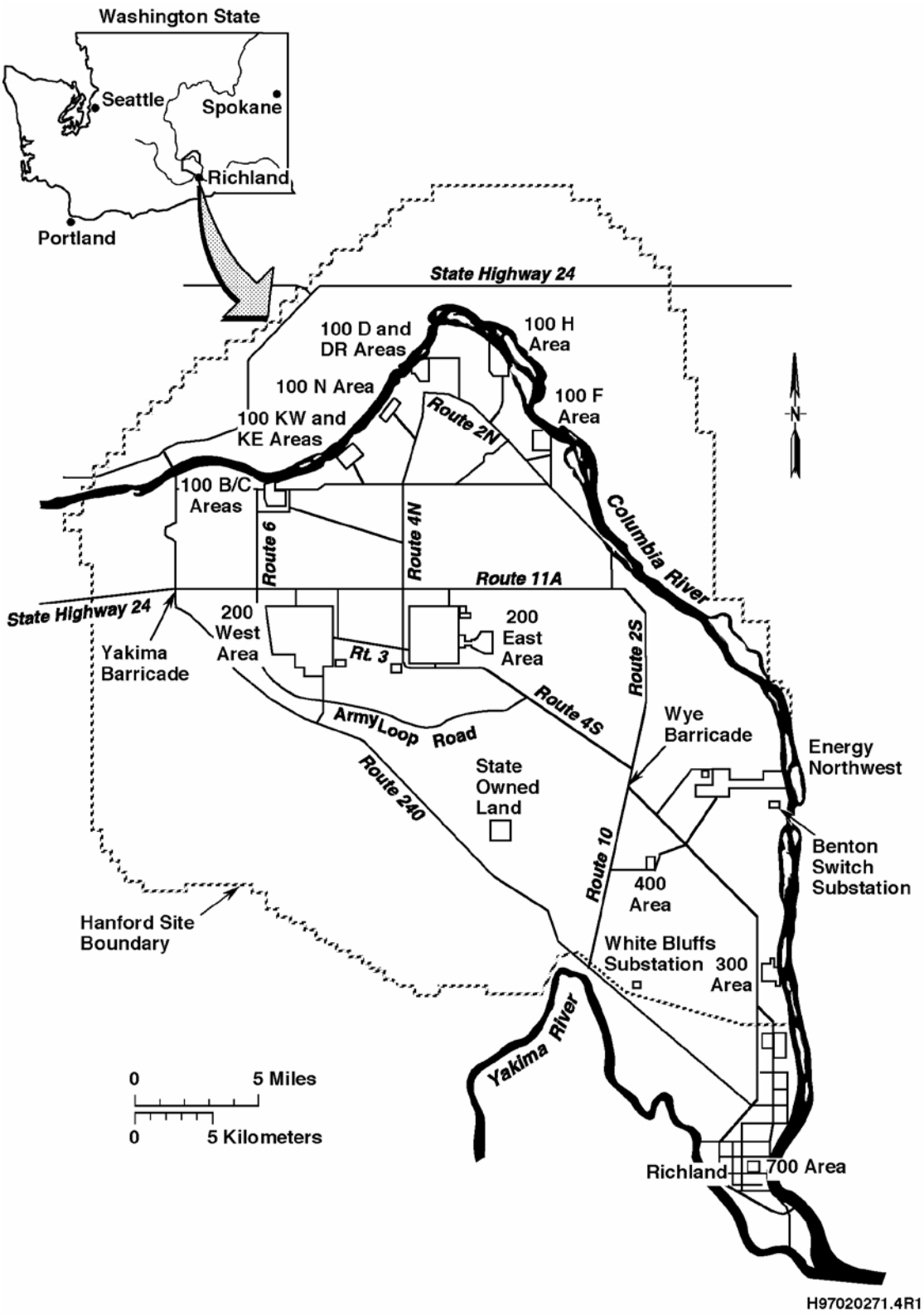


Table 1. Tank Farm locations.

Tank Farm	Latitude	Longitude
241-AP	46° 33’ 07” N	119° 30’ 57” W
241-SY	46° 32’ 26” N	119° 37’ 40” W
241-AY/AZ	46° 33’ 18” N	119° 31’ 03” W

Figure 2. Location of 241-SY Tank Farm.

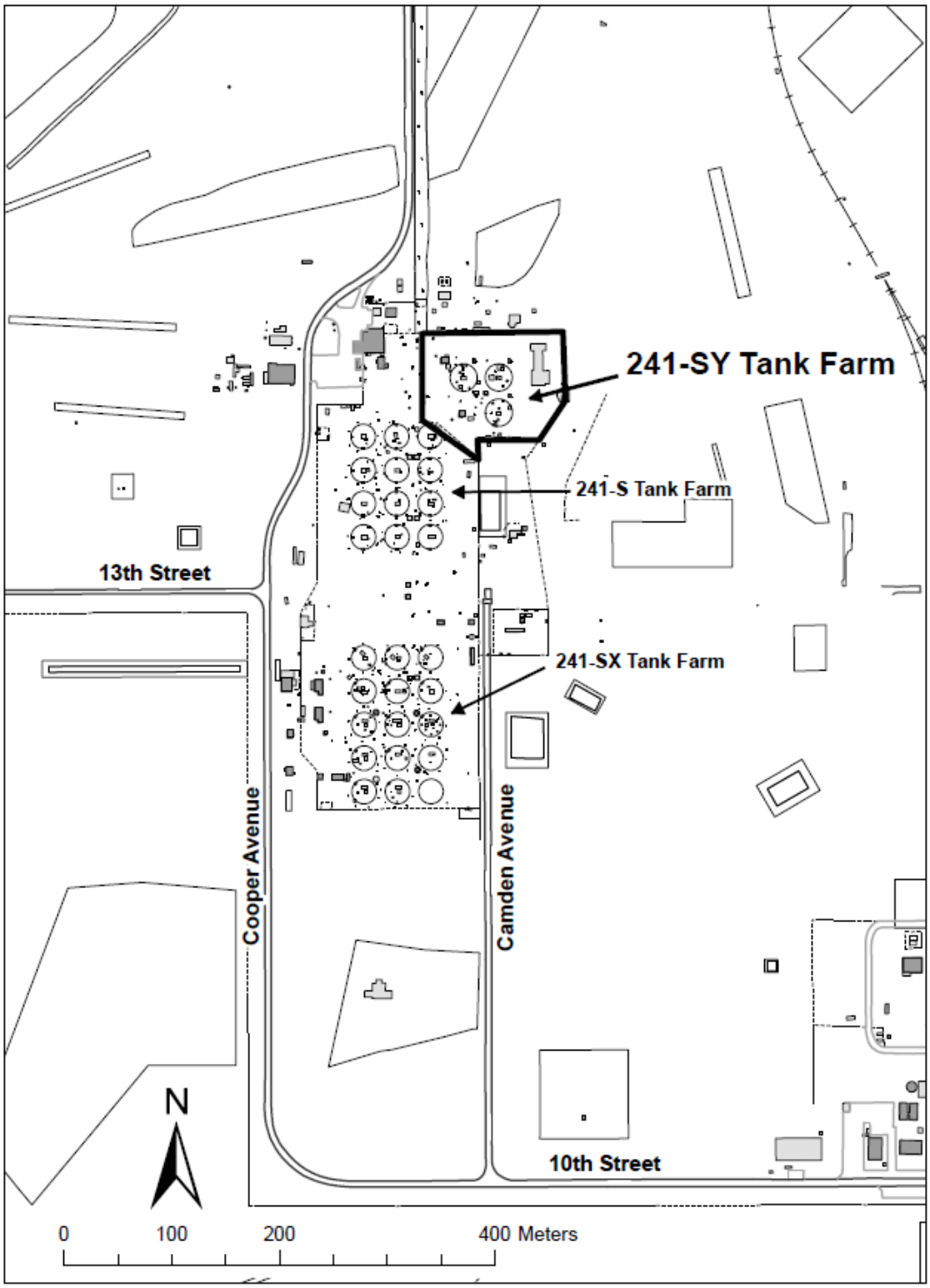


Figure 3. Aerial View of 241-SY Tank Farm.

Figure 4. Location of 241-AP Tank Farm.

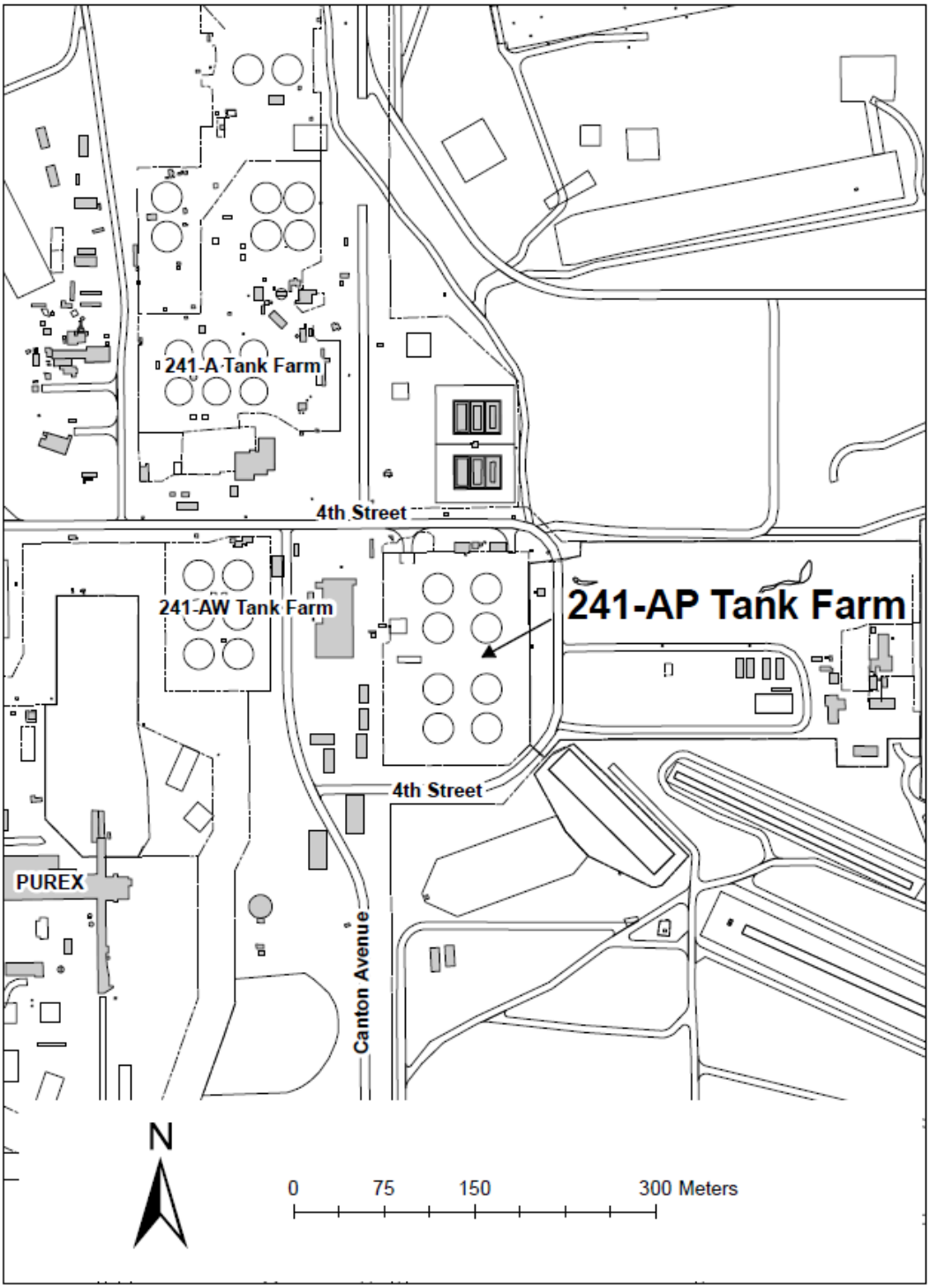


Figure 5. Aerial View of 241-AP Tank Farm.

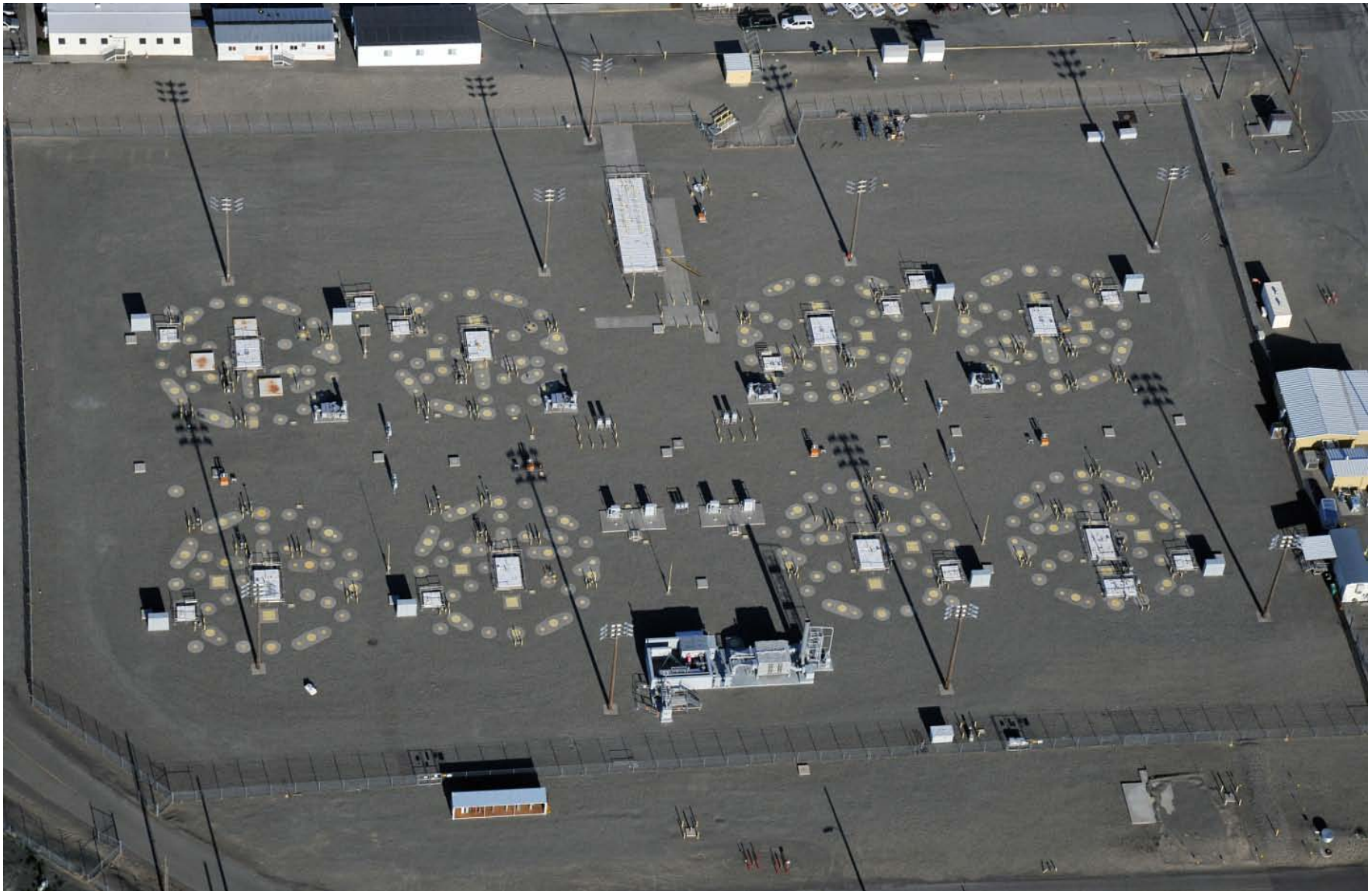


Figure 6. Location of 241-AY and 241-AZ Tank Farms.

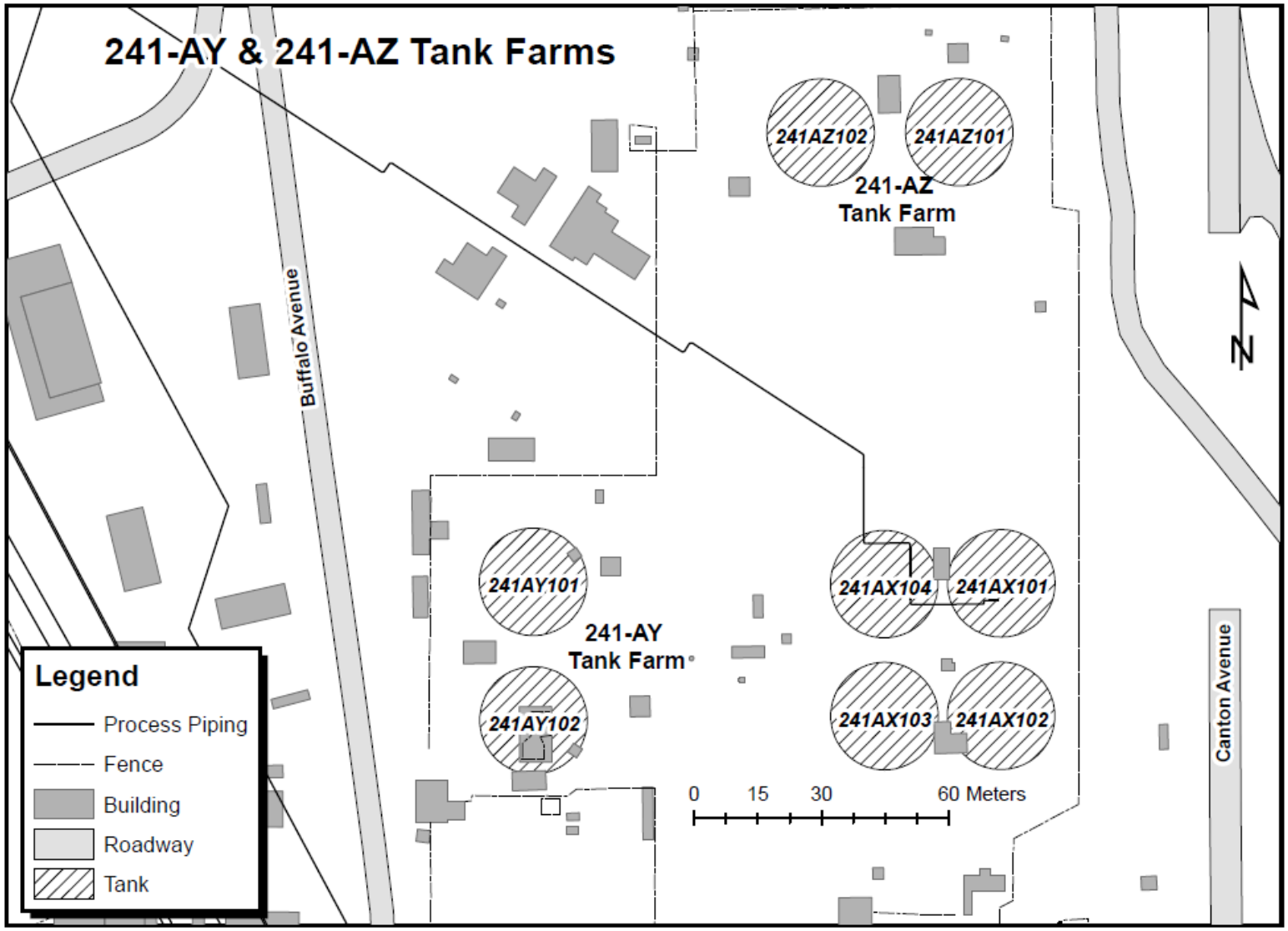


Figure 7. Aerial View of 241-AY, 241-AZ and 241-AX Tank Farms.

3.0 RESPONSIBLE MANAGER

The current responsible facility manager is:

Jonathan A. Dowell, Acting Manager
U.S. Department of Energy, Office of River Protection (ORP)
P.O. Box 550
Richland, Washington 99352
(509) 376-3389

4.0 PROPOSED ACTION

This NOC application is submitted for approval to install and operate new 241-SY, 241-AP, and 241-AY/AZ primary ventilation system exhausters. Approval is requested in this application to operate these new ventilation systems during operations for waste storage, treatment, retrieval, sampling and transfers of the waste to the WTP. The exhausters are being upgraded with increased air flow rates because thermal hydraulic analysis of the WFD process determined that increased air flow rates were necessary to assure the tanks are maintained within operating temperature limits. The following reports document the thermal hydraulic analysis for the 241-SY and 241-AP Tank Farms:

- RPP-43971, *Thermal Hydraulic Evaluation for 241-SY Tank Farm Primary Ventilation System*
- RPP-45912, *Thermal Hydraulic Evaluation for 241-AP Tank Farm Primary Ventilation System*

The thermal and hydraulic analysis for the 241-AY/AZ Tank Farm is yet to be completed.

The activities proposed with this NOC revision will increase emissions during WFD activities.

4.1 241-SY TANK FARM

The activities proposed in this NOC for the 241-SY Tank Farm include:

- Site preparation for the new exhauster skids.
- Isolation and removal of the existing exhausters.
- Installation of the new exhausters.
- Operation of one exhaust fan and train with a flow rate of 1,360 standard cubic feet per minute (scfm) for storage operations and most retrieval and sampling activities.
- Operation of one exhaust fan and train with a maximum flow rate of up to 2,500 scfm for WFD operations.

The planned schedule for delivery of the 241-SY Exhauster is July, 2011. Site preparation is scheduled to begin in October, 2011 and last through March, 2012. Testing of the installed unit will occur from April to September, 2012 and operations are scheduled to start in October, 2012. The exhauster will be designed for a 40 year design life, consistent with the scheduled Hanford Site cleanup completion.

4.2 241-AP TANK FARM

The activities proposed in this NOC for the 241-AP Tank Farm include:

- Site preparation for the new exhauster skids
- Isolation and removal of the existing exhausters.
- Installation of the new exhausters.
- Operation of one exhaust fan and train with a flow rate of 1,500 scfm for storage operations and most retrieval and sampling activities.

- Operation of one exhaust fan and train with a maximum flow rate of up to 3,000 scfm for WFD.

The planned delivery schedule for the 241-AP Exhauster is August, 2011. Site preparation is scheduled to occur from April through September, 2012. Testing of the installed unit is scheduled to occur from October, 2012 to July, 2013, with operations starting in August, 2013. The exhauster will be designed for a 40 year design life, consistent with the scheduled Hanford Site cleanup completion.

4.3 241-AY/AZ TANK FARMS

The activities proposed in this NOC for the 241-SY Tank Farm include:

- Site preparation for the new exhausters.
- Isolation and removal of the existing exhausters.
- Installation of the new exhausters.
- Operation of one exhaust fan and train with a flow rate of 1,500 scfm for storage operations and most retrieval and sampling activities. Operation of one exhaust fan and train with a maximum flow rate of up to 3,000 scfm for WFD.

The planned delivery schedule for the 241-AY/AZ Exhauster is July, 2012. Site preparation is scheduled to occur from October, 2012 through March, 2013. Testing of the installed unit will occur from April to September, 2013 and operations will begin in October, 2013. The exhauster will be designed for a 40 year design life, consistent with the scheduled Hanford Site cleanup completion.

5.0 STATE ENVIRONMENTAL POLICY ACT

In accordance with WAC 197-11, *State Environmental Policy Act of 1971* and the *Revised Code of Washington* (RCW) 43.21C Ecology requires all government agencies to consider the environmental impacts of a proposal before making decisions. An environmental review of the actions identified in this NOC application was conducted in the preparation of the National Environmental Policy Act (NEPA) of 1969 (title 10, *Code of Federal Regulations*, Part 1021, "National Environmental Policy Act" [10 CFR 1021]) documentation. Existing environmental documentation can be used to meet all or part of an agency's responsibilities under the State Environmental Policy Act (SEPA) as provided in WAC 197-11-600. These documents meet the agencies review needs for the current proposal:

- DOE/EIS-0189,"*Tank Waste Remediation System, Hanford Site, Richland, Washington, Final Environmental Impact Statement*"
- 62 FR 8693, "*Final Environmental Impact Statement: Disposal of Hanford Defense High-Level, Transuranic and Tank Wastes, Hanford Site, Richland WA*"

6.0 CHEMICAL AND PHYSICAL PROCESS

The 241-SY, 241-AP, and 241-AY/AZ Tank Farms all contain DSTs. The inner shell of each DST is constructed from heat-treated, stress-relieved steel, and the outer shell is constructed of non-stress-relieved steel. The inner tank where the waste is stored is 75 feet in diameter and is approximately 47 feet high at the crown. The two shells are separated by a 2.5-foot annulus, and both shells are contained within a concrete encasement.

Waste stored in the tanks consists of hazardous chemicals regulated under the *Resource Conservation and Recovery Act (RCRA) of 1976* and radioactive isotopes regulated under the *Atomic Energy Act (AEA) of 1954*. The DSTs are used to store, treat, or transfer waste to the WTP. The tanks contain mixed waste in the form of liquids and suspended or settled solids. Gases are generated by the reaction of radioactive and hazardous chemicals in the tanks. The contents of the tanks may be mixed periodically to entrain the solids. During storage activities and mixing, the ventilation system maintains the headspace in each tank below atmospheric pressure to retain containment on radioactive particulates.

The ventilation systems contain the radioactive particulates present in the tank headspace, remove flammable gases and vapors that evolve from the liquid surface, and remove heat. The ventilation systems operate by drawing outside air into the headspace. The air is drawn out of the tanks via a riser into a common ventilation header. The header is then connected to the exhauster. See Section 7 for a discussion of the exhauster process and abatement systems.

During storage operations, the tank waste is quiescent. Retrieval of wastes from single shell tanks (SSTs) will involve periodic transfers of waste between tanks. Supernatant from DSTs might be used to help mobilize sludge in the SSTs, and the resulting waste will be transferred back to the DSTs. Waste will also be transferred between and among tanks for space management. In the 200 East Area, waste will also be transferred between tanks to reach the 242-A Evaporator for volume reduction. Periodic sampling will also occur. The 241-SY Tank Farm will receive waste transfers from the 222-S Laboratory.

For waste transfer operations, a maximum of two mixer pumps and a transfer pump will be installed in each of two tanks in a farm. Waste transfers and testing will occur prior to WTP operation. The mixer pumps will be run to ensure that the waste is a homogeneous mixture for sampling and delivery to the WTP. Mixer pumps are operated in a batch mode as needed to maintain waste uniformity during staging and to mix the waste for a period of time before and during transfer. As required by operational directives, mixer pumps will be operated until waste samples verify that adequate mixing has occurred. Waste samples will be collected periodically. If dilution/conditioning is needed, the pH and temperature of the diluents will be adjusted by means of a caustic supply system.

The contents in each tank could be mixed periodically to control gas entrapment in the settled solids, to control temperature, to perform chemical treatment, or for waste retrieval. Contained solids are mobilized as part of the hydraulic action of the mixer pumps or by using air lift circulators in each of the tanks. Mobilization of solids normally occurs in a single tank at a time. During mixing as well as storage, the ventilation system will maintain the headspace below atmospheric pressure.

7.0 EMISSION ESTIMATES

Criteria and toxic air pollutants emissions are estimated and reported in RPP-RPT-44009, *Spreadsheet Description Document for Non-Rad Air Source Term for 241 -SY Farm and 241 – AP Farm Primary Ventilation System Upgrades,* and SVF-1821, *Non-Radiological Air Source Term for 241-SY Farm and 241-AP Farm Primary Ventilation System* on a per tank basis and a maximum tank farm basis. RPP-RPT-44009 and SVF-1821 calculate the maximum emissions for each TAP from all tanks, thus bounding the 241-AY/AZ exhauster emissions. For this analysis, the per tank emission rate from SVF-1821 was used to calculate the per tank farm emission rate for 241-SY, 241-AP, and 241-AY/AZ Tank Farms. Assumptions made in RPP-RPT-44009 for the evaluation were:

1. When the maximum value in the TWINS database is the measurement detection limit, that value is assumed to be the reported value.
2. Measurements were made over a quiescent waste and passively ventilated for all SSTs and actively ventilated DSTs. A constant emission rate was assumed as long as the tank waste remained quiescent.
3. SSTs were passively ventilated during measurements and each DST ventilation system was assumed to have a flow rate for each tank of 1,000 scfm divided by the number of tanks in the tank farm.
4. Based upon mixer pumps test in DST 241-AZ-101, it was assumed that the headspace concentrations increased by a factor of 10 during waste mixing activities (RPP-12735, *Tank Farm Source Term Document Corrections,* Rev. 0A).
5. No more than two tanks in a tank farm will have waste disturbing activities occurring simultaneously.
6. The emission rate from the highest tank for each TAP is contained in all tanks in the DST tank farm.

The unabated emissions of criteria and toxic pollutants from the 241-SY, 241-AP and 241-AY/AZ exhausters were estimated based upon measured headspace concentrations in the TWINS database. This database was searched for regulated criteria pollutants by the Chemical Abstracts Service (CAS) number for all tanks. Because waste transfers will occur between tanks during the lifetimes of the exhausters, the highest emission rate per tank was calculated. The maximum per tank emission rate was used for each farm, assuming that two of the tanks will be mixed in each farm.

7.1 ESTIMATED EMISSIONS OF CRITERIA POLLUTANTS

The annual emissions of criteria pollutants are shown in Table A-1 in Appendix A. Only NO_x and VOCs were above the de minimis annual emission limits. Nitrogen oxides had an annual emission rate of 7,630 lbs/year while the de minimis threshold is 4,000 lbs/year. Volatile organic compound emissions were estimated to be 20,100 lbs/year, while the de minimis threshold is 4,000 lbs/year.

7.2 ESTIMATED EMISSIONS OF TOXIC AIR POLLUTANTS

The emissions of TAPs are shown in Table A-2 in Appendix A. Ninety-one TAPs were identified in the tank headspace. Of these, only 44 had emissions above the de minimis emission threshold in WAC 173-460-150. Only 32 TAPs had emission rates above the SQER emission thresholds. Only dimethyl mercury was above the ASIL and an HIA per WAC 173-460-090 is being submitted separately.

7.3 AIR DISPERSION MODELING

Ambient air concentrations at the Hanford Site boundary were estimated using the EPA American Meteorological Society/U.S. Environmental Protection Agency Regulatory Model (AERMOD) dispersion model, Version 09292. EPA-454/B-03-001, *User's Guide for the AMS/EPS Regulatory Model – AERMOD,* was used as modeling guidance.

The model inputs included the physical parameters of the stack:

- Stack height - 40 feet
- Maximum flow rates (assuming mixing for all tank farms)
- Stack temperature of 293 degrees Kelvin.

The public access points to the site were used as the site boundaries. The surface meteorological inputs were from the Hanford Meteorological Station (HMS) and the upper air data was obtained from the Spokane, Washington, National Weather Service for the years 2001 through 2005. Digital elevation model data from the U.S. Geological Survey was used for model terrain input. The regulatory default mode was used. Based upon Ecology's 08-02-025, *Guidance Document: First, Second, and Third Tier Review of Toxic Pollution Source,* the receptor grid spacing was:

Table 2. Ecology recommended receptor grid spacing.

Distance from Source (m)	Grid Spacing (m)
0 – 350	10
350 – 800	25
800 – 4,000	50
4,000 – 8,000	100
30,000 > 8,000	200

The new exhausters were modeled at the same time and it was assumed that all were operating during mixing operations. The new exhausters were also assumed to be operating during mixing operations for the entire year to ensure that the worst case situation was modeled.

A total unitary emission rate for all exhausters of 1 gram per second (g/s) was used based upon the ratio of the emission factors per tank farm to the total of the three exhausters' emissions. This method allowed for the actual exhaust rate for each TAP from all the exhausters to be multiplied by the conversion factor to achieve the dispersed concentration. The 241-SY Tank Farm had an emission factor of 21, two tanks being mixed and one quiescent. The 241-AP Tank Farm had an emission factor of 26, two tanks mixed and 6 tanks quiescent. The 241-AY/AZ

Tank Farm had an emission factor of 22, two tanks mixed and two tanks quiescent. The emission factor for the 241-SY Tank Farm was 0.304 g/s (21/69), the 241-AP Tank Farm the emission factor was 0.377 g/s (26/69), and the 241-AY/AZ Tank Farm emission factor was 0.319 g/s (22/69).

Table 3 shows the dispersion factors for all three exhausters operating simultaneously along with the location of the highest receptor. The receptor with the highest concentration for each time period is along Highway 240 to the south and west of the 200 West Area.

Table 3. Air dispersion factors for the 241-SY, 241-AP, and 241-AY/AZ DST exhausters.

	(µg/m^3 per g/s)	**Easting (m)**	**Northing (m)**
1-hour	17	319,027	5,163,399
24-hour	1.9	294,104	5,157,438
Annual	0.056	293,339	5,158,813

The air dispersion factors, based upon the specific TAP averaging period, were multiplied by the total emission rate in g/s for the three tank farm exhausters to calculate the ambient air concentrations shown in Table A-2.

7.4 ESTIMATED AMBIENT CONCENTRATIONS COMPARED TO WAC 173-460-150 THRESHOLDS

The results of the emissions and modeling are shown in Table A-2 in Appendix A. Only dimethyl mercury exceeded the WAC 173-460-150 ASIL limits. The dispersed dimethyl mercury concentration was modeled to be 7.8E-08 microgram per cubic meter (µg/m^3). An HIA will be submitted separately describing the anticipated effect on human health from the dimethyl mercury emissions.

8.0 TANK VENTILATION PROCESS AND EMISSION CONTROL SYSTEMS

The abatement technology for this new system is described in RPP-SPEC-42594, *Procurement Specification SY/AP Primary Exhauster Skid For Waste Tank Ventilation*. The 241-AY/AZ specification is yet to be complete; however it is expected to be equivalent to the 241-SY and 241-AP system.

The upgraded ventilation systems will remove particulates and moisture, collect condensate, and reduce relative humidity in the exhaust stream. Inlet air for the tanks is primarily provided through inlet air filters, along with air infiltration through process pits and tank risers. Air flows from the tank to a common header. The major components of this DST primary ventilation system are:

- Cooler - to be installed prior to mixing (not a part of tBACT)
- De-entrainer
- Heater
- Prefilter
- HEPA filter banks in series (2)
- Fans
- Exhaust stack
- Monitoring and control instruments and equipment.

The air from the common header passes through a de-entrainer to remove large water droplets. The air next passes through a heater to lower the relative humidity, and then through a prefilter to remove large particles. The de-entrainers and heaters help protect the HEPA filter media from wetting, which could lead to wicking of contamination, plugging of a filter, or wetting of the exhaust system sample system filter and sample media. The air next passes through two nuclear grade HEPA filters that are rated to remove particles as small as 0.3 µm in diameter with a rated efficiency of no less than 99.97%. The face dimensions of the filters are 24 inches by 24 inches and the filter media is 11.5 inches deep. The monitoring and control instrumentation ensures that the pressure drop across the HEPA filters is within tolerances. The primary ventilation system will collect all condensate and return it to a designated DST.

The new systems will incorporate coolers to keep the air temperature within the operational range of the HEPA filters. The coolers, if necessary, would be placed on a skid before the de-entrainers. Testing of the heat generated from the mixer pumps will be conducted to determine if coolers are necessary.

8.1 BEST AVAILABLE CONTROL TECHNOLOGY

Pursuant to WAC 173-400-113(2), an analysis of Best Available Control Technology (BACT) for emissions of criteria pollutants was performed as well as a Best Available Control Technology for Toxics (tBACT) pursuant to WAC 173-460-060 (2) for toxics. Appendix B contains a copy of RPP-ENV-46679, *Evaluation of Best Available Control Technology for Toxics (tBACT) Double shell Tank Farms Primary Ventilation Systems Supporting Waste Transfer Operations.* This document serves as the tBACT analysis for this NOC application. The tBACT was based upon emissions from the 241-AP Tank Farm and is bounding for the other tank farms.

The tBACT analysis was performed using the “top-down” approach established for BACT. The approach consists of the following steps:

1) Identify all control technologies
2) Eliminate technically infeasible options
3) Rank remaining control technologies by control effectiveness
4) Evaluate most effective controls and document results
5) Select BACT.

Toxics with similar chemical and physical properties were grouped together with the assumption that similar control technologies would be effective. The four groups identified were:

- Ammonia
- Toxic organic compounds
- Mercury and mercury related compounds
- Particulate metal compounds

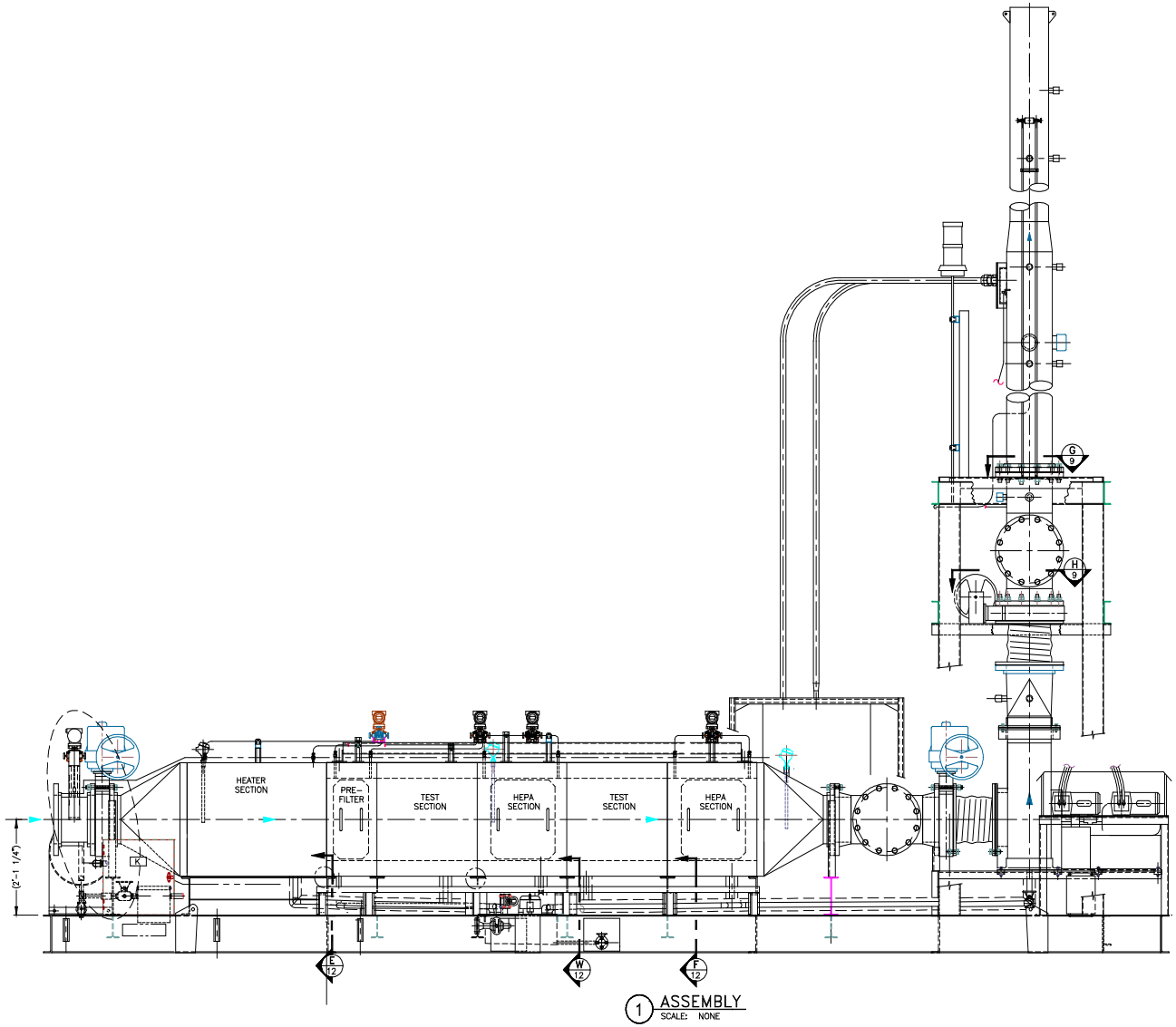
A detailed evaluation of the emission control technologies was performed. After an effectiveness analysis, a cost per ton of pollutant removed was calculated. Most of the costs per ton exceeded the cost ceiling estimates guidelines previously approved by Ecology and EPA as economically justifiable. Due to the low emission rates, the cost per ton to remove the pollutants becomes prohibitively expensive.

Based upon the results of this tBACT, the proposed tBACT control technology for the DST primary ventilation system consists of a moisture de-entrainer, heater, pre-filter, and two banks of nuclear grade HEPA filters in series.

9.0 APPLICABLE CONTROL TECHNOLOGY DRAWINGS

Figure 8 shows the new exhauster design. The design includes a de-entrainer, heater, pre-filter, and two banks of nuclear grade HEPA filters in series and exhaust stack.

Figure 8. Exhauster Layout



10.0 MONITORING DURING OPERATIONS

Annual sampling is proposed for NO_x and VOCs emissions are estimated to be above the SQERs. Annual sampling is also proposed for the 32 TAPs above the SQERs and for dimethyl mercury because it is above the ASIL.

11.0 REFERENCES

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RPP-42116, Rev 0, *Functions and Requirements – AP/SY Tank Farm Primary Ventilation System Upgrade*, Washington River Protection Solutions, Richland, Washington.

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WAC 246-247, "Radiation Protection – Air Emissions," *Washington Administrative Code*, as amended.

APPENDIX A
Criteria and Toxic Air Pollutant Emission Rates

Table A-1. Criteria pollutants emission rates and comparison to de minimis levels.

Chemical	CAS #	Averaging Period	Emission Rate (g/s)	Emission Rate (lbs/yr)	De Minimis (lbs/yr)	Above De Minimis
Nitrogen oxides	10102-44-0	Year	1.59E-03	7,630	4,000	Yes
VOCs		Year	4.20E-03	20,132	4,000	Yes
SOx (Sulfur oxides)	7446-09-05	Year	3.52E-06	17	4,000	No
Lead	7439-92-1	Year	9.50E-07	5	10	No
Carbon monoxide	630-08-0	Year	5.40E-04	2,592	10,000	No

Table A-2. Toxic air pollutant emission rates and comparison to the WAC 173-460-150 de minimis, SQER, and ASIL levels.

Chemical Name	CAS #	Avg. Period	Emissions				De Minimis (lbs/ avg period)	Above De Minimis ?	SQER (lbs/avg period)	Above SQER?	Dispersed Conc. (µg/m^3)	ASIL (µg/m^3)	Above ASIL?
			(g/s)	(lbs/hr)	(lbs/24-hr)	(lbs/yr)							
Ethylbenzene	100-41-4	Year	1.41E-03	-	-	98.1	3.84	Yes	76.8	Yes	7.90E-05	0.4	No
Styrene	100-42-5	24-hr	4.62E-04	-	0.088	-	5.91	No	118	No	8.79E-04	900	No
Benzyl Chloride	100-44-7	Year	1.34E-05	-	-	0.932	0.196	Yes	3.91	No	7.51E-07	0.0204	No
Nitrogen dioxide	10102-44-0	1-hr	5.51E-02	0.438	-	-	0.457	No	1.03	No	9.37E-01	470	No
n-Nitroso-n-methylethylamine	10595-95-6	Year	1.94E-06	-	-	0.135	0.00153	Yes	0.0305	Yes	1.09E-07	0.000159	No
p-Xylene	106-42-3	24-hr	1.63E-03	-	0.310	-	1.45	No	29	No	3.09E-03	221	No
1,4-Dichlorobenzene	106-46-7	Year	6.21E-05	-	-	4.32	0.872	Yes	17.4	No	3.48E-06	0.0909	No
1,2-Epoxybutane	106-88-7	24-hr	4.04E-05	-	0.00769	-	0.131	No	2.63	No	7.67E-05	20	No
1,2-Dibromoethane	106-93-4	Year	7.97E-05	-	-	5.54	0.135	Yes	2.71	Yes	4.46E-06	0.0141	No
1,3-Butadiene	106-99-0	Year	1.99E-04	-	-	13.9	0.0564	Yes	1.13	Yes	1.12E-05	0.00588	No
Acrolein	107-02-8	24-hr	2.98E-06	-	0.000568	-	0.000394	Yes	0.00789	No	5.66E-06	0.06	No
Allyl Chloride	107-05-1	Year	1.02E-05	-	-	0.709	1.6	No	32	No	5.71E-07	0.167	No
1,2-Dichloroethane	107-06-2	Year	1.63E-03	-	-	113.20	0.369	Yes	7.39	Yes	9.12E-05	0.0385	No
Acrylonitrile	107-13-1M	Year	1.23E-05	-	-	0.856	0.0331	Yes	0.662	Yes	6.90E-07	0.00345	No
Vinyl acetate	108-05-4	24-hr	4.48E-07	-	8.53E-05	-	1.31	No	26.3	No	8.51E-07	200	No
Methyl Isobutyl Ketone	108-10-1	24-hr	2.77E-03	-	0.527	-	19.7	No	394	No	5.26E-03	3000	No
m-Xylene	108-38-3M	24-hr	9.42E-04	-	0.179	-	1.45	No	29	No	1.79E-03	221	No
3-Methylphenol	108-39-4	24-hr	4.74E-06	-	0.00090	-	3.94	No	78.9	No	9.01E-06	600	No
Toluene	108-88-3	24-hr	4.09E-02	-	7.78	-	32.9	No	657	No	7.76E-02	5000	No
Chlorobenzene	108-90-7	24-hr	4.99E-04	-	0.095	-	6.57	No	131	No	9.49E-04	1000	No
Phenol	108-95-2	24-hr	8.14E-03	-	1.55	-	1.31	Yes	26.3	No	1.55E-02	200	No
n-Hexane	110-54-3	24-hr	5.16E-03	-	0.98	-	4.6	No	92	No	9.81E-03	700	No
Cyclohexane	110-82-7	24-hr	1.58E-03	-	0.301	-	39.4	No	789	No	3.01E-03	6001	No
Ethylene glycol monoethyl ether acetate	111-76-2	24-hr	1.52E-04	-	0.029	-	85.4	No	1710	No	2.88E-04	13000	No

Chemical Name	CAS #	Avg. Period	Emissions				De Minimis (lbs/ avg period)	Above De Minimis ?	SQER (lbs/avg period)	Above SQER?	Dispersed Conc. (µg/m^3)	ASIL (µg/m^3)	Above ASIL?
			(g/s)	(lbs/hr)	(lbs/24-hr)	(lbs/yr)							
Propylene	115-07-1	24-hr	3.93E-03	-	0.748	-	19.7	No	394	No	7.46E-03	3000	No
Di(2-ethylhexyl)phthalate	117-81-7	Year	7.46E-07	-	-	0.0518	0.4	No	8	No	4.18E-08	0.0417	No
1,4-Dioxane	123-91-1	Year	7.02E-04	-	-	48.8	1.25	Yes	24.9	Yes	3.93E-05	0.13	No
Perchloroethylene	127-18-4	Year	1.62E-03	-	-	112.4	1.62	Yes	32.4	Yes	9.06E-05	0.169	No
Vanadium Pentoxide	1314-62-1	1-hr	1.17E-04	0.00093	-	-	0.00329	No	0.0657	No	1.99E-03	30	No
Polychlorinated Biphenyls (PCBs)	1336-36-3	Year	2.04E-05	-	-	1.415	0.0168	Yes	0.336	Yes	1.14E-06	0.00175	No
Trans-1,2-dichloroethene	156-60-5	24-hr	1.19E-07	-	2.27E-05	-	5.3	No	106	No	2.27E-07	807	No
Butylated hydroxyanisole	25013-16-5	Year	1.42E-06	-	-	0.0989	168	No	3360	No	7.97E-08	17.5	No
Formaldehyde	50-00-0	Year	2.35E-05	-	-	1.64	1.6	Yes	32	No	1.32E-06	0.167	No
n-Nitrosodiethylamine	55-18-5	Year	1.94E-06	-	-	0.135	0.000959	Yes	0.0192	Yes	1.09E-07	0.0001	No
Carbon Tetrachloride	56-23-5	Year	1.64E-03	-	-	114.0	0.228	Yes	4.57	Yes	9.18E-05	0.0238	No
1,1-Dimethylhydrazine	57-14-7	24-hr	1.74E-06	-	0.000332	-	0.00329	No	0.0657	No	3.31E-06	0.5	No
Propylene Glycol	57-55-6	24-hr	2.25E-04	-	0.0429	-	0.187	No	3.75	No	4.28E-04	28.5	No
n-Nitrosomorpholine	59-89-2	Year	8.96E-06	-	-	0.623	0.00505	Yes	0.101	Yes	5.01E-07	0.000526	No
Dimethyl Mercury	593-74-8	24-hr	4.12E-08	-	7.85E-06	-	1E-99	Yes	1E-99	Yes	7.83E-08	1E-99	Yes
Acetamide	60-35-5	Year	6.05E-06	-	-	0.421	0.48	No	9.59	No	3.39E-07	0.05	No
n-Nitrosodimethylamine	62-75-9	Year	2.65E-03	-	-	184	0.00208	Yes	0.0416	Yes	1.48E-04	0.000217	No
n-Nitrosodi-n-propylamine	621-64-7	Year	1.94E-06	-	-	0.135	0.0048	Yes	0.0959	Yes	1.09E-07	0.0005	No
Methyl Isocyanate	624-83-9	24-hr	1.77E-06	-	0.000337	-	0.00657	No	0.131	No	3.36E-06	1	No
Carbon monoxide	630-08-0	1-hr	3.73E-02	0.296	-	-	1.14	No	50.4	No	6.34E-01	23000	No
Methyl Alcohol	67-56-1	24-hr	7.11E-02	-	13.5	-	26.3	No	526	No	1.35E-01	4000	No
Isopropyl Alcohol	67-63-0	1-hr	3.37E-03	0.0268	-	-	0.35	No	7.01	No	5.74E-02	3200	No
Chloroform	67-66-3	Year	1.64E-03	-	-	114.0	0.417	Yes	8.35	Yes	9.18E-05	0.0435	No
Hexachloroethane	67-72-1	Year	1.68E-03	-	-	117.0	0.872	Yes	17.4	Yes	9.42E-05	0.0909	No
Benzene	71-43-2	Year	1.63E-03	-	-	113.2	0.331	Yes	6.62	Yes	9.12E-05	0.0345	No

Chemical Name	CAS #	Avg. Period	Emissions				De Minimis (lbs/ avg period)	Above De Minimis ?	SQER (lbs/avg period)	Above SQER?	Dispersed Conc. (µg/m^3)	ASIL (µg/m^3)	Above ASIL?
			(g/s)	(lbs/hr)	(lbs/24-hr)	(lbs/yr)							
1,1,1-Trichloroethane	71-55-6	24-hr	6.74E-05	-	0.0128	-	6.57	No	131	No	1.28E-04	1000	No
Methyl Bromide	74-83-9	24-hr	6.42E-05	-	0.0122	-	0.0629	No	0.657	No	1.22E-04	5	No
Methyl Chloride	74-87-3	24-hr	2.24E-04	-	0.0426	-	0.591	No	11.8	No	4.25E-04	90	No
Hydrogen Cyanide	74-90-8	24-hr	5.69E-06	-	0.00108	-	0.0591	No	1.18	No	1.08E-05	9	No
Lead and compounds (NOS)	7439-92-1	Year	6.55E-05	-	-	4.56	10	No	16	No	3.67E-06	0.0833	No
Manganese & Compounds	7439-96-5	24-hr	6.55E-05	-	0.0125	-	0.000263	Yes	0.00526	Yes	1.25E-04	0.04	No
Mercury, Elemental	7439-97-6	24-hr	1.99E-05	-	0.00378	-	0.000591	Yes	0.0118	No	3.77E-05	0.09	No
Arsenic & Inorganic Arsenic Compounds	7440-38-2	Year	6.55E-05	-	-	4.56	0.00291	Yes	0.0581	Yes	3.67E-06	0.000303	No
Beryllium & Compounds (NOS)	7440-41-7	Year	3.28E-06	-	-	0.228	0.004	Yes	0.08	Yes	1.84E-07	0.000417	No
Cadmium & Compounds	7440-43-9	Year	3.28E-05	-	-	2.28	0.00228	Yes	0.0457	Yes	1.84E-06	0.000238	No
Chromium Hexavalent: Soluble, except Chromic Trioxide	7440-47-3	Year	1.00E-04	-	-	6.98	0.000064	Yes	0.00128	Yes	5.63E-06	6.67E-06	No
Cobalt	7440-48-4	24-hr	6.55E-05	-	0.0125	-	0.000657	Yes	0.013	No	1.25E-04	0.1	No
Copper & Compounds	7440-50-8	1-hr	3.28E-05	0.000261	-	-	0.011	No	0.219	No	5.58E-04	100	No
Sulfur dioxide	7446-09-05	1-hr	2.43E-04	0.00193	-	-	0.457	No	1.45	No	4.13E-03	660	No
Ethyl Chloride	75-00-3	24-hr	2.87E-04	-	0.0546	-	197	No	3940	No	5.44E-04	30000	No
Vinyl Chloride	75-01-4	Year	1.64E-03	-	-	114.0	0.123	Yes	2.46	Yes	9.18E-05	0.0128	No
Acetonitrile	75-05-8	Year	3.83E-03	-	-	266	576	No	11500	No	2.14E-04	60	No
Acetaldehyde	75-07-0	Year	4.10E-03	-	-	285	3.55	Yes	71	Yes	2.30E-04	0.37	No
Dichloromethane	75-09-2	Year	1.11E-02	-	-	773	9.59	Yes	192	Yes	6.23E-04	1	No
Carbon disulfide	75-15-0	24-hr	4.01E-04	-	0.0763	-	5.26	No	105	No	7.61E-04	800	No
Ethylene oxide	75-21-8	Year	7.73E-06	-	-	0.538	0.109	Yes	2.19	No	4.33E-07	0.0114	No
Bromoform	75-25-2	Year	8.76E-06	-	-	0.609	8.72	No	174	No	4.91E-07	0.909	No
1,1-Dichloroethane	75-34-3	Year	2.72E-05	-	-	1.89	6	No	120	No	1.52E-06	0.625	No
1,1-Dichloroethylene	75-35-4	24-hr	3.13E-03	-	0.595	-	1.31	No	26.3	No	5.94E-03	200	No
Chlorodifluoromethane	75-45-6	24-hr	9.98E-04	-	0.190	-	328	No	6570	No	1.90E-03	50000	No

Chemical Name	CAS #	Avg. Period	Emissions				De Minimis (lbs/ avg period)	Above De Minimis ?	SQER (lbs/avg period)	Above SQER?	Dispersed Conc. (µg/m^3)	ASIL (µg/m^3)	Above ASIL?
			(g/s)	(lbs/hr)	(lbs/24-hr)	(lbs/yr)							
1-Chloro-1,1-difluoroethane	75-68-3	24-hr	1.08E-03	-	0.206	-	329	No	6570	No	2.06E-03	50000	No
Ammonia	7664-41-7	24-hr	1.45E-02	-	191	-	0.465	Yes	9.31	Yes	2.76E-02	70.8	No
Selenium & Selenium Compounds (other than Hydrogen Selenide)	7782-49-2	24-hr	5.70E-06	-	0.00109	-	0.131	No	2.63	No	1.08E-05	20	No
1,2-Dichloropropane	78-87-5	Year	4.78E-05	-	-	3.32	0.959	Yes	19.2	No	2.68E-06	0.1	No
Methyl Ethyl Ketone	78-93-3	24-hr	9.59E-03	-	1.83	-	32.9	No	657	No	1.82E-02	5000	No
1,1,2-Trichloroethane	79-00-5	Year	5.92E-04	-	-	41.1	0.6	Yes	12	Yes	3.31E-05	0.0625	No
Trichloroethylene	79-01-6	Year	1.63E-03	-	-	113.2	4.8	Yes	95.9	Yes	9.12E-05	0.5	No
Acrylic Acid	79-10-7	24-hr	6.51E-04	-	0.124	-	0.00657	Yes	0.131	No	1.24E-03	1	No
1,1,2,2-Tetrachloroethane	79-34-5	Year	7.45E-04	-	-	51.8	0.165	Yes	3.3	Yes	4.17E-05	0.0172	No
2-Nitropropane	79-46-9M	24-hr	1.91E-04	-	0.0365	-	0.131	No	2.63	No	3.64E-04	20	No
Hexachlorobutadiene	87-68-3	Year	1.16E-03	-	-	80.8	0.437	Yes	8.73	Yes	6.50E-05	0.0455	No
Naphthalene	91-20-3M	Year	1.30E-05	-	-	0.903	0.282	Yes	5.64	No	7.28E-07	0.0294	No
n-Nitroso-di-n-butylamine	924-16-3	Year	1.94E-06	-	-	0.135	0.0031	Yes	0.062	Yes	1.09E-07	0.000323	No
n-Nitrosopyrrolidine	930-55-2	Year	1.94E-06	-	-	0.135	0.016	Yes	0.32	No	1.09E-07	0.00167	No
o-Xylene	95-47-6	24-hr	1.61E-03	-	0.306	-	1.45	No	29	No	3.05E-03	221	No
2-Methylphenol	95-48-7M	24-hr	2.85E-05	-	0.00542	-	3.94	No	78.9	No	5.41E-05	600	No
Cumene	98-82-8	24-hr	7.03E-05	-	0.0134	-	2.63	No	52.6	No	1.34E-04	400	No

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ENGINEERING CHANGE NOTICE

Page 1 of 2 ☒ DM ☐ FM ☐ TM

1a. ECN 10-000697 R 0

1b. Proj. ECN - - R

2. Simple Modification ☒ Yes ☐ No	3. Design Inputs – For full ECNs, record information on the ECN-1 Form (not required for Simple Modifications)		4. Date July 17, 2010
5. Originator's Name, Organization, MSIN, & Phone No. Dave Turner Mission Analysis Engineering MSIN: B1-55 Telephone: 376-4996	6. PrHA Number No. 01222 R - 2 ☐ N/A	7. USQ Number No. - - - R - ☒ N/A	8. Related ECNs 10-000359, Rev. 0
9. Title Revision of RPP-RPT-44009, Rev. 1	10. Bldg. / Facility No. N/A	11. Equipment / Component ID N/A	12. Approval Designator N/A
13. Engineering Documents/Drawings to be Changed (Incl. Sheet & Rev. Nos.) RPP-RPT-44009, Rev.1, Spreadsheet Description Document		14. Safety Designation ☐ SC ☐ SS ☐ GS ☒ N/A	15. Expedited/Off-Shift ECN? ☐ Yes ☒ No
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18. Description of the Change (Use ECN Continuation pages as needed)

Deleted Section 6.0, Testing, from document. Added Section 5.0, Test Plan, to document to comply with requirements of TFC-ENGR-DESIGN-C-32, Spreadsheet Development and Verification

19. Justification of the Change (Use ECN Continuation pages as needed)

Engineering Rework ☐ Yes ☒ No

Training Impact ☐ Yes ☒ No

Existing Test Program Worksheet (TWP): ☐, Work is TP-3 ☐, Test Program providing new TPW ☐

Revisions required to comply with requirements of TFC-ENGR-DESIGN-C-32, Spreadsheet Development and Verification

20. ECN Category

☒ Direct Revision

☐ Supplemental

☐ Void/Cancel

ECN Type

☐ Supersedure

☐ Revision

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ENGINEERING CHANGE NOTICE	1a. ECN 10-000697 R 0
Page 2 of 2 ☒ DM ☐ FM ☐ TM	1b. Proj. ECN - - R

22. **Revisions Planned** (Include a brief description of the contents of each revision)
N/A

Note: All revisions shall have the approvals of the affected organizations as identified in block 12 "Approval Designator," on page 1 of this ECN.

23. **Commercial Grade Item Dedication Numbers** (associated with this design change)
N/A

24. **Engineering Data Transmittal Numbers** (associated with this design change, e.g., new drawings, new documents)
N/A

25. **Other Non Engineering (not in HDCS) documents that need to be modified due to this change**

Type of Document	Document Number	Update Completed On	Responsible Engineer (print/sign and date)
Alarm Response Procedure	N/A		
Operations Procedure	N/A		
Maintenance Procedure	N/A		
N/A			

26. **Field Change Notice(s) Used?**
☐ **Yes** ☒ **No**
If Yes, Record Information on the ECN-2 Form, attach form(s), include a description of the interim resolution on ECN Page 1, block 18, and identify permanent changes.

NOTE: ECNs are required to record and approve all FCNs issued. If the FCNs have not changed the original design media then they are just incorporated into the design media via an ECN. If the FCN did change the original design media then the ECN will include the necessary engineering changes to the original design media.

27. **Design Verification Required?**
☐ **Yes** ☒ **No**
If Yes, as a minimum attach the one page checklist from TFC-ENG-DESIGN-P-17.

28. **Approvals**

Facility/Project Signatures		Date	A/E Signatures	Date
Resp. Engineer	D. A. Turner	7-21-10	Originator/Design Agent	
Resp. Manager	D. H. Shuford	8/2/2010	Professional Engineer	
Quality Assurance			Project Engineer	
IS&H Engineer			Quality Assurance	
NS&L Engineer			Safety	
Environ. Engineer			Designer	
Engineering Checker	M. J. Rodgers	7-21-10	Environ. Engineer	
Other	F. R. Miera	8/2/10	Other	
Other			Other	
Other			DEPARTMENT OF ENERGY / OFFICE OF RIVER PROTECTION	
Other			Signature or a Control Number that tracks the Approval Signature	
Other				
Other			ADDITIONAL SIGNATURES	
Other				
Other				

RPP-RPT-44009, Rev. 2

S

Spreadsheet Description Document for Non-Rad Air Source Term for 241-SY Farm and 241-AP Farm Primary Ventilation System Upgrades

Dave Turner
Washington River Protection Solutions, LLC
Richland, WA 99352
U.S. Department of Energy Contract DE-AC27-08RV14800

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Key Words: Spreadsheet, releases, non-rad, air, source term, TWINS, hazardous, chemical

Abstract: This spreadsheet assesses the unabated releases of hazardous chemicals from Hanford Site double-shell tank farm exhausters during waste feed delivery operations. Releases are determined by evaluating the headspace vapor sample data for the Hanford single-shell tanks (SSTs) and double-shell tanks (DSTs) in the TWINS database. The release rate of each hazardous chemical is calculated from the product of headspace concentration and ventilation flow rate. The release rates are then adjusted to conservatively estimate releases from a DST farm where the waste in two tanks is subject to waste disturbing activity (waste transfers or waste mixing operations) and the waste in the remaining tanks experiences quiescent conditions.

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Spreadsheet Description Document for Non-Rad Air Source Term for 241-SY Farm and 241-SYAP Farm Primary Ventilation System Upgrades

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RPP-RPT-44009
Rev. 2

SPREADSHEET DESCRIPTION DOCUMENT FOR NON-RAD AIR SOURCE TERM FOR 241-SY FARM AND 241-AP FARM PRIMARY VENTILATION SYSTEM UPGRADES

Dave Turner
Washington River Protection Solutions, LLC

Date Published
July 2010

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LIST OF TERMS

Abbreviations and Acronyms

AERMOD	Environmental Protection Agency Air Dispersion Model
ASIL	Acceptable Source Impact Level
CAS	Chemical Abstract Service
DST	Double-Shell Tank
EPA	Environmental Protection Agency
HISI	Hanford Information Systems Inventory
IDMS	Integrated Document Management System
NOC	Notice of Construction
NOx	Compounds of nitrogen and oxygen
PCB	Polychlorinated Biphenyl
PRIME	Plume Rise Model Enhancement
SOx	Compounds of sulfur and oxygen
SQER	Small Quantity Emission Rate
SST	Single-Shell Tank
tBACT	Best Available Control Technology for Toxics
TOC	Total Organic Carbon
SVF	Spreadsheet Verification Form
TWINS	Tank Waste Information Network System
WAC	Washington Administrative Code
WTP	Waste Treatment and Immobilization Plant

Units

ft	foot
ft^3/min	cubic feet per minute
g/sec	grams per second
$\mu g/m^3$	micrograms per cubic meter
mg/m^3	milligrams per cubic meter
m^3/h	cubic meters per hour
ppmv	parts per million by volume

1.0 Objective

The purpose of this document is to describe the spreadsheet developed to estimate toxic air pollutant emissions from double-shell tank (DST) farm exhausters during waste feed delivery operations. These exhausters provide a central discharge point for ventilation air from all of the tanks in a DST farm. This spreadsheet provides estimates of unabated emissions for the development of the Best Available Control Technology for Toxics (tBACT) analysis and Notice of Construction (NOC) permit application for the tank farm exhausters. The exhausters are being upgraded to support waste feed delivery to the Waste Treatment and Immobilization Plant (WTP).

Toxic air pollutants listed in Washington Administrative Code (WAC) 173-460-150 (September 2009) were compared to the tank headspace data in the Tank Waste Information Network System (TWINS). During operations to deliver waste feed to the WTP, all SST waste will be transferred to DSTs and DST waste will be mixed for acceptance by WTP. The potential release of each toxic air pollutant, in units of grams per second, is calculated from the product of headspace concentration and headspace ventilation flow rate. After calculating the highest potential release rate of each toxic air pollutant, the release rates from a hypothetical "worst case" tank are determined assuming that the waste responsible for each of the highest release rates is present in this tank. Further, for potential releases from a DST farm, it is assumed that each tank in the farm is a "worst case" tank. The release rate is further adjusted assuming that waste disturbing activities (for example, waste transfers, waste receipts or waste mixing operations) result in a headspace concentration a factor of ten higher than would exist in a tank with quiescent waste conditions. Each tank farm is assumed to include two tanks with waste disturbing activities and the remaining tanks with quiescent waste conditions. Finally, the estimated total release of each toxic air pollutant is compared to the respective regulatory trigger levels in WAC 173-460-150.

In summary, the non-radioactive air source term described herein represents a constant, maximum release rate from a single "worst case" DST with quiescent waste. This release rate is scaled upward to account for the presence of each tank in the farm and any waste disturbing activities taking place within the farm.

NOTE: because of the methodology employed to develop the non-radioactive air source term described in this document, the source term is applicable to primary ventilation system upgrades in all Hanford Site DST farms. The document title addresses only the 241-SY and 241-APFarms. This is based on two considerations. First, these two tank farms are the first scheduled to receive primary ventilation system upgrades. Secondly, 241-AP Farm establishes bounding source term conditions.

NOTE: 241-AP Farm establishes bounding source term conditions. It is assumed (refer to Assumption 5 below) that no more than two tanks in a DST farm have waste disturbing activity occurring simultaneously, while the remaining tanks experience quiescent waste conditions. 241-AP Farm bounds the non-radioactive air source term because it includes more tanks (8) than any other DST farm, resulting in the largest tank farm scaling factor (the multiplier used to estimate the total release from a DST farm based on the release from a "worst case" DST). This assumes waste disturbing activity in two 241-AP Farm

tanks (release rate of each = 10 times quiescent waste release rate) plus quiescent waste conditions in the remaining six 241-AP Farm tanks (release rate for six tanks = 6 times quiescent waste release rate) for a total 241-AP Farm release rate of 26 times quiescent waste release rate. This scaling factor bounds the release rates for all Hanford Site DST farms.

1.1 Background

Washington Administrative Code Title 173, Department of Ecology, Chapter 460, *Controls for New Sources of Toxic Air Pollutants*, Section 150, *Table of ASIL, SQER and De Minimis Emission Values* (WAC-173-460-150) provides a list of hazardous chemicals regulated as toxic air pollutants in the State of Washington. The Tank Waste Information Network System (TWINS) includes analytical results from tank headspace vapor sample analyses. Both WAC-173-460-150 and TWINS list chemicals by common name and by Chemical Abstract Service registration number (CAS #). CAS #s were used to compare the TWINS sample analysis results with WAC-173-460-150. The list of toxic air pollutants in WAC-173-460-150 was first sorted by CAS # to match the listing of CAS #s found in TWINS. In addition, TWINS data for seven metals were identified based on Common Name (CAS #s not given in WAC 173-460-150).

The TWINS headspace vapor sample analysis results were compared to the WAC-173-460-150 list. The sample analysis results for each of the toxic air pollutants were extracted from TWINS as Excel® worksheets. Each toxic air pollutant listed in TWINS has, at a minimum, a single sample result, with many toxic air pollutants having more than a thousand sample results. For each toxic air pollutant, the maximum concentration was selected for comparison with WAC-173-460-150. Approximately 90 chemicals reported in TWINS are listed in WAC-173-460-150 as toxic air pollutants. The headspace sample results include, among other data, the following information:

- Tank Name - Identifies the tank where the sample was taken
- Chemical Name - Identifies the common name of the chemical analyzed
- Molecular Weight - Identifies the molecular weight of the chemical
- Chemical ID - CAS number
- Reported Value - The reported value
- Units - The units of the reported value
- Concentration - mg/m^3 as measured at 25 °C

The sample results also include quality assurance data about the sample including sampling and analysis methodologies, sampling and analysis date and time and any qualifications to the data. For some toxic air pollutants, the sampling resulted in a determination that the measurement was less than the value representing the measurement limit of the analysis (detection limit).

2.0 Input Data

Input data for the spreadsheet includes:

- TWINS data downloaded during September and October 2009 (Vapor/Headspace Sample Analysis/Analysis Results)
- Information from WAC 173-460-150
- Dispersion factors from AERMOD dispersion calculations for the Hanford Site
- SST passive ventilation rates listed in HNF-3588, Rev. 1
- A tank farm scaling factor (multiplier), based on RPP-12735 Rev. 0B, to estimate tank farm release rates during waste disturbing activities.

3.0 Assumptions

Assumption 1:

When only a detection limit ("less than" value) is reported in TWINS for an analyte, and when the detection limit represents the maximum value for the analyte, the detection limit is assumed to be equal to a reported value.

NOTE: in the event this methodology resulted in the "Local Release" exceeding the de minimis value, the calculation results were assessed for applicability (refer to Treatment of Carbon Monoxide Data in Section 7.0).

Assumption 2:

Toxic air pollutants were measured over quiescent waste in a ventilated tank (passively ventilated for SSTs and actively ventilated for DSTs and DST ventilation systems). A constant steady state release rate of toxic air pollutants from tank waste is assumed as long as the waste in the tank remains quiescent.

Assumption 3:

SSTs are passively ventilated. Passive SST ventilation flow rates were obtained from HNF-3588 Rev. 1. For tanks not listed in HNF-3588 Rev. 1, or where the tanks listed in HNF-3588 Rev. 1 are known to have previously been actively ventilated, ventilation flow rates from a similar type SST are used. DST ventilation systems are assumed to have a flow rate of 1000 ft^3/min. All DST's in a tank farm are assumed to have the same ventilation flow rate, so the ventilation flow rate through a DST equals 1000 ft^3/min divided by the number of tanks in the farm.

Assumption 4:

Based on mixer pump tests in DST 241-AZ-101, it is assumed that headspace concentrations increase by a factor of 10 during waste disturbing activities. Of

the compounds analyzed for in tank 241-AZ-101's headspace during mixer pump operations, toluene was found to have the highest release factor, a factor of 7.5. This release factor was rounded to 10 for conservatism (RPP-12735 Rev. 0B)

Assumption 5:

It is assumed that no more than two tanks in a DST farm have waste disturbing activities (waste transfers, waste receipts or waste mixing operations) occurring simultaneously; the remaining tanks have quiescent waste conditions.

Assumption 6:

It is assumed that the waste which results in the largest potential release of each toxic air pollutant is contained in all of the tanks in a DST farm. Therefore, 241-AP Farm bounds the non-radioactive air source term because this farm includes more tanks (8) than any other DST tank farm.

4.0 Methodology

4.1 TWINS Analysis

WAC-173-460-150 lists toxic air pollutants controlled by the State of Washington. The WAC-173-460-150 list was converted into an Excel® spreadsheet, and sorted by CAS number for comparison to TWINS headspace vapor sample data. The TWINS headspace data was then searched for the CAS numbers in WAC-173-460-150. Each CAS number listed in both WAC-173-460-150 and the TWINS headspace data resulted in an Excel® worksheet listing all analytical results for that CAS number. In addition, the TWINS database was searched for data for toxic metals identified by common name in WAC 173-460-150. A worksheet for each of these toxic metals was then added to the Excel® spreadsheet. Approximately 90 toxic air pollutants listed in WAC-173-460-150 are found in the headspace data in TWINS, resulting in approximately 90 worksheets, with each worksheet listing a single toxic air pollutant. In some cases TWINS lists chemical constituents as a group: for example ethyl benzene is listed as both ethyl benzene (CAS # 100-41-4) and as ethyl benzene and others (CAS # 100-41-4M). In these cases both the individual listing and the group listing were compared, and the larger concentration of the two selected. The extracted TWINS data includes, among other data, the concentration of the toxic air pollutant (mg/m^3 at 25°C) and the tank where the sample was obtained.

4.2 Tank Flow Rates

DST ventilation flow rates were determined by assuming a flow rate for the tank farm of 1000 ft^3/min. The ventilation flow rate for an individual tank was determined by dividing 1000 ft^3/min. by the number of tanks in the farm (three tanks in SY Farm, two tanks each in AY and AZ

Farms, six Tanks in AW Farm, seven Tanks in AN Farm and eight tanks in AP Farm). DST ventilation systems provide a central discharge point for all of the tanks in a farm.

SST flow rates were taken from Table D-4 of HNF-3588, Rev. 1 with two exceptions:

- The ventilation rate shown for tank C-104 (114 m^3/h) is a measured flow rate. At the time, C-104 was connected to an actively ventilated tank via a 3 inch diameter cascade line. Since C-104 is no longer actively ventilated, a ventilation flow rate of 5 ft^3/min. is assumed.
- SX Farm tanks were actively ventilated with an estimated flow rate of 170 m^3/h. Since the SX Farm tanks are no longer actively ventilated, a ventilation flow rate of 5 ft^3/min. is assumed.

If not listed in Table D-4 of HNF-3588, Rev. 1, large 100 Series SSTs are assumed to have a ventilation flow rate of 5 ft^3/min, and small 200 Series SSTs and catch tanks a ventilation flow rate of 1.0 ft^3/min.

4.3 Emission Rate Calculation

The release of a toxic air pollutant is determined by multiplying the concentration (mg/m^3) of the toxic air pollutant in the tank's headspace by the ventilation flow rate (ft^3/min) and converting to a release rate in g/sec. The worksheets for each toxic air pollutant were sorted to determine the highest release rate.

For example, consider the release rate of a toxic air pollutant with a concentration of 1 mg/m^3 in the headspace of a SST:

- Headspace concentration = 1 mg/m^3
- SST flow rate = 5 ft^3/min
- 1 mg/m^3 x 5 ft^3/min = 5 mg ft^3/m^3 min
- 5 mg ft^3/m^3 min x (1 g/1000 mg) x (1 m^3/35.31 ft^3) x (1 min/60 sec) = 2.36×10^{-6} g/sec

A further step is required for those toxic air pollutants where the highest concentration is measured in a DST ventilation system. The release rate from a single tank needs to be determined. The release rate for a toxic air pollutant where the highest concentration was measured in a DST ventilation system is divided by the number of tanks in the tank farm. For example, consider the release rate of a toxic air pollutant with a concentration of 1 mg/m^3 in the AW Farm ventilation system:

- Ventilation system concentration = 1 mg/m^3
- DST ventilation system flow rate = 1,000 ft^3/min
- 1 mg/m^3 x 1,000 ft^3/min = 1,000 mg ft^3/m^3 min
- 1,000 mg ft^3/m^3 min x (1 g/1000 mg) x (1 m^3/35.31 ft^3) x (1 min/60 sec) = 4.72×10^{-4} g/sec

To determine the release rate for a single tank, 4.72×10^{-4} g/sec is divided by 6 (the number of tanks in AW Farm) resulting in a release rate of 7.87×10^{-5} g/sec.

For each toxic air pollutant, the SST or DST resulting in the highest per tank release rate (g/sec) was selected.

Following the methodology in RPP-12735 Rev. 0B, the release rate for each toxic air pollutant was multiplied by 10 to estimate the release rate from a tank with waste disturbing activities. Based on Assumption 5, it is assumed that no more than two tanks in a DST farm have waste disturbing activities occurring simultaneously; the remaining tanks have quiescent waste conditions.

The release rates from a hypothetical "worst case tank" were determined assuming that the waste responsible for each of the highest release rates was present in this tank. Based on Assumption 6, it is then assumed that all tanks in a DST farm are "worst case" tanks.

The release of toxic air pollutants from a DST Farm is determined by summing the releases from all tanks in the farm. With 8 tanks, AP Farm is then the bounding farm (three tanks in SY Farm, two tanks each in AY and AZ Farms, six tanks in AW Farm and seven tanks in AN Farm). The total release rate from AP Farm is calculated by summing releases from two tanks with waste disturbing activity and six tanks with quiescent waste conditions (refer to "NOTE" in Section 1.0).

Polychlorinated biphenyls (PCBs) are regulated as a class and the total is determined by adding the contributions of several compounds. None of the PCBs found in the tanks are individually regulated as toxic air pollutants, but all are regulated as a group.

In addition to the toxic air pollutants, total organic carbon (TOC), total nitrogen oxides (NO_x), total sulfur oxides (SO_x), carbon monoxide, and lead are listed as criteria air pollutants. TWINS data includes total non-methane hydrocarbon measurements, which is reported here as TOC. Total NO_x is determined by summing the maximum nitrogen oxide (NO) value reported with the maximum nitrogen dioxide (NO_2) value reported. Total SO_x is reported in TWINS, but SO_2 is not reported in TWINS. The maximum value for SO_x reported in TWINS is used to evaluate both SO_x and SO_2 releases.

4.4 AERMOD Modeling

WAC-173-460-150 lists an averaging period, "acceptable source impact level" (ASIL), "small quantity emission rate" (SQER), and "de minimis emissions" rate for each toxic air pollutant. For comparison to the ASIL, the release rate is multiplied by a dispersion factor to determine concentrations at the Hanford Site boundary.

Emission concentrations at the site boundary were estimated using dispersion factors from a previous run of the EPA developed dispersion model, AERMOD, for the AN and AW exhausters. The modeling results are preliminary and represent an initial estimate of off-site concentrations. More refined modeling will be conducted as part of the NOC. The AERMOD

model combines simple and complex terrain algorithms, and includes the Plume Rise Model Enhancement (PRIME) algorithms to account for building downwash and cavity zone impacts.

The complete AERMOD modeling system is comprised of three parts: the AERMET pre-processor, the AERMAP pre-processor, and the AERMOD model. The AERMET pre-processor compiles the surface and upper-air meteorological data and formats the data for AERMOD input. The AERMAP pre-processor is used to obtain elevation and controlling hill heights for AERMOD input.

The AERMOD model was used with regulatory default options as recommended in the EPA Guideline on Air Quality Models as listed below:

- Use stack-tip downwash
- Use of the PRIME algorithm for sources influenced by building downwash
- Use default wind profile exponents
- Use default vertical potential temperature gradients

Dispersion factors for 24-hour and annual average releases were developed on April 30, 2007 (Technical Memorandum, "AERMOD Dispersion Calculations", May 2, 2007):

Table 4-1: AN and AW AERMOD Modeling Results Dispersion Factors

Source Name	Description	Annual Dispersion Factor* (µg/m3)/(g/sec)	Distance from Source to Location of Maximum Impact	24 Hour Dispersion Factor** (µg/m3)/(g/sec)	Distance from Source to Location of Maximum Impact
E10_2000	2000 cfm, 10" diameter, 28' stack height	0.05182	15 km east	1.10331	15 km east
E6_1000	1000 cfm, 6" diameter, 17' stack height	0.05548	15 km east	1.3288	15 km east
E6_500	500 cfm, 6" diameter, 17' stack height	0.05979	15 km east	1.81318	15 km east
W6_1000N	1000 cfm, 6" diameter, 17' stack height, northern release point	0.06092	14.8 km northwest	1.5428	20.8 km north
W6_1000S	1000 cfm, 6" diameter, 17' stack height, southern release point	0.05278	16.5 km northwest	1.30867	22.9 km north
W6_500N	500 cfm, 6" diameter, 17' stack height, northern release point	0.06836	14.7 km northwest	2.07995	20.5 km north
W6_500S	500 cfm, 6" diameter, 17' stack height, southern release point	0.05732	16.3 km northwest	1.72854	22.7 km north

*Annual averaging period – includes conversion factor to convert from g/s to µg/m³

**24 hour averaging period – includes conversion factor to convert from g/s to $\mu g/m^3$

Based on the dispersion factors listed in Table 4-1, the W6_500N source was used to determine a preliminary estimate of concentrations at the Hanford Site boundary. The calculated DST farm release rates in g/s are multiplied by the annual or 24 hour dispersion factors, as appropriate, to determine the maximum concentration ($\mu g/m^3$) at the Hanford Site boundary. The averaging periods listed in WAC-173-460-150 are 1-hr, 24-hr, and year, and these averaging periods were used to determine which of the concentration values to use. The 24-hr value was used for those toxic air pollutants with a 1-hr averaging period because 1-hour modeling data was not available. The NOC will have the 1-hour modeling results.

The maximum concentration at the Hanford Site boundary is compared to the ASIL value listed in WAC 173-460-150. The calculated DST farm release rate is converted to determine the total release rate for the averaging period. The total release rate for the averaging period is then compared to the SQER and de minimis values.

Maximum annual releases were also determined for the criteria air pollutants NO_x, SO_x, TOCs, lead and carbon monoxide. The annual release rates for these criteria pollutants are compared to the de minimis values.

4.5 Spreadsheet Description

The spreadsheet includes worksheets in the following order:

- 1 Documentation worksheet
- 1 Summary worksheet
- 1 worksheet containing relevant WAC 173-460-150 information
- 1 Factor worksheet summarizing factors used in release rate calculations
- 108 worksheets with data from TWINS with one CAS # per worksheet
- 1 PCB summary worksheet
- 15 worksheets containing PCB data from TWINS

Documentation Worksheet

The Documentation worksheet includes a brief summary of the methodology and key assumptions employed in spreadsheet development, identification of input information and explanatory notes.

Summary Worksheet - Toxic Air Pollutants

On the Summary worksheet the flux (g/sec) from the CAS # worksheets (Column D) was multiplied by the tank farm scaling factor (Column E), the number of seconds in the averaging period and divided by 453.6 g/lb to determine the quantity (lbs) discharged per averaging period

(Column I). Also calculated on the Summary worksheet is the offsite concentration (Column H) which was determined by multiplying the flux from the tank (Column D), the tank farm scaling factor (Column E) and the dispersion factor for the averaging period (Column G).

The offsite concentration was then compared to the ASIL limit (Column M) and the lbs/averaging period was compared to the SQER and De Minimis limits (Columns N and O, respectively).

Summary Worksheet - Criteria Pollutants

On the Summary worksheet the flux (g/sec) from the CAS # worksheets (Column E) was multiplied by the tank farm scaling factor (Column F), the number of seconds in the averaging period and divided by 453.6 g/lb to determine the quantity (lbs) discharged per averaging period (Column I). The lbs/averaging period was compared to the De Minimis limits (Column K).

CAS# Worksheets

Each of the CAS # worksheets includes the data from TWINS and a calculation determining the flux rate (g/sec) for each data point (Column AE) based on the ventilation flow rate from the tank where the sample was taken (Column AD) and the concentration of the toxic air pollutant in mg/m^3 at 25 degrees C (Column L).

The spreadsheet contains two macros. The first macro, named "sort", sorts the first half of the CAS # worksheets by flux rate from greatest to least. The second macro, named "sortb", sorts the second half of the CAS # worksheets by flux rate from greatest to least. This allows the Summary worksheet to select the maximum flux rate for each toxic air pollutant by referencing the top line of data from each CAS # worksheet.

NOTE: the macros "sort" and "sortb" were employed to sort the CAS # worksheets by flux rate from greatest to least for all toxic air pollutants and criteria pollutants except CAS# 630-08-0 (carbon monoxide). As explained in Section 7.0 (Treatment of Carbon Monoxide Data), use of the procedure employed to calculate releases for all the other pollutants results in an excessively conservative computed carbon monoxide "Local Release".

PCB Summary Worksheet

The PCB summary worksheet combines the data from the PCB data worksheets to provide a combined PCB concentration.

5.0 TEST PLAN

5.1 Methodology Selected for Verification

Verification of the spreadsheet was accomplished by hand calculations to ensure the spreadsheet formulas produce the correct results. Calculations to verify the spreadsheet calculations for ethylbenzene (Chemical ID 100-41-4) were accomplished by hand using a digital calculator. Spreadsheet calculations for all the other toxic air pollutants listed in the Summary worksheet are performed in a manner identical to that for ethylbenzene. Therefore, verifying the spreadsheet

calculations for ethylbenzene effectively verifies the spreadsheet calculations for all toxic air pollutants listed in the Summary worksheet. The hand calculations are appended to Spreadsheet Verification and Release Form SVF-1821, Rev. 2.

5.2 Rationale for Methodology Selected for Verification

Calculations performed in the spreadsheet are limited to simple multiplications involving three to six factors (including unit conversion factors). Hand calculations provide the most direct and transparent method of spreadsheet verification.

5.3 Test Approach

Data for ethylbenzene, the first toxic air pollutant listed on the Summary worksheet, was used to ensure the spreadsheet formulas produce the correct results. The maximum headspace concentration for ethylbenzene (0.26 mg/m^3) listed in worksheet 100-41-4 (Column L, Line 2) was multiplied by the AW Farm ventilation flow rate (167.6667 ft^3/min) listed in the Factors worksheet (Column C, Line 189), and appropriate unit conversion factors, to determine the release rate (flux) of ethylbenzene (2.0457 E-05 g/sec). This verifies the spreadsheet calculation of 2.0451 E-05 g/sec, shown in Column AE, Line 2 of worksheet 100-41-4, within 0.0313%. The Summary worksheet acquires flux values in Column D, via a lookup procedure, from Column AE, Line 2 of each toxic air pollutant worksheet. The flux for ethylbenzene appears in Column D, Line 4 of the Summary worksheet.

The Maximum Offsite Concentrations (μg/m^3) of toxic air pollutants in Column H of the Summary worksheet are computed by multiplying the respective entries in Columns D, E and G. For ethylbenzene, the spreadsheet calculation is 3.6349 E-05 μg/m^3. The hand calculated value is 3.6360 μg/m^3 which verifies the spreadsheet calculation within 0.0313%.

The Local Releases (lb/averaging period) of toxic air pollutants in Column I of the Summary worksheet are computed by multiplying the respective entries in Columns D and E, times the number of seconds in the averaging period (31,557,600 seconds/year for ethylbenzene), and converting units from grams to pounds. For ethylbenzene the spreadsheet calculation is 36.9930 lb/yr. The hand calculated value is 37.0046 μg/m^3 which verifies the spreadsheet calculation within 0.0313%.

The "Exceeds ASIL" decision in Column M of the Summary worksheet is made for each toxic air pollutant by determining if the respective value in Column H exceeds the respective value in Column J (e.g. value in Column H/value in Column J $\geq$ 1). The hand calculation indicates that the value in Column H/value in Column J = 9.1 E-05 for ethylbenzene. The spreadsheet correctly indicates that the answer to "Exceeds ASIL" is "No".

The "Exceeds SQER" decision in Column N of the Summary worksheet is made for each toxic air pollutant by determining if the respective value in Column I exceeds the respective value in Column K (e.g. value in Column I/value in Column K $\geq$ 1). The hand calculation indicates that the value in Column I/value in Column K = 0.4818 for ethylbenzene. The spreadsheet correctly indicates that the answer to "Exceeds SQER" is "No".

The "Exceeds De Minimis" decision in Column O of the Summary worksheet is made for each toxic air pollutant by determining if the respective value in Column I exceeds the respective value in Column L (e.g. value in Column I/value in Column L ≥ 1). The hand calculation indicates that the value in Column I/value in Column L = 9.6366 for ethylbenzene. The spreadsheet correctly indicates that the answer to "Exceeds De Minimis" is "Yes".

5.4 Minimum Documentation Required for Test Execution and Results

The hand calculations for ethylbenzene (Chemical ID 100-41-4) appended to Spreadsheet Verification and Release Form SVF-1821, Rev. 2 represent necessary and sufficient documentation for test execution and test results. The hand calculations verify that spreadsheet formulas produce the correct results.

RPP-ENV-48231, Rev. 0, Appendix B

6.0 Computer Software Use and Verification

The spreadsheet was developed in MS Excel 2003® and MS Excel 2007®. The file name of the spreadsheet is Non-Rad Air Source Term for 241-SY Farm and 241-AP Farm Primary Ventilation System Upgrades.xlsm.SVF-1821, Rev. 2 documents verification of the spreadsheet. The spreadsheet has been registered in HISI.

7.0 Results

Toxic Air Pollutants

The Summary worksheet includes all the toxic air pollutants found in TWINS that are listed in WAC 173-460-150 along with the maximum release expected. The Summary worksheet includes the tank which produces the highest calculated flux and pounds per averaging period for each toxic air pollutant. The Summary worksheet also shows which toxic air pollutants exceed the ASIL, SQER, and De Minimis values. Toxic air pollutants exceeding at least one of these limits are summarized in the table below.

Table 7-1: Summary of Tank Farm Emission Rate to WAC 173-460-150 Threshold Levels.

WAC 173-460-150 Name	Tank Name	Exceeds ASIL	Exceeds SQER	Exceeds De Minimis
Ethylbenzene	AW Ventilation	No	No	Yes
Benzyl Chloride	241-BY-107	No	No	Yes
n-Nitroso-n-methylethylamine	241-AP-106	No	Yes	Yes
1,4-Dichlorobenzene	241-BY-101	No	No	Yes
1,2-Dibromoethane	241-BY-108	No	No	Yes
1,3-Butadiene	241-BY-108	No	Yes	Yes
1,2-Dichloroethane	241-SY-102	No	Yes	Yes
Acrylonitrile	241-BY-106	No	No	Yes
1,4-Dioxane	241-AN-106	No	No	Yes
Perchloroethylene	241-SY-102	No	Yes	Yes
Polychlorinated Biphenyls (PCBs)	PCB	No	Yes	Yes
n-Nitrosodiethylamine	241-AP-106	No	Yes	Yes

Carbon Tetrachloride	241-SY-102	No	Yes	Yes
n-Nitrosomorpholine	241-U-108	No	Yes	Yes
Dimethyl Mercury	241-U-105	Yes	Yes	Yes
n-Nitrosodimethylamine	241-AP-102	No	Yes	Yes
n-Nitrosodi-n-propylamine	241-AP-106	No	No	Yes
Chloroform	241-SY-102	No	Yes	Yes
Hexachloroethane	241-SY-102	No	Yes	Yes
Benzene	241-SY-102	No	Yes	Yes
Manganese & Compounds	AP Ventilation	No	No	Yes
Mercury, Elemental	241-C-104	No	No	Yes
Arsenic & Inorganic Arsenic Compounds	AP Ventilation	No	Yes	Yes
Beryllium & Compounds (NOS)	AP Ventilation	No	Yes	Yes
Cadmium & Compounds	AP Ventilation	No	Yes	Yes
Chromium Hexavalent: Soluble, except Chromic Trioxide	241-C-104	No	Yes	Yes
Cobalt	AP Ventilation	No	No	Yes
Vinyl Chloride	241-SY-102	No	Yes	Yes
Acetaldehyde	241-AY-102	No	Yes	Yes
Dichloromethane	241-BY-108	No	Yes	Yes
Ethylene oxide	241-TY-104	No	No	Yes
Ammonia	241-SY-102	No	Yes	Yes
1,2-Dichloropropane	241-BY-108	No	No	Yes
1,1,2-Trichloroethane	241-SY-102	No	Yes	Yes
Trichloroethylene	241-SY-102	No	No	Yes
Acrylic Acid	241-C-103	No	No	Yes
1,1,2,2-Tetrachloroethane	241-SY-102	No	Yes	Yes
Hexachlorobutadiene	241-SY-102	No	Yes	Yes
Naphthalene	241-T-111	No	No	Yes
n-Nitroso-di-n-butylamine	241-AP-106	No	No	Yes
n-Nitrosopyrrolidine	241-AP-106	No	No	Yes

Dimethyl mercury is the only toxic air pollutant that exceeds the ASIL value. The maximum concentrations of all other toxic air pollutants are below the ASIL values.

The total release for the averaging period exceeds the de minimis values for forty-one toxic air pollutants. Of these forty-one, twenty-four also exceed SQER values.

Criteria Pollutants

The annual release rates of criteria pollutants were also determined and compared to de minimis values. Only TOC exceeds the de minimis value (Line 103, Column K of the Summary worksheet). The annual releases of NO_x, SO_x, lead and carbon monoxide were less than their respective de minimis values.

Treatment of Ammonia Data

The highest calculated flux of ammonia is from tank SY-102 based on a sample taken September 12, 2000. The reported ammonia concentration is 383.6 mg/m^3 (Line 2, Column L of worksheet 7664-41-7). Saltwell pumping of waste from tank U-103 to tank SY-102 was in progress at the time, resulting in disturbed waste conditions. The 383.6 mg/m^3 ammonia concentration was

divided by 10 to account for the disturbed waste conditions, resulting in an ammonia concentration for quiescent waste conditions of 38.4 mg/m^3. This concentration results in a per tank flux of 0.00603 g/s. Multiplying by 26 results in an ammonia release of 29.9 lb/day and a maximum offsite concentration of 0.326 µg/ m^3 (Line 116, Column I and Line 116, Column H of the Summary worksheet, respectively).

An ammonia sample from the SY Farm ventilation system taken August 30, 2000 results in the highest per tank flux when the September 12, 2000 sample from tank SY-102 is adjusted to account for disturbed waste conditions. The reported ammonia concentration for the August 30, 2000 sample is 307.7 mg/m^3 (Line 4, Column L of worksheet 7664-41-7). Saltwell pumping of waste from tank U-103 to tank SY-102 was in progress at the time, resulting in disturbed waste conditions. However, since tanks SY-101 and SY-103 were not subject to disturbed waste conditions, it is assumed only SY-102 contributed to the reported ventilation system ammonia concentration. Therefore, the ventilation system ammonia concentration of 307.7 mg/m^3 was multiplied by 3, resulting in a tank SY-102 ammonia concentration of 923 mg/m^3. The 923 mg/m^3 ammonia concentration was divided by 10 to account for the disturbed waste conditions, resulting in an ammonia concentration for quiescent waste conditions of 92.3 mg/m^3. This concentration results in a per tank flux of 0.01452 g/s. Multiplying by 26 results in an ammonia release of 71.9 lb/day and a maximum offsite concentration of 0.785 µg/ m^3 (Line 117, Column I and Line 117, Column H of the Summary worksheet, respectively).

Based on this analysis, "Local Release" and "Maximum Offsite Concentration" for ammonia are based on the August 30, 2000 SY Farm ventilation system sampling event (Line 117 of the Summary worksheet).

Treatment of Carbon Monoxide Data

The "Local Release (lb/yr)" for carbon monoxide (Chemical ID 630-08-0) on Line 47 and Lines 110 and 111 of the Summary worksheet requires clarification. The "Local Release" on Line 110 is based on a sample obtained from tank 241-SY-102 on March 18, 1998. "Local Release" is computed to be 3.26E+04 lb/yr, a factor of 3.26 greater than the annual de minimis release rate of 10,000 lb/yr. This is the result of equating a "reported value" to a detection limit ("less than value") when the detection limit is the maximum value reported for the toxic air pollutant. This procedure results in an excessively conservative computed carbon monoxide "Local Release".

Review of worksheet 630-08-0 indicates that all double-shell-tank and double-shell-tank ventilation system results reported for carbon monoxide are detection limits. Unlike hydrogen and ammonia, there is no known mechanism to produce significant amounts of carbon monoxide in tank waste.

A more reasonable, but yet conservative, estimate for carbon monoxide "Local Release" is provided by a sample obtained from tank 241-A-106 on January 16, 1997 (Line 47 and Line 111 of the Summary worksheet). Carbon monoxide concentration is reported to be 100 ppmv (Line 506, Column G of worksheet 630-08-0), the highest concentration of carbon monoxide reported on worksheet 630-08-0. "Local Release" is computed to be 997 lb/yr which is less than 10% of the de minimis release rate.

Based on this analysis, it is concluded that the emission of carbon monoxide will not exceed the annual de minimis release rate (Line 47 and Line 111 of the Summary worksheet).

8.0 Configuration Management

The master copy of the Non-Rad Air Source Term for 241-SY Farm and 241-AP Farm Primary Ventilation System Upgrades.xlsm spreadsheet is maintained in the Integrated Document Management System (IDMS).

9.0 Qualification

No additional qualifications are required for the spreadsheet developer/owner and verifier in addition to those identified in TFC-ENG-DESIGN-C-32.

10.0 References

HNF-3588, 2003, *Organic Complexant Topical Report*, Rev. 1, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-12735, 2004, *Organic Vapor Source Term for Double-Shell Tanks During Phase I Waste Retrieval Operations*, Rev.0B, CH2M HILL Hanford Group, Inc., Richland, Washington.

SVF-1821, 2009, *Spreadsheet Verification Form, Non-Rad Air Source Term for 241-SY Farm and 241-AP Farm Primary Ventilation System Upgrades.xlsm*, Rev. 2, Washington River Protection Solutions, Richland, Washington.

TFC-ENG-DESIGN-C-32, *Spreadsheet Development and Verification*, Rev. B-11, Washington River Protection Solutions, LLC, Richland, Washington.

WAC 173-460-150, "Controls for New Sources of Toxic Air Pollutants," Washington Administrative Code, as amended.

Technical Memorandum, "AERMOD Dispersion Calculations", Rebecca King to Lucinda Penn, May 2, 2007

APPENDIX B
RPP-ENV-46679, Evaluation of Best Available Control Technology for Toxics (tBACT) Double-Shell Tank Farms Primary Ventilation Systems Supporting Waste Transfer Operation

ENGINEERING CHANGE NOTICE	1a. ECN – 10 – 000520
Page 1 of 3 ☒ DM ☐ FM ☐ TM	1b. Proj. ECN - - R

2. Simple Modification ☒ Yes ☐ No	3. Design Inputs – For full ECNs, record information on the ECN-1 Form (not required for Simple Modifications)		4. Date 6/17/2010
5. Originator's Name, Organization, MSIN, & Phone No. Steven E. Kelly	6. PrHA Number No. 01411 R - 1 ☐ N/A	7. USQ Number No. - - - R - ☒ N/A	8. Related ECNs N/A
9. Title List of Table Correction for tBACT Double Shell Tank Farms Primary Ventilation Systems	10. Bldg. / Facility No. N/A	11. Equipment / Component ID N/A	12. Approval Designator E
13. Engineering Documents/Drawings to be Changed (Incl. Sheet & Rev. Nos.) RPP-ENV-46679 Rev. 0		14. Safety Designation ☐ SC ☐ SS ☐ GS ☒ N/A	15. Expedited/Off-Shift ECN? ☐ Yes ☒ No
16a. Work Package Number N/A	16b. Modification Work Completed N/A Responsible Engineer / Date	16c. Restored to Original Status (TM) N/A Responsible Engineer / Date	17. Fabrication Support ECN? ☐ Yes ☒ No

18. Description of the Change (Use ECN Continuation pages as needed)
Corrected "List of Tables" on page ii. This required removing <enter> (hard returns) from some of the titles of tables. The hard returns were there to make the titles look better but caused format issues in the "List of Tables" for the "Table of Contents".

19. Justification of the Change (Use ECN Continuation pages as needed)

Engineering Rework ☐ Yes ☒ No
Training Impact ☐ Yes ☒ No

Existing Test Program Worksheet (TWP): ☐, Work is TP-3 ☐, Test Program providing new TPW ☐

Based upon review of RPP-ENV-46679, Rev. 1, the document does not require a USQ Evaluation as it is outside the scope of the USQ process pursuant to the requirements of 10 CFR 830.203. Block ~~13~~ 17 of the ~~EDT~~ ECN Form can be marked as "N/A" for USQ No. SEK SEK

20. ECN Category
☒ Direct Revision
☐ Supplemental
☐ Void/Cancel

ECN Type
☐ Supersedure
☒ Revision

NF 6-29-10

21. Distribution

Name	MSIN	Name	MSIN
C. L. Slack	E6-32	T. A. Erickson	R3-26
T. L. Bennington	R3-25	L. L. Penn	R1-51
B. P. Rumburg	E6-32	G. T. Wells	E6-32
D. Turner	B1-55	J. J. Mazurek	R2-54
T. P. Moberg	R3-26	F.R. Mieng	E6-32

Release Stamp
JUN 24 2010
DATE:
STA: 15
HANFORD RELEASE
ID: 65

ECN R

A-6003-563.1 (REV 9)

ENGINEERING CHANGE NOTICE	1a. ECN R
Page 2 of 3 ☒ DM ☐ FM ☐ TM	1b. Proj. ECN - - R

22. **Revisions Planned** (Include a brief description of the contents of each revision)
N/A

Note: All revisions shall have the approvals of the affected organizations as identified in block 12 "Approval Designator," on page 1 of this ECN.

23. **Commercial Grade Item Dedication Numbers** (associated with this design change)
N/A

24. **Engineering Data Transmittal Numbers** (associated with this design change, e.g., new drawings, new documents)
823603

25. **Other Non Engineering (not in HDCS) documents that need to be modified due to this change**

Type of Document	Document Number	Update Completed On	Responsible Engineer (print/sign and date)
Alarm Response Procedure			
Operations Procedure			
Maintenance Procedure			
N/A			

26. **Field Change Notice(s) Used?**
☐ Yes ☒ No
If Yes, Record Information on the ECN-2 Form, attach form(s), include a description of the interim resolution on ECN Page 1, block 18, and identify permanent changes.

NOTE: ECNs are required to record and approve all FCNs issued. If the FCNs have not changed the original design media then they are just incorporated into the design media via an ECN. If the FCN did change the original design media then the ECN will include the necessary engineering changes to the original design media.

27. **Design Verification Required?**
☐ Yes ☒ No
If Yes, as a minimum attach the one page checklist from TFC-ENG-DESIGN-P-17.

28. **Approvals**

Facility/Project Signatures		Date	A/E Signatures		Date
Resp. Engineer	Steve E. Kelly	6/17/2010	Originator/Design Agent		
Resp. Manager	D. H Shuford	6/17/2010	Professional Engineer		
Quality Assurance			Project Engineer		
IS&H Engineer			Quality Assurance		
NS&L Engineer			Safety		
Environ. Engineer	G. M. Crummel	6/17/2010	Designer		
Engineering Checker	D. A. Turner	6/17/2010	Environ. Engineer		
Other	~~R. R. Miera~~	6/17/2010	Other		
Other			Other		
Other			DEPARTMENT OF ENERGY / OFFICE OF RIVER PROTECTION		
Other			Signature or a Control Number that tracks the Approval Signature		
Other					
Other			ADDITIONAL SIGNATURES		
Other					
Other					

RPP-ENV-46679, Rev. 1

Evaluation of Best Available ControlTechnology for Toxics (tBACT) Double Shell Tank Farms Primary Ventilation Systems Supporting Waste Transfer Operations

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Columbia Nuclear International LLC / Washington River Protection Solutions
Richland, WA 99352
U.S. Department of Energy Contract DE-AC27-08RV14800

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Cost Center:	2MH00	Charge Code:	200478
B&R Code:		Total Pages:	112~~3~~ N.F 6-24-10

Key Words: tBACT, BACT, Ecology, Primary Ventilation Systems, 241-AN, 241-AP, 241-AW, 241-AY, 241-AZ, 241-SY, ASIL

Abstract: This report is an evaluation of Best Available Control Technology for Toxics (tBACT) for installation and operation of the Hanford double shell (DST) tank primary ventilation systems. The DST primary ventilation systems are being modified to support Hanford's waste retrieval, mixing, and delivery of single shell tank (SST) and DST waste through the DST storage system to the Waste Treatment and Immobilization Plang (WTP).

TRADEMARK DISCLAIMER. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof or its contractors or subcontractors.

JUN 24 2010
DATE:
STA: 15
HANFORD RELEASE
ID:
65

Nancy A Fouad — Release Approval
6-24-10 — Date
Release Stamp

Approved For Public Release

Tank Operations Contractor (TOC) **RECORD OF REVISION**	(1) Document Number: **RPP-ENV-46679**	Page 1

(2) Title:

Evaluation of Best Available Control Technology for Toxics (tBACT)
Double Shell Tank Farms Primary Ventilation Systems Supporting Waste Transfer Operations

Change Control Record

(3) Revision	(4) Description of Change – Replace, Add, and Delete Pages	Authorized for Release	
		(5) Resp. Engr. (print/sign/date)	(6) Resp. Mgr. (print/sign/date)
1 RS	Updated page ii, "List of Tables".	Steven E. Kelly 6/17/10	David H. Shuford 6/17/10

A-6003-835 (REV 2)

EXECUTIVE SUMMARY

This report is an evaluation of Best Available Control Technology for Toxics (tBACT) for installation and operation of the Hanford double shell tank (DST) primary ventilation systems. The DST primary ventilation systems are being modified to support Hanford's waste retrieval, mixing, and delivery of single shell tank (SST) and DST waste through the DST storage system to the Waste Treatment and Immobilization Plant (WTP). The retrieval, pumping, and mixing of waste are expected to increase emissions of toxic air pollutants (TAPs) as defined in Washington Administrative Code (WAC) 173-460-150, *Controls for New Sources of Toxic Air Pollutants*. WAC 173-460-150 provides acceptable source impact levels (ASILs), small quantity emission rates (SQERs), and de minimis values for each TAP. WAC 173-460-060(2), *Emission Standards for New and Modified Emission Units*, requires that tBACT be employed for all TAPs for which the increase in emissions exceed the de minimis values.

The process used in this tBACT evaluation was similar to that prior process used, documented, and approved by Ecology in the following tBACT evaluations.

- Letter July 31, 2007, J.A. Hedges to S Olinger, Approval of Criteria and Toxic Emissions Notice of Construction (NOC) Application, Hanford Single-Shell Tank Waste Retrieval, Approval Order DE05NWP-002 Rev. 2.
- Letter October 12, 2005, M.A. Wilson to R.J. Schepens, Approval of Criteria and Toxic Emissions Notice of Construction (NOC) Application for Operations of Waste Retrieval Systems in Single-Shell Tank (SST) Farms as Supplemented with C Farm Exhauster Operation Incorporating C-200 Series Tanks and Aggregated Exhaust Points for the 241-C Tank Farm, Approval Order DE05NWP-002, Rev. 1.
- Letter February 18, 2005, M.A. Wilson to R.J. Schepens, Approval of Non-Radioactive Air emissions Notice of Construction (NOC) for Operation of New Ventilation Systems in AN and AW Tank Farms, Approval Order DE05NWP-001.

The development of this tBACT followed guidance provided from Washington State Department of Ecology (Ecology) and the U.S. Environmental Protection Agency (EPA) for the process to determine best available control technologies (BACT). This tBACT follows the five-step BACT process, the steps are the following.

- Step 1 - Identify all available control technologies for each pollutant subject to review.
- Step 2 - Eliminate all technically infeasible control technologies.
- Step 3 - Rank the remaining control technologies by control effectiveness.
- Step 4 - Evaluate the feasible control technologies, beginning with the most efficient, with respect to economic, energy, and environmental impacts.
- Step 5 - Select as tBACT the most effective control technology that is not rejected based on adverse economic, environmental, and/or energy impacts.

This tBACT evaluation addresses 41 TAPs that exceed the de minimis values. TAPs with similar chemical and physical properties were placed into groups with the assumption that similar control technologies would be effective in abatement. The four separate groups that exceeded de minimis values were as follows:

- Ammonia
- Toxic organic compounds
- Mercury and mercury related compounds
- Particulate metal compounds.

After a detailed evaluation of the four TAPs and/or groups and the effectiveness and costs of emission control technologies for each, a $/ton cost was determined to implement a control technology as identified in Table ES-1. Most of the identified technologies were eliminated, because their $/ton costs exceeded the cost ceiling guidelines previously approved by Ecology and EPA as economically unjustifiable. Although the evaluated technology would remove 98-99% of the pollutants, the cost of the abatement becomes prohibitive on a per ton basis due to the low emission rates.

Based on the results of this tBACT evaluation, the proposed tBACT control technology for the DST primary ventilation systems consists of a moisture de-entrainer, pre-heater, pre-filters, and a High Efficiency Particulate Air (HEPA) filtration system in the treatment train.

This tBACT evaluation is one part of the Notice of Construction (NOC) application that will be submitted to Ecology. It provides information on TAP emissions, control technologies proposed, why they were proposed, or why a technology was not feasible for mitigation of toxic emissions during DST waste operations.

Table ES-1. Total Annualized Costs of Abatement Technologies, Emissions per Year, and the Cost of Removal per Ton Compared to the Ceiling Cost Effectiveness Threshold.

	Total Annualized Costs ($/year)	Emissions per Year (tons)	Annual Cost of Removal ($/ton)[a]	Ceiling Cost Effectiveness Threshold ($/ton)[b]
Toxic Organic Compounds				
Thermal Non-Catalytic Oxidizer	$2,925,000	0.481	$6,081,000	$105,000
Activated Carbon Adsorption	$790,000	0.481	$1,643,000	$105,000
Ammonia				
Thermal Non-Catalytic Oxidizer	$2,925,000	13.12	$223,000	$105,000
Activated Carbon Adsorption	$5,148,000	13.12	$392,000	$105,000
Scrubber	$7,583,000	13.12	$577,000	$105,000
Mercury and Mercury Related Compounds				
Activated Treated Carbon Adsorption	$92,000	2.61E-04	$352,000,000	$105,000
Particulate Metal Compounds	Particulate metal compounds are removed by the required particulate filtration train for removal of radionuclides at a 99.95% removal rate.			

Notes:
[a]Cost of Removal equals the Total Annualized Cost ($/year) divided by the Emissions per Year (tons).
[b]See Section 2, tBACT Methodology, for a detailed discussion.

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Terms, Acronyms, and Abbreviations

ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
ASIL	Acceptable Source Impact Level
BACT	Best Available Control Technology
BARCT	Best Available Radionuclide Control Technology
CAA	Clean Air Act
CAS#	Chemical Abstract Service Registration Number
CFM	Cubic Feet Per Minute
CFR	Code of Federal Regulations
DF	Decontamination Factor
DOE	Department of Energy
DOE-ORP	Department of Energy, Office of River Protection
DST	Double Shell Tank
Ecology	Washington State Department of Ecology
ETF	Effluent Treatment Facility
EPA	Environmental Protection Agency
ERDF	Environmental Restoration Disposal Facility
Ft	Foot
HEPA	High-Efficiency Particulate Air (Filter)
IAC	Impregnated Activated Carbon
LAER	Lowest Achievable Emission Rate
Lbs	Pounds
LEL	Lower Explosive Limit
MTZ	Mass Transfer Zone
NOC	Notice of Construction
NOx	Compounds of Nitrogen and Oxygen
NRC	National Research Council
NSR	New Source Review
RCW	Revised Code of Washington
RSD	Relative Standard Deviation
SQER	Small Quantity Emission Rate
SST	Single Shell Tank
TAPs	Toxic Air Pollutants
tBACT	Best Available Control Technology for Toxics
TOC	Total Organic Carbon
TWINS	Tank Waste Information Network System
VOC	Volatile Organic Compounds
WAC	Washington Administrative Code
WRPS	Washington River Protection Solutions, LLC
WTP	Waste Treatment and Immobilization Plant
Yr	Year
$	U.S. Dollars
$/yr	U.S. dollars per year
mg/m^3	milligrams per cubic meter
$\mu g/m^3$	micrograms per cubic meter
g/sec	gram per second

1.0 INTRODUCTION

The waste feed delivery mission requires all single shell tank (SST) wastes be transferred to the double shell tank (DST) system for future delivery to the Waste Treatment and Immobilization Plant (WTP). In preparation for this mission, new primary ventilation systems are being planned and designed for each DST farm. The first such primary ventilation system will replace the current primary ventilation system installed in the SY-241 Tank Farm.

Currently, DST farms are exhausted through a primary ventilation system that serves as a containment system for radioactive particulates present in the tank headspace, vents flammable gases and vapors that evolve from the liquid surface in the DSTs, and removes heat. The ventilation system operates by drawing outside air into and through the tank headspace. After the air leaves the headspace, the ventilation system conditions the outlet stream to remove entrained moisture, reduce relative humidity, and filter particulates. During exhaust it is discharged to atmosphere through the stack, the exhaust is monitored and sampled for radioactive particulates.

The new DST farm primary ventilation systems will replace the existing two parallel exhaust trains with two new parallel exhaust trains, each capable of providing up to nominally 2,000 ft^3/min (standard) and maximum 3,000 ft^3/min (standard) exhaust flow. Primary ventilation systems are operated during all storage, treatment, retrieval, and transfer operations of the waste contained in the DSTs.

The new replacement primary ventilation systems are considered modifications to the DST system and require a new air source review in accordance with WAC 173-460-040, *Controls of New Sources of Air Toxic Pollutants and* WAC 173-400-110, New Source Review (NSR). In addition, a Notice of Construction (NOC) permit application is required if there are new pollutants emissions or if increases exceed the de minimis values listed in WAC 173-460-150, *Controls for New Sources of Toxic Air Pollutant*. In addition, an NOC application for all new or modified toxic air pollutant sources must demonstrate that the new or modified emission units employ tBACT for all toxic air pollutants (TAPs) where the increase in emissions exceed the de minimis emission values found in WAC 173-460-150.

RPP-RPT-44009 Rev 1, *Spreadsheet Description Document for Non-Radiological Air Source Term for 241-SY Farm and 241-AP Farm Primary Ventilation Systems Upgrades* (May 2010) and SVF-1821, Rev 1, *Non-Rad Air Source Term for 241-SY Farm and 241-AP Farm Primary Ventilation System Upgrades.xlsx* (May 2010) assessed unabated emissions to the DST farm primary ventilation systems. Several pollutants exceeded the WAC 173-460-150 de minimis values and one pollutant (dimethyl mercury) exceeded the Acceptable Source Impact Level (ASIL).

This tBACT evaluation is one part of the NOC application. It provides information on toxic air pollutant (TAP) emissions, control technologies proposed, why they were proposed, or why a technology was not feasible for mitigation of toxic emissions during DST waste operations.

2.0 REGULATORY REQUIREMENTS AND METHODOLOGY

WAC 173-460-020 defines "Best available control technology for toxics (tBACT)" as that term is defined in WAC 173-400-030, as applied to toxic air pollutants. Toxic air pollutants are defined as any toxic air pollutant listed in WAC 173-460-150.

WAC-173-400-030, defines "Best available control technology (BACT)" as:

> "An emission limitation based on the maximum degree of reduction for each air pollutant subject to regulation under chapter 70.94 RCW emitted from or which results from any new or modified stationary source, which the permitting authority, on a case-by-case basis, taking into account energy, environmental, and economic impacts and other costs, determines is achievable for such source or modification through application of production processes and available methods, systems, and techniques, including fuel cleaning, clean fuels, or treatment or innovative fuel combustion techniques for control of each such pollutant. In no event shall application of "best available control technology" result in emissions of any pollutants which will exceed the emissions allowed by any applicable standard under 40 CFR Part 60 and Part 61. Emissions from any source utilizing clean fuels, or any other means, to comply with this paragraph shall not be allowed to increase above levels that would have been required under the definition of BACT in the Federal Clean Air Act as it existed prior to enactment of the Clean Air Act Amendments of 1990."

This tBACT demonstration is a modification of EPA's BACT analysis procedure delineated in the *New Source Review Workshop Manual, Prevention of Significant Deterioration and Nonattainment Area Permitting* (EPA, 1990). It is commonly referred to as the EPA Puzzle Book. There are five basic steps to EPA's "top-down" BACT process for evaluation of pollutant emission control technologies. These steps include the following:

- Step 1 - Identify all available control technologies for each pollutant subject to review.
- Step 2 - Eliminate all technically infeasible control technologies.
- Step 3 - Rank the remaining control technologies by control effectiveness.
- Step 4 - Evaluate the feasible control technologies, beginning with the most efficient, with respect to economic, energy, and environmental impacts.
- Step 5 - Select as BACT the most effective control technology that is not rejected based on adverse economic, environmental, and/or energy impacts.

Each step is described below:

Step 1: Identifies all commercially available toxic air emission control options. This step involves a search for available technologies that can reduce the emission levels for the toxic contaminants of concern. Technologies required under previously completed lowest achievable emission rate (LAER) determinations are available for BACT purposes and are also included as control alternatives. They usually represent the "top" alternative (the highest emission reduction). The information sources used to identify control technologies include:

- Previous BACT and tBACT demonstrations.
- EPA's reasonably available control technology (RACT)/BACT/LAER Clearinghouses.
- Regulatory authorities.
- Federal, State and local new source review (NSR) permits.
- Control technology vendors.
- Literature search.
- Internet Searches.
- Similar commercial government applications.

Step 2: Eliminates all of the above identified technically infeasible options and develops a short list of control technologies for further analysis. Screening criteria is applied to eliminate any control technology that is not available (cannot be obtained commercially) or not applicable (able to be reasonably installed and operated for control of tank farm process emissions). The determination of feasibility is based on evaluating vendor specifications and commercial or government application experience data for available control technologies previously identified. If a control technology has been installed and operated successfully on emissions with similar chemical and physical characteristics to those from processes that are being evaluated, it is demonstrated and is technically feasible.

The screening criteria developed for application to the suite of control technologies are as follows:

- The control technology has not been demonstrated at sufficient scale or removal efficiency for the application.
- The control technology introduces additional hazards above and beyond the primary control hazard.
- The control technology uses materials of construction that are unsuitable in a radiation field anticipated during operations or impact the integrity of materials of construction (i.e., corrosion) and no suitable alternative materials can be substituted.
- The control technology would be very difficult to modify for applicable field operations and maintenance activities anticipated during operations.
- Control technology would generate secondary waste streams.
- The control technology requires testability requirements where extraordinary measures would be required to ensure operational performance.

Step 3: Ranks the remaining control technologies in order of effectiveness for each unabated emission off gas stream under evaluation. The most effective control technology is ranked at the top.

Step 4: Evaluates economic impacts for highly-ranked applicable technologies for each unabated emission off gas stream analyzed. The purpose of the economic evaluations is to determine and

compare "cost reasonableness" ($/ton pollutant reduction) of the highly ranked technologies, in order, to determine whether impacts were acceptable. The economic analyses include factors for environmental impacts (e.g., secondary waste treatment, disposal costs) and energy impacts (e.g., utility costs). These economic impacts are based on average and incremental cost effectiveness or reasonableness of these analyses, expressed as cost per ton of pollutant removed. In addition, impacts on worker health and safety, such as labor for equipment maintenance, can be included.

Step 5: The control technology with the highest control efficiency is evaluated first for tBACT. If this technology is found to have acceptable energy, environmental, or economic impacts, then it is proposed as tBACT and no further analysis is necessary. If the top technology is shown to be inappropriate, based on energy, environmental, or economic impacts, the applicant must fully document the justification for this conclusion. Then the next most effective control technology on the list becomes the new candidate and is similarly evaluated. This process continues until the technology under consideration cannot be eliminated due to energy, environmental, or economic impacts, which would demonstrate the technology to be appropriate as tBACT.

General Approach to Economic Impact Evaluation

An economic determination is made whether there is any unacceptable environmental, energy, or economic impacts for the highest ranked technology. If there are no unacceptable impacts, then the highest ranked technology is proposed as tBACT for each unabated off gas stream. Economic evaluations are performed consistently across all technologies, and are rough order of magnitude cost estimates and employ the procedure found in the *Office of Air Quality Planning and Standards Air Pollution Control Cost Manual, Sixth Edition* (EPA, 2002). The results of the economic analyses are included as cost tables.

The economic impacts of the control technology options are evaluated by calculating the cost effectiveness. This calculation is performed by estimating the total annualized cost of control ($/yr) and dividing by the annual amount of emission reduction that would be achieved (tons/yr). The resulting cost effectiveness value ($/ton) is compared to costs for similar applications and to guidance provided by regulatory agencies.

Typically, cost effectiveness evaluations are compared to survey values compiled by Federal and State regulatory agencies. In general, tBACT cost effectiveness for pollutants are considered relative to “Plateau” and “Ceiling” values. Plateau level values are those below which a control technology is rarely thrown out as economically unjustifiable. The tBACT cost Ceiling value is a value above which a control technology is rarely judged economically justifiable. No similar cost guidance has been developed for tBACT. However, previous tBACT evaluations submitted from Hanford and approved by Ecology have used an additional factor for determination of cost ceiling values. These previous tBACT evaluations are as follows:

- Letter July 31, 2007, J.A. Hedges to S. Olinger, Approval of Criteria and Toxic Emissions Notice of Construction (NOC) Application, Hanford Single-Shell Tank Waste Retrieval, Approval Order DE05NWP-002 Rev. 2.
- Letter October 12, 2005, M.A. Wilson to R.J. Schepens, Approval of Criteria and Toxic Emissions Notice of Construction (NOC) Application for Operations of Waste Retrieval Systems in Single-Shell Tank (SST) Farms as Supplemented with C Farm Exhauster Operation Incorporating C-200 Series Tanks and Aggregated Exhaust Points for the 241-C Tank Farm, Approval Order DE05NWP-002, Rev. 1.

- Letter February 18, 2005, M.A. Wilson to R.J. Schepens, Approval of Non-Radioactive Air emissions Notice of Construction (NOC) for Operation of New Ventilation Systems in AN and AW Tank Farms, Approval Order DE05NWP-001.

The maximum previous plateau tBACT value was $5,700/ton and the maximum ceiling value was $10,500/ton. The additional tBACT factors used in the previous tBACT evaluations were based upon two options. These options took into account the toxicity and carcinogenicity of the various TAPs to scale the tBACT cost factors to reflect the hazards of these pollutants based upon either the classification of each TAP (Class A or B) or the ASIL associated with each TAP.

Option 1: The first option used in the previous tBACT evaluations refers to the Class A and Class B TAP classification defined in the previous (prior to June 20, 2009) WAC 173-460 regulation. For Class A TAPs, the "Plateau" and "Ceiling" values were multiplied by a factor of 10. For Class B TAPs, the "Plateau" and "Ceiling" values were multiplied by a factor of 5.

As of June 20, 2009, the revised WAC 173-460-150 no longer uses the Class A and Class B designations for identification of TAPs to use this method, however, it was noted that the previous Class A TAPs had, for the most part, annual averaging periods and Class B TAPs had 24-hour averaging periods. The current version of the regulations use annual, 24-hour, and hourly averaging periods and no longer designate Class A and B. None of the TAPs with hourly averaging periods were above the de minimis.

The "Plateau" and "Ceiling" values used for all current TAPs with annual averaging periods were multiplied by a factor of 10. **Table 2-1** takes the highest "Plateau" of $5,700 and the "Ceiling" of $10,500 values from the previous tBACTs and multiplies these by the factors of 5 and10 to demonstrate this tBACT adjustment described above.

Table 2-1. tBACT Cost Factors

Method	Cost Factor	Cost Effectiveness Threshold ($/ton)	
		Plateau	Ceiling
Toxic Air Pollutants (TAP) Classification			
Annual Averaging TAP	10	$57,000	$105,000
24-hour Averaging TAP	5	$28,500	$52,500

Option 2: The second option used in the previous tBACT evaluations for assessing tBACT cost effectiveness was based on individual pollutant ASILs and involves calculating a pollutant-specific cost factor using the following:

$$\text{Cost Factor} = \log_{10}(27{,}000 \div \text{ASIL})$$

The cost effectiveness thresholds for tBACT "Plateau" and "Ceiling" values were then determined for each pollutant by multiplying the maximum pollutant "Plateau" and "Ceiling" values by the pollutant-specific cost factor. **Table 2-2** demonstrates these cost factors for all pollutants determined to be above the de minimis for purposes of this tBACT evaluation.

Designated Methodology: All of the tBACT cost factors from Option 2 were under a factor of 10, except for dimethyl mercury. A multiplier of 10 was determined to be the upper limit for adjustment of the previously used tBACT "Plateau" and "Ceiling" values. The upper and bounding "Plateau" and "Ceiling" values used for this tBACT evaluation were then $57,000/ton and $105,000/ton respectively.

Table 2-2. ASIL Based Cost Factor Calculations for Compounds Above De Minimis Thresholds		
Compound Name	**ASIL ($\mu g/m^3$)**	**ASIL Based Cost Factor (Cost Factor = log10(27,000/ASIL)**
Ammonia	70.8	2.6
Particulate Metal Compounds		
Arsenic & Inorganic Arsenic Compounds	0.000303	7.9
Beryllium & Compounds (NOS)	0.000417	7.8
Cadmium & Compounds	0.000238	8.1
Chromium Hexavalent: Soluble, except Chromic Trioxide	6.67E-6	9.6
Cobalt	0.1	5.4
Manganese & Compounds	0.04	5.8
Mercury Compounds		
Mercury, Elemental	0.09	5.5
Dimethyl Mercury	1.00E-99	103.4
Organic Compounds		
1,1,2,2-Tetrachloroethane	0.0172	6.2
1,1,2-Trichloroethane	0.0625	5.6
1,2-Dibromoethane	0.0141	6.3
1,2-Dichloroethane	0.0385	5.8
1,2-Dichloropropane	0.1	5.4
1,3-Butadiene	0.00588	6.7
1,4-Dichlorobenzene	0.0909	5.5
1,4-Dioxane	0.13	5.3
Acetaldehyde	0.37	4.9
Acrylic Acid	1	4.4
Acrylonitrile	0.00345	6.9
Benzene	0.0345	5.9
Benzyl Chloride	0.0204	6.1
Carbon Tetrachloride	0.0238	6.1
Chloroform	0.0435	5.8
Dichloromethane	1	4.4
Ethylbenzene	0.4	4.8
Ethylene oxide	0.0114	6.4
Hexachlorobutadiene	0.0455	5.8
Hexachloroethane	0.0909	5.5
Naphthalene	0.0294	6.0
n-Nitrosodiethylamine	1.00E-04	8.4
n-Nitrosodimethylamine	0.000217	8.1
n-Nitroso-di-n-butylamine	0.000323	7.9
n-Nitrosodi-n-propylamine	0.0005	7.7
n-Nitrosomorpholine	0.000526	7.7
n-Nitroso-n-methylethylamine	0.000159	8.2
n-Nitrosopyrrolidine	0.00167	7.2
Perchloroethylene	0.169	5.2
Polychlorinated Biphenyls (PCBs)	0.00175	7.2
Trichloroethylene	0.5	4.7
Vinyl Chloride	0.0128	6.3

Source: RPP-RPT-44009 Rev 1, Spreadsheet Description Document for Non-Radiological Air Source Term for 241-SY Farm and 241-AP Farm Primary Ventilation Systems Upgrades (May 2010) and SVF-1821, Rev 1, Non-Rad Air Source Term for 241-SY Farm and 241-AP Farm Primary Ventilation System Upgrades.xlsm (May 2010)

3.0 Double Shell Tank System Primary Ventilation System Description and Associated Source Term

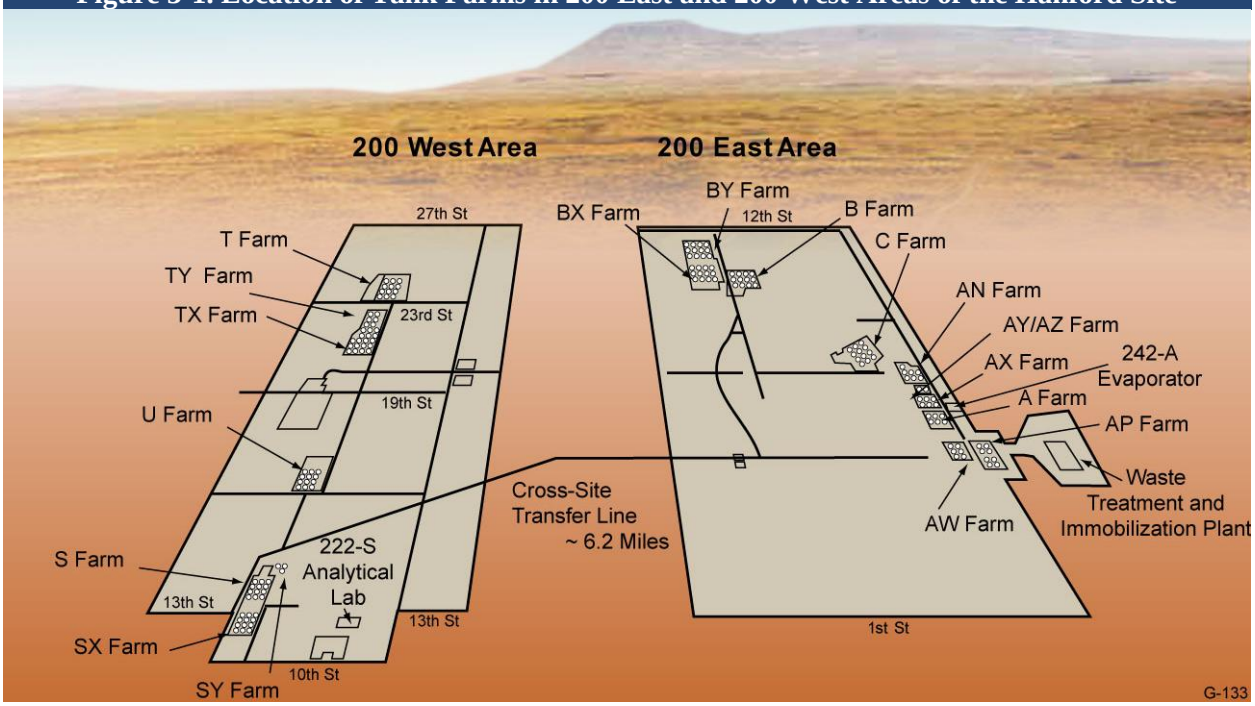
System Description

Figure 3-1 shows overall configuration of the Hanford tank farms that are located in the 200 East and 200 West area of the Hanford Site. The DST farms are used for storage, treatment, retrieval, and transfer of the tank waste, including future transfers to the WTP.

Each DST farm currently exhausts emissions through a primary ventilation system. These primary ventilation systems serve as a containment system for radioactive particulates present in the tank headspace, vent flammable gases and vapors that evolve from the liquid surface in the DSTs, and remove heat. The system operates by drawing outside air into and through the tank headspace. After the air leaves the headspace, the ventilation system conditions the outlet stream to remove entrained moisture, reduces relative humidity, and filters particulates. During exhaust discharge to atmosphere through the stack, the exhaust is monitored and sampled for radioactive particulates.

Ventilation system upgrades for each of the DST farms are needed for operational reliability and to support future waste feed delivery for the WTP. The primary ventilation system upgrades includes design, fabrication, installation, and construction acceptance testing. Each Tank Farm will have two parallel systems to include exhausters, deentrainer, heater, pre-filter, HEPA filter trains (two in series), fan, exhaust stack, ventilation system ducting, and stack and associated stack monitoring equipment including record samplers, continuous air monitors and other detectors.

Figure 3-1. Location of Tank Farms in 200 East and 200 West Areas of the Hanford Site



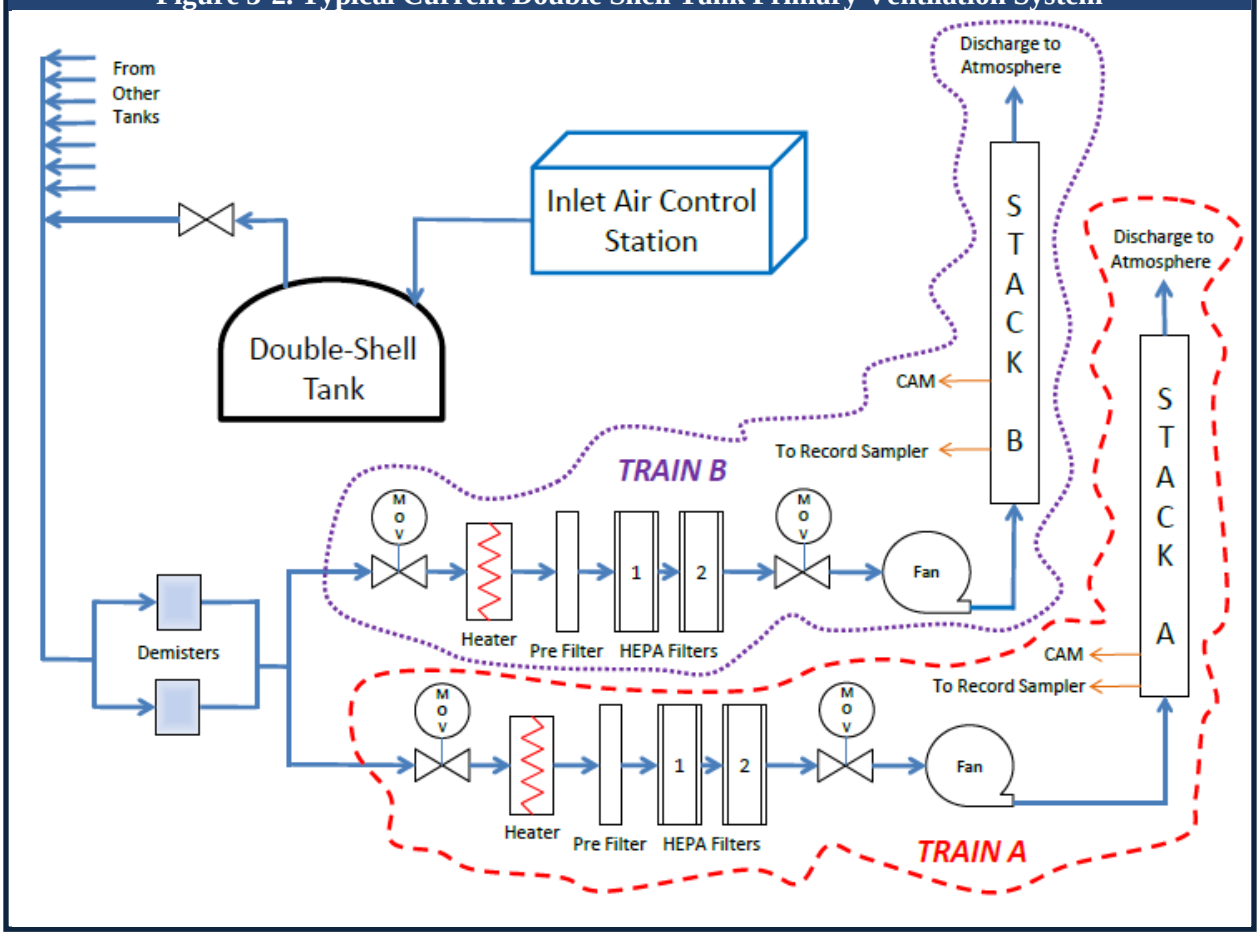
Currently, the primary ventilation system requirements are:

- Remove heat from the primary tank by removing water vapors from the headspace.
- Confine materials by maintaining vacuum conditions within the tank.
- Remove moisture from the exhaust air by condensation and de-entrainment.
- Remove radioactive particulate materials from the gaseous effluent.
- Remove flammable gases from the primary tank vapor space.

The major components of the current primary ventilation subsystem include: filtration, fan/blower, stack, and monitoring and control instruments as shown in **Figure 3-2.** The exhaust fans maintain a negative pressure on the tanks, thereby eliminating fugitive emissions, maintain an adequate airflow for cooling of the tanks, and remove any accumulated flammable gases. In the event of a failure of the operating filtration train and/or exhaust fan, the standby filter bank and exhaust fan are activated.

An exhaust air cooler is optionally placed in the flow stream between the storage tanks and the deentrainer (moisture separator). The function of the cooler is to reduce the temperature of the air stream so as not to exceed the maximum operating temperature of the stack monitoring and control system. Moisture is removed by the primary ventilation system via the deentrainer. Collected condensate is returned to a designated DST in the farm. The system reduces the relative humidity by heating the exhaust air stream before it enters the prefilter and the HEPA filters. The prefilter removes the large particulates and reduces the load on the HEPA filters.

Figure 3-2. Typical Current Double Shell Tank Primary Ventilation System



Two HEPA filters are used in series; these filters are test qualified by the manufacturer to comply with ASME AG-1, Section FC, and remove 99.97% of particulate greater or smaller than 0.3 microns.

The exhauster train has a centrifugal fan, which induces the air flow through the DSTs to the HEPA filters. It is located downstream of the HEPA filters and discharges into the stack. Each train is self contained; each exhaust system has its own stack.

Source Term

The source term data used for this tBACT demonstration is documented in RPP-RPT-44009 and SVF-1821. The source term assesses potential release rates of hazardous chemicals to double-shell tank farm ventilation exhausters during waste storage operations and operations supporting waste feed delivery to the WTP. The source term is bounded by potential releases of hazardous chemicals from 241-AP Farm as discussed below. The following methodology was used to determine the Hanford DST farm source term:

- Compare WAC-173-460-150, *Table of ASIL, SQER and De Minimis Values* and Tank Waste Information Network System (TWINS) listed substances by common name and by Chemical Abstract Service registration number (CAS#). CAS#s were used to sort and match the listing of CAS#s found in TWINS.
- TWINS data is for both SSTs and DSTs
- Extract common entries for evaluation as a TAP and calculate release rates for each by multiplying measured headspace concentrations by the headspace ventilation flow rate.
- Equate potential release rate of each to the highest calculated release rate.
- Increase potential release rates for tanks with waste disturbing activity (waste transfer or waste mixing operations) by a factor of ten to account for the increased headspace concentration. Assume that up to two tanks in a farm have waste disturbing activities in progress and that the waste in the remaining tanks experience quiescent conditions.
- Select the DST Farm with the largest number of tanks (e.g. 241-AP Farm with eight tanks).
- Determine the source term multiplier for the selected tank farm [for 241-AP Farm: two tanks with waste disturbing activity (2 x 10 = 20) plus six tanks with quiescent waste conditions (6 x 1 = 6) for a total source term multiplier of 26].
- The bounding DST farm source term for each hazardous chemical is equal to the highest calculated release rate multiplied by 26.

Approximately 90 chemical compounds were identified as TAPs. Of the 90 identified TAPs, 41 were identified to be above the de minimis values in accordance with WAC-173-460-150 (*Table of ASIL, SQER, and De Minimis Values*). These 41 TAPs are listed in **Table 3-1.** Based on these 41 compounds, four tBACT analyses (reflecting similar physical and chemical properties) are required to assess emission control technologies for all TAPs above de minimis thresholds:

- Toxic organic compounds (Section 4.0)
- Ammonia (Section 5.0)
- Mercury compounds (Section 6.0)
- Particulate metal compounds (Section 7.0).

Table 3-1. TAPs With Emissions Above De Minimis Rates				
Compound Name	**Chemical Abstract #**	**Averaging Period**	**Release Rate (lb/avg. period)**	**De Minimis Release Rate (lb/avg. period)**
Ammonia	7664-41-7	24-hr	7.19E+01	0.465
Toxic Organic Compounds				
1,1,2,2-Tetrachloroethane	79-34-5	Year	1.95E+01	0.165
1,1,2-Trichloroethane	79-00-5	Year	1.55E+01	0.6
1,2-Dibromoethane	106-93-4	Year	2.09E+00	0.135
1,2-Dichloroethane	107-06-2	Year	4.27E+01	0.369
1,2-Dichloropropane	78-87-5	Year	1.25E+00	0.959
1,3-Butadiene	106-99-0	Year	5.22E+00	0.0564
1,4-Dichlorobenzene	106-46-7	Year	1.63E+00	0.872
1,4-Dioxane	123-91-1	Year	1.84E+01	1.25
Acetaldehyde	75-07-0	Year	1.08E+02	3.55
Acrylic Acid	79-10-7	24-hr	4.67E-02	0.00657
Acrylonitrile	107-13-1M	Year	3.23E-01	0.0331
Benzene	71-43-2	Year	4.27E+01	0.331
Benzyl Chloride	100-44-7	Year	3.51E-01	0.196
Carbon Tetrachloride	56-23-5	Year	4.30E+01	0.228
Chloroform	67-66-3	Year	4.30E+01	0.417
Dichloromethane	75-09-2	Year	2.92E+02	9.59
Ethylbenzene	100-41-4	Year	3.70E+01	3.84
Ethylene oxide	75-21-8	Year	2.03E-01	0.109
Hexachlorobutadiene	87-68-3	Year	3.04E+01	0.437
Hexachloroethane	67-72-1	Year	4.41E+01	0.872
Naphthalene	91-20-3M	Year	3.41E-01	0.282
n-Nitrosodiethylamine	55-18-5	Year	5.08E-02	0.000959
n-Nitrosodimethylamine	62-75-9	Year	6.94E+01	0.00208
n-Nitroso-di-n-butylamine	924-16-3	Year	5.08E-02	0.0031
n-Nitrosodi-n-propylamine	621-64-7	Year	5.08E-02	0.0048
n-Nitrosomorpholine	59-89-2	Year	2.35E-01	0.00505
n-Nitroso-n-methylethylamine	10595-95-6	Year	5.08E-02	0.00153
n-Nitrosopyrrolidine	930-55-2	Year	5.08E-02	0.016
Perchloroethylene	127-18-4	Year	4.24E+01	1.62
Polychlorinated Biphenyls (PCBs)	1336-36-3	Year	5.34E-01	0.0168
Trichloroethylene	79-01-6	Year	4.27E+01	4.8
Vinyl Chloride	75-01-4	Year	4.30E+01	0.123
Mercury Compounds				
Mercury, Elemental	7439-97-6	24-hr	1.43E-03	0.000591
Dimethyl Mercury	593-74-8	24-hr	2.96E-06	1.00E-99
Particulate Metals Compounds				
Arsenic & Inorganic Arsenic Compounds	7440-38-2	Year	1.72E+00	0.00291
Beryllium & Compounds (NOS)	7440-41-7	Year	8.61E-02	0.004
Cadmium & Compounds	7440-43-9	Year	8.61E-01	0.00228
Chromium Hexavalent: Soluble, except Chromic Trioxide	7440-47-3	Year	2.63E+00	6.40E-05
Cobalt	7440-48-4	24-hr	4.70E-03	0.000657
Manganese & Compounds	7439-96-5	24-hr	4.70E-03	0.000263

4.0 Identification and Evaluation of Emission Control Technology Options for Toxic Organic Compounds

This section covers the detailed tBACT evaluation for toxic organic compound emissions for the DST farm system. Toxic organic compound emissions have been evaluated and defined by RPP-RPT-44009 and SVF-1821. Thirty-two (32) different, toxic, organic compounds have been estimated to be above their de minimis levels (see Section 3.0, Table 3-1 as defined in RPP-RPT-44009 and SVF-1821). All toxic organic compounds will be treated as a group of TAPs because they have similar physical and chemical properties and similar control technologies. The total annual toxic organic compounds emitted from the operations of a primary ventilation system of a DST farm are estimated to be 0.48 tons/year (derived from Table 3-1).

Step 1: Emission Control Technologies Identified for Toxic Organic Compounds

The following emission control technologies have been identified for the destruction and/or removal of toxic organic compound emissions.

- Activated carbon adsorption.
- Wet scrubber absorption.
- Thermal catalytic oxidation.
- Thermal non-catalytic oxidation

Step 2: Elimination of Technically Infeasible Options/Development of Short List for Toxic Organic Compounds

Qualitative screening and elimination criteria were developed for the selective elimination of control technologies evaluated to be technically infeasible or not applicable for treatment of toxic organic compound emissions from the primary ventilation system in DST farm processes. The screening criteria were applied for the suite of control technologies for toxic organic compounds listed above and are shown in **Table 4-1.** The only identified emission control technology that was determined to be technically infeasible and eliminated for this application is thermal catalytic oxidation.

Table 4-1. Toxic Organic Compounds – Potential tBACT

Control	Description	Screening Results
1	Activated Carbon Adsorption	Applicable
2	Wet Scrubber Absorption	Applicable
3	Thermal Catalytic Oxidizer	Eliminated
4	Thermal Non-Catalytic Oxidation	Applicable

Thermal Catalytic Oxidation: Thermal catalytic oxidation can be used to reduce volatile or toxic organic compound emissions from a variety of sources. Generally high flow, low concentration applications are best suited to produce high removal efficiencies for this technology. Particulates or halogenated volatile organic compounds and heavy metals can clog the packed bed or poison or deactivate the catalyst reducing the design life of the unit. Specific poisons include halogenated compounds, mercury, arsenic, sulfur, sodium, and calcium. Many of these compounds are found in the tank waste in high concentrations.

Step 3: Rank Remaining Control Technologies by Control Effectiveness

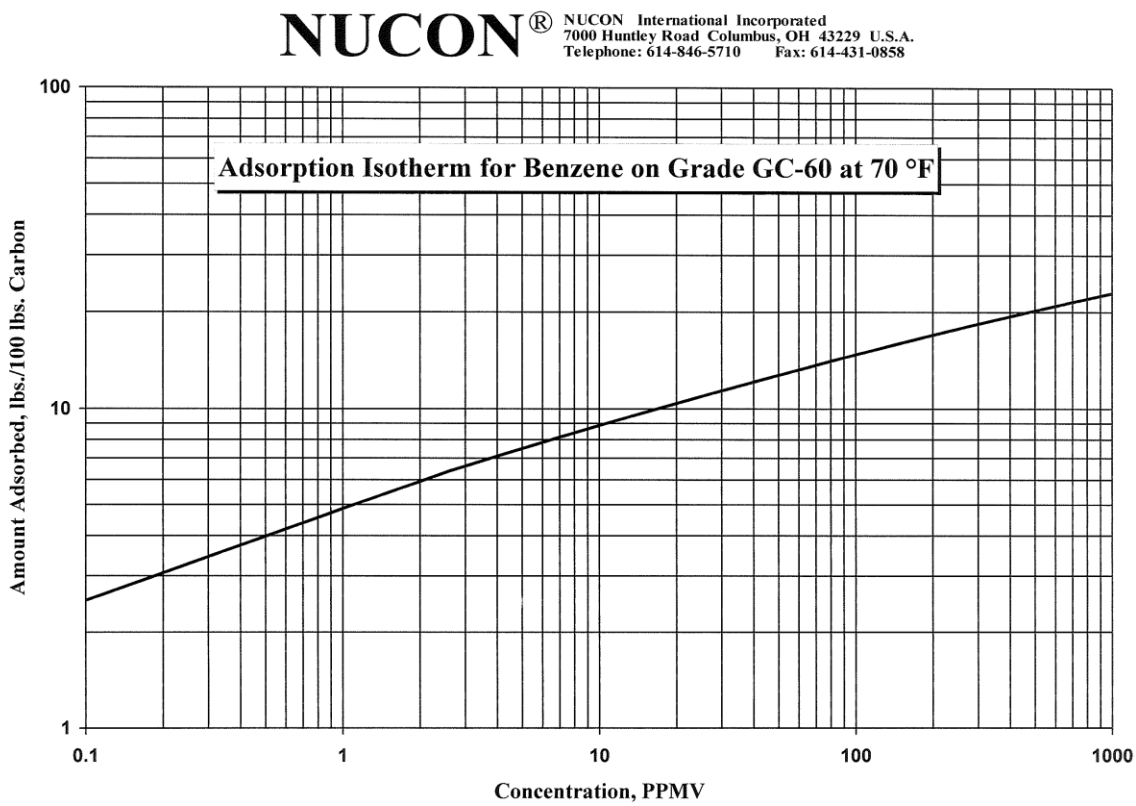
Effectiveness is defined by the ability of the control technology to reduce the post treatment emission rate for a given TAP or group of TAPs. The short list of tBACT technologies for toxic organic compounds in order of removal efficiency is provided in **Table 4-2.** The technologies with a removal efficiency of 99% or greater were down-selected for further tBACT economic evaluation which include activated carbon adsorption and thermal non-catalytic oxidation. Nevertheless, a general technology overview of wet scrubber absorption is described below for evaluation completeness.

Table 4-2. tBACT Ranking by Effectiveness for Control of Toxic Organic Compounds

Ranking/Technology	Removal Efficiency
1a. Activated Carbon Adsorption	99%
1b. Thermal Non-Catalytic Oxidation	99%
3. Wet Scrubber Absorption	70-90%

Activated Carbon Adsorption: The principal use of activated carbon as a control technology is for the removal of VOCs such as hydrocarbons, solvents, toxic gases and organic based odors. In addition, chemically impregnated activated carbons can be used to control certain inorganic pollutants such as hydrogen sulfide, mercury, or radon. When properly applied, the adsorption process will remove pollutants for which it is designed, to virtually nondetectable levels. Carbon adsorption is equally effective on single component emissions as well as complex mixtures of pollutants.

Figure 4-1. Typical Adsorption Isotherm (Benzene)



Physical adsorption is dependent on the characteristics of the pollutant to be adsorbed, the temperature of the gas stream to be processed, and the concentration of the contaminant in the gas stream. The adsorption capacity for a particular pollutant represents the amount of the pollutant that can be adsorbed on a unit weight of activated carbon consumed at the conditions present in the application. Typical adsorption capacities for moderately adsorbed compounds range from 5 to 30 percent of the weight of the carbon. A typical carbon adsorption isotherm (i.e., benzene) is shown in **Figure 4-1**. This figure shows that the adsorption of a compound is inversely proportional to the concentration when plotted on a log-log scale.

Activated carbon adsorption is applicable to low boiling point, small toxic, and volatile organic molecules. Large toxic or organic molecules are very difficult to remove from an activated carbon bed either by steam or by hot inert gas stripping and frequently result in decomposition or permanent plugging of the carbon bed. When a small fraction of the toxic organic compound "high boilers" (large molecular weight, high boiling point compounds) are present, a sacrificial guard bed is used to protect the main regenerable beds from poisoning. The guard bed is replaced when breakthrough occurs. Large toxic or organic molecule activated carbon adsorption is economical only when the recoverable toxic organic compound is the significant fraction of the total toxic organic compounds with a small percentage of high boilers.

For toxic or volatile organic compounds at low concentration (below 100 vppm), the typical control technology is fixed bed adsorption on activated carbon and disposal of carbon off site. In most cases, the adsorbent can be "reactivated" under similar conditions as the "activation process (~1000 C steam/air environment) where the adsorbed compounds are destroyed and the carbon is returned to near its original capacity. In addition, fixed adsorption is analogous to chromatography, the various organic compounds adsorbing have a significant impact on the adsorption capacity of other organic molecules, due to both displacement and to near permanent deposition on the carbon bed. Thus, while the adsorbent may indicate a relatively high pure component adsorption capacity for a particular component, when the gas stream has a large variety of organic molecule sizes and boiling points, the equilibrium capacity indicated by adsorption isotherms for that component cannot be approached.

As an example, a pure component isothermal capacity of 10 wt% may be reduced to as low as 0.1wt% in a multi-component system due to displacement by other components of the gas stream or by the "plugging" of otherwise available surface by high molecular weight compounds. The effect of "co-adsorbates" in the individual breakthrough adsorption time of the toxic organic compounds was estimated by the National Research Council (NRC) in relation to chemical agent incineration effluent control in a dynamic system. (NRC 1999, *The Disposal of Activated Carbon from Chemical Agent Disposal Facilities*) and is shown in **Table 4-3** (on next page)**.**

Also, many emission source terms are defined with many safety factors, typically increasing the assumed concentration of the toxic organic compounds in the inlet gas stream, often by as much as an order of magnitude. Adsorption capacity is concentration dependent and an order magnitude decrease in organic compound concentration typically results in halving the adsorption capacity. Therefore, using an inflated source term for toxic organic compound concentrations, results in an undersized adsorption system.

Table 4-3. Estimated Carbon Filter Breakthrough Times for Substances of Potential Concern in Stack Gases from Chemical Agent Disposal Facility Liquid Incinerator

Volatile Organic Compound	Estimated Initial Concentration (ng/m3)[a]	Estimated Breakthrough Time as Single Component[b]	Estimated Time for Multi-Component PFS Flue Gas[c]
Benzene	90,000	2.4 years	14.2 hours
Carbon tetrachloride	35,000	4.1 years	7.1 minutes
Chloroform	22,000	2.5 years	5.7 hours
Vinyl chloride	4,500	1.7 days	9.5 minutes

Notes: [a]Bed dimensions = 214 square feet, 1 foot deep, 3,030 kg of carbon
[b]Calculated based on D-R equation assuming complete saturation of filter at 135°F
[c]Based on multi-component computer model, 135°F, 67 percent relative humidity
Source: National Research Council, 1999

Furthermore, due to mass transfer limitations, only very large adsorbent beds approach the equilibrium capacity under dynamic conditions. The length of the mass transfer zone (MTZ) is again highly dependent on the properties of both the adsorbent structure (macro and micro porosity) and the properties of the organic compounds. This is further complicated in case of variable concentration of organic compounds entering the adsorbent bed, because both adsorption and desorption mass transfer needs to be considered. In most cases, the desorption MTZ is significantly longer than the adsorption MTZ. These factors establish the minimum bed depth (in the flow direction) criterion for adsorbent bed design. Typically, the minimum bed depth, for long term use applications, should be several orders of magnitude longer than the MTZ. Therefore, adsorbent beds cannot be designed solely on the adsorbent mass basis, the geometry is also important. If the bed depth is shorter than one MTZ for a particular compound, then instantaneous breakthrough of the organic compound will occur. (Schweitzer, 1988, *Handbook of Separation Techniques for Chemical Engineers, 2nd Editio*n).

In summary, activated carbon has been shown to be applicable for treatment of a wide variety of environmental pollutants. It is a proven technology that is simple to install and easy to operate and maintain. Capital costs are among the least expensive for most alternative treatment technologies. Operating costs are primarily related to the amount of activated carbon consumed in the adsorption process.

Thermal Non-Catalytic Oxidation: Thermal non-catalytic oxidation is the process of oxidizing combustible materials by raising the temperature of the material above its auto-ignition point in the presence of oxygen, and maintaining it at high temperature for sufficient time to complete combustion to carbon dioxide and water. Time, temperature, turbulence (for mixing), and the availability of oxygen all affect the rate and efficiency of the combustion process. These factors provide the basic design parameters for oxidation systems (ICAC 1999, *Institute of Clean Air Companies, Control Technology Information - Thermal Oxidation*).

Typical thermal oxidation design efficiencies range from 98 to 99.99% and above, depending on system requirements and characteristics of the pollutants (EPA 1992; *Control Techniques for Volatile Organic Emissions from Stationary Sources*; EPA 1996, *OAQPS Control Cost Manual*). Thermal oxidation often the best choice when high efficiencies are needed and the waste gas is above 20% of the Lower Explosive Limit (LEL). Oxidation units, in general, are not recommended for controlling gases containing halogen- or sulfur-containing compounds because of the formation of highly corrosive acid gases. It may be necessary to install a post-oxidation acid gas treatment system in such cases, depending on the outlet concentration to reduce increased corrosion rates (EPA, 1996). Thermal incinerators are also not generally cost-effective for low-concentration, high-flow organic vapor streams (EPA 1995, *Control and Pollution Prevention Options for Ammonia Emission*).

Wet Scrubber Absorption: Wet scrubber absorption is widely used as a raw material and/or product recovery technique in separation and purification of gaseous streams containing high concentrations of volatile and toxic organic compounds, especially water soluble compounds such as methanol, ethanol, isopropanol, butanol, acetone, and formaldehyde (Croll Reynolds 1999, *Croll Reynolds Company, Inc., web site http://www.croll.com*). However, as an emission control technique, it is much more commonly employed for controlling inorganic gases than for volatile or toxic organic compounds. When using absorption as the primary control technique for organic vapors, the spent solvent must be easily regenerated or disposed of in an environmentally acceptable manner (EPA 1991, *Control Technologies for Hazardous Air Pollutants*). When used for particulate control, high concentrations can clog the bed, limiting these devices to controlling streams with relatively low dust loadings (EPA 1998, *Stationary Source Control Techniques Document for Fine Particulate Matte*r).

Physical absorption depends on properties of the gas stream and liquid solvent, such as density and viscosity, as well as specific characteristics of the pollutant(s) in the gas and the liquid stream (e.g., diffusivity, equilibrium solubility). These properties are temperature dependent, and lower temperatures generally favor absorption of gases by the solvent. Absorption is also enhanced by greater contacting surface, higher liquid-gas ratios, and higher concentrations in the gas stream (EPA, 1991). Chemical absorption may be limited by the rate of reaction, although the rate-limiting step is typically the physical absorption rate, not the chemical reaction rate (EPA, 1996). In addition, spent scrubbing waste water will be generated during unit operations and usually is not returned to the original system for recycle.

Step 4: Evaluation of Most Effective Control Technologies

To generate the data for the evaluation of the most effective control technologies for toxic organic compounds, an economic evaluation of the two highest ranked technologies with efficiencies of 99% or greater was performed. The economic evaluations, total capital and annual operating costs, for thermal non-catalytic oxidation and activated carbon adsorption are given in **Table 4-4 and 4-5**, respectively.

The economic analyses included evaluation of direct and indirect capital costs (equipment and installation), as well as annual operating costs (utilities, labor, and maintenance costs). To estimate the technology equipment costs, the equipment was sized based on the flow of each unabated off-gas stream. The equipment cost estimates were based on EPA guidance documents and vendor information. Next, factors for fabrication from corrosion resistant materials were applied. The above costs do not include disposal of secondary waste or post-oxidation acid gas treatment.

The equipment costs used in this evaluation were obtained by NUCON International, Inc by obtaining quotes from suppliers (**Appendix 1**) and using previous experience and expertise in ammonia TBACT evaluations; and reviewing costs from letter 0401233/DOE-ORP: 04-ED-057,"Submittal of Toxic Best Available Control Technology (tBACT) Determination and Revised Pages to Non-Radiological Notice of Construction for Operation of New Ventilation Systems In AN and AW Tank Farms (RPP-20774)"- Letter.

and 24590-WTP-RPT-ENV-01-005, *Best Available Control Technology Analysis for Toxic Air Pollutants for the WTP* (2002*)*. Specific quote costs were given priority over the report estimated costs, which were 2002 and 2004 vintage, although in several cases where comparisons were made between estimates and quotes; the differences in cost were minor. The total annualized costs were based on a 10% rate of return and a 40-year facility life for activated carbon adsorption with treated adsorbent and a 10-year facility life for thermal non-catalytic oxidation due to corrosion issues mainly from halogenated organic compounds.

Step 5: Select tBACT

The cost/ton for removal of toxic organic compounds exceeds the cost effective threshold previously acceptable to Ecology. Therefore, no specific control technologies were selected for toxic organic compounds removal. The annualized costs are summarized in Section 8.

Table 4-4. Toxic Organic Compounds -- Thermal Non-Catalytic Oxidation Capital and Annual Cost Summary		
Cost Item	**Basis**	**Cost**
Total Capital Costs (TCC)		**$795,000**
Total Direct Costs		$615,680
Purchased Equipment costs		
Equipment		$340,000
Required Ancillary Equipment ($10/cfm)	3000	$30,000
Instrumentation and Control	15% of Equipment	$51,000
Freight	5% of Equipment	$17,000
Sub-total Purchased Equipment Costs (PEC)		$438,000
Direct Installation Costs		
Foundation & Support	8% of Subtotal PEC	$35,040
Handling & Erection	14% of Subtotal PEC	$61,320
Electrical	4% of Subtotal PEC	$17,520
Piping and Duct Work	4% of Subtotal PEC	$17,520
Insulation for Piping and Equipment	4% of Subtotal PEC	$17,520
Painting	2% of Subtotal PEC	$8,760
Sub-Total Installation costs (IC)		$157,680
Site Preparation	Equipment Specific	$20,000
Building Costs (Equipment footprint - ft^2)	Not Addressed	N/A
Total Indirect Capital Costs		$179,580
Engineering	10% of Subtotal PEC	$43,800
Construction and Field Expenses	5% of Subtotal PEC	$21,900
Start-up	10% of Subtotal PEC	$43,800
Performance Tests	1% of Subtotal PEC	$4,380
Contingencies	15% of Subtotal PEC	$65,700
Total Annual Costs (TAC)		**$666,000**
Direct Annual Costs		
Utilities		
Electricity	$0.08/kWhr	$515
Steam	$6.00/1000 lbs	$0
Water	$0.25/1000 gallons	$0
Natural Gas	$5.37/MCF	$635,056
Materials/Chemicals	Process Specific	$0
Operating Expenses		
Operator	$62.75/Hr	$3,263
Supervisor	15% of Operator	$498
Secondary Waste	$129.24/cf	$0
Maintenance		
Labor	$62.75/Hr	$2,510
Materials		$680
Indirect Annual Costs		
Overhead	Included in Labor Costs	$0
Administrative	2 % of TCC	$15,905
Insurance	1% of TCC	$7,952
Rate of Return on Capital Investment	**10%**	
Service Life (years)	**10 years - Due to equipment corrosion**	
Capital Recovery Factor	**2.84**	
Annualized Capital Investment (ACI)		**$2,258,000**
Grand Total Annualized Costs (ACI + TAC)		**$2,925,000**
Tons of Toxic Organic Compounds/Year		**0.481**
Annualized Cost per Ton of Toxic Organic Compounds		**$6,081,000**
See Appendix 1-B.		

Table 4-5. Toxic Organic Compounds -- Activated Carbon Adsorption Capital and Annual Cost Summary		
Cost Item	**Basis**	**Cost**
Total Capital Costs (TCC)		**$865,000**
Total Direct Capital Costs		$669,536
Purchased Equipment costs		
Equipment		$373,000
Required Ancillary Equipment ($10/cfm)	3000	$30,000
Instrumentation and Control	15% of Equipment	$55,950
Freight	5% of Equipment	$18,650
Sub-total Purchased Equipment Costs (PEC)		$477,600
Direct Installation Costs		
Foundation & Support	8% of Subtotal PEC	$38,208
Handling & Erection	14% of Subtotal PEC	$66,864
Electrical	4% of Subtotal PEC	$19,104
Piping and Duct Work	4% of Subtotal PEC	$19,104
Insulation for Piping and Equipment	4% of Subtotal PEC	$19,104
Painting	2% of Subtotal PEC	$9,552
Sub-Total Installation costs (IC)		$171,936
Site Preparation	Equipment Specific	$20,000
Building Costs (Equipment footprint - ft^2)	Not Addressed	N/A
Total Indirect Capital Costs		$195,816
Engineering	10% of Subtotal PEC	$47,760
Construction and Field Expenses	5% of Subtotal PEC	$23,880
Start-up	10% of Subtotal PEC	$47,760
Performance Tests	1% of Subtotal PEC	$4,776
Contingencies	15% of Subtotal PEC	$71,640
Total Indirect Costs		$195,640
Total Annual Costs (TAC)		**$702,000**
Direct Annual Costs		
Utilities		
Electricity	$0.08/kWhr	$0
Steam	$6.00/1000 lbs	$0
Water	$0.25/1000 gallons	$0
Natural Gas	$5.37/MCF	$0
Materials/Chemicals	Process Specific	$0
Operating Expenses		
Operator	$62.75/Hr	$3,263
Supervisor	15% of Operator	$489
Secondary Waste T&D (1/2 year carbon life)	$129.24/cf	$420,030
Maintenance		
Labor	$62.75/Hr	$8,032
Materials		$244,400
Indirect Annual Costs		
Overhead	Included in Labor Costs	$0
Administrative	2 % of TCC	$17,307
Insurance	1% of TCC	$8,653
Rate of Return on Capital Investment	**10%**	
Service Life (years)	**40**	
Capital Recovery Factor	**0.102**	
Annualized Capital Investment (ACI)		**$88,000**
Grand Total Annualized Costs (ACI + TAC)		**$790,000**
Tons of Toxic Organic Compounds/Year		**0.481**
Annualized Cost per Ton of Toxic Organic Compounds		**$1,643,000**
See Appendix 1-C.		

5.0 Identification and Evaluation of Emission Control Technology Options for Ammonia

This section covers the detailed evaluation for ammonia emissions tBACT. Ammonia emissions have been defined by RPP-RPT-44009 and SVF-1821. Emissions are estimated to be 72 lb/24 hr averaging period derived from Table 3-1 or 13 tons/year.

Step 1: Emission Control Technologies Identified

EPA documents present add-on control technologies used for ammonia emissions control (Control and Pollution Prevention Options for Ammonia Emissions, EPA-456/R-95-002). The add-on control technologies identified are wet scrubbers and condensation. These technologies are thoroughly described in the EPA references (EPA-456/R-95-002 and EPA/452/B-02-001) and in letter 0401233/DOE-ORP: 04-ED-057. Use of the EPA cost estimating program also suggests two other technologies may be considered as control technologies including activated carbon adsorption and thermal oxidation. The following emission control technologies have been identified for the destruction and/or removal of ammonia:

- Wet scrubber absorption
- Activated carbon adsorption with untreated adsorbent
- Activated carbon adsorption with treated adsorbent
- Thermal non-catalytic oxidation
- Thermal catalytic oxidation
- Biofiltration
- Condensation

Step 2: Elimination of Technically Infeasible Options

Qualitative screening and elimination criteria were developed for the selective elimination of control technologies evaluated to be technically infeasible or not applicable for treatment of ammonia emissions from the primary ventilation system for DST farm operations. The screening criteria were applied for the suite of control technologies for ammonia removal and/or destruction listed above and are shown in **Table 5-1**. The identified emission control technologies that are technically infeasible and eliminated include:

- Activated carbon adsorption with untreated adsorbent
- Thermal catalytic oxidation
- Biofiltration
- Condensation

Activated Carbon Adsorption with Untreated Adsorbent: Activated carbon adsorption with untreated adsorbent is not suitable for the DST farm source term. This is due to low adsorption capacity/efficiency of most commercially available adsorbents and associated at the low ammonia concentrations that exist in the DST farm exhaust. See Section 4.0, Activated Carbon Adsorption discussion, for additional details.

Table 5-1. Ammonia – Potential tBACT		
Control	**Technology**	**Screening Results**
1	Wet Scrubber Absorption	Acceptable
2	Activated Carbon Adsorption with Untreated adsorbent	Eliminated
3	Activated Carbon Adsorption with Chemically Treated Adsorbent	Acceptable
4	Thermal Non-Catalytic Oxidation	Acceptable
5	Thermal Catalytic Oxidation	Eliminated
6	Biofiltration	Eliminated
7	Condensation	Eliminated

Thermal Catalytic Oxidation: Thermal catalytic oxidation can be used to reduce volatile organic compounds and ammonia emissions from a variety of sources. Generally high flow, low concentration applications are best suited to control these process units. Particulates or halogenated volatile organic compounds and heavy metals can clog the packed bed or poison or deactivate the catalyst reducing the design life of the unit. Specific poisons include halogenated compounds, mercury, arsenic, sulfur, sodium, and calcium. See Section 4.0, Thermal Catalytic Oxidation discussion, for further details.

Biofiltration: A bio-filter consists of a bed packed with biological material, sometimes even two or three beds. The gas stream is lead through the filter bed where the contaminants are removed from the waste gas by adsorption to and absorption by the filtering material. The components are then decomposed by micro-organisms. The bed consists of a carrier containing biological material such as: compost, tree bark, coconut fibers or peat. To decrease the amount of acidification, calcium or dolomite is sometimes added to the packing material. At high concentrations of nitrogenous, sulfurous or halogenated compounds, the forming of respectively nitric acid, sulfuric acid and hydrochloric acid may acidify the filtering material reducing the overall removal efficiency of the process, thus, drastically increasing the replacement frequency of the filtering material.

Condensation: Condensation technology removes pollutants from a gas stream that is saturated with water or warm and damp, by condensing to far below the water's dew point. The condensate that forms on the heat exchanger, serves as an absorption liquid for contaminants that are easily dissolvable in water. The relatively large contact surface that is required for the exchange of heat is also used as a contact surface for the exchange of dust. After passing through the condenser the gas stream is 100% saturated with water and the remaining condensate drips are collected with a demister, thus, the contaminants are captured and removed in the liquid phase. Due to the low concentration of ammonia and high moisture content of the DST farm emissions, the ventilation exhaust would have to be dried to lower dew points than the ammonia condensation temperature to prevent freezing and clogging of the condenser.

Step 3: Rank Remaining Control Technologies by Control Effectiveness

The remaining applicable and available best control technologies for ammonia are shown in **Table 5-2**. All of these control technologies have a removal efficiency of 99% or greater and are ranked equally.

Table 5-2. tBACT Ranking by Effectiveness for Control of Ammonia

Ranking/Technology	Removal Efficiency
1a. Activated Carbon Adsorption with Chemically Treated Adsorbent	>99%
1b. Thermal Non-Catalytic Oxidation	>99%
1c. Wet Scrubber Absorption	99%

Activated Carbon Adsorption with Chemically Treated Adsorbent: For the removal of ammonia, the activated carbon needs to be chemically treated with phosphoric acid (between 15-30 wt%) to obtain removal efficiencies of greater than 99%. The activated carbon acts a collection substrate while the ammonia removal takes place by a reaction between the ammonia and the phosphoric acid. The ammonia removal capacity under equilibrium conditions is near stochiometric and is related to the phosphoric acid concentration. Adsorption efficiency is affected by other compounds that can be adsorbed on the activated carbon but will not be poisoned by them.

Removal efficiency is greater than 99% for fresh adsorbent and decreases near the stochiometric loading of the adsorbent. Adsorption on chemically treated activated carbon is more suitable for low concentrations of ammonia but it is capable of handling limited ammonia concentration spikes. Spent chemically treated adsorbent, while theoretically can be re-activated by thermal treatment, is typically disposed in landfills. See Section 4.0, Activated Carbon Adsorption discussion, for further details.

Thermal Non-Catalytic Oxidation: Thermal non-catalytic oxidation is a high temperature air-ammonia process reaction without the use of a catalyst. The destruction efficiency depends on the temperature of the unit operations. Greater than 99% ammonia destruction can be achieved at low temperature.

This technology is also capable of handling various concentrations of ammonia in the inlet stream and it is not sensitive to concentration spikes. In addition, thermal non-catalytic oxidation is not sensitive to halogenated or metallic compounds in the inlet stream (i.e., treats and destroys the majority of toxic or volatile organic compounds). However, acids and dioxins will be generated during the destruction of halogenated organic compounds, which will contribute an increased corrosion rate on materials of construction, thus, shortening the design life of the process unit. Oxides of nitrogen are also generated by this process, which depending on concentration may require additional treatment. See Section 4.0, Thermal Non-Catalytic Oxidation discussion, for further details.

Wet Scrubber Absorption: Scrubber absorption is a common emission technology for ammonia reduction, however it is used at higher concentrations than present in defined DST farm source term (RPP-RPT-44009 and SVF-1821). At defined source term concentrations, the scrubbing liquid has to be acidified to efficiently collect the ammonia. The scrubbing liquid is replenished based on the conversion rate to salt and needs to be treated as secondary waste.

The spent scrubbing secondary waste water cannot be returned to the DST system and will need to be sent to the effluent treatment facility (ETF). The quantity of ammonium sulfate which would have to be treated by the ETF, based on the source term value, is in excess of 100 tons/year and exceeds the current ETF treatment capacity. See Section 4.0, Wet Scrubber Absorption discussion, for further details.

Step 4: Evaluation of Most Effective Control Technologies

To generate the data for the evaluation of the most effective control technologies for ammonia, an economic evaluation of the above identified technologies applied to each unabated off gas stream was performed. The economic evaluations for ammonia control technologies are shown in the following tables:

- **Table 5-3** – Thermal non-catalytic oxidation
- **Table 5-4** – Activated carbon adsorbers with treated adsorbent
- **Table 5-5** – Wet scrubber absorption

The economic analyses included evaluation of direct and indirect capital costs (equipment, installation), as well as annual operating costs (utilities, labor, and maintenance costs). To estimate the technology equipment costs, the equipment was sized based on the flow of each unabated off gas stream. The equipment cost estimates were based on EPA guidance documents and vendor information. Factors for fabrication from corrosion resistant materials and adaptation to field operations and maintenance were applied. The above costs do not include disposal of secondary waste or post-oxidation acid gas treatment.

The equipment costs used in this evaluation were obtained by NUCON International, Inc by supporting the design and fabrication of similar facilities by obtaining quotes from suppliers (**Appendix 1**) and using previous experience and expertise in ammonia tBACT evaluations; and reviewing costs from letter 0401233/DOE-ORP: 04-ED-057. Specific quote costs were given priority over the report estimated costs, which were 2002 and 2004 vintage, although in several cases where comparisons were made between estimates and quotes the differences in cost were minor. The total annualized costs were based on a 10% rate of return and a 40-year facility life for activated carbon adsorption with treated adsorbent and a 10-year facility life for thermal non-catalytic oxidation and wet scrubber absorption due to corrosion issues mainly from halogenated organic compounds and sulfuric acid scrubbing liquids, respectively.

Step 5: Select tBACT

The $/ton for removal of ammonia exceeds the cost effective threshold previously acceptable to Ecology. Therefore, no specific control technologies were selected for ammonia removal. The annualized costs are summarized in Section 8.

Table 5-3. Ammonia -- Thermal Non-Catalytic Oxidation Capital and Annual Cost Summary		
Cost Item	**Basis**	**Cost**
Total Capital Costs (TCC)		**$795,000**
Total Direct Capital Costs		$615,680
Purchased Equipment costs		
Equipment		$340,000
Required Ancillary Equipment ($10/cfm)	3000	$30,000
Instrumentation and Control	15% of Equipment	$51,000
Freight	5% of Equipment	$17,000
Sub-total Purchased Equipment Costs (PEC)		$438,000
Direct Installation Costs		
Foundation & Support	8% of Subtotal PEC	$35,040
Handling & Erection	14% of Subtotal PEC	$61,320
Electrical	4% of Subtotal PEC	$17,520
Piping and Duct Work	4% of Subtotal PEC	$17,520
Insulation for Piping and Equipment	4% of Subtotal PEC	$17,520
Painting	2% of Subtotal PEC	$8,760
Sub-Total Installation costs (IC)		$157,680
Site Preparation	Equipment Specific	$20,000
Building Costs (Equipment footprint - ft^2)	Not Addressed	N/A
Total Indirect Capital Costs		$179,580
Engineering	10% of Subtotal PEC	$43,800
Construction and Field Expenses	5% of Subtotal PEC	$21,900
Start-up	10% of Subtotal PEC	$43,800
Performance Tests	1% of Subtotal PEC	$4,380
Contingencies	15% of Subtotal PEC	$65,700
Total Annual Costs (TAC)		**$666,000**
Direct Annual Costs		
Utilities		
Electricity	$0.08/kWhr	$515
Steam	$6.00/1000 lbs	$0
Water	$0.25/1000 gallons	$0
Natural Gas	$5.37/MCF	$635,056
Materials/Chemicals	Process Specific	$0
Operating Expenses		
Operator	$62.75/Hr	$3,263
Supervisor	15% of Operator	$489
Secondary Waste T&D (1/2 year carbon life)	$129.24/cf	$0
Maintenance		
Labor	$62.75/Hr	$2,510
Materials		$680
Indirect Annual Costs		
Overhead	Included in Labor Costs	$0
Administrative	2 % of TCC	$15,905
Insurance	1% of TCC	$7,952
Rate of Return on Capital Investment	**10%**	
Service Life (years)	**10 years - Due to equipment corrosion**	
Capital Recovery Factor	**2.84**	
Annualized Capital Investment (ACI)		**$2,258,000**
Grand Total Annualized Costs (ACI + TAC)		**$2,925,000**
Tons of Ammonia/Year		**13.12**
Annualized Cost per Ton of Ammonia		**$223,000**
See Appendix 1-B.		

Table 5-4. Ammonia -- Activated Carbon Adsorbers with Treated Adsorbent Capital and Annual Cost Summary		
Cost Item	**Basis**	**Cost**
Total Capital Costs(TCC)		**$929,000**
Total Direct Capital Costs		$718,496
Purchased Equipment costs		
Equipment		$403,000
Required Ancillary Equipment ($10/cfm)	3000	$30,000
Instrumentation and Control	15% of Equipment	$60,450
Freight	5% of Equipment	$20,150
Sub-total Purchased Equipment Costs (PEC)		$513,600
Direct Installation Costs		
Foundation & Support	8% of Subtotal PEC	$41,088
Handling & Erection	14% of Subtotal PEC	$71,904
Electrical	4% of Subtotal PEC	$20,544
Piping and Duct Work	4% of Subtotal PEC	$20,544
Insulation for Piping and Equipment	4% of Subtotal PEC	$20,544
Painting	2% of Subtotal PEC	$10,272
Sub-Total Installation costs (IC)		$184,896
Site Preparation	Equipment Specific	$20,000
Building Costs (Equipment footprint - ft^2)	Not Addressed	N/A
Total Indirect Capital Costs		$210,576
Engineering	10% of Subtotal PEC	$51,360
Construction and Field Expenses	5% of Subtotal PEC	$25,680
Start-up	10% of Subtotal PEC	$51,360
Performance Tests	1% of Subtotal PEC	$5,136
Contingencies	15% of Subtotal PEC	$77,040
Total Annual Costs (TAC)		**$5,052,000**
Direct Annual Costs		
Utilities		
Electricity	$0.08/kWhr	$0
Steam	$6.00/1000 lbs	$0
Water	$0.25/1000 gallons	$0
Materials/Chemicals	Process Specific	$0
Operating Expenses		
Operator	$62.75/Hr	$3,263
Supervisor	15% of Operator	$489
Secondary Waste T&D (1/2 year carbon life)	$129.24/cf	$2,584,800
Maintenance		
Labor	$62.75/Hr	$56,224
Materials		$2,380,000
Indirect Annual Costs		
Overhead	Included in Labor Costs	$0
Administrative	2 % of TCC	$18,581
Insurance	1% of TCC	$9,290
Rate of Return on Capital Investment	**10%**	
Service Life (years)	**40**	
Capital Recovery Factor	**0.102**	
Annualized Capital Investment (ACI)		**$95,000**
Grand Total Annualized Costs (ACI + TAC)		**$5,148,000**
Tons of Ammonia/Year		**13.12**
Annualized Cost per Ton of Ammonia		**$392,000**
See Appendix 1-C.		

Table 5-5. Ammonia -- Wet Scrubber Adsorption Capital and Annual Cost Summary		
Cost Item	**Basis**	**Cost**
Total Capital Costs (TCC)		**2,619,000**
Total Direct Capital Costs		$2,017,568
Purchased Equipment costs		
Equipment		$1,224,000
Required Ancillary Equipment ($10/cfm)	3000	$0
Instrumentation and Control	15% of Equipment	$183,600
Freight	5% of Equipment	$61,200
Sub-total Purchased Equipment Costs (PEC)		$1,468,800
Direct Installation Costs		
Foundation & Support	8% of Subtotal PEC	$117,504
Handling & Erection	14% of Subtotal PEC	$205,632
Electrical	4% of Subtotal PEC	$58,752
Piping and Duct Work	4% of Subtotal PEC	$58,732
Insulation for Piping and Equipment	4% of Subtotal PEC	$58,732
Painting	2% of Subtotal PEC	$29,376
Sub-Total Installation costs (IC)		$528,768
Site Preparation	Equipment Specific	$20,000
Building Costs (Equipment footprint - ft^2)	Not Addressed	N/A
Total Indirect Capital Costs		$602,208
Engineering	10% of Subtotal PEC	$146,880
Construction and Field Expenses	5% of Subtotal PEC	$73,440
Start-up	10% of Subtotal PEC	$146,880
Performance Tests	1% of Subtotal PEC	$14,688
Contingencies	15% of Subtotal PEC	$220,320
Total Annual Costs (TAC)		**$143,000**
Direct Annual Costs		
Utilities		
Electricity	$0.08/kWhr	$0
Steam	$6.00/1000 lbs	$0
Water	$0.25/1000 gallons	$10,000
Materials/Chemicals	Process Specific	$50,000
Operating Expenses		
Operator	$62.75/Hr	$3,263
Supervisor	15% of Operator	$489
Secondary Waste T&D in excess of EFF capacity (cannot be directly calculated but is very high)	$129.24/cf	$0
Maintenance		
Labor	$62.75/Hr	$753
Materials		$204
Indirect Annual Costs		
Overhead	Included in Labor Costs	$0
Administrative	2 % of TCC	$52,395
Insurance	1% of TCC	$26,197
Rate of Return on Capital Investment	**10%**	
Service Life (years)	**10 years - Based on corrosion issues in a wet environment**	
Capital Recovery Factor	**2.84**	
Annualized Capital Investment (ACI)		**$7,439,000**
Grand Total Annualized Costs (ACI + TAC)		**7,583,000**
Tons of Ammonia/Year		**13.12**
Annualized Cost per Ton of Ammonia		**$577,000**
See Appendix 1-D.		

6.0 IDENTIFICATION AND EVALUATION OF EMISSION CONTROL TECHNOLOGY OPTIONS FOR MERCURY COMPOUNDS

This section covers the detailed tBACT evaluation for mercury and related compounds including dimethyl mercury for the DST farm system. Mercury and related compound emissions have been evaluated and defined by RPP-RPT-44009 and SVF-1821. Dimethyl mercury is the only compound identified exceeding its ASIL limit (1.00E-99 µg/m³). The maximum off-site concentration for dimethyl mercury is estimated to be 3.23E-8 µg/m³, with a corresponding release rate of 5.40E-7 tons/year (derived from Table 3-1).

Step 1: Emission Control Technologies Identified for Mercury Compounds

The following emission control technologies have been identified for mercury compounds including dimethyl mercury:

- Wet scrubber Absorption.
- Powdered Carbon Injection
- Powdered Carbon Injection with chemically treated carbon
- Fixed Carbon Beds
- Fixed Carbon Beds with chemically treated carbon
- Depleted Brine Scrubbing
- Selenium Filters
- Gold Amalgamation

Step 2: Elimination of Technically Infeasible Options

Qualitative screening and elimination criteria were developed for the selective elimination of control technologies evaluated to be technically infeasible or not applicable for treatment of mercury compounds, including dimethyl mercury, emissions from the primary ventilation system of the DST farm operations. The screening criteria for applicability were applied to the control technologies listed above and are shown in **Table 6-1**. All identified control technologies except for one has been eliminated for the removal of mercury compounds. The primary reason for elimination of these technologies is due to they have not been proven at a sufficient scale and irresolvable technical difficulties. A brief description of each of each control technology is given below:

Table 6-1. Mercury Compounds – Potential tBACT

Control	Technical Description	Screening Results
1	Wet scrubber Absorption	Eliminated
2	Powdered Carbon Injection	Eliminated
3	Powdered Carbon Injection with chemically treated carbon	Eliminated
4	Fixed Carbon Beds	Eliminated
5	Fixed Carbon Beds with chemically treated carbon	Applicable
6	Depleted Brine Scrubbing	Eliminated
7	Selenium Filters	Eliminated
8	Gold Amalgamation	Eliminated

Wet Scrubber Absorption: Wet scrubbing, requires highly reactive sulfur containing additives in the scrubbing liquor and has reasonable efficiency for water soluble mercury compounds only. It has been applied on some coal fired power plants where the primary purpose of the scrubbing is acid gas removal. There is no chemical reason or any experimental data indication to expect that organic mercury compounds can be removed. For example, dimethyl mercury, an organic mercury compound, is not water soluble and is not applicable for wet scrubbing abatement technologies. Extensive waste liquid disposal or collection and treatment are required to support this technology. See Section 5.0, Wet Scrubber Absorption discussion, for further details.

Powdered Carbon Injection: Powdered carbon injection is an existing control technology for power plants where powdered carbon is injected into the flue gas and reacts with mercury both in the gas phase and upon deposition in the particulate collecting bag-house of the power plant. It can be considered only when bag-house collectors are installed downstream and the carbon is continually injected and removed in conjunction with the ash collected in the bag-house. Mercury removal efficiencies have been cited between 50 - 70% for elemental mercury.

Powdered Carbon Injection with Treated Carbon: Powdered Carbon Injection with chemically treated carbon, is a variation of the above process, resulting in somewhat higher mercury removal efficiency at an increased carbon cost and commensurate corrosion problems from the typical additive bromine.

Fixed Carbon Beds with Untreated Carbon: Fixed carbon beds are used in several applications for mercury vapor control, but their use has been almost completely superseded by the use of chemically treated carbon in the fixed beds. The mercury is only physically adsorbed on untreated activated carbon and migrates through the adsorbent bed according to the mass transfer conditions in the fixed bed. Untreated carbon is more sensitive to the presence toxic organic compounds and inorganic vapors than the treated carbons. (EPA-452-R-R7-010, *Mercury Study Report to Congress, Volume VIII: An Evaluation of Mercury Control Technologies and Costs*, December 1997 and EG&G-2008-EERC-01-02, *EG&G Carbon Evaluation for Mercury Removal*)

Depleted Brine Scrubbing: Depleted brine scrubbing is applicable only to chlor-alkali plants where the brine is one of the flow streams. This technology is not applicable and is not used in the other applications.

Selenium Filters: Selenium on adsorbent based filters was eliminated due to selenium being a toxic material. Sulfur on adsorbents is equally reactive without the additional toxic hazards and is lower in cost.

Gold Amalgamation: Gold amalgamation is not an industrial process and has only been applied in mercury concentration measuring instruments only. There is no commercial or industrial destruction or removal application for this process Sjostrom, et.al, EPA, "*Development and Demonstration of Mercury Control by Adsorption Processes* (MerCAP™[1])."

[1] MerCAP™ is a Trademark of Lesman Instrument Company, Bernice, Illonois

Step 3: Rank Remaining Control Technologies by Control Effectiveness

Effectiveness is defined by the ability of the control technology to reduce the post treatment emission rate for dimethyl mercury. The only control technology found to be applicable for mercury (including dimethyl mercury) control is fixed carbon beds with chemically treated activated carbon.

Carbon, that is chemically treated with sulfur or iodine, can remove mercury compounds. The most common in industrial applications is the sulfur impregnation of the carbon and is used in similar composition and size off gas control in the U.S. (e.g., chemical weapons incineration off gas mercury control, mixed waste incinerator off gas control, nuclear waste melter off gas control, petrochemical processing). In these applications, the impregnated activated carbon (IAC) is placed in a fixed bed, either vertically or horizontally and used until the exhaustion of the IAC. The life of the IAC is dependent on total mercury inlet concentration.

Several laboratory, pilot and full scale tests have been performed with varying degrees of inlet mercury concentrations in air, in natural gas, and with organic compounds present in the off-gases of melters, incinerators and other gaseous waste treatment facilities. [INEEL/CON-97-01225 1997, *Mercury Emissions Control Technologies for Mixed Waste Thermal Treatment (1997)*; INEEL/CON-00-01332 2001, *Removal of Mercury from the Off-Gas from Thermal Treatment of Radioactive Liquid Wastes (2001)]*. One of the common IACs is MERSORB®[2] for which additional test reports are also attached. (**Appendix 2)**

Impregnated Activated Carbon mercury vapor abatement technologies are mature and have been successfully used for the control of effluents and emissions in both nuclear and military applications. The nuclear application typically treats radioactive waste melter effluents and incineration off gases from processes such as the THOR® Process[3] [Soelberg, et al, *IT3 2007 Conference, Off-Gas Mercury control using Sulfur Impregnated Activated Carbon – Test Results*, (May 2007)]. The military applications consist primarily of the effluent control from chemical agent destruction either by thermal or chemical processes.

Several of the tests reported in the MERSORB® Bulletin were performed using radioactive mercury (^{159}Hg). Comparing the total mercury decontamination results between the air gas carrier and natural gas carrier gas streams indicates that the total mercury removal was better from the natural gas stream, where organic mercury could form from the air stream. The manner, in which the tests were run, would have indicated different movement of mercury species by dual radioactivity peaks. No movement of mercury species were observed for long-term test data generated under chemical agent incineration condition air flows and operations.

There are also reports showing that dimethyl mercury in the presence of methanol decomposes to methane and elemental mercury [Wongkasemjit, *Laboratory Study of Corrosion Effect of Dimethyl Mercury on Natural Gas Processing Equipment* (2000)]. Considering that the methanol flux in the gas stream is about six orders of magnitude higher than the dimethyl mercury flux, it is expected that during adsorption treatment of both compounds through the IAC bed, it would give sufficient contact time to decouple the mercury from the methyl group.

In addition, the Washington State Department of Ecology evaluated mercury and dimethyl mercury releases from several landfills. [Prestbo, *Determination of Total and Dimethyl Mercury*

[2] MERSORB is a registered trademark of Nucon International, Columbus, OH
[3] THOR is a trademark of THOR Treatment Technologies, Richland, WA

in Raw Landfill Gad with Site Screening for Elemental Mercury at Eight Washington State Landfills for the Washington State Department of Ecology)July 2003)] The sampling train which used an untreated carbon substrate without impregnation, preferentially adsorbed dimethyl mercury to elemental mercury.

Under the current Ecology regulations, evaluation of dimethyl mercury abatement systems is triggered at levels over 1.00E-99.

The landfill study, cited above, used the best available detection method and resulted in a dimethyl mercury analysis above 20 ng/m3. This resulted in a reasonable relative standard deviation (RSD) of ~10 %. Below 2 ng/m3 the RSD increased to above 80%. Based on this report, in a similar gas stream matrix, the minimum reliable detection limit for dimethyl mercury is 10 ng/m3 or 110E-2 µg/m³.

Step 4: Evaluation of Most Effective Control Technologies

On the basis of the above, the only available, proven technology for total mercury control, even in the presence of dimethyl mercury, is treatment of the gas stream by IAC. The sizing, costing and operating costs are based on one of the IACs MERSORB®. The economic evaluations, total capital and annual costs, are shown in **Table 6-2**.

The economic analyses included evaluation of direct and indirect capital costs (e.g., equipment, installation), as well as annual operating costs (e.g., utilities, labor, and maintenance costs). To estimate the technology equipment costs, the equipment was sized based on the flow of each unabated off-gas stream. The equipment cost estimates were based on EPA guidance documents and vendor information. Next, factors for fabrication from corrosion resistant materials and adaptation to radioactive environment operations and maintenance were applied. The above costs do not include disposal of secondary waste or post-oxidation acid gas treatment.

The equipment costs used in this evaluation were obtained by NUCON International, Inc. who owns MERSORB® technology. The total annualized costs were based on a 10% rate of return and a 40-year facility life and a 10% rate of return on capital for mercury compounds including dimethyl mercury emissions control.

Step 5: Select tBACT

The cost/ton for removal of mercury and mercury related compounds exceeds the cost effective threshold previously acceptable to Ecology. Therefore, no specific control technologies were selected for mercury and mercury related compounds removal. The annualized costs are summarized in Section 8.

Table 6-2. Mercury and Mercury Related Compounds – Fixed Carbon Beds with Chemically Treated Adsorbent tBACT Control Technology – Capital and Annual Cost Summary		
Cost Item	**Basis**	**Cost**
Total Capital Costs (TCC)		$598,000
Total Direct Capital Costs		$463,904
Purchased Equipment costs		
Equipment		$247,000
Required Ancillary Equipment ($10/cfm)	3000	$30,000
Instrumentation and Control	15% of Equipment	$37,050
Freight	5% of Equipment	$12,350
Sub-total Purchased Equipment Costs (PEC)		$326,400
Direct Installation Costs		
Foundation & Support	8% of Subtotal PEC	$26,112
Handling & Erection	14% of Subtotal PEC	$45,696
Electrical	4% of Subtotal PEC	$13,056
Piping and Duct Work	4% of Subtotal PEC	$13,056
Insulation for Piping and Equipment	4% of Subtotal PEC	$13,056
Painting	2% of Subtotal PEC	$6,528
Sub-Total Installation costs (IC)		$117,504
Site Preparation	Equipment Specific	20,000
Building Costs (Equipment footprint - ft^2)	Not Addressed	N/A
Total Indirect Capital Costs		$133,824
Engineering	10% of Subtotal PEC	$32,640
Construction and Field Expenses	5% of Subtotal PEC	$16,320
Start-up	10% of Subtotal PEC	$32,640
Performance Tests	1% of Subtotal PEC	$3,264
Contingencies	15% of Subtotal PEC	$48,960
Total Annual Costs (TAC)		**$33,000**
Total Annual Direct Costs		
Utilities		
Electricity	$0.08/kWhr	$0
Steam	$6.00/1000 lbs	$0
Water	$0.25/1000 gallons	$0
Materials/Chemicals	Process Specific	$0
Operating Expenses		
Operator	$62.75/Hr	$3,263
Supervisor	15% of Operator	$489
Secondary Waste T&D (1/2 year carbon life)	$129.24/cf	$4,061
Maintenance		
Labor	$62.75/Hr	$401
Materials		$4,675
Total Annual Indirect Costs		
Overhead	Included in Labor Costs	$0
Administrative	2 % of TCC	$11,954
Insurance	1% of TCC	$5,977
Rate of Return on Capital Investment	**10%**	
Service Life (years)	**40**	
Capital Recovery Factor	**0.102**	
Annualized Capital Investment (ACI)		**$61,000**
Grand Total Annualized Costs (ACI + TAC)		**$92,000**
Tons of Mercury Compounds/Year		**0.000261**
Annualized Cost per Ton of Mercury and Mercury Related Compounds		**$352,000,000**
See Appendix 1-C.		

7.0 Identification and Evaluation of Emission Control Technology Options for Particulate Metal Compounds

This section covers the detailed tBACT evaluation for non-mercury metal compounds for the DST farm system. Several of the non-mercury metal compounds have emissions above the de minimis levels. RPP-RPT-44009 and SVF-1821 and are summarized in **Table 7-1**. These compounds will be present in particulate form as metals or metal salts.

Table 7-1. Particulate Concentrations

Particulate	Concentration (µg/m³)
Arsenic (particulate form only; excludes hydrides)	1.69E-06
Beryllium	8.46E-08
Cadmium	8.46E-07
Chromium	2.59E-06
Cobalt	5.14E-05
Manganese	5.14E-05

WAC 173-480-060, *Emission Standards for New and Modified Emission Units* and WAC 246-247-040, *Radiation Protection – Air Emissions* state that a BARCT for radionuclides (particulates) is required and that, at a minimum, a filter train consisting of prefilters, mist eliminators, and dual HEPA filters must be employed. Since these technologies have already been evaluated for radionuclides, they will control emissions of particulate metal compounds identified in Table 7-1. No further technology selection or evaluation steps were performed except for the evaluation of the radiological control required filtering components efficiency for these pollutants.

The individual technology components in-place stage efficiencies of exhaust trains required by WAC 173-480-060 are: Mist Eliminator - 99%, Prefilter - 80%, and HEPA Filtration each stage 99.95 %. This combination results in higher than 99.99% combined removal efficiency, but a conservative removal efficiency value of 99.99% is used. The efficiencies listed for HEPA filters are based on the 0.1-0.3 micrometer size, least filterable, particle size range. The efficiency for this type of HEPA filter is higher for both smaller and larger particle sizes.

The combination of the above listed particulate metal compounds control technologies achieve a combined removal efficiency of 99.99% (in-place), when assembled according to ASME/ANSI N-509 Standard and have components that meet ASME AG-1 Code: Section FA (mist eliminators), Section FB (pre-filters), and Section FC (HEPA filters). This combination of air cleaning control technology components is currently required for primary ventilation of DST farms. Therefore, no further tBACT evaluations are required for particulate metal compounds. This set of control technologies are credited by a decontamination factor (DF) of 10,000 for the above listed particulate metal compounds TAPs, which brings all of these untreated TAP concentrations to the following treated values.

Justification of the 99.99% mass based removal of metal aerosols: The existing and proposed DST farm Air Cleaning Unit (ACU) consists of particle removal components: demister (mist agglomerator); prefilter; HEPA filter 1; and HEPA filter 2.

These elements remove various size aerosols at the currently accepted efficiency of:

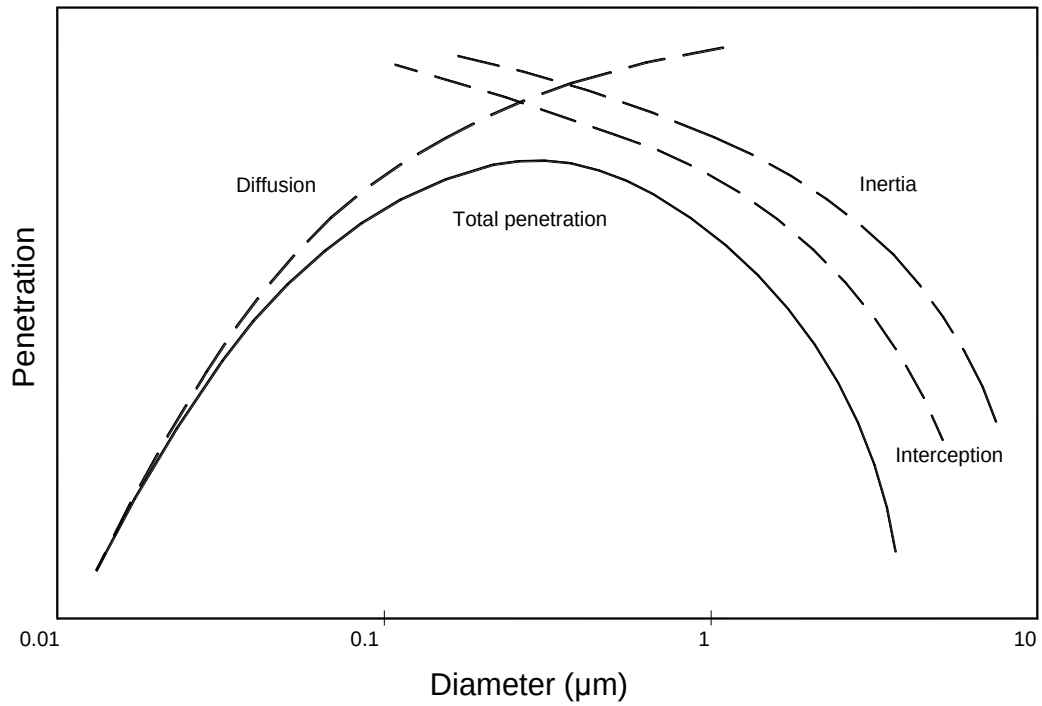
- Demister → 99 % liquid droplets by mass minimum and 99% minimum for 5-10 micron range
- Pre-Filter → ~ 30-80% Atmospheric dust depending on type
- 1st HEPA Filter → 99.97% Hot DOP minimum at 0.3 micron (AMAD size)
- 2nd HEPA Filter → 99.97% Hot DOP minimum at 0.3 micron (AMAD size)

The above listed efficiencies are all based on single component efficiencies. The same efficiencies may not be true when applied to a system containing multiple components. Components that are installed in a "filter train" may have installation irregularities, in-place testing occurs using heterogeneous aerosol particles with a median diameter of 0.7 microns, and thus, each single bank installed HEPA filter leak tightness has to be a minimum of 99.95%. These qualifications and in place tests are not "mass based" with the exception of mist eliminator which has a required mass basis a minimum of 99% efficiency.

The HEPA filters are qualification tested with 0.3 micron liquid aerosol droplets (DOP, Polyolefin, etc). The particle removal efficiency of the HEPA filters is higher for both larger and smaller aerosol sizes as shown on **Figure 7-1**. (Vendel 2009, NEA/CSNI/R 2009). The typical metal and metal oxide aerosols are heterogeneous in distribution and typically larger than the minimum efficiency filterable 0.3 micron. (Bowling 1941, Lujaniene 1995, Ogordkinov 2004, Papastefanos 2009). The removal efficiency for multiple banks HEPA filters while difficult to determine using the conventional DOP aerosol test method (due to inadequate test aerosol after the first stage) has been determined using radioactive aerosols. For example, a 0.22-0.66 micron ^{238}PuO2 aerosol resulted in a DF of 1.88E12 to 1.7E13 and for three HEPA filters in series the DF was from 2.1E12 to 4.7E13 [(Gonzales, *Performance of Multiple HEPA Filters against Plutonium Aerosols* (1974); Linck, *In-Place Testing of Multiple Stage HEPA Filter Plenums* (1974)]

In this evaluation, the decontamination credit of 99.99 % by mass (DF of 10E4) for the metal aerosol compounds is assigned to the combination of a moisture separator, a prefilter and two HEPA filters in series when built according to the ASME AG-1 Code and in place tested according to ASME/ANSI N-510 (i.e. each HEPA stage in place tested individually). This combined mass removal efficiency can be achieved solely by the combined filtration efficiency of the above listed air cleaning elements without including the additional removal of the water droplet scrubbing of these aerosols on the mist eliminator.

Figure 7-1. Filter Penetration Versus Particle Size



8.0 tBACT Recommendation

After detailed evaluation of the four TAPs and/or groups of TAPs and the effectiveness and costs of emission control technologies for each, a $/ton was determined to implement a control technology as identified in **Table 8-1**. All of the identified technologies were eliminated because their cost per ton exceeded the cost ceiling guidelines previously approved by Ecology and EPA as economically unjustifiable. Although the evaluated technology would remove 98-99% of the pollutants, the cost of the abatement becomes prohibitive on a per ton basis due to the low emission rates.

Based on the results of this tBACT evaluation, the proposed tBACT control technology for the DST primary ventilation systems consists of a moisture de-entrainer, pre-heater, pre-filters, and a HEPA filtration system in the treatment train.

Table 8-1. Total Annualized Costs of Abatement Technologies, Emissions per Year, and the Cost of Removal per Ton Compared to the Ceiling Cost Effectiveness Threshold.

	Total Annualized Costs ($/year)	Emissions per Year (tons)	Annual Cost of Removal ($/ton)[a]	Ceiling Cost Effectiveness Threshold ($/ton)[b]
Toxic Organic Compounds				
Thermal Non-Catalytic Oxidizer	$2,925,000	0.481	$6,081,000	$105,000
Activated Carbon Adsorption	$790,000	0.481	$1,643,000	$105,000
Ammonia				
Thermal Non-Catalytic Oxidizer	$2,925,000	13.12	$223,000	$105,000
Activated Carbon Adsorption	$5,148,000	13.12	$392,000	$105,000
Scrubber	$7,583,000	13.12	$577,000	$105,000
Mercury and Mercury Related Compounds				
Activated Treated Carbon Adsorption	$92,000	2.61E-04	$352,000,000	$105,000
Particulate Metal Compounds	Particulate metal compounds are removed by the required particulate filtration train for removal of radionuclides at a 99.99% removal rate.			

Notes:
[a]Cost of Removal equals the Total Annualized Cost ($/year) divided by the Emissions per Year (tons).
[b]See Section 2, tBACT Methodology, for a detailed discussion.

9.0 REFERENCES

ASME/ANSI N-509 Standard

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Appendix A

The cost basis used to generate the data for each of the cost estimates for toxic organic compounds, ammonia, and mercury and mercury related compound were developed using previous experience and expertise in ammonia BACT evaluations; and reviewing costs from letter 0401233/DOE-ORP: 04-ED-057 and 24590-WTP-RPT-ENV-01-005, *Best Available Control Technology Analysis for Toxic Air Pollutants for the WTP* (2002*)*. Specific quote costs were given priority over the report estimated costs, which were 2002 and 2004 vintage, although in several cases where comparisons were made between estimates and quotes; the differences in cost were minor. In addition, equipment cost estimates were based on EPA guidance documents and vendor information. Factors for fabrication from corrosion resistant materials were applied when necessary. Cost estimates do not include disposal of secondary waste or potential post-treatment gas treatment.

Appendix 1-A Thermal Oxidizer Cost Estimates

SYSTEMS
Thermal Oxidation
A Met-Pro Product Recovery/Pollution Control Technologies Company

THERMAL OXIDIZER

Budget Proposal No. 4665

NUCON International, Inc.

DECEMBER 10, 2009

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MET PRO CORPORATION

SYSTEMS Thermal Oxidation
A Met-Pro Product Recovery/Pollution Control Technologies Company

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NUCON International, Inc.
DECEMBER 10, 2009

INTRODUCTION

COMPANY INTRODUCTION

Met-Pro Systems is pleased to submit this proposal for your consideration. Met-Pro Corporation, a NYSE listed company headquartered in Pennsylvania, USA is one of the world's leading suppliers of air and fluid purification and handling technology, products and solutions. With 10 divisions and multiple subsidiaries in the USA and Europe, Met-Pro Corporation has the global experience with over 30,000 installations in over 70 countries to provide unequalled integrated product and systems solutions.

Met-Pro Corporation was recently recognized, for the second consecutive year, as one of America's "200 Best Small Companies" by Forbes magazine. Through its business units, in the United States, Canada, Europe and The People's Republic of China, a wide range of products and services are offered for industrial, commercial, municipal and residential markets worldwide. These include product recovery and pollution control technologies for purification of air and liquids; fluid handling technologies for corrosive, abrasive and high temperature liquids; and filtration and purification technologies including proprietary water treatment chemicals and filter products.

Met-Pro Corporation has been recognized for the second consecutive year as one of the world's "Top Small to Midsize Manufacturers" by Start-It magazine. According to Start-It, the "SMB 1200," is "a complete list of the top small and medium-sized manufacturers in the world". All of the companies that appear on the SMB 1200 have annual revenues between $40 million and just under $1 billion, and many, according to Start-It, "have shown intense resilience even as industry continues to face significant market pressures."

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SYSTEMS Thermal Oxidation
A Met-Pro Product Recovery/Pollution Control Technologies Company

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EQUIPMENT DESCRIPTION

The thermal oxidizer is used to convert hydrocarbons to carbon dioxide and water. This occurs by heating the hydrocarbons in an oxygen rich atmosphere to a temperature that will allow the oxidation reaction to occur at a rapid rate. The thermal oxidizer operates at 2200°F. The reactants are held at this temperature level for approximately 2 seconds. This will provide a minimum destruction efficiency of 99.99% of the organic contaminants.

The thermal oxidizer shall be of a cylindrical configuration and mounted horizontally or vertically, depending on required pollution control equipment downstream. Support legs shall be fastened to a foundation with embedded anchor bolts and grouted in place (by others). The casing shall be constructed of carbon steel plate and standard structural shapes. The exterior shall be painted with a single coat of high temperature silicone-based paint and the interior shall be refractory lined.

Air for combustion shall be drawn from ambient air and blended with the process air to achieve a level of oxygen required for flame stability (oxygen in the process is low because of the high water vapor content).

During "Heat-up", "Idle", and "Cool-Down" periods, no waste shall enter the unit. Fresh ambient air shall be forced through the system using the fan. Dampers on the inlet of the fan shall isolate the unit from the process and provide an inlet for the ambient air. Heat-up ramp rate is 50°F to 100°F per minute. Cold start to operation time is less than 30 minutes.

Overall Length:	23'
Casing Diameter:	7' – 4"
Estimated Equipment Weight:	15,000 lbs
Combustion/Dilution Air Connection:	14"
Natural Gas Connection:	3"

Ancillary equipment for the thermal oxidizer shall include:

- One (1) Nozzle Mix Burner
- One (1) NEMA 12 Control Enclosure with Sub-Panel
- One (1) Allen Bradley SLC5/05 PLC Controller
- One (1) lot of Field Instrumentation for Met-Pro supplied equipment.

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- Interconnecting carbon steel Ductwork with Expansion Joints between Met-Pro Supplied Equipment.
- One (1) Gas Train Assembly with Temperature Control Valve for natural gas
- Class I, Division II Outdoor Electrical Classification
- One (1) Combustion/Dilution Air Blower with Starter
- Two (2) Control Dampers for Combustion and Dilution air
- Two (2) Pneumatic Dampers for Process and Fresh Air Isolation

UTILITIES

Combustion Air Blower:	10 hp
Natural Gas Supply:	270 SCFM @ 10 PSIG
Compressed Air Supply:	275 lb/hr @ 80 PSIG
Electrical Power:	460 volt / 3 Phase / 60 Hz
Control Power:	120 volt / 1 Phase / 60 Hz

PERFORMANCE

Destruction and Removal Efficiency of Organic Compounds: 99.99%

SCOPE OF WORK

Supply by Met-Pro

- Equipment arrangement and design
- Equipment Supply and Fabrication (see " Equipment Description" above)
- Programming of Local control system and HMI
- Operating and Maintenance Manuals
- Installation Instructions

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Supply by Others

The following items are to be supplied by others and are not included in Met-Pro Systems scope of supply:

- Demolition of existing equipment or facilities
- Any modifications to existing equipment
- Building, structural, foundations, anchor bolts, grouting, embedded materials, or any other Civil Design, Materials, and Installation
- Cranes and other tools required for demolition or installation.
- Installation labor and materials
- Design and supply of any equipment upstream of the Thermal Oxidizer.
- Any freeze or personnel protection equipment or materials including insulation and cladding.
- Design and supply of utilities.
- Design, programming, and hardware for integration with plant control system and data acquisition.
- All Interconnecting wiring, conduit, termination, and supports
- All Interconnecting piping, tubing, and supports.
- Interconnecting ductwork and supports for supply to Met-Pro Equipment.
- Transportation and receiving of materials to site
- Installation supervision or commissioning services

Our service department can provide installation supervision and commission services if desired at our standard rates.

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PRICING

The pricing given is for the supply of equipment only. Installation design, labor, materials, and supervision shall be by others.

Met-Pro Supply as described above is:.....$340,000

Field Supervision, Commissioning, and Training

Field Supervision, Commissioning, and Training Services are not included in the Met-Pro Supply price given above. These services are offered at the following rates:

Field Service Personnel.....$ 1,500/Day/Person

Travel and Living Expenses.....$ Cost + 10%

Validity

Pricing is valid for 30 days, excluding escalation, from the date given on the cover page of this document.

Escalation

Due to current market volatility in steel, nickel, chrome, copper, precious, and other metals, pricing provided may be subject to escalation at time of Met-Pro issuance of purchase orders to its suppliers.

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ENGINEERING AND FABRICATION SCHEDULE

Based upon current equipment and material availability, we anticipate the following schedule applying to this project:

MILESTONE	TIME	ELAPSED TIME
Receipt of purchase order	0	0
Drawings for approval	6 weeks	6 weeks
Approval of drawings	2 weeks	8 weeks
Fabrication	16 weeks	24 weeks
Delivery	1 weeks	25 weeks

This schedule is predicated on customer approval within the time frame noted. Delays in approval will extend the completion date by at least the time equal to the delay. Lengthy delays may result in rescheduling of manufacturing, which could result in a greater offset of shipping dates and increased prices as a result of raw material increases. Shipment timing may change depending upon shop load at the time of order.

COMMERCIAL TERMS

- All Pricing is in US Dollars.
- All credit subject to approval.
- Payment Terms
  - 25% of order upon award
  - 25% of order upon complete submittal of the approval drawings
  - 25% of order with drawing approval/release to manufacturing
  - 25% of order with shipment

Met-Pro Systems Terms and Conditions are attached hereto and form an integral part of this proposal.

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MET-PRO TERMS AND CONDITIONS OF SALE

The following terms and conditions form part of each proposal submitted by Met-Pro Corporation, its divisions or subsidiaries, hereinafter called "Seller," for the sale of equipment, machinery, materials, consumables or services (collectively the "Contract Goods") to a Client/Customer, hereafter called "Buyer", and any contract made by and between the parties includes as part thereof these terms and conditions. Any provisions or conditions of Buyer's order which are in any way inconsistent with, or in addition to Seller's terms and conditions shall not be binding on Seller, and shall not be applicable, except with Seller's written acceptance. No changes in, modifications of, or additions to the terms and conditions of this form shall be binding on Seller unless in writing and signed by a representative of Seller duly authorized for that purpose. Any contract resulting from this proposal shall be construed and enforced in accordance with the laws of the Commonwealth of Pennsylvania without giving effect to the choice or conflict of law provisions or rules thereof. The parties agree that any action arising out of or relating to this sale, shall be brought only in the Court of Common Pleas of Montgomery County, Pennsylvania, or the United States District Court for the Eastern Division of Pennsylvania, and hereby consent to venue in such courts.

MATERIAL WARRANTY

Warranty – Seller warrants to Buyer that the Contract Goods manufactured by it is free from defects in material and workmanship under normal use and service for a period of eighteen (18) months after shipment or twelve (12) months after initial operation, whichever occurs first, or for such period of time as is specifically provided for on the face of the written quotation or order form, and for no additional period of time unless Seller expressly agrees in writing to a longer warranty. All auxiliary equipment not manufactured by Seller carries such warranty as given by the manufacturer thereof and which is hereby assigned to Buyer without recourse to Seller. Seller's warranty for consumables shall be pro-rated over the applicable aforementioned period.

No warranty is offered as to refractories or protective coatings, other than the material composition is in compliance with specifications

Terms – Upon discovery of defects in materials or workmanship during such eighteen (18) months after shipment or twelve (12) months after initial operation as described above, Seller shall either repair or replace the equipment, on the condition that the conditions set forth immediately below are met. Even if Seller repairs or replaces the equipment, its original warranty term is not extended. Seller's obligation under this warranty is, at Seller's sole option, to a one-time repair or replacement of any part which is shown to Seller's reasonable satisfaction to have been defective as to material, workmanship or design, provided that:

1. written notice of such defect is given to Seller within ten (10) calendar days of discovery thereof;
2. the equipment has been installed and operated in accordance with the purpose for which it was purchased and the installation, operating, and maintenance instructions provided by Seller;
3. no alterations or substitutions have been made in the equipment;
4. Seller may require the return of the defective material to establish any claim or make repairs but in no event shall the material be returned without Seller's consent. All returned equipment or parts must be free from any hazardous materials;
5. No payment or allowances will be made for repairs or alterations in the equipment unless Seller's prior written approval has been obtained. All removal, shipping, and reinstallation costs shall be to Buyer's account; and
6. Seller shall not be required to honor any warranty obligation until such time as it shall have been paid in full by Buyer.

PATENT WARRANTY

Seller shall defend at its expense any suit or proceeding brought against Buyer based on any claim that the equipment manufactured by Seller, except for equipment/material manufactured and/or designed to Buyer's specifications, infringes any United States patent issued as of the date of the proposal or contract provided Buyer gives to Seller immediate notice in writing of the institution of the suit or proceedings and permits Seller, through its Counsel, to defend the same and gives Seller all needed information, assistance and authority to enable Seller to do so. On any equipment or component manufactured by others, Seller shall pass through any patent indemnity offered by said manufacturer. Seller's liability shall be limited to rendering reasonable assistance to Buyer to enforce said indemnity, which term shall not be deemed to include the payment of any fees or expenses of Buyer's legal counsel or to require Seller to institute suit or to participate in any such litigation.

IMPLIED WARRANTIES AND DISCLAIMER

THE WARRANTIES FURNISHED BY SELLER AS EXPRESSLY INCLUDED HEREIN CONSTITUTE SELLER'S SOLE OBLIGATION HEREUNDER AND ARE IN LIEU OF ANY OTHER WARRANTIES, EXPRESSED OR IMPLIED, INCLUDING WITHOUT LIMITATION

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WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE, EVEN IN THE EVENT OF A FUNDAMENTAL BREACH BY SELLER. THERE ARE NO WARRANTIES, WHICH EXTEND BEYOND THE DESCRIPTION ON THE FACE HEREOF.

DISCLAIMER OF WARRANTIES
SELLER SHALL NOT BE LIABLE TO BUYER OR BUYER'S CUSTOMER FOR INCIDENTAL, CONSEQUENTIAL OR LIQUIDATED DAMAGES INCLUDING, BUT NOT LIMITED TO, LOSS OF PROFITS OR REVENUE, LOSS OF USE OF CONTRACT GOODS, COSTS OF REPLACEMENT POWER OR CONTRACT GOODS, ADDITIONAL EXPENSES INCURRED IN THE USE OF CONTRACT GOODS OR FACILITIES, OR THE CLAIMS OF THIRD PARTIES, EVEN IF SELLER HAS BEEN ADVISED OF POSSIBILITY OF SUCH DAMAGES. THIS DISCLAIMER SHALL APPLY TO INCIDENTAL, CONSEQUENTIAL OR LIQUIDATED DAMAGES BASED UPON ANY CAUSE OF ACTION WHATSOEVER ASSERTED AGAINST SELLER, INCLUDING ONE ARISING OUT OF PRINCIPLES OF CONTRACT, ANY BREACH OF WARRANTY, EXPRESSED OR IMPLIED, GUARANTEE, EQUIPMENT OR OTHER CONTRACT GOODS LIABILITY, NEGLIGENCE, TORT, OR ANY OTHER CAUSE PERTAINING TO PERFORMANCE OR NON-PERFORMANCE TO THE PROPOSAL OR CONTRACT BY SELLER. BUYER SHALL HOLD SELLER HARMLESS FROM ANY SUCH CLAIMS BY BUYER'S CUSTOMER.

INSPECTION

If upon receipt of the Contract Goods by Buyer, the same shall not conform to Buyer's order, Buyer shall notify Seller in writing within ten (10) days from receipt of the Contract Goods and before any part of the Contract Goods has been changed from its original condition. Such notification shall provide detailed information as to the nonconformity or shortage and Buyer shall hold the Contract Goods for Seller's disposition and afford Seller a reasonable opportunity to inspect the Contract Goods. Seller may, at its option, replace without charge, refund the purchase price, or make a fair allowance for defects or shortages demonstrated to Seller's satisfaction to have existed at the time of delivery. Seller may require the return of the Contract Goods to establish any claim but in no event shall Contract Goods be returned without Seller's consent.

LIMITATION OF LIABILITY OF SELLER
In addition to the other limitations on Seller's liability provided for herein, in no event will Seller's liability to Buyer for any and all claims, including property damage or personal injury claims, allegedly resulting from breach of contract, warranty, strict liability, tort, or any other theory of liability involving this proposal or contract exceed the amount of the purchase price paid to Seller.

PRICE

1. Prices are F.O.B. point of shipment.
2. Oral and written quotations are subject to acceptance within thirty (30) days from date.
3. Prices on equipment of Seller's manufacture are firm, provided it is shipped within the quoted and agreed upon shipment schedule. If Buyer causes shipment to be delayed Seller reserves the right to invoice at Seller's price effective at time of shipment.
4. Any excise, sales, use taxes or other taxes imposed by Federal, State, or municipal authority and incurred by Seller applicable to the material sold, shall be to Buyer's account and are in addition to the prices quoted, unless Buyer provides Seller with a proper tax-exemption certificate. Buyer hereby agrees to indemnify, defend and hold harmless Seller from any taxes, fines, penalties and costs, including attorneys' fees, incurred or paid by Seller arising out of any such claim of exemption. This defense and indemnity requirement shall survive this contract and any releases resulting from same.

TERMS
Terms of payment are in accordance with the proposed payment terms and are payable 30 days net from the date of invoice.
For late payment, Buyer is subject to a late charge of eighteen percent (18%) of the unpaid fees per annum (1.5% per month) or the maximum allowed by law, whichever is less.
If Seller does not receive payment in full for the Contract Goods and any monies otherwise due by the due date then Seller may, at its option at any time while the whole or any part of the monies due remain outstanding, take possession of the Contract Goods, or any part, delay or stop future deliveries, and terminate this agreement, in which case Seller is entitled to recover any loss, including loss of profit, which loss will carry interest under paragraph 2 of this Section.
Pro rata retainage fees or backcharges will not be accepted by Seller.
Buyer will be responsible for all expenses incurred from any collection proceedings.

DELIVERY

Delivery dates are estimated by Seller on the basis of the best available information and cannot be guaranteed.
Where Contract Goods are delivered in multiple deliveries, Seller may deem each delivery to be a separate contract, and no default or failure by Seller in respect of any one or more installments shall vitiate any contracts with respect to Contract Goods previously delivered or undelivered.

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Force Majeure – Seller shall not be liable for any loss or damage arising out of delay in shipment or delivery, or failure to manufacture, or failure of equipment to operate, due to causes beyond its reasonable control, such as but not limited to, Acts of God, Acts of Buyer, Acts of Civil or Military Authority, priorities, fires, strikes, floods, epidemics, quarantine restrictions, war, riot, delays in transportation, car shortages, and Seller's inability to obtain necessary labor, materials, or manufacturing facilities. In the event of any such delay, the date of delivery shall be extended for a period equal to the time lost by reason of the delay and Seller shall be entitled to an equitable adjustment in the sales price for increased costs incurred.

All risk of loss or damage to Contract Goods furnished hereunder shall pass to Buyer, F.O.B. point of shipment.

Seller reserves the right to ship all or any part of the Contract Goods from any shipping point of any of its sources of supply other than the shipping point specified herein. Shipment will be made by the method or carrier deemed most feasible by Seller unless otherwise requested in writing by Buyer.

GRANT OF SECURITY INTEREST

As security for the payment in full for the Contract Goods, as a condition of the passage of title to Buyer for the Contract Goods as provided for hereunder, Buyer grants to Seller a first priority security interest in the Contract Goods, wherever located, together with all Accounts, Products and Proceeds of any and all of the Contract Goods (as such terms are defined by the Uniform Commercial Code as from time to time in effect in any applicable jurisdiction). Upon default in payment by Buyer, Seller may exercise all rights of a Secured Party as provided for by the Uniform Commercial Code.

CANCELLATION

Cancellation of order by Buyer, or any part thereof, will not be effective unless accepted by Seller in writing. Accepted cancellation will be subject to a charge to cover all costs incurred to the date of acceptance, plus reasonable cancellation costs, plus profit on the completed work.

SUSPENSION

In the event Buyer suspends the execution of work, Buyer shall reimburse Seller for all costs incurred by Seller as a result of such suspension, including, without limitation, all borrowing and opportunity costs. In the event the suspension exceeds 180 days in duration, in addition to being entitled to full reimbursement of costs as aforesaid, Seller shall have the unqualified right to cancel the unfinished portion of the contract without liability to Buyer of any kind.

GENERAL CONDITIONS

1. Non-stock Contract Goods made specifically to order are not subject to return for credit. Any portion of non-stock Contract Goods in process of manufacture is not subject to cancellation. Any charges after manufacture has started could necessitate additional charges for work done and material consumed.
2. Quotations are merely negotiations to trade and not offers to contract.
3. Seller reserves the right to correct any factory, engineering, clerical and/or stenographic errors or omissions.
4. Changes in design are made at Seller's discretion. Seller has no obligation to incorporate these changes in units manufactured prior to the change.
5. It is expressly understood that any and all drawings, instructions, and/or technical and engineering services, which Seller may furnish with reference to the installation or use of its Contract Goods, are furnished solely for the review and approval of Buyer and its engineers. Seller makes no representation or warranty with respect to the accuracy or sufficiency of any such information and assumes no obligation or liability for results obtained.
6. Waiver by Seller of a breach of any of these Terms and Conditions shall not be construed as a waiver of any other breach.
7. To combat corrosion, abrasion, or erosion, or operation at elevated temperatures, any such recommendations will be based on the best available experience of Seller and the supplier of the material, BUT WILL NOT CONSTITUTE A GUARANTEE AGAINST THESE EFFECTS.

Appendix 1-B Thermal Non-Catalytic Cost Estimates

Table B-4. TBACT Control Technology Cost Estimate

Thermal Noncatalytic Oxidation

Stream S120 **HLW Melter Offgas Unabated**

Cost Item	Basis		Example Cost
Direct Costs			
Purchased Equipment Costs			
Equipment			$382,316.00
Required Ancillary Equipment			$0.00
Instrumentation and Control	15% of Equipment		$57,347.40
Freight	5% of Equipment		$19,115.80
Subtotal Purchased Equipment Costs (PEC)			$458,779.20
Direct Installation Costs			
Foundations & Supports	8% of Subtotal PEC		$36,702.34
Handling & Erection	14% of Subtotal PEC		$64,229.09
Electrical	4% of Subtotal PEC		$18,351.17
Piping and Duct Work	4% of Subtotal PEC		$18,351.17
Insulation for Piping & Equipment	4% of Subtotal PEC		$18,351.17
Painting	2% of Subtotal PEC		$9,175.58
Subtotal Installation Costs (IC)			$165,160.51
Site Preparation	Equipment Specific		$20,000.00
Building Costs	see cost factors below	equipment size	
C5 Location per square foot	$1,388/sf	66 sf	$91,608.00
Subtotal - Building (per highest applicable cost area)	Equipment Specific		$91,608.00
Total Direct Cost			$735,547.71
Indirect Costs (Installation)			
Engineering	10% of PEC		$45,877.92
Construction and Field Expenses	5% of PEC		$22,938.96
Start-up	10% of PEC		$45,877.92
Performance Tests	1% of PEC		$4,587.79
Contingencies	15% of PEC		$68,816.88
Total Indirect Costs			$188,099.47
Total Capital Costs (TCC)			$923,647.18

Source: Modified from EPA Handbook *Control Technologies for Hazardous Air Pollutants* (June 1991).

Table B-4. TBACT Control Technology Cost Estimate

Thermal Noncatalytic Oxidation

Stream S120 **HLW Melter Offgas Unabated**

Cost Item	Factor		Example Cost
Direct Annual Costs			
Utilities			
Electricity	$0.08/kWhr		$5,000.00
Steam	$6.00/1000 lb		$0.00
Water	$0.25/1000 gal.		$0.00
Materials/Chemicals			$52,013.00
Operating Expenses			
Operator	$20/Hr	52 hr	$1,040.00
Supervisor	15% of Operator		$156.00
Secondary Waste T&D	Process Specific		$100,000.00
Maintenance			
Labor	$17/Hr	24 hr/2 yr	$204.00
Materials	100% of Maintenance Labor		$204.00
Indirect Annual Costs			
Overhead	6% of Labor Costs		$840.00
Administrative	2% of TCC		$18,472.94
Insurance	1% of TCC		$9,236.47
Total Annual Costs (TAC)			$187,166.42
Rate of Return on Capital Investment	10.00%		
Service Life (years)	40		
Capital Recovery Factor	0.1023		
Annualized Capital Investment (ACI)			$94,451.62
Grand Total Annualized Costs	**ACI + TAC**		**$281,618.04**

Source: Modified from EPA Handbook *Control Technologies for Hazardous Air Pollutants* (June 1991).

Table B-4. TBACT Control Technology Cost Estimate
Thermal Noncatalytic Oxidation
Stream S74/S1 LPP LAW Melter Feed Evaporator

Cost Item	Basis		Example Cost
Direct Costs			
Purchased Equipment Costs			
Equipment			$427,609.00
Required Ancillary Equipment			$0.00
Instrumentation and Control	15% of Equipment		$64,141.35
Freight	5% of Equipment		$21,380.45
Subtotal Purchased Equipment Costs (PEC)			$513,130.80
Direct Installation Costs			
Foundations & Supports	8% of Subtotal PEC		$41,050.46
Handling & Erection	14% of Subtotal PEC		$71,838.31
Electrical	4% of Subtotal PEC		$20,525.23
Piping and Duct Work	4% of Subtotal PEC		$20,525.23
Insulation for Piping & Equipment	4% of Subtotal PEC		$20,525.23
Painting	2% of Subtotal PEC		$10,262.62
Subtotal Installation Costs (IC)			$184,727.09
Site Preparation	Equipment Specific		$20,000.00
Building Costs	see cost factors below	equipment size	
C5 Location per square foot	$1,388/sf	88 sf	$122,144.00
Subtotal - Building (per highest applicable cost area)	Equipment Specific		$122,144.00
Total Direct Cost			$840,001.89
Indirect Costs (Installation)			
Engineering	10% of PEC		$51,313.08
Construction and Field Expenses	5% of PEC		$25,656.54
Start-up	10% of PEC		$51,313.08
Performance Tests	1% of PEC		$5,131.31
Contingencies	15% of PEC		$76,969.62
Total Indirect Costs			$210,383.63
Total Capital Costs (TCC)			$1,050,385.52

Source: Modified from EPA Handbook *Control Technologies for Hazardous Air Pollutants* (June 1991).

Table B-4. TBACT Control Technology Cost Estimate

Thermal Noncatalytic Oxidation

Stream S41Z **PT Vessel Vents Unabated**

Cost Item	Basis		Example Cost
Direct Costs			
Purchased Equipment Costs			
Equipment			$393,515.00
Required Ancillary Equipment			$0.00
Instrumentation and Control	15% of Equipment		$59,027.25
Freight	5% of Equipment		$19,675.75
Subtotal Purchased Equipment Costs (PEC)			$472,218.00
Direct Installation Costs			
Foundations & Supports	8% of Subtotal PEC		$37,777.44
Handling & Erection	14% of Subtotal PEC		$66,110.52
Electrical	4% of Subtotal PEC		$18,888.72
Piping and Duct Work	4% of Subtotal PEC		$18,888.72
Insulation for Piping & Equipment	4% of Subtotal PEC		$18,888.72
Painting	2% of Subtotal PEC		$9,444.36
Subtotal Installation Costs (IC)			$169,998.48
Site Preparation	Equipment Specific		$20,000.00
Building Costs	see cost factors below	equipment size	
C5 Location per square foot	$1,388/sf	66 sf	$91,608.00
Subtotal - Building (per highest applicable cost area)	Equipment Specific		$91,608.00
Total Direct Cost			$753,824.48
Indirect Costs (Installation)			
Engineering	10% of PEC		$47,221.80
Construction and Field Expenses	5% of PEC		$23,610.90
Start-up	10% of PEC		$47,221.80
Performance Tests	1% of PEC		$4,722.18
Contingencies	15% of PEC		$70,832.70
Total Indirect Costs			$193,609.38
Total Capital Costs (TCC)			$947,433.86

Source: Modified from EPA Handbook *Control Technologies for Hazardous Air Pollutants* (June 1991).

Table B-4. TBACT Control Technology Cost Estimate
Thermal Noncatalytic Oxidation
Stream S74/S1 LPP LAW Melter Feed Evaporator

Cost Item	Factor		Example Cost
Direct Annual Costs			
Utilities			
Electricity	$0.08/kWhr		$5,000.00
Steam	$6.00/1000 lb		$0.00
Water	$0.25/1000 gal.		$0.00
Materials/Chemicals			$74,019.00
Operating Expenses			
Operator	$20/Hr	52 hr	$1,040.00
Supervisor	15% of Operator		$156.00
Secondary Waste T&D	Process Specific		$100,000.00
Maintenance			
Labor	$17/Hr	24 hr/2 yr	$204.00
Materials	100% of Maintenance Labor		$204.00
Indirect Annual Costs			
Overhead	6% of Labor Costs		$840.00
Administrative	2% of TCC		$21,007.71
Insurance	1% of TCC		$10,503.86
Total Annual Costs (TAC)			$212,974.57
Rate of Return on Capital Investment	10.00%		
Service Life (years)	40		
Capital Recovery Factor	0.1023		
Annualized Capital Investment (ACI)			$107,411.81
Grand Total Annualized Costs	**ACI + TAC**		**$320,386.37**

Source: Modified from EPA Handbook *Control Technologies for Hazardous Air Pollutants* (June 1991).

Table B-4. TBACT Control Technology Cost Estimate
Thermal Noncatalytic Oxidation
Stream S41Z **PT Vessel Vents Unabated**

Cost Item	Basis		Example Cost
Direct Costs			
Purchased Equipment Costs			
Equipment			$393,515.00
Required Ancillary Equipment			$0.00
Instrumentation and Control	15% of Equipment		$59,027.25
Freight	5% of Equipment		$19,675.75
Subtotal Purchased Equipment Costs (PEC)			$472,218.00
Direct Installation Costs			
Foundations & Supports	8% of Subtotal PEC		$37,777.44
Handling & Erection	14% of Subtotal PEC		$66,110.52
Electrical	4% of Subtotal PEC		$18,888.72
Piping and Duct Work	4% of Subtotal PEC		$18,888.72
Insulation for Piping & Equipment	4% of Subtotal PEC		$18,888.72
Painting	2% of Subtotal PEC		$9,444.36
Subtotal Installation Costs (IC)			$169,998.48
Site Preparation	Equipment Specific		$20,000.00
Building Costs	see cost factors below	equipment size	
C5 Location per square foot	$1,388/sf	66 sf	$91,608.00
Subtotal - Building (per highest applicable cost area)	Equipment Specific		$91,608.00
Total Direct Cost			$753,824.48
Indirect Costs (Installation)			
Engineering	10% of PEC		$47,221.80
Construction and Field Expenses	5% of PEC		$23,610.90
Start-up	10% of PEC		$47,221.80
Performance Tests	1% of PEC		$4,722.18
Contingencies	15% of PEC		$70,832.70
Total Indirect Costs			$193,609.38
Total Capital Costs (TCC)			$947,433.86

Source: Modified from EPA Handbook *Control Technologies for Hazardous Air Pollutants* (June 1991).

Table B-4. TBACT Control Technology Cost Estimate
Thermal Noncatalytic Oxidation
Stream S41Z **PT Vessel Vents Unabated**

Cost Item	Factor		Example Cost
Direct Annual Costs			
Utilities			
Electricity	$0.08/kWhr		$5,000.00
Steam	$6.00/1000 lb		$0.00
Water	$0.25/1000 gal.		$0.00
Materials/Chemicals			$52,013.00
Operating Expenses			
Operator	$20/Hr	52 hr	$1,040.00
Supervisor	15% of Operator		$156.00
Secondary Waste T&D	Process Specific		$0.00
Maintenance			
Labor	$17/Hr	24 hr/2 yr	$204.00
Materials	100% of Maintenance Labor		$204.00
Indirect Annual Costs			
Overhead	6% of Labor Costs		$840.00
Administrative	2% of TCC		$18,948.68
Insurance	1% of TCC		$9,474.34
Total Annual Costs (TAC)			$87,880.02
Rate of Return on Capital Investment	10.00%		
Service Life (years)	40		
Capital Recovery Factor	0.1023		
Annualized Capital Investment (ACI)			$96,884.03
Grand Total Annualized Costs	**ACI + TAC**		**$184,764.05**

Source: Modified from EPA Handbook *Control Technologies for Hazardous Air Pollutants* (June 1991).

TCI-TI2 DST AN or AW 70% HR

TCI-TI2 DST Recup TO-VOC

TOTAL ANNUAL COST SPREADSHEET PROGRAM--THERMAL INCINERATOR		70% Heat Recovery	
COST BASE DATE: April 1988 [1]			
VAPCCI (Third Quarter 2003--PRELIMINARY): [2]	109.9	From Chemical Engineering	
	INPUT PARAMETERS	COMMENTS	
-- Gas flowrate (scfm):	4,000		
-- Reference temperature (oF):	70		
-- Inlet gas temperature (oF):	170		
-- Inlet gas density (lb/scf):	0.0749		
-- Primary heat recovery (fraction):	0.70		
-- Waste gas heat content (BTU/scf):	0.018		
-- Waste gas heat content (BTU/lb):	0.24		
-- Gas heat capacity (BTU/lb-oF):	0.255		
-- Combustion temperature (oF):	1,600		
-- Preheat temperature (oF):	1,171		
-- Fuel heat of combustion (BTU/lb):	22,886	Adjusted for representative natural gas.	
-- Fuel density (lb/ft3):	0.0452	Adjusted for representative natural gas.	
	DESIGN PARAMETERS		
-- Auxiliary Fuel Reqrmnt (lb/min):	1.979		
(scfm):	43.8		
-- Total Gas Flowrate (scfm):	4,044		
	CAPITAL COSTS		
Equipment Costs ($):			
-- Incinerator:			
@ 0 % heat recovery:	0		
@ 35 % heat recovery:	0		
@ 50 % heat recovery:	0		
@ 70 % heat recovery:	170,189		
-- Other (auxiliary equipment, etc.):	0		
Total Equipment Cost--base:	170,189		
' ' ' --escalated:	233,945		
Purchased Equipment Cost ($):	252,661	This is sent to the "TCI Adjust" sheet as the equipment value.	
No. of Tanks over life of oxidizer	1		
Total Capital Investment ($):	1,544,539	This is the total TCI for all tanks, based on the number of installations and the TCI values from the "TCI Adjust" sheet.	
==========	==========	==========	
	ANNUAL COST INPUTS		
Operating factor (hr/yr):	8,760		
Operating labor rate ($/hr):	51.58		
Maintenance labor rate ($/hr):	50.78		
Operating labor factor (hr/sh):	0.0		
Maintenance labor factor (hr/sh):	0.5		
Electricity price ($/kwh):	0.080		
Natural gas price ($/mscf):	5.00		
Annual interest rate (fraction):	0.07		
Control system life (years):	11		
Capital recovery factor:	0.1334		

Page 1 of 3

5/3/2004

TCI-TI2 DST AN or AW 70% HR

TCI-TI2 DST Recup TO-VOC

Taxes, insurance, admin. factor:		0.04			
Pressure drop (in. w.c.):		19.0			
	ANNUAL COSTS				
Item		Cost ($/yr)	Wt. Factor	W.F.(cond.)	
Operating labor		0	0.000	----	
Supervisory labor		0	0.000	----	
Maintenance labor		27,802	0.058	----	
Maintenance materials		27,802	0.058	----	
Natural gas		115,089	0.239	----	
Electricity		10,500	0.022	----	
Overhead		33,362	0.069	0.184	
Taxes, insurance, administrative		61,782	0.128	----	
Capital recovery		205,975	0.427	0.555	
Total Annual Cost		482,312	1.000	1.000	

[1] Original equipment costs reflect this date.
[2] VAPCCI = Vatavuk Air Pollution Control Cost Index (for thermal incinerators) corresponding to year and quarter shown. Original equipment cost, purchased equipment cost, and total capital investment have been escalated to this data via the VAPCCI and control equipment vendor data.

Total Unabated VOC Emissions =	0.96	For AN or AW individually
Emission Control Efficiency =	99.00%	
Total Abated VOC Emissions =	0.9504	
Cost-Effectiveness, $/ton =	$507,483	

Heat Recovery	Cost-Effect	TCI	Total Annual Cost	Annual VOC Reduced, tons
	507,483	1,544,539	482,312	0.9504
0.70	507,483	1,544,539	482,312	0.9504
0.50	506,606	1,238,126	481,479	0.9504
0.35	514,211	1,044,408	488,706	0.9504
0.00	547,353	663,548	520,204	0.9504

TCI-TI2 70% HR AN or AW

TCI-TI2 DST TO-All TAPs

TOTAL ANNUAL COST SPREADSHEET PROGRAM--THERMAL INCINERATOR 70% Heat Recovery			
COST BASE DATE: April 1988 [1]			
VAPCCI (Third Quarter 2003--PRELIMINARY): [2]	109.9	From Chemical Engineering	
INPUT PARAMETERS		COMMENTS	
-- Gas flowrate (scfm):	4,000		
-- Reference temperature (oF):	70		
-- Inlet gas temperature (oF):	170		
-- Inlet gas density (lb/scf):	0.0749		
-- Primary heat recovery (fraction):	0.70		
-- Waste gas heat content (BTU/scf):	0.018		
-- Waste gas heat content (BTU/lb):	0.24		
-- Gas heat capacity (BTU/lb-oF):	0.255		
-- Combustion temperature (oF):	1,800		
-- Preheat temperature (oF):	1,311		
-- Fuel heat of combustion (BTU/lb):	22,886	Adjusted for representative natural gas.	
-- Fuel density (lb/ft3):	0.0452	Adjusted for representative natural gas.	
DESIGN PARAMETERS			
		Fuel Input (MMBtuh), LHV Basis	
-- Auxiliary Fuel Reqrmnt (lb/min):	2.258		
(scfm):	49.9	2.80	
-- Total Gas Flowrate (scfm):	4,050		
CAPITAL COSTS			
Equipment Costs ($):			
-- Incinerator:			
@ 0 % heat recovery:	0		
@ 35 % heat recovery:	0		
@ 50 % heat recovery:	0		
@ 70 % heat recovery:	170,254		
-- Other (auxiliary equipment, etc.):	0		
Total Equipment Cost--base:	170,254		
' ' ' --escalated:	234,034		
Purchased Equipment Cost ($):	252,757	This is sent to the "TCI Adjust" sheet as the equipment value.	
No. of Tanks over life of System	1		
Total Capital Investment ($):	1,545,126	This is the total TCI for all tanks, based on the number of installations and the TCI values from the "TCI Adjust" sheet.	
==========	==========	==========	
ANNUAL COST INPUTS			
Operating factor (hr/yr):	8,760		
Operating labor rate ($/hr):	51.58		
Maintenance labor rate ($/hr):	50.78		
Operating labor factor (hr/sh):	0.0		
Maintenance labor factor (hr/sh):	0.5		
Electricity price ($/kwh):	0.080		
Natural gas price ($/mscf):	5.00		
Annual interest rate (fraction):	0.07		
Control system life (years):	11	From series in Chemical Engineering by Vatavuk/EPA for thermal oxidizers.	
Capital recovery factor:	0.1334		

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5/25/2004

TCI-TI2 70% HR AN or AW

TCI-TI2 DST TO-All TAPs

Taxes, insurance, admin. factor:		0.04			
Pressure drop (in. w.c.):		19.0			
	ANNUAL COSTS				
Item		Cost ($/yr)	Wt. Factor	W.F.(cond.)	
Operating labor		0	0.000	----	
Supervisory labor		0	0.000	----	
Maintenance labor		27,802	0.056	----	
Maintenance materials		27,802	0.056	----	
Natural gas		131,263	0.263	----	
Electricity		10,516	0.021	----	
Overhead		33,362	0.067	0.178	
Taxes, insurance, administrative		61,805	0.124	----	
Capital recovery		206,053	0.413	0.537	
Total Annual Cost		498,604	1.000	1.000	

[1] Original equipment costs reflect this date.
[2] VAPCCI = Vatavuk Air Pollution Control Cost Index (for thermal incinerators) corresponding to year and quarter shown. Original equipment cost, purchased equipment cost, and total capital investment have been escalated to this data via the VAPCCI and control equipment vendor data.

	Non-NH3	NH3	Total TAP
Total Unabated Emissions =	0.96	0.96	1.92
Emission Control Efficiency =	99.00%	99.00%	
Total Abated Emissions =	0.95	0.95	1.90
Cost-Effectiveness, $/ton =	$524,625	$524,625	$262,313

Heat Recovery	Cost-Effect	TCI	Total Annual Cost	Annual TAP Reduced, tons
	262,313	1,545,126	498,604	1.90
0.70	262,313	1,545,126	498,604	1.90
0.50	266,137	1,238,828	505,873	1.90
0.35	273,134	1,045,178	519,174	1.90
0.00	297,137	664,189	564,797	1.90

Appendix 1-C Adsorber Costs

NUCON International, Inc
7000 Huntley Road
Columbus, OH 43229

Phone: 614-846-5710
Fx: 614-431-0858
www.nucon-int.com

QUOTATION/PROPOSAL

Proposal No.:	12328	Date:	12 Apr 10
Attachments:	Vessel Description Adsorbent data sheet	Exp. Date:	12June 10

Name:	Phone:	Fax:	Email:

Company: Columbia Nuclear International LLC
Address:

Ref	Description	Qty.	Unit Price	Total Price
	Adsorber vessel per attached description with 11,000 lbs of NUCON MERSORB 3 Mercury Adsorbent	lot	$247,000	$247,000
	Terms: Net 30 days			
	Shipment: 20 weeks after drawing approval			
	FOB: Columbus, OH			
			Total	$247,000

Please Contact:	Joe Enneking	Phone Ext.: 111	Email: joe.enneking@nucon-int.com

Form: FP-24 (2004-11-10)

Date: 24-Feb-10

NUCON International, Inc.

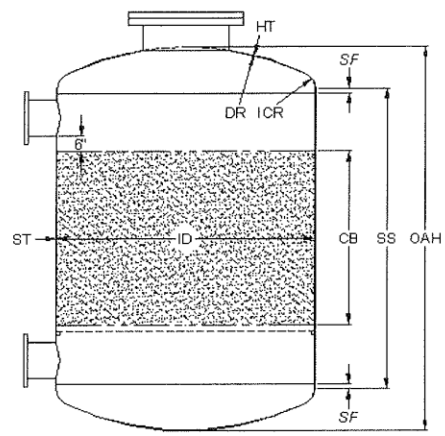
7000 Huntley Road, Columbus OH 43229

Phone: 614-846-5710 FAX: 614-431-0858 Internet: www.nucon-int.com

Preliminary Design for a Vertical Adsorber with ASME Flanged & Dished Heads

Client: Hanford Hg Adsorber

Fluid Properties:	
Fluid flow rate, lb.hr	9150
Fluid pressure, psia (Ref. only)	14.7
Fluid temp., °F (Ref, only)	167
Average mol. wt.(Ref. only)	28.966
Viscosity, Centipoise	0.0209
Fluid actual density, lb/cu ft	0.050754
Compressibility factor (Ref. only)	
Dew Point, °F (Ref only)	50
Vessel Design:	
Material (CS or SS)	ss
Diameter, ft	10.0
Design Temp, °F	200
Design Pressure, psig	15
Corrosion allowance, in.	
Joint efficiency	1
Activated Carbon:	
Pellet diameter, mm.	3
Carbon weight,, lb	11000
Carbon bulk density, lb/cu ft	35
Calculations:	
Inlet & outlet nozzles, in.	14
Carbon volume, cu ft	314
Carbon depth, ft	4.0
Carbon depth. in.	48
Design stress, psi	16700
Shell thickness, in	3/16
Head thickness, in	3/16
Cylinder length, inches	90
Over all vessel height, ft	10.9
Total steel weight, lb	3969
Flow area, sq ft	79
Superficial velocity, ft/min	38.26
Superficial velocity, ft/sec	0.64
Total Flow,acfm	3005
Mass velocity, lb/hr/sq ft	117
Empty Bed Contact Time, sec	6
Delta P, "WG/ft	0.66
Total Bed Delta P, "WG	2.63
Total Bed Delta P, psi	0.10



VESSEL SKETCH IS NOT TO SCALE

All Dimensions in Inches

CB =	48
DR =	120
HT =	3/16
ICR =	7.3
ID =	120
OAH =	131
SF =	1 1/2
SS =	90
ST =	3/16

Beta Version 1.07

PROJECT RESPONSIBILITY Proposal 13238

The following project responsibility matrix is the basis for this proposal. Any changes in scope may result in price adjustments.

ACTIVITY		RESPONSIBILITY	
		NUCON	CLIENT
5.1	ENGINEERING AND DESIGN		
5.1.1	Verification of design data - operational flow rates, adsorbate compositions, etc.		X
5.1.2	Equipment specifications	X	
5.1.3	Electrical engineering	N/A	
5.1.4	Fire protection & safety engineering		X
5.1.5	Process engineering	X	
5.1.6	Mechanical engineering	X	
5.1.7	Insulation specifications	X	
5.1.8	Software validation (when required)	N/A	
5.1.9	Process review of vendor drawings	X	
5.1.10	Dimensional review of vendor drawings	X	
5.1.11	Safety review (pre-shipment)	X	
5.1.12	Control system engineering	N/A	
5.1.13	Heat and material balance flow sheet	N/A	
5.1.14	Design criteria		X
5.1.15	Instrument loop diagrams	N/A	
5.1.16	Piping and instrumentation diagram	X	
5.1.17	Construction drawings (civil and foundation)		X
5.1.18	Demolition drawings (civil and foundation)		X
5.1.19	Drawing revisions and updates	X	
5.1.20	System layout drawings	X	
5.1.21	Equipment arrangements drawings	X	

ACTIVITY		RESPONSIBILITY	
		NUCON	CLIENT
5.1.22	Process flow diagrams	X	
5.1.23	Piping schedule (line list)	X	
5.1.24	Instrument specifications	N/A	
5.2	PROCUREMENT		
5.2.1	Process equipment procurement	X	
5.2.2	Process Safety equipment procurement	N/A	
5.2.3	Shop inspection	X	
5.2.4	Receiving/storing/warehousing	X	
5.2.5	Expediting	X	
5.2.6	Fire protection equipment procurement		X
5.2.7	Handling and distribution of vendor drawings	X	
5.2.8	Spare parts		X
5.2.9	Quality Assurance	X	
5.3	FIELD CONSTRUCTION		
5.3.1	Site studies and preparation		X
5.3.2	Demolition		X
5.3.3	Construction specifications		X
5.3.4	Construction contracts		X
5.3.5	Equipment/materials protection		X
5.3.6	Insulation shop installed at NUCON	X	
5.3.7	Insulation field installed on-site		X
5.3.8	Field construction management and supervision		X
5.3.9	Field inspection		X
5.3.10	On-site space and services for NUCON personnel		X

ACTIVITY		RESPONSIBILITY	
		NUCON	CLIENT
5.4	UTILITIES		
5.4.1	Electrical power		X
5.4.2	MCC		X
5.4.3	Steam (Not applicable this Proposal)		
5.4.4	Cooling water		X
5.4.5	Chilled water		X
5.4.6	Plant compressed air		X
5.4.7	Instrument air		X
5.4.8	Nitrogen		X
5.4.9	Process Control Computer	N/A	
5.5	PROJECT CONTROL & MONITORING		
5.5.1	Project management	X	
5.5.2	Scheduling	X	
5.5.3	Progress/status reporting	X	
5.6	OPERATIONS		
5.6.1	Commissioning Technical Assistance	X	
5.6.2	Start-up Technical Assistance	X	
5.6.3	Pre-operational safety check		X

NUCON International, Inc.

P.O. BOX 29151 7000 HUNTLEY ROAD
COLUMBUS, OHIO 43229 U.S.A.

TELEPHONE: (614) 846-5710
FAX: (614) 431-0858
WEB SITE: www.nucon-int.com

Technical Data Sheet:
MERSORB®-3 (2005/03)

NUSORB® MERSORB®-3

TYPICAL APPLICATIONS: **Mercury control**

RAW MATERIAL:	Coal
ACTIVATION METHOD:	High Temperature Steam
PARTICLE TYPE:	Pellet
IMPREGNANT:	Sulfur

PHYSICAL PROPERTIES:

APPARENT DENSITY	(ASTM D2854)	0.55 g/ml, Typical
HARDNESS	ASTM D3802)	98 % Typical
ASH	(ASTM D2866)	10 wt %Typical
MOISTURE CONTENT, as packaged	(ASTM D2867)	5 % Maximum
PARTICLE SIZE,		3 mm Diameter
CARBON TETRACHLORIDE ACTIVITY	(ASTM D3467)	60 % Minimum
SULFUR CONTENT		13 % Typical

Additional ASTM or custom testing available on request

PACKAGING: Square fiber drums (150 pounds) or "tote bags"(1,000 pounds)

Information herein is accurate to the best of our knowledge. User should determine the suitability of the product for the intended use; liability consists of replacing product. NUCON INTERNATIONAL, INC., does not suggest violation of any existing patents or give permission to practice any patented invention without a license.

For additional information contact:

NUCON International, Inc,
7000 Huntley Road, Columbus, OH 43229, USA
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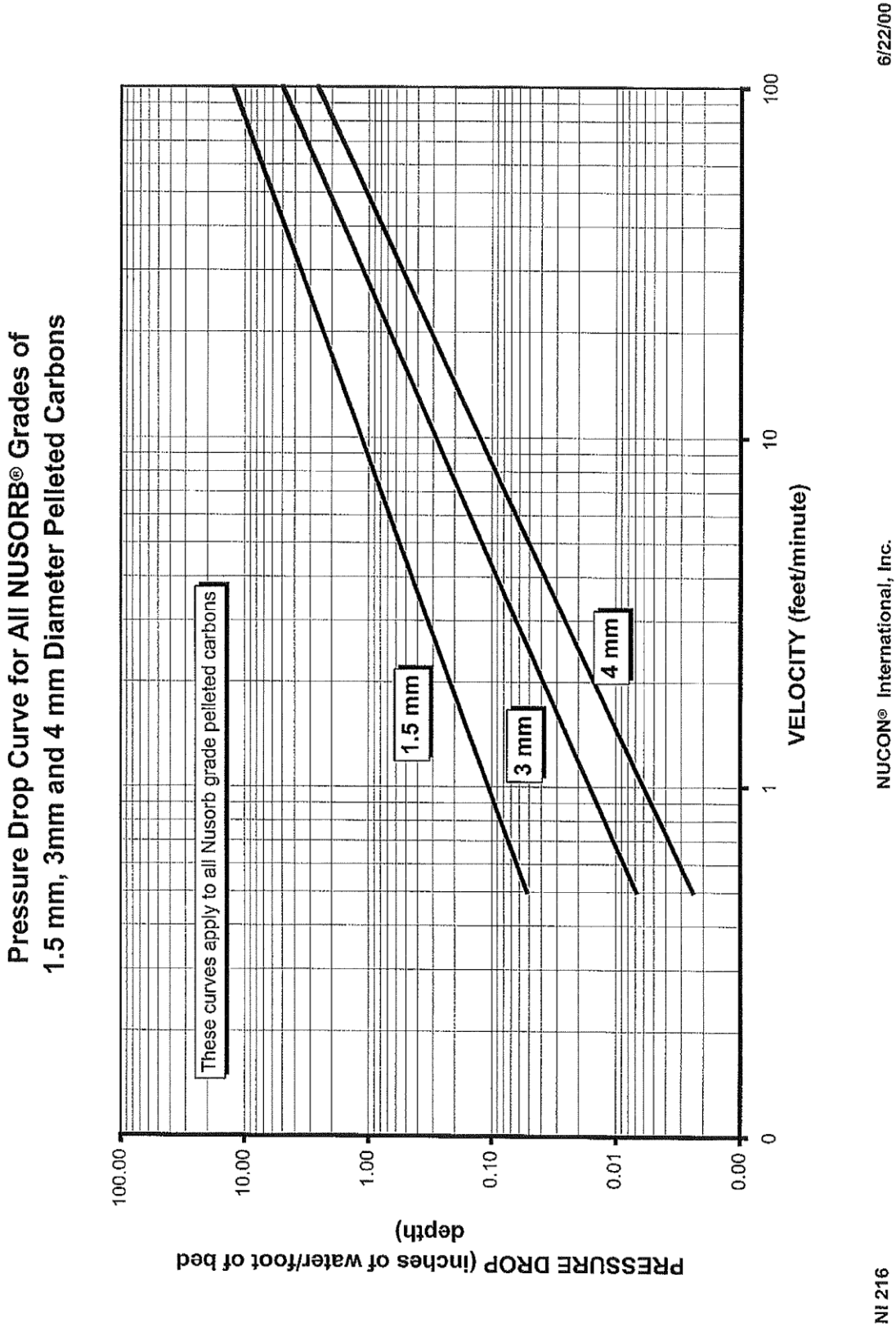

Pressure Drop Curve for All NUSORB® Grades of
1.5 mm, 3mm and 4 mm Diameter Pelleted Carbons
These curves apply to all Nusorb grade pelleted carbons
1.5 mm
3 mm
4 mm
PRESSURE DROP (inches of water/foot of bed depth)
100.00
10.00
1.00
0.10
0.01
0.00
0
1
10
100
VELOCITY (feet/minute)
NUCON® International, Inc.
6/22/00
NI 216

Table B-4. TBACT Control Technology Cost Estimate
Activated Carbon Adsorber
Stream S120 **HLW Melter Offgas Unabated**

Cost Item	Basis		Example Cost
Direct Costs			
Purchased Equipment Costs			
Equipment			$1,977,962.00
Required Ancillary Equipment ($10/cfm)			$23,000.00
Instrumentation and Control	15% of Equipment		$296,694.30
Freight	5% of Equipment		$98,898.10
Subtotal Purchased Equipment Costs (PEC)			$2,396,554.40
Direct Installation Costs			
Foundations & Supports	8% of Subtotal PEC		$191,724.35
Handling & Erection	14% of Subtotal PEC		$335,517.62
Electrical	4% of Subtotal PEC		$95,862.18
Piping and Duct Work	4% of Subtotal PEC		$95,862.18
Insulation for Piping & Equipment	4% of Subtotal PEC		$95,862.18
Painting	2% of Subtotal PEC		$47,931.09
Subtotal Installation Costs (IC)			$862,759.58
Site Preparation	Equipment Specific		$20,000.00
Building Costs	see cost factors below	equipment size	
C5 Location per square foot	$1,388/sf	52 sf	$72,176.00
Subtotal - Building (per highest applicable cost area)	Equipment Specific		$72,176.00
Total Direct Cost			$3,351,489.98
Indirect Costs (Installation)			
Engineering	10% of PEC		$239,655.44
Construction and Field Expenses	5% of PEC		$119,827.72
Start-up	10% of PEC		$239,655.44
Performance Tests	1% of PEC		$23,965.54
Contingencies	15% of PEC		$359,483.16
Total Indirect Costs			$982,587.30
Total Capital Costs (TCC)			$4,334,077.29

Source: Modified from EPA Handbook *Control Technologies for Hazardous Air Pollutants* (June 1991).

Table B-4. TBACT Control Technology Cost Estimate
Activated Carbon Adsorber
Stream S120 **HLW Melter Offgas Unabated**

Cost Item	Factor		Example Cost
Direct Annual Costs			
Utilities			
Electricity	$0.08/kWhr		$0.00
Steam	$6.00/1000 lb		$0.00
Water	$0.25/1000 gal.		$0.00
Materials/Chemicals	Process Specific		$0.00
Operating Expenses			
Operator	$20/Hr	52 hr	$1,040.00
Supervisor	15% of Operator		$156.00
Secondary Waste T&D	184 cf/yr x $129.24/cf		$23,780.16
Maintenance			
Labor	$17/Hr	72 hr/2 yr	$612.00
Materials	5,520 lbs/yr		$5,520.00
Indirect Annual Costs			
Overhead	6% of Labor Costs		$1,084.80
Administrative	2% of TCC		$86,681.55
Insurance	1% of TCC		$43,340.77
Total Annual Costs (TAC)			$162,215.28
Rate of Return on Capital Investment	10.00%		
Service Life (years)	40		
Capital Recovery Factor	0.1023		
Annualized Capital Investment (ACI)			$443,200.21
Grand Total Annualized Costs	**ACI + TAC**		**$605,415.48**

Source: Modified from EPA Handbook *Control Technologies for Hazardous Air Pollutants* (June 1991).

Table B-4. TBACT Control Technology Cost Estimate
Activated Carbon Adsorber
Stream S74/S1 LPP LAW Melter Feed Evaporator

Cost Item	Factor		Example Cost
Direct Annual Costs			
Utilities			
Electricity	$0.08/kWhr		$0.00
Steam	$6.00/1000 lb		$0.00
Water	$0.25/1000 gal.		$0.00
Materials/Chemicals	Process Specific		$0.00
Operating Expenses			
Operator	$20/Hr	52 hr	$1,040.00
Supervisor	15% of Operator		$156.00
Secondary Waste T&D	296 cf/yr x $129.24/cf		$38,255.04
Maintenance			
Labor	$17/Hr	72 hr/2 yr	$612.00
Materials	5,520 lbs/yr		$10,000.00
Indirect Annual Costs			
Overhead	6% of Labor Costs		$1,084.80
Administrative	2% of TCC		$115,524.16
Insurance	1% of TCC		$57,762.08
Total Annual Costs (TAC)			$224,434.08
Rate of Return on Capital Investment	10.00%		
Service Life (years)	40		
Capital Recovery Factor	0.1023		
Annualized Capital Investment (ACI)			$590,671.66
Grand Total Annualized Costs	**ACI + TAC**		**$815,105.74**

Source: Modified from EPA Handbook *Control Technologies for Hazardous Air Pollutants* (June 1991).

Table B-4. TBACT Control Technology Cost Estimate

Activated Carbon Adsorber

Stream S41Z **PT Vessel Vents Unabated**

Cost Item	Basis		Example Cost
Direct Costs			
Purchased Equipment Costs			
Equipment			$2,128,949.00
Required Ancillary Equipment ($10/cfm)			$26,000.00
Instrumentation and Control	15% of Equipment		$319,342.35
Freight	5% of Equipment		$106,447.45
Subtotal Purchased Equipment Costs (PEC)			$2,580,738.80
Direct Installation Costs			
Foundations & Supports	8% of Subtotal PEC		$206,459.10
Handling & Erection	14% of Subtotal PEC		$361,303.43
Electrical	4% of Subtotal PEC		$103,229.55
Piping and Duct Work	4% of Subtotal PEC		$103,229.55
Insulation for Piping & Equipment	4% of Subtotal PEC		$103,229.55
Painting	2% of Subtotal PEC		$51,614.78
Subtotal Installation Costs (IC)			$929,065.97
Site Preparation	Equipment Specific		$20,000.00
Building Costs	see cost factors below	equipment size	
C5 Location per square foot	$1,388/sf	52 sf	$72,176.00
Subtotal - Building (per highest applicable cost area)	Equipment Specific		$72,176.00
Total Direct Cost			$3,601,980.77
Indirect Costs (Installation)			
Engineering	10% of PEC		$258,073.88
Construction and Field Expenses	5% of PEC		$129,036.94
Start-up	10% of PEC		$258,073.88
Performance Tests	1% of PEC		$25,807.39
Contingencies	15% of PEC		$387,110.82
Total Indirect Costs			$1,058,102.91
Total Capital Costs (TCC)			$4,660,083.68

Source: Modified from EPA Handbook *Control Technologies for Hazardous Air Pollutants* (June 1991).

Table B-4. TBACT Control Technology Cost Estimate
Activated Carbon Adsorber
Stream S41Z **PT Vessel Vents Unabated**

Cost Item	Factor		Example Cost
Direct Annual Costs			
Utilities			
Electricity	$0.08/kWhr		$0.00
Steam	$6.00/1000 lb		$0.00
Water	$0.25/1000 gal.		$0.00
Materials/Chemicals	Process Specific		$0.00
Operating Expenses			
Operator	$20/Hr	52 hr	$1,040.00
Supervisor	15% of Operator		$156.00
Secondary Waste T&D	208 cf/yr x $129.24/cf		$26,881.92
Maintenance			
Labor	$17/Hr	72 hr/2 yr	$612.00
Materials	6240 lbs/yr		$6,240.00
Indirect Annual Costs			
Overhead	6% of Labor Costs		$1,084.80
Administrative	2% of TCC		$93,201.67
Insurance	1% of TCC		$46,600.84
Total Annual Costs (TAC)			$175,817.23
Rate of Return on Capital Investment	10.00%		
Service Life (years)	40		
Capital Recovery Factor	0.1023		
Annualized Capital Investment (ACI)			$476,537.43
Grand Total Annualized Costs	**ACI + TAC**		**$652,354.66**

Source: Modified from EPA Handbook *Control Technologies for Hazardous Air Pollutants* (June 1991).

TOTAL ANNUAL COST SPREADSHEET PROGRAM--CARBON ADSORBERS [1]							
COST BASE DATE: Third Quarter 1989 [2]							
VAPCCI (Third Quarter 2003--PRELIMINARY): [3]			113.8				
INPUT PARAMETERS:							
-- Inlet stream flowrate (acfm):			4,988				
-- Inlet stream temperature (oF):			120				
-- Inlet stream pressure (atm):			1				
-- VOC to be condensed:			Mix of volatile organics (primarily)				
-- Inlet VOC flowrate (lb/hr):			0.22	Annual average.			
-- VOC molecular weight (lb/lb-mole):			80.00				
-- VOC inlet volume fraction:			3.9E-06				
-- VOC inlet concentration (ppmv):			3.9				
-- VOC inlet partial pressure (psia):			0.000057				
-- Required VOC removal (fraction):			0.98				
-- Freundlich isotherm equation constants for VOC (see Table 1 below):							
	VOC number (enter Table 1 # or zero, if no data):		0				
		K:	0.000				
		M:	0.000				
-- Yaws isotherm equation constants (see Table 2 below):							
	VOC number (enter Table 2 #or zero, if no data):		0				
			0.00000				
			0.00000				
			0.00000				
-- Adsorption time (hr):			8.0				
-- Desorption time (hr):			4.0				
-- Number of adsorbing vessels:			1				
-- Superficial carbon bed velocity (ft/min):			75				
-- Carbon price ($/lb):			2.00				
-- Material of construction (see list below):[4]			1.3				
		DESIGN PARAMETERS:					
-- Carbon equilibrium capacity--Freundlich (lb VOC/lb carb):			0.0000	Void for this project.			
" " " -- Yaws et al " " " "			0.0000	Void for this project.			
-- Carbon working capacity (lb VOC/lb carbon):			0.3241	Linked to "Carbon Capacity Estimate" sheet.			
-- Number of desorbing vessels:			1				
-- Total number of vessels:			2				
-- Carbon requirement, total (lb):			11				
-- Carbon requirement per vessel (lb):			5				
-- Gas flowrate per vessel (acfm):			4988				
-- Adsorber vessel diameter (ft):			9.202				
-- Adsorber vessel length (ft):			4.003				
-- Adsorber vessel surface area (ft2):			248.73				
-- Carbon bed thickness (ft):			0.003				
-- Carbon bed pressure drop (in. w.c.): [5]			0.009				
		CAPITAL COSTS			Accessories		
Equipment Costs ($):				Item	Cost	Comments	
-- Adsorber vessels			51,501	HX for cooling and dehumid	178,000	Hudson Products software	
-- Carbon			22	HX fan, duct, damper, and temp control			
-- Other equipment (condenser, decanter, etc.)			58,636	Heating coil with temp control			
Total equipment cost ($)--base:			96,627				
" " " " --escalated:			121,948				
Purchased Equipment Cost ($):			131,704				
Accessories			178,000	Total	178,000		
PEC, with Accessories			309,704				
No. of Tanks over life of unit			1				
Total Capital Investment ($):			1,456,281				
" " " ($/acfm):			292.0				
		ANNUAL COST INPUTS:					
Operating factor (hr/yr):		8760					
Operating labor rate ($/hr):		51.58					
Maintenance labor rate ($/hr):		50.78					
Operating labor factor (hr/sh):		0.0					
Maintenance labor factor (hr/sh):		0.5					
Electricity price ($/kWhr)		0.08					

TCI-CA5X DST AN or AW

TCI-CA5X DST AN or AW Carbon Ad

Recovered VOC value ($/lb):		0.0000		
Steam price ($/1000 lb):		6.00		
Cooling water price ($/1000 gal):		0.20		
Carbon replacement labor ($/lb):		0.05		
Overhead rate (fraction):		0.6		
Annual interest rate (fraction):		0.07		
Control system life (years):		11		
Capital recovery factor (system):		0.1334		
Carbon life (years):		5		
Capital recovery factor (carbon):		0.2439		
Taxes, insurance, admin. factor:		0.04		
	ANNUAL COSTS:			
Item		Cost ($/yr)	Wt. Factor	W.F.(cond.)
Operating labor		0	0.000	----
Supervisory labor		0	0.000	----
Maintenance labor		27,802	0.081	----
Maintenance materials		27,802	0.081	----
Electricity		7	0.000	----
Steam		40	0.000	----
Cooling water		5	0.000	----
Carbon replacement		6	0.000	----
Overhead		33,362	0.098	0.261
Taxes, insurance, administrative		58,251	0.171	----
Capital recovery		194,202	0.569	0.739
Total Annual Cost (without credits)		341,478	1.000	1.000
Recovery credits		0		
Total Annual Cost (with credits)		341,478		
" " " ($/million acf)		130.25		
Total Unabated Organic TAP Emissions, tons =		0.96		
Emission Control Efficiency =		0.98		
Total Abated Organic TAP Emissions, tons =		0.94		
Cost-Effectiveness, $/ton =		362,965		

Notes

[1] This program has been based on data and procedures in Chapter 4 of the OAQPS CONTROL COST MANUAL (5th edition).

[2] Base equipment costs reflect this date.

[3] VAPCCI = Vatavuk Air Pollution Control Cost Index (for carbon adsorbers) corresponding to year and quarter shown. Base equipment cost, purchased equipment cost, and total capital investment have been escalated to this date via the VAPCCI and control equipment vendor data.

[4] Enter one of the following: carbon steel--'1'; 316 stainless steel--'1.3'; Carpenter 20 (CB-3)--'1.9'; Monel-400--'2.3', Nickel-200--'3.2', titanium--'4.5'.

[5] This is the carbon bed pressure drop ONLY. There will be additional pressure drop through the ductwork. For estimating ductwork pressure losses, see Chapter 10 of the OAQPS CONTROL COST MANUAL (5th edition).

Table 1. Freundlich Constants for Selected Compounds [6]

VOC name	VOC number	K	M	Temperature (F	Correlation Range (psia) Minimum	Maximum
Benzene	1001	0.597	0.176	77	0.0001	0.05
Chlorobenzene	1002	1.05	0.188	77	0.0001	0.01
Cyclohexane	1003	0.508	0.210	100	0.0001	0.05
Dichloroethane	1004	0.976	0.281	77	0.0001	0.04
Phenol	1005	0.855	0.153	104	0.0001	0.03
Trichloroethane	1006	1.06	0.161	77	0.0001	0.04
Vinyl chloride	1007	0.200	0.477	100	0.0001	0.05
m-Xylene (low-pressure range)	1008	0.708	0.113	77	0.0001	0.001
m-Xylene (high-pressure range)	1009	0.527	0.0703	77	0.001	0.05
Acrylonitrile	1010	0.935	0.424	100	0.0001	0.015
Acetone	1011	0.412	0.389	100	0.0001	0.05
Toluene	1012	0.551	0.110	77	0.0001	0.05

[6] These constants fit the following equation:

$Q = K(P)^M$

Appendix 1-D

Wet Caustic Scrubber Cost Estimate

Table B-4. TBACT Control Technology Cost Estimate
Wet Caustic Scrubber
Stream S9v/S17 **PT LAW Evaporator Offgas Unabated**

Cost Item	Basis		Example Cost
Direct Costs			
Purchased Equipment Costs			
Equipment			$552,000.00
Required Ancillary Equipment			$0.00
Instrumentation and Control	15% of Equipment		$82,800.00
Freight	5% of Equipment		$27,600.00
Subtotal Purchased Equipment Costs (PEC)			$662,400.00
Direct Installation Costs			
Foundations & Supports	8% of Subtotal PEC		$52,992.00
Handling & Erection	14% of Subtotal PEC		$92,736.00
Electrical	4% of Subtotal PEC		$26,496.00
Piping and Duct Work	4% of Subtotal PEC		$26,496.00
Insulation for Piping & Equipment	4% of Subtotal PEC		$26,496.00
Painting	2% of Subtotal PEC		$13,248.00
Subtotal Installation Costs (IC)			$238,464.00
Site Preparation	Equipment Specific		$20,000.00
Building Costs	see cost factors below	equipment size	
C5 Location per square foot	$1,388/sf	18 sf	$24,984.00
Subtotal - Building (per highest applicable cost area)	Equipment Specific		$24,984.00
Total Direct Cost			$945,848.00
Indirect Costs (Installation)			
Engineering	10% of PEC		$66,240.00
Construction and Field Expenses	5% of PEC		$33,120.00
Start-up	10% of PEC		$66,240.00
Performance Tests	1% of PEC		$6,624.00
Contingencies	15% of PEC		$99,360.00
Total Indirect Costs			$271,584.00
Total Capital Costs (TCC)			$1,217,432.00

Source: Modified from EPA Handbook *Control Technologies for Hazardous Air Pollutants* (June 1991).

Table B-4. TBACT Control Technology Cost Estimate
Wet Caustic Scrubber
Stream S9v/S17 PT LAW Evaporator Offgas Unabated

Cost Item	Factor		Example Cost
Direct Annual Costs			
Utilities			
Electricity	$0.08/kWhr		$0.00
Steam	$6.00/1000 lb		$0.00
Water	$0.25/1000 gal.		$5,000.00
Materials/Chemicals	Process Specific		$25,000.00
Operating Expenses			
Operator	$20/Hr	52 hrs	$1,040.00
Supervisor	15% of Operator		$156.00
Secondary Waste T&D	Process Specific		$0.00
Maintenance			
Labor	$17/Hr	24 hr/2 yr	$204.00
Materials	100% of Maintenance Labor		$204.00
Indirect Annual Costs			
Overhead	6% of Labor Costs		$840.00
Administrative	2% of TCC		$24,348.64
Insurance	1% of TCC		$12,174.32
Total Annual Costs (TAC)			$68,966.96
Rate of Return on Capital Investment	10.00%		
Service Life (years)	40		
Capital Recovery Factor	0.1023		
Annualized Capital Investment (ACI)			$124,493.88
Grand Total Annualized Costs	**ACI + TAC**		**$193,460.84**

Source: Modified from EPA Handbook *Control Technologies for Hazardous Air Pollutants* (June 1991).

Table B-4. TBACT Control Technology Cost Estimate
Wet Caustic Scrubber
Stream S41 **PT PJM/RFD Offgas Unabated**

Cost Item	Basis		Example Cost
Direct Costs			
Purchased Equipment Costs			
Equipment			$1,224,000.00
Required Ancillary Equipment (heat xers, quench, etc.)			$0.00
Instrumentation and Control	15% of Equipment		$183,600.00
Freight	5% of Equipment		$61,200.00
Subtotal Purchased Equipment Costs (PEC)			$1,468,800.00
Direct Installation Costs			
Foundations & Supports	8% of Subtotal PEC		$117,504.00
Handling & Erection	14% of Subtotal PEC		$205,632.00
Electrical	4% of Subtotal PEC		$58,752.00
Piping and Duct Work	4% of Subtotal PEC		$58,752.00
Insulation for Piping & Equipment	4% of Subtotal PEC		$58,752.00
Painting	2% of Subtotal PEC		$29,376.00
Subtotal Installation Costs (IC)			$528,768.00
Site Preparation	Equipment Specific		$20,000.00
Building Costs	see cost factors below	equipment size	
C5 Location per square foot	$1,388/sf	36 sf	$49,968.00
			$0.00
Subtotal - Building (per highest applicable cost area)	Equipment Specific		$49,968.00
Total Direct Cost			$2,067,536.00
Indirect Costs (Installation)			
Engineering	10% of PEC		$146,880.00
Construction and Field Expenses	5% of PEC		$73,440.00
Start-up	10% of PEC		$146,880.00
Performance Tests	1% of PEC		$14,688.00
Contingencies	15% of PEC		$220,320.00
Total Indirect Costs			$602,208.00
Total Capital Costs (TCC)			$2,669,744.00

Source: Modified from EPA Handbook *Control Technologies for Hazardous Air Pollutants* (June 1991).

Table B-4. TBACT Control Technology Cost Estimate

Wet Caustic Scrubber

Stream S41 **PT PJM/RFD Offgas Unabated**

Cost Item	Factor		Example Cost
Direct Annual Costs			
Utilities			
Electricity	$0.08/kWhr		$0.00
Steam	$6.00/1000 lb		$0.00
Water	$0.25/1000 gal.		$10,000.00
Materials/Chemicals	Process Specific		$50,000.00
Operating Expenses			
Operator	$20/Hr	52 hr/yr	$1,040.00
Supervisor	15% of Operator		$156.00
Secondary Waste T&D	Process Specific		$0.00
Maintenance			
Labor	$17/Hr	24 hr/2 yr	$204.00
Materials	100% of Maintenance Labor		$204.00
Indirect Annual Costs			
Overhead	6% of Labor Costs		$840.00
Administrative	2% of TCC		$53,394.88
Insurance	1% of TCC		$26,697.44
Total Annual Costs (TAC)			$142,536.32
Rate of Return on Capital Investment	10.00%		
Service Life (years)	40		
Capital Recovery Factor	0.1023		
Annualized Capital Investment (ACI)			$273,006.46
Grand Total Annualized Costs	**ACI + TAC**		**$415,542.78**

Source: Modified from EPA Handbook *Control Technologies for Hazardous Air Pollutants* (June 1991).

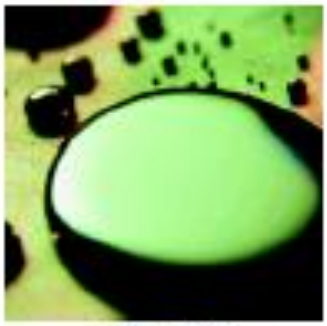
Appendix 2

MERSOB® Mercury Adsorbents NUCON Bulletin 11B28, August 2004

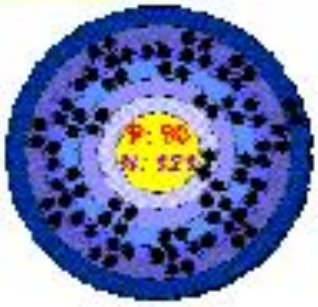
NUCON International, Inc

MERSORB® Mercury Adsorbents

Design and Performance Characteristics



MERSORB®-1.5
MERSORB®-3
MERSORB®-4
MERSORB®-LW
MERSORB®-LH
MERSORB®-HT
MERSORB®-CR



NUCON Bulletin 11B28 – August 2004

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MERSORB®
Mercury Adsorbents
Bulletin 11B28
August 2004

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MERSORB®
Mercury Adsorbents
Bulletin 11B28
August 2004

BACKGROUND

Mercury is a historically important and useful industrial material. Mercury and mercury compounds have been used for thousands of years as pigments in inks (cinnabar, red sulfide), as aids to early metallurgy (gilding copper), and instrumentation (thermometers, barometers).

Mercury is the only metallic element that is liquid at room temperature. It is present throughout the earth.

Mercury is toxic and human ingestion and exposure must be prevented. When present in industrial process fluids, mercury causes corrosion and should be removed to prolong the life of the equipment.

Mercury has low vapor pressure and low solubility. Therefore, any mercury removal process must be effective at very low concentrations. Adsorption is such a process. Unimpregnated activated carbon is a fair adsorbent for mercury. But its capacity is significantly increased by impregnation with a material that chemically reacts with, and holds, the mercury. The choice of impregnant is dictated by the process conditions and the composition of the fluid. Sizing of adsorption equipment is determined by the flow rate of the fluid stream and the desired operational life of the adsorbent.

This bulletin describes NUCON® products and processes for control of mercury and its compounds.

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MERSORB®
Mercury Adsorbents
Bulletin 11B28
August 2004

INTRODUCTION

Mercury is used in many industrial processes and products including:

- As the cathode in the generation of chlorine by electrolysis of chloride salts,
- Manufacture of batteries,
- Catalysts,
- Specialty chemicals,
- Fungicides.
- Electronics manufacturers use mercury for switches and measuring instruments.
- Mercury is present in fluorescent lamps, high intensity lamps and LCD computer screens.

Mercury is hazardous. The Threshold Limit Values-Time Weighted Average (TLV-TWA), established by AIGCH, is 0.05 mg mercury per cubic meter air.[2] The typical concentration of mercury found in urban air is 0.000007 mg mercury per cubic meter.[3] (In remote and rural areas it is approximately 10% of that level). These levels are considered harmless because they are 10 million times less than the TLV. However, in some industrial environments, concentrations as high as 5 mg per cubic meter of air have been measured. This level is 100 times the TLV.

Many petroleum products contain mercury. A number of tests have been made to determine the concentration of mercury in natural gas supplies in various parts of the U.S. Locations in South Texas have shown concentrations ranging from 0.002 mg/m^3 to over 4.5 mg/m^3.[1] Mercury is also present in condensates from other parts of the world such as Indonesia and North Africa.
The exhaust gases from waste incinerators and coal burning power plants contain mercury. It is estimated that half of the global emissions of mercury come from fossil fuel combustion. Although the total quantity emitted by waste incinerators is less, the concentrations are much higher.

Mercury-containing waste has contaminated soil and water. Materials containing mercury are sometimes stored in landfills that are not completely isolated from the surrounding environment.
Mercury can amalgamate with metals used in process equipment, causing corrosion and failure. Therefore, natural gas processing and liquefaction plants use mercury adsorbents to protect their "cold box" heat exchangers. It is a poison for some catalysts used in hydrocarbon processing. Catalysts are protected in some ethylene plants, synthesis gas and steam reforming units and for hydrogen and ammonia production

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PHYSICAL PROPERTIES

General physical properties are shown in Table 1:

Table 1. Physical Properties of Mercury

Solubility in water	0.064 mg per liter[4]
Saturation concentration, 20° C	14 mg per cubic meter air
Melting point	-38.9° C
Boiling point	356.6° C
Density	13.5 g per ml
Molecular Weight	200.59

The solubility of mercury in hydrocarbon liquids at room temperature is shown in Table 2.[5]

Table 2. Solubility of Mercury in Organic Liquids, mg/liter

Heptane	1.3
Benzene	2.4
Iso Octane	0.8
Isopropyl Ether	1.0

Typically, the solubility of mercury in hydrocarbons is ten times greater than in water. Since some geologic formations contain both liquid mercury and hydrocarbons, the natural gas and hydrocarbon liquids recovered can have very high mercury content.

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CONTROL METHODS

Most mercury control techniques use adsorbents (plain or impregnated) in some form. The high surface area of the adsorbents attracts the mercury and facilitates physical adsorption or chemical reaction. The most common base material is activated carbon. Impregnants are chosen for suitability in a particular environment.

NUCON International, Inc. (NUCON) has developed the MERSORB* family of adsorbents for almost every type of mercury removal application.

For processing natural gas, hydrocarbon liquids, and small air streams, fixed beds of pelleted MERSORB* adsorbents are used. Even though the adsorbents are optimized for maximum mass transfer rates, the relatively slow reaction rate of the mercury vapor with the impregnant requires a relatively long residence time. The amount of adsorbent required to achieve high removal efficiency will generally give a very long service life.

When mercury is present at very low concentrations in relatively large gas streams (such as effluent gases from coal fired power plants or waste incinerators), powdered adsorbents can be used. The powdered adsorbents can be injected into the gas stream and, after an appropriate residence time, filtered out in a dust collector. Tests have shown various degrees of effectiveness.

GAS PHASE APPLICATIONS

Various diffusion processes control the rate of mercury removal by impregnated carbons. Bulk diffusion to the surface of the particle, pore diffusion, and reactant and reaction-product diffusion in the deposited impregnant layer all affect performance. NUCON base adsorbents have been selected for their optimized pore structure.

MERSORB* adsorbents:

- Are well suited for protecting catalyst beds and aluminum heat exchangers
- Remove mercury from process-gas streams.
- Have high capacity and removal efficiency, and low-pressure drop.

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Long-Term Laboratory Tests

Mercury removal efficiency and adsorption capacity testing, using radioactive mercury, have been performed in the NUCON radioisotope laboratory using ^{198}Hg.

The test parameters were:

Gas	Air
Temperature:	30° C
Bed Diameter:	25 mm
Bed Depth:	150 mm
Particle Size:	3 mm pellets
Inlet Concentration:	32 mg Hg./m^3 air
Pressure:	1.0 ATM
Linear Velocity:	3 ft./min.

Tests were conducted using six bed segments, each being 25 mm deep and 25 mm diameter.
The radioactive isotope content of the samples of gas between the segments was analyzed at periodic intervals. The results of the tests for mercury removal from air are shown in Figure 1.

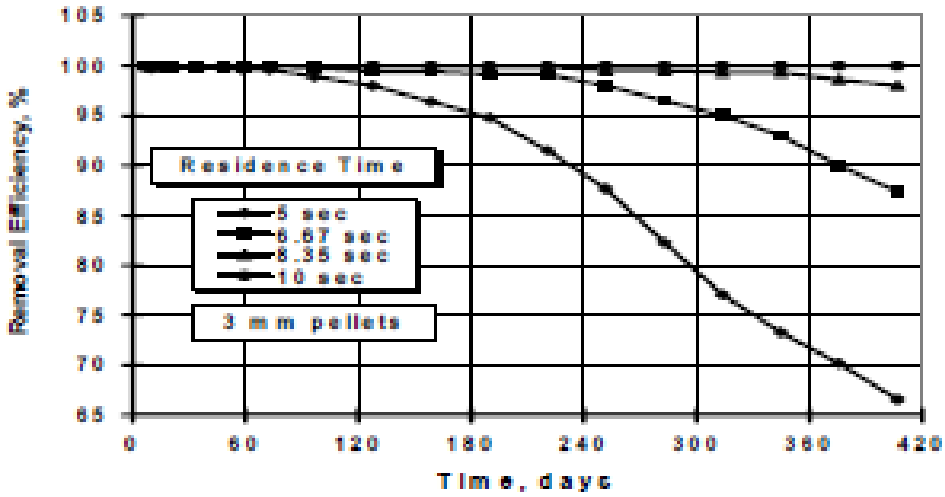

Figure 1 – Mercury Removal Efficiency from Air at Various Residence Times

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Similar tests for mercury removal efficiency and capacity from natural gas have also been performed. The test parameters were the same as in the air tests. Results are shown in Figure 2.

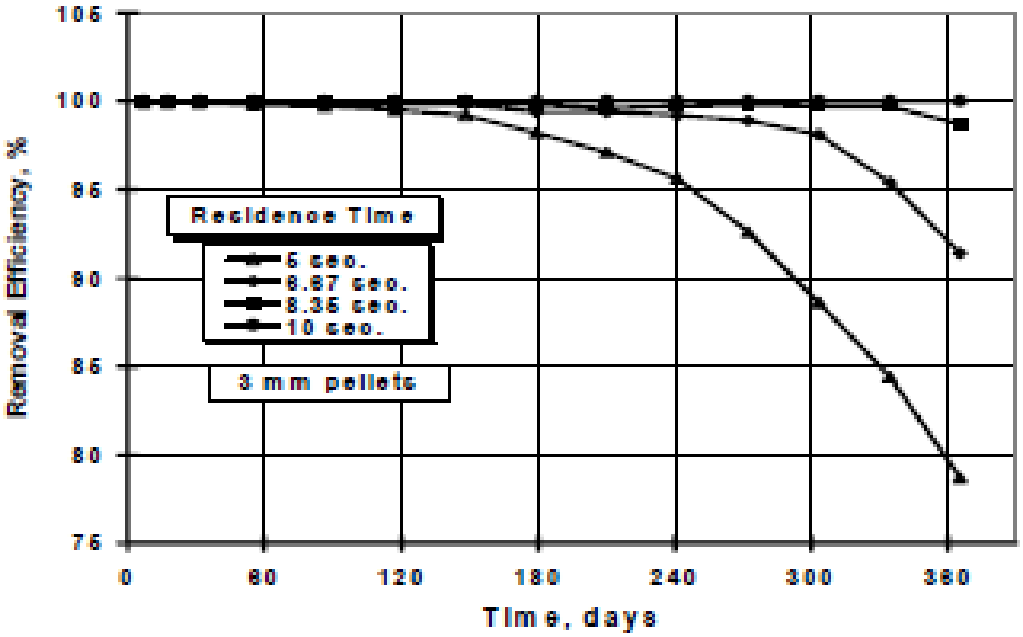

Figure 2 – Mercury Removal Efficiency from Natural Gas at various Residence Times

For both air and natural gas, when the gas stream is saturated with mercury, a 10-second residence time is recommended to achieve complete removal of the mercury. At these high concentrations, MERSORB® adsorbent removed 100% of the mercury for over one year. In most commercial applications the mercury concentration is only a fraction of the saturation level, and the life of the MERSORB® adsorbent is typically several years.

An alternate approach can be used if removal efficiencies of less than 100% are acceptable. A smaller bed will give adequate performance for a slightly shorter period of time. For example, a 5 second residence time provided 240 days life at efficiencies above 95% in the natural gas tests (Figure 2). Similarly, at low mercury concentrations, 100% removal can be achieved at less than 10 seconds residence time.

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Adsorption Capacity

The theoretical equilibrium adsorption capacity of MERSORB® pellets is 85 g Hg/100 g MERSORB® adsorbent. However, it is impractical to reach that level in commercial applications. An extremely long time would be required to obtain diffusion of the mercury into the adsorbent and for the chemical conversion to take place. In the region of the mass transfer zone, the amount adsorbed is always less than the maximum. Dynamic adsorption capacity data for the extended dynamic adsorption tests are shown in Table 3.

Table 3. Dynamic Adsorption Capacity of MERSORB® 3 mm Pellets

	Air	Natural Gas
Test Duration, days	407	365
Bed Segment No.		Amount Adsorbed, g Hg/100 g MERSORB®
1	23	31
2	19	28
3	15	19
4	15	14
5	14	12
6	0.3	0.3

While Bed Segment No. 6 adsorbed a small amount of mercury, there was no detectable breakthrough from the bed at the end of the test.

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Particle Size Effects

The particle size of the MERSORB® adsorbent affects several operating parameters. Data concerning the two most important criteria, performance and pressure drop, has been developed.

Performance

The dynamic performance of small particle size adsorbents is always better than for that of larger sizes. Figure 3 shows the difference in performance between MERSORB® 1.5 mm and 3 mm pellets. These tests were conducted using air saturated with mercury at 30°C. The test bed dimensions were 25 mm diameter by 25 mm long.

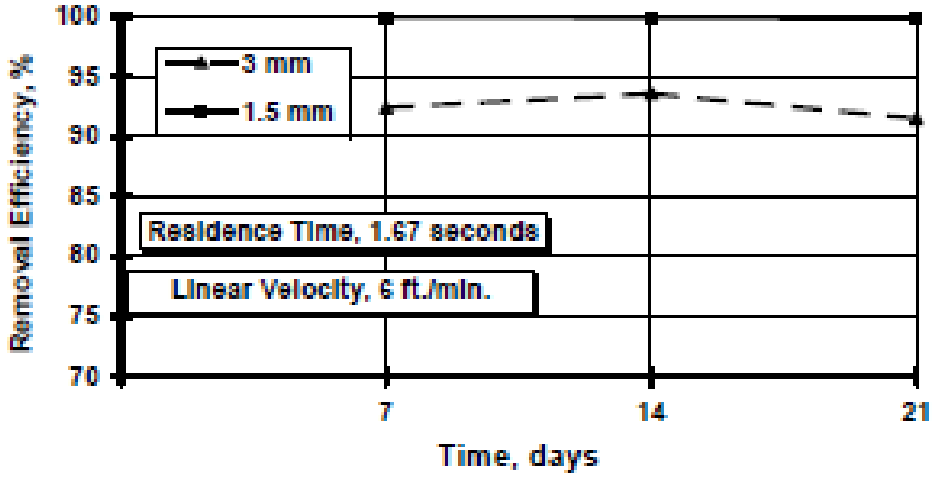

Figure 3 – Effect of Particle Size on Mercury Removal from Air

The difference is very noticeable at short residence times. The initial efficiency for 1.5 mm pellets at 1.67 seconds residence time is 100%, while for 3 mm it is around 93%.

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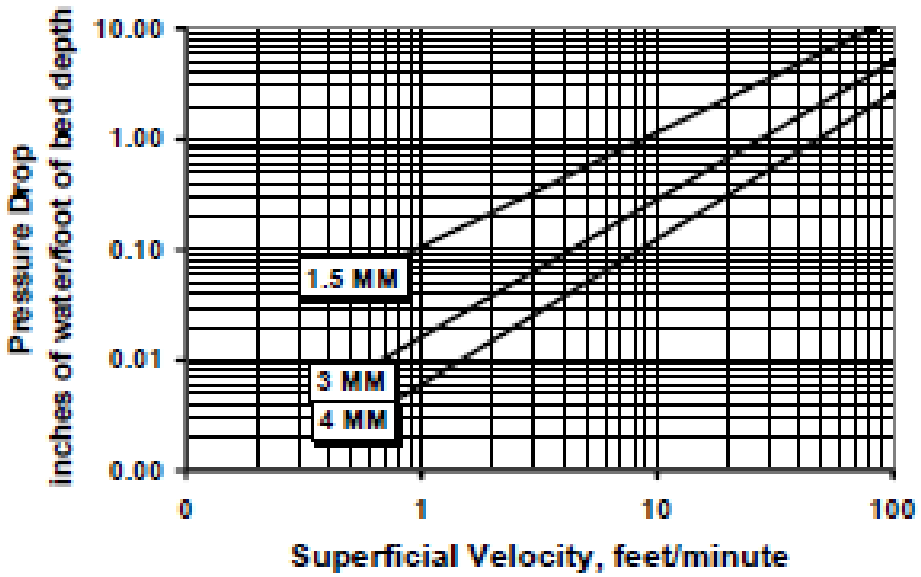
Pressure Drop

The pressure drop through a packed bed increases as particle size decreases. Pressure drop curves for MERSORB® pellets at atmospheric pressure are shown in Figure 4.

Figure 4 – Pressure Drop of Air Through Packed Beds



Natural gas processing is normally done at high pressure. Flow resistance for a typical operating pressure is shown in Figure 5.

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Velocity Effects

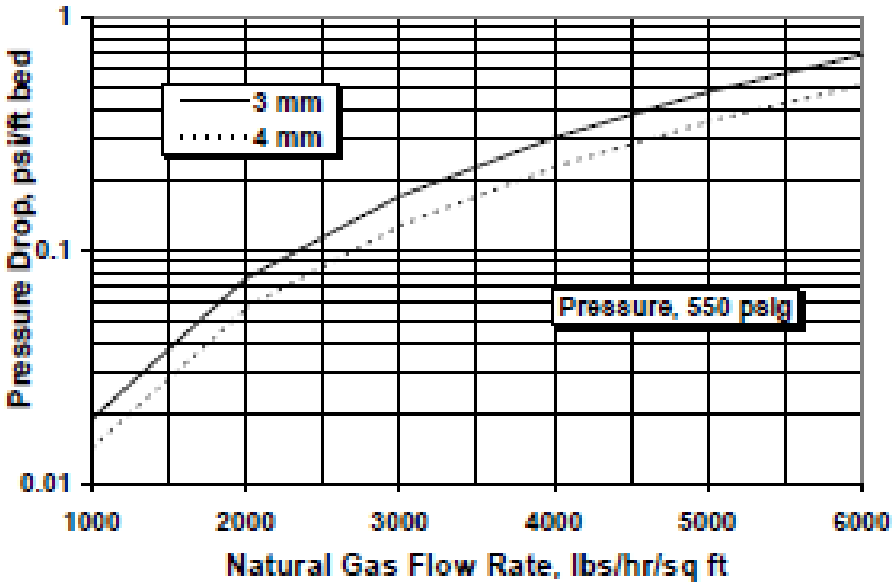

Figure 5 – Pressure Drop Through MERSORB® Pelleted Adsorbent

NUCON ran laboratory tests on 4 mm MERSORB® pellets using two different gas velocities with the bed depth of 12 inches. The comparative results after 30 days of testing are shown in Table 4.

Table 4. Effect of Velocity on Dynamic Adsorption

	Removal Efficiency (%)	
Residence Time, sec	3 ft/min	6 ft/min
1.67	42.8	58.4
3.33	80.3	88.7
5.00	90.7	100.0

Removal efficiency is generally perceived as a function of the residence time. However, at higher superficial gas velocity, the removal efficiency at a given residence time improves due to favorable diffusion effects.

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Temperature Effects

Operation of mercury removal systems at high temperatures is sometimes necessary. There are two major effects upon performance at elevated temperatures. The sulfur impregnant can:

- Vaporize in inert atmospheres, or
- Oxidize in air atmospheres.

NUCON uses a unique manufacturing method to make the MERSORB® sulfur-impregnated adsorbents. The result is a product that retains the impregnant better at high operating temperatures than the adsorbents manufactured by others. Thermogravimetric analysis of the NUCON and competitive product has substantiated this fact.

The results of thermogravimetric analysis of samples of 3 mm MERSORB® mercury adsorbent and a competitive 4x10 mesh size granular adsorbent are shown in Figure 6. For the competitive (granular) product, almost half of the impregnant was lost at temperatures around the boiling point of water. On the other hand, the MERSORB® shows no weight loss until the temperature exceeds 200° C.

The differences are even more noticeable for tests conducted in air (See Figure 7). The weight loss at temperatures above 275°C for the competitive product indicates that both the sulfur impregnant and some of the carbon is being oxidized. For the NUCON MERSORB® material, only a small portion of the sulfur is lost at that temperature.

A special grade, MERSORB® HT, is available for high temperature applications (greater than 100 °C). Through a unique manufacturing process, the sulfur is converted to a form that is very stable. The weight loss of MERSORB® HT when subjected to a temperature of 200 °C is typically 2%.

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Weight Loss

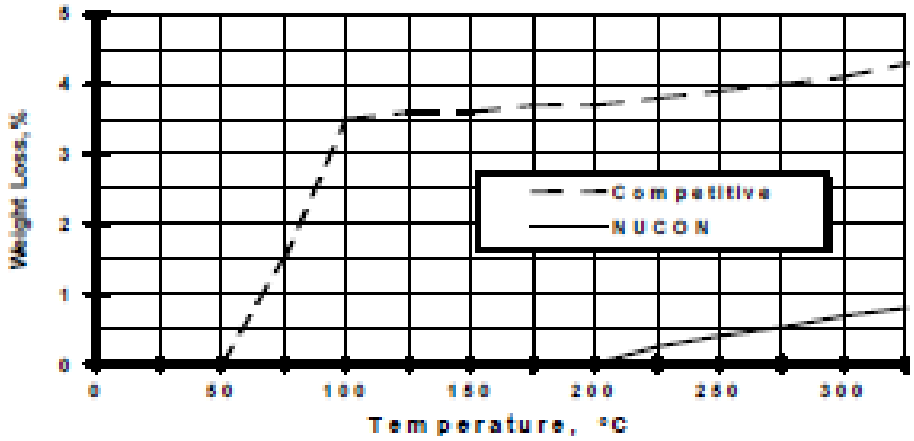

Figure 6 – Weight Loss of Mercury Adsorbents in Inert Atmosphere

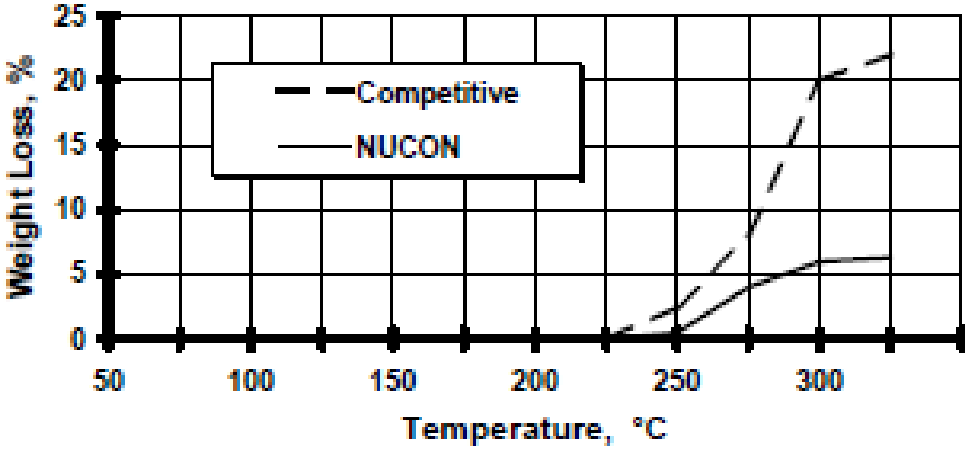

Figure 7 – Weight Loss of Mercury Adsorbents in Air

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All thermogravimetric tests were performed on carbon that had been dried to remove moisture.

Other tests were conducted with a stream of methane flowing through a bed of MERSORB® 1.5 pellets at 150°C. After 24 hours, the impregnant loss was only 0.5%.

The MERSORB® sulfur impregnated adsorbents are quality control tested at 200°C to insure stability of the impregnant.

The typical loss of impregnant content for MERSORB® HT is 2 %.

LABORATORY TEST RESULTS

The results of laboratory tests performed on several simulated gas streams have been used as a basis for the design of mercury removal processes. They include offgas from mixed waste incineration, a plasma enhanced melter, ventilation of a hot cell, and a chemical munitions incineration process. Table 5 shows the results of these tests.

Table 5. Laboratory Experiments, Gas Phase Mercury Removal

Application	Mixed Waste Incineration[9]	Mixed Waste Incineration[10]	Hot Cell Vent SNS Facilities[11]	Plasma-Enhanced Incineration[12]
Gas	Inert Off Gas	Inert Off Gas	Air	Syngas
Impurities	NO_2, HCL			Nitrogen
Mercury Conc., mg/cu m	10	16	0.055	0.55
Temperature, °C	150	107	38	30
Residence Time, sec	0.99	0.63	0.7	20
Test Duration, hr	1000	100	60	9
Mercury Removal Eff., %	99.9	99.997	99.8	99.99

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LIQUID PHASE APPLICATIONS

NUCON also produces mercury removal adsorbents for liquid phase applications. The MERSORB® L designation is used for products designed to remove mercury from the liquid phase. There are two products used for liquid phase application:

- MERSORB® LW for liquid phase, aqueous solutions
- MERSORB® LH for liquid phase hydrocarbons

The impregnant used to make LW grade is insoluble in water. The impregnant used to make LH grade is insoluble in common hydrocarbons.

The standard LW and the LH grades are supplied as 1.5 and 0.9 mm diameter pellets. Custom particle sizes are available.

Mercury Removal from Water

The MERSORB® LW grades chemically react with elemental mercury or water-soluble mercury salts within the pore structure of the adsorbent. Even though the solubility of elemental mercury in water is low (0.064 mg/liter), environmental authorities often specify even lower levels. Soluble mercury salts can be present at much higher concentrations in various contaminated streams.

The mercury adsorption capacity of MERSORB® LW is concentration dependent. Typical design contact times are in the range of 20-40 minutes at ambient temperature. The MERSORB® LW grades can be used at temperatures up to 90° C.

If large amounts of dissolved organic material are also present in the aqueous streams, an unimpregnated carbon (NUSORB® GC60-1.5) should be used as a guard bed to increase the life and efficiency of the MERSORB® LW for mercury removal.

Adsorption Capacity

Figure 8 shows an isotherm for adsorption of ionic mercury from water. Water (pH 7) containing 50 ppm mercury (as Hg^{+2} from $HgCl_2$) was contacted with various amounts of MERSORB® LW-3 ground to -325 mesh. After 24 hours the carbon was filtered out and the residual mercury concentration in the filtrate was determined by Atomic Absorption Spectroscopy.

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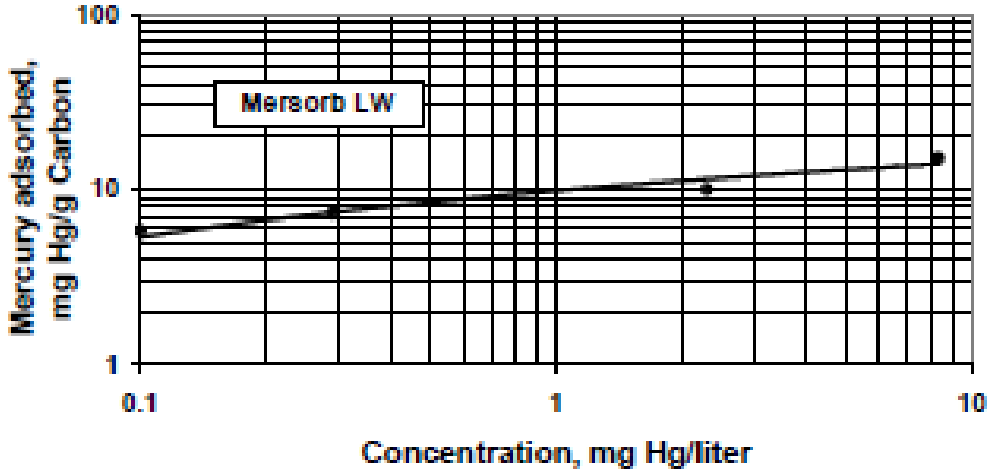

Figure 8 – Adsorption of Mercury from Water by MERSORB® LW

Effect of Acidity

The pH of the water influences the adsorption capacity for mercury. MERSORB® LW was ground to -325 mesh and 0.1 g was mixed with 100 ml of reagent grade water containing 97.4 mg mercury/liter water. The pH was adjusted with NaOH solution. The residual mercury concentration was measured after 24 hours. Those results are shown in Table 6.

Table 6. Effect of pH on Mercury Removal

pH	3.2	7	8	10
Amount removed, %	44	80	95	99

Less than half of the mercury was removed at pH 3.2 while over 99% was removed at pH 10.

The effect of other ions in the water on mercury adsorption can be substantial. Contact your MERSORB® applications engineer for advice in these cases.

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Oak Ridge National Laboratory Studies

Mixed wastes containing mercury must be treated at a number of nuclear facilities. As a part of a program to obtain preliminary technical data, a team at Oak Ridge National Laboratory performed lab studies using a solution of mercury in water synthesized to duplicate some of the actual wastes.[6] They found that MERSORB® LW was effective in this application. By varying solution conditions, they found that mercury uptake was slightly slower at low pH and that competing cations reduced the total amount of mercury removed. While the theoretical capacity is 0.71 g/g of MERSORB® LW, at the low concentrations used for the tests, the capacity was 0.12 g/g at neutral pH. The rate of mercury adsorption was found to follow first-order kinetic behavior.

In another study, MERSORB® LW was evaluated for its mercury removal from water streams which contain dissolved mercury salts[8]. In these experiments, the weight Distribution Coefficient (D), that is, the adsorbed amount per kilogram of dry adsorbent divided by the amount per liter of solution, was determined at two mercury concentrations from a 0.05 M sodium nitrate and a 0.05 M sodium chloride solution. The mercury in the influent was present as Hg^{+2}.

Table 7. Distribution Coefficient of Hg^{+2} on MERSORB® LW

Hg^{+2} Salt Concentration	Trace	0.001 mol Hg/kg
From 0.05 M $NaNO_3$	16,500 (l/kg)	76,200 (l/kg)
From 0.05 M NaCl	1,000,000 (l/kg)	175,000 (l/kg)

Mercury Cell Chlorine Caustic Plant Waste

Wastewater discharges from the HoltraChem chlor-alkali plant in Maine exceeded the newly established mercury concentration limits imposed by the EPA [7]. An extensive process system was installed which included optimization of the sulfide pre-treatment step, adjustment of pH and the addition of 0.5 micron particle filters, followed by a polishing bed of MERSORB® LW mercury adsorbent. The result was a reduction in the effluent concentration to below 50 ppTw. Process conditions for the MERSORB® adsorber were:

Flow:	100 gpm
Residence time	45 minutes
Inlet Mercury Concentration	8 ppb
Mercury Removal Efficiency	98.64%

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Mercury Removal from Hydrocarbon Liquids

Tests have been performed in the NUCON laboratory using MERSORB® LH to remove elemental mercury from heptane. Equilibrium adsorption results are shown in Figure 9.

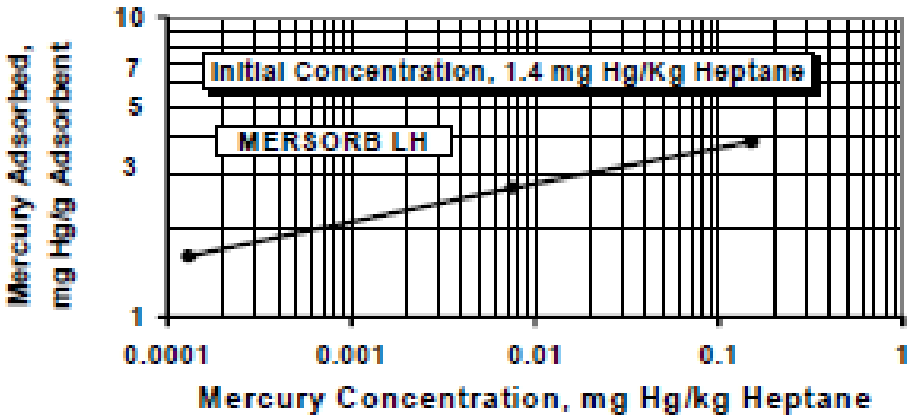

Figure 9 – Mercury Adsorption from Heptane, MERSORB® LH

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CASE HISTORIES

Water from Air Scrubbers

For some small medical waste incinerators, the exhaust gas is passed through a water scrubber to remove particulates and water-soluble compounds. Any mercury present in the waste is contained in the scrubber water. During a four-month demonstration project, scrubber water containing an average of 300 ppbw Hg was passed through a column of MERSORB® LW to remove the mercury. An average effluent level of less than 2 ppbw Hg was maintained over this period.

Mercury Cell Hydrogen

High purity hydrogen chloride (HCl) is manufactured by reacting hydrogen and chlorine. A facility using hydrogen from chlorine/caustic mercury cells must remove the mercury in the hydrogen to meet specifications for the HCl. Mercury concentrations up to 300 ppb were reduced to less than 0.01 ppb in a single column of MERSORB® 3 mm diameter pellets. This system has been in operation for over eight years with 100% mercury removal efficiency.

LNG Production Plant—Hg in Natural Gas

A western USA natural gas processing plant produces LNG in order to reject nitrogen from the gas. This plant has its mercury removal section upstream of the CO_2 removal section. The plant was using a competitive mercury adsorbent and suffered mercury corrosion downstream due to poor mercury removal efficiency. Sulfur contamination in the NGL was also observed, due to loss of sulfur from the mercury adsorbent caused by water-glycol carryover. The plant installed MERSORB® mercury adsorbent and sulfur contamination of their NGL was eliminated and the concentration mercury/cubic meter in the treated gas is consistently < 2 nanograms.

Mine Atmosphere

A gold mining plant in Nevada encountered concentrations well above the TLV in the enclosed processing area. An air purification system containing MERSORB® 3 mm pellets was installed. The mercury level has been reduced to below the TLV.

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Mercury Waste Recycler—Hg in Hot Retort Off-Gas

A recycler plant uses a retort to process its mercury-bearing wastes. Using a competitive mercury adsorbent to filter the 250°F off-gas, they experienced repeated bed fires. After lab testing all available mercury adsorbents, they switched to MERSORB® mercury adsorbent. There have been no further problems with bed fires and mercury emission requirements are met.

Mercury Waste Recycler—Hg in Water

Treating retort condensate water for mercury removal using a competitor's product did not achieve the desired performance. After installing MERSORB® LW mercury adsorbent, the user reduced mercury levels in the treated water from as high as 1,000 ppbw Hg to less than 1 ppbw Hg.

Fluorescent Lamp Recycling System OEM—Hg in Air

An OEM tried several competitive mercury adsorbent products and decided to use MERSORB® mercury adsorbent. Over 20 systems installed all meet mercury emissions regulations. Even with a three-shift lamp recycling operation, the mercury adsorbent lasts several years.

Fluorescent Lamp Plant—Hg in Air

The plant needed to control the mercury emissions from their fluorescent lamp curing ovens. An air collection system was installed, including an adsorber containing MERSORB® LH mercury adsorbent. Mercury concentrations around the unit were reduced from > 100 micrograms Hg/cubic meter to non-detectable levels of < 1 microgram Hg/cubic meter, even though the treated air temperature was over 160 °F.

Mercury-Cell Chlor-Alkali Plant—Hg in Brine, Hg in Water

The plant needed to drastically reduce the mercury emissions in its spent brine. A 100 gpm secondary treatment system using MERSORB® LW mercury adsorbent was installed. The process reduced mercury levels in the brine from > 50 ppbw Hg to < 0.050 ppbw Hg (<50 ppTrillion Hg by weight).

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OPERATING GUIDELINES

The following are general guidance for typical applications. Contact us to discuss MERSORB® applications tailored to your specific operating conditions.

1. Do not use these products for acidic solutions. Acids reacting with sulfur compounds can generate hydrogen sulfide (H_2S), which is poisonous. Removal efficiency for ionic mercury decreases at a pH below 7. For elemental mercury, a pH as low as 4 can be used.

2. When non-mercury impurities must also be removed, it may be desirable to use "guard" adsorbent beds in service upstream of the MERSORB® adsorbent beds to remove these impurities and increase the life of the mercury adsorption bed.

3. Mercury removed by the sulfur impregnated MERSORB® is converted by the adsorbent to mercuric sulfide, a naturally occurring compound. Spent adsorbent should be handled according to appropriate disposal procedures and according to applicable safety and transportation regulations.

4. For optimum removal efficiency, it is always preferable to operate a deep bed at high velocity rather than shallow adsorbent bed at a low velocity.

5. It is important to have effective liquid knockout upstream of gas phase mercury adsorption beds. Liquid hydrocarbons can dissolve the sulfur impregnant. Any liquids entering or condensing in the adsorbent bed interfere with the mercury adsorption rate and capacity. It is also common for natural gas streams to be saturated with water. Since high relative humidity interferes with mercury adsorption, it is important to raise the temperature of the gas enough to reduce the relative humidity less than 90%. This will also minimize the possibility of getting liquid water on the adsorbent beds. It is also helpful to heat trace the piping between the heater and the adsorber to prevent cooling and condensation.

6. The MERSORB® mercury adsorbents have been shown to be effective at relatively high operating temperatures. Please contact your MERSORB® applications engineer for specific product recommendations for your particular situation.

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TECHNICAL SUPPORT

NUCON technical personnel can provide:

A. Adsorption equilibrium data.

B. Dynamic adsorption data.

C. Process design engineering of the mercury removal process.

D. System fabrication and installation

E. On-site technical services.

D. Pilot scale adsorbers for slip stream tests.

MERSORB® applications engineers can advise users concerning potential recovery of mercury from spent adsorbent beds.

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