0054449

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Office of River Protection
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JAN 11 2001

00-EVD-021

CH0121

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EDMC

Mr. Michael A. Wilson, Program Manager
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State of Washington
Department of Ecology
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Addressees:

WASTE TREATMENT PLANT (WTP) RISK ASSESSMENT MEETING, NOVEMBER 1 AND 2, 2000, SEATTLE, WASHINGTON

On November 1 and 2, 2000, staff from the U.S. Environmental Protection Agency (EPA) and State of Washington Department of Ecology (Ecology) met with staff from the U.S. Department of Energy, Office of River Protection and CH2M HILL Hanford Group, Inc. to discuss the Risk Assessment Work Plan for the WTP. Attachment 1 is the minutes from the meeting. Attachment 2 is one of the documents requested by Ecology and EPA staff in support of the risk assessment effort, "HLW Vitrification Process Offgas System Evaluation," RPT-W375HV-PR00001 Revision 0, dated October 30, 1999.

If you have any questions, please contact Lori A. Huffman, (509) 376-0104.

Sincerely,

W J Taylor

William J. Taylor
Acting Assistant Manager
for Systems Acquisition

EVD:LAH

Attachments (2)

cc: See page 2

JAN 1 1 20

cc w/attachs:
S. Dahl, Ecology
S. Skurla, Ecology
J. Yokel, Ecology
D. Delistraty, Ecology
M. Bailey, EPA
C. Massimino, EPA
C. E. Clark, RL
T. C. McKarns, RL
B. G. Erlandson, CHG
Administrative Record

CH2MHILL
Hanford Group, Inc.

016485C

Group Chair/ Secretary: *Risk Assessment Work Plan Comment Resolution*

Meeting Minutes

Meeting: *Date / Time: 11/1-2/00*
Location EPA Region 10, 1200 6th Avenue, Seattle, Washington

Next Meeting: *Date / Time:*
Location:

Purpose: Discuss Proposed Resolution of Comments Received on the Risk Assessment Work Plan

Prepared by: Lee Bostic

The meeting began with a review of the agenda (Attachment 1) and opening remarks. Jeff Markillie provided an overview of the melter design (Attachment 2) as context for the upcoming discussion of risk assessment comments.

Barney Cornaby then walked through the list of comments proposed for discussion and how they were organized on the agenda. EPA and Ecology added other comments of interest to the agenda (12, 46, 53, 77, 112, 69, 91, 16 and 122) and they were placed on the agenda with like comments for discussion. Later in the meeting, John Cook provided an overview of the Waste Treatment Plant emissions estimate (Attachment 3) as a prelude to discussion on related comments.

The remainder of these minutes is organized by comment number and generally reflects the discussion surrounding each topic. Actions resulting from the discussion were captured during the meeting and reviewed with meeting participants at that time. These action items are contained in the action item table following these minutes. Action items are numbered to correspond with the associated minute number.

1 Comment 67 – Sensitive receptors. It was agreed to add locations of sensitive receptors such as day care organizations, hospitals, etc. on a map and explain in the Risk Assessment Work Plan (RAWP) the margin of safety for those receptors not modeled in the Screening Level Risk Assessment (SLRA). These locations will be plotted on a RAWP map following the initial run of the Preliminary Risk Assessment (PRA). It was agreed that DOE would not have to anticipate what additional receptors, if any, the public may want modeled. The public may request that risk estimates be provided for representative sensitive receptors during the public comment period, and the project should be prepared to make these estimates if requested.

2 Comment 69 – For ease of following the RAWP discussion, EPA proposed that CH2M Hill Hanford Group, Inc. (CHG) number the equations in the RAWP. CHG explained the magnitude of the effort required. It was agreed to make a more specific reference to the pertinent equation while the RAWP is in draft. The final document will have numbered equations.

3 Comment 72 – Cesium was removed from the list of volatile ROPCs. The EPA is currently re-evaluating the slope factor for 2,3,7,8, TCDD. The new numbers that may be published may be ~ 6.5 times the current value.

4 Comment 74 – Response was accepted, as written.

5 Comment 77 – Response is accepted if the "or" is changed to "and".

6 Comment 84, 86 – A background evaluation will be conducted for the nursing infant only. Background radionuclide concentrations in human breast milk are not available for Hanford. The risk assessment will use background for comparison purposes for the nursing infant for dioxins and coplanar PCBs. A general risk assessment considering background for all other exposure scenarios will not be produced. The incremental risks from radionuclides or dioxins in breast milk at the levels anticipated would be very small. DOE is concerned that this is a very conservative approach.

The RAWP should explain that the cancer risks for an infant are very conservative upper bound risks. Following completion of the emissions estimate, the calculation of risk to the nursing infant due to dioxin and coplanar PCBs will be reviewed by the agencies.

7 Comment 86 – Propose the hierarchy of toxicity values in the RAWP. Ecology/EPA will identify any necessary changes to the toxicity values at the time of RAWP approval. If an AEGL-1 value is not available, an AEGL-2 value will be used unless there is a more conservative value elsewhere in the hierarchy. The latest AEGL value will be used in the work plan. If EPA has a newer value, it will be provided during their approval of the RAWP.

EPA/Ecology requested that CHG evaluate the possibility of an acute upset scenario (1-hour exposure) (e.g., pressure relief valve or rupture actuation and bypass of pollution control equipment); note, a blown rupture disk or relief valve may or may not be an accident condition. If a routine (i.e., monthly or yearly) upset can be identified, these scenarios must be evaluated as an additional acute scenario for inhalation exposure only. If the only acute scenario that can be identified is an accident which has a very low probability of occurring, this scenario will not be evaluated in the risk assessment because accidents are evaluated as part of other licensing requirements. CHG will look at the acute scenario evaluated in the ATG risk assessment as part of their evaluation of whether or not a similar scenario is applicable to the RPP-WTP or explain why not.

8 Comment 79, 83, 85 – Dioxin and coplanar PCB risks will be combined to present a total risk from "dioxin-like" compounds. Dioxin and coplanar PCB risks need to be evaluated separately as well to determine what controls, such as offgas control equipment of feed limits, are needed (if any). Dioxin and coplanar PCB dose estimates for the nursing infant will be evaluated separately for comparison to background.

9 Comment 91 – Any segregation of Hazard Indices (HIs) by endpoint will require Ecology/EPA approval. EPA/Ecology will help in resolving issues as necessary.

10 Emissions estimate – The methodology for preparing the emissions estimate was presented by John Cook. The consensus was that the methodology was a logical path and should produce a defensible emissions estimate. CHG will determine whether high-resolution methods were used by PNNL for determining the expected detection limits for the products of incomplete combustion that were not looked for during small scale melter and offgas system testing at the Vitreous State Laboratory (VSL). DOE has the action to provide EPA a copy of the VSL test report *Determination of the Fate of Hazardous Organics During Vitrification of RPP-WTP LAW and HLW Simulants* (10/99). Provide a briefing on the proposed new VSL testing.

11 Comment 25 – It was agreed that the RAWP needed to be re-worded. The work plan needs to be revised to state that the list of 46 radionuclides is the entire list of possible radionuclides in the tanks and not a subset of any other list. In the response, provide a better explanation of the rationale for selecting the 46 ROPCs. List the 16 ROPCs that comprise 99.99% of the radioactivity and list those ROPCs that were added to the 16 because of their toxicity.

12 Comment 5 – EPA believes that the 99.99% Destruction and Removal Efficiency (DRE) for organics and the appropriate System Removal Efficiency/Maximum Available Control Technology (SRE/MACT) standards are the appropriate limits for metals treated in the vitrification units. Because the melter is a miscellaneous unit does not mean that standards do not apply, but that the permit writer will select appropriate standards from other sections of the regulations. EPA believes that CHG has moved away from an informal agreement to demonstrate 4-9s in testing. It was explained that the testing has not been conducted yet and, therefore, a determination of whether the 4-9s standard can be met has not been made by CHG. The test plan which supports the emission estimate and DRE capability of the melter system will be provided to EPA.

Ecology wants the best treatment train available for the Waste Treatment Plant (WTP). CHG agreed to provide a copy of the equipment selection study to EPA/Ecology for review. EPA believes the 4-9s requirements are routinely met even by poorly operating thermal units.

EPA believes there are other thermal oxidizers that may be more efficient than the catalytic oxidizer selected. CHG agreed to arrange for further discussions with the engineering organizations, and asked EPA to provide information on other thermal oxidizers.

Ecology/EPA explained that they understand 4-9s DRE cannot be proved at low organic concentrations. In the performance demonstration, the regulatory agencies expect that the input organic concentrations will need to be raised to the point they can be measured in the offgas and the 4-9s demonstrated at that point. It was emphasized that the purpose of the performance demonstration is to develop a set of operating conditions that achieved 99.99% DRE under the specific test conditions.

CHG agreed to provide a copy of the research and technology development test plan for the planned integrated melter and offgas system testing for Ecology/EPA review. CHG also agreed to provide copies of the LAW vitrification and HLW vitrification offgas equipment selection documents.

The difficulty of retesting after the units receive radioactive waste was discussed. EPA explained that Waste Experimental Reduction Facility (WERF) incinerator located at Idaho National Engineering & Environmental Laboratory (INEEL) was tested after it had received radioactive waste and the WTP should be able to also. The regulatory agencies may require retesting every 5 years; it will be up to the permit writer.

Revise the response to address the above discussion.

13 Comment 8 – Change response to reflect the discussion on comment 5 in item 12.

14 Comment 9 – Make clear that the emissions estimate will be provided along with the Work Plan.

15 Comment 34 – Revise the response to discuss what information will be included in the emissions report. Provide a summary of the data sources (e.g., emissions rates, fate determination report).

The Defense Nuclear Facilities Safety Board (DNFSB) has published literature on High Efficiency Particulate Air (HEPA) filters that may question some of the efficiency assumptions. The web page for the information is http:// tis.eh.doe.gov/hepa/. The material was distributed by EPA at the meeting (Attachment 4)

Some of the Hanford assumptions for efficiencies and air model input are less conservative than Advanced Mixed Waste treatment Facility (AMWTF). The EPA provided copies of the AMWTF emissions estimate (Attachment 5 and 6).

16 Comment 35 – Reference the emissions estimate in the Work Plan. The RAWP approval will reflect the inclusion of the emissions estimate.

17 Comment 41 – Expand the explanation of "scaled up". Provide a sample calculation.

18 Comment 42, 43, 46 – EPA/Ecology introduced the concept of abated fugitive emissions. CHG should determine whether the ventilation for the bulges, cabinets, etc. exit through the normal vessel vent system or through the cell ventilation system. If the ventilation for these areas exit through the vessel ventilation systems, there is no abated fugitive emission issue. If the ventilation for these areas exit through the cell ventilation system, there may be a source of abated fugitive emissions because the treatment system is less robust. If the ventilation for the bulges, cabinets, etc. do not exit through the vessel vent systems, calculate the values for various sources such as valve leaks, etc. or demonstrate there are none. Values are provided in a reference in the Human Health Risk Assessment Protocol (HHRAP). There is a procedure to come up with our own fugitive emissions numbers. If we have different valves, pumps, etc., we will need to document the different emissions rates and provide the source of the data.

19 Comment 14 – Make it clear in the RAWP that the risk assessment includes emissions from pretreatment, High-Level Waste Vitrification, Low-Activity Waste Vitrification and their associated process chemicals. EPA/Ecology requested that CHG assume some level of reduced efficiency for the HEPA filters in selecting an upset factor for particulates (i.e., assume an upset factor greater than 1). EPA provided the AMWTF and HEPA filter information to aid in selecting a particulate upset factor (provided as Attachments 4, 5, and 6).

20 Comment 53 – In the response, make it clear that the ISCST3 model will be used for the initial SLRA and might be changed to CALPUFF because more site-specific data can be input, not because the SLRA failed the risk criteria. EPA commented that CALPUFF can model stagnant air conditions and long-range, beyond 50 km, where ISCST-3 cannot. More data is required to run the CALPUFF model. Cathy will check with the EPA modeler to see if the data sets are available to run CALPUFF for the Hanford area. CALPUFF may soon be an EPA preferred model. See Attachment 7 for a comparison of CALPUFF with ISC3.

21 Comment 63 – Look at the decay products for radionuclides that may sink to the sediment.

22 Comment 64, 65 – Use different soil/food chain and different water/food chain concentration factors for the HHRA and the Ecological RA; use the values specified by the respective guidance.

23 The EPA is currently re-evaluating the slope factor for 2,3,7,8, TCDD. The new numbers that may be published in the next two to three months may be ~ 6.5 times the current value.

24 Comment 72 – John Mauro of Sandy Cohen & Associates, said I-129, H-3, and C-14 are volatile in the sweat lodge scenario. Cs does not volatilize below 600 °F so it will not be volatile in the sweat lodge scenario. It is appropriate to remove Cs-134 and Cs-137 from the list of radionuclides evaluated in the sweat lodge scenario. Sb-125, Ru-106, and Tc-99

become a residue when water is boiled off and could possibly become airborne. Rh and other transitional metals should be reviewed because they may be volatile under certain circumstances. John will review the entire list of 46 radionuclides for this scenario, and will provide more information.

For the dermal and air inhalation pathway, H-3 is the only candidate in the list provided in the comment 72 response. John is hesitant on I-129; others are unlikely to have significant dermal absorption component. John will look more closely at I-129 for inhalation and to determine if it has a gamma or x-ray component which might make the external exposure significant.

John believes that the dose conversion values and HEAST slope factors include a dermal component for radionuclides that may have significant dermal absorption (e.g. H-3 which has 50% of the dose assigned to inhalation and 50% assigned to dermal absorption); he will review the Federal Guidance Report # 14 and HEAST for confirmation. The C-14 is the same as H-3.

25 Comment 86 Continued, discussion with John Mauro – For determining the maximum 1-hour exposure, the Derived Air Concentrations (DACs) based on the annual limit on intake (ALI) aren't applicable.

There is a 10 mrem/yr annual exposure limit to deliver a lifetime 10^{-4} risk. It is inappropriate to extrapolate to shorter time periods. A 1-hour acute exposure that would cause an effect would be significantly above the ALIs.

John was asked to provide some background information on exposure related to Japanese radiological weapon survivors. He explained that without medical care, the LD-50 is 350 rem; with aggressive medical care, 500 rem. A 1-hour exposure of 1000 mrem would cause blood changes and might be similar to an acute chemical exposure. This value could increase detectable risk to the developing fetus. There are textbook references available supporting this value; John will provide a reference. It was generally felt that this did not match with the NESHAP requirements or safety documentation.

In the RAWP explain why acute effects aren't calculated or use 1 rem as an acute criterion; it is the choice of DOE and the WTP how to do it.

The only radionuclide of significance in breast milk is K-40. There are some manmade radionuclides such as Cs-137 and Pu. John will look for literature values in breast milk. The values can be compared with the Hanford annual reports of emissions. The emissions could be compared with the larger effort to get an idea of risk.

26 Comment 1 – Don't undertake a large effort to gather data about the 30 chemicals that are in the guidance. Focus on the 440 for which there are no data. Ecology/EPA fears pursuing the unknown path of using site specific data. If site-specific data are used, a justification and supporting documentation must be provided for EPA/Ecology review and approval. Before running the initial run of the PRA, change the approach to follow the guidance.

27 Comment 100 – Add a herbivorous bird guild.

28 Comment 101, 12 – Addressing risk to salmonids is a risk communication issue and will help demonstrate the WTP is consistent with the Endangered Species Act. Include two tables in the risk assessment report, one addressing the risk to aquatic life and the other addressing risk to salmonids. The analysis will be performed on salmonids in general, not specific salmonid species. Include references for data used to calculate risk; these values should reside in the ECOTOX database. EPA observed that limited data would be available. Look at the ATG table addressing salmonids; provide a reference for the data (ATG did not).

29 Comment 98 – Look at guidance for direction.

Bullet 1 Analyze a herbivorous bird feeding guild (see comment 100, item 27)

Bullet 2 Response is okay.

Bullet 3 Conservative body weights will be used. Calculate soil, water, food, and sediment ingestion rates using allometric equations in the Screening Level Ecological Risk Assessment Protocol (SLERAP) to convert body weights. The guidance does not support body weight scaling.

Bullet 4 – To convert for body weight, do not scale for body weight; use the smallest body weight number. Calculate the soil/water ingestion rates using allometric equations. For predators, base soil ingestion rates on life history.

30 Comment 60, 115 – Do not cover the synergistic effects quantitatively; cover in uncertainty discussion. Work is being done to lower the No Observed Radiological Effects Level (NOREL) thresholds; cover in the uncertainty discussion. Cover root hairs, eggs, embryos, etc. in the uncertainty discussion.

31 Comment 119, 120, 133 – Cover in uncertainty section. SLERAP, Page 2-70 suggests screening. Use 1 rad/day and discuss 0.1 rad/day in the uncertainty discussion. Review the research and development, and the microdosimetry work being done in narrative fashion. The 1 rad/day value doesn't address the microdosimetry issues.

32 Comment 108 – Do food chain multiplier (FCM) for aquatic and terrestrial organisms. Compare aquatic FCMs with terrestrial FCMs. Discuss the comparisons in the uncertainty discussion. This method will work for any organic.

For inorganics, except methyl mercury and selenium, set Bioconcentration Factor (BCF) at 1 – unless guidance recommended values are available.

Do all you can with hierarchy, defaults, etc.

In the absence of data, use a surrogate. Wait until emissions estimate is available; look at the higher numbers. Those are the candidates for using surrogates. If surrogates are needed, the Agencies will provide direction and data for surrogates in the RAWP review stage.

33 Comment 122 – SLERAP recommends using arithmetic mean for some metals. Confirm the SLERAP discussion of arithmetic mean and make appropriate changes to the response. If there are enough data, use it to determine the appropriate mean, either geometric or arithmetic.

34 Comment 148 – Regarding the distinction between vegetative (i.e., leaves) and reproductive (i.e., seeds), go to the distinction only if there's a reason to do so, i.e., when we discuss the need to go from a screening to a more specific Risk Assessment (RA). Adjust the response to clarify this approach. For now, cease making a distinction between vegetative and reproductive; use the SLERAP recommended total plant approach.

35 Comment 116 – Discussion with John Mauro. He felt CHG should use the QF of 5 rather than 20; it was agreed that the QF of 5 would be used. DOE and CHG requested the EPA/Ecology technical basis for this value.

36 Comment 117 – Discussion with John Mauro. The response is acceptable. ATG used the volumetric approach. For human health exposures; use ratio to convert the Health Effects Summary Table (HEAST) slope factor:

$$\text{Adjustment factor} = \left(\frac{\text{Dose conversion factor for 1 cm}}{\text{Dose conversion factor for infinite depth}} \right) * (\text{HEAST value})$$

37 Comment 2 – Response is okay.

38 Comment 13 – For chemicals with multiple values, use the most conservative. Follow the explicit guidance for selecting No Observed Adverse Effects Levels (NOAELs) over Lowest Observed Adverse Effects Levels (LOAELs), etc. Continue to use the table format to present the information. Be specific as to source of the data. Look in SLERAP, Appendix E for guidance.

39 Comment 15 – Take out the Region 5 EDQL. Look at the 1999 version of the SLERAP; go to literature if values not available there. Bill Desmond will confirm the hierarchy published in the response is okay.

40 Comment 16 – Add a statement saying that relevance and appropriateness will be discussed. Follow the hierarchy strictly. Set up a table to show the hierarchy. Also follow the NOAEL/LOAEL hierarchy.

41 Comment 105 – Remove first sentence of the response. DOE agreed to write an explanation addressing the rationale for selecting the spotted sandpiper and bald eagle.

42 Comment 121 – Discuss the hierarchy thought process for things not in the guidance. Provide a general discussion/explanation of how values were assigned for things not in the guidance and the assigned hierarchy.

43 Comment 130 – Use the Oak Ridge studies, but do not necessarily adopt their benchmarks. Be able to document the number used.

44 Comment 10 – Make it clear that all surface water concentrations for human health and ecological exposures are the maximum values for the Columbia River.

45 Comment 104 – Same direction as comment 10. Grids are set up so that we could do habitat if necessary. Discuss in the next phase of the RA if needed. Take food web to maximum exposure locations. Put in descriptions of how we do surface water; how long we assume water is stagnant for the sake of conservatism.

46 Comment 112 – Explicitly describe how we will take food web to points of maximum exposure.

47 Comment 94 – Collect all parameters together for the uncertainty discussion. Discuss effects parameters and non effects parameters, separately. In the effects discussion discuss, neurological and other effects parameters and the lack of toxicity information. Present a general discussion in the Work Plan and say what will be described when actual emissions values are available in the SLRA. Accept a certain amount of uncertainty in the FRA. Make the uncertainty discussion related to this RAWP. State in the work plan how uncertainty will be handled. Focus on risk drivers specific to this study. Put larger discussion in text. Put other information in tables. Change the unknown column in the table to "both under or over-estimate". Add distinction of "unknown data" and "variable data".

Action Table			
Action Item	Responsibility	Due Date	Action to Close
1.1 Comment 67	DOE/CHG	1/15/01 Note (1)	Add detail to text – explain why individuals are okay even though their specific location was not considered (i.e., place resident at maximum location)
1.2 Comment 67	DOE/CHG	RAWP Rev 2	Map locations of sub-populations in work plan – post May 2001 PRA
1.3 Comment 67	DOE/CHG	Completed	Be open to doing another receptor location following public comment.
2.1 Comment 69	DOE/CHG	RAWP Rev 2	Link text to equation – either by category or by number. (numbers will not be added until later to avoid constantly changing text)
5.1 Comment 77	DOE/CHG	1/15/01 Note (1)	Change "or" to "and" in response.
6.1 Comment 84	DOE/CHG	Note (5)	Schedule telecon post emissions estimate to discuss further.
7.1 Comment 86	DOE/CHG EPA/Ecology	1/15/01 Note (1)	Use latest acute toxicity values in risk assessment – EPA will identify and correct values when they review/approve work plan
7.2 Comment 86	DOE/CHG	Note (2)	Explain acute 1-hour exposure – Need to explain/evaluate by-pass scenario. Explain whether the treatment pathway is different. Look at the ATG scenario, specifically, where they did a different acute inhalation scenario when they by-pass the residence chamber.
7.3 Comment 86	DOE/CHG	1/15/01 Note (1)	Use AGEL-2 value if AGEL-1 is not available, unless something else in hierarchy is more conservative.
8.1 Comment 79, 83 & 85	DOE/CHG	1/15/01 Note (1)	Present dioxins and PCBs separately for use in determining process controls (e.g., feed or emissions)
8.2 Comment 79, 83 & 85	DOE/CHG	1/15/01 Note (1)	Sum dioxins and coplanar PCBs together and discuss toxicity
9.1 Comment 91	DOE/CHG	1/15/01 Note (1))	Change EPA/Ecology input to approval
10.1 Emissions estimate	DOE/CHG	Completed Note (6)	Determine whether PNNL provided detection limits based on high-resolution methods?

Action Table			
Action Item	Responsibility	Due Date	Action to Close
10.2 Emissions estimate	DOE/CHG	Note (7)	Provide a copy of 10/99 Fate of Hazard Organics report – minus data to start (transmit consistent with rules for proprietary information)
10.3 Emissions estimate	DOE/CHG	Complete	Add proprietary information discussion to IPT agenda (e.g., WAC requirements)
10.4 Emissions estimate	DOE/CHG	Note (4)	Let EPA/Ecology know when pilot tests are scheduled. They may want to observe the testing.
10.5 Emissions estimate	DOE/CHG	before testing	Provide briefing on VSL testing. (telecon)
11.1 Comment 25	DOE/CHG	RAWP Rev 2	Provide a better explanation of ROPCs in work plan (i.e., 46 is all there is)
12.1 Comment 5	DOE/CHG	12/14/00	Provide EPA/Ecology with equipment selection document
12.2 Comment 5	DOE/CHG	Note (4)	Provide EPA/Ecology Test Plan for R&T Work
12.3 Comment 5	DOE/CHG	Note (5)	Schedule meeting with Process Engineering/EPA/Ecology on equipment selection
12.4 Comment 5	DOE/CHG	1/15/01 Note (1)	Clarify response to address design of system consistent with R&T and Ecology/EPA expectations re: 4-9's, emissions standards for metals, acid gases, containment, etc., (i.e., criteria for subpart X).
13.1 Comment 8	DOE/CHG	1/15/01 Note (1)	Same as comment 5, item 12.
14.1 Comment 9	DOE/CHG	post initial run of PRA	EPA /Ecology must approve emission estimates for dispersion modeling
15.1 Comment 34	DOE/CHG	1/15/01 Note (1)	Clarify how and when we will provide emissions estimate and emissions data from performance demonstration in response.
15.2 Comment 34	DOE/CHG	1/15/01 Note (1)	Include source of data in response; summarize emission rates, cite fate determination report (refer to pilot work).
16.1 Comment 35	DOE/CHG	1/15/01 Note (1)	Clarify how and when we will provide emissions data per comment 34, item 15 with attention to source.
17.1 Comment 41	DOE/CHG	1/15/01 Note (1)	Add detail on what "scaling up" means. Include a sample calculation.
18.1 Comment 42, 43 & 46	DOE/CHG	Note (5)	Look into "abated" fugitive emissions.

Action Table			
Action Item	Responsibility	Due Date	Action to Close
18.2 Comment 42, 43 & 46	DOE/CHG	Note (5)	Determine whether we have emissions from equipment that follow a less rigorous treatment path. If no "abated" fugitive emissions exist – demonstrate it
18.3 Comment 42, 43 & 46	DOE/CHG	Note (5)	The human health risk assessment guidance includes a reference on how to calculate leakage; determine whether it is applicable.
18.4 Comment 42, 43 & 46	DOE/CHG	Note (5)	Close loop with Ecology and EPA on abated fugitive emissions.
19.1 Comment 14	DOE/CHG	1/15/01 Note (1)	Add clarification to the work plan that the emissions estimate is across entire process including pretreatment.
19.2 Comment 14	EPA/Ecology Cathy Massimino	completed	Provide advanced mixed waste risk assessment and HEPA filter website. Look at being consistent on HEPA filter efficiency.
20.1 Comment 53	DOE/CHG	1/15/01 Note (1)	Provide better description of why we might switch to CALPUFF model (e.g., handles more details – not because we do not like results).
20.2 Comment 53	EPA/Ecology Cathy Massimino		Talk to EPA air modeler re: availability of other meteorological data sets
21.1 Comment 63	DOE/CHG	May 2001	Look at partitioning rad into sediment in river.
22.1 Comment 64 & 65	DOE/CHG	1/15/01 Note (1)	Modify response to reflect appropriate guidance for human health and ecological risk.
24.1 Comment 72	EPA/Ecology John Mauro	Note (3)	Check whether antimony, ruthenium, technetium can become volatile in the sweat lodge scenario.
24.2 Comment 72	EPA/Ecology John Mauro	Note (3)	Check whether other radionuclides (from the list of 46) could become volatile in the sweat lodge scenario.
24.3 Comment 72	EPA/Ecology John Mauro	Note (3)	Check whether the HEAST slope factors for inhalation include dermal absorption where appropriate.
24.4 Comment 72	DOE/CHG	1/15/01 Note (1)	Revise list of volatile ROPCs to reflect that Iodine, Tritium C-14 are volatile, Cs is not.
25.1 Comment 86	EPA/Ecology John Mauro	Note (3)	Provide reference for the exposure to 1000 mrem for 1 hour causing blood changes.
25.2 Comment 86	EPA/Ecology John Mauro	Note (3)	Provide general radionuclide background for human breast milk
25.3 Comment 86	DOE/CHG	1/15/01 Note (1)	Decide how to present acute radionuclide exposure effects.

Action Table			
Action Item	Responsibility	Due Date	Action to Close
26.1 Comment 1	DOE/CHG	1/15/01 Note (1)	Clarify response – do not gather a lot of indefensible date – wildlife exposure did not follow guidance.
27.1 Comment 100	DOE/CHG	1/15/01 Note (1)	Add herbivorous bird feeding guild.
28.1 Comment 101 & 12	DOE/CHG	1/15/01 Note (1)	Add a table for Salmonids (in addition to aquatic table), use ECOTOX and ATG data
29.1 Comment 98	DOE/CHG	1/15/01 Note (1)	Bullet 1 – Add herbivorous bird feeding guild (same as comment 100, item 27)
29.2 Comment 98	DOE/CHG	1/15/01 Note (1)	Bullet 3 – Use body weights (from wildlife exposure handbook) then calculate soil, water, food and sediment ingestion rates from body weights using allometric equations from guidance
29.3 Comment 98	DOE/CHG	1/15/01 Note (1)	Bullet 4 – For predators that ingest soil, do in accordance with bullet 3, item 29.2 based on life history.
30.1 Comment 60, 115,	DOE/CHG	1/15/01 Note (1)	Delete response. Provide robust qualitative discussion in uncertainty section
31.1 Comment 119, 120 & 133	DOE/CHG	1/15/01 Note (1)	Keep first part of response re: 1.0 rad/day not 0.1 rad/day. Provide discussion (recognize – don't quantify) of uncertainty associated with 1 rad – re: microdosimetry. Discuss ongoing research
32.1 Comment 108	DOE/CHG	1/15/01 Note (1)	Delete "tentative" from response – use food chain multiplier approach for both aquatic and terrestrial food chains.
32.2 Comment 108	DOE/CHG	1/15/01 Note (1)	Discuss uncertainty with terrestrial food chain multipliers in uncertainty section.
32.3 Comment 108	DOE/CHG	1/15/01 Note (1)	For metals and inorganics food chain multiplier will be set to 1.0 – if another value is not available.
32.4 Comment 108	DOE/CHG EPA/Ecology	1/15/01 Note (1)	Do not use surrogates at this time. EPA will reevaluate when emission values are available.
33.1 Comment 122	DOE/CHG	1/15/01 Note (1)	Confirm what SLERAP says re: arithmetic mean. Modify response as appropriate.
33.2 Comment 122	DOE/CHG	1/15/01 Note (1)	When data sets are sufficient – calculate appropriate means based on the data distribution.
34.1 Comment 148	DOE/CHG	1/15/01 Note (1)	Cease making distinction between (vegetative) leaves and (reproductive) seeds – tissue; use total plants. Consider partitioning after PRA as appropriate.

Action Table			
Action Item	Responsibility	Due Date	Action to Close
34.2 Comment 148	DOE/CHG	1/15/01 Note (1)	Provide short example of when you might partition.
34.3 Comment 148	EPA/Ecology	Note (3)	Provide technical basis for QF of 5.
36.1 Comment 117	DOE/CHG	1/15/01 Note (1)	Related issue – not specific to comment 117. When using volumetric equations from HEAST tables, also need to do areal/volumetric dose conversion.
38.1 Comment 13	DOE/CHG	1/15/01 Note (1)	Clarify tables to demonstrate source of values are traceable (per appendix E of SLERAP)
39.1 Comment 15	DOE/CHG	1/15/01 Note (1)	Bullet 3 – remove Region 5 EDQL reference.
39.2 Comment 15	EPA/Ecology Bill Desmond	Note (3)	Confirm hierarchy provided in response is appropriate except for EDQL.
40.1 Comment 16	DOE/CHG	1/15/01 Note (1)	Explain in a footnote to table why values are relevant and appropriate. May add column on preferred value to tables. Follow hierarchy in guidance.
41.1 Comment 105	DOE/CHG	1/15/01 Note (1)	Remove "tentative" from accepted.
41.2 Comment 105	DOE/CHG	1/15/01 Note (1)	Add discussion on how we selected our receptors.
42.1 Comment 121	DOE/CHG	1/15/01 Note (1)	Discuss how we assign hierarchy of sources – provide citation and explanation for selection of source values. Provide general discussion not chemical by chemical.
43.1 Comment 130	DOE/CHG	RAWP Rev. 2	Use Oak Ridge studies – but not their bench marks (their explanations are insufficient)
44.1 Comment 10	DOE/CHG	1/15/01 Note (1)	Clarify – how receptors are moved to maxima, i.e., moving food web to maximum concentration location.
45.1 Comment 104	DOE/CHG	1/15/01 Note (1)	Same as comment 10, item 44. Include discussion of water residence time (see comment 63, item 21)
46.1 Comment 112	DOE/CHG	1/15/01 Note (1)	Same as comment 10, item 44. Explicitly describe how we will take food webs to point of maximum concentrations.
47.1 Comment 94	DOE/CHG	1/15/01 Note (1)	Collect all similar parameters together for the uncertainty discussion
47.2 Comment 94	DOE/CHG	1/15/01 Note (1)	Discuss effects parameters and non-effects parameters, exposure separately.
47.3 Comment 94	DOE/CHG	1/15/01 Note (1)	In the effects discussion, present neurological and other effects parameters and the lack of toxicity information.

Action Table			
Action Item	Responsibility	Due Date	Action to Close
47.4 Comment 94	DOE/CHG	1/15/01 Note (1)	Present a general discussion in the RAWP and identify what will be discussed when the SLRA is run.
47.5 Comment 94	DOE/CHG	1/15/01 Note (1)	Put other information in tables. Change the "unknown" column heading to "both over and under estimate". Add distinction of unknown and variable data.

Note (1): To be completed upon issuance of revised responses to Regulatory Agency comments dated July 26, 2000. Revised responses will be issued by 1/15/2001 to DOE for transmittal to the regulatory agencies.
Note (2): CHG will evaluate the acute inhalation scenario resulting from melter offgas venting to the melter cell, and will determine whether the acute inhalation scenario is an accident. We propose to discuss the results of our determination on February 15, 2001.
Note (3): To be useful in May 2001 preliminary risk assessment activities, this information is needed no later than January 15, 2001.
Note (4): Budget restrictions have forced the realignment of the WTP Research and Technology program, including the DM1200 integrated testing. Once new schedules have been prepared, they will be shared with the regulatory agencies.
Note (5): We propose a meeting on February 15, 2001 to discuss a number of topics: the results of the emissions estimate, the equipment selection documents, the acute inhalation scenario, and progress on abated fugitive emissions.
Note (6): The dioxin and furan detection limits were derived using high resolution mass spectrometry (EPA Method 5). Detection limits for other organics were derived based upon standard quadripole mass spectrometry (Method TO-14, TO-15, SW-846 Method 8270, etc.). The detection limits derived using quadripole mass spectrometry would not significantly differ from detection limits derived from high resolution methods. Quadripole mass spectrometry methods that require the full scanning technique, such as EPA Method TO-15 and SW-846 Method 8270 will have higher detection limits than methods that use selective ion monitoring techniques such as SW-846 Method 8280A (dioxins using low-resolution GC/MS), SW-846 Method 8290 (dioxins using high-resolution GC/MS), EPA Method 5, or Method TO-14 (VOCs using GC/MS SIM, GC/PID, GC/PID). The estimated detection limits for the dioxins and furans were based on GC/MS SIM measurements. All others estimated detection limits were based on full scanning GC/MS or other selective detectors.
Note (7): *Determination of the Fate of Hazardous Organics During Vitrification of RPP-WTP LAW and HLW Simulants* (Volume I) (TRPT-W375-99-00002, Rev. 0), October 4, 1999 will be forwarded to DOE for transmittal to the agencies upon finalization of proprietary information concerns.

JMcl. for

Lee Bostic
12/1/00

Attendees			
M. Bailey	U.S. EPA 1200 6th Avenue Mail Stop EOA-095 Seattle, WA 98101	L. Bostic	CH2M Hill Hanford Group Inc. 3000 George Washington Way Mail Stop H4-20 Richland, WA 99352
M. Burandt	DOE Office of River Protection 2440 Stevens Drive Mail Stop H6-60 Richland, WA 99352	J. Cook	CH2M Hill Hanford Group Inc. 3000 George Washington Way Mail Stop H4-20 Richland, WA 99352
B. Cornaby	SAIC PO Box 2502 800 Oak Ridge Turnpike Oak Ridge, TN 37831	D. Delistraty	Washington Dept. of Ecology N. 4601 Monroe Spokane, WA 99205
B. Desmond	Tetra Tech EMI, Inc. 350 N. St. Paul Street Suite 2600 Dallas, TX 75201	B. Erlandson	CH2M Hill Hanford Group Inc. 3000 George Washington Way Mail Stop H4-20 Richland, WA 99352
J. Grantham	Washington Dept. of Ecology Nuclear Waste Program PO Box 47600 Olympia, WA 98504-7600	C. Massimino	U.S. EPA 1200 6th Avenue Mail Stop WCM-127 Seattle, WA 98101
J. Markillie	CH2M Hill Hanford Group Inc. 3000 George Washington Way Mail Stop H4-20 Richland, WA 99352	J. Mauro (telecon)	Sandy Cohen & Assoc. C/O Bill Desmond Tetra Tech EMI, Inc. 350 N. St. Paul Street Suite 2600 Dallas, TX 75201
E. Morton	Tetra Tech EMI, Inc. 350 N. St. Paul Street Suite 2600 Dallas, TX 75201	S. Robers	SAIC 2409 B. Bunker Lane Willoughby, OH 44094
S. Skurla	Washington Dept. of Ecology Nuclear Waste Program 1315 W. 4th Avenue Mil Stop B5-18 Kennewick, WA 99336-6018	J. Yokel	Washington Dept. of Ecology Nuclear Waste Program 1315 W. 4th Avenue Mil Stop B5-18 Kennewick, WA 99336-6018

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Attachment 1

AGENDA

Consisting of 7 pages
including cover page

CH2MHILL
Hanford Group, Inc.

River Protection Project
Waste Treatment Plant
3000 George Washington Way
Richland, WA 99352
Tel: 509 371 3500
Fax: 509 371 3504

Resolution of Comments from Ecology and USEPA on RAWP

Agenda

Date: November 1, 2000

Time: 9:30 a. m.

Location: EPA Region 10, 1200 6th Avenue, Seattle, Washington

Chairman/Secretary: Bradley Erlandson/Jeffrey Markillie

Goals/Objectives: Resolve Comments from Ecology and USEPA on the Risk Assessment Work Plan

	Agenda Item/Issue	Allocated Time
1.	**Introductions – Brad Erlandson**	**5 Minutes**
2.	**Opening Statements – Brad Erlandson** • **Ecology and EPA** • **CHG and SAIC** • **DOE**	**15 Minutes**
3.	**Purpose – Lee Bostic** • **To understand Ecology and EPA comments on methods/data and to reach resolutions on the path forward** • **To document decisions and action items relative to going forward**	**10 Minutes**
4.	**Overview of the melter – Jeff Markillie** • **Purpose** • **Pretreatment** • **Vitrification** • **Progress on schedule** • **Role of the RAWP and PRA in permitting**	**40 Minutes**
5.	**Master schedule and timing – Jeff Markillie**	**10 Minutes**
6.	**Break**	**15 Minutes**
7.	**Overview of comments about the RAWP for the melter – Barney Cornaby** • **There are 163 comments on the RAWP and some comments are compound** • **We recognize eight categories of comments: emissions, COPCs, air model, fate and transport, human health risk**	**10 Minutes**

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Resolution of Comments from Ecology and USEPA on RAWP

Agenda

Date: November 1, 2000

Time: 9:30 a. m.

Location: EPA Region 10, 1200 6th Avenue, Seattle, Washington

	Agenda Item/Issue	Allocated Time
	assessment, ecological risk assessment, editorial/minor technical, and joint human/ecological	
	• Of the 163, 54 (33%) are editorial/minor technical and need no discussion; we agree with all	
	• Of the 163, 40 (25%) are environmental, e.g., emissions, COPCs, air model and F&T	
	• Of the 163, 69 (42%) are human health and ecological risk related and constitute the majority of the comments to discuss/ resolve	
8.	Resolution for 8 human health risk assessment comments (see attachment) – Barney Cornaby and Sharon Robers	2 Hours
	• RAWP Tracking Numbers: 67, 72, 74, 84, 86, 79, 83, 85	
	• Others for Ecology and EPA	
	• Summary of Resolutions	
9.	Lunch	1 Hour and 15 Minutes
10.	Resolution of 13 environmental comments (see attachment) – Barney Cornaby	3 Hours
	• COPCs: RAWP Tracking Number 25	
	• Emissions: RAWP Tracking Numbers 5, 8, 9, 34, 35, 41, 42, 43, 14	
	• F&T: RAWP Tracking Numbers 63, 64, 65	
	• Others for Ecology and EPA	
	• Summary of Resolutions	
	Adjourn Day 1	

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Resolution of Comments from Ecology and USEPA on RAWP

Agenda

Date: November 2, 2000

Time: 8:30 a. m.

Location: EPA Region 10, 1200 6th Avenue, Seattle, Washington

Chairman/Secretary: Bradley Erlandson/Jeffrey Markillie

Goals/Objectives: Resolve Comments from Ecology and USEPA on the Risk Assessment Work Plan

	Agenda Item/Issue	Allocated Time
1.	Purpose of meeting and summary of first day's work – Jeff Markillie	20 Minutes
2.	Resolution for 20 ecological risk assessment comments (see attachment) – Barney Cornaby and all • RAWP Tracking Numbers: 1, 98, 100, 101, 60, 115, 117, 120, 133, 119, 108, 148, 2, 13, 15, 105, 121, 130, 10, 104 • Others for Ecology and EPA • Summary of Resolutions	4 Hours with a break
3.	Lunch	1 Hour and 15 Minutes
4.	Resolution for other comments as time permits – Barney Cornaby, Sharon Robers and all	1 Hour and 15 Minutes
5.	Review of action items – Jeff Markillie • Master schedule and timing of work • List of resolved comments/responses • Plan to resolve any lingering comments/responses	1 Hour
6.	Closing statements and goodbyes – Brad Erlandson • Ecology and EPA • CHG and SAIC • DOE	

Adjourn Day 2

Eight Human Health Risk Assessment Comments for Discussion and Resolution

Tracking Number RAWP	Category	Gist of Comment
067	HHRA Method	Identify types and locations of special subpopulations (i.e., day care centers)
072	HHRA Completeness	Identify ROPCs that are considered volatile and give rationale for excluding a sweat lodge dermal absorption pathway for ROPCs
074	HHRA Method	Add methods for tritium and C-14
084	HHRA Method	Add background concentrations of radionuclides in the environment
086	HHRA Method	Clarify the difference between acute exposure and accident-related exposure. Explain why DACs and ALIs are used. Use AEGL-2 values when AEGL-1 values are unavailable.
079	HHRA Method	Clarify that TEQs for dioxin-like PCBs will be added to TEQs for PCDDs/PCDFs for estimating cancer risks from dioxin-like compounds
[illegible]	HHRA Method	Clarify that coplanar PCBs will be evaluated additively with PCDD/PCDF TEQs for the nursing infant assessment

Thirteen Environmental Comments for Discussion and Resolution

Tracking Number RAWP	Category	Gist of Comment
025	COPC Method	List all rads in tanks and revise selection of ROPCs
005	Emissions Completeness	Document DRE for organics. Document ability to meet 99.99% DRE and how to minimize dioxin formation.
008	Emissions Completeness	Provide evidence for 99.99% DRE for organics. Provide emissions rates in work plan
009	Emissions Completeness	Provide emission rates and document how they were calculated
034	Emissions Completeness	Document the source of emission rate estimates
035	Emissions Completeness	Provide surrogate emissions data that is being considered for evaluation in the PRA
041	Emissions Completeness	Refer to 5.2.1.4 regarding scaling factor. Explain how identified organics will be quantified.
042	Emissions Method	Clarify estimation of fugitive emissions, including ventilation systems
043	Emissions Method	Document sources of fugitive emissions and emission models, including sample calculations
014	Emissions Completeness	Include NOx, melter offgas, pretreatment, and vitrification chemicals in list of COPCs
063	F&T Method	Consider ROPC daughter products in surface water modeling
064	F&T Method	Clarify whether Cdw or Cwtot will be used to calculate fish tissue concentrations and why it was selected
065	F&T Use of Guidance	Clarify and justify the use of whole water concentrations rather than Cdw for estimating fish concentrations

10/16/2000

Twenty Ecological Risk Comments for discussion and Resolution

Tracking Number RAWP	Category	Gist of Comment
001	ERA Use of Guidance	Recognize that methods surpass available data. Discuss simplifying assumptions
098	ERA Method	Add exposure pathways to the conceptual model and the risk assessment
100	ERA Method	Add herbivorous birds to the risk assessment (but, this is counter to screening per RAWP 001)
101	ERA Method	Evaluate exposure of protected fish species
060	F&T Method	Discuss uptake of radionuclides by critical organs of organisms
115	ERA Method	Expand discussion of radiological impacts to biota to include critical organ, microdosimetric and other issues
117	ERA Method	Use area dose conversion factor rather than volumetric dose conversion factor for external exposure to ROPCs in soil. Evaluate external exposure of root hairs.
120	ERA Method	Justify using 1 rad/d DOE benchmark
133	ERA Method	Justify using 1 rad/d as benchmark
119	ERA Method	Include evaluation of alpha emitters in external exposure of fish eggs and larvae
108	ERA Use of Guidance	Consider using FCM method from SLERAP. Discuss how COPCs without BCFs will be evaluated
148	F&T Data	Explain why "calculated from EPA (1999)" and "SAIC compiled SPv" both cite "Baes and others" but have different values. Correct values for nickel
002	ERA Use of Guidance	Document methods better or revert to EPA SLERAP
013	ERA Completeness	Document ecological effects of COPCs/ROPCs not in EPA SLERAP
015	ERA & HHRA Method	Describe the hierarchy to select parameters from more than one source. Describe basis of each value.
105	ERA Completeness	Justify selection of measurement endpoints or receptors
121	ERA Data (uptake)	Document sources of ingestion and inhalation uptake parameters
130	ERA Data (toxicity)	Document toxicity benchmarks
010	ERA Completeness	Clarify receptor locations; include runoff in surface water calculation
104	ERA Method	Evaluate habitat types separately or justify not doing so

10/16/2000

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Attachment 2

RPP-WTP PVERVIEW SLIDES

Consisting of 9 pages
including cover page

RPP-WTP Overview

Jeff Markillie, REM

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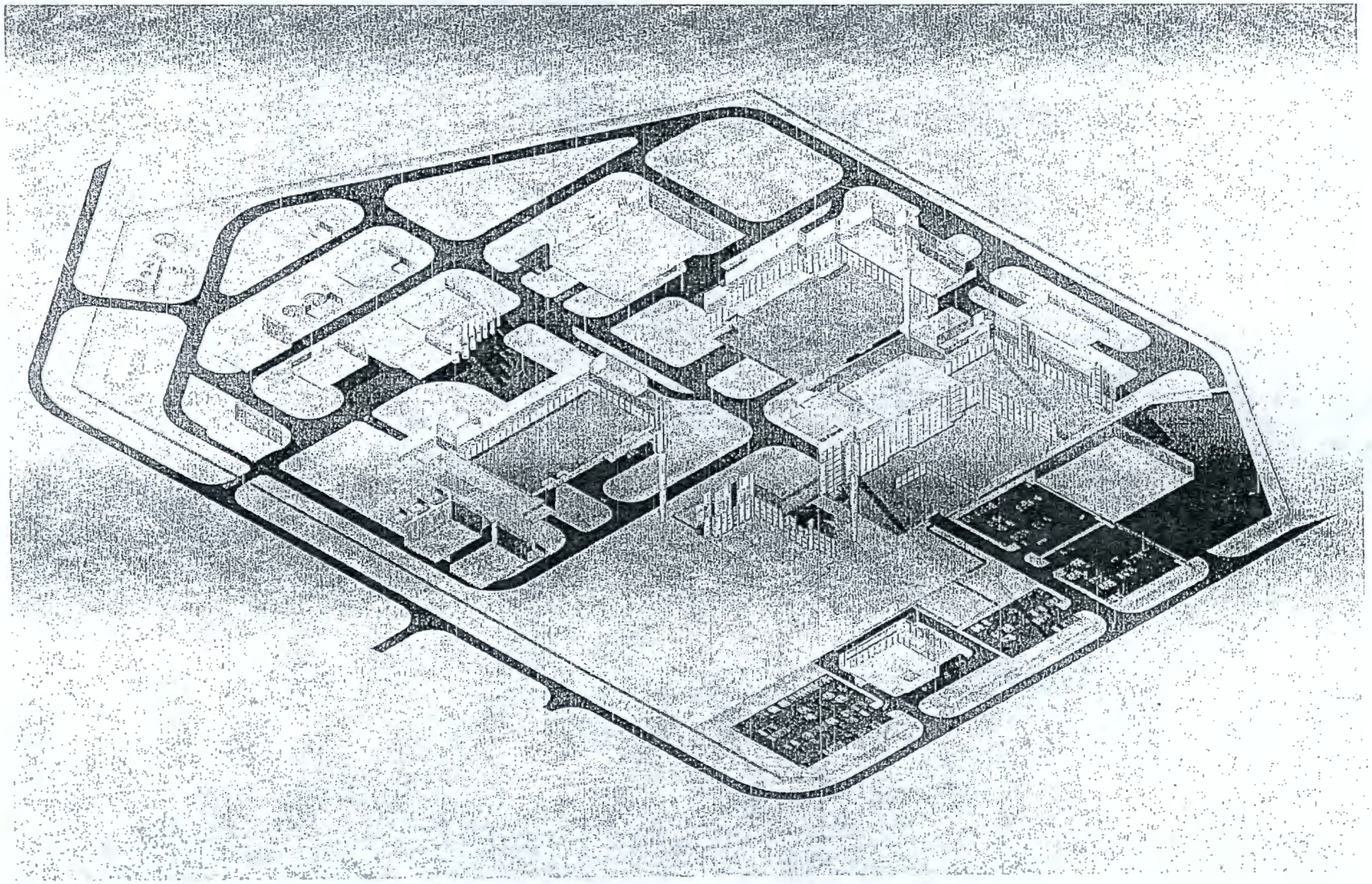
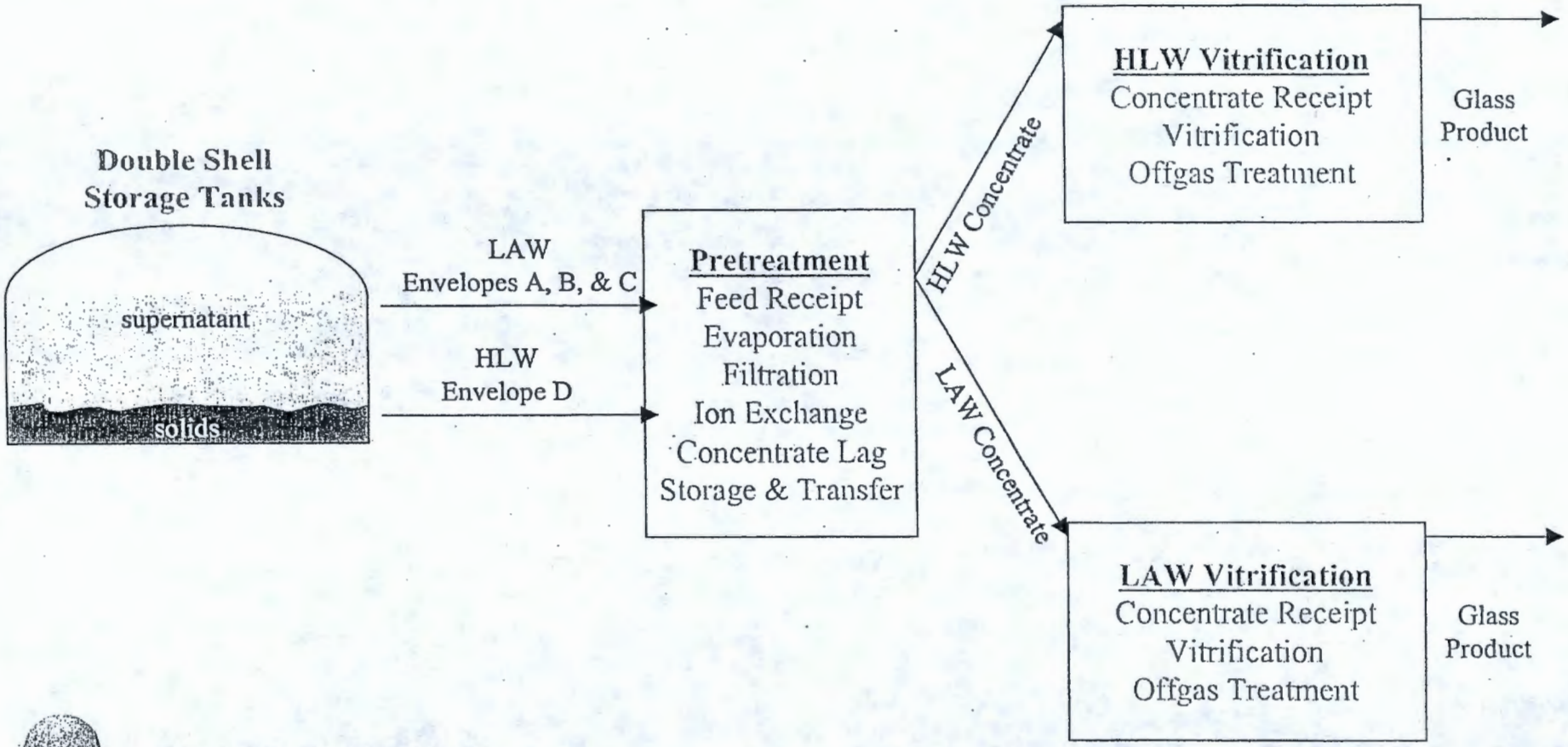


RPP-WTP Treatment Process



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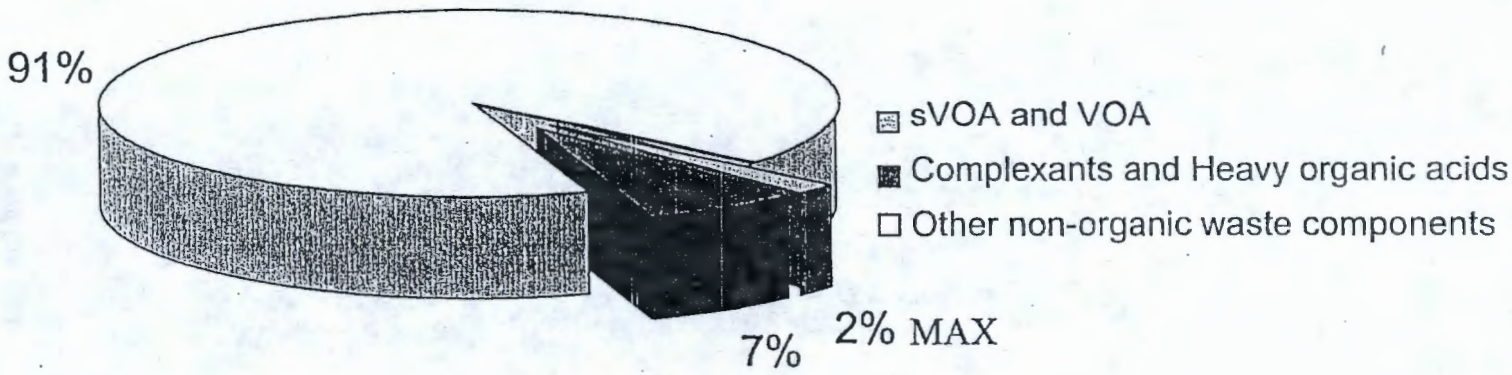
Hanford Tank Waste Constituents



(Campbell, J.A., 1995, Flammable Gas Safety Program Organic Analysis and Analytical Methods Development FY1995 Progress Report, PNL-10776, Pacific Northwest Laboratory, Richland, Washington)

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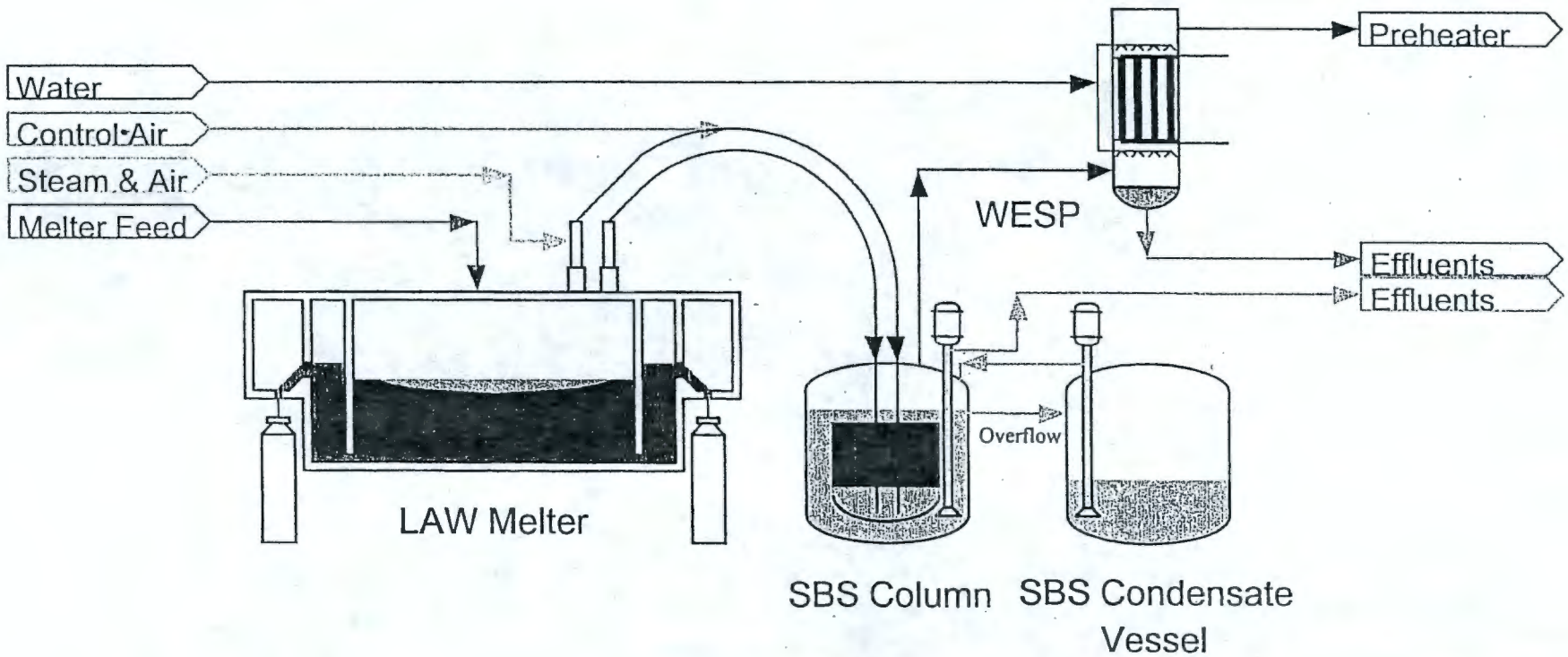
LAW Vitrification Melter and Primary Offgas System



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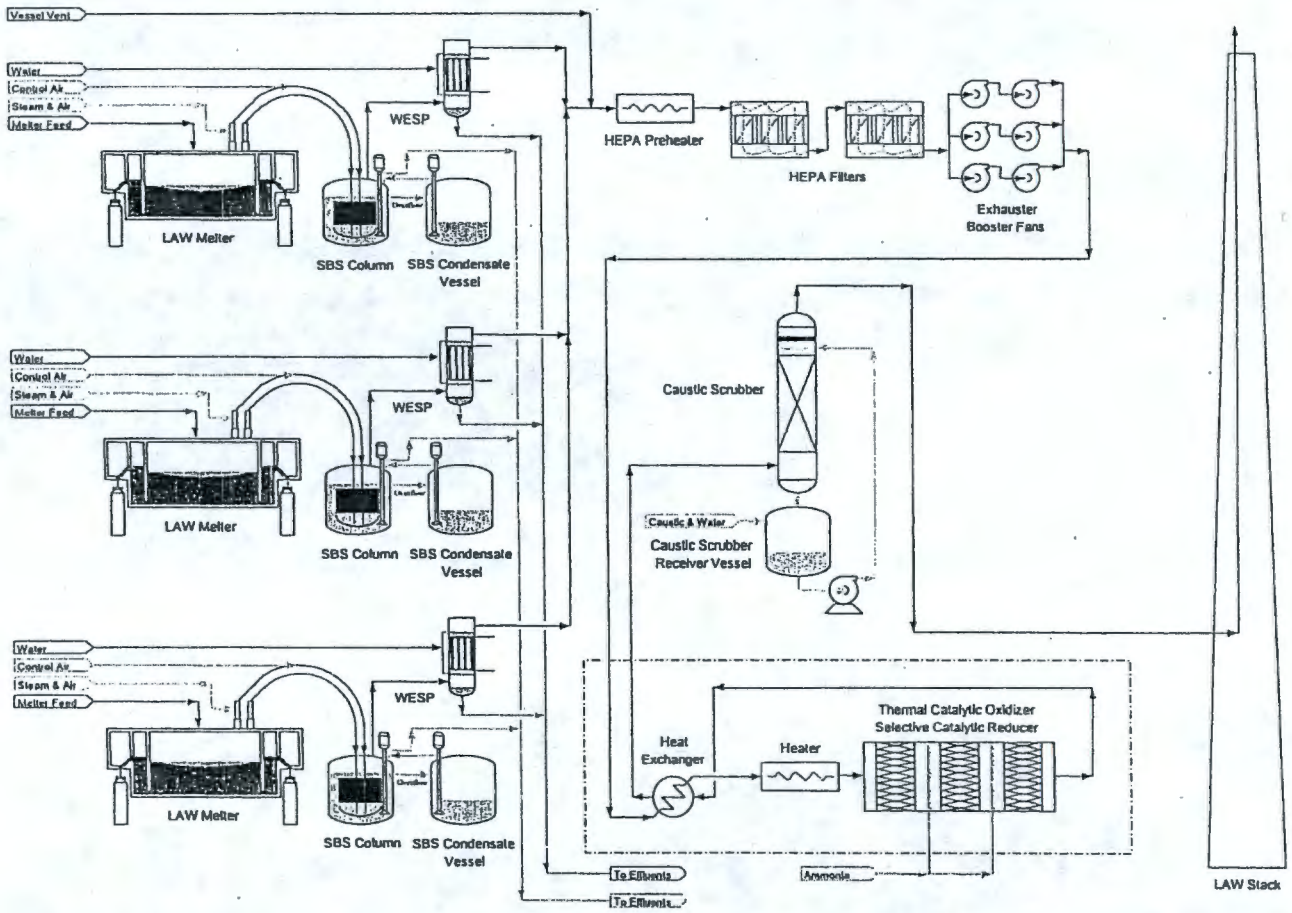
LAW Vitrification Overview



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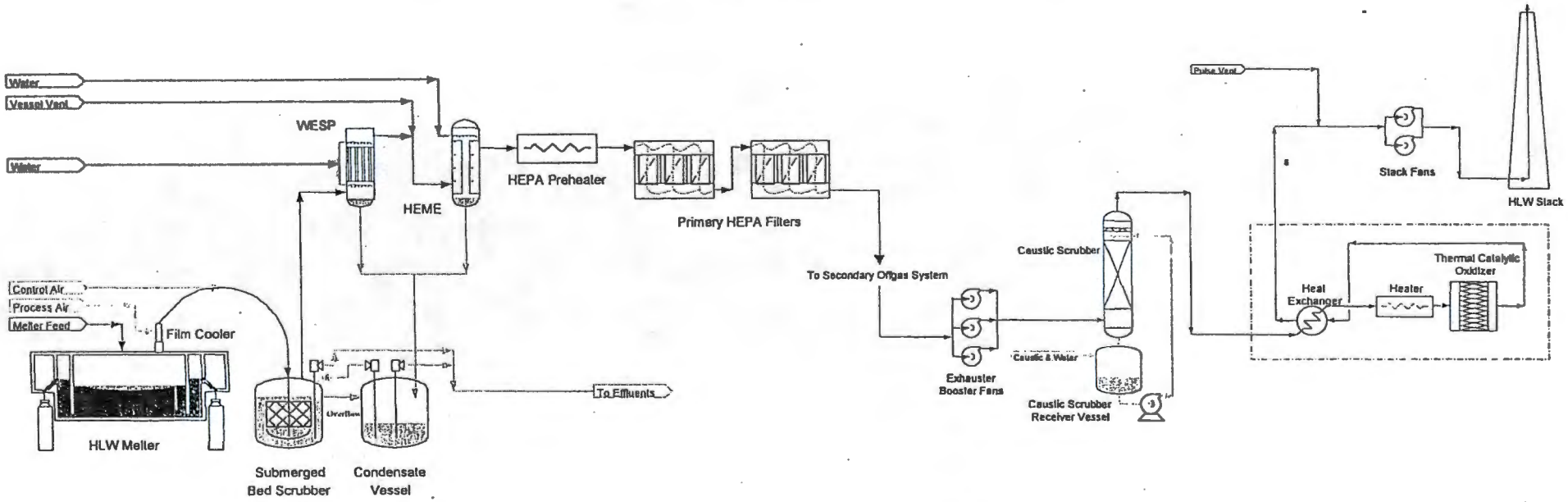
HLW Vitrification Overview



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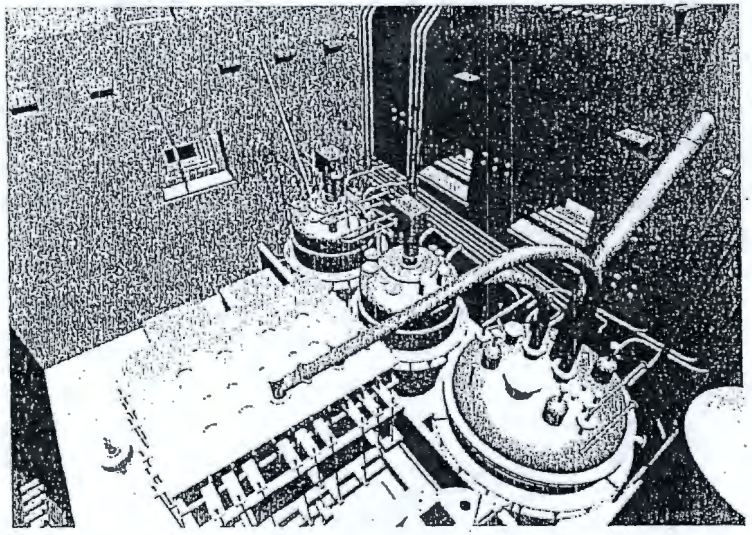
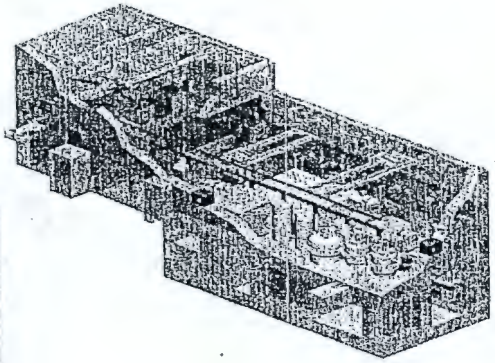
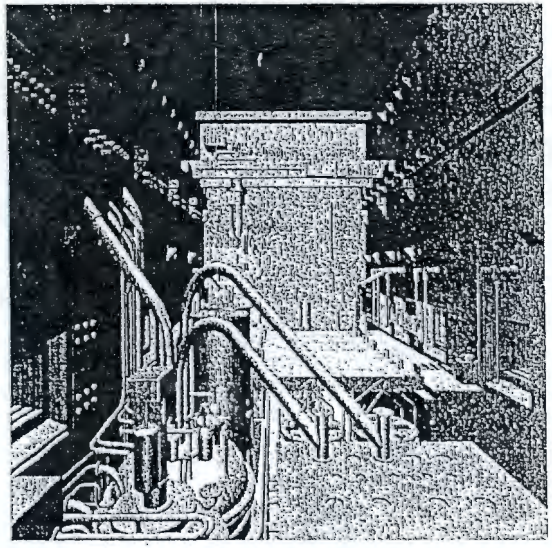
HLW Vitrification Melter Cell Images







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Attachment 3

RPP-WTP EMISSIONS ESTIMATE

Consisting of 7 pages
including cover page

RPP-WTP Emissions Estimate

John Cook

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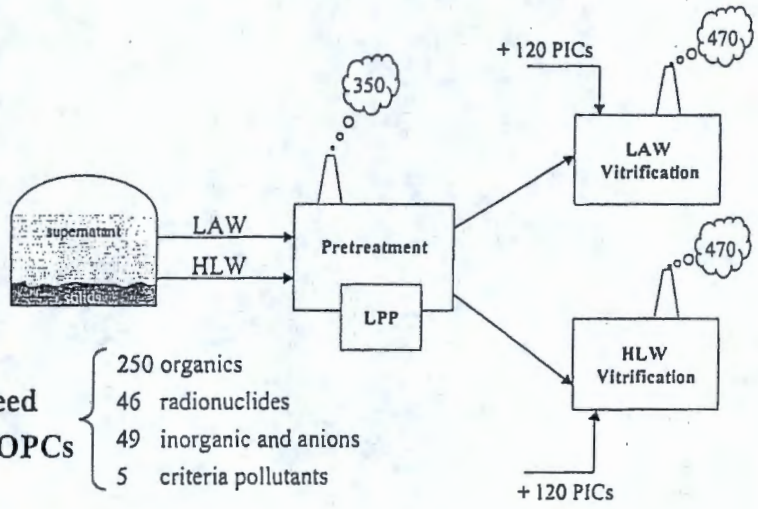
Flowsheet Objectives



Feed COPCs
- 250 organics
- 46 radionuclides
- 49 inorganic and anions
- 5 criteria pollutants

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Modeling Package

- Aspen OLI Custom Modeler (ACM) software
- Steady-state mass and energy balance used to predict and track solid, liquid and vapor phase separations and thermodynamic properties of aqueous systems
- Contains physical properties for 79 inorganic elements and their associated aqueous species, as well as over 3000 organics
- Most mixtures of chemicals in water can be modeled

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Rationale for Using ACM

- Consistency
  - Model used to support engineering design, safety and waste form qualification activities
- Efficiency
  - Waste Treatment Plant specific unit operations and parameters have already been entered into ACM
- Versatility
  - Allows for use of simple decontamination factors (DFs)
  - Accommodates methodology for addressing product of incomplete combustion (PIC) generation

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Major Modeling Assumptions

- Uses April 24, 2000 RPP-WTP design configuration
- Relies upon equipment decontamination factors (DFs) documented in approved engineering calculations, available R&T testing data, and ACM calculations
- Estimates PIC emissions based upon small-scale melter testing at Vitreous State Laboratory of Catholic University
- Addresses the complete list of COPCs using a subset of representative compounds

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PIC Estimation

- "PICs" defined as compounds not present in the waste feed stream that are identified in Table A-1 of the *Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities*
- Test work done by the Vitreous State Laboratory documented in *Determination of the Fate of Hazardous Organics During Vitrification of RPP-WTP LAW and HLW Simulants* (10/99)
- LAW and HLW simulants were spiked with organic compounds (benzene, phenol and trichloroethylene) and resulting offgas was measured for PICs

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PIC Estimation (continued)

- Combinations of differing test parameters (e.g., plenum temperature, feed composition, presence of reductant, residence time) were evaluated
- Small but detectable amounts of dioxins, furans and other organic byproducts (e.g., acrylonitrile, 2,4-dinitrophenol) were produced
- Ratio of the maximum TOC feed rate to the plant to the TOC feed rate was used to scale the maximum PIC emission rates observed
- Undetected compounds were scaled using detection limits
- Resulting emission rates will be added to melter offgas streams in the ACM model

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Modeling Protocol - Organics

- Organics will be predominantly sensitive to 3 physical properties
  - boiling point (volatile, semivolatile, non-volatile)
  - offgas phase (vapor, particle/particle-bound)
  - solubility (insoluble, partially soluble)
- 28 organics and 12 PICs have been selected to represent the 370 organics and PICs on the COPC list
- Selected compounds represent all of the applicable combinations of physical properties (e.g. volatile-vapor-insoluble, volatile-particle-insoluble, etc..) as well as all of the compound families identified in the Work Plan
- Conservative feed concentrations used (based upon *Bounding the Hazardous Organics of Incoming Feed Streams* memorandum)

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Modeling Protocol - Inorganics

- 31 inorganics and anions used to represent the 49 inorganics/anions on the COPC list
- Inorganics selected based on compounds modeled in support of engineering design
- All unmodeled constituents are represented by a modeled element of the same elemental group (e.g., beryllium (an unmodeled constituent) can be represented by the modeled calcium since they are in the same group (IIA) and their physical properties (boiling point, melting point) are comparable)
- Chemical compositions are based on actual tank data for an actual Envelope A feed tank (241-AW-101)

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Modeling Protocol - Radionuclides

- 28 radionuclides used to represent the 46 radionuclides on the COPC list
- Modeled compounds comprise >99.99 % of the activity in the DST system
- All unmodeled constituents are represented by a modeled element of the same elemental group or a comparable consideration to the physical properties and number of valence electrons
- Feed concentrations for radionuclides established at Contract Maximum levels for HLW solids and LAW supernatants

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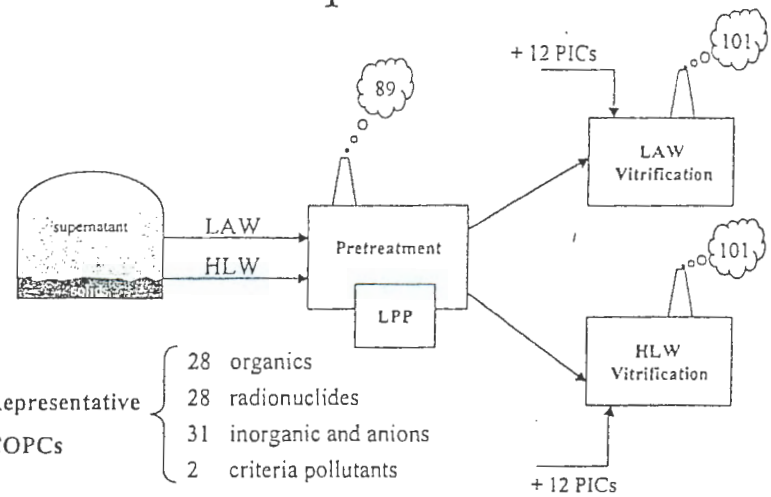
Simplified Model



Representative COPCs
- 28 organics
- 28 radionuclides
- 31 inorganic and anions
- 2 criteria pollutants

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Emissions Package

- Document the assumptions and rationale used in the emissions estimate
- Identify the modeled compounds and provide a one-to-one crosswalk between the modeled compounds to the COPC represented
- Record the actual ACM modeling results
- Compile a complete list of the 470 COPC emission rates based upon the modeling results and constituent-specific feed concentration (this will be the basis for air dispersion modeling)
- Scheduled for completion 1/15/01

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Attachment 4

HEPA FILTERS USED IN THE DEPARTMENT OF ENERGY'S HAZARDOUS FACILITES

Consisting of 11 pages
including cover page

June 8, 1999

The Honorable Bill Richardson
Secretary of Energy
1000 Independence Avenue, SW
Washington, DC 20585-1000

Dear Secretary Richardson:

Since its inception, the Defense Nuclear Facilities Safety Board (Board) has provided its observations on a number of issues associated with confinement ventilation systems installed in the facilities under the Board's purview. In particular, issues involving high-efficiency particulate air (HEPA) filters identified by the Board's staff during its reviews of ventilation systems have been highlighted in the Board's correspondence. Many of these issues remain unresolved, as indicated in the enclosed report by our staff.

The report describes significant degradation of the infrastructure supporting the Department of Energy's (DOE) HEPA filter program. Confinement viability demands high dependability of these filters, yet beyond question their efficacy has deteriorated. The filters can be restored to an acceptable level of reliability only if the robust infrastructure required to support continued assurance of their performance is restored. The Board's staff has identified a number of actions that could be taken to achieve that restoration and the Board believes that DOE should act promptly to initiate a definitive corrective action plan to address those issues.

Accordingly, pursuant to 42 U.S.C. § 2286b(d) the Board requests that DOE provide a report within 60 days outlining the steps it plans to resolve these issues in a manner that restores confidence that confinement ventilation systems using HEPA filters do, indeed, adequately protect workers, the public, and the environment.

In the future, the Board intends to closely examine operational and maintenance aspects of confinement ventilation systems in general, and will share our findings with you upon completion of that review.

Sincerely,

John T. Conway
Chairman

c: Mr. Mark B. Whitaker, Jr.

Enclosure

DNFSB/TECH-23

HEPA Filters
Used in the
Department of Energy's Hazardous Facilities

Defense Nuclear Facilities Safety Board

Technical Report

May 1999

HEPA Filters
Used in the
Department of Energy's Hazardous Facilities

This technical report was prepared for the Defense Nuclear Facilities Safety Board by the following staff members:

Roger Zavadoski
Dudley Thompson

with assistance from:

Ronald Barton
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EXECUTIVE SUMMARY

Confinement ventilation systems are important safety features of Department of Energy (DOE) facilities in which hazardous materials are handled in dispersible form. High-efficiency particulate air (HEPA) filters are critical elements of these confinement systems. They are the final physical barrier to the release of material to the atmosphere and thereby serve to protect workers, the public, and the environment. For accident scenarios, HEPA filters are credited with reducing emissions by factors of thousands to billions.

Reviews of ventilation systems at DOE defense nuclear facilities conducted by the staff of the Defense Nuclear Facilities Safety Board (Board) during the early 1990s led to the Board's first report on this subject, *Overview of Ventilation Systems at Selected DOE Plutonium Processing and Handling Facilities* (DNFSB/TECH-3). More recent reviews have identified additional potentially significant weaknesses in the maintenance and operation of these systems, particularly in the procurement, testing, application, and use of HEPA filters. These weaknesses support the conclusion that confinement ventilation systems at some DOE facilities may be vulnerable to failure when most needed.

For many years, an informal but highly effective nationwide infrastructure supported production of and quality assurance for HEPA filters for safety-related service in a variety of hazardous operations, including those conducted in DOE facilities. Today there is convincing evidence that this infrastructure is failing; this report describes significant degradation of the infrastructure supporting DOE's HEPA filter program. Confinement viability demands that these filters be highly dependable, yet beyond question their efficacy has deteriorated. The filters can be restored to an acceptable level of reliability only if the robust infrastructure required to support continued assurance of their performance is restored. This report identifies a number of actions that could be taken to achieve that restoration.

The Board will continue to focus attention on deficiencies and weaknesses in confinement ventilation systems at DOE facilities. These efforts will be aimed at identifying situations in which DOE can act to improve protection of workers, the public, and the environment.

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1. INTRODUCTION

Confinement, the Department of Energy's (DOE) preferred method for protecting the public and workers from exposure to hazardous materials, encompasses both the physical structures in which the material resides and the associated ventilation systems. Before air from the confinement is released to the environment, it is filtered through high-efficiency particulate air (HEPA) filters to ensure that any residual contamination is well below acceptable, safe levels for public exposure (Burchsted et al., 1976). In such applications, HEPA filters can reduce emissions by factors of thousands to billions.

An acceptable confinement system starts with a robust and well-documented design—robust not only in the physical structures involved, but also in the attributes of defense in depth incorporated in the overall system design. Confinement systems are expected to be documented comprehensively in safety documents, such as Safety Analysis Reports (SARs), Technical Safety Requirements (TSRs), and Operational Safety Requirements (OSRs) (DiNunno, May 31, 1995). Typically, the strenuous demands imposed by the need for uninterrupted operation of confinement ventilation systems for extended periods of time—often decades—have led to the rugged designs often found in DOE facilities. Redundant filter banks and power supplies are common in modern applications (U.S. Department of Energy, April 6, 1989; October 24, 1996). Despite their otherwise robust construction, however, all confinement ventilation systems that use HEPA filters are vulnerable to failure of their most fragile component, the HEPA filter itself, which uses a medium no thicker than the typical desk blotter. Like paper, this medium becomes brittle with age and is significantly degraded by wetting. As a result, HEPA filters must be regarded as consumables that require replacement at defined intervals. However, DOE does not currently require replacement.

On March 20, 1995, the Defense Nuclear Facilities Safety Board (Board) issued a technical report entitled *Overview of Ventilation Systems at Selected DOE Plutonium Processing and Handling Facilities* (DNFSB/TECH-3) (Defense Nuclear Facilities Safety Board, March 20, 1995). This report identifies numerous instances of a lack of adequate accounting of how and whether facilities met and maintained compliance with specific requirements. The report concludes that as a result of these shortcomings, confinement systems at DOE's plutonium facilities might not perform as expected in the event of an accident.

In its letter forwarding this report (Conway, June 15, 1995) and in subsequent correspondence (Conway, July 21, 1995), the Board requested that DOE evaluate the design, construction, operation, and maintenance of ventilation systems at its plutonium processing and handling facilities and set forth a plan for corrective actions deemed necessary as a result of this evaluation. DOE formally responded to these requests in early spring 1996 (O'Leary, March 15, 1996). Approximately one-quarter of the 36 actions proposed by DOE in its corrective action plan still remain open.

Since the issuance of DNFSB/TECH-3, several related issues have been identified. These include (1) the need for pre-installation filter test facilities (Zavadoski, May 24–26, 1994; July 11–13, 1995); (2) the need for a Qualified Products List (QPL) test laboratory (Zavadoski,

August 4–8, 1997; Conway, October 30, 1997); (3) the problem of filter wetting (Zavadoski, August 4–8, 1997; Conway, October 30, 1997; Frethold et al., July 14, 1997); (4) the effects of aging on the integrity of filters (Zavadoski, August 4–8, 1997; Frethold et al., July 14, 1997); (5) by-pass leakage considerations (Frethold et al., July 14, 1997; Roberson, March 3, 1997); (6) radiation-induced degradation (Conway, May 9, 1996); and (7) issues involving the infrastructure associated with HEPA filters (Alm, January 15, 1998; Conway, February 9, 1998; March 26, 1998; Owendoff, April 27, 1998). In addition, relevant research results that raise questions about fundamental assumptions used in Safety Analysis Reports have been presented in national and international forums (Frethold et al., July 14, 1997; Bergman et al., 1994; Carbaugh, 1982; Johnson et al., 1988; Moeller, 1982; First, 1996; Robinson et al., 1985). These issues are explored in the following sections.

2. HEPA FILTER INFRASTRUCTURE

The program for producing high-quality HEPA filters and fabricating the filter banks used in nuclear installations has evolved during the past 50 years. This evolution has involved many interrelated assumptions associated with materials, specifications, testing, and use (Burchsted et al., 1976; Frethold et al., July 14, 1997; Johnson et al., 1988; First, 1996).

As the name suggests, HEPA filters are high-efficiency air filters designed to remove extremely fine particles suspended in the air; they do not remove gases. HEPA filters are expendable, extended-pleated-medium, dry-type filters with (1) a rigid casing enclosing the full depth of the pleats; (2) a minimum particle removal efficiency of 99.97 percent of thermally generated dioctalphthalate (DOP) 0.3 micron smoke particles (particles about one- third of one-thousandth of a millimeter in diameter) or larger (i.e., 99.97 percent of these particles are stopped by the filter); and (3) at a maximum a pressure drop of 1 inch of water gauge when clean and operated at rated airflow capacity (Burchsted et al., 1976). Such filters offer a high-volume, high-efficiency cleanup mechanism for relatively low concentrations of airborne particulate contaminants.

Safety analyses for confinement systems using HEPA filters routinely take credit for reductions in airborne contamination by factors of thousands to billions. These reduction factors are reasonable for intact filters installed in well-designed and well-constructed filter banks that are properly maintained. These conditions are difficult to attain, however, partly because of the fragile nature of the filter medium. A very few small holes in the filter medium (on the order of 1–10 mm in diameter) can reduce filter efficiency significantly.

HEPA filters are manufactured by a process similar to that used for making paper, but with fiberglass strands as the principal ingredient. After the medium is formed into a sheet similar in appearance and texture to a large desk blotter, it is carefully folded into a series of accordion pleats (125 pleats in the most widely used standard industrial HEPA filter). The folded medium is then mounted with the edges sealed in a plywood or metal case. This constitutes a single HEPA filter unit. Dozens or even hundreds of such units may be installed in a single confinement filter installation.

2.1 ACHIEVING INITIAL PRODUCT QUALITY

2.1.1 Specifications

HEPA filters are produced with a high degree of quality and uniformity through the application of stringent yet manageable specifications. The foundation for HEPA quality includes sample specifications found in the 1976 Nuclear Air Cleaning Handbook (Burchsted et al., 1976), issued by the Energy Research and Development Administration, and more recently in DOE Standard 3020-97 (DOE-STD-3020-97), *Specification for HEPA Filters Used by DOE Contractors* (U.S. Department of Energy, 1997), together with the numerous standards they cite and the QPL and Filter Test Facility (FTF) testing they call for. Nevertheless, there are ongoing

technical issues associated with each of these building blocks that have serious implications for maintaining the quality of the filters.

The current version of the Nuclear Air Cleaning Handbook is more than 20 years old. In the intervening years, several unsuccessful attempts have been made to revise and update the handbook, primarily to accommodate numerous changes in applicable national standards. In 1996, the Secretary of Energy made a commitment to the Board (O'Leary, March 15, 1996) to have a revised draft available by the end of that year. That draft has not yet been produced, nor are there any indications that a revised handbook may emerge in the near future.

2.1.2 Filter Testing

Both the Nuclear Air Cleaning Handbook and DOE-STD-3020-97 call for manufacturers to retain their QPL[1] listings. This mandate includes, among other requirements, providing representative sample filter units to an independent, certified QPL laboratory for destructive testing at least once every 5 years.

In the past, manufacturers could choose to have their QPL testing done at either the Army's Edgewood Arsenal or the Rocky Flats Environmental Technology Site (RFETS). Today, the Edgewood Arsenal facility no longer performs QPL testing, and the test facility at RFETS is closed. Edgewood Arsenal still has the capability to run such tests, but there is no budget for maintenance of the necessary equipment. During 1997, the QPL test equipment at RFETS was sent to Lawrence Livermore National Laboratory (LLNL), where most of it remains—still crated and unfunded. The Assistant Secretary of Energy for Environmental Management informed the Board in writing (Alm, January 15, 1998) that a QPL testing laboratory would be available for testing of HEPA filters to be used in DOE facilities. No time frame was specified for that commitment, and such a laboratory has not yet been designated.

In addition to QPL testing, both the handbook and DOE-STD-3020-97 call for representative filters to be provided routinely to a designated FTF for the purpose of verifying filter efficiency. The current DOE standard recognizes that manufacturers may themselves conduct tests similar to those performed at a designated FTF. Even in such cases, however, the standard requires that all filters destined for use in DOE facilities be tested at an independent FTF prior to installation.

For years, manufacturers routinely pretested their HEPA filters before sending them to a DOE FTF. Even with this pretesting, rejection rates of 3–6 percent were common at DOE's three FTFs. Such rejection rates support the value of testing at a DOE FTF, since the tests help avoid the unnecessary generation of contaminated waste and contribute to lowering personnel exposure. This avoidance comes about because the filters that fail the FTF tests are not installed, as they would have been in the absence of the tests; thus the need to remove substandard filters contaminated in service is avoided.

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[1] Products on QPLs have met stringent requirements for quality and reliability, demonstrated by periodic independent testing at certified testing laboratories, most of which are operated by the federal government.

Currently, DOE operates only one FTF (at Oak Ridge). Despite the DOE-STD-3020-97 specification calling for FTF testing of HEPA filters prior to installation in DOE facilities, and in the face of DOE's own studies (Lytle, August 1996), there have been repeated proposals to stop testing of filters at the Oak Ridge FTF. Indeed, testing there was stopped in January 1999, but was resumed 2 months later with user fees being imposed for tests. This situation tends to discourage FTF usage and increase per-filter test costs. Ongoing attempts to find a programmatic solution have thus far been unsuccessful.

2.2 MAINTAINING PERFORMANCE

HEPA filters cannot simply be installed and forgotten. Once installed in safety systems, they are subject to significant operating constraints to ensure the desired level of performance. Typically, these constraints involve TSRs and/or OSRs (U.S. Department of Energy, April 30, 1992) that specify a maximum pressure drop for system operation and a level of efficiency as demonstrated by periodic in-place leakage tests. Operating procedures, specific surveillance actions, and scheduled maintenance are usually prescribed to ensure that these performance requirements are met.

Industry consensus standards for in-place HEPA filter testing stress the need for visual inspections and system-specific procedures (American Society of Mechanical Engineers, December 15, 1989). Although specific procedures addressing filter operation are required by industry standards, they are typically lacking throughout the defense nuclear complex (Conway, January 30, 1998) and have not been made mandatory by DOE. These procedures are important for ensuring the safety of workers, the public, and the environment. Only the Savannah River Site has employed them extensively.

For most other systems and components, meeting TSRs ensures that a constrained or challenged item will perform its intended function as called for by the design. This assumption is not valid when nondestructive in-place field tests address only the tightness of the filter's fit against the frame and the absence of other gross leakage paths. There is a widespread assumption that periodic in-place DOP field testing demonstrates the ability of a HEPA filter to perform under accident conditions. Yet, experience has shown that filters can be severely weakened and still successfully pass these in-place tests (Frethold et al., July 14, 1997; Johnson et al., 1988; First, 1996). Under accident conditions, such filters are vulnerable to subsequent failure in use, for example, after becoming heavily loaded with smoke particles.

The question of whether a HEPA filter will perform as intended in the future cannot be answered simply by examining adherence to existing TSRs. Filter performance does not lend itself to a simple "go-no go" test. With today's technology, that assurance is available only through a reliable and effective infrastructure that addresses all aspects of HEPA filter quality—design, manufacture, installation, operation, and maintenance.

2.3 CHALLENGES

2.3.1 Fires

The largest potential threat to the public from a facility that houses processes in which relatively large quantities of radioactive materials are handled is most commonly a fire accident scenario. Since fires often generate large volumes of smoke, they pose a potential threat to the effective functioning of filtration systems because the filters can become rapidly loaded with smoke particles. This increases the pressure drop across the filter, potentially leading to a breach of confinement. There are times during some fire scenarios when it may be necessary to stop flow to the filter systems to prevent their destruction. Such scenarios need to be carefully evaluated ahead of time; a mitigating strategy must be developed, clearly captured in procedures, and rigorously practiced (Defense Nuclear Facilities Safety Board, March 20, 1995; Conway, January 30, 1998; Klein, April 24, 1998).

In the event of a breakthrough of the filter during a fire, the particulate material deposited on the filters is readily lifted by buoyancy into the atmosphere, where it can be further dispersed in potentially unfavorable downwind patterns. As a result, some fires can be more serious than explosions, which generally drive much of the particulate matter into surrounding structures rather than elevating it into the atmosphere and dispersing it via prevailing winds.

2.3.2 Heat and Elevated Temperatures

Because of their materials of construction, HEPA filter installations can easily be damaged or destroyed by heat if they are not properly designed and maintained. Exposure of the filter medium to temperatures of 700–750°F for only 5 minutes can significantly reduce filter efficiency (Burchsted et al., 1976). Fires involving burning metals, which may be encountered in many defense nuclear facilities, can produce flame temperatures of several thousand degrees. With sufficient flow of cooler air, these high temperatures can be reduced to acceptable levels in the downstream HEPA filters. If this cooling effect is to be provided, however, detailed plans and designs are essential. Such plans and designs in turn require appropriate guidance.

In this connection, DOE Handbook 3010 (DOE-HDBK-3010-94) (U.S. Department of Energy, December 1994) implies that HEPA filters can withstand temperatures substantially greater than 1500° F for tens of minutes without losing their nominal efficiency of 99.97 percent. This is not correct, since fiberglass will melt before reaching such temperatures. This erroneous information was used in a recent Basis for Interim Operation (U.S. Department of Energy, April 1998) in which a filter efficiency of 99.8 plus percent was assumed in calculating dose assessments. In this instance, recalculation determined that the temperature likely to be encountered at that facility would not have reached 750°F. However, the same error (i.e., the assumption of no filter damage and filter availability for dose reduction) could recur if the handbook is not revised.

2.3.3 Wetting

Like paper, HEPA filter medium is especially susceptible to water damage, despite the fact that water repellents are applied to the medium during manufacture. When installed fire suppression systems are activated to protect systems, structures, and components inside

confinement, the moisture-laden air carried downstream to the HEPA filters can seriously degrade filter performance—at a time when high-efficiency filter performance is crucial.

2.3.4 Filter Strength

The remaining strength of HEPA filters must be adequately considered, especially under challenging conditions, such as having to cope with a fire. Making this determination is particularly difficult, however, since no nondestructive in-place test is available. Further, many unpredictable factors can degrade the filter installation's strength without the operators' knowledge. Filter strength is affected by such factors as manufacturing variables, aging, loss of binder, loss of water-repellent capability, shelf life, history of prior wetting, exposure to high temperature, exposure to high radiation, exposure to chemicals, and exposure to moisture-laden air (Frethold et al., July 14, 1997; Bergman et al., 1994; Carbaugh, 1982; Johnson et al., 1988; Moeller, 1982; First, 1996). While many of these factors have been investigated, a quantitative assessment does not appear possible at this time. More important, a conservative limit on filter life is not currently mandated by DOE.

2.3.5 Air Leaks

Careful design, attentive operation, and disciplined maintenance of a HEPA installation can be negated by air leaks in the negative pressure region of the system downstream of the filters and upstream of the fans. Leaking gaskets, fan seals, and damper actuator penetrations are particularly vulnerable. These regions are not routinely checked for leaks (Frethold et al., July 14, 1997; Roberson, March 3, 1997). When RFETS addressed this issue, such leaks were found.

2.4 RESULTS OF PRIOR RESEARCH

The literature is replete with studies that examine possible negative influences on HEPA filter performance (Frethold et al., July 14, 1997; Bergman et al., 1994; Johnson et al., 1988; Robinson et al., 1985). The data presented in these studies are based almost entirely on HEPA filters less than 15 years old. A few of the filters examined in the studies were 15–20 years old, and a very few were older than that (the age of these filters typically includes both shelf and service life).

Frethold's work (Appendix 4, Figure 4-1) (Frethold et al., July 14, 1997) shows some unused but aged filters with less than minimum specified initial tensile strength of 2.5 pounds per inch for unfolded media and 2.0 pounds per inch for folded media. "Folded" versus "unfolded" here is significant because the most commonly observed failure point on a HEPA filter is on the downstream fold. Further, Frethold's work (Figure 6-1) reveals variability for this parameter by factors of 2–3 for the same manufacturer.

The loss of water-repellent capability has also been observed by several investigators. This can be a significant factor if moisture carryover or sprays from firefighting efforts impinge on the filters. Filters untreated for water repellency are expected to absorb some fraction of the

impinging moisture or water. This moisture absorption can dramatically increase the pressure drop across the filter and lead to filter failures. According to Frethold (Figures 2-1 and 2-2), loss of the ability to repel water does not appear to be a problem in storage, but can be significant in service. Johnson's data (Johnson et al., 1988) show a 57–100 percent loss of water-repellent capability among filters in service for 13–14 years.

These data suggest that remaining strength and ability to repel water are important considerations for continued HEPA filter use, but it is not possible to specify an exact service life. Qualitatively, however, the data clearly indicate that filters cannot stay in service indefinitely. Since an exact service life cannot be determined and data variability is significant, individual vulnerability assessments that examine the expected efficiency, life, and mission for installed HEPA filters would appear to be desirable.

Frethold (Appendix 3) presents the results of soaking a HEPA filter, drying it, and then testing the dried media for tensile strength. This investigation was designed to simulate the effects of direct impingement spray testing for fire protection purposes. The results revealed that one soaking can reduce the strength of the filter media to less than the initial purchase specification value. Additional tests conducted by Frethold without presoaking also demonstrated weakening of the filters. On the basis of these data, the safety significance of the application, and a consideration of future building use, one DOE site (RFETS) decided to replace various previously wetted HEPA stages (in Buildings 371 and 707). The choice appears to have been a prudent one.

It should be noted that most of the investigations cited above were carried out under funding provided by DOE and its predecessor agencies. Today almost no funding is available for conducting such investigations, even though there are many unanswered questions. No programmatic office within DOE has stepped forward to set priorities regarding the additional information required.

Taken collectively, the published data also suggest that there could be some unused HEPA filters in storage—ready to be installed in safety systems—that would not meet newly purchased filter specifications. Further, the data suggest that installed HEPA filters could be so degraded by age and loss of ability to repel water that they might not perform their expected safety function when called upon to do so.

Several attempts have been made to establish an age limit for HEPA filters, taking into consideration the weaknesses observed during testing. First (1996) of the Harvard Air Cleaning Laboratory recommends 5 years for HEPA filters used in biological cabinets. The Savannah River Site has a 5-year limit in place, including both shelf life and service life. LLNL previously proposed an 8-year limit, and is currently proposing a 10-year limit. Some DOE facilities have filters in service that were installed more than 20 years ago. A prominent filter manufacturer claims a 3-year shelf life, but only under proper storage conditions. No other age limits at DOE facilities have been proposed to date. Nor have any additional routine measurements or assessments to evaluate the residual strength of HEPA filters been proposed.

3. REVIVING THE INFRASTRUCTURE

To be effective, any management system requires feedback. In the case of HEPA filters, there are many indications that an acceptable program for feedback of experience is either absent or seriously degraded. At a time when additional HEPA filter investigations may be called for, budgets have been cut to the point that meaningful research in this area is no longer possible. Moreover, after nearly 50 years of continuing support for the Nuclear Air Cleaning Conferences, DOE has decided to withdraw support for future conferences, seriously compromising opportunities for feedback from peer review and a free exchange of ideas. Reconsideration of this decision is warranted in order to restore vigor to this important safety-related research area and to provide better assurance of adequate information exchange on the subject of ventilation filtration. This report should be regarded as an impetus for a revitalized feedback and improvement program for DOE's HEPA filter program, following the tenets set forth in Board Recommendations 95-2, *Safety Management*, and 98-1, *Integrated Safety Management*.

There is physical evidence that some HEPA filters presently in service may be too weak to perform their safety function effectively (Frethold et al., July 14, 1997), and there is continued reliance on a field test that provides no information on the filters' remaining physical strength. Indeed, physical evidence suggests that even unused but aged filters may not meet minimum strength requirements. These findings indicate a need to strengthen quality assurance and quality control programs for HEPA filters. At the same time, however:

- The QPL laboratory committed to by senior DOE management is not yet in place.
- The existence of the last remaining FTF is tenuous.
- An updated Nuclear Air Cleaning Handbook, a draft revision of which was originally committed to by December 1996, is not yet available.
- There is a serious need to update a related DOE Handbook to correct errors that could lead to nonconservative analyses, as has occurred at least once.

To address these issues and restore vitality to its filter program, DOE should give serious consideration to the following actions:

- Designate a location and firmly commit to providing funding, personnel and physical resources, and continued programmatic support for a replacement for the QPL laboratory, on an expedited schedule.
- Ensure continued operation of the Oak Ridge FTF.
- Identify needed resources and assign responsibility for early publication of a revised Nuclear Air Cleaning Handbook, in order to make accurate, up-to-date guidance on the subject available.

- Revise, update, and implement DOE-HDBK-3010-94 to eliminate confusing guidance regarding the performance characteristics of installed HEPA filters, and to improve the quality and reliability of assumptions supporting safety analyses involving these critical components of confinement systems protecting workers, the public, and the environment.

- Establish a conservative maximum age limit for HEPA filters involved in safety-related service. Such a limit should be established, simply because the filters degrade with time, and only 10–15 years of meaningful data is available to justify extended service life. Any age limit established should be supported by a systematic evaluation of how the strength of HEPA filters varies over time, for both installed filters and those in storage.

The above actions are called for to restore DOE's failing infrastructure supporting its HEPA filter program. At this time, however, higher priority should be attached to prompt completion of a vulnerability assessment of each facility relying on HEPA filters for accident mitigation. Filters specifically required to operate (and those being stored in place that could interact with these filters—as in the case of standby, bypass filter banks) in a stressed situation (e.g., in fires, during sprays, or in high temperatures) while called upon to perform a safety function should be assessed for their ability to perform acceptably. Installed filters that have already exceeded their useful life should be replaced on a prioritized basis. Finally, systematic evaluations of the anticipated performance of installed HEPA filters compared with the tasks they are expected to perform should be completed. These evaluations should be based on reasonable but conservative assumptions regarding potential mechanisms for filter degradation, pending the conduct of meaningful research aimed at definitively establishing a better understanding of how filter strength varies with time.

This report has described a significantly degraded DOE infrastructure for HEPA filters. Confinement viability demands high dependability of these filters. An acceptable level of reliability can be assured only if the robust infrastructure required to support continued assurance of their performance is restored.

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GLOSSARY OF ACRONYMS

Abbreviation	Definition
Board	Defense Nuclear Facilities Safety Board
DOE	Department of Energy
DOP	Dioctalphthalate
FTF	Filter Test Facility
HEPA	High-Efficiency Particulate Air
LLNL	Lawrence Livermore National Laboratory
OSR	Operational Safety Requirements
QPL	Qualified Products List
RFETS	Rocky Flats Environmental Technology Site
SAR	Safety Analysis Reports
TSR	Technical Safety Requirements

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Attachment 5

PORTION OF PERMIT APPLICATION – AMWTF HWMA/TSCA PERMIT APPLICATION

Consisting of 14 pages
including cover page

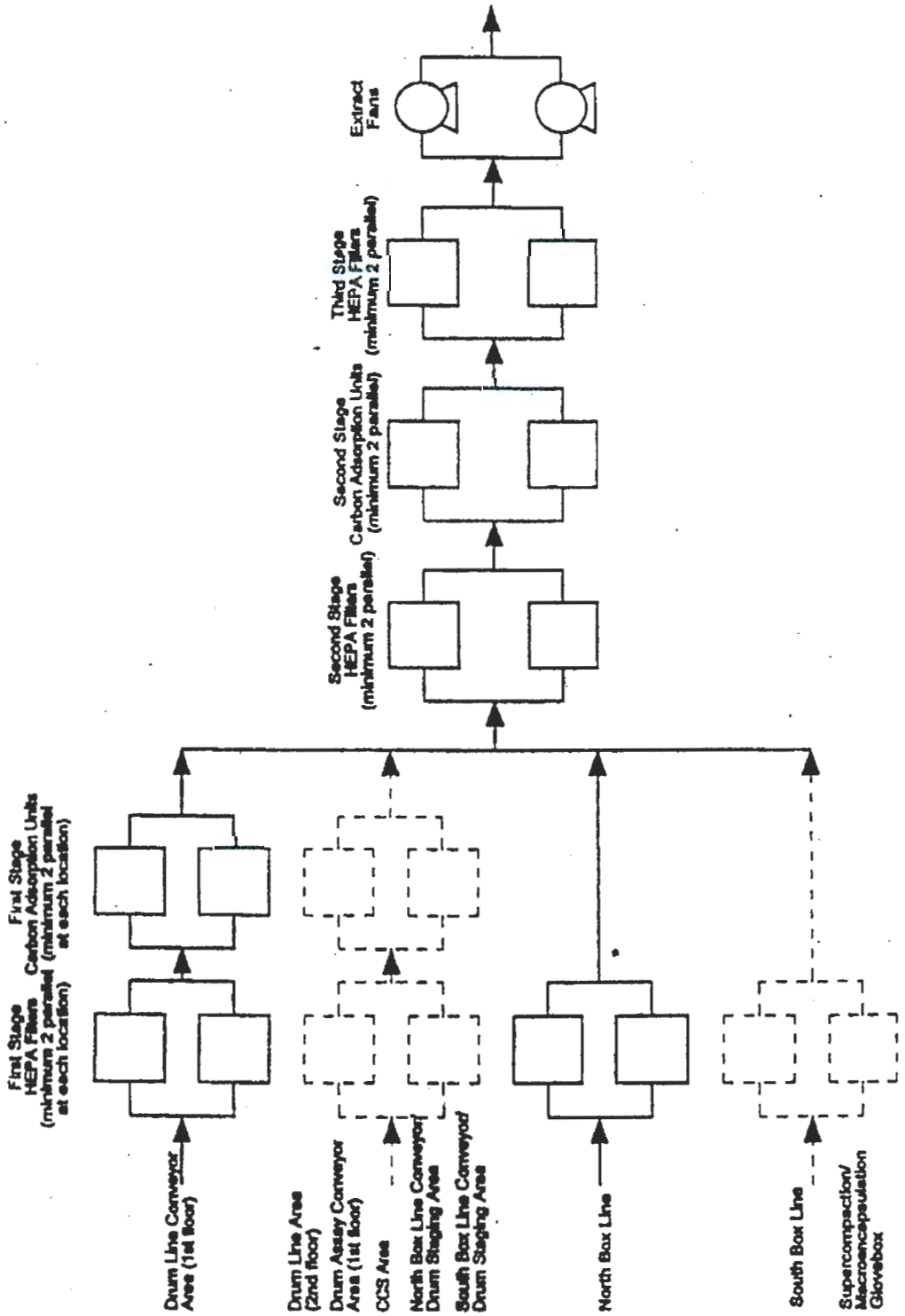


Figure 1-9 Simplified Diagram of the East Zone 3 Ventilation Extract System.

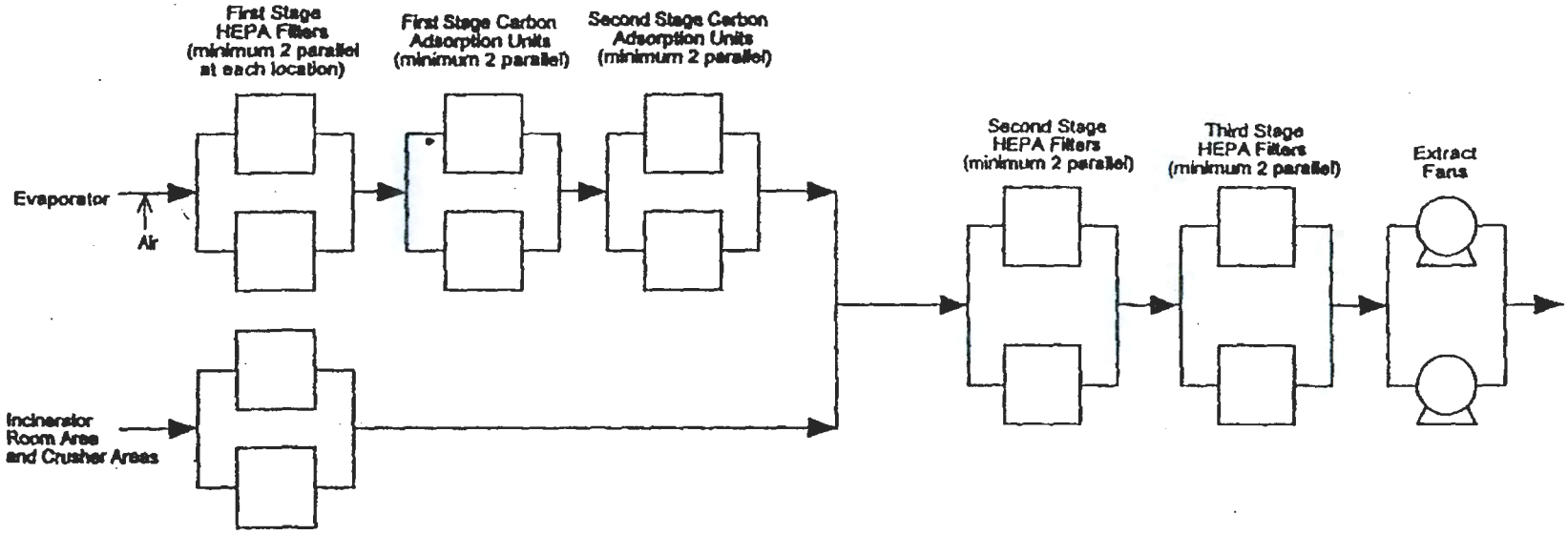
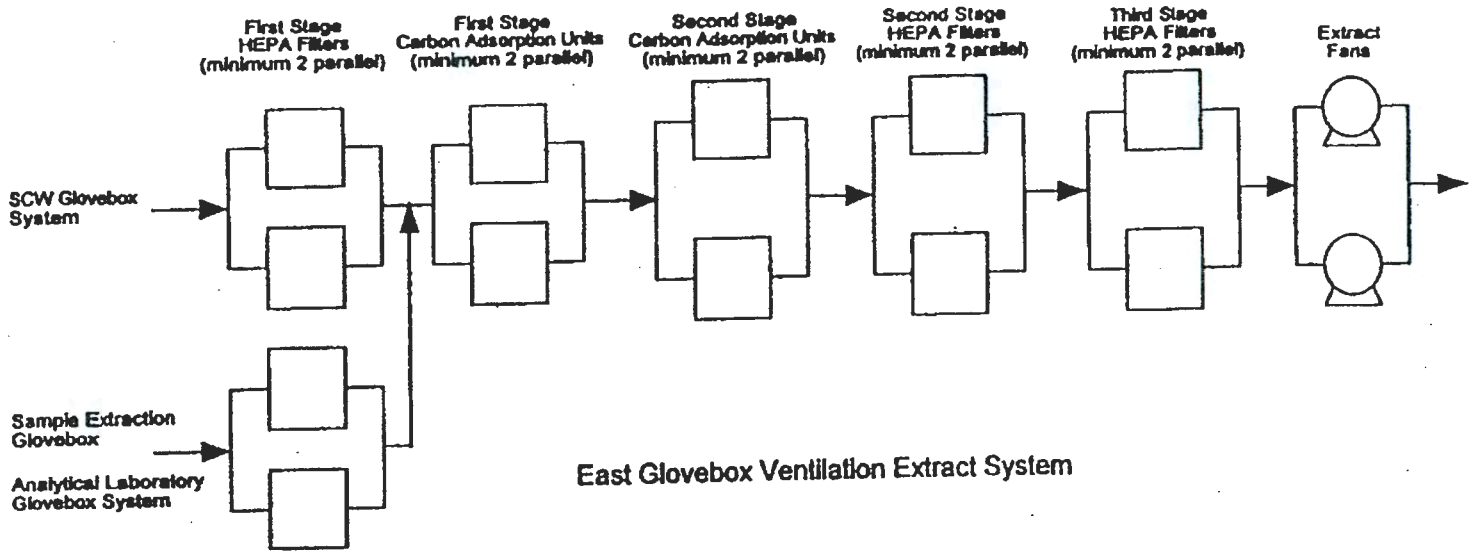


Figure 1-10 Simplified Diagram of the West Zone 3 Ventilation Extract System



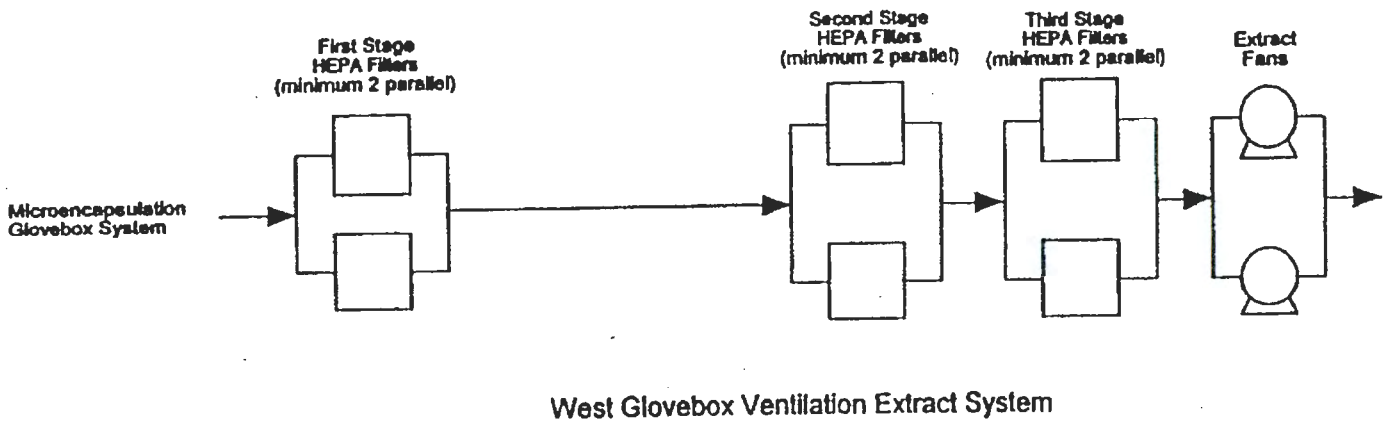


Figure 1-11. Simplified Diagram of the Glovebox Ventilation Extract System./

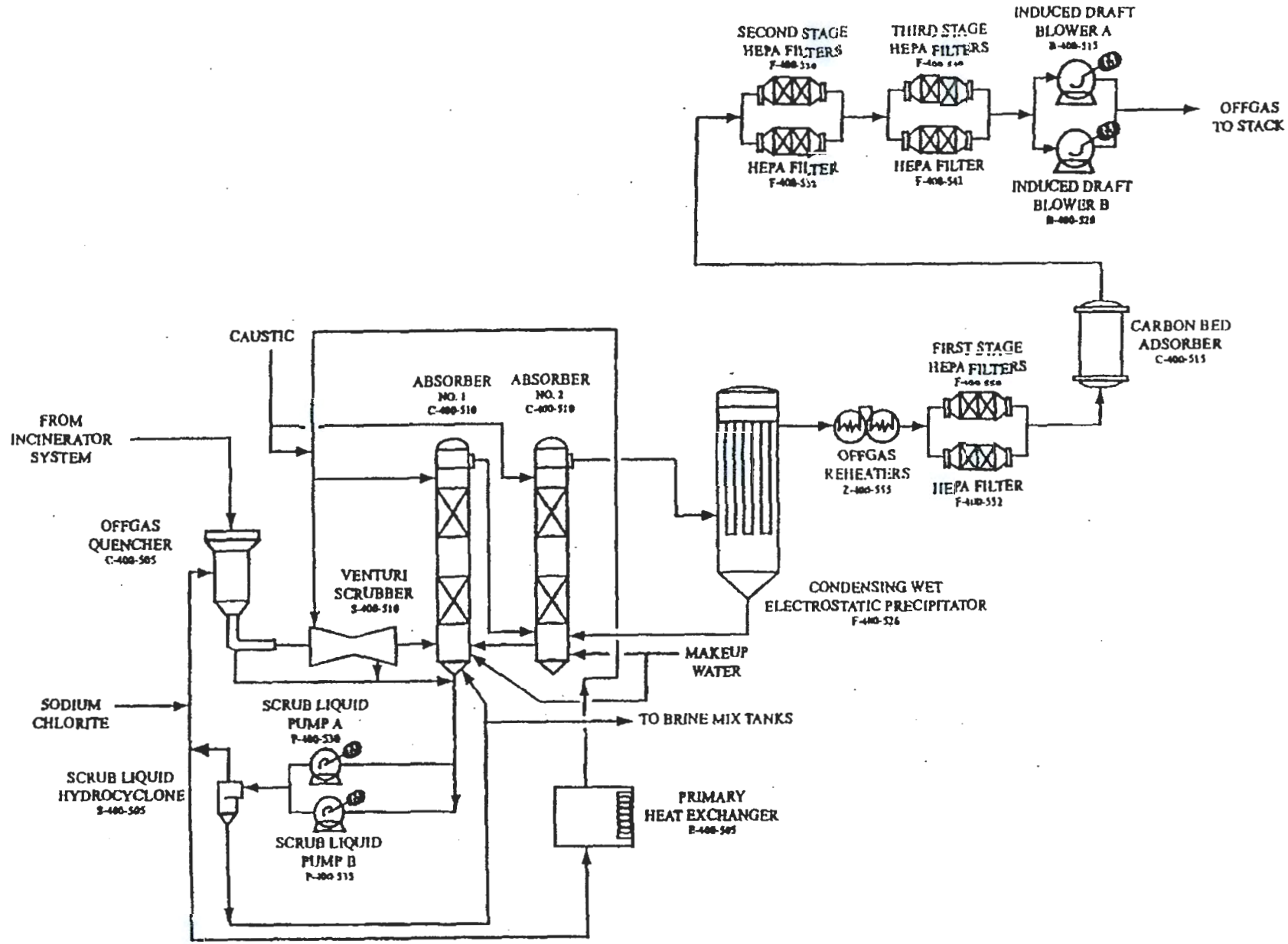


Figure 1-12. Simplified Diagram of the Incinerator APCS.

Table 1-1. Estimate of Hazardous Compounds in Worst Case TSA Waste (wt%).

COPC	IHS	OHS	S	CBD	G	HD	ID	MD	OD	PRPR
Acetone	0.01	1				1	1	1		1
Benzene	1				1	1	1	1		1
Butyl alcohol	0.001	0.001	0.001			1				
Carbon tetrachloride	0.075	5	0.07		1	1	1	0.001	1	1
Chlorobenzene	1									
Chloroform	1	1			1	1	1	1		1
Cyclohexane	1							1		1
1,2-Dichoroethane	1									1
Dichloroethene								1		
cis-1,2-Dichoroethene										1
1,1-Dichoroethylene	1	1				1	1	1	1	1
2-Ethoxyethanol	1									
Ethyl benzene	1					1		1		1
Ethyl ether						1				
Isopropanol									1	
Methane								1		1
Methanol	0.003	0.001	0.001		1	1		1		1
Methyl ethyl ketone	1					1			1	1
Methylene chloride	0.07	0.005	0.005	1	1	1	1	0.02	0.1	1
Nitrobenzene	1	1	1			1				
1,1,2,2-Tetrachloroethane										1
Tetrachloroethylene	1	1	1		1	1	1			1
Toluene	1	1		1	1	1	1	1	1	1
1,1,1-Trichloroethane	0.2	15	0.02	1	1	1	1	0.008	1	1
1,1,2-Trichloroethane	1									
Trichlorethylene	0.01	1	1	0.1		1	1	1	1	1
1,1,2-Trichloro-1,2,2-trifluoroethane	0.01	5	0.01		1	1	1	1	0.15	1
1,2,4-Trimethylbenzene										1
1,3,6-Trimethylbenzene										1
Xylene	0.005	0.001	0.001	1		1	1	1	1	1
Arsenic	1	1		1		1	1	1		1
Barium	1	1		1		1	1	1	1	1
Beryllium	1	1						1		
Cadmium	0.001	0.001	1	1		1	1	1		1
Chromium	1	1	1	1		1	1	1		1
Lead	0.001	0.001	1	1		10	5	5	25	56
Mercury	2.5	1	0.03	1	1	1	1	1	1	1
Nickel	1	1								
Selenium	1	1	1	1		1	1	1		1
Silver	1	1	1	1		1	1	1		1
Asbestos							45			
Cyanide	1									
Polychlorinated biphenyls (PCBs)		15				1				
Matrix (approximate wt percent) [a]	76	45	92	88	90	64	31	74	65	15

a. Hazardous compounds consist of a small percentage by weight of each waste type, with the remainder composed of matrix material. For example, on this table COPCs account for about 12% of the CBD waste. The remainder is matrix—contaminated brick or ceramic material. The values in the table for hazardous compounds represent the highest value for the estimated concentration of a particular pollutant in any of the waste streams in that waste category and, thus, are very conservative estimates of the actual COPC mass in the waste.

IHS = inorganic homogeneous solids MD = metal debris HD = heterogeneous debris
OHS = organic homogeneous solids ID = inorganic debris CBD = ceramic/brick debris
PRPR = paper/rags/plastic/rubber OD = organic debris G= graphite S = soil

Table 1-2. Radionuclide Inventory for TSA Waste and as Scaled for the AMWTF.

Radionuclide[a]	Best Estimate Activity[b] (Ci)	Scaled Best Estimate Activity[c] (Ci)	Scaled Activity Non-debris[d] (Ci)	Scaled Activity Debris[e] (Ci)	Activity Concentration Non-debris[f] (Ci/kg)	Activity Concentration Debris[g] (Ci/kg)
Am-241	1.22E+05	1.60E+05	7.02E+04	8.93E+04	4.37E-03	4.38E-03
Pu-238	1.16E+05	1.52E+05	6.67E+04	8.49E+04	4.16E-03	4.17E-03
Pu-239	6.87E+04	8.98E+04	3.95E+04	5.03E+04	2.46E-03	2.47E-03
Pu-240	1.59E+04	2.08E+04	9.15E+03	1.16E+04	5.70E-04	5.71E-04
Pu-242	1.04E+00	1.36E+00	5.98E-01	7.62E-01	3.73E-08	3.74E-08
Pu-241	1.61E+05	2.11E+05	9.26E+04	1.18E+05	5.77E-03	5.79E-03
Ba-137m	2.25E+03	2.94E+03	1.29E+03	1.65E+03	8.06E-05	8.09E-05
Cs-137	2.26E+03	2.96E+03	1.30E+03	1.66E+03	8.10E-05	8.12E-05
Sr-90	2.02E+03	2.64E+03	1.16E+03	1.48E+03	7.24E-05	7.26E-05
Y-90	2.02E+03	2.64E+03	1.16E+03	1.48E+03	7.24E-05	7.26E-05
U-233	1.02E+03	1.33E+03	5.87E+02	7.47E+02	3.65E-05	3.67E-05
Cm-244	5.39E+02	7.05E+02	3.10E+02	3.95E+02	1.93E-05	1.94E-05
H-3	2.64E+02	3.45E+02	1.52E+02	1.93E+02	9.46E-06	9.49E-06
Cs-134	1.11E+02	1.45E+02	6.39E+01	8.13E+01	3.98E-06	3.99E-06
Co-60	1.00E+02	1.31E+02	5.75E+01	7.32E+01	3.58E-06	3.59E-06
Bi-212	2.66E+01	3.48E+01	1.53E+01	1.95E+01	9.53E-07	9.56E-07
C-14	2.38E+00	3.11E+00	1.37E+00	1.74E+00	8.53E-08	8.55E-08
Ce-144	2.71E+01	3.54E+01	1.56E+01	1.98E+01	9.71E-07	9.74E-07
Fe-55	1.13E+00	1.48E+00	6.50E-01	8.28E-01	4.05E-08	4.06E-08
Kr-85	6.86E+00	8.97E+00	3.95E+00	5.02E+00	2.46E-07	2.47E-07
Ni-63	3.57E+00	4.67E+00	2.05E+00	2.61E+00	1.28E-07	1.28E-07
Pb-212	2.66E+01	3.48E+01	1.53E+01	1.95E+01	9.53E-07	9.56E-07
Pm-147	2.73E+01	3.57E+01	1.57E+01	2.00E+01	9.78E-07	9.81E-07
Po-212	1.70E+01	2.22E+01	9.78E+00	1.24E+01	6.09E-07	6.11E-07
Po-216	2.66E+01	3.48E+01	1.53E+01	1.95E+01	9.53E-07	9.56E-07
Pr-144	2.72E+01	3.56E+01	1.57E+01	1.99E+01	9.74E-07	9.78E-07
Ra-224	2.66E+01	3.48E+01	1.53E+01	1.95E+01	9.53E-07	9.56E-07
Sb-125	1.65E+00	2.16E+00	9.49E-01	1.21E+00	5.91E-08	5.93E-08
Th-228	2.66E+01	3.48E+01	1.53E+01	1.95E+01	9.53E-07	9.56E-07
Th-232	7.31E+00	9.56E+00	4.21E+00	5.35E+00	2.62E-07	2.63E-07
Tl-208	9.54E+00	1.25E+01	5.49E+00	6.99E+00	3.42E-07	3.43E-07
U-232	2.60E+01	3.40E+01	1.50E+01	1.90E+01	9.31E-07	9.34E-07
U-234	5.78E+00	7.56E+00	3.33E+00	4.23E+00	2.07E-07	2.08E-07
Ac-227	4.08E-02	5.34E-02	2.35E-02	2.99E-02	1.46E-09	1.47E-09
242mAM	3.00E-04	3.92E-04	1.73E-04	2.20E-04	1.07E-11	1.08E-11
Am-243	3.80E-01	4.97E-01	2.19E-01	2.78E-01	1.36E-08	1.37E-08
Bk-249	5.71E-04	7.47E-04	3.29E-04	4.18E-04	2.05E-11	2.05E-11
Cf-249	9.73E-03	1.27E-02	5.60E-03	7.13E-03	3.49E-10	3.50E-10
Cf-252	4.08E-03	5.34E-03	2.35E-03	2.99E-03	1.46E-10	1.47E-10
Cm-242	1.44E-06	1.88E-06	8.29E-07	1.05E-06	5.16E-14	5.18E-14
Cm-243	1.53E-02	2.00E-02	8.80E-03	1.12E-02	5.48E-10	5.50E-10
Cm-246	1.53E-03	2.00E-03	8.80E-04	1.12E-03	5.48E-11	5.50E-11
Cm-248	4.17E-08	5.45E-08	2.40E-08	3.05E-08	1.49E-15	1.50E-15

Table 1-2. Radionuclide Inventory for TSA Waste and as Scaled for the AMWTF (cont.).

Radionuclide[a]	Best Estimate Activity[b] (Ci)	Scaled Best Estimate Activity[c] (Ci)	Scaled Activity Non-debris[d] (Ci)	Scaled Activity Debris[e] (Ci)	Activity Concentration Non-debris[f] (Ci/kg)	Activity Concentration Debris[g] (Ci/kg)
Co-58	1.10E-07	1.44E-07	6.33E-08	8.06E-08	3.94E-15	3.95E-15
Eu-152	6.76E-02	8.84E-02	3.89E-02	4.95E-02	2.42E-09	2.43E-09
Eu-154	7.10E-01	9.28E-01	4.09E-01	5.20E-01	2.54E-08	2.55E-08
Eu-155	1.86E-01	2.43E-01	1.07E-01	1.36E-01	6.66E-09	6.68E-09
I-129	1.83E-04	2.39E-04	1.05E-04	1.34E-04	6.56E-12	6.58E-12
Mn-54	2.29E-01	2.99E-01	1.32E-01	1.68E-01	8.20E-09	8.23E-09
Np-237	3.55E-01	4.64E-01	2.04E-01	2.60E-01	1.27E-08	1.28E-08
Pb-210	1.76E-02	2.30E-02	1.01E-02	1.29E-02	6.31E-10	6.33E-10
Pu-236	1.48E-02	1.94E-02	8.52E-03	1.08E-02	5.30E-10	5.32E-10
Ra-226	1.09E-01	1.43E-01	6.27E-02	7.98E-02	3.90E-09	3.92E-09
Ra228	3.06E-02	4.00E-02	1.76E-02	2.24E-02	1.10E-09	1.10E-09
Ru-106	1.87E-01	2.45E-01	1.08E-01	1.37E-01	6.70E-09	6.72E-09
Ta-182	1.55E-05	2.03E-05	8.92E-06	1.14E-05	5.55E-13	5.57E-13
Tc-99	5.37E-01	7.02E-01	3.09E-01	3.93E-01	1.92E-08	1.93E-08
Th-230	2.00E-02	2.62E-02	1.15E-02	1.46E-02	7.16E-10	7.19E-10
U-235	8.61E-02	1.13E-01	4.95E-02	6.31E-02	3.08E-09	3.09E-09
U-236	1.20E-03	1.57E-03	6.90E-04	8.79E-04	4.30E-11	4.31E-11
U-238	1.47E-01	1.92E-01	8.46E-02	1.08E-01	5.27E-09	5.28E-09
Zn-65	1.87E-08	2.45E-08	1.08E-08	1.37E-08	6.70E-16	6.72E-16
Zr-95	2.34E-09	3.06E-09	1.35E-09	1.71E-09	8.38E-17	8.41E-17
	4.94E+05	6.47E+05	2.85E+05	3.62E+05	1.77E-02	1.78E-02

a. Radionuclides present in waste from Table 4-1 INEL-95/0412, (Raivo 1995).
b. Best estimate activities from Table 4-1 INEL-95/0412 (Raivo 1995).
c. Scaling factor is 85,000 m^3 / 65,000 m^3 to adjust for 20,000 m^3 of waste in addition to TSA inventory (see text).
d. Non-Debris mass is 44.08% (44%) of total waste mass.
e. Debris mass is 55.92% (56%) of total waste mass.
f. Based on Total Non-Debris Mass of 16,061,160 kg (AMWTF Process flow sheet).
g. Based on Total Debris Mass of 20,376,746 kg (AMWTF Process flow sheet).

Table 1-3. Risk Characterization Summary for Exposure to AMWTF Emissions (COPCs).

CHRONIC EFFECTS						
	Chemical Cancer Risk (Excess Lifetime Risk)[a]					
Receptor Scenario (Lifestyle)	Subsistence Farmer		Native American		Resident	
	Adult	Child	Adult	Child	Adult	Child
Hypothetical Location	5.11E-06	1.11E-06	*2.59E-06*	*7.83E-07*	5.02E-07	1.23E-07
Frenchman's Cabin	4.24E-06	9.20E-07	*2.31E-06*	*6.99E-07*	4.16E-07	1.02E-07
Cerro Grande	7.36E-07	1.59E-07	*1.20E-06*	*3.62E-07*	7.24E-08	1.77E-08
Butte City	1.76E-07	3.80E-08	-	-	-	-
Howe	2.50E-07	5.38E-08	-	-	-	-
Mud Lake	3.95E-07	8.52E-08	-	-	-	-
Atomic City	3.94E-07	8.50E-08	-	-	-	-
Arco	1.16E-07	2.51E-08	-	-	-	-
Mooreland	5.84E-08	1.26E-08	-	-	-	-
Mackay	6.78E-08	1.46E-08	-	-	-	-
	INEEL Worker (chronic)		-	-	-	-
EBR-I	1.91E-08	NA	-	-	-	-
CFA	3.38E-09	NA	-	-	-	-
	Noncarcinogenic Risk (Hazard Index)[b]					
Receptor Scenario (Lifestyle)	Subsistence Farmer		Native American		Resident	
	Adult	Child	Adult	Child	Adult	Child
Hypothetical Location	0.105	0.198	*0.044*	*0.098*	0.035	0.076
Frenchman's Cabin	0.087	0.164	*0.038*	*0.084*	0.029	0.063
Cerro Grande	0.015	0.029	*0.013*	*0.028*	0.0050	0.011
Butte City	0.004	0.007	-	-	-	-
Howe	0.005	0.010	-	-	-	-
Mud Lake	0.008	0.015	-	-	-	-
Atomic City	0.008	0.015	-	-	-	-
Arco	0.002	0.005	-	-	-	-
Mooreland	0.001	0.002	-	-	-	-
Mackay	0.001	0.003	-	-	-	-
	INEEL Worker (chronic)		-	-	-	-
EBR-I	0.0175	NA	-	-	-	-
CFA	0.00308	NA	-	-	-	-

ACUTE EFFECTS (Acute Hazard *Index*)[c]						
Native American	*INEEL Worker (acute)*		*Public Highway Traveler*			
20-km Area	*EBR-I*	*CFA*	*EBR-I Visitor's Center*	*Big Lost River Rest Area*	*Highway 20/26 (max. exposure)*	*Craters of the Moon Visitor's Center*
0.038	*0.088*	*0.024*	*0.088*	*0.034*	*0.105*	*0.002*

a. Cancer risk: 1×10^{-5} is assumed protective of human health. A risk of 1×10^{-5} means that an individual has no more than, and probably less than, a 1 in 100,000 chance of developing cancer from the exposure being evaluated.

b. Noncarcinogenic Effects: An HI value below 0.25 is deemed acceptable and is sufficiently protective of human health).

c. Acute effects: An AH*I* below 0.25 is deemed acceptable and is sufficiently protective of human health.

Table 1-4. Excess Cancer Risks (ROPCs) for the AMWTF Preliminary Risk Assessment.

Receptor Scenario (Lifestyle)	Rediological Cancer Risk (excess lifetime risk)					
	Subsistence Farmer		Native American		Resident	
	Adult	Child	Adult	Child	Adult	Child
Hypothetical Location	1.34E-07	2.77E-08	*1.71E-07*	*2.25E-08*	9.68E-08	2.14E-08
Frenchman's Cabin	1.12E-07	2.31E-08	*1.09E-07*	*2.00E-08*	8.14E-08	1.80E-08
Cerro Grande	1.93E-08	3.99E-09	*4.00E-08*	*5.0[illegible]E-09*	1.40E-08	3.09E-09
Butte City	4.53E-09	9.33E-10	-	-	-	-
Howe	6.54E-09	1.35E-09	-	-	-	-
Mud Lake	1.02E-08	2.10E-09	-	-	-	-
Atomic City	1.02E-08	2.10E-09	-	-	-	-
Arco	3.06E-09	6.28E-10	-	-	-	-
Mooreland	1.54E-09	3.16E-10	-	-	-	-
Mackay	1.73E-09	3.58E-10	-	-	-	-

Table 1-5. Excess Cancer Risks for Infant Exposure to ROPCs via Breast Milk.

Receptor Scenario (Lifestyle)	Infant Exposure to ROPCs via Breast Milk (ELCR)			
	Subsistence Farmer (infant)	Native American (infant)	Resident (infant)	INEEL Worker (infant)
Hypothetical Maximum	7.90E-13	*4.97E-13*	7.82E-14	1.33E-15
Frenchman's Cabin	6.46E-13	*4.24E-13*	6.40E-14	-
Cerro Grande	1.43E-13	*1.71E-13*	1.14E-14	-

Table 1-6. Daily Exposure to Dioxin/Furans.

	Daily Exposure to Dioxin/Furans (pg/kg-d)							
	Subsistence Farmer		Native American		Adult Resident		INEEL Worker	
	Infant	Adult	Infant	Adult	Infant	Adult	Infant	Adult
Hypothetical	0.72[illegible]	0.0277	*0.107*	*0.005*	0.004	0.00012	-	-
Frenchman's Cabin	0.599	0.0188	*0.104*	*0.003*	0.003	0.00010	-	-
Cerro Grande	0.104	0.0033	*0.093*	*0.003*	0.001	0.00002	-	-
EBR-I							0.006	0.00018
CFA							0.001	0.00003

Criterion level for daily exposure to dioxin/furan: 1 to 3 pg TEQ/kg/day for adults and 60 pg TEQ/kg/day for nursing infants. The results for dioxin include the coplanar PCBs and the seventeen (dioxin and furan) congeners per HHRAP.
Note: Units for equivalent concentration of 2,3,7,8-TCDD (TEQ) are commonly expressed simply as pg/kg-day.

Table 1-7. Ecological Screening Quotients for the AMWTF Preliminary Risk Assessment.

Measurement Endpoint Receptor	Zone of Maximum Contamination (Exclusive diet)	Zone of Maximum Contamination (Equal diet)	*20-km* Average *Concentration* (Equal diet)
Plants	2.74E-07	NA	*3.21E-09*
Soil invertebrates	6.20E-05	NA	*7.42E-07*
Pygmy rabbit	1.14E-05	1.14E-05 (one food type)	*1.32E-07*
Deer Mouse	1.31E-02	6.57E-03	*7.85E-05*
Mourning dove	4.53E-04	4.53E-04 (one food type)	*5.11E-06*
Western meadowlark	1.13E-01	5.65E-02	*6.76E-04*
Peregrine falcon	1.31E-01	6.56E-02	*7.84E-04*
Ferruginous hawk	1.31E-01	8.74E-02	*1.05E-03*
Bald Eagle	1.31E-01	*9.27E-02*	*1.11E-03*
Coyote	6.54E-03	4.36E-03	*5.21E-05*
Gray Wolf	6.73E-03	*4.60E-03*	*5.49E-05*

Equal diet assumes receptor's diet is composed of all diet items in equal portions.
Exclusive diet assumes receptor's diet is composed of only the diet item that poses the maximum risk.

Table 1-8. Estimated Dose Rate for Ecological Receptors for the AMWTF Preliminary Risk Assessment.

Measurement Endpoint Receptor	Exposure[a] (rad/day)	Exposure[a] (mGy/day)
Plants	8.37E-07	8.37E-06
Soil invertebrates	1.83E-06	1.83E-05
Pygmy rabbit	1.41E-07	1.41E-06
Deer Mouse	1.91E-07	1.91E-06
Mourning dove	2.81E-07	2.81E-06
Western meadowlark	9.40E-08	9.40E-07
Peregrine falcon	1.31E-07	1.31E-06
Ferruginous hawk	1.31E-07	1.31E-06
Bald Eagle	1.14E-07	1.14E-06
Coyote	8.91E-08	8.91E-07
Gray Wolf	6.28E-08	6.28E-07
Raser	7.63E-08	7.63E-07

a. Assumes an equal diet

2. DERIVATION OF EMISSION ESTIMATES

The purpose of this PSLRA is to perform a screening level evaluation of the potential risks from direct and indirect exposure to AMWTF emissions. This section addresses the first step described in the introduction: characterization of the facility emissions, including identification of emission sources, identification of COPCs, measurement of facility emissions, and estimation of the concentration of non-detected compounds that are COPCs. Most of the information in this section was presented in the RAWP, and is reproduced here with the addition of changes requested by DEQ/EPA (DEQ/EPA 1999).

2.1 Section Overview

Section 2.2 lists emission sources for potentially-hazardous compounds at the AMWTF. The procedures used to select the COPCs for the PSLRA are described in Section 2.3. Section 2.4 describes how facility emissions estimates were derived, and Section 2.5 discusses the conservative assumptions used in that derivation.

2.2 Emissions Sources

As discussed in Section 1, the AMWTF will have one emission source for hazardous waste, a main stack comprising seven individual flues, five of which potentially will emit COPCs. All five flues—listed below along with the areas served–will have a similar discharge velocity (4,000 ft/min).

- East (Area 300) Zone 3 Extract: East areas designated Zone 3 including box lines, central conveyor system, drum line, drum staging areas, and supercompaction/macroencapsulation gloveboxes,
- East (Area 300) Glovebox Extract: East areas designated Zone 3 gloveboxes including analytical laboratory gloveboxes and the special case waste glovebox,
- West (Area 400) Zone 3 Extract: West areas designated Zone 3 including evaporator offgas,
- West (Area 400) Glovebox Extract: West areas designated Zone 3 gloveboxes including microencapsulation (including ash and salt handling), and
- Incineration Offgas.

2.3 COPC Selection

This subsection describes the procedures used to select the COPCs and to develop the emission estimates used in the AMWTF PSLRA. Each identified emission source at the facility is a possible source for emission of COPCs, including ROPCs. COPCs are compounds that (1) are likely to be emitted, based on the presence of the compound or its precursors in the waste feed, (2) are potentially toxic to humans, and/or (3) have a definite propensity for bioaccumulating or bioconcentrating in human and ecological food chains. The COPCs identified for the PSLRA are constituents present in the waste streams, products of incomplete combustion, and other compounds likely to be formed in the combustion process.

The estimated concentrations (bounding estimates based on existing documentation plus assumptions) of pollutants in each TSA waste stream are listed in Section 1 (Table 1-1). While the methods for estimating emissions from hazardous waste combustion sources are reasonably well established and are later confirmed through the trial burn process, the methods for estimating air emissions from associated nonthermal treatment processes are not well established. The process used for estimating emissions from both thermal and nonthermal treatment of the waste containing identified TSA pollutants is presented in Section 2.4, below. The reader is directed to Attachment L for more detail. Attachment L presents detailed calculations for the estimation of compounds that are contained in the feed and a few compounds that are expected to be products of the treatment process (dioxins/furans, chlorine, hydrogen chloride, hydrogen fluoride, nitrogen oxides, sulfur dioxide, and carbon monoxide).

2.3.1 COPC Selection Overview

The first step outlined in the HHRAP for assembling a COPC list assumes a trial burn has been conducted. The steps presented below are derived from the HHRAP method, with modifications applicable to the proposed AMWTF:

Step 1: Evaluate analytical protocol for the stack tests to be performed during the trial burn. Prepare a list that includes all the compounds specified in the analytical methods for the trial burn.

Step 2: Evaluate the type of mixed waste and TSCA-regulated PCB waste to be processed at the AMWTF facility—including all wastes that the units will be permitted to process—to determine which compounds should be retained for evaluation as COPCs because they are present in the waste.

Step 3: Delete from the list of COPCs those compounds that are not components of any process unit feed stream, are not expected products of incomplete combustion (PICs) from the incinerator

process, and do not have toxicological data. Those compounds that are listed as present in TSA waste but have no toxicological data are accounted for qualitatively in the uncertainty analysis.

Step 4: (Reserved for FSLRA)

Step 5: Evaluate any compound that may be of concern due to other site-specific factors (e.g., community and regulatory concern, high background concentrations). Include as COPCs those compounds that (1) are a concern due to site-specific factors, and (2) may be emitted by the combustion unit.

2.3.2 COPC Selection Worksheet

The worksheet used to develop the COPC list includes the name of the compound, the Chemical Abstract Service (CAS) number, the reason for inclusion on the list, and the availability of toxicological data. Compounds were included on the list if they were identified in the waste feed, or if they can be detected by the offgas sampling and analysis protocols defined for the trial burn. The offgas sampling protocols, described in the Quality Assurance Project Plan for the AMWTF incinerator trial burn (Appendix D-5 of Book 4 of the AMWTF HWMA/TSCA permit application [BNFL 1999]), were selected to allow detection of a comprehensive set of volatile organic compounds, semi-volatile organic compounds, polychlorinated dibenzo(p)dioxins/polychlorinated dibenzo furans (PCDDs/PCDFs), toxic metals, and other compounds identified in the HHRAP as potential COPCs. These compounds include all of the PICs identified in Table A-1 of Appendix A of the HHRAP, as well as, many other potential PICs.

The COPC worksheet developed for the AMWTF SLRA is presented in Table 2-1 of this report. This list consists of compounds in the following categories:

- Volatile organic compounds that are expected feed materials and potential PICs.
- Semivolatile organic compounds that are expected feed materials and potential PICs. Only cyclohexane, 1,2,4-trimethylbenzene, nitrobenzene, and 1,3,5-trimethylbenzene were identified as feed materials; the other 29 compounds are included as potential PICs.
- PCDDs and PCDFs: Dioxins/furans are included due to their high toxicity and because they are likely PICs. For the FSLRA, the seventeen (dioxin and furan) congeners listed in the HHRAP guidance are assumed to be included in the emission estimate for 2,3,7,8 TCDD.
- PAHs are included due to their toxicity and because they are likely PICs. The common carcinogenic PAHs that are included are: benzo(a)anthracene, benzo(a)pyrene (BaP), benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, and indeno(1,2,3-cd)pyrene. These compounds

are evaluated per the HHRAP. The following common PAHs are evaluated for noncarcinogenic health effects: acenaphthene, anthracene, fluoranthene, fluorene, naphthalene, and pyrene.

- Polychlorinated biphenyl compounds. PCBs are identified as present in at least two waste streams stored at TSA, and the AMWTF seeks a TSCA permit for PCB disposal.
- Nitroaromatic compounds. The HHRAP guidance does not automatically recommend the inclusion of nitroaromatics unless they are expected to be in the feed material or the feed contains large quantities of fuel bound nitrogen. As a conservative measure, and because of the wide range of materials included in the AMWTF waste feed, nitroaromatics are included in the COPC list.
- Phthalates. The HHRAP guidance also cautions against automatic inclusion of phthalates in the COPC list. Again, as a conservative measure and because of the variety of the waste feed materials, phthalates are included in the COPC list.
- Metals currently regulated as toxic (antimony, arsenic, barium, beryllium, cadmium, chromium, lead, mercury, silver, and thallium), plus nickel, selenium, cobalt, copper, iron, and zinc are included.
- Other compounds are included to ensure that compounds of concern that could be in the wastes to be permitted are considered. This includes (per the HHRAP) hydrogen chloride/chlorine gas (irritants that can cause adverse effects in the upper respiratory tract, including the nose, mouth, and throat); hydrogen fluoride, manganese, strontium, uranium (as a COPC), and zirconium (per regulator request).
- Criteria pollutants: carbon monoxide, nitrogen oxides, sulfur dioxide, ozone, lead (addressed under metals), and particulate matter are included per regulator request.

The worksheet identifies those compounds that were retained in the human health risk assessment. COPCs were retained if they were listed as possibly present in the feed, can be detected by the sampling and analysis protocols defined for the trial burn, and have toxicity data. During preparation of the PSLRA, analytical techniques more sensitive for analysis of pesticides, di-n-octyl phthalate, and PAHs were identified for use in the trial burn, and the emissions estimates for those compounds were adjusted to remain consistent with the detection limits for those methods. (See Section 2.4 and Table 2-2 for discussion of compounds that are in the feed, but are not detected in the trial burn emissions.) COPCs were excluded if they were not present in the feed and did not have toxicity data. Several compounds were identified that are present in the feed, cannot be detected by the proposed sampling and analysis protocols, but have toxicity data. These COPCs were evaluated in the PSLRA, and based on their estimated emissions, their contribution to the overall risk was evaluated.

The potential PICs identified in the previous section are likely to be formed in any combustion process. However, the AMWTF air pollution control system has been specifically designed to provide an

exceptionally high degree of removal of organic compounds, metals, and acid gases. This multistage system includes wet scrubbing, absorption, three stage HEPA filtration, and activated carbon adsorption. Because of the design of this system, none of the PICs (volatile, semivolatile, PCDD/PCDF, PAH, and others) are expected to be present in measurable quantities in the stack emissions.

The worksheet also includes COPCs that are listed as present in TSA waste but have no toxicological data or suitable surrogate toxicity values. The risk associated with these COPCs (dibromomethane, isopropanol, and methane) and other compounds that are potentially emitted, but would not be detected using selected methods, were estimated by using a multiplication factor. The multiplication factor is equal to the total estimated organic compound emissions divided by the total (estimated) emissions of identified organic compounds. The emission rate of each COPC is then increased by multiplying the estimated emission by this factor, which (for the PSLRA) is 2.0. The multiplication factor is discussed in more detail in Section 2.5.5. The worksheet also indicates which compounds are evaluated in the quantitative analysis and which compounds are evaluated in the qualitative section of the uncertainty analysis. COPCs that reasonably can be expected to be emitted, but which cannot be detected by offgas sampling and analysis protocols are discussed as nonconservative uncertainties.

A philosophy similar to that used to identify COPCs for the human assessment was used to select compounds for the ecological risk assessment: Compounds on the master COPC list were included if ecological data (toxicity reference values for invertebrates, mammals, and birds) were available. The impacts associated with exclusion of COPCs lacking data are discussed in the uncertainty section of the report.

2.3.3 Physical, Chemical, and Toxicological Data Critical for COPC Selection

After compiling the list of chemicals shown in the worksheet (Table 2-1), a search was conducted to determine data availability. Data for the physical and transport properties, chronic health effects, acute health effects, and ecological risks were obtained from a variety of sources. The following sections present the results of the data search.

2.3.3.1 Physical and Transport Properties

Physical and transport properties are required to model the transfer of chemicals from the air and soil deposits to plants, animals, and humans. The physical and transport properties include such data as the chemical molecular weight, volatility, soil transport, biological transfer, and biological accumulation factors. The transport properties were primarily obtained from Attachment A of the HHRAP, with corrections provided or approved by DEQ/EPA (DEQ/EPA 1999). The properties for the non-radioactive chemicals are

shown in Table A-1 of Attachment A of this report, along with the source of the data. Table A-5 of Attachment A of this report presents the data and data sources for radioactive chemicals. The data for the radioactive elements were derived from a number of sources, including the Allied Technology Group (ATG) RAWP (ATG 1998).

2.3.3.2 Chronic Health Effects

The risk assessment is based on estimates of the chronic health effects of carcinogenic and noncarcinogenic compounds. *Estimates of excess individual lifetime cancer risks were made using chemical-specific cancer slope factors.* Noncancer health effects were calculated from reference concentration (RfC) and reference dose (RfD) values for direct and indirect exposure pathways. The values for these parameters were obtained primarily from the IRIS database and the health effects assessment summary tables (HEAST) document (EPA 1997b). Table A-2 and Table A-3 of Attachment A present the values used in this risk assessment along with the sources for these values.

The carcinogenic risk from direct and indirect exposure to radionuclides was also calculated using carcinogenic slope factors. Table A-6 of Attachment A presents the values used in this risk assessment. These values were obtained from HEAST (EPA 1995b). Additional information regarding these values is presented in Section 5.3.

2.3.3.3 Acute Health Effects

Acute health effects were estimated by comparing the short-term (maximum 1-hour) inhalation of vapors and particulate COPCs with acute exposure inhalation criteria (AEIC). Section 4.5.1.4 presents the hierarchical approach used to identify sources for the criteria. The AEIC data used in this risk assessment, and their sources, are presented in Table A-4.

2.3.3.4 Ecological Toxicity Data

The ecological toxicity was evaluated by using the modeled soil and air concentrations and a simplified food web to compute the exposure to plants and animals at the INEEL. The modeled exposure was compared with TRVs for various plants and animals. The TRVs were obtained from Region 10 EPA (See Section 6).

2.3.4 Selection of ROPCs

The radionuclides selected for the AMWTF risk assessment include all those present in the TSA waste, based on historical data, process knowledge, and limited characterization (Raivo 1995). By far, americium

and plutonium are the largest contributors to the radionuclide inventory, accounting for almost 98% of the total activity. Table 2-4 lists the radioactive elements that were considered in the PSLRA.

2.4 Emissions Estimate Overview

The PSLRA is based on estimated emissions of the COPCs from the AMWTF. The emission estimates were modified for startup, shutdown, process upsets, and unidentified organic compounds, as described in Section 2.5.

The basis, methodology, and results of the emission estimates for both thermal and nonthermal processes at the proposed facility are presented below. Tables 2-3 and 2-4 list the total emissions estimated for the COPCs and ROPCs identified for TSA waste, including those for nonthermal sources and evaporator and incinerator offgas. The results of the estimated emissions from thermal and nonthermal sources were added to provide a total estimated emission for the facility.

2.4.1 Hazardous Emissions Estimates

The sources of emissions in the AMWTF are identified as the areas and/or equipment that process or contain mixed waste. Emissions from these sources exit the facility through five of the seven individual flues that make up the main stack. In addition to emissions from the main stack, two grout preparation areas emit PM, filtered by baghouses. However, these emissions are not included in the PSLRA analysis, which considers only the PM associated with pretreatment and treatment areas. Besides the stack emissions, the PSLRA accounts for emissions from startup/shutdown and process upsets, fugitive sources, and unidentified organic compounds, as discussed in Section 2.5, below.

The emissions for all compounds were initially estimated (for the Application [to the State of Idaho] to Construct an Air Pollution Emitting Facility [BNFL 1998]) using extremely conservative (but simple) assumptions for both thermal and nonthermal processes. In line with HHRAP recommendations to use "*reasonable*—not theoretical worst-case maximum" assumptions, the derivation of emissions estimates for mercury, dioxin/furans, PCBs, and semivolatile compounds were re-evaluated to incorporate more reasonable—but still conservative—assumptions appropriate for a screening level approach. A more detailed analysis is also required for these compounds in order to correctly link the incinerator emission estimates, APCS removal efficiencies, and evaporator emission estimates. The analysis is presented in Attachment L.

Initial mercury estimates were derived by assuming the incinerator feed contained 1% mercury in all of the 85,000 m^3 of waste to be processed at the facility in the 13-year operational period. The assumption of

maximum feed (650 lb/hr) to the incinerator resulted in 6.5 pounds of mercury exiting the SCC. This number is unrealistic, if not impossible. Even if the incinerated waste actually did contain 1% mercury, due to mercury's physical and chemical characteristics, only an estimated 70 grams (0.15 lb) would exit the SCC each hour, maximum. Given the assumption for incinerator operations used to derive the emissions estimates (8,760 hr/yr for 13 yr at the maximum feed rate), over 113,000 lb mercury would be processed. In actuality, only about 8,609 lb (3,905 kg) of mercury is estimated to be present in an uncontainerized form in the 36,000,000 lb (16,330,266 kg) of waste to be processed. Most mercury is expected to exist within containers that will be retrieved in the pretreatment lines. The revised incinerator emissions mercury estimate of 1.47 E-05 g/s (see Figure L-1 in Attachment L) is based on the assumption that all 8,609 lb (3,905 kg) of uncontainerized mercury is distributed homogeneously throughout the waste to be incinerated. All other assumptions (such as maximum feed rate, 100% release from the SCC, and conservative air pollution control efficiencies) remain the same.

The PCB content of the waste was also evaluated in a similar manner. The PCB emissions are based on the assumption that the PCB-containing waste streams average 15% PCBs and that the incinerator and APCS provides 99.99999% destruction and removal efficiency (DRE). Both of these assumptions are conservative.

The following sections summarize the emission estimation process for the nonthermal and thermal processes. The reader is directed to Attachment L for more detail. Attachment L presents detailed calculations for the estimation of compounds that are contained in the feed and compounds that are expected to be products of the treatment process (dioxin/furans, chlorine, hydrogen chloride, hydrogen fluoride, nitrogen oxides, sulfur dioxide, and carbon monoxide).

2.4.1.1 Nonthermal Process Emissions

To calculate emissions from nonthermal sources (i.e., all identified treatment sources except the evaporator and incinerator), total VOC emissions were first estimated for each process/area. VOCs were accounted for in areas where waste containers are not tightly lidded, or where waste containing organic constituents is disturbed by sizing, drilling, or other disruptive activities. Of the waste categories, only the non-debris, sludge-type wastes, especially organic homogeneous solids, are expected to emit VOCs. Where appropriate, emission factors from the EPA publication AP-42, *Supplement F of the Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources*, (EPA 1995d), hereafter referred to as AP-42, were used. If a good match is not identified in AP-42 for a process, a conservative emissic factor was derived from process knowledge and best engineering judgement.

Preliminary

Removal efficiencies for emission control equipment were applied to each source to determine the abated emission rates. The carbon adsorption unit removal efficiency is assumed to be a conservative 95% for VOCs. No credit is taken for the second stage backup carbon adsorption units.

From total VOCs values, individual COPC emissions were determined by multiplying the worst-case concentration percentage of each constituent in the waste by the total VOCs emitted for that process/area. VOC emissions from the debris waste type were considered negligible. (Process experience has shown that debris waste, which consists of pieces of material with high surface areas exposed to surrounding air, will retain a negligible amount of the original concentration of organic constituent. The VOCs will have also escaped the headspace of the drum over time.) The majority of the debris waste type organic COPCs are also listed as non-debris COPCs; therefore, conservative emissions estimated from the worst-case non-debris waste type cover the small amount of organic COPCs that may be present in debris waste. Some organic COPCs that are listed only for the debris waste type (dichlorethene; cis-1,2-dichloroethene; ethyl ether; isopropanol; methane; and 1,1,2,2-tetrachloroethane) are not encompassed by non-debris VOC estimates. As a conservative measure, they were included in the non-debris waste at their respective debris waste concentrations. This allowed calculation of emission estimates for these COPCs. They were, however, evaluated for risk at their individual detection limits as part of the PSLRA analysis. Table 2-3 presents the estimates for COPC emissions, including those from nonthermal sources.

The above analysis does not address semi-volatile contaminants contained in the feed. This affects four compounds (cyclohexane, nitrobenzene; 1,2,4-trimethylbenzene; and 1,3,5-trimethylbenzene). The emissions of these compounds in the nonthermal treatment process were estimated by using the same methods and assumptions as presented for the volatile compounds. These methods were also applied to the additional metals (cobalt, copper, iron, manganese, strontium, thorium, uranium, and zirconium) included per regulator request. These metals, although not identified in the feed (because they are not regulated by RCRA and therefore were not measured), are most likely contained in the feed. These metals are assumed to be present at the 1% level (the same level as the RCRA metals), with the exception of iron, which will be assumed to be present at 5%.

2.4.1.2 Thermal Process Emissions

Incinerator Emissions. Incinerator organic emissions were conservatively estimated based on feeding the worst-case non-debris feed at the process capacity of 650 lb/hr and include PICs and compounds formed in the incinerator process (e.g., PCDDs and PCDFs). A conservative 99.99% (99.999869% for PCBs) DRE was assumed for the incinerator PCC and SCC. These minimum DREs are required to be demonstrated in the

HWMA/TSCA trial burn, and the actual DREs are expected to exceed these estimates by one to two orders of magnitude. The carbon adsorbers are expected to remove VOCs from the offgas; however, no credit was taken for their removal efficiencies. [Details of the incinerator APCS are found in Section D-5 of Book 4 of the AMWTF HWMA/TSCA permit application (BNFL 1999)].

Metal and PM removal efficiencies for the various control devices in the incinerator APCS were based on the conservative guidance provided in Dempsey, Clyde R. and E. Timothy Oppelt, *Incineration of Hazardous Waste: A Critical Review Update*, Air and Waste, Vol. 43, pp. 25-73, January 1993, (Dempsey 1993), hereafter referred to as Dempsey. Conservative estimates of metals partitioning to the APCS were taken from the same source. Dempsey's estimates of metals partitioning are for waste metal concentrations of 100 ppm for each metal. The authors state the following, "For a given set of combustion chamber conditions, the maximum amount of metal which will be vaporized will become constant as the metal concentration in the solids increases." No credit is taken in the AMWTF analysis for the fact that the metals content in the feed is 0.5 to 6.5 lb/h, which corresponds to concentrations of 770 to 10,000 ppm (1 wt%). It is expected that metals partitioning to the offgas will be significantly lower than the highly conservative value of 100% assumed for most of the metals. Nickel and selenium values are not given in Dempsey, so the same removal efficiencies were given to these metals as for the metals arsenic, cadmium, and lead.

The HEPA filter removal efficiency for PM and metals (except mercury) was assigned 99.9%; no credit was taken for removal of metals or PM by the HEPA pre-filters. A removal efficiency of 0% was assigned to the HEPA filters for mercury. Mercury removal efficiencies for the carbon bed absorbers in the incinerator APCS were assigned as 98% and 95%.

Table 2-3 lists the estimated emissions for all of the COPCs identified in the COPC selection worksheet.

Evaporator Emissions. The evaporator emissions calculations followed a similar methodology as the comparable incineration emissions calculations, with several adjustments due to processing differences. The composition of the feed to the brine mix tanks is based on the conservative estimates from the incineration calculation adjusted by the removal efficiencies of the APCS equipment up through the WESP. The additional waste feed streams from the decontamination wastewater tank and the overflow from sumps have minor flow rates with lower concentrations of heavy metals (due to dilution with makeup water). Hence, these conservative estimates for the incineration feed represent a worst-case scenario for feed to the brine mix tanks.

In the brine mix tanks, the stabilizing agent [2,4,6-trimercapto-s-triazine sodium salt, (TMT)] is assumed added to form insoluble metal complexes with several of the heavy metals, and the pH is adjusted to neutral

(pH=7) by adding caustic [50 wt% sodium hydroxide (NaOH)]. Vendor literature (*Heavy Metal Removal from Flue Gas Scrubber Water of Garbage Incinerators with TMT*, by Norbert Steiner) (Steiner), available from Degussa Corporation, reported the heavy metal removals measured in a weekly survey. Based on this guidance, the conservative assumptions used in the calculations are 95% for cadmium, lead, and mercury, and 85% for nickel.

Since the Degussa Corporation data sheet on TMT-15 (15-wt% aqueous solution of TMT) indicates that silver also forms an insoluble complex, it is assumed that silver is removed at the same rate as the lowest removal rate (85%). With the addition of caustic until a neutral pH is reached, it is assumed that all of the acid gases (HCl and SO_2) are completely converted to their corresponding soluble sodium salts.

In the evaporator, the brine feed is concentrated to a dry salt by evaporating the water in a thin film of brine solution spread over a heated wall by a slowly rotating rotor. Normally, only a small portion of the salt is entrained in the water vapor effluent. For conservatism, the calculations assume a high carryover amount of 5 wt% for PM, soluble salts, and low volatility metals (beryllium and chromium) that is comparable to the incinerator SCC carryover fraction.

In the condenser, the vapor effluent from the evaporator is sub-cooled to liquefy a portion of the predominately water vapor for use as process water makeup to the incinerator scrubbers and quencher. No credit is taken for metals removal for these conservative calculations.

The carbon adsorption unit is assumed to remove mercury (at a conservative 98%) and VOCs at 95% (except for cyanide, which is not greatly abated by activated carbon) and the HEPA filters are assumed to remove 99.9% of the PM and soluble salts, as well as the heavy metals (except mercury, which is assumed to be in the elemental gaseous form).

2.4.2 Radioactive Emissions Estimate

The source term for atmospheric radionuclide releases from the AMWTF depends on several assumptions, including the amount of each radionuclide to be processed in each area, the release of the radionuclide from each area/process, and the removal efficiencies of the filters for each flue that could contribute to the source term. The HHRAP presents, as an option, use of output from the CAP-88 code used for National Emission Standard for Hazardous Air Pollutants (NESHAPs) analysis, but recommends using the ISCST3 air dispersion model. In response to the AMWTF regulator's guidance, this PSLRA uses the EPA-preferred ISCST3 model and the GENII model, along with the source term derived for the AMWTF

based on historical databases, process knowledge, and limited characterization of TSA waste. Basic assumptions used to derive the source term for radionuclides at the AMWTF include:

- The 20,000 m^3 of yet unidentified DOE waste to be treated will be similar (in radionuclide content, waste-type composition, and treatment required) to the 65,000 m^3 of waste currently at the TSA,
- The facility will process 85,000 m^3 (approximately 3.58E+07 kg) over a 13-year period, and operate 24 hours a day, 330 days a year, and
- The radionuclide inventory is evenly distributed throughout the waste.

Waste Description. As discussed previously, the AMWTF will treat 65,000 m^3 of alpha low-level mixed waste and TRU, contact-handled mixed and radioactive only waste in storage at the TSA, plus an additional 20,000 m^3 of DOE waste (similar in content to the 65,000 m^3). The estimates for radioactive emissions were derived as follows.

Annual Throughput/Process Inputs. A combination of process knowledge, regulatory direction, and experience with the technologies to be used at the AMWTF was used to identify the areas that may contribute to airborne radionuclide emissions. Waste in intact, unopened containers will not contribute, so the areas where waste would be managed in lidded containers were not included. Macroencapsulation of compacted pucks and metal debris is unlikely to emit radionuclides, and the contribution from that area was also assumed negligible. Care was taken to account for processes that reasonably would be expected to contribute to radioactive emissions at the facility but that are not detailed on process flow sheets (e.g., the evaporator and laboratory). For example, to account for samples to be analyzed in the laboratory it was assumed a sample core of 0.06 ft^3 from each of 23 drums processed per day would be transferred to the analytical laboratory. It is very unlikely this many non-debris waste drums will be sampled over the 13-year operating period.

Release Fractions. During processing, some fraction (release fraction) of the radionuclides in waste will be released to the offgas. To determine that fraction for the processes to be used at the AMWTF, the very conservative values in 40 Code of Federal Regulations (CFR) 61, Appendix D for the physical state of the waste were used. For example, for incineration, the release fraction is conservatively assumed to be 100%. In practice, a significant quantity (well over 90%) of radioactive material is expected to remain in the bottom ash, based on experience with other radioactive waste incinerators. Evaporation is a thermal process (temperature greater than 100°C), and a 100% release fraction was applied to that process, also.

Air Pollution Control. The radionuclides released into the offgas will be treated by the incinerator APCS and ventilation extract system pollution control equipment (for the evaporator and nonthermal processes), abating radionuclide releases to the atmosphere. Values established in 40 CFR 61, Appendix D were used to determine an adjustment factor (filtration factor) due to air pollution control equipment for each of the five flues. The filtration factors used for the analysis do not take credit for equipment not listed in 40 CFR 61, or for the actual efficiency of those that are listed. In practice, the filtration factor is expected to be significantly higher when the actual equipment and efficiencies are taken into account.

Estimated Emissions. Table 2-4 presents the estimated emissions for each of the flues that exhaust areas that process radioactive waste at the AMWTF. The conservative assumptions used for the average yearly throughput, plus conservative radionuclide concentrations, release fractions, and filtration efficiencies, represent a worst-case, bounding scenario. These conservatisms add about 2.28 E+06 Ci to the source term.

2.5 High-End Assumptions Used for Estimates

For the PSLRA, the COPCs (including ROPCs) emitted by the facility were based on emission estimates calculated for the AMWTF. These estimates are based on conservative assumptions for the thermal and nonthermal processes, air pollution control equipment, and feed.

2.5.1 Waste Feed Rates, Processes, and Conservation Between Processes

Conservative waste assumptions include use of worst-case waste with extremely high concentrations of hazardous constituents, high throughput rates, and conservation of waste between processes. For example, it was assumed all radionuclides (except tritium, which was assumed completely released in pretreatment) entering the pretreatment lines in IHS, OHS, non-debris SCW, and soil waste also entered the incinerator, but were all also included in the estimate for microencapsulation, and a portion was counted again for evaporation.

2.5.2 Conservative Treatment Efficiencies

As described in Section 2.4, conservative filtration efficiencies for the various control devices in the incinerator APCS and control equipment for nonthermal treatment areas were used to estimate emissions for use in the PSLRA, and no credit was taken for some equipment. For example, for the incinerator a conservative 99.99% (99.999869% for PCBs) DRE for organics is assumed for the PCC and SCC (actual DREs are expected to be one to two orders of magnitude higher) and no credit is taken for carbon adsorbers,

which are expected to remove VOCs from the offgas. Similarly, metals partitioning to the offgas is assumed to be 100%, and no credit is taken for removal of metals or PM by the incinerator HEPA pre-filters.

2.5.3 Startup/Shutdown and Process Upset Emissions

To account for startup/shutdown and process upset emissions, nonmetal emissions from the facility were multiplied by a factor of 2.8 to account for a 20% operational period when the system may not be operating at peak performance. The 2.8 multiplication factor was determined by assuming that for 20% of the time, emissions were 10 times the detected levels [(0.80)(1) + (0.20)(10)]. For metals, an upset factor of 1.45 was used. The 1.45 multiplication factor was determined by assuming that for 5% of the time, emissions were 10 times the detected levels [(0.95)(1) + (0.05)(10) = 1.45]. These upset factors were used for the PSLRA.

2.5.4 Fugitive Emissions

The AMWTF will be a completely enclosed facility designed and operated to provide complete radiological and hazardous chemical containment. Waste will arrive at the AMWTF in intact, covered containers that will only be opened in continuously-confined (Zone 3) areas, and operations will be conducted remotely. Cascade ventilation and extracted air filtration will capture and treat all fugitive emissions. Air extracted from Zone 3 areas will be passed through three stages of HEPA filtration and carbon adsorption units (for areas that have potential to release organic emissions) before release to the environment. Second stage carbon adsorption units located downstream of the first stage units will provide backup control of potential fugitive organic emissions in the event a first stage carbon unit fails. Additionally, the entire contents of waste containers are accounted for in the extraordinarily conservative emissions estimates used for the AMWTF, thereby accounting for contributions from fugitive emissions at the facility.

2.5.5 Unidentified Organic Compounds

Following the guidance of the EPA (EPA 1998a) to account for risks from unidentified organic compounds, it is assumed that the unidentified organic compounds are similar in toxicity and chemical properties to those of the identified organic compounds taken as a whole. Under this assumption, the total risks from organic compounds are equal to the risks from the identified organic compounds multiplied by the ratio of the mass of total organic compounds to the mass of the identified organic compounds. This is accomplished computationally by increasing the emission rate of each of the detected and identified organic compounds by the ratio of the concentration of total organic compounds to the concentration of all the identified organic compounds combined. Mathematically, this may be written as follows:

$$Q_{i,adj} = Q_i \, x \, \frac{C_{TOC}}{\Sigma_i C_i}$$

where:

$Q_{i,adj}$ = adjusted emission rate of compound i,

Q_i = emission rate of identified compound i,

C_i = stack concentration of identified compound i (carbon basis), and

C_{TOC} = stack concentration of total organic compounds.

U.S. EPA developed the total organic emissions (TOE) test to measure the quantity of the total organic compound emissions. The TOE tests measure the total quantity of volatile, semi-volatile, and non-volatile hydrocarbons. As shown above, the multiplication factor is calculated by dividing the TOE measurement (C_{TOC}) by the sum of the identified organic compound emissions. A single multiplication factor can be calculated for all of the organic compounds.

For the PSLRA, a multiplication factor of 2 was used for both the volatile and semivolatile compounds (including PAH, nitroaromatic, PCB, and phthalate COPCs). This is a relatively low multiplication factor, although the Waste Experimental Reduction Facility (WERF) facility at the INEEL measured a value of 1.68 in a recent trial burn test. However, the organic emissions estimates for the PSLRA are very conservative. The emission estimates (for non-PCB compounds) are based on a 99.99% DRE. The regulatory requirement for PCB DRE is 99.9999%. Since the incinerator has been designed to meet this requirement, it is likely that the non-PCB DREs will also meet or exceed 99.9999%. Thus, the emission estimates are expected to be 10 to 100 times greater than the measured emissions.

Table 2-1. COPC Selection Worksheet for the Human Health Risk Assessment.

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				Data Availability			Human Health Risk Assessment			
					Toxicity		Chronic Exposure (c,d,f)			
CAS #	Volatile COPCs	Feed (e) Compound	S&A Methods	Transport Properties	Chronic (a)	Acute (b)	Retain	Quantitative	Qualitative	Acute Exposure
67641	Acetone	Y	Y	Y	Y	5	Y	Y	N	Y
107131	Acrylonitrile	N	Y	Y	Y	3	Y	Y	N	Y
71432	Benzene	Y	Y	Y	Y	4	Y	Y	N	Y
75274	Bromodichloromethane	N	Y	Y	Y	5	Y	Y	N	Y
75252	Bromoform	N	Y	Y	Y	5	Y	Y	N	Y
74839	Bromomethane	N	Y	Y	Y	5	Y	Y	N	Y
71363	Butanol, n-	Y	N	Y	Y	5	Y	Y	N	Y
78933	Butanone, 2- (Methyl ethyl ketone)	Y	N	Y	Y	4	Y	Y	N	Y
75150	Carbon disulfide	N	Y	Y	Y	3	Y	Y	N	Y
56235	Carbon tetrachloride	Y	Y	Y	Y	3	Y	Y	N	Y
108907	Chlorobenzene	Y	Y	Y	Y	5	Y	Y	N	Y
75003	Chloroethane (Ethyl chloride)	N	Y	Y	Y	5	Y	Y	N	Y
67663	Chloroform	Y	Y	Y	Y	4	Y	Y	N	Y
74873	Chloromethane	N	Y	Y	Y	5	Y	Y	N	Y
74953	Dibromomethane	N	Y	Y	N	5	Y	N	Y	Y
75343	Dichloroethane, 1,1-	N	Y	Y	Y	5	Y	Y	N	Y
107062	Dichloroethane, 1,2-	Y	Y	Y	Y	5	Y	Y	N	Y
75354	Dichloroethylene, 1,1-	Y	Y	Y	Y	5	Y	Y	N	Y
156592	Dichloroethylene, cis-1,2-	Y	N	Y	Y	5	Y	Y	N	Y
156605	Dichloroethylene, trans-1,2-	Y	Y	Y	Y	5	Y	Y	N	Y
78875	Dichloropropane, 1,2-	N	Y	Y	Y	5	Y	Y	N	Y
542756	Dichloropropene, cis-1,3-	N	Y	Y	Y	5	Y	Y	N	Y
110805	Ethoxyethanol, 2-	Y	N	Y	Y	5	Y	Y	N	Y
60297	Ethyl ether	Y	N	Y	Y	5	Y	Y	N	Y
100414	Ethylbenzene	Y	Y	Y	Y	5	Y	Y	N	Y
67630	Isopropanol	Y	N	N	N	5	Y	N	Y	Y
74828	Methane	Y	N	N	N	5	Y	N	Y	Y
67561	Methanol	Y	N	Y	Y	5	Y	Y	N	Y
75092	Methylene chloride (Dichloromethane)	Y	Y	Y	Y	3	Y	Y	N	Y
100425	Styrene	N	Y	Y	Y	3	Y	Y	N	Y

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Attachment 6

ATTACHMENT L TO AMWTF HWMA/TSCA PERMIT APPLICATION

Consisting of 17 pages
including cover page

ATTACHMENT L

AMWTF Emissions Estimates

ESTIMATED EMISSIONS

Estimates of emissions expected from the Advanced Mixed Waste Treatment Facility (AMWTF) during normal operation are presented herein. The sources of emissions in the AMWTF are identified as the areas and/or equipment that process or contain mixed waste. Emissions from these sources exit the facility through five of the seven individual flues that make up the main stack, as described in Section 1. In addition to emissions from the main stack, two grout preparation areas emit particulate matter (PM), filtered by baghouses. The facility ventilation system, including discussion of control equipment configuration, and details of the air pollution control system (APCS) for the incinerator are found in Section 1.

Compounds of Potential Concern

Each identified emission source is expected to emit compounds of potential concern (COPCs). COPCs are compounds that (1) are likely to be emitted, based on the presence of the compound or its precursors in the waste feed, (2) are potentially toxic to humans, and/or (3) have a definite propensity for bioaccumulating or bioconcentrating in human and ecological food chains. The COPCs identified here for the AMWTF are constituents present in the waste streams, compounds likely to be formed in the combustion process, and compounds that are of concern due to their toxicity.

The estimated concentrations (bounding estimates based on existing documentation plus assumptions) of pollutants in each waste stream are found in the Idaho National Engineering and Environmental Laboratory (INEEL) document, *"Waste Description Information for Transuranic-Contaminated Wastes Stored at the Idaho National Engineering Laboratory," INEL-95/0412 (Table 5 of Appendix A and B)*. For each waste category (WC), the highest value for the estimated concentration of a particular pollutant in any of the waste streams in that WC is assigned to that pollutant (for the WC). For example, of the eleven waste streams in the organic homogeneous solids (OHS) WC, waste stream RFETS-003 has the highest estimated concentration (5% by weight) of carbon tetrachloride. Therefore, for the OHS WC, the conservative concentration of 5 wt% is assigned to carbon tetrachloride. Where no concentration is given in the "estimated concentration" column for a pollutant, the analysis uses the concentration given in the "maximum expected" column. Each waste stream is cross-referenced with the engineering design file (EDF) RWMC-803, current revision, *Chemical Constituents in Transuranic Storage Area Waste*, hereafter referred to as EDF-803; which lists pollutants expected to be found in TSA waste, but does not give concentrations. Pollutants listed in EDF-803 , but not in INEL-95/0412 are assigned a conservative concentration of 1%. Table L-1 summarizes the worst-case pollutant concentrations for each WC; a summary is also given for the worst-case general waste types, non-debris [inorganic homogeneous solids (IHS), OHS, and soils (S)]] and debris [ceramic/brick debris (CBD), graphite (G), heterogeneous debris (HD), inorganic debris (ID), metal debris (MD), organic debris (OD), and paper/rags/plastic/rubber (PRPR)]. Two compounds required special considerations. Dichlorethylene appears in the description of one

waste type (MD) and is conservatively assumed to be 1,1-dichloroethylene. The compound 1,3,6-trimethylbenzene appears in the description for waste type PRPR, however, this is not a correct compound name. Using these methyl-group positions, the compound is equivalent to 1,2,4-trimethylbenzene, another and more likely possibility is that it is a typographical error and should be 1,3,5-trimethylbenzene. The latter assumption was used because it is more conservative in that it adds another compound to the list of COPCs contained in the feed.

Nonthermal Process Emissions

To calculate emissions from nonthermal sources (i.e., all identified sources except the evaporator and incinerator), total volatile organic compound (VOC) and total PM emissions are first estimated for each process/area. Table L-2 summarizes the assumptions and factors used to calculate total "VOCs."

This calculation is based on the emission factors from the Environmental Protection Agency (EPA) publication AP-42, "*Supplement F of the Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources*," (hereafter referred to as AP-42). If a good match is not identified in AP-42 for a process, a conservative emission factor is derived from process knowledge and best engineering judgement. For the OHS waste stream, the AP-42 emission factor for solvent operations was applied. However, the "solvents" are contained in a liquid (for example, lathe cutting oil) which has then been stabilized with silica gel. The emission factors have been applied to the liquid fraction of the waste and quotation marks are used to indicate the loose interpretation of "VOC" emissions. Total PM estimates are summarized in Table L-3. Configurations of the various filters for each process are found in Section 1.

In general, processes that disturb the waste matrix, such as drilling, dumping, sorting, sizing, grinding, shredding, and handling, are assumed to emit PM. VOCs are accounted for in areas where waste containers are not tightly lidded, or where waste containing organic constituents is disturbed by sizing, drilling, or other disruptive activities. Of the WCs, the non-debris, sludge-type wastes, especially OHS, are expected to emit the most VOCs. Also included in the VOC estimates are semivolatile COPCs and mercury. Since these compounds are less volatile than VOCs, the emission estimates for these compounds are conservative.

Removal efficiencies for emission control equipment are applied to each source to determine the abated emission rates. The high efficiency particulate air (HEPA) filters in the AMWTF are rated at a minimum removal efficiency of 99.97% for 0.15 to 0.3 micron particles with an increasing efficiency for larger and smaller particles. A conservative removal efficiency of 99.9% is used in the emissions calculations (an order of magnitude less than the certified particulate removal efficiency). Drum and box line PM is further abated by the local filters described in Section 1. The grout preparation areas are filtered by local baghouses only.

The carbon adsorption unit removal efficiency is a conservative 95% for VOCs and semivolatiles. No credit is taken for the second stage backup carbon adsorption units.

From total VOCs and PM values, individual COPC emissions are determined by multiplying the worst-case concentration percentage of each constituent in the applicable waste type (non-debris or debris) by the total VOCs or PM emitted for that process/area. The COPCs are separated into those that are likely to be emitted as VOCs and those likely to be emitted as PM. These emission estimates are presented in Tables L-4 and L-5. VOC emissions from the debris waste type are considered negligible. Process experience has shown that debris waste, which consists of pieces of material with high surface areas exposed to surrounding air, will retain a negligible amount of the original concentration of organic constituent. The VOCs will have also escaped the headspace of the drum over time. The majority of the debris waste type organic COPCs are also listed as non-debris COPCs; therefore, conservative emissions estimated from the worst-case non-debris waste type cover those COPCs. The organic COPCs listed only for the debris waste type (dichlorethene; cis-1,2-dichloroethene; ethyl ether; isopropanol; methane; 1,1,2,2-tetrachloroethane; 1,2,4-trimethylbenzene; and 1,3,5-trimethylbenzene) would not be encompassed by the non-debris emission estimates. Therefore, for these COPCs, a concentration of 1% in the non-debris waste was assumed and their emissions from the incinerator and evaporator were estimated accordingly.

Incinerator Emissions

Table L-6 lists incinerator emissions resulting from feeding an assumed worst-case feed, as well as for products of incomplete combustion and compounds formed in the incinerator process. Details of the incinerator APCS are found in Section 1.

Incinerator organic emissions are conservatively estimated based on feeding the worst-case non-debris feed at the process capacity of 650 lb/hr. A conservative 99.99% destruction removal efficiency (DRE) is assumed for the incinerator primary combustion chamber (PCC) and secondary combustion chamber (SCC). These minimum DREs are required to be demonstrated in the Hazardous Waste Management Act (HWMA)/Toxic Substances Control Act (TSCA) trial burn and the actual DREs are expected to exceed these estimates by one to two orders of magnitude. The carbon adsorbers are expected to remove organic compounds from the offgas; however, no credit is taken for their removal efficiencies.

Metal and PM removal efficiencies for the various control devices in the incinerator APCS are based on the conservative guidance provided in Dempsey, Clyde R. and E. Timothy Oppelt, *"Incineration of Hazardous Waste: A Critical Review Update,"* Air and Waste, Vol. 43, pp. 25-73, January 1993, hereafter referred to as Dempsey. Conservative estimates of metals partitioning to the APCS are taken from the same source. Dempsey's estimates of metals partitioning are for waste metal concentrations of 100 ppm for each metal. The authors state the following, "For a given set of combustion chamber conditions, the maximum amount of metal which will be vaporized will become constant as the metal concentration in the solids increases." No credit is taken in the AMWTF analysis for the fact that the metals content in the feed is 0.5 to 6.5 lb/h, which corresponds to concentrations of 770 to 10,000 ppm (1 wt%). It is expected that metals partitioning to the offgas will be significantly lower than the highly conservative value of 100% assumed for most of the metals. Nickel and selenium values are not given in Dempsey, so the same removal efficiencies are given to these metals as for the metals arsenic, cadmium, and lead.

Like the nonthermal source emissions calculations, the HEPA filter removal efficiency for PM and metals (except mercury) is assigned 99.9%; no credit is taken for removal of metals or PM by the HEPA pre-filters. A removal efficiency of 0% is assigned to the HEPA filters for mercury. Mercury removal efficiencies for the carbon bed absorbers in the incinerator APCS are given as 98% and 95%.

Evaporator Emissions

Evaporator emissions estimates are presented in Table L-7. The evaporator emissions calculations follow a similar methodology as the comparable incineration emissions calculations with several adjustments due to processing differences. The composition of the feed to the brine mix tanks is based on the removal efficiencies used for the wet APCS equipment [quench, venturi scrubber, absorber #1, absorber #2, and wet electrostatic precipitator (ESP)]. The additional waste feed streams from the wastewater tank and the overflow from sumps have minor flow rates with lower concentrations of heavy metals (due to dilution with makeup water). Hence, these conservative estimates for the incineration feed represent a worst-case scenario for feed to the brine mix tanks.

In the brine mix tanks, the stabilizing agent [2,4,6-trimercapto-s-triazine sodium salt, (TMT)] is added to form insoluble metal complexes with several of the heavy metals and the pH is adjusted to neutral (pH=7) by adding caustic [50 wt% sodium hydroxide (NaOH)]. Vendor literature (*"Heavy Metal Removal from Flue Gas Scrubber Water of Garbage Incinerators with TMT," by Norbert Steiner*) available from Degussa Corporation reported the heavy metal removals measured in a weekly survey. Based on this guidance, the conservative assumptions used in the calculations are 95% for cadmium, lead, mercury, and 85% for nickel. Cobalt, manganese, and strontium, which also have low volatility in metal, oxide, and chloride forms were assigned a value of 50% retention in the evaporator.

Since the Degussa Corporation data sheet on TMT-15 (15 wt% aqueous solution of TMT) indicates that silver also forms an insoluble complex, it is assumed that silver is removed at the same rate as the lowest removal rate (85%). With the addition of caustic until a neutral pH is reached, it is assumed that all of the acid gases (HCl and SO_2) are completely converted to their corresponding soluble sodium salts.

In the evaporator, the brine feed is concentrated to a dry salt by evaporating the water in a thin film of brine solution spread over a heated wall by a slowly rotating rotor. Normally only a small portion of the salt is entrained in the water vapor effluent. For conservatism, the calculations assume a high carryover amount of 5 wt% for PM, soluble salts, and low volatility metals (beryllium and chromium) that is comparable to the incinerator SCC carryover fraction.

In the condenser, the vapor effluent from the evaporator is sub-cooled to liquefy a portion of the predominately water vapor for use as process water makeup to the incinerator scrubbers and quencher. No credit is taken for metals removal for these conservative calculations.

The carbon adsorption unit is assumed to remove mercury (at a conservative 98%) and organic compounds at 95% (except for cyanide, which is not greatly abated by activated carbon).

The HEPA filters are assumed to remove 99.9% of the PM and soluble salts, as well as the heavy metals (except mercury, which is assumed to be in the elemental gaseous form).

Mercury

Figure L-1 presents a detailed explanation of the calculations used to estimate the mercury emissions. The waste stream data was analyzed to determine the total amount of waste that contained mercury and the total quantity of mercury that is expected to be processed at the AMWTF. Assuming a homogeneous distribution, a mercury-processing rate was determined. This is a reasonable assumption since these estimates will be used to evaluate long term emissions. By assuming that 100% of the mercury is released from the PCC & SCC, the quantity of mercury entering the APCS was determined. Applying the mercury removal rates mentioned above allows calculation of the mercury emissions from the incinerator as well as the quantity of mercury transfer to and emission from the evaporator.

Polychlorinated Biphenyls (PCBs)

Figure L-2 presents a similar calculation for estimating the emissions of PCBs. Again, the PCB content of the waste was evaluated to determine the PCB processing rate. By setting the PCC & SCC destruction efficiency to 99.999925%, it was possible to fix the PCB content of the brine at 3 ppb (assuming removal efficiencies in the wet APCS of 10% in the quench, 48% in the venturi, and 48% in the ESP). The permit application has recommended a 3 ppb limit for PCBs in the brine; these calculations are designed to determine the PCB emissions at this worst case condition. Using this basis, the emissions of PCBs from the incinerator and evaporator were estimated. A conservative removal efficiency of 95% was applied to the carbon adsorption units downstream of the incinerator and evaporator. This resulted in an overall PCB DRE of 99.999996% which is slightly greater than the regulatory limit of 99.9999%, but lower than the expected DRE.

Dioxin / Furans

Figure L-3 presents the calculations for estimating the emissions of dioxins and furans. These compounds are expected byproducts of the combustion process. The incinerator and APCS have been designed to minimize the emission of dioxins. In order to estimate the potential emissions for the evaporator and incinerator, the emissions from the incinerator were set equal to the proposed Maximum Achievable Control Technology (MACT) standard of 0.2 ng/dscm. The estimated quantities of dioxins were then back-calculated using the following assumptions:

- 95% removal of dioxins in the carbon adsorption unit (this is conservative; typically these units will remove from 98% to greater than 99% of dioxins),
- 0% removal in the HEPA filters,

- 47.5% removal in the ESP,
- 47.5% removal in the venturi scrubber, and
- 10% removal in the quench.

The basis for these assumptions is that dioxins are associated with particulate. As a conservative measure, no removal credit is taken for the HEPA filters. In the wet APCS, only 50% of the particulate removal efficiency is applied. This should provide a realistic estimate of the quantities that will be absorbed in the brine and transferred to the evaporator. In the evaporator, 50% of the dioxins are assumed to be emitted. This is a very conservative assumption; only 5% of the particulate has been assumed to be emitted and dioxins are not volatile at the low temperatures encountered in the evaporator.

Semivolatile Organic Compounds

Figure L-4 presents the calculations for estimating the emissions of semivolatile organic compounds that are not contained in the feed. These compounds are expected byproducts of the combustion process [products of incomplete combustion (PICs)]. The incinerator and APCS have been designed to minimize the emission of the compounds. In order to estimate the potential emissions from the evaporator and incinerator, the emissions from the incinerator were set equal to the expected detection limit of 5 μg/dscm. The estimated quantities of these semivolatile compounds were then back-calculated using the following assumptions:

- 95% removal of dioxins in the carbon adsorption unit (this is conservative; typically these units will remove from 98% to greater than 99% of dioxins),
- 0% removal in the HEPA filters,
- 47.5% removal in the ESP,
- 47.5% removal in the venturi scrubber, and
- 10% removal in the quench.

The basis for these assumptions is the same as that discussed for dioxins in the preceding section. As a conservative measure, no removal credit is taken for the HEPA filters. In the wet APCS, only 50% of the particulate removal efficiency is applied. This should provide a realistic estimate of the quantities that will be absorbed in the brine and transferred to the evaporator. In the evaporator, 50% of the semivolatiles are assumed to be emitted. This is a very conservative assumption; only 5% of the particulate was assumed to be emitted and the semivolatile compounds have very low vapor pressures at the low temperatures encountered in the evaporator.

Summary

Table L-8 presents a summary of the estimated emissions of COPCs for the AMWTF, including nonthermal sources and the incinerator and evaporator offgas.

Figure L-1. Calculations for Estimating the Mercury Emissions from the AMWTF

Waste Stream Data from Attached Table:

Waste Stream	Incinerate (kg)	Non-thermal (kg)	Incinerate (%)
Subtotal LLW	2,292,785	207,423	91.70%
Subtotal TRU	4,512,685	149,291	96.80%
Total	**6,805,470**	**356,714**	**95.02%**

Total Mercury Content from INEL-95/0412:

Total Mercury in Waste	4,110 kg
Fraction of Mecury containing waste to be incinerated	95%
Total Mercury to Incinerator	3,905 kg

Processing Rate Information:

Facility Operation	12	years
Operating Time (70%)	6,132	hours / year
Total Time to Process Waste	73,584	hours
Mercury Processing Rate	0.0531	kg/hr
	0.0147	g/s

Destruction and Removal of Mercury:

Destruction in PC & SCC (100% to APCS)		0%	
Mercury to wet APCS		1.47E-02 g/s	
Wet APCS removal efficiency (typical for mercury):			
Mercury (removed by Venturi)	20%	2.95E-03 g/s	
Mercury (removed by Absorber #1)	80%	9.44E-03 g/s	
Mercury (removed by Absorber #2)	30%	7.08E-04 g/s	
Mercury (removed by ESP)	60%	9.91E-04 g/s	
Mercury to Brine (sum of removal by wet APCS)		1.41E-02 g/s	
Brine flow (blowdown from APCS)		2,428 lb/hr	
		306 g/s	
Mercury content of brine		46 ppm	
Emission of Mercury from Evaporator			
Mercury retained in evaporator solids	95%	1.34E-02 g/s	
Mercury exiting evaporator		7.04E-04 g/s	
Mercury removal by carbon adsorber	98%	6.90E-04 g/s	
Mercury emission from evaporator			**1.41E-05 g/s**
Emission of Mercury from Incinerator			
Mercury emissions leaving wet APCS		6.60E-04 g/s	
Mercury removal by carbon adsorber #1	98%	6.47E-04 g/s	
Mercury removal by carbon adsorber #2	95%	1.25E-05 g/s	
Mercury emissions from incinerator			**6.60E-07 g/s**
Total Mercury Emissions			**1.47E-05 g/s**

Figure L-2. Calculations for Estimating the PCB Emissions from the AMWTF

Waste Stream Data from Table 5 of Appendix A & Appendix B,
"Waste Description Information for TRU Contaminated Waste Stored at the INEL", INEL-95/0412

	Waste Quantity		PCB Content	
Waste Stream	m3	kg	PCB (%)	PCB (kg)
ID-BCO-203	21	4,400	15%	660
ID-BCO-203T	6	2,500	15%	375
ID-RFO-003, RFETS 003	1,002	1,009,100	15%	151,365
ID-RFO-003T, RFETS 003	569	631,400	15%	94,710
Total	**1,598**	**1,647,400**		**247,110**

Processing Rate Information:

Facility Operation	12	years
Operating Time (70%)	6,132	hours / year
Total Time to Process Waste	73,584	hours
PCB Processing Rate	3.36	kg/hr
	0.93	g/s

Average Brine Flow Rate Calculations:

		Mass	Blowdown	
Feed	Total Mass (kg)	(%)	(lb/hr)	(gpm)
IHS	12,842,705	81%	515	1.05
OHS	2,730,192	17%	5,558	11.50
Soil	339,539	2%	915	1.86
Total	15,912,436	100%		
Average Blowdown			1,389	2.86
Permit Limit			2,428	5.00

Destruction and Removal of PCBs:

Destruction in PCC & SCC			99.999 869%
(Minimum DRE that results in 3 ppb in brine)			
PCBs (to wet APCS)			1.22E-06 g/s
PCBs (removed by Quench)	10%	1.22E-07 g/s	
PCBs (removed by Venturi)	48%	5.22E-07 g/s	
PCBs (removed by ESP)	48%	2.74E-07 g/s	
(Wet APCS removal efficiency (typical for particulate - maximum transfer of PCB to brine)			
PCB (to Brine)		9.18E-07 g/s	
Brine flow (blowdown from APCS)		2,428 lb/hr	
		306 g/s	
PCB content of brine		3.00 ppb	

Emission of PCBs from Evaporator

PCBs retained in evaporator solids	0%	0.00E+00 g/s	
PCB evaporator emissions		9.18E-07 g/s	

Emission of PCBs from Incinerator & Evaporator

PCB (incinerator emissions prior to HEPA / Carbon Bed)		3.03E-07 g/s
PCB (evaporator emissions prior to HEPA / Carbon Bed)		9.18E-07 g/s
PCB Incin. Emissions w/ Carbon Bed RE	**95.00%**	**1.52E-08 g/s**
PCB Evap. Emissions w/ Carbon Bed RE	**95.00%**	**4.59E-08 g/s**
PCB Total Emissions w/ Carbon Bed RE	**95.00%**	**6.11E-08 g/s**
Total PCB DRE		**99.999 993% (7+ 9's)**

Figure L-3. Calculations for Estimating the Dioxin / Furan Emissions from the AMWTF - Based on Meeting the Proposed MACT Standard

Emissions Estimation:

Based on back calculating the concentrations in the APCS & incinerator from an estimate of the stack emission. For PCDD / PCDF the stack emission is based on the proposed MACT standard.

Stack Flow				
Total offgas flow (wet)	836.0	scfm		
Water content of stack gas	8.7	moles water		
Total offgas flow rate	132.2	moles total	12.4	moles O2
Dry gas fraction	0.93	dry fraction	9.4%	% O2
Total offgas flow (dry)	781.2	dscfm		
Oxygen correction factor	0.83	(21 - % O2) / (21 - 14)		
Conversion factor	0.02831	m3 / ft3		
Total offgas flow	18.3	dry m3/min		
	0.3	dry m3/s		
Concentration of PCDD / PCDF at Stack			0.20	ng / dscm
(Based on meeting proposed MACT standard)				
PCDD / PCDF emissions at stack			0.0611	ng/s
			6.11E-11	g/s
Removal by Carbon Bed	95.00%	1.16E-09 g/s		
Removal by HEPA	0.00%	0.00E+00 g/s		
Emissions prior to HEPA			1.22E-09	g/s
(Wet APCS removal efficiency (typical for particulate - transfer of PCDD/PCDF to brine)				
PCDD/PCDFs (removed by ESP)	48%	1.10E-09 g/s		
PCDD/PCDFs (removed by Venturi)	48%	2.10E-09 g/s		
PCDD/PCDFs (removed by Quench)	10%	4.92E-10 g/s		
PCDD/PCDF (to Brine)		2.60E-09 g/s		
Brine flow (blowdown from APCS)		2,428 lb/hr		
		306 g/s		
PCDD/PCDF content of brine		0.008 ppb		
Emission of PCDD/PCDFs from Evaporator				
PCDD/PCDFs retained in solids	50%	1.30E-09 g/s		
PCDD/PCDF evaporator emissions	-		1.30E-09	g/s
Emission of PCDD/PCDFs from Incinerator & Evaporator				
PCDD/PCDF (incinerator emissions prior to HEPA / Carbon Bed)			1.22E-09	g/s
PCDD/PCDF (evaporator emissions prior to HEPA / Carbon Bed)			1.30E-09	g/s
PCDD/PCDF Incin. Emissions w/ carbon bed RE of -		**95.00%**	**6.11E-11**	**g/s**
PCDD/PCDF Evap. Emissions w/ carbon bed RE of -		**95.00%**	**6.49E-11**	**g/s**
PCDD/PCDF Total Emissions w/ carbon bed RE of -		**95.00%**	**1.26E-10**	**g/s**

Figure L-4. Calculations for Estimating the Semivolatile Organic Compound Emissions from the AMWTF - Based on Estimated Detection Limits

Emissions Estimation:

Based on back calculating the concentrations in the APCS & incinerator from an estimate of the stack emission. For semivolatile COPCs the stack emission is based on a unit emission rate.

Stack Flow				
Total offgas flow (wet)	836.0	scfm		
Water content of stack gas	8.7	moles water		
Total offgas flow rate	132.2	moles total		
Dry gas fraction	0.93	dry fraction		
Total offgas flow (dry)	781.2	dscfm		
Conversion factor	0.02831	m3 / ft3		
Total offgas flow	22.12	dry m3/min		
	0.3687	dry m3/s		
Concentration of Semi-vols at Stack			5.00	ug / dscm
(Based on meeting proposed MACT standard)				
Semi-vols emissions at stack			1.8433	ug/s
			1.84E-06	g/s
Removal by Carbon Bed	95.00%	3.50E-05 g/s		
Removal by HEPA	0.00%	0.00E+00 g/s		
Emissions prior to HEPA			3.69E-05	g/s
(Wet APCS removal efficiency (typical for particulate - transfer of Semi-vols to brine)				
Semi-vols (removed by ESP)	48%	3.34E-05 g/s		
Semi-vols (removed by Venturi)	48%	6.35E-05 g/s		
Semi-vols (removed by Quench)	10%	1.49E-05 g/s		
Semi-vols (to Brine)		7.84E-05 g/s		
Brine flow (blowdown from APCS)		2,428 lb/hr		
		306 g/s		
Semi-vols content of brine		0.256 ppm		
Emission of Semi-vols from Evaporator				
Semi-volss retained in solids	50%	3.92E-05 g/s		
Semi-vols evaporator emissions			3.92E-05	g/s
Emission of Semi-vols from Incinerator & Evaporator				
Semi-vols (incinerator emissions prior to HEPA / Carbon Bed)			3.69E-05	g/s
Semi-vols (evaporator emissions prior to HEPA / Carbon Bed)			3.92E-05	g/s
Semi-vols Incin. Emissions w/ carbon bed RE of -		**95.00%**	**1.84E-06**	**g/s**
Semi-vols Evap. Emissions w/ carbon bed RE of -		**95.00%**	**1.96E-06**	**g/s**
Semi-vols Total Emissions w/ carbon bed RE of -		**95.00%**	**3.80E-06**	**g/s**

Table L-1. Worst-Case Estimated COPC Concentrations in AMWTF Waste

COPC	IHS wt%	OHS wt%	S wt%	Worst-Case Non-Debris wt%	CBD wt%	G wt%	HD wt%	ID wt%	MD wt%	OD wt%	PRPR wt%	Worst-Case Debris wt%
Volatiles												
Acetone	0.01	1		1			1	1	1		1	1
Benzene	1			1		1	1	1	1		1	1
Butanol, n-	0.001	0.001	0.001	0.001			1					1
2-Butanone (Methyl ethyl ketone)	1			1			1			1	1	1
Carbon tetrachloride	0.075	5	0.07	5		1	1	1	0.001	1	1	1
Chlorobenzene	1			1								0
Chloroform	1	1		1		1	1	1	1		1	1
1,2-Dichoroethane	1			1							1	1
Dichloroethylene				0					1			1
cis-1,2-Dichoroethylene				0							1	1
1,1-Dichoroethylene	1	1		1			1	1	1	1	1	1
2-Ethoxyethanol	1			1								0
Ethyl benzene	1			1			1		1		1	1
Ethyl ether				0			1					1
Isopropanol				0						1		1
Methane				0					1		1	1
Methanol	0.003	0.001	0.001	0.003		1	1		1		1	1
Methylene chloride	0.07	0.005	0.005	0.07	1	1	1	1	0.02	0.1	1	1
1,1,2,2-Tetrachloroethane				0							1	1
Tetrachloroethylene	1	1	1	1		1	1	1			1	1
Toluene	1	1		1	1	1	1	1	1	1	1	1
1,1,1-Trichloroethane	0.2	15	0.02	15	1	1	1	1	0.008	1	1	1
1,1,2-Trichloroethane	1			1								0
Trichlorethylene	0.01	1	1	1	0.1		1	1	1	1	1	1
1,1,2-Trichloro-1,2,2-trifluoroethane	0.01	5	0.01	5		1	1	1	1	0.15	1	1
Xylene	0.005	0.001	0.001	0.005	1		1	1	1	1	1	1

Table L-1. Worst-Case Estimated COPC Concentrations in AMWTF Waste (continued)

COPC	IHS wt%	OHS wt%	S wt%	Worst-Case Non-Debris wt%	CBD wt%	G wt%	HD wt%	ID wt%	MD wt%	OD wt%	PRPR wt%	Worst-Case Debris wt%
Semivolatiles												
Cyclohexane	1			1					1		1	1
Nitrobenzene	1	1	1	1			1					1
1,2,4-Trimethylbenzene				0							1	1
1,3,5-Trimethylbenzene				0							1	1
Polychlorinated biphenyls (PCBs)		15		15			1					1
Metals												
Arsenic	1	1		1	1		1	1	1		1	1
Barium	1	1		1	1		1	1	1	1	1	1
Beryllium	1	1		1					1			1
Cadmium	0.001	0.001	1	1	1		1	1	1		1	1
Chromium	1	1	1	1	1		1	1	1		1	1
Cobalt												0
Copper				0								0
Iron				0								0
Lead	0.001	0.001	1	1	1		10	5	5	25	56	56
Manganese				0								0
Mercury	2.5	1	0.03	2.5	1	1	1	1	1	1	1	1
Nickel	1	1		1								0
Selenium	1	1	1	1	1		1	1	1		1	1
Silver	1	1	1	1	1		1	1	1		1	1
Strontium				0								0
Thallium				0								0
Thorium				0								0
Uranium				0								0
Vanadium				0								0
Zinc				0								0
Zirconium				0								0
Other COPCs												
Asbestos				0				45				45
Cyanide	1			1								0

Table L-2. Total VOCs from Nonthermal Sources

Process Area	Notes	Process Rate	Waste Type	Waste Density	Waste Throughput	Liquid Throughput	Emission Factor	"VOC" Emissions
			a		b	c	d	e
	f	dm/dy		lb/dm	ton/hr	ton/hr	lb/ton	lb/hr
Drum Line	g	32	ND	469	0.312	0.12	0.72	9.00E-02
Box Lines	h	61	D	292	0.371	-	-	0.00E+00
Drum Staging Areas	i		ND		0.400	0.16	0.02	3.20E-03
CCS	j		ND		0.712	0.28	0.02	5.70E-03
SC/ME Glovebox	k	96	D	292	0.584	-	-	0.00E+00
SCW Glovebox System	l		ND		0.003	0.00	0.72	8.64E-04
Analytical Lab Gloveboxes	l		ND		0.003	0.00	0.72	8.64E-04
Sample Extraction Glovebox	l		ND		0.003	0.00	0.72	8.64E-04
Macroencapsulation Grout Preparation	m	24	NA	1998	0.999	-	-	0.00E+00
Microencapsulation Grout Preparation	m	14	NA	1446	0.422	-	-	0.00E+00
Microencapsulation Glovebox System	n		ND		0.420	-	-	0.00E+00

a. Waste types: ND=Non-debris (OHS, IIIS, S); D=Debris (CBD, G, HD, ID, MD, OD, PRPR); NA=Not applicable (no regulated waste).
b. For processes with process rates given in drums per day, Waste Throughput (ton/hr) = Process Rate (dm/dy) x Waste Density (lb/dm) / (2000 lb/ton x 24 hr/day).
c. The concentration of liquid in the stabilized waste stream is assumed to be 40% of the total waste; therefore, Liquid Throughput = 0.40 x Waste Throughput.
d. Emission factors are from AP-42, Table 4.7-1, Emission Factors for Solvent Reclaiming. Processes handling (disturbing) waste use 0.72 lb VOCs emitted per ton of solvent (liquid). Areas where waste is not disturbed use 0.02 lb/ton (factor for a solvent storage tank vent). Also, liquid is not all VOCs (mostly oil).
e. Total "VOCs" Emitted (lb/hr) = Liquid Throughput (ton/hr) x Emission Factor (lb/ton). "VOCs" = Industrial lubricant (oil) contaminated with VOCs.
f. Unit appreviations: dm=drum; dy=day; lb=pound; hr=hour; RE=removal efficiency.
g. The waste density is the maximum average non-debris density (OHS).
h. No VOC emissions are expected from the box lines.
i. The waste throughput for the drum staging areas is the feed rate of the incinerator, since these areas primarily stage non-debris wastes awaiting incineration.
j. The waste throughput of the CCS is the sum of the drum line (transfer from drum line to drum staging) and incinerator (transfer from drum staging to incinerator).
k. No VOC emissions are expected from the supercompaction/macroencapsulation glovebox.
l. The worst-case VOC emissions in these areas are from samples cored from non-debris sludges processed in the drum line. The samples are assumed to be 2 in. in diameter by 33 in. long (height of a 55-gal drum).
m. No VOC emissions are expected from the grout preparation areas, since no regulated VOCs are present in the constituents that make up the grout.
n. No VOC emissions are expected from the microencapsulation glovebox system, since they were destroyed in the incinerator.

Table L-3. Total PM from Nonthermal Sources

Process Area	Notes	Process Rate	Waste Type	Waste Density	Waste Throughput	Emission Factor	Baghouse Filter	HEPA Filter #1	HEPA Filter #2	HEPA Filter #3	Total PM Emitted
			a		b			c	c	c	d
	e	dm/dy		lb/dm	ton/hr	PM emitted	PM RE	PM RE	PM RE	PM RE	lb/hr
Drum Line	f,g	32	ND	469	0.31	5%	85%	99.9%	99.9%	99.9%	4.7E-09
Box Lines	h,i	61	D	292	0.37	5%	85%	99.9%	99.9%	99.9%	5.6E-09
Drum Staging Areas	j		ND		0.4	0	0	99.9%	99.9%	99.9%	0.0E+00
CCS	j		ND		0.71	0	0	99.9%	99.9%	99.9%	0.0E+00
SC/ME Glovebox	k,l	96	D	292	0.58	1%	0	99.9%	99.9%	99.9%	1.2E-08
SCW Glovebox System	f,m		ND		0.003	5%	0	99.9%	99.9%	99.9%	3.0E-10
Analytical Lab Gloveboxes	m		ND		0.003	0	0	99.9%	99.9%	99.9%	0.0E+00
Sample Extraction Glovebox	n		ND		0.003	0	0	99.9%	99.9%	99.9%	0.0E+00
Macroencapsulation Grout Preparation	o,p,q	24	NA	1998	1.0	0.1	95%	0	0	0	5.0E-03
Microencapsulation Grout Preparation	o,p,q	14	NA	1446	0.42	0.1	95%	0	0	0	2.1E-03
Microencapsulation Glovebox System	o,p	14	ND	1446	0.42	0.1	0	99.9%	99.9%	99.9%	4.2E-11

a. Waste types: ND=Non-debris (OHS, IHS, S); D=Debris (CBD, G, HD, ID, MD, OD, PRPR); NA=Not applicable (no regulated waste).

b. For processes with process rates given in drums per day, Waste Throughput (ton/hr) = Process Rate (dm/dy) x Waste Density (lb/dm) / (2000 lb/ton x 24 hr/day).

c. The HEPA filters in the AMWTF are rated at a minimum RE of 99.97% for 0.15 to 0.3 micron particles with increasing efficiency for larger and smaller particles. This calculation assumes a conservative overall RE of 99.9% per HEPA filter.

d. Total PM Emitted (lb/hr) = Waste Throughput (ton/hr) x Emission Factor (lb/ton) x [1 - (PM RE1 (%) / 100)] x [1 - (PM RE2 (%) / 100)] x [1 - (PM RE3 (%) / 100)] x [1 - (PM RE4 (%) / 100)].

e. Unit appreviations: dm=drum; dy=day; lb=pound; hr=hour; RE=removal efficiency

f. The waste density is the maximum average non-debris density (OHS).

g. Worst-case PM emissions are assumed to be generated by sample coring at a very conservative assumption of 5%. The PM emission factor of 5% (100 lb/ton) is 1,000 times greater than the emission factor for concrete batching (0.1 lb/ton), which is a much dustier operation than sample core drilling. A local reverse-jet (baghouse-type) filter abates the PM generated during this process.

h. The process rate of 4 boxes/day is equivalent to 61 55-gal drums/day (4x4x7 ft). The waste density is the maximum average debris density (CBD).

i. Worst-case PM emissions are assumed to be generated by box sorting/sizing at a very conservative assumption of 5%. The PM emission factor of 5% (100 lb/ton) is 1,000 times greater than the emission factor for concrete batching (0.1 lb/ton), which is a much dustier operation than box sorting/sizing. A local reverse-jet (baghouse-type) filter abates the PM generated during this process.

j. Waste handled in the drum staging and CCS areas is primarily bound in sludge and, because it is not significantly mechanically disturbed, no PM is assumed to be emitted.

k. The waste density is the maximum average debris density (CBD).

l. Worst-case PM emissions are assumed to be generated by the supercompaction process at a very conservative assumption of 1%. The PM emission factor of 1% (20 lb/ton) is 200 times greater than the emission factor for concrete batching (0.1 lb/ton), which is a much dustier operation than supercompaction.

m. Worst-case PM emissions are assumed to be generated by preparing core samples for the analytical laboratory. The PM emission factor of 5% (100 lb/ton) is 1,000 times greater than the emission factor for concrete batching (0.1 lb/ton), which is a much dustier operation than core sample handling. The samples are assumed to be 2 in. in diameter by 33 in. long (height of a 55-gal drum) at 32 samples per day.

n. No PM is expected to be emitted from the sample extraction glovebox because the samples are only being transferred and bagged, not disturbed mechanically.

o. The waste density specified for the grout preparation and microencapsulation areas is based on the density of Portland cement (76 gal grout per drum for macroencapsulation and 55 gal grout perdrum for microencapsulation).

p. The emission factor is in lb PM emitted/ton processed from AP-42, Table 11.12-2, Emission Factors for Concrete Batching. The factor is listed for "total process emissions" from a truck mix concrete process, which is similar to the grout preparation and microencapsulation processes. For each process, PM is generated when cement (and other material) is stored, conveyed, measured, and/or mixed. The grout preparation processes prepare grout from cement and other materials for use in the micro- and macroencapsulation processes. In the microencapsulation process, grout is mixed with fly ash or brine salt.

q. The grout preparation processes have baghouse-type filter systems on the exhaust to the outside air.

Table L-4. Individual VOC & Semivolatile Emissions from Nonthermal Sources

COPC		Worst-Case Non Debris	Worst-Case Debris	Drum Line	Box Lines	Drum Staging Areas	CCS	SC/ME Glovebox	SCW Glovebox System	Analytical Laboratory Gloveboxes	Sample Extraction Glovebox
	Notes			*a*	*b*	*a*	*a*	*b*	*a*	*a*	*a*
		wt%	wt%	lb/hr	lb/hr	lb/hr	lb/hr	lb/hr	lb/hr	lb/hr	lb/hr
"VOC" Emissions	*e*			9.0E-02	0.0E+00	3.2E-03	5.7E-03	0.0E+00	8.6E-04	8.6E-04	8.6E-04
Volatiles											
Acetone		1	1	9.0E-04	0.0E+00	3.2E-05	5.7E-05	0.0E+00	8.6E-06	8.6E-06	8.6E-06
Benzene		1	1	9.0E-04	0.0E+00	3.2E-05	5.7E-05	0.0E+00	8.6E-06	8.6E-06	8.6E-06
Butyl alcohol		0.001	1	9.0E-07	0.0E+00	3.2E-08	5.7E-08	0.0E+00	8.6E-09	8.6E-09	8.6E-09
Carbon tetrachloride		5	1	4.5E-03	0.0E+00	1.6E-04	2.8E-04	0.0E+00	4.3E-05	4.3E-05	4.3E-05
Chlorobenzene		1	0	9.0E-04	0.0E+00	3.2E-05	5.7E-05	0.0E+00	8.6E-06	8.6E-06	8.6E-06
Chloroform		1	1	9.0E-04	0.0E+00	3.2E-05	5.7E-05	0.0E+00	8.6E-06	8.6E-06	8.6E-06
1,2-Dichoroethane		1	1	9.0E-04	0.0E+00	3.2E-05	5.7E-05	0.0E+00	8.6E-06	8.6E-06	8.6E-06
Dichloroethene	*h*	1	1	9.0E-04	0.0E+00	3.2E-05	5.7E-05	0.0E+00	8.6E-06	8.6E-06	8.6E-06
cis-1,2-Dichoroethene	*h*	1	1	9.0E-04	0.0E+00	3.2E-05	5.7E-05	0.0E+00	8.6E-06	8.6E-06	8.6E-06
1,1-Dichoroethylene		1	1	9.0E-04	0.0E+00	3.2E-05	5.7E-05	0.0E+00	8.6E-06	8.6E-06	8.6E-06
2-Ethoxyethanol		1	0	9.0E-04	0.0E+00	3.2E-05	5.7E-05	0.0E+00	8.6E-06	8.6E-06	8.6E-06
Ethyl benzene		1	1	9.0E-04	0.0E+00	3.2E-05	5.7E-05	0.0E+00	8.6E-06	8.6E-06	8.6E-06
Ethyl ether	*h*	1	1	9.0E-04	0.0E+00	3.2E-05	5.7E-05	0.0E+00	8.6E-06	8.6E-06	8.6E-06
Isopropanol	*h*	1	1	9.0E-04	0.0E+00	3.2E-05	5.7E-05	0.0E+00	8.6E-06	8.6E-06	8.6E-06
Methane	*h*	1	1	9.0E-04	0.0E+00	3.2E-05	5.7E-05	0.0E+00	8.6E-06	8.6E-06	8.6E-06
Methanol		0.003	1	2.7E-06	0.0E+00	9.6E-08	1.7E-07	0.0E+00	2.6E-08	2.6E-08	2.6E-08
Methyl ethyl ketone		1	1	9.0E-04	0.0E+00	3.2E-05	5.7E-05	0.0E+00	8.6E-06	8.6E-06	8.6E-06
Methylene chloride		0.07	1	6.3E-05	0.0E+00	2.2E-06	4.0E-06	0.0E+00	6.0E-07	6.0E-07	6.0E-07
Nitrobenzene		1	1	9.0E-04	0.0E+00	3.2E-05	5.7E-05	0.0E+00	8.6E-06	8.6E-06	8.6E-06
1,1,2,2-Tetrachlorothane	*h*	1	1	9.0E-04	0.0E+00	3.2E-05	5.7E-05	0.0E+00	8.6E-06	8.6E-06	8.6E-06
Tetrachlorothylene		1	1	9.0E-04	0.0E+00	3.2E-05	5.7E-05	0.0E+00	8.6E-06	8.6E-06	8.6E-06
Toluene		1	1	9.0E-04	0.0E+00	3.2E-05	5.7E-05	0.0E+00	8.6E-06	8.6E-06	8.6E-06
1,1,1-Trichloroethane		15	1	1.3E-02	0.0E+00	4.8E-04	8.5E-04	0.0E+00	1.3E-04	1.3E-04	1.3E-04
1,1,2-Trichloroethane		1	0	9.0E-04	0.0E+00	3.2E-05	5.7E-05	0.0E+00	8.6E-06	8.6E-06	8.6E-06
Trichlorethylene		1	1	9.0E-04	0.0E+00	3.2E-05	5.7E-05	0.0E+00	8.6E-06	8.6E-06	8.6E-06
1,1,2-Trichloro-1,2,2-trifluoroethane		5	1	4.5E-03	0.0E+00	1.6E-04	2.8E-04	0.0E+00	4.3E-05	4.3E-05	4.3E-05
Xylene		0.005	1	4.5E-06	0.0E+00	1.6E-07	2.8E-07	0.0E+00	4.3E-08	4.3E-08	4.3E-08
Semivolatiles											
Cyclohexane		2.5	1	2.2E-03	0.0E+00	8.0E-05	1.4E-04	0.0E+00	2.2E-05	2.2E-05	2.2E-05
1,2,4-Trimethylbenzene	*h*	1	1	9.0E-04	0.0E+00	3.2E-05	5.7E-05	0.0E+00	8.6E-06	8.6E-06	8.6E-06
1,3,6-Trimethylbenzene	*h*	1	1	9.0E-04	0.0E+00	3.2E-05	5.7E-05	0.0E+00	8.6E-06	8.6E-06	8.6E-06
Mercury		2.5	1	2.2E-03	0.0E+00	8.0E-05	1.4E-04	0.0E+00	2.2E-05	2.2E-05	2.2E-05

a. Emission Rate (lb/hr) = Worst-Case Non-Debris Concentration (wt%/100) x Total VOCs (lb/hr).
b. Emission Rate (lb/hr) = Worst-Case Debris Concentration (wt%/100) x Total VOCs (lb/hr).
c. The grout preparation areas do not handle HWMA- or TSCA-regulated waste; estimates are for total PM only.
d. Estimates for cyanide emissions are extremely conservative, since this compound will have been destroyed in the incinerator.
e. See Table L-2 for calculations of total VOCs.
f. See Table L-3 for calculations of total PM.
g. The worst-case debris concentration for lead is adjusted from the maximum expected concentration of 56% to a very conservative 25%. The lead in the debris waste is primarily in the form of lead shielding bricks, which are not size-reduced; therefore, little PM is generated during handling.
h. These COPCs have been assigned a composition of 1% in the non-debris waste code to allow calculation of emissions.

Table L-4. Individual VOC & Semivolatile Emissions from Nonthermal Sources (cont.)

COPC		Macroen-capsulation Grout Preparation	Microen-capsulation Grout Preparation	Microen-capsulation Glovebox	Carbon Adsorption Unit #1	Total Nonthermal Emissions
	Notes	*c*	*c*	*a,d*		
		lb/hr	lb/hr	lb/hr	RE	lb/hr
"VOC" Emissions	*e*	0.0E+00	0.0E+00	0.0E+00		
Volatiles						
Acetone		0.0E+00	0.0E+00	0.0E+00	95%	5.1E-05
Benzene		0.0E+00	0.0E+00	0.0E+00	95%	5.1E-05
Butyl alcohol		0.0E+00	0.0E+00	0.0E+00	95%	5.1E-08
Carbon tetrachloride		0.0E+00	0.0E+00	0.0E+00	95%	2.5E-04
Chlorobenzene		0.0E+00	0.0E+00	0.0E+00	95%	5.1E-05
Chloroform		0.0E+00	0.0E+00	0.0E+00	95%	5.1E-05
1,2-Dichloroethane		0.0E+00	0.0E+00	0.0E+00	95%	5.1E-05
Dichloroethene		0.0E+00	0.0E+00	0.0E+00	95%	5.1E-05
cis-1,2-Dichloroethene		0.0E+00	0.0E+00	0.0E+00	95%	5.1E-05
1,1-Dichloroethylene		0.0E+00	0.0E+00	0.0E+00	95%	5.1E-05
2-Ethoxyethanol		0.0E+00	0.0E+00	0.0E+00	95%	5.1E-05
Ethyl benzene		0.0E+00	0.0E+00	0.0E+00	95%	5.1E-05
Ethyl ether		0.0E+00	0.0E+00	0.0E+00	95%	5.1E-05
Isopropanol		0.0E+00	0.0E+00	0.0E+00	95%	5.1E-05
Methane		0.0E+00	0.0E+00	0.0E+00	95%	5.1E-05
Methanol		0.0E+00	0.0E+00	0.0E+00	95%	1.5E-07
Methyl ethyl ketone		0.0E+00	0.0E+00	0.0E+00	95%	5.1E-05
Methylene chloride		0.0E+00	0.0E+00	0.0E+00	95%	3.6E-06
Nitrobenzene		0.0E+00	0.0E+00	0.0E+00	95%	5.1E-05
1,1,2,2-Tetrachlorothane		0.0E+00	0.0E+00	0.0E+00	95%	5.1E-05
Tetrachlorothylene		0.0E+00	0.0E+00	0.0E+00	95%	5.1E-05
Toluene		0.0E+00	0.0E+00	0.0E+00	95%	5.1E-05
1,1,1-Trichloroethane		0.0E+00	0.0E+00	0.0E+00	95%	7.6E-04
1,1,2-Trichloroethane		0.0E+00	0.0E+00	0.0E+00	95%	5.1E-05
Trichlorethylene		0.0E+00	0.0E+00	0.0E+00	95%	5.1E-05
1,1,2-Trichloro-1,2,2-trifluoroethane		0.0E+00	0.0E+00	0.0E+00	95%	2.5E-04
Xylene		0.0E+00	0.0E+00	0.0E+00	95%	2.5E-07
Semivolatiles						
Cyclohexane		0.0E+00	0.0E+00	0.0E+00	95%	1.3E-04
1,2,4-Trimethylbenzene		0.0E+00	0.0E+00	0.0E+00	95%	5.1E-05
1,3,6-Trimethylbenzene		0.0E+00	0.0E+00	0.0E+00	95%	5.1E-05
Mercury		0.0E+00	0.0E+00	0.0E+00	95%	1.3E-04

a. Emission Rate (lb/hr) = Worst-Case Non-Debris Concentration (wt%/100) x Total VOCs (lb/hr).
b. Emission Rate (lb/hr) = Worst-Case Debris Concentration (wt%/100) x Total VOCs (lb/hr).
c. The grout preparation areas do not handle HWMA- or TSCA-regulated waste; estimates are for total PM only
d. Estimates for cyanide emissions are extremely conservative, since this compound will have been destroyed in the incinerator.
e. See Table L-2 for calculations of total VOCs.
f. See Table L-3 for calculations of total PM.
g. The worst-case debris concentration for lead is adjusted from the maximum expected concentration of 56% to a very conservative 25%. The lead in the debris waste is primarily in the form of lead shielding bricks, which are not size-reduced; therefore, little PM is generated during handling.
h. These COPCs have been assigned a composition of 1% in the non-debris waste code to allow calculation of emissions.

Table L-5. Individual Metals & Particulate Emissions from Nonthermal Sources

COPC		Worst-Case Non Debris	Worst-Case Debris	Drum Line	Box Lines	Drum Staging Areas	CCS	SC/ME Glovebox	SCW Glovebox System	Analytical Laboratory Gloveboxes	Sample Extraction Glovebox
	Notes			*a*	*b*	*a*	*a*	*b*	*a*	*a*	*a*
		wt%	wt%	lb/hr	lb/hr	lb/hr	lb/hr	lb/hr	lb/hr	lb/hr	lb/hr
Total PM	*f*	NA	NA	4.7E-09	5.6E-09	0.0E+00	0.0E+00	1.2E-08	3.0E-10	0.0E+00	0.0E+00
Metals											
Antimony		1	1	4.7E-11	5.6E-11	0.0E+00	0.0E+00	1.2E-10	3.0E-12	0.0E+00	0.0E+00
Arsenic		1	1	4.7E-11	5.6E-11	0.0E+00	0.0E+00	1.2E-10	3.0E-12	0.0E+00	0.0E+00
Barium		1	1	4.7E-11	5.6E-11	0.0E+00	0.0E+00	1.2E-10	3.0E-12	0.0E+00	0.0E+00
Beryllium		1	1	4.7E-11	5.6E-11	0.0E+00	0.0E+00	1.2E-10	3.0E-12	0.0E+00	0.0E+00
Cadmium		1	1	4.7E-11	5.6E-11	0.0E+00	0.0E+00	1.2E-10	3.0E-12	0.0E+00	0.0E+00
Chromium		1	1	4.7E-11	5.6E-11	0.0E+00	0.0E+00	1.2E-10	3.0E-12	0.0E+00	0.0E+00
Cobalt		1	1	4.7E-11	5.6E-11	0.0E+00	0.0E+00	1.2E-10	3.0E-12	0.0E+00	0.0E+00
Copper		1	1	4.7E-11	5.6E-11	0.0E+00	0.0E+00	1.2E-10	3.0E-12	0.0E+00	0.0E+00
Iron		5	5	2.3E-10	2.8E-10	0.0E+00	0.0E+00	5.8E-10	1.5E-11	0.0E+00	0.0E+00
Lead	*g*	1	25	4.7E-11	1.4E-09	0.0E+00	0.0E+00	2.9E-09	3.0E-12	0.0E+00	0.0E+00
Manganese		1	0	4.7E-11	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.0E-12	0.0E+00	0.0E+00
Nickel		1	0	4.7E-11	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.0E-12	0.0E+00	0.0E+00
Selenium		1	1	4.7E-11	5.6E-11	0.0E+00	0.0E+00	1.2E-10	3.0E-12	0.0E+00	0.0E+00
Silver		1	1	4.7E-11	5.6E-11	0.0E+00	0.0E+00	1.2E-10	3.0E-12	0.0E+00	0.0E+00
Strontium		1	1	4.7E-11	5.6E-11	0.0E+00	0.0E+00	1.2E-10	3.0E-12	0.0E+00	0.0E+00
Thallium		1	1	4.7E-11	5.6E-11	0.0E+00	0.0E+00	1.2E-10	3.0E-12	0.0E+00	0.0E+00
Vanadium		1	1	4.7E-11	5.6E-11	0.0E+00	0.0E+00	1.2E-10	3.0E-12	0.0E+00	0.0E+00
Zinc		1	1	4.7E-11	5.6E-11	0.0E+00	0.0E+00	1.2E-10	3.0E-12	0.0E+00	0.0E+00
Other COPCs											
Asbestos		0	45	0.0E+00	2.5E-09	0.0E+00	0.0E+00	5.3E-09	0.0E+00	0.0E+00	0.0E+00
Cyanide		1	0	4.7E-11	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.0E-12	0.0E+00	0.0E+00

a. Emission Rate (lb/hr) = Worst-Case Non-Debris Concentration (wt%/100) x Total PM (lb/hr).
b. Emission Rate (lb/hr) = Worst-Case Debris Concentration (wt%/100) x Total PM (lb/hr).
c. The grout preparation areas do not handle HWMA- or TSCA-regulated waste; estimates are for total PM only.
d. Estimates for cyanide emissions are extremely conservative, since this compound will have been destroyed in the incinerator.
e. See Table L-2 for calculations of total VOCs.
f. See Table L-3 for calculations of total PM.
g. The worst-case debris concentration for lead is adjusted from the maximum expected concentration of 56% to a very conservative 25%. The lead in the debris waste is primarily in the form of lead shielding bricks, which are not size-reduced; therefore, little PM is generated during handling.
h. These COPCs have been assigned a composition of 1% in the non-debris waste code to allow calculation of emissions.

Table L-5. Individual Metals & Particulate Emissions from Nonthermal Sources (cont.)

COPC	Notes	Macroen-capsulation Grout Preparation	Microen-capsulation Grout Preparation	Microen-capsulation Glovebox	Carbon Adsorption Unit #1	Total Nonthermal Emissions
		c	c	a,d		
		lb/hr	lb/hr	lb/hr	RE	lb/hr
Total PM	f	5.0E-03	2.1E-03	4.2E-11	0%	7.1E-03
Metals						
Antimony		0.0E+00	0.0E+00	4.2E-13	0%	2.2E-10
Arsenic		0.0E+00	0.0E+00	4.2E-13	0%	2.2E-10
Barium		0.0E+00	0.0E+00	4.2E-13	0%	2.2E-10
Beryllium		0.0E+00	0.0E+00	4.2E-13	0%	2.2E-10
Cadmium		0.0E+00	0.0E+00	4.2E-13	0%	2.2E-10
Chromium		0.0E+00	0.0E+00	4.2E-13	0%	2.2E-10
Cobalt		0.0E+00	0.0E+00	4.2E-13	0%	2.2E-10
Copper		0.0E+00	0.0E+00	4.2E-13	0%	2.2E-10
Iron		0.0E+00	0.0E+00	2.1E-12	0%	1.1E-09
Lead	g	0.0E+00	0.0E+00	4.2E-13	0%	4.4E-09
Manganese		0.0E+00	0.0E+00	4.2E-13	0%	5.0E-11
Nickel		0.0E+00	0.0E+00	4.2E-13	0%	5.0E-11
Selenium		0.0E+00	0.0E+00	4.2E-13	0%	2.2E-10
Silver		0.0E+00	0.0E+00	4.2E-13	0%	2.2E-10
Strontium		0.0E+00	0.0E+00	4.2E-13	0%	2.2E-10
Thallium		0.0E+00	0.0E+00	4.2E-13	0%	2.2E-10
Vanadium		0.0E+00	0.0E+00	4.2E-13	0%	2.2E-10
Zinc		0.0E+00	0.0E+00	4.2E-13	0%	2.2E-10
Other COPCs						
Asbestos		0.0E+00	0.0E+00	0.0E+00	0%	7.8E-09
Cyanide		0.0E+00	0.0E+00	4.2E-13	0%	5.0E-11

a. Emission Rate (lb/hr) = Worst-Case Non-Debris Concentration (wt%/100) x Total PM (lb/hr).
b. Emission Rate (lb/hr) = Worst-Case Debris Concentration (wt%/100) x Total PM (lb/hr).
c. The grout preparation areas do not handle HWMA- or TSCA-regulated waste; estimates are for total PM only.
d. Estimates for cyanide emissions are extremely conservative, since this compound will have been destroyed in the incinerator.
e. See Table L-2 for calculations of total VOCs.
f. See Table L-3 for calculations of total PM.
g. The worst-case debris concentration for lead is adjusted from the maximum expected concentration of 56% to a very conservative 25%. The lead in the debris waste is primarily in the form of lead shielding bricks, which are not size-reduced; therefore, little PM is generated during handling.
h. These COPCs have been assigned a composition of 1% in the non-debris waste code to allow calculation of emissions.

Table L-6. Estimated Incinerator Emissions

COPC	Notes	Wt% in Feed	Feed Rate (lb/hr)	PCC/SCC DRE	Partitioning to Offgas	Quencher RE	Venturi Scrubber RE	Absorber #1 RE	Absorber #2 RE	Wet ESP RE	Total Wet RE	HEPA Filter #1 RE	Carbon Adsorber #1 RE	Carbon Adsorber #2 RE	2 Prefilters RE	HEPA Filter #2 RE	HEPA Filter #3 (SS/Hi-Temp.) RE	Incinerator Emission Rate (lb/hr)
		a	b	c	d	e	e	e	e	e		g	e,h	e,h	f	g	g	i
Volatiles																		
Acetone		1%	6.5	99.99%	NA	10%	10%	0%	0%	10%	27.1%	0%	0%	0%	0%	0%	0%	4.7E-04
Benzene		1%	6.5	99.99%	NA	10%	10%	0%	0%	10%	27.1%	0%	0%	0%	0%	0%	0%	4.7E-04
Butyl alcohol		0.001%	0.0065	99.99%	NA	10%	10%	0%	0%	10%	27.1%	0%	0%	0%	0%	0%	0%	4.7E-07
Carbon tetrachloride		5%	32.5	99.99%	NA	10%	10%	0%	0%	10%	27.1%	0%	0%	0%	0%	0%	0%	2.4E-03
Chlorobenzene		1%	6.5	99.99%	NA	10%	10%	0%	0%	10%	27.1%	0%	0%	0%	0%	0%	0%	4.7E-04
Chloroform		1%	6.5	99.99%	NA	10%	10%	0%	0%	10%	27.1%	0%	0%	0%	0%	0%	0%	4.7E-04
1,2-Dichloroethane		1%	6.5	99.99%	NA	10%	10%	0%	0%	10%	27.1%	0%	0%	0%	0%	0%	0%	4.7E-04
Dichloroethene		1%	6.5	99.99%	NA	10%	10%	0%	0%	10%	27.1%	0%	0%	0%	0%	0%	0%	4.7E-04
cis-1,2-Dichloroethene		1%	6.5	99.99%	NA	10%	10%	0%	0%	10%	27.1%	0%	0%	0%	0%	0%	0%	4.7E-04
1,1-Dichloroethene		1%	6.5	99.99%	NA	10%	10%	0%	0%	10%	27.1%	0%	0%	0%	0%	0%	0%	4.7E-04
2-Ethoxyethanol		1%	6.5	99.99%	NA	10%	10%	0%	0%	10%	27.1%	0%	0%	0%	0%	0%	0%	4.7E-04
Ethylbenzene		1%	6.5	99.99%	NA	10%	10%	0%	0%	10%	27.1%	0%	0%	0%	0%	0%	0%	4.7E-04
Ethyl ether		1%	6.5	99.99%	NA	10%	10%	0%	0%	10%	27.1%	0%	0%	0%	0%	0%	0%	4.7E-04
Isopropanol		1%	6.5	99.99%	NA	10%	10%	0%	0%	10%	27.1%	0%	0%	0%	0%	0%	0%	4.7E-04
Methane		1%	6.5	99.99%	NA	10%	10%	0%	0%	10%	27.1%	0%	0%	0%	0%	0%	0%	4.7E-04
Methanol		0.003%	0.020	99.99%	NA	10%	10%	0%	0%	10%	27.1%	0%	0%	0%	0%	0%	0%	1.4E-06
Methyl ethyl ketone		1%	6.5	99.99%	NA	10%	10%	0%	0%	10%	27.1%	0%	0%	0%	0%	0%	0%	4.7E-04
Methylene chloride		0.07%	0.46	99.99%	NA	10%	10%	0%	0%	10%	27.1%	0%	0%	0%	0%	0%	0%	3.3E-05
Nitrobenzene		1%	6.5	99.99%	NA	10%	10%	0%	0%	10%	27.1%	0%	0%	0%	0%	0%	0%	4.7E-04
1,1,2,2-Tetrachlorothane		1%	6.5	99.99%	NA	10%	10%	0%	0%	10%	27.1%	0%	0%	0%	0%	0%	0%	4.7E-04
Tetrachloroethene		1%	6.5	99.99%	NA	10%	10%	0%	0%	10%	27.1%	0%	0%	0%	0%	0%	0%	4.7E-04
Toluene		1%	6.5	99.99%	NA	10%	10%	0%	0%	10%	27.1%	0%	0%	0%	0%	0%	0%	4.7E-04
1,1,1-Trichloroethane		15%	97.5	99.99%	NA	10%	10%	0%	0%	10%	27.1%	0%	0%	0%	0%	0%	0%	7.1E-03
1,1,2-Trichloroethane		1%	6.5	99.99%	NA	10%	10%	0%	0%	10%	27.1%	0%	0%	0%	0%	0%	0%	4.7E-04
Trichloroethene		1%	6.5	99.99%	NA	10%	10%	0%	0%	10%	27.1%	0%	0%	0%	0%	0%	0%	4.7E-04
1,1,2-Trichloro-1,2,2-trifluoroethane		5%	32.5	99.99%	NA	10%	10%	0%	0%	10%	27.1%	0%	0%	0%	0%	0%	0%	2.4E-03
Xylene		0.005%	0.033	99.99%	NA	10%	10%	0%	0%	10%	27.1%	0%	0%	0%	0%	0%	0%	2.4E-06
Semivolatiles																		
Cyclohexane		1%	6.5	99.99%	NA	10%	48%	0%	0%	48%	75.2%	0%	0%	0%	0%	0%	0%	1.6E-04
1,2,4-Trimethylbenzene		1%	6.5	99.99%	NA	10%	48%	0%	0%	48%	75.2%	0%	0%	0%	0%	0%	0%	1.6E-04
1,3,6-Trimethylbenzene		1%	6.5	99.99%	NA	10%	48%	0%	0%	48%	75.2%	0%	0%	0%	0%	0%	0%	1.6E-04

Table L-6. Estimated Incinerator Emissions (continued)

COPC		Wt% in Feed	Feed Rate (lb/hr)	PCC/SCC DRE	Partitioning to Offgas	Quencher RE	Venturi Scrubber RE	Absorber #1 RE	Absorber #2 RE	Wet ESP RE	Total Wet RE	HEPA Filter #1 RE	Carbon Adsorber #1 RE	Carbon Adsorber #2 RE	2 Prefilters RE	HEPA Filter #2 RE	HEPA Filter #3 (SS/Hi-Temp.) RE	Incinerator Emission Rate (lb/hr)
	Notes	a	b	c	d	e	e	e	e	e		g	e,h	e,h	f	g	g	i
PM	k	NA	329	0%	2.5%	20%	95%	0%	0%	95%	99.8%	99.9%	0%	0%	0%	99.9%	99.9%	1.64E-11
Metals																		
Antimony	n	1	650	0%	100%	0%	20%	30%	30%	95%	98.0%	99.9%	0%	0%	0%	99.9%	99.9%	1.27E-08
Arsenic	l	NA	1	0%	100%	0%	20%	40%	50%	95%	98.8%	99.9%	0%	0%	0%	99.9%	99.9%	1.20E-11
Barium	l	NA	1	0%	100%	0%	90%	50%	50%	97%	99.9%	99.9%	0%	0%	0%	99.9%	99.9%	7.50E-13
Beryllium	l	NA	1	0%	5%	0%	90%	50%	50%	97%	99.9%	99.9%	0%	0%	0%	99.9%	99.9%	3.75E-14
Cadmium		1%	6.5	0%	100%	0%	20%	40%	50%	95%	98.8%	99.9%	0%	0%	0%	99.9%	99.9%	7.80E-11
Chromium	l	NA	1	0%	5%	0%	90%	50%	50%	96%	99.9%	99.9%	0%	0%	0%	99.9%	99.9%	5.00E-14
Cobalt	n	1%	6.5	0%	50%	0%	20%	30%	30%	95%	98.0%	99.9%	0%	0%	0%	99.9%	99.9%	6.37E-11
Copper	n	1%	6.5	0%	100%	0%	20%	30%	30%	95%	98.0%	99.9%	0%	0%	0%	99.9%	99.9%	1.27E-10
Iron	n	5%	32.5	0%	100%	0%	20%	30%	30%	95%	98.0%	99.9%	0%	0%	0%	99.9%	99.9%	6.37E-10
Lead		1%	6.5	0%	100%	0%	20%	40%	50%	95%	98.8%	99.9%	0%	0%	0%	99.9%	99.9%	7.80E-11
Manganese	n	1%	6.5	0%	50%	0%	20%	30%	30%	95%	98.0%	99.9%	0%	0%	0%	99.9%	99.9%	6.37E-11
Nickel		1%	1	0%	100%	0%	20%	40%	50%	95%	98.8%	99.9%	0%	0%	0%	99.9%	99.9%	1.20E-11
Selenium	l	NA	0.5	0%	100%	0%	20%	40%	50%	95%	98.8%	99.9%	0%	0%	0%	99.9%	99.9%	6.00E-12
Silver	l	NA	0.5	0%	100%	0%	90%	50%	50%	97%	99.9%	99.9%	0%	0%	0%	99.9%	99.9%	3.75E-13
Strontium	n	1%	6.5	0%	50%	0%	20%	30%	30%	95%	98.0%	99.9%	0%	0%	0%	99.9%	99.9%	6.37E-11
Thallium	n	1%	6.5	0%	100%	0%	20%	30%	30%	95%	98.0%	99.9%	0%	0%	0%	99.9%	99.9%	1.27E-10
Vanadium	n	1%	6.5	0%	100%	0%	20%	30%	30%	95%	98.0%	99.9%	0%	0%	0%	99.9%	99.9%	1.27E-10
Zinc	n	1%	6.5	0%	100%	0%	20%	30%	30%	95%	98.0%	99.9%	0%	0%	0%	99.9%	99.9%	1.27E-10
Other COPCs																		
Chlorine (Cl_2)	k	0%	5.0	0%	100%	0%	0%	80%	80%	0%	96.0%	0%	0%	0%	0%	0%	0%	1.99E-01
Carbon monoxide (CO)	k	0%	0.47	50%	100%	0%	0%	0%	0%	0%	0.0%	0%	0%	0%	0%	0%	0%	2.35E-01
Cyanide		1%	6.5	99.99%	100%	0%	0%	0%	0%	0%	0.0%	0%	0%	0%	0%	0%	0%	6.50E-04
Hydrogen chloride (HCl)	k	0%	195	0%	100%	30%	40%	90%	95%	0%	99.8%	0%	0%	0%	0%	0%	0%	4.10E-01
Hydrogen fluoride (HF)	k	0%	0.0082	0%	100%	30%	40%	90%	95%	0%	99.8%	0%	0%	0%	0%	0%	0%	1.72E-05
Nitrogen oxides (NO_x)	k	0%	4.5	0%	100%	0%	0%	0%	0%	0%	0.0%	0%	0%	0%	0%	0%	0%	4.50E+00
Sulfur dioxide (SO_2)	k	0%	0.0062	0%	100%	0%	0%	0%	90%	0%	90.0%	0%	0%	0%	0%	0%	0%	6.20E-04

Notes:

a. The waste type processed by the incinerator is non-debris.
b. The maximum incinerator feed rate is 650 lb/hr. Except where otherwise noted, COPC Feed Rate (lb/hr) = (Wt% in Feed / 100) x 650 lb/hr.
c. The PCC and SCC together are designed to destruct a minimum of 99.99% of VOCs and 99.9999% of PCBs.
d. Conservative estimates for metals partitioning to the APCS were taken from Dempsey, Clyde R. and E. Timothy Oppelt, "Incineration of Hazardous Waste: A Critical Review Update," Air and Waste, Vol. 43, pp. 25-73, January 1993
e. Conservative removal efficiencies (REs) for the various APCS equipment were assigned from the guidance provided by Dempsey, Clyde R. and E. Timothy Oppelt, "Incineration of Hazardous Waste: A Critical Review Update," Air and Waste, Vol. 43, pp. 25-73, January 1993. Slight removal efficiencies (10%, 20%, 48%) are included for VOCs and SVOCs in the wet APCS, this allows for transfer of these compounds to to the evaporator.
f. No credit is taken for removal of metals or particulate by the HEPA pre-filters.
g. The HEPA filters in the AMWTF are rated at a minimum RE of 99.97% for 0.15 to 0.3 micron particles with increasing efficiency for larger and smaller particles. This calculation assumes a conservative overall RE of 99.9% per HEPA filter
h. No credit is taken for removal of VOCs by the carbon adsorbers.
i. Incinerator Emission Rate (lb/hr) = Feed Rate (lb/hr) x [1 - (PCC/SCC DRE (%) / 100)] x [Partitioning to Offgas (%) / 100)] x [1 - (RE1 (%) / 100)] x [1 - (RE2 (%) / 100)] ... x [1 - (RE12 (%) / 100)].
k. Feed rates for these constituents are from the mass and energy balance calculations in Appendix D-3 of Book 4 of the HWMA/TSCA permit application (BNFL, 1999).
l. A realistic feed rate of 0.5 or 1 lb/hr is assumed for these metals rather than the worst-case waste concentration; this is a trial burn condition of operation.
m. The incinerator APCS is designed to control dioxin/furans to less than 2.0E-9 lb TEQ/hr through use of a rapid water quench.
n. Metals added per regulator request, not identified as contained in the feed - but probable feed contaminants. Concentration in the feed assumed to be 1%, except for iron which is assumed to be 5%.

Table L-7. Estimated Evaporator Emissions

COPC	Notes	Feed Rate to Evaporator (lb/hr)	Partitioning to Vapor	HEPA Filter #1 RE	Carbon Adsorption Unit #1 RE	Carbon Adsorption Unit #2 RE	HEPA Filter #2 RE	HEPA Filter #3 RE	Evaporator Emission Rate (lb/hr)
		a	b	c	d	d	c	c	e
Volatiles									
Acetone		1.8E-04	NA	0%	95%	0%	0%	0%	8.8E-06
Benzene		1.8E-04	NA	0%	95%	0%	0%	0%	8.8E-06
Butyl alcohol		1.8E-07	NA	0%	95%	0%	0%	0%	8.8E-09
Carbon tetrachloride		8.8E-04	NA	0%	95%	0%	0%	0%	4.4E-05
Chlorobenzene		1.8E-04	NA	0%	95%	0%	0%	0%	8.8E-06
Chloroform		1.8E-04	NA	0%	95%	0%	0%	0%	8.8E-06
1,2-Dichloroethane		1.8E-04	NA	0%	95%	0%	0%	0%	8.8E-06
Dichloroethene		1.8E-04	NA	0%	95%	0%	0%	0%	8.8E-06
cis-1,2-Dichoroethene		1.8E-04	NA	0%	95%	0%	0%	0%	8.8E-06
1,1-Dichoroethene		1.8E-04	NA	0%	95%	0%	0%	0%	8.8E-06
2-Ethoxyethanol		1.8E-04	NA	0%	95%	0%	0%	0%	8.8E-06
Ethylbenzene		1.8E-04	NA	0%	95%	0%	0%	0%	8.8E-06
Ethyl ether		1.8E-04	NA	0%	95%	0%	0%	0%	8.8E-06
Isopropanol		1.8E-04	NA	0%	95%	0%	0%	0%	8.8E-06
Methane		1.8E-04	NA	0%	95%	0%	0%	0%	8.8E-06
Methanol		5.3E-07	NA	0%	95%	0%	0%	0%	2.6E-08
Methyl ethyl ketone		1.8E-04	NA	0%	95%	0%	0%	0%	8.8E-06
Methylene chloride		1.2E-05	NA	0%	95%	0%	0%	0%	6.2E-07
Nitrobenzene		1.8E-04	NA	0%	95%	0%	0%	0%	8.8E-06
1,1,2,2-Tetrachlorothane		1.8E-04	NA	0%	95%	0%	0%	0%	8.8E-06
Tetrachloroethene		1.8E-04	NA	0%	95%	0%	0%	0%	8.8E-06
Toluene		1.8E-04	NA	0%	95%	0%	0%	0%	8.8E-06
1,1,1-Trichloroethane		2.6E-03	NA	0%	95%	0%	0%	0%	1.3E-04
1,1,2-Trichloroethane		1.8E-04	NA	0%	95%	0%	0%	0%	8.8E-06
Trichloroethene		1.8E-04	NA	0%	95%	0%	0%	0%	8.8E-06
1,1,2-Trichloro-1,2,2-trifluoroethane		8.8E-04	NA	0%	95%	0%	0%	0%	4.4E-05
Xylene		8.8E-07	NA	0%	95%	0%	0%	0%	4.4E-08
Semivolatiles									
Cyclohexane		4.9E-04	NA	0%	95%	0%	0%	0%	2.4E-05
1,2,4-Trimethylbenzene		4.9E-04	NA	0%	95%	0%	0%	0%	2.4E-05
1,3,6-Trimethylbenzene		4.9E-04	NA	0%	95%	0%	0%	0%	2.4E-05

Table L-7. Estimated Evaporator Emissions (continued)

COPC		Feed Rate to Evaporator (lb/hr)	Partitioning to Vapor	HEPA Filter #1 RE	Carbon Adsorption Unit #1 RE	Carbon Adsorption Unit #2 RE	HEPA Filter #2 RE	HEPA Filter #3 RE	Evaporator Emission Rate (lb/hr)
PM	g	8.20	5%	99.9%	0%	0%	99.9%	99.9%	4.1E-10
Metals									
Antimony		637.26	100%	99.9%	0%	0%	99.9%	99.9%	6.4E-07
Arsenic		0.99	100%	99.9%	0%	0%	99.9%	99.9%	9.9E-10
Barium		1.00	100%	99.9%	0%	0%	99.9%	99.9%	1.0E-09
Beryllium		0.05	5%	99.9%	0%	0%	99.9%	99.9%	2.5E-12
Cadmium		6.42	5%	99.9%	0%	0%	99.9%	99.9%	3.2E-10
Chromium		0.05	5%	99.9%	0%	0%	99.9%	99.9%	2.5E-12
Cobalt		3.19	50%	99.9%	0%	0%	99.9%	99.9%	1.6E-09
Copper		6.37	100%	99.9%	0%	0%	99.9%	99.9%	6.4E-09
Iron		31.86	100%	99.9%	0%	0%	99.9%	99.9%	3.2E-08
Lead		6.42	5%	99.9%	0%	0%	99.9%	99.9%	3.2E-10
Manganese		3.19	50%	99.9%	0%	0%	99.9%	99.9%	1.6E-09
Nickel		0.99	15%	99.9%	0%	0%	99.9%	99.9%	1.5E-10
Selenium		0.49	100%	99.9%	0%	0%	99.9%	99.9%	4.9E-10
Silver		0.50	15%	99.9%	0%	0%	99.9%	99.9%	7.5E-11
Strontium		3.19	50%	99.9%	0%	0%	99.9%	99.9%	1.6E-09
Thallium		6.37	100%	99.9%	0%	0%	99.9%	99.9%	6.4E-09
Vanadium		6.37	100%	99.9%	0%	0%	99.9%	99.9%	6.4E-09
Zinc		6.37	100%	99.9%	0%	0%	99.9%	99.9%	6.4E-09
Other COPCs									
Chlorine (Cl_2)		-	100%	0.0%	0%	0%	0.0%	0.0%	0.0E+00
Carbon monoxide (CO)		-	100%	0.0%	0%	0%	0.0%	0.0%	0.0E+00
Cyanide		-	100%	0.0%	0%	0%	0.0%	0.0%	0.0E+00
Hydrogen chloride (HCl)		-	100%	0.0%	0%	0%	0.0%	0.0%	0.0E+00
Hydrogen fluoride (HF)		-	100%	0.0%	0%	0%	0.0%	0.0%	0.0E+00
Nitrogen oxides (NO_x)		-	100%	0.0%	0%	0%	0.0%	0.0%	0.0E+00
Sulfur dioxide (SO_2)		-	100%	0.0%	0%	0%	0.0%	0.0%	0.0E+00

Table L-7. Estimated Evaporator Emissions (continued)

Notes:

a. The feed rate for each COPC (except PCBs, see note h) is based on the feed rate to the incinerator, adjusted by the PCC/SCC DRE, partitioning to incinerator offgas, and the removal efficiencies of the quencher, venturi scrubber, absorbers, and wet ESP (see Table 5 for values). Example calculation for cadmium (other inorganics similar): Feed Rate to Evaporator (lb/hr) = Incinerator Feed Rate (6.5 lb/hr) - Incinerator Feed Rate (6.5 lb/hr) x Partitioning to Offgas (1.00) x [1-Quencher RE (0)] x [1-Venturi Scrubber RE (0.20)] x [1-Absorber#1 RE (0.40)] x [1-Absorber#2 RE (0.50)] x [1-Wet ESP RE (0.95)]; Feed Rate to Evaporator = 6.4 lb/hr. Example for butyl alcohol (other VOCs similar): Feed Rate to Evaporator (lb/hr) = Incinerator Feed Rate (0.0065 lb/hr) x [1-PCC/SCC DRE (0.9999)]; Feed Rate to Evaporator = 3.2E-08 lb/hr.

b. Partitioning assumptions are conservative based on *"Heavy Metal Removal from Flue Gas Scrubber Water of Garbage Incinerators with TMT," by Norbert Steiner* from the Degussa Corporation.

c. The HEPA filters in the AMWTF are rated at a minimum RE of 99.97% for 0.15 to 0.3 micron particles with increasing efficiency for larger and smaller particles. This calculation assumes a conservative overall RE of 99.9% per HEPA filter.

d. Carbon adsorption unit RE for VOCs is a conservative 95%. Mercury in the gaseous form is removed by the carbon adsorption unit at a conservative 98%.

e. Evaporator Emission Rate (lb/hr) = Feed Rate to Evaporator (lb/hr) x [Partitioning to Offgas (%) / 100)] x [1 - (RE1 (%) / 100)] x [1 - (RE2 (%) / 100)] ... x [1 - (RE5 (%) / 100)].

f. Total VOCs for the evaporator are estimated by summing the individual VOCs.

g. The PM feed rate for the evaporator is the sum of PM, sodium chloride, and sodium sulfate from the mass and energy balance calculations in Appendix D-3 of Book 4 of the HWMA/TSCA permit application (BNFL, 1999).

h. The feed rate of PCBs is based on the PCB limit for the brine feed (maximum 3 ppb). Assuming brine at specific gravity = 1, PCB Feed Rate = Maximum PCBs in Brine (0.003 mg/L) x Brine Feed Rate (1,136 L/hr) / 453,600 mg/lb; PCB Feed Rate = 7.5E-06 lb/hr.

Table L-8. Estimated Emissions of COPCs for use in Chronic and Acute Risk Scenarios

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			Estimated Emissions				Scenario (b,c)	
CAS #	Volatile COPCs	Note	Nonthermal (g/s)	Evaporator (g/s)	Incinerator (g/s)	Total (g/s)	Chronic (g/s)	Acute (g/s)
67641	Acetone		6.40E-06	1.11E-06	5.98E-05	6.73E-05	3.77E-04	6.73E-04
107131	Acrylonitrile	a		1.96E-06	1.84E-06	3.80E-06	2.13E-05	3.80E-05
71432	Benzene		6.40E-06	1.11E-06	5.98E-05	6.73E-05	3.77E-04	6.73E-04
75274	Bromodichloromethane	a		1.96E-06	1.84E-06	3.80E-06	2.13E-05	3.80E-05
75252	Bromoform	a		1.96E-06	1.84E-06	3.80E-06	2.13E-05	3.80E-05
74839	Bromomethane	a		1.96E-06	1.84E-06	3.80E-06	2.13E-05	3.80E-05
71363	Butanol, n-		6.40E-09	1.11E-09	5.98E-08	6.73E-08	3.77E-07	6.73E-07
78933	Butanone, 2- (Methyl ethyl ketone)		6.40E-06	1.11E-06	5.98E-05	6.73E-05	3.77E-04	6.73E-04
75150	Carbon disulfide	a		1.96E-06	1.84E-06	3.80E-06	2.13E-05	3.80E-05
56235	Carbon tetrachloride		3.20E-05	5.55E-06	2.99E-04	3.36E-04	1.88E-03	3.36E-03
108907	Chlorobenzene		6.40E-06	1.11E-06	5.98E-05	6.73E-05	3.77E-04	6.73E-04
75003	Chloroethane (Ethyl chloride)	a		1.96E-06	1.84E-06	3.80E-06	2.13E-05	3.80E-05
67663	Chloroform		6.40E-06	1.11E-06	5.98E-05	6.73E-05	3.77E-04	6.73E-04
74873	Chloromethane	a		1.96E-06	1.84E-06	3.80E-06	2.13E-05	3.80E-05
74953	Dibromomethane	a		1.96E-06	1.84E-06	3.80E-06	2.13E-05	3.80E-05
75343	Dichloroethane, 1,1-	a		1.96E-06	1.84E-06	3.80E-06	2.13E-05	3.80E-05
107062	Dichloroethane, 1,2-		6.40E-06	1.11E-06	5.98E-05	6.73E-05	3.77E-04	6.73E-04
75354	Dichloroethylene, 1,1-		6.40E-06	1.11E-06	5.98E-05	6.73E-05	3.77E-04	6.73E-04
156592	Dichloroethylene, cis-1,2-		6.40E-06	1.11E-06	5.98E-05	6.73E-05	3.77E-04	6.73E-04
156605	Dichloroethylene, trans-1,2-	a		1.96E-06	1.84E-06	3.80E-06	2.13E-05	3.80E-05
78875	Dichloropropane, 1,2-	a		1.96E-06	1.84E-06	3.80E-06	2.13E-05	3.80E-05
542756	Dichloropropene, cis-1,3-	a		1.96E-06	1.84E-06	3.80E-06	2.13E-05	3.80E-05
110805	Ethoxyethanol, 2-		6.40E-06	1.11E-06	5.98E-05	6.73E-05	3.77E-04	6.73E-04
60297	Ethyl ether		6.40E-06	1.11E-06	5.98E-05	6.73E-05	3.77E-04	6.73E-04
100414	Ethylbenzene		6.40E-06	1.11E-06	5.98E-05	6.73E-05	3.77E-04	6.73E-04
67630	Isopropanol		6.40E-06	1.11E-06	5.98E-05	6.73E-05	3.77E-04	6.73E-04
74828	Methane		6.40E-06	1.11E-06	5.98E-05	6.73E-05	3.77E-04	6.73E-04
67561	Methanol		1.92E-08	3.33E-09	1.79E-07	2.02E-07	1.13E-06	2.02E-06
75092	Methylene chloride (Dichloromethane)		4.48E-07	7.78E-08	4.18E-06	4.71E-06	2.64E-05	4.71E-05
100425	Styrene	a		1.96E-06	1.84E-06	3.80E-06	2.13E-05	3.80E-05

Table L-8. Estimated Emissions of COPCs for use in Chronic and Acute Risk Scenarios

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			Estimated Emissions				Scenario (b,c)	
CAS #	Volatile COPCs	Note	Nonthermal (g/s)	Evaporator (g/s)	Incinerator (g/s)	Total (g/s)	Chronic (g/s)	Acute (g/s)
630206	Tetrachloroethane, 1,1,1,2-	a		1.96E-06	1.84E-06	3.80E-06	2.13E-05	3.80E-05
79345	Tetrachloroethane, 1,1,2,2-		6.40E-06	1.11E-06	5.98E-05	6.73E-05	3.77E-04	6.73E-04
127184	Tetrachloroethylene		6.40E-06	1.11E-06	5.98E-05	6.73E-05	3.77E-04	6.73E-04
108883	Toluene		6.40E-06	1.11E-06	5.98E-05	6.73E-05	3.77E-04	6.73E-04
71556	Trichloroethane, 1,1,1-		9.60E-05	1.67E-05	8.96E-04	1.01E-03	5.65E-03	1.01E-02
79005	Trichloroethane, 1,1,2-		6.40E-06	1.11E-06	5.98E-05	6.73E-05	3.77E-04	6.73E-04
79016	Trichloroethylene		6.40E-06	1.11E-06	5.98E-05	6.73E-05	3.77E-04	6.73E-04
75694	Trichlorofluoromethane	a		1.96E-06	1.84E-06	3.80E-06	2.13E-05	3.80E-05
96184	Trichloropropane, 1,2,3-	a		1.96E-06	1.84E-06	3.80E-06	2.13E-05	3.80E-05
76131	Tricloro-1,2,2-trifluoroethane, 1,1,2-		3.20E-05	5.55E-06	2.99E-04	3.36E-04	1.88E-03	3.36E-03
75014	Vinyl chloride	a		1.96E-06	1.84E-06	3.80E-06	2.13E-05	3.80E-05
108383	m-Xylene		1.07E-08	1.85E-09	9.96E-08	1.12E-07	6.28E-07	1.12E-06
95476	o-Xylene		1.07E-08	1.85E-09	9.96E-08	1.12E-07	6.28E-07	1.12E-06
106423	p-Xylene		1.07E-08	1.85E-09	9.96E-08	1.12E-07	6.28E-07	1.12E-06

			Estimated Emissions				Scenario (b,c)	
CAS #	Semi-volatile COPCs	Note	Nonthermal (g/s)	Evaporator (g/s)	Incinerator (g/s)	Total (g/s)	Chronic (g/s)	Acute (g/s)
309002	Aldrin	f		3.92E-08	3.69E-08	7.61E-08	4.26E-07	7.61E-07
319857	BHC, b-	a		1.96E-06	1.84E-06	3.80E-06	2.13E-05	3.80E-05
111444	Bis(2-chloroethyl) ether	a		1.96E-06	1.84E-06	3.80E-06	2.13E-05	3.80E-05
91587	Chloronaphthalene, 2-	a		1.96E-06	1.84E-06	3.80E-06	2.13E-05	3.80E-05
95578	Chlorophenol, 2-	a		1.96E-06	1.84E-06	3.80E-06	2.13E-05	3.80E-05
110827	Cyclohexane		1.60E-05	3.08E-06	2.03E-05	3.94E-05	2.21E-04	3.94E-04
72548	DDD, 4,4'-	a		1.96E-06	1.84E-06	3.80E-06	2.13E-05	3.80E-05
72559	DDE, 4,4'-	f		3.92E-08	3.69E-08	7.61E-08	4.26E-07	7.61E-07
50293	DDT, 4,4'-	a		1.96E-06	1.84E-06	3.80E-06	2.13E-05	3.80E-05
95501	Dichlorobenzene, 1,2-	a		1.96E-06	1.84E-06	3.80E-06	2.13E-05	3.80E-05
541731	Dichlorobenzene, 1,3-	a		1.96E-06	1.84E-06	3.80E-06	2.13E-05	3.80E-05
106467	Dichlorobenzene, 1,4-	a		1.96E-06	1.84E-06	3.80E-06	2.13E-05	3.80E-05

Table L-8. Estimated Emissions of COPCs for use in Chronic and Acute Risk Scenarios

			Estimated Emissions				Scenario (b,c)	
CAS #	Semi-volatile COPCs	Note	Nonthermal (g/s)	Evaporator (g/s)	Incinerator (g/s)	Total (g/s)	Chronic (g/s)	Acute (g/s)
91941	Dichlorobenzidine, 3,3'-	a		1.96E-06	1.84E-06	3.80E-06	2.13E-05	3.80E-05
120832	Dichlorophenol, 2,4-	a		1.96E-06	1.84E-06	3.80E-06	2.13E-05	3.80E-05
60571	Dieldrin	a		1.96E-06	1.84E-06	3.80E-06	2.13E-05	3.80E-05
105679	Dimethylphenol, 2,4-	a		1.96E-06	1.84E-06	3.80E-06	2.13E-05	3.80E-05
122667	Diphenylhydrazine, 1,2-	a		1.96E-06	1.84E-06	3.80E-06	2.13E-05	3.80E-05
76448	Heptachlor	a		1.96E-06	1.84E-06	3.80E-06	2.13E-05	3.80E-05
1024573	Heptachlor epoxide	a		1.96E-06	1.84E-06	3.80E-06	2.13E-05	3.80E-05
118741	Hexachlorobenzene	a		1.96E-06	1.84E-06	3.80E-06	2.13E-05	3.80E-05
87683	Hexachlorobutadiene	a		1.96E-06	1.84E-06	3.80E-06	2.13E-05	3.80E-05
67721	Hexachloroethane	a		1.96E-06	1.84E-06	3.80E-06	2.13E-05	3.80E-05
78591	Isophorone	a		1.96E-06	1.84E-06	3.80E-06	2.13E-05	3.80E-05
621647	N-Nitrosodi-n-propylamine	a		1.96E-06	1.84E-06	3.80E-06	2.13E-05	3.80E-05
87865	Pentachlorophenol	a		1.96E-06	1.84E-06	3.80E-06	2.13E-05	3.80E-05
108952	Phenol	a		1.96E-06	1.84E-06	3.80E-06	2.13E-05	3.80E-05
120821	Trichlorobenzene, 1,2,4-	a		1.96E-06	1.84E-06	3.80E-06	2.13E-05	3.80E-05
88062	Trichlorophenol, 2,4,6-	a		1.96E-06	1.84E-06	3.80E-06	2.13E-05	3.80E-05
95636	Trimethylbenzene, 1,2,4-		6.40E-06	3.08E-06	2.03E-05	2.98E-05	1.67E-04	2.98E-04
108678	Trimethylbenzene, 1,3,5-		6.40E-06	3.08E-06	2.03E-05	2.98E-05	1.67E-04	2.98E-04

			Estimated Emissions				Scenario (b,c)	
CAS #	PCDD/PCDF COPCs	Note	Nonthermal (g/s)	Evaporator (g/s)	Incinerator (g/s)	Total (g/s)	Chronic (g/s)	Acute (g/s)
1746016	2,3,7,8-Tetrachlorodibenzo-p-dioxin			6.49E-11	6.11E-11	1.26E-10	7.05E-10	1.26E-09
40321764	1,2,3,7,8-Pentachlorodibenzo-p-dioxin							
39227286	1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin							
57653857	1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin							
19408743	1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin							

Table L-8. Estimated Emissions of COPCs for use in Chronic and Acute Risk Scenarios

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CAS #	PCDD/PCDF COPCs	Note	Estimated Emissions				Scenario (b,c)	
			Nonthermal (g/s)	Evaporator (g/s)	Incinerator (g/s)	Total (g/s)	Chronic (g/s)	Acute (g/s)
35822394	1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin							
3268879	1,2,3,4,6,7,8,9-Octachlorodibenzo-p-dioxin							
51207319	2,3,7,8-Tetrachlorodibenzofuran							
57117416	1,2,3,7,8-Pentachlorodibenzofuran							
57117314	2,3,4,7,8-Pentachlorodibenzofuran							
70648269	1,2,3,4,7,8-Hexachlorodibenzofuran							
57117449	1,2,3,6,7,8-Hexachlorodibenzofuran							
72918219	1,2,3,7,8,9-Hexachlorodibenzofuran							
60851345	2,3,4,6,7,8-Hexachlorodibenzofuran							
67562394	1,2,3,4,6,7,8-Heptachlorodibenzofuran							
55673897	1,2,3,4,7,8,9-Heptachlorodibenzofuran							
39001020	1,2,3,4,6,7,8,9-Octachlorodibenzofuran							

CAS #	PCB COPCs	Note	Estimated Emissions				Scenario (b,c)	
			Nonthermal (g/s)	Evaporator (g/s)	Incinerator (g/s)	Total (g/s)	Chronic (g/s)	Acute (g/s)
	3,3',4,4'-tetrachlorobiphenyl							
	2,3,3',4,4'-pentachlorobiphenyl							
	2,3,4,4',5-pentachlorobiphenyl							
	2,3',4,4',5-pentachlorobiphenyl							
	2',3,4,4',5-pentachlorobiphenyl							
	3,3',4,4',5-pentachlorobiphenyl							
	2,3,3',4,4',5-hexachlorobiphenyl							
	2,3,3',4,4',5'-hexachlorobiphenyl							

Table L-8. Estimated Emissions of COPCs for use in Chronic and Acute Risk Scenarios

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CAS #	PCB COPCs	Note	Estimated Emissions Nonthermal (g/s)	Evaporator (g/s)	Incinerator (g/s)	Total (g/s)	Scenario (b,c) Chronic (g/s)	Acute (g/s)
	2,3',4,4',5,5'-hexachlorobiphenyl							
	3,3',4,4',5,5'-hexachlorobiphenyl							
	2,2',3,3',4,4',5-heptachlorobiphenyl							
	2,2',3,4,4',5,5'-heptachlorobiphenyl							
	2,3,3',4,4',5,5'-heptachlorobiphenyl							
1336363	PCBs			4.59E-08	1.52E-08	6.11E-08	3.4202E-07	6.11E-07

CAS #	PAH COPCs	Note	Estimated Emissions Nonthermal (g/s)	Evaporator (g/s)	Incinerator (g/s)	Total (g/s)	Scenario (b,c) Chronic (g/s)	Acute (g/s)
83329	Acenaphthene	f		3.92E-08	3.69E-08	7.61E-08	4.26E-07	7.61E-07
120127	Anthracene	f		3.92E-08	3.69E-08	7.61E-08	4.26E-07	7.61E-07
56553	Benzo(a)anthracene	f		3.92E-08	3.69E-08	7.61E-08	4.26E-07	7.61E-07
50328	Benzo(a)pyrene	f		3.92E-08	3.69E-08	7.61E-08	4.26E-07	7.61E-07
205992	Benzo(b)fluoranthene	f		3.92E-08	3.69E-08	7.61E-08	4.26E-07	7.61E-07
207089	Benzo(k)fluoranthene	f		3.92E-08	3.69E-08	7.61E-08	4.26E-07	7.61E-07
218019	Chrysene	f		3.92E-08	3.69E-08	7.61E-08	4.26E-07	7.61E-07
53703	Dibenz(a,h)anthracene	f		3.92E-08	3.69E-08	7.61E-08	4.26E-07	7.61E-07
206440	Fluoranthene	f		3.92E-08	3.69E-08	7.61E-08	4.26E-07	7.61E-07
86737	Fluorene	f		3.92E-08	3.69E-08	7.61E-08	4.26E-07	7.61E-07
193395	Indeno(1,2,3-cd)pyrene	f		3.92E-08	3.69E-08	7.61E-08	4.26E-07	7.61E-07
91203	Naphthalene	f		3.92E-08	3.69E-08	7.61E-08	4.26E-07	7.61E-07
85018	Phenanthrene	f		3.92E-08	3.69E-08	7.61E-08	4.26E-07	7.61E-07
129000	Pyrene	f		3.92E-08	3.69E-08	7.61E-08	4.26E-07	7.61E-07

CAS #	Nitroaromatic COPCs	Note	Estimated Emissions Nonthermal (g/s)	Evaporator (g/s)	Incinerator (g/s)	Total (g/s)	Scenario (b,c) Chronic (g/s)	Acute (g/s)
98953	Nitrobenzene		6.40E-06	1.11E-06	5.98E-05	6.73E-05	3.77E-04	6.73E-04
121142	2,4-Dinitrotoluene	a		1.96E-06	1.84E-06	3.80E-06	2.13E-05	3.80E-05
606202	2,6-Dinitrotoluene	a		1.96E-06	1.84E-06	3.80E-06	2.13E-05	3.80E-05

Table L-8. Estimated Emissions of COPCs for use in Chronic and Acute Risk Scenarios

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			Estimated Emissions				Scenario (b,c)	
CAS #	Pthalate COPCs	Note	Nonthermal (g/s)	Evaporator (g/s)	Incinerator (g/s)	Total (g/s)	Chronic (g/s)	Acute (g/s)
117817	Bis(2-ethylhexyl) phthalate	a		1.96E-06	1.84E-06	3.80E-06	2.13E-05	3.80E-05
85687	Butyl benzyl phthalate	a		1.96E-06	1.84E-06	3.80E-06	2.13E-05	3.80E-05
84662	Diethyl phthalate	a		1.96E-06	1.84E-06	3.80E-06	2.13E-05	3.80E-05
131113	Dimethyl phthalate	a		1.96E-06	1.84E-06	3.80E-06	2.13E-05	3.80E-05
84742	Di-n-butyl phthalate	a		1.96E-06	1.84E-06	3.80E-06	2.13E-05	3.80E-05
117840	Di-n-octyl phthalate	a		1.96E-07	1.84E-07	3.80E-07	2.13E-06	3.80E-06
CAS #	Metal COPCs							
7440360	Antimony		2.81E-11	8.04E-08	1.61E-09	8.20E-08	1.19E-07	8.20E-07
7440382	Arsenic		2.81E-11	1.25E-10	1.51E-12	1.54E-10	2.24E-10	1.54E-09
7440393	Barium		2.81E-11	1.26E-10	9.46E-14	1.54E-10	2.24E-10	1.54E-09
7440417	Beryllium		2.81E-11	3.15E-13	4.73E-15	2.84E-11	4.12E-11	2.84E-10
7440439	Cadmium		2.81E-11	4.05E-11	9.84E-12	7.84E-11	1.14E-10	7.84E-10
18540299	Chromium (VI)	d	2.81E-11	3.15E-13	6.31E-15	2.84E-11	4.12E-11	2.84E-10
16065831	Chromium (III)	d	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
7440484	Cobalt		2.81E-11	2.01E-10	8.03E-12	2.37E-10	3.44E-10	2.37E-09
7440508	Copper		2.81E-11	8.04E-10	1.61E-11	8.48E-10	1.23E-09	8.48E-09
7439896	Iron		1.40E-10	4.02E-09	8.03E-11	4.24E-09	6.15E-09	4.24E-08
7439921	Lead		5.50E-10	4.05E-11	9.84E-12	6.00E-10	8.70E-10	6.00E-09
7439965	Manganese		6.34E-12	2.01E-10	8.03E-12	2.15E-10	3.12E-10	2.15E-09
7439976	Mercury	e	1.60E-05	1.41E-05	6.60E-07	3.07E-05	4.46E-05	3.07E-04
7487947	Mercuric Chloride	e				0.00E+00	0.00E+00	0.00E+00
22967926	Methylmercury	e				0.00E+00	0.00E+00	0.00E+00
7440020	Nickel		6.34E-12	1.87E-11	1.51E-12	2.65E-11	3.85E-11	2.65E-10
7782492	Selenium		2.81E-11	6.23E-11	7.57E-13	9.11E-11	1.32E-10	9.11E-10
7440224	Silver		2.81E-11	9.45E-12	4.73E-14	3.76E-11	5.45E-11	3.76E-10
7440246	Strontium		2.81E-11	2.01E-10	8.03E-12	2.37E-10	3.44E-10	2.37E-09
7440280	Thallium		2.81E-11	8.04E-10	1.61E-11	8.48E-10	1.23E-09	8.48E-09
7440611	Uranium-238 (soluble salts)		6.43E-11	1.56E-11	1.57E-12	8.15E-11	4.56E-10	8.15E-10
7440622	Vanadium		2.81E-11	8.04E-10	1.61E-11	8.48E-10	1.23E-09	8.48E-09
7440666	Zinc		2.81E-11	8.04E-10	1.61E-11	8.48E-10	1.23E-09	8.48E-09
7440677	Zirconium		2.81E-11	8.04E-10	1.61E-11	8.48E-10	1.23E-09	8.48E-09

Table L-8. Estimated Emissions of COPCs for use in Chronic and Acute Risk Scenarios

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			Estimated Emissions				Scenario (b,c)	
CAS #	Other COPCs	Note	Nonthermal (g/s)	Evaporator (g/s)	Incinerator (g/s)	Total (g/s)	Chronic (g/s)	Acute (g/s)
57125	Cyanide		6.34E-12		8.20E-05	8.20E-05	2.30E-04	8.20E-04
7782505	Chlorine				2.51E-02	2.51E-02	7.02E-02	2.51E-01
7647010	Hydrogen Chloride				5.16E-02	5.16E-02	1.45E-01	5.16E-01
1332214	Asbestos		9.78E-10			9.78E-10	2.74E-09	9.78E-09
7664393	Hydrogen Fluoride				2.17E-06	2.17E-06	6.08E-06	2.17E-05

			Estimated Emissions				Scenario (b,c)	
CAS #	Criteria Pollutants	Note	Nonthermal (g/s)	Evaporator (g/s)	Incinerator (g/s)	Total (g/s)	Chronic (g/s)	Acute (g/s)
630080	Carbon monoxide				2.96E-02	2.96E-02	8.30E-02	2.96E-01
N/A	Nitrogen Oxides				5.68E-01	5.68E-01	1.59E+00	5.68E+00
7446095	Sulfur Dioxide				7.82E-05	7.82E-05	2.19E-04	7.82E-04
N/A	Particulate matter		8.96E-04	5.17E-11	2.07E-12	8.96E-04	2.51E-03	8.96E-03

Notes:

a The emissions for these compounds have been estimated based on an estimate of the stack flow and a detection limit of 5 ug/dscm. The distribution between the incinerator and evaporator is per the semivolatile estimation sheet.

b The estimated emissions for the chronic scenario are equal to the estimated emissions times a TOE multiplication factor of 2.0 and an upset factor of 2.8 (for organics) or 1.45 (for metals).

c The estimated emissions for the acute scenario are equal to the estimated emissions times an upset factor of 10.

d The Chromium emissions from the nonthermal, evaporator, and incinerator emissions are assumed to be Chromium (VI). The Chromium (VI) line shows the total Chromium emissions, while the Chromium (III) emissions have been set to zero.

e The distribution of mercury between elemental, mercuric chloride, and methyl mercury is performed in the model.

f The emissions for these compounds have been estimated based on an estimate of the stack flow and a detection limit of 0.1 ug/dscm. The distribution between the incinerator and evaporator is per the semivolatile estimation sheet (scaled by a factor of 0.1/5).

016485C

Attachment 7

A COMPARISON OF CALPUFF WITH ISC3

Consisting of 26 pages
including cover page

United States
Environmental Protection
Agency

Office of Air Quality
Planning and Standards
Research Triangle Park, NC 27711

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AIR

EPA

A Comparison of CALPUFF with ISC3

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DISCLAIMER

This report was reviewed by the Office of Air Quality Planning and Standards, EPA for approval for publication. Mention of trade names or commercial products is not intended to constitute endorsement or recommendation for use.

PREFACE

In this report a comparison is made of two different dispersion models, CALPUFF and ISC3. CALPUFF is a Lagrangian puff model which simulates continuous puffs of pollutants released into the ambient flow, whereas ISC3 is a Gaussian plume model that treats emissions from a source as a contiguous mass. CALPUFF may be configured to treat emissions as integrated *puffs* or as *slugs*. ISC3 is currently recommended for routine use in assessing source impacts involving transport distances of less than 50km. This report is being released to establish part of the basis for review of the consequences resulting from use of CALPUFF in routine dispersion modeling of air pollution impacts.

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1. Introduction

With the initial use of models such as CALPUFF for regulatory applications, there is the question of how the model will behave with respect to more widely used models like the Industrial Source Complex Short Term (ISC3ST) model, hereafter ISC3. Several sensitivity and comparison studies were designed and performed to determine how CALPUFF would behave when set to emulate ISC3. The results of those runs were analyzed and are discussed here.

This evaluation features a systematic, phased series of implementation modes. Section 3.1 involves simple screening modes in which conditions are extremely limited and controlled. Section 3.2 addresses the more general mode in which meteorological conditions are allowed to vary hourly. Section 4 provides a summary and conclusions from this investigation. References are listed in Section 5, followed by the appendices.

2. Technical Background

CALPUFF is a Lagrangian puff model. The model is programmed to simulate continuous puffs of pollutants being emitted from a source into the ambient wind flow. As the wind flow changes from hour to hour, the path each puff takes changes to the new wind flow direction. Puff diffusion is Gaussian and concentrations are based on the contributions of each puff as it passes over or near a receptor point. For these tests, CALPUFF was set to emit 99 puffs per hour (default). A sufficiently large number of puffs is necessary to adequately reproduce the plume solution at near-field receptors.

CALPUFF was originally designed for mesoscale applications and treated emissions as integrated puffs. As features were added to the model for handling local-scale applications, it was realized that use of the integrated puff approach was inefficient. A more efficient approach was developed to treat the emissions as a *slug*, in which the slug is stretched so as to better characterize local source impacts. The slug can be visualized as a group of overlapping circular puffs having very small separation distances. When run in the slug mode, the hourly averaged pollutant mass is spread evenly throughout the slug. For a given hour, if all of the hourly slug has not passed over a receptor, concentrations are reduced by the mass that has not passed over the receptor (Appendix E; Section 2.1 of Reference #2). Note that when run in a *slug* mode, once the slug's lateral dispersion (σ_y) approaches the length of the slug itself (as eventually happens with downwind distance), CALPUFF samples the pollutant mass as a *puff* to improve computational efficiency. At sufficient downwind distance, there becomes no benefit or advantage for the slug simulation.

In the comparison studies described in this report, CALPUFF was run in both the puff mode (emissions simulated as integrated puffs) and the slug mode (emissions simulated as slugs). When the distinction between puffs and slugs is important or significant, they will appear in italics (i.e., *slugs* or *puffs*; see Appendix E). In the generic sense, the use of "puffs" will be used to connote the characterization of a continuous release of a series of overlapping averaged puffs, in which the transport and dispersion of each puff is treated independently, based on local (time and space varying) meteorological conditions. Whereas, the use of "plume" will be used to connote the characterization of a continuous release, in which the release and sampling times are long compared with the travel time from source to receptor, and the meteorological conditions are steady state over the travel time.

3. Results

In this comparison, CALPUFF (Version 4.0, level *960612*) was compared with the latest version of ISC3 (dated *96113*). CALPUFF was run in a mode that enabled ISC3-type meteorological data as input, and therefore winds are horizontally homogeneous for each hour. ISC3 was implemented in the "Regulatory Default" mode and the input file for CALPUFF was configured so as to emulate this to the best extent possible (see Appendix A). Both surface and elevated sources were simulated for *rural* environments in flat terrain, free of obstacles.

3.1 Steady State (screening) Meteorological Conditions

In this approach to the comparison, meteorological conditions were held constant (as in SCREEN3) so as to express true model differences, i.e., without the bias of a varying (temporally and spatially) meteorological regime. Meteorological data sets were synthesized with fixed meteorological conditions (Pasquill-Gifford stability category, wind speed, and mixing height) and were of duration estimated to be sufficient to advect CALPUFF's puffs to the edge of domain (generally 24 - 48 hours). (Of course, ISC3's steady state plume reaches the edge of the domain instantaneously.) For Pasquill-Gifford (P-G) stability category *A*, 5 wind speeds were used, for *B*, there were 9 wind speeds, for *C*, 11 wind speeds, for *D*, 13 wind speeds, for *E*, 9 wind speeds, and for *F*, 7 wind speeds. A matrix describing the basis for the 54 meteorological conditions used is provided in Appendix B.

The elevated point sources were 35m, 100m and 200m, respectively. Surface releases were simulated with a 2m point source, a 500m X 500m area source, and a typical volume source. Characteristics for each source type are described in Appendix C. Sources were placed at the center of a 2 X 2 grid cell domain, with grid spacing set to 150km. While effects within the first 50km are of most interest and significance, straight-line receptors were located with decreasing density out to 100km (Appendix D). The 62 receptors were placed along a radial aligned at 360°, coincident with the bearing used for transport winds.

Unique model runs were made for each combination of source type and meteorological condition (i.e., Pasquill-Gifford stability category, wind speed, and mixing height). Each model was configured to output the highest hourly average concentration for SO_2 (no deposition or chemical transformation).

3.1.1 Residual Analysis

For each pair of model runs (CALPUFF and ISC3), a signed residual (R_i, $\chi_{CALPUFF}$ - χ_{ISC3}, μgm^{-3}) was computed at each of the 62 receptors. From the 62 residuals, a mean ($\bar{R}$, μgm^{-3}), standard deviation (σ_R, μgm^{-3}), and sum of residuals squared ($\Sigma\ R_i^2$) were computed. The statistic $\bar{R}$ provides an indication (sign) of bias along the receptor radial. The statistic σ_R provides general indication of the variance along the receptor radial. Because many of the absolute residuals were quite small, $\Sigma\ R_i^2$ provides a relatively robust indicator of accord along the receptor radial.

Another robust statistic was envisioned in which the absolute residual at each receptor was related to, say, ISC3's predicted concentration value at that receptor. Because of the mathematical problem posed by zero values (can't divide by zero), the statistic $\%R_i$ (*% residual*) was defined in terms of the *maximum* concentration predicted by ISC3 for each run:

$$\%R_i = \left(\frac{R_i}{\chi_{ISC3max}}\right) 100$$

The *mean % residual* follows as:

$$\overline{\%R} = \frac{\Sigma\ \%R_i}{62}$$

As with $\bar{R}$, the statistic $\overline{\%R}$ provides an indication (sign) of bias along the receptor radial.

Another statistic of interest was the Fractional Bias (FB):

$$FB_i = \frac{R_i}{\frac{\chi_{CALPUFF} + \chi_{ISC3}}{2}}$$

Having by definition a distribution from -2 to +2, a value of zero indicates no bias between $\chi_{CALPUFF}$ and χ_{ISC3}.

One problem that arises with the FB statistic is when the mean paired concentration is very close to zero: the FB statistic can be artificially inflated to a value close to ±2. Since cases in which the mean is close to zero are of little interest in this comparison, a filter was applied:

$$If \ \left(\frac{\chi_{CALPUFF} + \chi_{ISC3}}{2}\right) < 0.001 \mu gm^{-3}, \ then \ FB_i = 0.0$$

For each run pair (i.e., CALPUFF versus ISC3), a mean fractional bias was computed as:

$$\overline{FB} = \frac{\Sigma FB_i}{62} \qquad \text{(62 receptors)}$$

As with $\bar{R}$ and $\overline{\%R}$, $\overline{FB}$ provides an indication (sign) of bias along the receptor radial. While a value of zero would be ideal for $\overline{FB}$, the following was established as a "goal":

$$-0.10 \leq \overline{FB} \leq 0.10$$

Specific instances for which this goal was not met were noted.

There are some caveats to the interpretation of FB. Its behavior is closely related to its structure. Its value is influenced not only by the absolute difference of the paired concentrations, but by their relative magnitude as well. Thus, modest R_i's related to "large" χ's (e.g., from a low level release) yield modest FB_i's (and a modest $\overline{FB}$). Such a scenario can include a fairly large variance ($\sigma_R = 56\ \mu gm^{-3}$) and mean residual (e.g., $\bar{R} = -32\ \mu gm^{-3}$) along the receptor radial but still result in a fairly low $\overline{FB}$ (e.g., $\overline{FB} = -0.06$). Conversely, modest R_i's related to "small" χ's (e.g., from an elevated release) may yield substantial FB_i's. Such a scenario can include a modest variance ($\sigma_R = 0.5\ \mu gm^{-3}$) and mean residual (e.g., $\bar{R} = 0.3\ \mu gm^{-3}$) along the receptor radial but still result in a sizeable $\overline{FB}$ (e.g., $\overline{FB} = 0.35$). While a useful indicator of correspondence between two quantities, the FB must be interpreted in the context of other comparison statistics.

At the conclusion of the runs, a performance matrix was created and aggregate statistics were compiled. For basic residual analysis, the value, run (distinct combination of source type, wind speed, P-G category, mixing height) and receptor for $R_{i(min)}$ and $R_{i(max)}$ were noted. Likewise, across all runs, the value and run for $\overline{\%R}_{min}$ and $\overline{\%R}_{max}$ were noted, as were the value and run for $\bar{R}_{min}$ and $\bar{R}_{max}$. Across all runs, the value and run for $\sigma_{R(min)}$ and $\sigma_{R(max)}$ were also noted.

Finally, for the FB statistic, the value, run and receptor for $FB_{i(min)}$ and $FB_{i(max)}$ were noted. Across all runs, the value and run for $\overline{FB}_{min}$ and $\overline{FB}_{max}$ were noted. The values and cases in which $\overline{FB}$ did not meet the "10% goal" were also noted.

3.1.2 Point Sources (surface and elevated)[1]

3000m mixing height

To model the four point sources, CALPUFF had to be run 216 times while ISC3 was run 54 times.[2] As indicated in Appendix A, CALPUFF was run in the *slug* mode to emulate ISC3's Gaussian plume simulation.[3] The results indicated good accord (Appendix F). For all cases, $|\overline{FB}| \leq 0.10$ ($\overline{FB}_{max} = 0.02$). The *maximum* residual was 25.0 μgm^{-3} (0.13% of the concentration mean at the incident receptor), while the *minimum* residual was -8.0 μgm^{-3} (0.03% of the concentration mean at the incident receptor). Mean residuals for any run were less than one μgm^{-3}, and total range for σ_R was 0.0 - 3.2 μgm^{-3}. Overall, perhaps the most practical performance parameter was $\overline{\%R}$, which indicates accord well within one percent across all release heights, meteorological conditions and receptors (the value for $\overline{\%R}_{min}$ was -0.04% and $\overline{\%R}_{max}$ was 0.13%). A qualitative inspection of residuals as they appear along the receptor array indicated no distinct pattern of bias for any case. Across all runs, a slight negative bias (CALPUFF relative to ISC3) is apparent for the 2m source, and the greatest variance is associated with the 2m source, especially for P-G category *A*.

500m mixing height

The array of runs was redone (again, using *slugs*) with mixing height reduced to 500m to assess CALPUFF's response to reflection and to evaluate whether reflection is handled equivalently. The results were quite good. In 43 cases, the plume centerline computed by ISC3 exceeded the mixing height and set ground level concentrations to zero. CALPUFF treated the same cases equivalently. For the remaining 173 cases, $|\overline{FB}| \leq 0.10$ ($\overline{FB}_{max} = 0.02$). The comparison statistics bear a striking resemblance to those for $Z_i = 3000$m. Mean residuals for

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[1]Certain runs may be referenced, e.g., D20H100 or B1p5H2. Under this nomenclature, the first signifies a 100m source running under *D* stability with 20 ms^{-1} winds. The second would be a 2m source running under *B* stability with 1.5 ms^{-1} winds.

[2]Each source was modeled 54 times for each of two mixing heights. In the current version of CALPUFF, it is impossible to isolate impacts from more than one source per run. ISC3, however, may be configured to simulate multiple sources during a single run and isolate impacts individually.

[3]For a description of integrated *puff* and *slug* formulations, see Sections 2.1.1 and 2.1.2 of the CALPUFF User's Guide (Reference #2) and Appendix E of this report.

any run were also less than one μgm^{-3}, and $\overline{\%R}$ indicates accord to well within one percent across all release heights, meteorological conditions and receptors (the value for $\overline{\%R}_{min}$ was 0.0% and $\overline{\%R}_{max}$ was 0.08%). A qualitative inspection of residuals as they appear along the receptor array also indicated no distinct pattern of bias for any case. As with the 3000m Z_i case, a slight negative bias is apparent for the 2m source, and the greatest variance is associated with the 2m source, especially for P-G category *A*.

3.1.3 Area Source

The area source was modeled with emissions simulated as *slugs*. While a significant difference would be expected between the behavior of *puffs* and *slugs*, *slugs* are considered to treat the area source more closely to the way of ISC3. This is because the "line-source" integrator, similar to that used in ISC3 to model area sources, is only implemented when emissions are simulated as *slugs*. *Puffs* use the effective σ_y treatment for area sources. If there are receptors within or very near an area source, the *slug* treatment is a better representation. If receptors are farther away, the *puff* treatment is reasonable, and less time-consuming. Mixing height was fixed at 3000m. These runs were done both for $\sigma_{z(init)} = 0$ and for $\sigma_{z(init)} = 2.5$m (specification of non-zero $\sigma_{z(init)}$ is optional in both models). The best accord was seen for the set in which $\sigma_{z(init)} = 0$ (Appendix G). For about one fifth of the cases, $|\overline{FB}| > 0.10$ ($\overline{FB}_{min} = -0.16$). The *maximum* residual was 561 μgm^{-3} (2.2% of the concentration mean at the incident receptor), while the *minimum* residual was -1537 μgm^{-3} (33% of the concentration mean at the incident receptor). Mean residuals and mean standard deviations among runs ranged over three orders of magnitude. Analysis of the residuals and fractional biases indicate a definite trend toward negative bias (CALPUFF relative to ISC3), and best accord for any P-G category was seen for the *higher wind speeds*. Also, within any P-G category, the variance falls off with higher wind speed. The parameter $\overline{\%R}$ indicates accord within two percent across meteorological conditions and receptors (the value for $\overline{\%R}_{min}$ was -1.5% and $\overline{\%R}_{max}$ was -0.07%) and again, the tendency toward negative bias is indicated. A qualitative inspection of residuals as they appear along the receptor array indicated no distinct pattern of bias for any case.

3.1.4 Volume Source

The volume source was modeled with emissions simulated as *slugs*. Because ISC3 does not compute concentrations for receptors within $2.15\sigma_y$ of the source (it's actually $2.15\sigma_y + 1$m), no residuals were analyzed for receptors closer than 200m.

There is a fundamental feature of the way in which ISCST3 treats virtual sources (such as the volume source in question) that is at odds with the way in which CALPUFF treats such sources. The phenomenon is described and illustrated in Appendix H. A modified version of ISCST3 was created to ensure conformity in the treatment of virtual sources by both models. Once this modification was made, the accord between CALPUFF and ISC3 was quite good (Appendix I).

For all cases $|\overline{FB}| = 0.0$. The *maximum* residual was 0.15 μgm^{-3} (0.1% of the concentration mean at the incident receptor), while the *minimum* residual was -0.92 μgm^{-3} (0.4% of the concentration mean at the incident receptor). Mean residuals for any run ranged from -0.2 μgm^{-3} to 0.0 μgm^{-3}, and total range for σ_R was 0.0 - 0.22 μgm^{-3}. The parameter $\overline{\%R}$ indicates accord well within a tenth of one percent across all meteorological conditions and receptors (the value for $\overline{\%R}_{min}$ was -0.07% and $\overline{\%R}_{max}$ was 0.01%). A slight tendency for negative bias was apparent for the stable P-G categories. As seen for the area source, for any of the stable P-G categories, variance falls off with higher wind speed. A qualitative inspection of residuals as they appear along the receptor array indicated slightly more bias for receptors in the near field of the source.

3.2 Variable Meteorological Conditions

3.2.1 Scenarios for Sensitivity Study

For the sensitivity study comparing CALPUFF and ISC3, meteorological conditions were allowed to vary hourly. The first test scenario was devised to see what effects variable meteorology would have on hourly averaged concentrations. One annual period of hourly averaged meteorological data was selected from each of three climatically different regions of the United States. The concentrations between CALPUFF (emissions simulated as a continuous series of puffs) and ISC3 (emission release simulated as a continuous plume) were compared in time and space. The comparisons were examined to try to find the underlying cause of significant differences. The second scenario was a rerun of the first case with some modifications. The averaging times were extended to 3-, 24-hour and annual periods. Maximum concentrations were compared for individual receptor rings at 15 downwind distances. The suite of four point sources described in Appendix C was used in these comparisons.

The meteorological data consist of hourly values of wind speed and direction, ambient temperature, stability class, and mixing heights. The three sites selected were: 1991 Boise, Idaho; 1990 Medford, Oregon; and 1964 Pittsburgh, Pennsylvania.

The Boise data set was selected because of the very directional nature of it winds (see 1991 Boise wind rose, Appendix J). Over 33% of the winds have a northwesterly component and over 33% of the winds have a southeasterly component with the majority of those winds having speeds greater than 2 ms^{-1}. With such persistence in wind direction, the puffs simulated by CALPUFF would be expected to be transported to the most distant receptors.

The Medford data set was selected because of the high number of calm wind situations (see 1990 Medford wind rose, Appendix J). In 1990, Medford Oregon recorded a value of 22.5% of calm winds. This compares to the average of 6.5% for the other two sets of data. Since CALPUFF processes calm winds and ISC3 "zeros" concentrations during calm wind events, there is good reason to expect differences to be seen in the simulated patterns of surface concentration values estimated by the two models.

The 1964 Pittsburgh data set was selected because it has been used as a standard test set for a number of years and because of its fairly well distributed wind directions and wind speeds (see 1964 Pittsburgh wind rose, Appendix J). Although there is a bias in the wind direction toward the southwest, this set was included because many data sets show a similar bias for a particular wind direction and also have a low number of calm winds.

The receptor placement consisted of 15 rings of 36 receptors each for a total of 540 receptors. The rings were spaced at distances of 0.5, 1, 2, 3, 5, 10, 15, 20, 30, 50, 100, 150, 200, 250, and 300km from the source. On each ring, the receptors were spaced every 10° starting at 360°.

3.2.2 Preliminary Studies

Three preliminary studies were done prior to the sensitivity study. In the first preliminary study, CALPUFF and ISC3 were run to create a plot of concentration curves under steady state conditions for centerline and laterally placed receptors. If there were differences in the way dispersion coefficients were calculated between the two models, that would become apparent in plots of concentration distributions. In the second preliminary study, the *puff* and *slug* models were run for a two-hour segment where a large wind shift occurred in the second hour. The purpose was to compare concentration footprints from *puff* and *slug* mode results. This study highlights the different manner in which *puffs* and *slugs* are treated in CALPUFF. In the third preliminary study, a detailed examination was made of the concentration output from CALPUFF (*puff* mode) and ISC3 using the Boise meteorological data to help understand the large differences in concentrations between these two models over a multi-hour period involving calm winds and a wind shift.

First Study

The first study was done to see whether CALPUFF would calculate σ_y and σ_z values differently than ISC3. The same standard input file was created for ISC3 and CALPUFF with the idea being that any difference in the way the sigmas were calculated would be evident in the concentration results. In this comparison, CALPUFF was run in both the *puff* and *slug* modes. The models were run for a 2m point source and the basic switch settings for CALPUFF set per Appendix A. The meteorological data were kept constant except for P-G stability category. For each run, the stability category was changed until all six stability categories, A through F, were used for all three models (i.e., ISC3, CALPUFF *puff* model, and CALPUFF *slug* model). A preliminary group of receptors was created with the centerline along the 360° axis and the receptors spaced every 1° for 44°.

The resulting concentrations were compared on a receptor-by-receptor basis. When the same input data were used, all three models produced concentrations that were within a few fractions of a percent of one another (Figure 1). Figure 1 displays six sets of three curves, one set of curves for each stability category. Each curve in each set overlaps the other curves in that set. The only common difference in each set is that both CALPUFF curves are truncated. This can be seen by the extrapolation of the ISC3 thin dashed line after the thick dashed line and thin solid lines of the two CALPUFF curves. This disparity results from CALPUFF concentration values set to zero for receptors that are more than $3\sigma_y$ from the centerline (Appendix E), whereas ISC3 sets concentration values to zero for receptors that are more than $11.75\sigma_y$ from the centerline. However, lateral plume spread in ISC3 is limited to 50° either side of the centerline and may be further decreased by vertical mixing conditions.

Second Study

In the second study, CALPUFF's treatment of emissions, *puffs* versus *slugs*, was evaluated (Appendix E), using synthesized meteorological data. There is a general difference in the extent of the hourly CALPUFF concentration "footprints" using the *puff* and *slug* models (Appendix K). Concentrations produced by the puff model produce a concentration field similar to a concentration field produced by ISC3 but are restricted to the trajectory algorithms in CALPUFF. The extent of each CALPUFF downwind concentration field is limited by the average wind speed occurring over a particular hour. The extent of the downwind concentration field in ISC3 is limited only by the farthest downwind receptor. The extent of the downwind concentration field when the *slug* model is used is the same as that for the *puff* model. However, when the wind direction changes from one hour and to the next, the directional orientation of the *slug* is maintained while the *slug* is advected downwind (Figure 2). During Hour 1, the wind was from

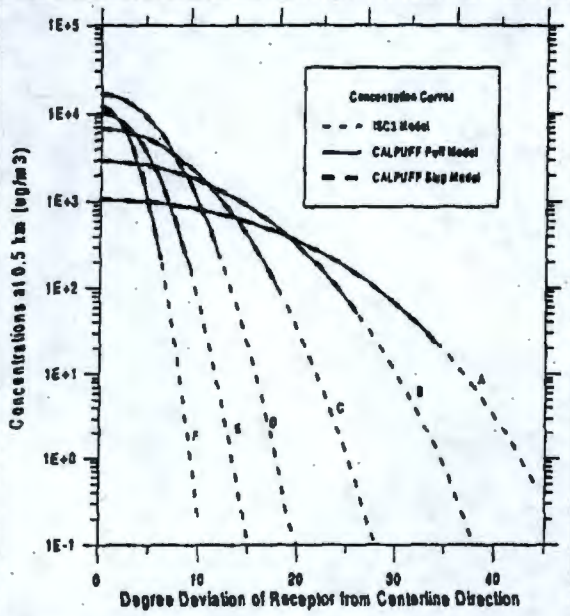


Figure 1. Plot of ISC3 and CALPUFF *slug* and *puff* model concentrations at a distance of 0.5 km from the source for all stability classes. The curves for CALPUFF are truncated because CALPUFF and ISC3 use different y/σ_y criteria for deciding whether to compute a concentration for a given receptor.

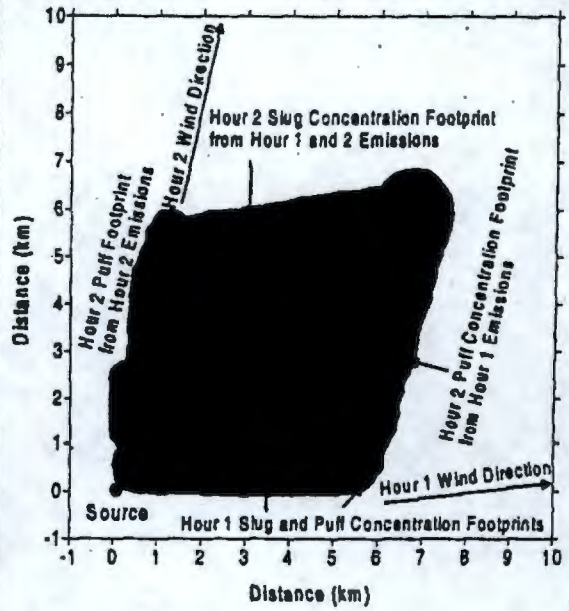


Figure 2. Plot of CALPUFF *slug* and *puff* one-hour concentration footprints during a 2-hour, 70 degree wind shift. Note the broad Hour 2 *slug* area which was advected from the area of the Hour 1 *slug* footprint. This area was coupled with the Hour 2 emissions.

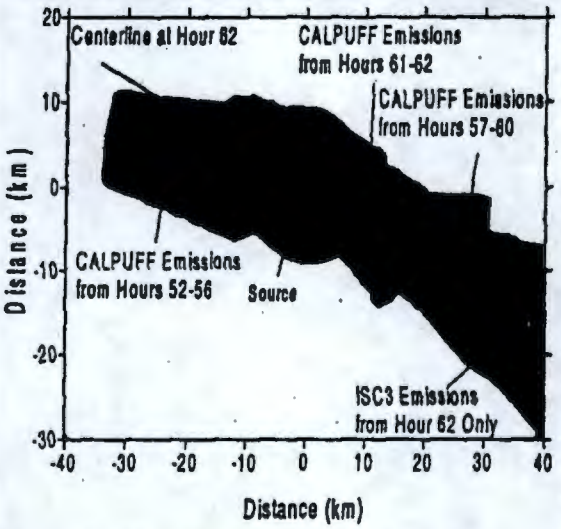


Figure 3. Plot of concentration footprints at Hour 62 from three CALPUFF hourly emission groups and one ISC3 emission group. The Hour 62 ISC3 plume centerline orientation is drawn through the source location. Note the overlap of groups in the 5 to 15km downwind range.

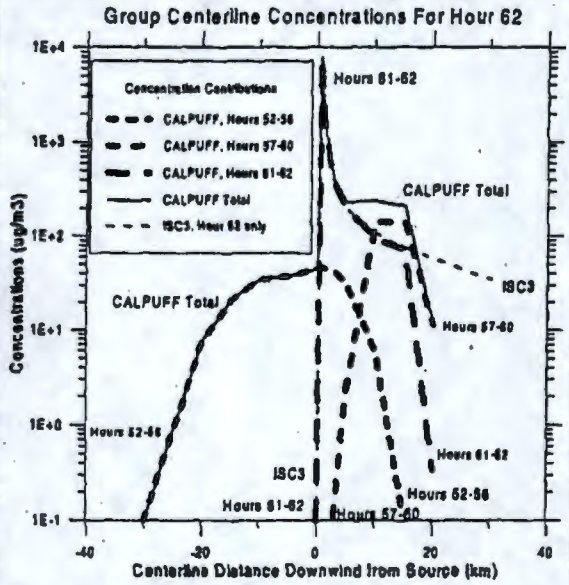


Figure 4. Plot of Figure 3 CALPUFF group and total and ISC3 one-hour concentrations at Hour 62. Note that the CALPUFF total is approximately 50% greater than ISC3 concentrations at 15km.

263°; during Hour 2, the wind switched to 193°. In Hour 1, the *puff* and *slug* model concentration footprints are almost exactly the same. However, in the next hour, the east-west oriented slug is advected north-northeastward. This results in a number of receptors being impacted but at a much lower concentration of about 280 μgm^{-3}. At the end of Hour 2, an area of approximately 25 km^2 has been impacted by the *slug* model. The puff impacts are restricted to relatively narrow corridors.

Note that during Hour 2, the *slug* and *puff* models have been simulating emissions from the source. The emissions have been transported north-northeastward (Figure 2). The concentrations produced by both models are similar but the puff concentrations are higher in the area of the maximum (Appendix K), due to the way in which dispersion is treated in the *slug* model. Since the slug is elongated and the mass of effluent is spread evenly throughout its volume, the newly emitted effluent close to the end of the hour has not had time to be transported past the receptors farther out. At distances of 0.5, 1, 2, 3 and 5km along the 10 degree radial, the Hour 2 slug concentrations are 91, 82, 64, 46, and 11 percent of the respective puff concentrations. While the *slug* model may have a broader spatial impact, its average concentrations are generally lower than those of the *puff* model.

Remember that receptors were placed on rings within the modeled domain and that there were no rings between 5km and 10km. With this arrangement a truncation appeared in the *puff* concentration footprint for Hour 2 beyond 5km from the source, and the actual footprint (appearing as right side Hour 2 in Figure 2) was not detected. (This truncation was not as evident for the Hour 2 *slug* footprint). To address this artifact, a finer Cartesian grid was developed for the second preliminary study that used a spacing of 400 meters and the right side Hour 2 *puff* footprint was then detected and expressed (Fig. 2). Note that the right side Hour 2 *puff* footprint originates from the terminus of the Hour 1 *puff*. The left side Hour 2 *puff* footprint is the result of Hour 2 emissions from the source. Also note the 400 meter grid resolution was not fine enough to properly contour the left side Hour 2 *puff* concentration isopleths. There was no such contouring problem evident within the other *puff* and *slug* concentration footprints. Note that the Hour 2 *slug* footprint is superimposed by the Hour 1 and Hour 2 *puff* footprints and by the exposed area between them.

Third Study

In the third study, a detailed examination was done on the concentration output from CALPUFF (*puff* mode) and ISC3 using the Boise meteorological data to examine the cause of a large difference in concentrations between these two models' results. These concentrations

occurred 5 to 15km downwind from the source at Hour 62 and after a 4-hour period of calm winds and then a wind reversal (Figure 3).

During the 10 hours preceding Hour 62, hourly emissions were released into one of three wind regimes. First, there were 5 hours of east-southeasterly winds, followed by 4 hours of calm winds, followed by a 180-degree wind shift for 2 hours. Emissions were advected west-northwesterly, then stagnated but the puffs spread out evenly during this calm wind regime, and finally all emissions were advected east-southeasterly until Hour 62.

The CALPUFF concentration field at Hour 62 consists of three groups of concentrations based upon the prevailing wind direction at the time of emission release. One group had releases during Hours 52 through 56. The next group had releases during the calm wind Hours 57 through 60, and the final group had releases during Hours 61 and 62. The fields were depicted to show their respective group concentration footprints at Hour 62.

In Figure 3, note that all three groups overlap each other in the 5 to 12km range downwind. This is also affirmed in Figure 4, which shows the centerline concentrations oriented on the Hour 62 wind direction for each group, the total of the three groups, and the ISC3 centerline concentrations for the receptors nearest the centerline. The centerline concentrations from the three groups were added together to produce concentrations a factor of two greater than those estimated by ISC3 at 15km.

Leading up to Hour 62, there were four hours of calm wind conditions. During calm winds, CALPUFF assumes that the wind speed is zero. However, unlike ISC3 which treats the calm hour as missing, CALPUFF increases the sigma values of each puff with respect to time. During an hour of calm winds, the puffs have grown to the point that ground-level concentrations in this study were calculated at 0.5 and 1.0 km from the puff centers in all directions for the first hour of calm. After two hours, the effluent reached as far as 2km. The broadness of the Hour 52-56 and Hour 57-60 groups is reflective of the puff spreading during the calm wind period.

Details of this type of dispersion phenomena can be seen in Table 1. During Hour 57, the Hour 57 puff releases penetrated a low mixing height (inversion) and continued to spread horizontally without any concentrations contacting the ground. During the inversion rise in Hour 58, emissions were then mixed to the ground and Hour 57 emissions impacted receptors 0.5, 1 and 2km distance from the source while Hour 58 emissions were dispersed only to receptors at 0.5 and 1 km distance from the source.

3.2.3 Sensitivity Study

One of the major tasks of this study is to understand what types of concentrations will be produced by CALPUFF with respect to ISC3. The results of ISC3 versus CALPUFF using the *puff* and *slug* models were compared for three different climatological regions of the country. The results are displayed as a series of figures plotting the percent difference in concentrations at various downwind distances with only ISC3 results in the denominator. Results consist of maximum and highest of the second highest percent differences for 1-, 3-, 24-hour and annual averages.

Table 1
CALPUFF Concentration Estimates under Calm Wind Conditions

Receptor Coordinates		Concentrations (μgm^{-3}) produced by:		
X	Y	Hour 57 emissions at Hour 57	Hour 57 emissions at Hour 58	Hour 58 emissions at Hour 58
0.00	0.50	0.00	1340.44	2989.86
0.00	1.00	0.00	822.80	315.08
0.00	2.00	0.00	115.98	0.00
0.00	3.00	0.00	0.00	0.00
0.00	5.00	0.00	0.00	0.00
0.09	0.49	0.00	1340.68	2992.90
0.17	0.99	0.00	822.44	314.55
0.35	1.97	0.00	115.86	0.00
0.52	2.95	0.00	0.00	0.00
0.87	4.92	0.00	0.00	0.00

As illustrated in Figures 3 and 4, the explanation of why and how one model produces higher concentrations than another can be complex. The effects of inversions, calm winds, wind shifts, wind reversals, and plume and puff trajectory differences can all lead to enhanced or reduced effluent impact. The results of these interactions are shown in Figures 5 and 6 (the series is continued as Figures L-1 through L-7 in Appendix L).

As shown in Figure 5, the Medford plots contain the largest number of positive percentage differences over the widest range of downwind distances. As was seen in Figures 3 and 4, the results of calm winds and wind reversals can lead to higher than ISC3 average concentrations at

respective downwind distances. With the high percentage of calm winds, note also in the annual average panel (Figure 5d) how the differences increase dramatically for the higher stacks as the downwind distance decreases. This is caused by the ISC3 plume not reaching the ground, or not fully dispersing to the ground, whereas CALPUFF can model effluent dispersion with wind reversals for receptors near the stack base.

As shown in Figure 6, the overall difference pattern with respect to stack height and downwind distances among the three sites is remarkably similar. Only the magnitude of the differences and the downwind distance at which the values initially converge is different. The Pittsburgh plots tend to slope downward with respect to the others but overall the patterns remain the same with respect to stack height and downwind distance.

As illustrated in Figures L - 1 through L - 7 (Appendix L), sometimes a pattern or trend can be seen by comparing subsequent or related figures only to find an exception in another figure. All of this may be the result of complex interactions that are likely to occur in any of the climatological regimes. For instance, Medford, Oregon has a high percentage of calm winds. If these calm wind events are coupled with a wind reversal, the same situation illustrated in Figure 3 for Boise, Idaho can occur. The patterns in the percentage differences may reflect a general pattern found at that site but the pattern can be overlaid by a situation often found at another site.

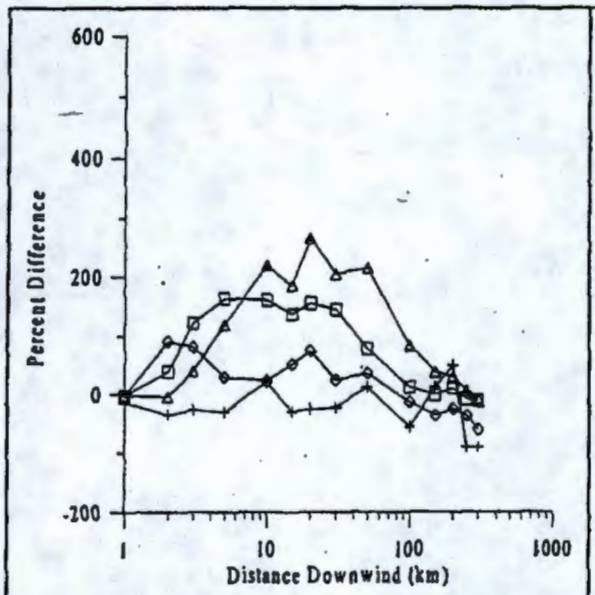


Figure 5a. Results for 1-hour averages using 1990 Medford data.

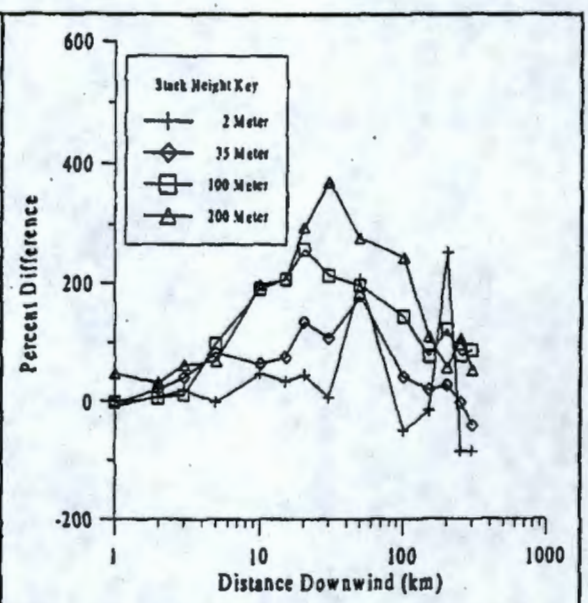


Figure 5b. Results for 3-hour averages using 1990 Medford data.

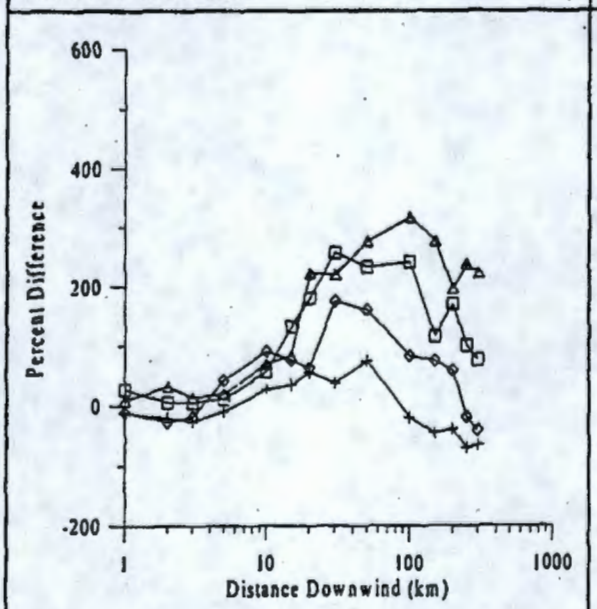


Figure 5c. Results for 24-hour averages using 1990 Medford data.

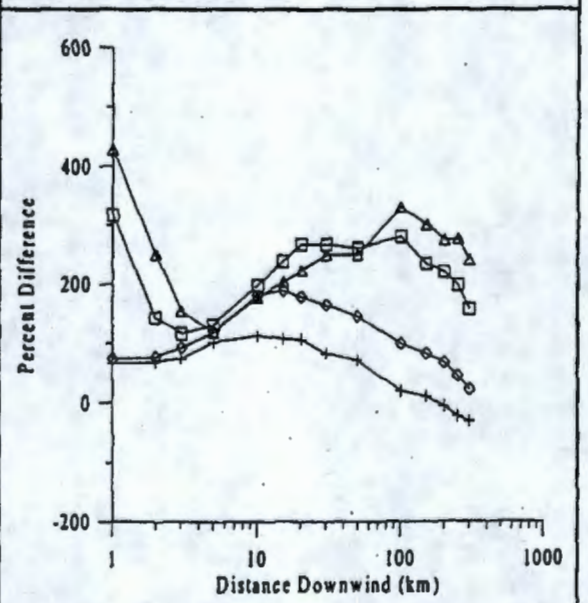


Figure 5d. Results for annual averages using 1990 Medford data.

Figure 5. Percent differences (ISC3 vs. CALPUFF *slug* model) as a function of downwind distance for the highest 2nd high concentrations; 1-, 3-, 24-, and annual averages. Data are for Medford, Oregon. Note: $\% \ Difference = 100 \left(\frac{\chi_{CALPUFF} - \chi_{ISC3}}{\chi_{ISC3}}\right)$.

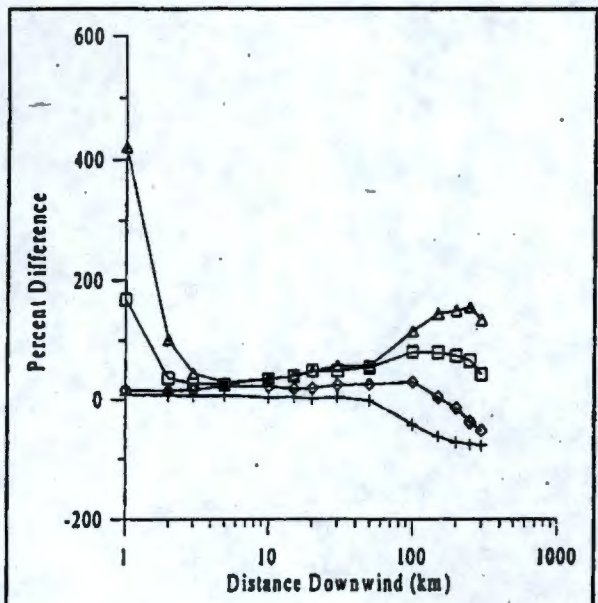


Figure 6a. Results for annual averages using 1991 Boise data.

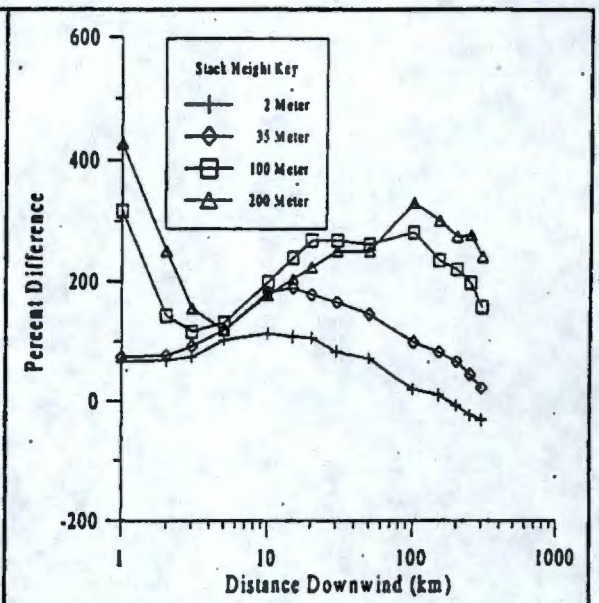


Figure 6b. Results for annual averages using 1990 Medford data (repeat of Fig. 5d).

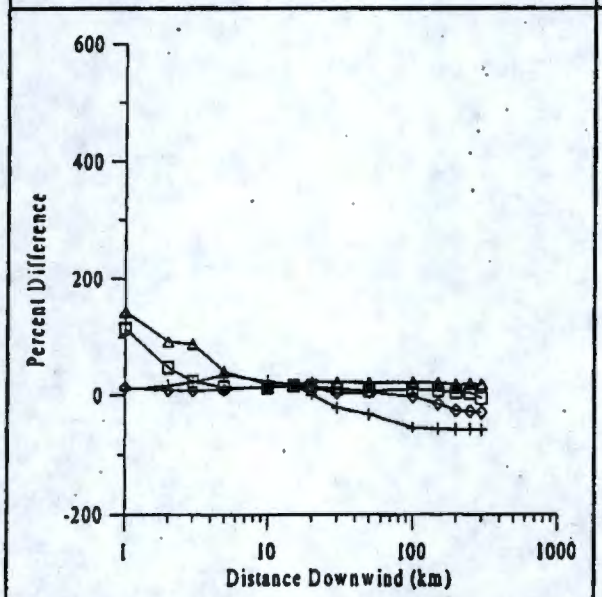


Figure 6c. Results for annual averages using 1964 Pittsburgh data.

Figure 6. Percent differences (ISC3 vs. CALPUFF *slug* model) as a function of downwind distance for annual averages, all three sites. Note: $\% \ Difference = 100 \left(\frac{\chi_{CALPUFF} - \chi_{ISC3}}{\chi_{ISC3}}\right)$.

4. Summary and Conclusions

4.1 Steady State Meteorological Conditions

CALPUFF and ISCST3 were run with identical meteorological data sets to compare their estimates. The meteorological data sets were synthesized to represent a variety of wind speeds in each of the six P-G stability categories (54 cases in all). ISC3 was run in the "regulatory default" mode and CALPUFF runs were configured to emulate this mode, which included the simulation of emission releases as *slugs* (versus *integrated puffs*). Receptors were located along a straight line ("due north") at successively distant intervals. Sources included three elevated point sources (35m, 100m and 200m). Surface releases included a 2m point source and a rectangular area source 500m on a side. A typical volume source was also examined. For point sources, model runs were done for two regimes, one in which the mixing height (Z_i) was set to 3000m, and the other for Z_i = 500m. The latter regime was explored to inspect CALPUFF's treatment of reflection. For each source type, a comparison matrix was created to assess comparison across all meteorological conditions in terms of a variety of robust statistical indicators.

For all point sources (with Z_i = 3000m), the results indicated good accord between the two dispersion models. For all meteorological conditions, the mean fractional bias across the receptor radial was well below 10%. Maximum residuals at any receptor were on the order of 0.1% of the concentration mean at the incident receptor. While a qualitative inspection of residuals as they appear along the receptor array indicated no distinct pattern of bias, a slight negative bias (CALPUFF relative to ISC3) is apparent for the 2m source, while the reverse is true for the elevated sources. For the low mixing height regime (Z_i = 500m), the comparison results were strikingly similar, suggesting that both CALPUFF and ISC3 treated reflection identically.

The area source was simulated with mixing height set to 3000m. One set of runs was done with initial σ_z set to 0, while the other was set to 2.5m. The best accord was seen for the former case, but for about one fifth of the cases, the mean fractional bias was greater than 10%. The maximum absolute residual was 33% of the concentration mean at the incident receptor. There was an apparent trend toward negative bias (CALPUFF relative to ISC3), but there was substantial variance as well. Mean residuals and mean standard deviations ranged over three orders of magnitude. Accord improved (and variance diminished) with higher wind speeds, which is expected as the slugs are stretched from the point of origin.

With a test version of ISC3 in which the virtual source treatment was "corrected", the models showed close agreement in their treatment of the volume source. Maximum absolute residual was well below one percent of respective concentration means at incident receptors. For all cases, mean fractional bias was zero. A very slight tendency for negative bias was seen for the stable stability categories, and (as for the area source) variance diminished with higher wind

speed. A qualitative inspection of residuals as they appear along the receptor array indicated slightly more bias for receptors in the near field of the source.

4.2 Variable Meteorological Conditions

To examine differences in model estimates when variable meteorological data are used, several studies were done. Actual full-year data sets from three climatologically different sites were used. The sites chosen were Boise, Idaho (1991), Medford, Oregon (1990) and Pittsburgh, Pennsylvania (1964). Using a synthesized meteorological data set, a preliminary set of studies was done to examine (1) differences in the way both models treat lateral σ's (CALPUFF was run using both *puffs* and *slugs*), and (2) *puff* versus *slug* differences within CALPUFF alone. Another study was done using the Boise data to examine the occurrence and location of concentration maxima estimated by ISC3 and the CALPUFF *puff* model. Then for all three sites, extensive sensitivity studies were done in which estimates by ISC3 were compared to CALPUFF (*puff* and *slug* models). In general, 36 - 45 receptors were placed on each of 15 concentric rings at successively more distant intervals.

In general, the differences between CALPUFF and ISC3 concentration results are caused by how emissions are transported and dispersed. CALPUFF limits downwind transport in based on the wind speed while there is no such limitation in ISC3 (it is a plume model). Under calm wind conditions, CALPUFF continues to disperse each puff while the ISC3 model is arbitrarily set to not determine concentrations when the wind speed is less than 1 ms^{-1}. CALPUFF is capable of tracking the puff emitted before, during and after wind shifts and reversals while ISC3 is only concerned with the current hour transport of its plume(s). CALPUFF continues to disperse each puff even when they are above an inversion layer while ISC3 determines its plume is above the inversion layer and cannot be advected to the ground (e.g,. concentrations = 0.0). When the inversion rises above the old puffs, they are dispersed to the ground creating impacts for any nearby receptors.

When all these and other meteorological conditions are recorded on an hourly basis and form a complete year of meteorological data, the effects on concentrations vary between the models and from region to region. The meteorologically induced variations in concentrations do not appear to be so much a regional phenomena, but the variations are related to how the hourly meteorological conditions occur preceding and during a given averaging period. It is possible to have 4 or 5 hours of winds in one general direction followed by 4 hours of calm winds, and then followed by several hours of reversed wind flow. This can occur in any one of the regions. However, the potential frequency of this occurrence may be higher for one region than another. Since calm winds have a causal relationship leading to higher concentrations, then a site such as Medford with a relatively greater incidence of calms (i.e., 22% calm hours versus the other regions having around 6%) will have higher concentrations associated with CALPUFF.

4.3 Conclusion

Even though ISC3 and CALPUFF can be made to produce the same concentrations in a steady state environment, a variable state environment can produce higher-than-ISC3 ground-level concentrations with CALPUFF. Climatological characteristics of a region appear to be a factor, but the accumulation of hour by hour meteorological conditions on the transport of CALPUFF puffs is the key to understanding the differences that are produced by these two models. This should come as no surprise as the meteorological assumptions used in formulating the downwind transport of the ISC3 and CALPUFF effluents and the dispersion from the respective plumes and puffs are different. This is also compounded by the different treatment of dispersion during calm wind conditions.

This complex interaction of transport, vertical mixing, and dispersion have an effect on concentrations with respect to downwind distances in CALPUFF. Occasionally, the accumulation of mass released over several hours will be transported in such a manner that the combined effect is to produce sharp localized maxima in simulated concentration values. The occurrence of such events is not predictable. It seems to occur with greater frequency at Medford. Calm winds play a part in these events. These maxima seem to occur at most locations in the receptor network, at all downwind distances. When they occur, they seem to affect in particular the results for the shorter averaging periods.

Overall trends have been noted in the percentage difference comparisons in simulated concentration values between CALPUFF and ISC3. For taller point sources, there is a trend toward higher concentrations being simulated by CALPUFF in comparison to ISC3. For annual averages, the closer a receptor is to the source and the taller the stack, the greater the chance that the CALPUFF concentration values will be higher than those simulated by ISC3. At the more distant downwind receptor rings, the bias changes direction from CALPUFF yielding higher concentrations, to CALPUFF yielding relatively lower concentrations and sometimes these concentrations are lower than their respective ISC3 counterpart.

5. References

1. Environmental Protection Agency, 1995. User's Guide for the Industrial Source Complex (ISC3) Dispersion Models. Volumes I - III. EPA-454/B-95-003a-c.

2. Environmental Protection Agency, 1995. A User's Guide for the CALPUFF Dispersion Model. EPA-454/B-95-006.

3. Environmental Protection Agency, 1995. SCREEN3 User's Guide. EPA-454/B-95-004.

Appendix A

Switch settings for CALPUFF input file to emulate ISC3's "Regulatory Default" mode

For these comparisons, CALPUFF was run to emulate ISC3's "regulatory mode" (i.e., default). Thus, to ensure equivalence for this emulation, certain of CALPUFF's switches were set as follows:

METFM	= 2	ASCII input file used for input
MSLUG	= 1	Puffs emitted as *slugs*
MDRY	= 0	Dry deposition NOT used, unless specified otherwise
MWET	= 0	Wet deposition NOT used, unless specified otherwise
MSHEAR	= 0	Vertical wind shear NOT modeled
WSCALM	= 0.9999	A value of 1 ms^{-1} for the calm wind speed threshold causes a rounding problem
AVET	= 3	Averaging times for σ's is 60 min; σ_y is adjusted as $(AVET/60)^{0.2}$
MTRANS	= 0	NO transitional plume rise (i.e., final plume rise only)
MDISP	= 3	PG dispersion coefficients for RURAL areas, computed using the ISC multi-segment approximation
MGAUSS	= 1	Vertical dispersion used in the near-field is Gaussian
MCHEM	= 0	NO chemical treatment used
MROUGH	= 0	PG σ_y and σ_z NOT adjusted for roughness
MPARTL	= 0	No partial plume penetration of elevated inversion
MCTADJ	= 1	ISC-type of terrain adjustment
MTIP	= 1	Stack tip downwash used
PLXO(6)		Default wind speed profile power-law exponents for P-G categories A-F
PTGO(2)		Default vertical Θ gradient (Km^{-1}) for stable P-G categories E & F

For all applicable sources, CALPUFF employs buoyancy induced dispersion (BID); a feature enabled in ISC3's regulatory mode. Consistent with ISC3's regulatory default mode, missing data processing was NOT used.

Appendix B

Meteorological conditions for the steady state CALPUFF/ISC3 comparisons[1]

P-G	Wind Speed (ms^{-1})												
A	1.0	1.5	2.0	2.5	3.0								
B	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0				
C	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	8.0	10.0		
D	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	8.0	10.0	15.0	20.0
E	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0				
F	1.0	1.5	2.0	2.5	3.0	3.5	4.0						

[1]Wind speed is at 10m and values are the same as those used in SCREEN3. For each combination of P-G stability category, comparisons for point sources were made with Z_i = 500m and 3000m. For the area and volume source, Z_i = 3000m.

Appendix C

Characteristics for sources used in the CALPUFF/ISC3 comparisons

Point Sources					
Stack height (m)	X,Y location & base elevation (m)	Emission rate (gs^{-1})	Exit velocity (ms^{-1})	Stack diameter (m)	Temperature (K)
2	0, 0, 0	100	10.0	0.5	300
35	0, 0, 0	100	11.7	2.4	432
100	0, 0, 0	100	18.8	4.6	416
200	0, 0, 0	100	26.5	5.6	425

Ground-level Area Source				
Area (m^2)	Length of side (m)	Emission rate ($gs^{-1}m^{-2}$)	Effective Release Height (m)	Initial σ_z (m)[1]
250,000	500	0.0004	1.0	2.5

Volume Source[2]	
Emission Rate (gs^{-1}):	1.0
Release height (m):	10
Initial σ_y (m):	50
Initial σ_z (m):	20

[1]In one set of comparisons, $\sigma_{z(ini)}$ was set to zero.

[2]Parameter values taken from Figure 9 of SCREEN3 User's Guide (Reference 3); buoyancy flux and momentum flux = 0; rural option.

Appendix D

Receptor array used in the steady state CALPUFF/ISC3 comparisons

Receptors are aligned along a 360° radial at these distances (m):

1	100	32	4000
2	200	33	4500
3	300	34	5000
4	400	35	5500
5	500	36	6000
6	600	37	6500
7	700	38	7000
8	800	39	7500
9	900	40	8000
10	1000	41	8500
11	1100	42	9000
12	1200	43	9500
13	1300	44	10000
14	1400	45	15000
15	1500	46	20000
16	1600	47	25000
17	1700	48	30000
18	1800	49	35000
19	1900	50	40000
20	2000	51	45000
21	2100	52	50000
22	2200	53	55000
23	2300	54	60000
24	2400	55	65000
25	2500	56	70000
26	2600	57	75000
27	2700	58	80000
28	2800	59	85000
29	2900	60	90000
30	3000	61	95000
31	3500	62	100000

Appendix E

Puffs versus Slugs: CALPUFF's Two Simulation Modes

CALPUFF may be operated in one of two modes for simulating emissions: *puff* or *slug*. In the *puff* mode, a continuous plume is represented as a number of discrete packets of pollutant material. Most puff models evaluate the contributions of a puff to the concentration at a receptor by a "snapshot" approach, where each puff is "frozen" at particular time intervals, the concentration due to the frozen puff at that time is computed, and the puff is then allowed to move, evolving in size, strength, etc. until the next sampling step. The total concentration at a receptor is the sum of the contributions of all nearby puffs averaged for all sampling steps within the basic time step. A traditional drawback of the puff approach has been the need for the release of many puffs to adequately represent a continuous plume close to the source. Another potential problem arises if the puffs do not overlap sufficiently, causing concentrations at receptors located in the gap between puffs at the time of the "snapshot" to be underestimated, while those at the puff centers are overestimated. One alternative to the problems posed by the "snapshot" approach is the use of the integrated sampling function (originally implemented in MESOPUFF II). This technique is available in CALPUFF as the *integrated puff* approach, and is fully described in Section 2.1.1 of the CALPUFF User's Guide (Reference 2).

Another approach available in CALPUFF uses a non-circular puff (*slug*) elongated in the direction of the wind to eliminate the need for frequent releases of puffs. Thus in the *slug* model, the "puffs" consist of Gaussian packets of pollutant material stretched in the along wind direction. A slug can be visualized as a group of overlapping circular puffs having very small puff separation distances. Actually, the slug represents the continuous emission of puffs, each containing an infinitesimal mass. The concentrations near the endpoints of the slug (both inside and outside of the body of the slug) fall off in such a way that if adjacent slugs are present, the plume predictions will be reproduced when the contributions of those slugs are included (and this is with steady state conditions). As with circular puffs, each slug is free to evolve independently in response to local effects of dispersion, chemical transformation, removal, etc. However, unlike puffs, the endpoints of adjacent slugs are constrained to remain connected (like country sausages). This ensures continuity of a simulated plume without the gaps associated with the puff approach. It should be noted that all receptors lying outside of the slug's $\pm 3\sigma_y$ envelope during the entire averaging time interval are eliminated from consideration. And for those receptors remaining, integration time limits are computed such that sampling is not performed when the receptor is outside of the $\pm 3\sigma_y$ envelope. This technique is available in CALPUFF as the *slug* approach, and is fully described in Section 2.1.2 of the CALPUFF User's Guide (Reference 2).

When initial CALPUFF runs were made for point sources, a disparity was seen between concentration estimates produced by CALPUFF run in the *slug* mode versus those produced by ISC3. This discrepancy was unexpected and the matter was brought to the attention of Earth Tech (CALPUFF's developer). Earth Tech determined that the reason the *slug* model in Version *960612* did not reproduce the plume model (ISC3) was due to the computation algorithm for sigmas. In the *960612* version, the receptor-specific sigma was computed by determining the

sigma that the puff would have at the receptor, even if the puff hasn't reached the receptor yet (as does a plume model). This gave nearly exact reproduction of plume results under steady-state conditions.

However, under non-steady conditions and very high sigma growth rates (e.g., under P-G category *A*), this extrapolation can produce puff impacts prematurely (and hence the *causality* effect is compromised somewhat). Therefore, the sigmas were "clipped" at the value at the end of the slug when the receptor is beyond the end of the slug. This arrangement did reasonably well for *causality* effects, but caused some deviation from the plume results under steady state conditions.

As a result of Earth Tech's investigation of this disparity, an experimental version of CALPUFF was made available to EPA for the purposes of this comparison, and all analyses were done with this version. This version compromised between the two solutions described above. The version only allows concentrations to be computed for receptors that are within 4 σ_x (where σ_x is the horizontal puff dispersion parameter) of a puff centroid. This technique was seen to perform much better with respect to both treating *causality* and reproducing plume results, and will be incorporated in the next model to be released (Joe Scire, *pers. comm.*, December 1997).

Appendix F

Summary statistics from performance matrix - point sources (Z_i = 3000m)

Emissions simulated as:	SLUGS[a]
$\overline{\%R}_{min}$ (%)	-0.04 (C1H200)
$\overline{\%R}_{max}$ (%)	0.13 (D1H100)
$R_{i(min)}$ (μgm^{-3})	-8.0 (A3H2 @ 100m)[b]
$R_{i(max)}$ (μgm^{-3})	25.0 (F2p5H2 @ 500m)[c]
$\bar{R}_{min}$ (μgm^{-3})	-0.1 (see footnote e)
$\bar{R}_{max}$ (μgm^{-3})	0.4 (F2p5H2)
$\sigma_{R(min)}$ (μgm^{-3})	0.0 (see footnote e)
$\sigma_{R(max)}$ (μgm^{-3})	3.2 (F2p5H2)
# cases $\overline{FB}$ "out of range":[d]	NONE
$\overline{FB}_{min}$	0.0 (see footnote e)
$\overline{FB}_{max}$	0.02 (D20H100)
$FB_{i(min)}$	-0.18 (A1H2 @ 100km)
$FB_{i(max)}$	0.53 (D20H100 @ 800m)

[a]See text for explanation of (C1H200), etc.

[b]This value for R_i is 0.03% of $\bar{\chi}$ $\left(= \frac{\chi_{CALPUFF} + \chi_{ISC3}}{2}\right)$ at this receptor. $\chi_{CALPUFF}$ = 24836 μgm^{-3}; χ_{ISC3} = 24844 μgm^{-3}

[c]This value for R_i is 0.13% of $\bar{\chi}$ at this receptor. $\chi_{CALPUFF}$ = 19040 μgm^{-3}; χ_{ISC3} = 19015 μgm^{-3}

[d]There were 216 distinct cases. The "goal" for this range is: $-0.10 \le \overline{FB} \le 0.10$

[e]There is no unique run associated with this value.

Appendix G

Summary statistics from performance matrix - area source (emissions simulated as *slugs*)

Initial σ_y (m):	0	2.5
$\overline{\%R}_{min}$ (%)	-1.5 (F1AREA)	-3.2 (F1AREA)
$\overline{\%R}_{max}$ (%)	-0.07 (see footnote a)	-0.66 (see footnote a)
$R_{i(min)}$ (μgm^{-3})	-1537 (F1AREA @ 3500m)[b]	-4212 (F1AREA @ 300m)
$R_{i(max)}$ (μgm^{-3})	561 (E1AREA @ 100m)[c]	0.08 (A1AREA @ 85km)
$\bar{R}_{min}$ (μgm^{-3})	-548 (F1AREA)	-969 (F1AREA)
$\bar{R}_{max}$ (μgm^{-3})	-1.1 (D20AREA)	-10.5 (D20AREA)
$\sigma_{R(min)}$ (μgm^{-3})	2.4 (D20AREA)	28.3 (D20AREA)
$\sigma_{R(max)}$ (μgm^{-3})	510 (F1AREA)	895 (F1AREA)
# cases $\overline{FB}$ "out of range":[d]	10	19
$\overline{FB}_{min}$	-0.16 (see footnote a)	-0.19 (F1AREA)
$\overline{FB}_{max}$	-0.02 (see footnote a)	-0.04 (see footnote a)
$FB_{i(min)}$	-0.39 (E1AREA @ 4000m)	-0.40 (E1AREA @ 4000m)
$FB_{i(max)}$	0.05 (A1AREA @ 85km)	0.05 (A1AREA @ 85km)

[a]There is no unique run associated with this value.

[b]This value for R_i is 33% of $\bar{\chi}$ ($= \frac{\chi_{CALPUFF} + \chi_{ISC3}}{2}$) at this receptor. $\chi_{CALPUFF} = 3869\ \mu gm^{-3}$; $\chi_{ISC3} = 5406\ \mu gm^{-3}$

[c]This value for R_i is 2.2% of $\bar{\chi}$ at this receptor. $\chi_{CALPUFF} = 25719\ \mu gm^{-3}$; $\chi_{ISC3} = 25158\ \mu gm^{-3}$

[d]There are 54 distinct cases. The "goal" for this range is: $-0.10 \le \overline{FB} \le 0.10$

Appendix H

ISCST3's Treatment of Virtual Sources

For volume sources and point sources subject to building wake dispersion, ISC3 makes use of a *virtual source* to simulate an initial plume size. That is, if a source has a finite size at the point of release, its initial σ_y and σ_z are "matched" to a point on the corresponding dispersion curve. Because these curves prescribe the dispersion parameters as a function of distance (starting with a value of zero at a downwind distance equal to zero), matching the curve to a source with a non-zero initial sigma entails shifting the apparent position of the source upwind. This shift is known as the *virtual position* of the source. If x_v denotes the distance of the virtual location of the source upwind of its actual location, then the value of the dispersion parameter at some distance (x) downwind of the source should be evaluated at the modified distance $(x + x_v)$.

ISC3 adopts this general method, but modifies its implementation in the following way. Because the P-G curves for σ_z are expressed as the function ax^b, where the parameters a and b themselves depend on the distance, "the ISC model programs check to ensure that the x_v used to calculate σ_z at $(x + x_v)$ is calculated using coefficients a and b that correspond to the distance category specified by the quantity $(x + x_v)$." (Vol. II of the ISC3 User's Guide (Section 1.1.5.2, p. 1-20) with the notation for the virtual distance changed from x_z to x_v. The term x_v is calculated using Equation 1-36.)

The result of this implementation is that the virtual distance becomes a function of receptor distance downwind of the source, and in fact x_v is reevaluated at each receptor the plume encounters as it moves downwind. Thus, the computed curve of σ_z as a function of distance is no longer the continuous P-G curve. This error is illustrated in the following figures. ISC3 was applied to a volume source with an initial σ_z of 5m and 20m, respectively, and concentrations were obtained at receptors within 1000m, for both P-G stability classes A and F (Figs. H-1 to H-4). Using strategically placed write statements in CALC1.FOR (one of ISCST3's files), the computed virtual distances and the corresponding σ_z values were written to a diagnostic file. These values were then plotted in the figures below as open squares (virtual distances) and as solid circles (σ_z) in the figures below. Figures H-1 and H-2 are for the P-G A stability category, while Figures H-3 and H-4 are for P-G F.

In Figure H-1, the virtual distance begins at 33.76m, and grows in steps corresponding to the "distance ranges" (Table 1-3 of Vol. II) for this P-G curve to almost 120m. The corresponding σ_z values "jump" each time a new virtual distance is used. The same phenomenon can be seen in the other figures, and the departure (ISC3 σ_z versus P-G σ_z) increases with downwind distance. Had more receptors been placed near each of the transition points, a clear "break" in the σ_z curve would have been resolved.

For the purpose of the CALPUFF/ISC3 comparison, ISCST3 was re-configured so that a single value of the virtual distance is computed as a joint function of P-G category and initial σ_z, with due regard for the distance ranges imposed on selecting a & b. This single value is then added to all receptor distances, and the corresponding value for σ_z computed. Figure H-1 indicates the resulting contour (depicted with open triangles) and suggests the *continuous* P-G curve for stability class A, for a virtual location 33.76m upwind of x = 0m.

A version of ISC3 with a corrected virtual source algorithm (dated *97363*), as was used in this comparison, was released in January 1998 and uploaded to EPA's SCRAM web site for public use.

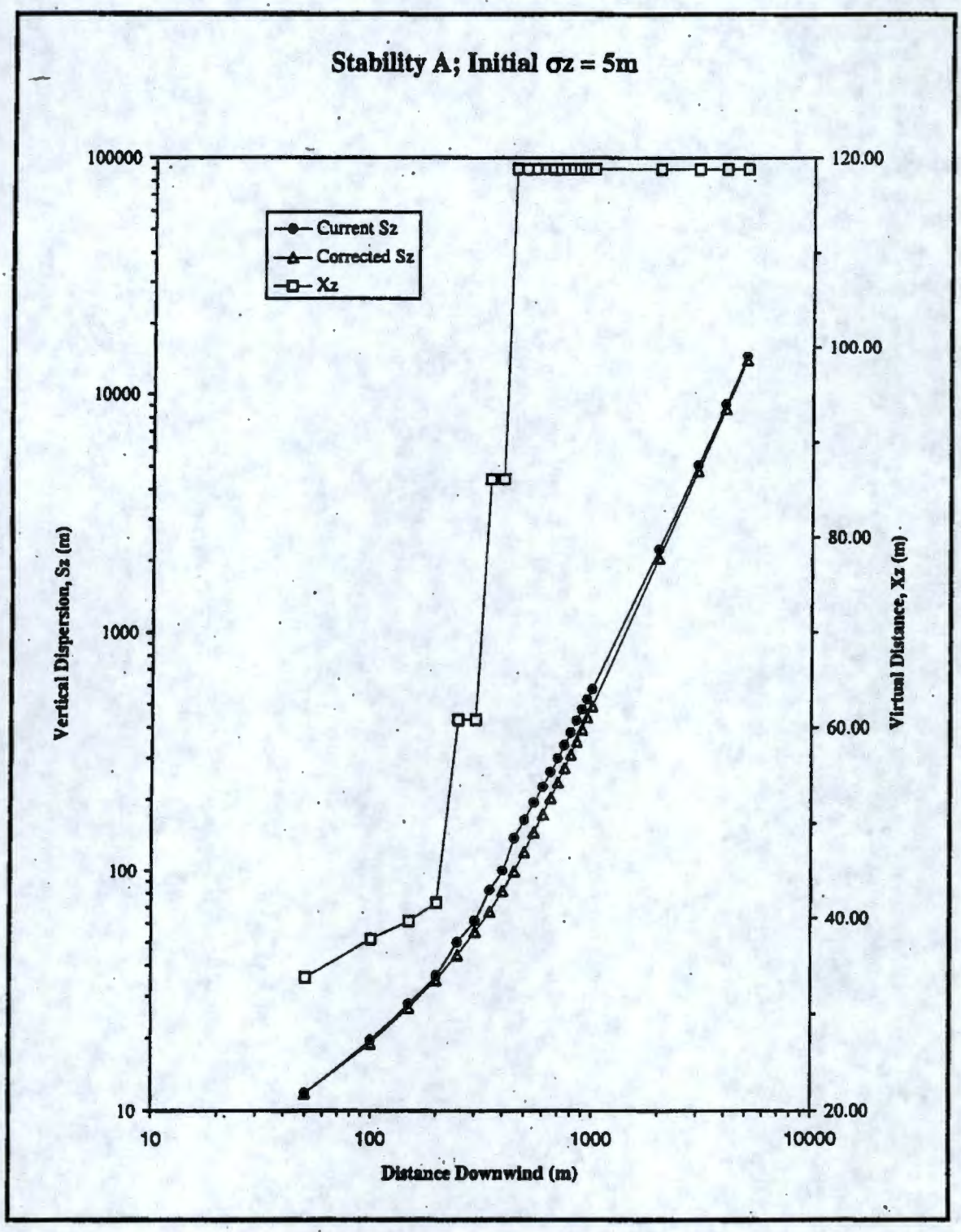


Figure H-1. Profile of σ_z with distance (m); P-G A and $\sigma_{z(init)}$ = 5m.

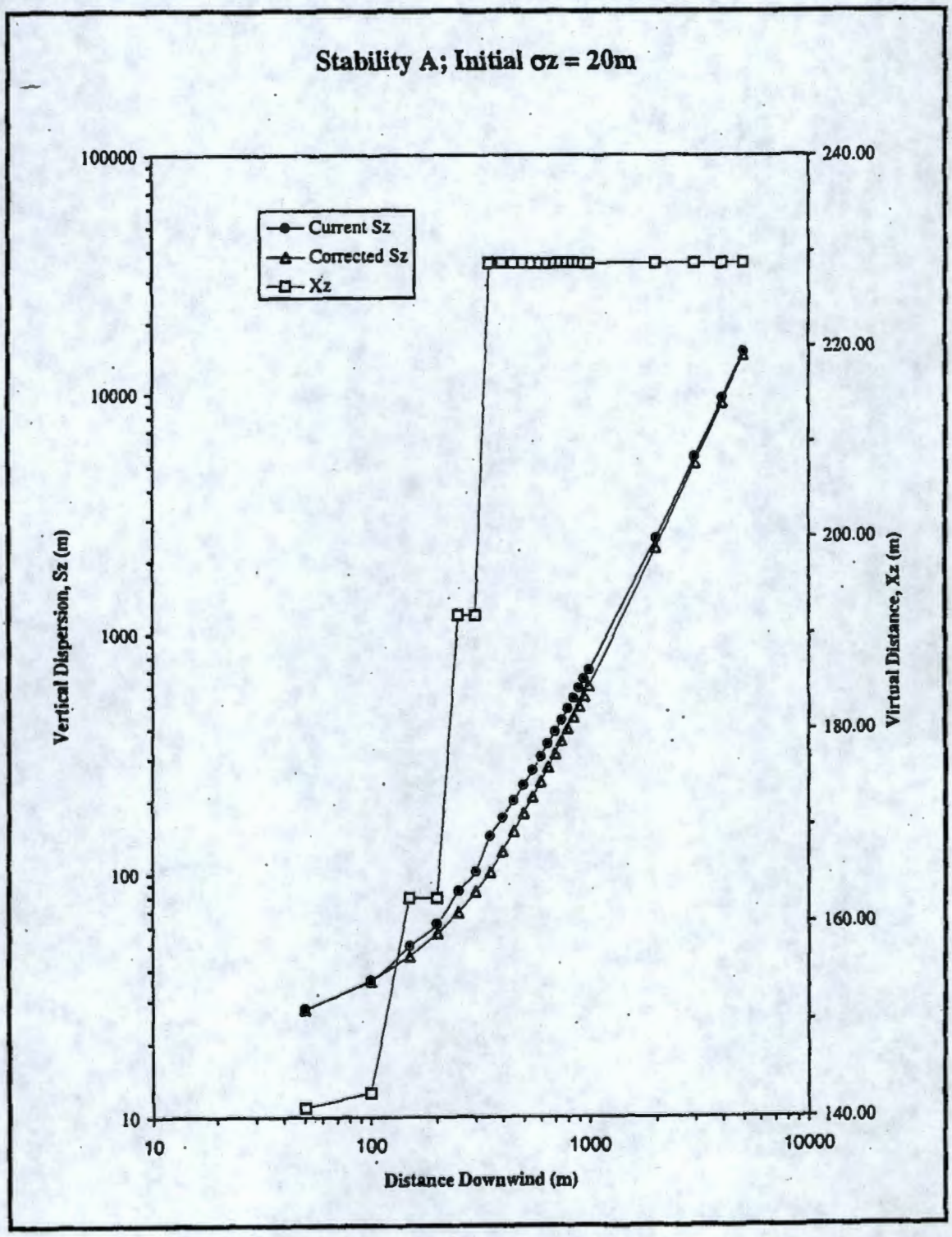


Figure H-2. Profile of σ_z with distance (m); P-G A and $\sigma_{z(init)}$ = 20m.

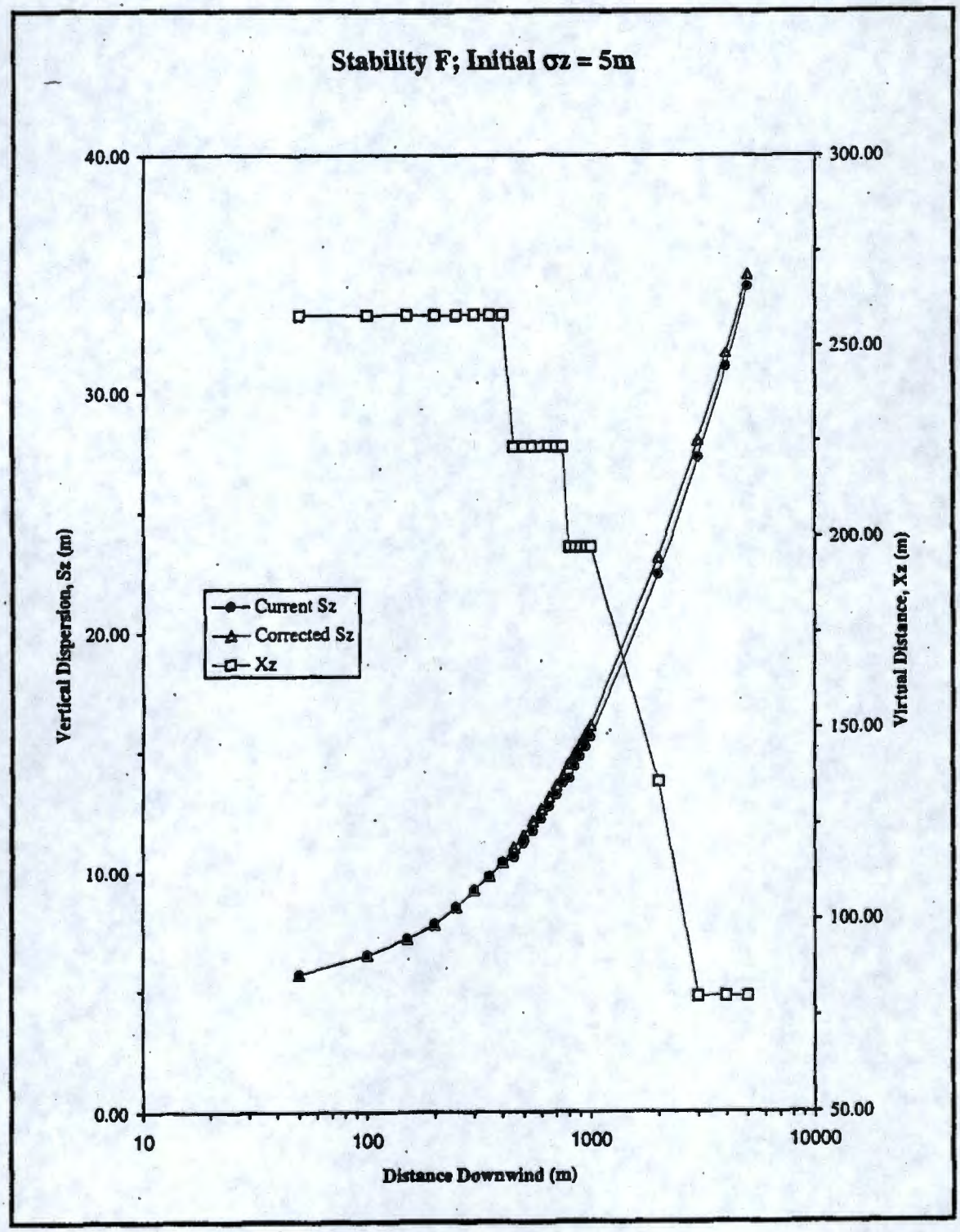


Figure H-3. Profile of σ_z with distance (m); P-G F and $\sigma_{z(init)}$ = 5m.

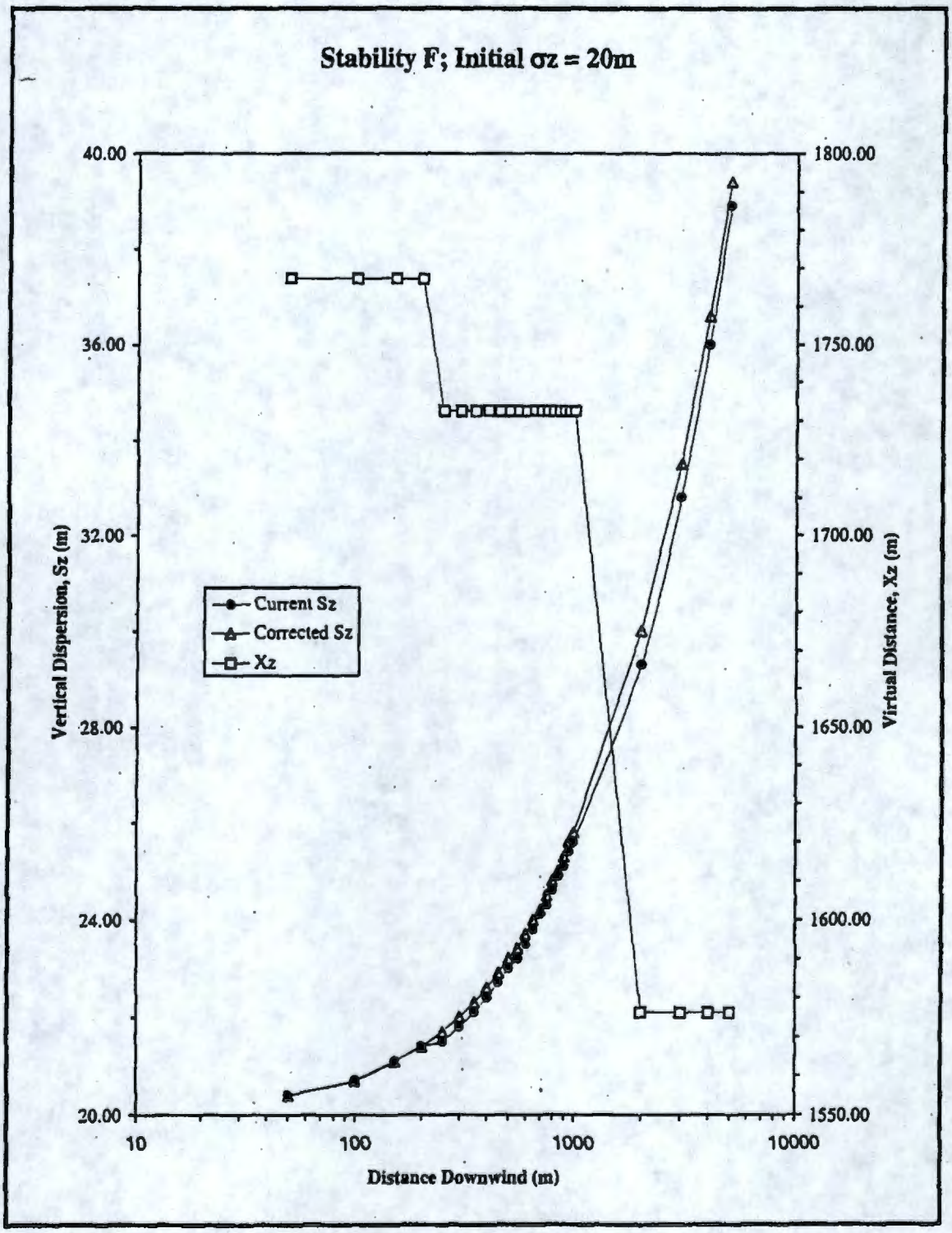


Figure H-4. Profile of σ_z with distance (m); P-G F and $\sigma_{z(init)}$ = 20m.

Appendix I

Summary statistics from performance matrix - volume source

Emissions simulated as:	SLUGS
$\overline{\%R}_{min}$ (%)	-0.07 (see footnote a)
$\overline{\%R}_{max}$ (%)	0.01 (see footnote a)
$R_{i(min)}$ (μgm^{-3})	-0.92 (F1VOL @ 200m)[b]
$R_{i(max)}$ (μgm^{-3})	0.15 (C1VOL @ 200m)[c]
$\bar{R}_{min}$ (μgm^{-3})	-0.2 (F1VOL)
$\bar{R}_{max}$ (μgm^{-3})	0.0 (see footnote a)
$\sigma_{R(min)}$ (μgm^{-3})	0.0 (see footnote a)
$\sigma_{R(max)}$ (μgm^{-3})	0.22 (F1VOL)
# cases $\overline{FB}$ "out of range":[d]	NONE
$\overline{FB}_{min}$	0.0 (see footnote a)
$\overline{FB}_{max}$	0.0 (see footnote a)
$FB_{i(min)}$	-0.18 (A1VOL @ 100km)
$FB_{i(max)}$	0.06 (A1VOL @ 85km)

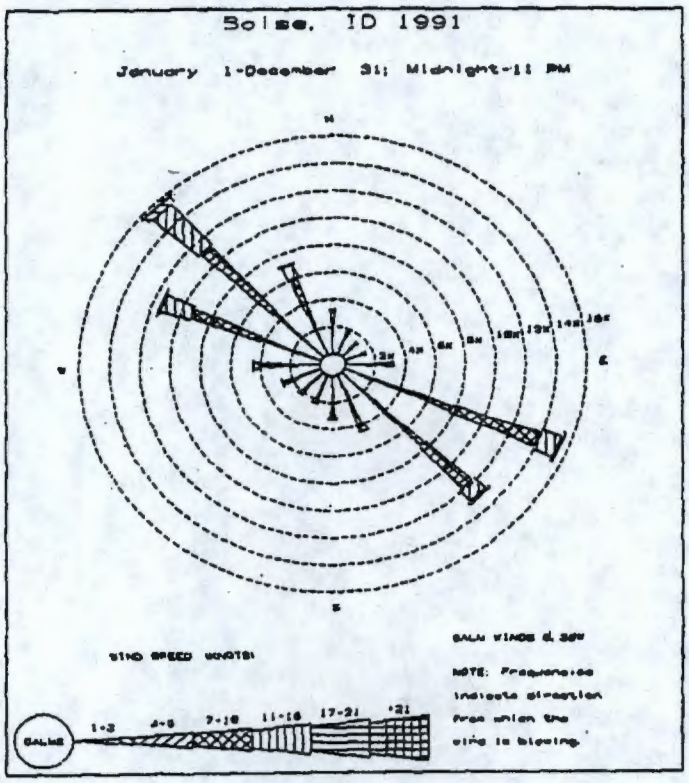
[a]There is no unique run associated with this value.

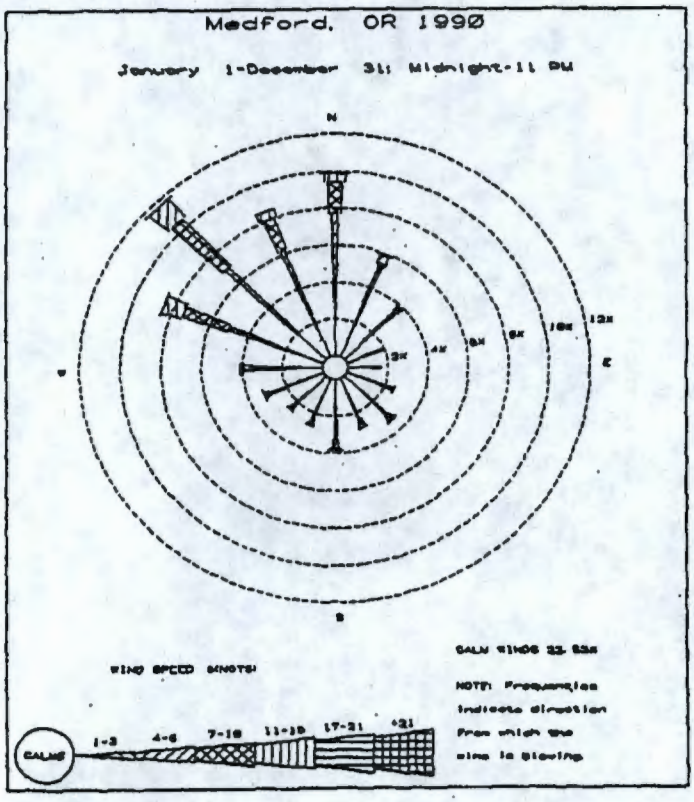
[b]This value for R_i is 0.4% of $\bar{\chi}$ $\left(= \frac{\chi_{CALPUFF} + \chi_{ISC3}}{2}\right)$ at this receptor. $\chi_{CALPUFF} = 238.6\ \mu gm^{-3}$; $\chi_{ISC3} = 239.5\ \mu gm^{-3}$

[c]This value for R_i is 0.1% of $\bar{\chi}$ at this receptor. $\chi_{CALPUFF} = 135.1\ \mu gm^{-3}$; $\chi_{ISC3} = 135.0\ \mu gm^{-3}$

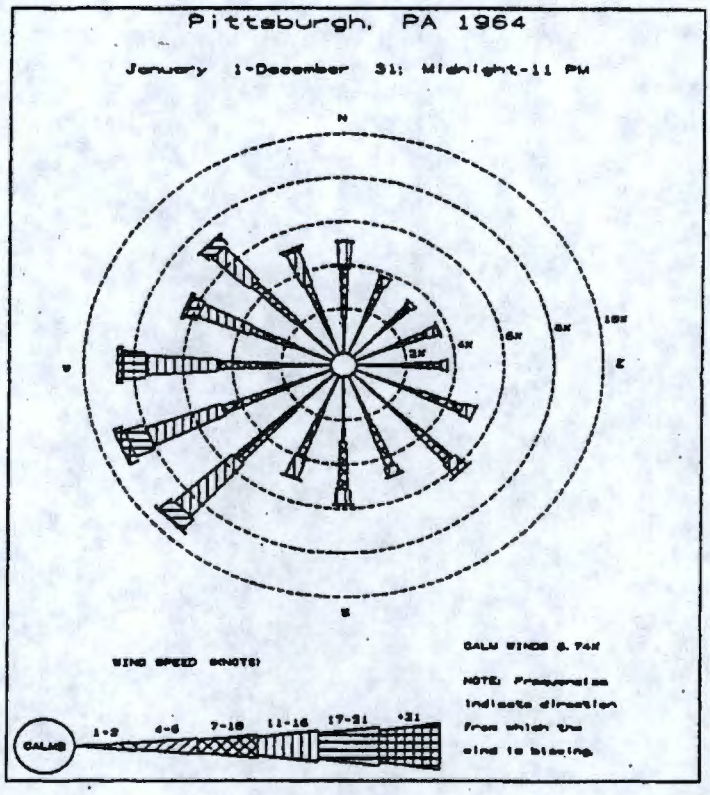
[d]There were 54 distinct cases. The "goal" for this range is: $-0.10 \le \overline{FB} \le 0.10$

Appendix J
Wind Rose Patterns





Appendix J, continued.



Appendix K

CALPUFF Concentrations Estimated by *Integrated Puff* and *Slug* Model

Coordinates		Hour 1	Hour 2	
X	Y	Puff	Puff	Slug
0	0.5	0	0	0
0	1	0	0	0
0	2	0	0	0
0	3	0	0	0
0	5	0	0	0
0.09	0.49	0	4400.88	4011.7
0.17	0.99	0	4606.96	3785.43
0.35	1.97	0	2366.87	1525.9
0.52	2.95	0	1408.23	658.51
0.87	4.92	0	670.78	74.94
0.17	0.47	0	0	75.18
0.34	0.94	0	0	211.99
0.68	1.88	0	0	284.43
3.19	2.82	0	0	271.96
1.71	4.7	0	0	233.71
0.25	0.43	0	0	93.83
0.5	0.87	0	0	234.87
1	1.73	0	0	284.04
1.5	2.6	0	0	266.32
2.5	4.33	0	0	229.02
0.32	0.38	0	0	108.62
0.64	0.77	0	0	248.26
1.29	1.53	0	0	282.78
1.93	2.3	0	0	262.57
3.21	3.83	0	0	226.52
0.38	0.32	0	0	118.39
0.77	0.64	0	0	254.07
1.53	1.29	0	0	261.61
2.3	1.93	0	0	261.61
3.83	3.21	0	0	226.13
0.43	0.25	0	0	122.47
0.87	0.5	0	0	255.92
1.73	1	0	0	281.55
2.6	1.5	0	0	261.75
4.33	2.5	0	0	227.49
0.47	0.17	0	0	120.31
0.94	0.34	0	0	254.23
1.88	0.68	0	0	282.08
2.82	1.03	0	0	263.61
4.7	1.71	0	0	230.65
0.49	0.09	4445.83	0	103.69
0.99	0.17	4593.7	0	234.05
1.97	0.35	2440.53	0	269.69
2.95	0.52	1413.91	0	254.14
4.92	0.87	678.28	0	226.08
0.5	0	0	0	0

Puff vs. ISC3

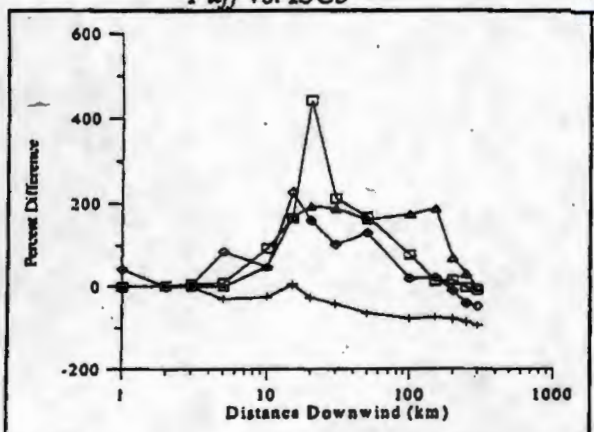


Figure L-1(a). Boise meteorological data.

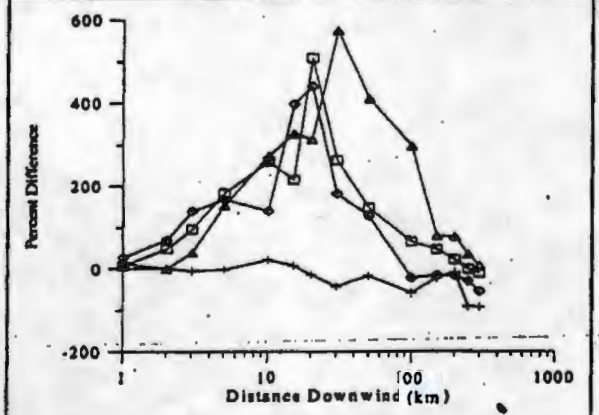


Figure L-1(c). Medford meteorological data.

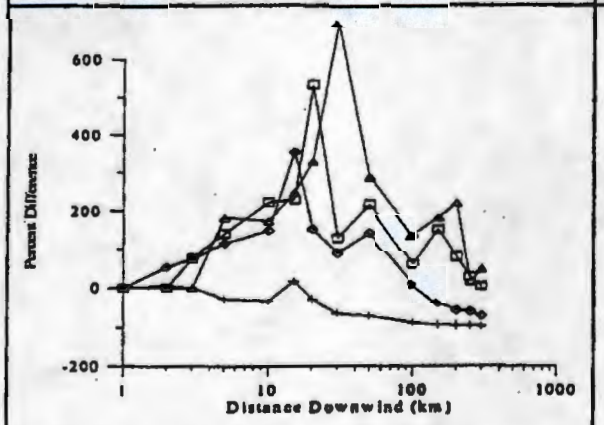


Figure L-1(e). Pittsburgh meteorological data.

Slug vs. ISC3

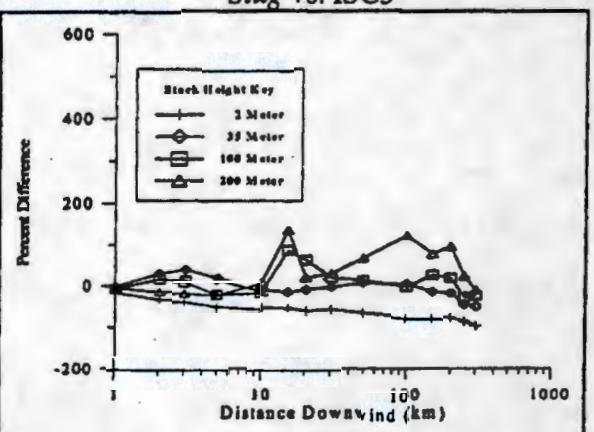


Figure L-1(b). Boise meteorological data.

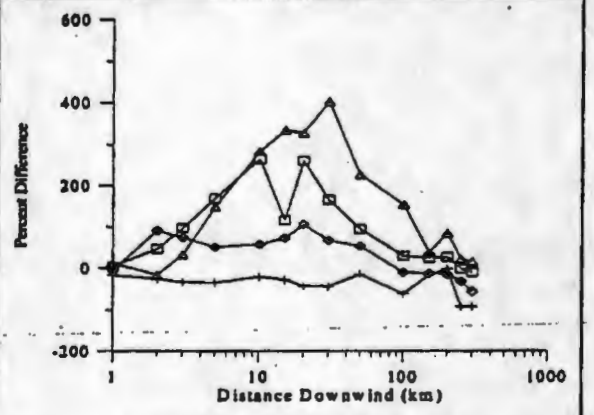


Figure L-1(d). Medford meteorological Data.

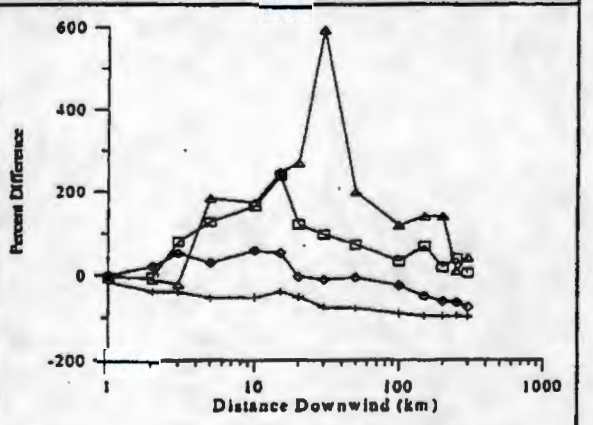


Figure L-1(f). Pittsburgh meteorological data.

Figure L-1. Maximum 1-hour average concentrations by distance. Figures a, c, & e show CALPUFF *puffs*, whereas figures b, d, & f show *slugs*.
Note: $\%\ Difference = 100\left(\frac{\chi_{CALPUFF} - \chi_{ISC3}}{\chi_{ISC3}}\right)$.

Puff vs. ISC3

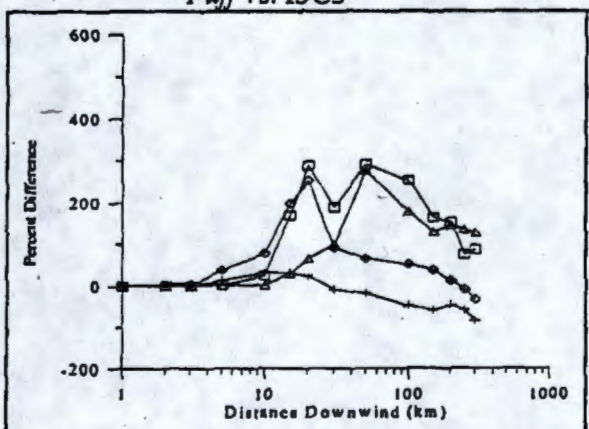


Figure L-2(a). Boise meteorological data.

Slug vs. ISC3

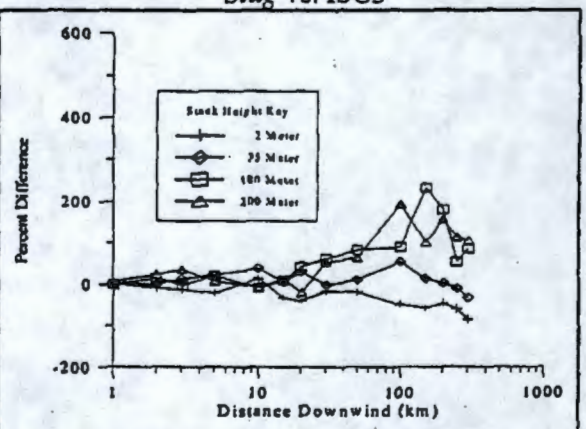


Figure L-2(b). Boise meteorological data.

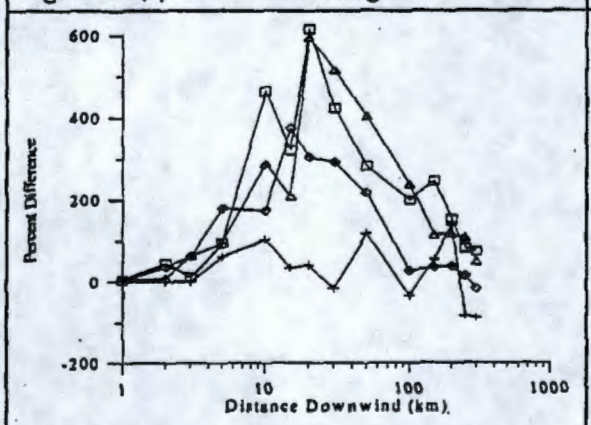


Figure L-2(c). Medford Meteorological Data.

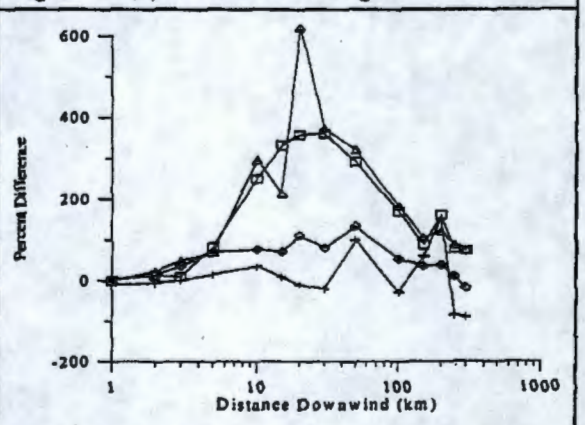


Figure L-2(d). Medford meteorological Data.

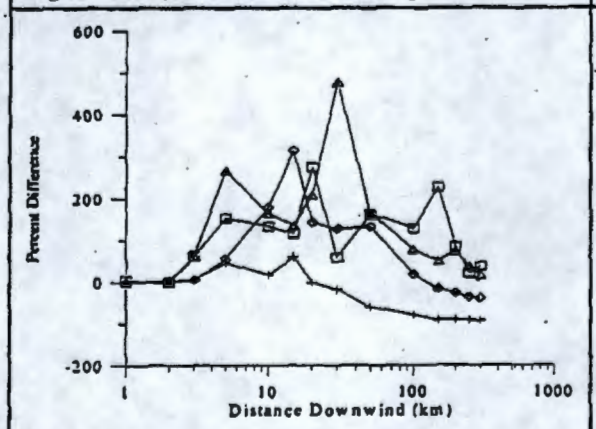


Figure L-2(e). Pittsburgh meteorological data.

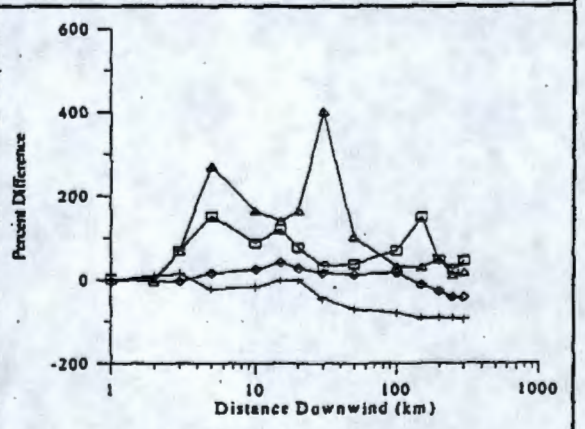


Figure L-2(f). Pittsburgh meteorological data.

Figure L-2. Maximum 3-hour average concentrations by distance. Figures a, c, & e show CALPUFF *puffs*, whereas figures b, d, & f show *slugs*.
Note: $\%\ Difference = 100\left(\frac{\chi_{CALPUFF} - \chi_{ISC3}}{\chi_{ISC3}}\right)$.

Puff vs. ISC3

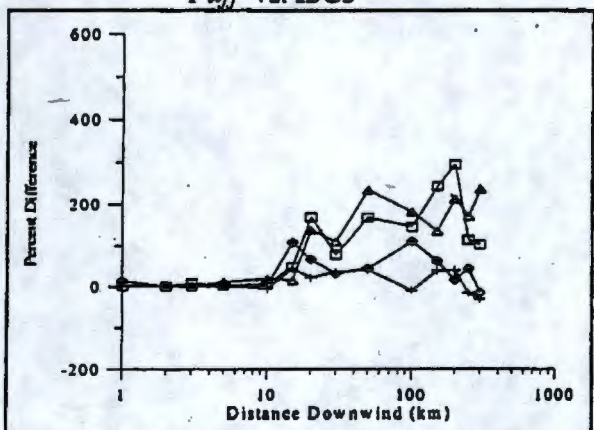


Figure L-3(a). Boise meteorological data.

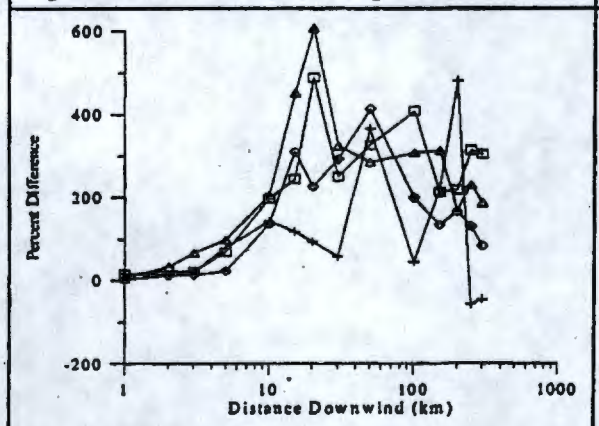


Figure L-3(c). Medford meteorological data.

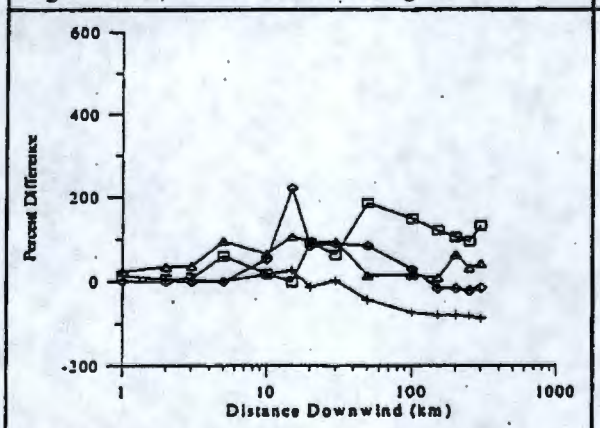


Figure L-3(e). Pittsburgh meteorological data.

Slug vs. ISC3

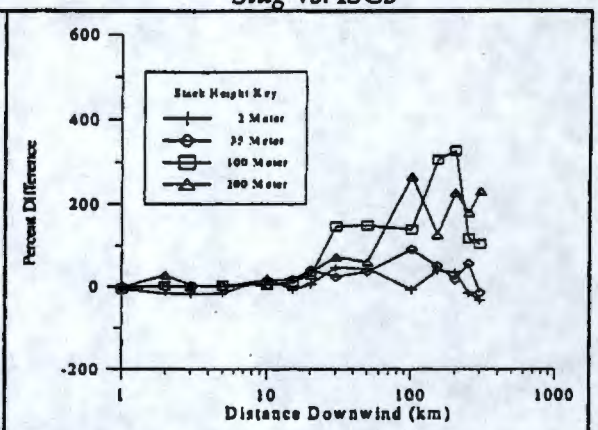


Figure L-3(b). Boise meteorological data.

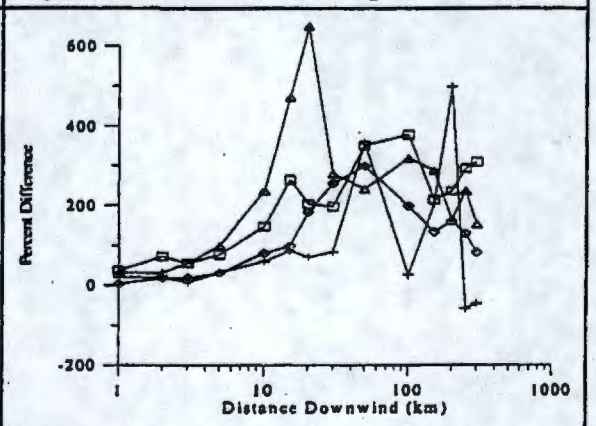


Figure L-3(d). Medford meteorological data.

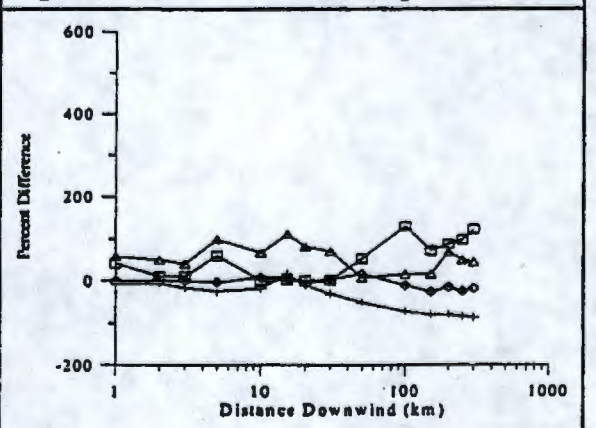


Figure L-3(f). Pittsburgh meteorological data.

Figure L-3. Maximum 24-hour average concentrations by distance. Figures a, c, & e show CALPUFF *puffs*, whereas figures b, d, & f show *slugs*.
Note: $\%\ Difference = 100\left(\frac{\chi_{CALPUFF} - \chi_{ISC3}}{\chi_{ISC3}}\right)$.

Puff vs. ISC3 | *Slug* vs. ISC3

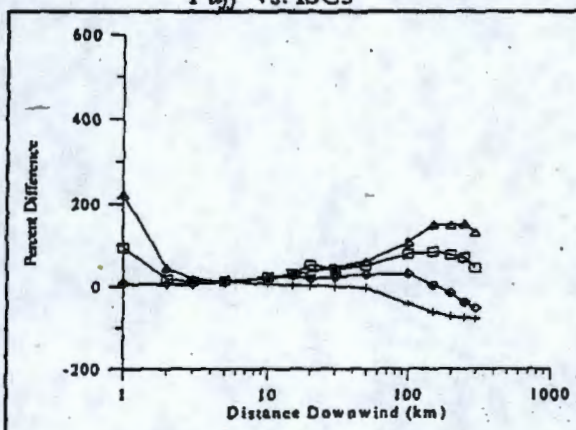


Figure L-4(a). Boise meteorological data.

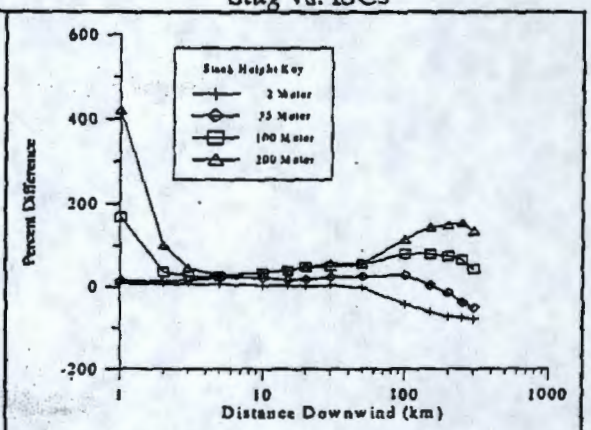


Figure L-4(b). Boise meteorological data.

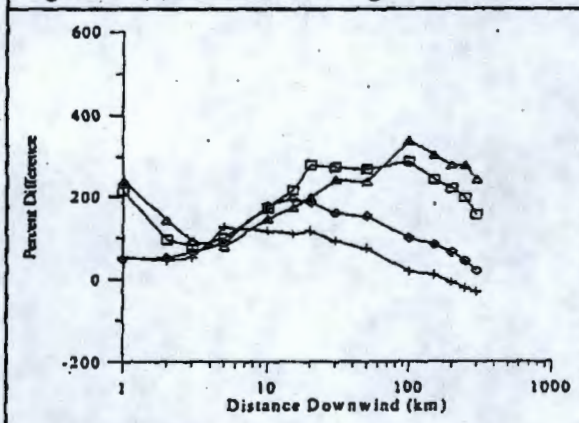


Figure L-4(c). Medford meteorological data.

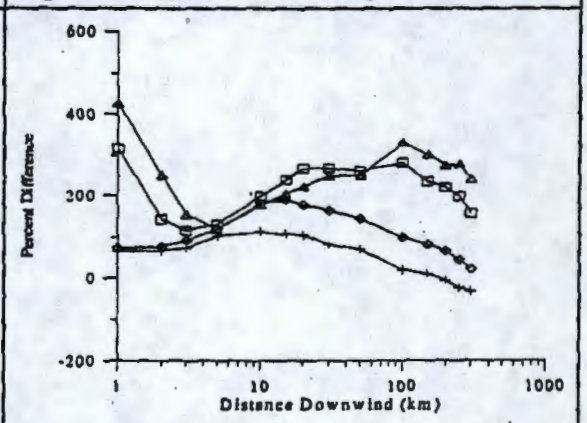


Figure L-4(d). Medford meteorological data.

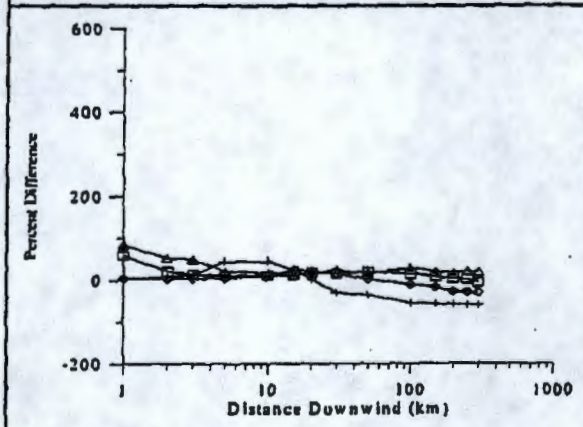


Figure L-4(e). Pittsburgh meteorological data.

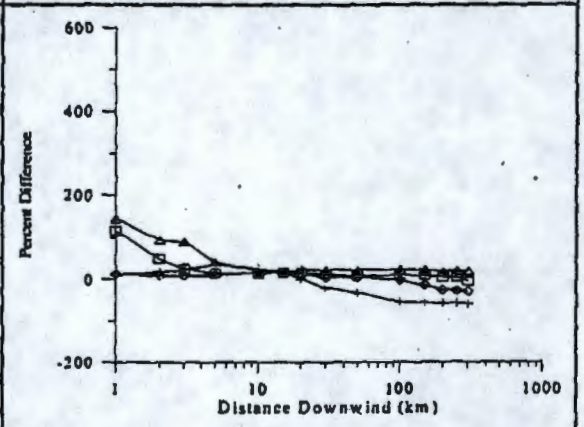


Figure L-4(f). Pittsburgh meteorological data.

Figure L-4. Maximum annual average concentrations by distance. Figures a, c, & e show CALPUFF *puffs*, whereas figures b, d, & f show *slugs*.
Note: $\%\ Difference = 100\left(\frac{\chi_{CALPUFF} - \chi_{ISC3}}{\chi_{ISC3}}\right)$.

Puff vs. ISC3 | *Slug* vs. ISC3

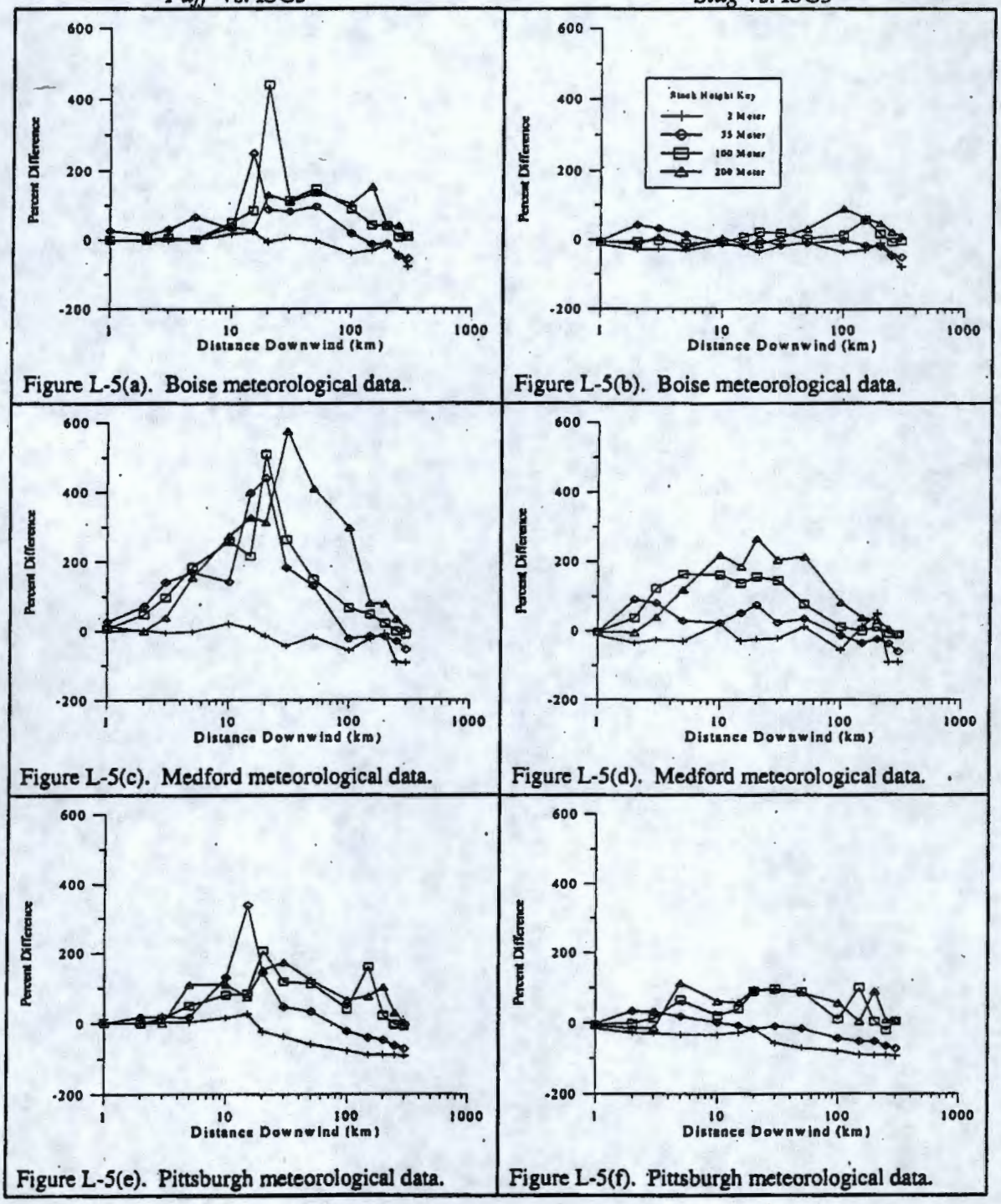


Figure L-5(a). Boise meteorological data.

Figure L-5(b). Boise meteorological data.

Figure L-5(c). Medford meteorological data.

Figure L-5(d). Medford meteorological data.

Figure L-5(e). Pittsburgh meteorological data.

Figure L-5(f). Pittsburgh meteorological data.

Figure L-5. Highest of the second highest 1-hour average concentrations by distance. Figures a, c, & e show CALPUFF *puffs*, whereas figures b, d, & f show *slugs*.
Note: $\% \ Difference = 100 \left(\frac{\chi_{CALPUFF} - \chi_{ISC3}}{\chi_{ISC3}}\right)$.

Puff vs. ISC3 | *Slug* vs ISC3

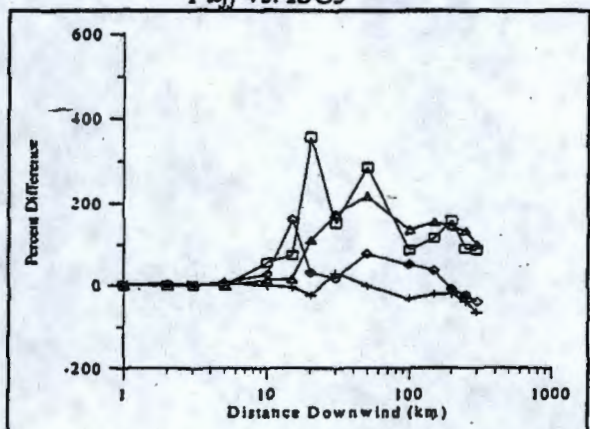


Figure L-6(a). Boise meteorological data.

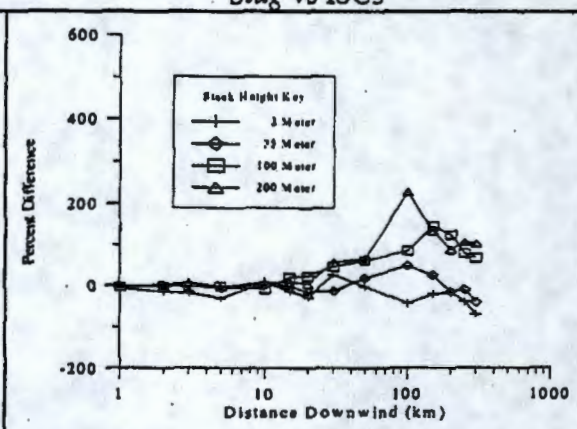


Figure L-6(b). Boise meteorological data.

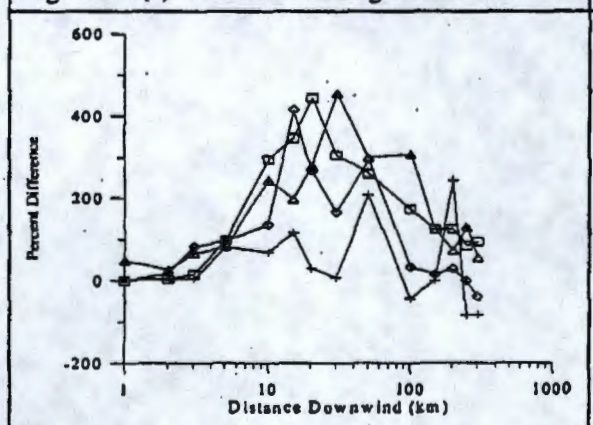


Figure L-6(c). Medford meteorological data.

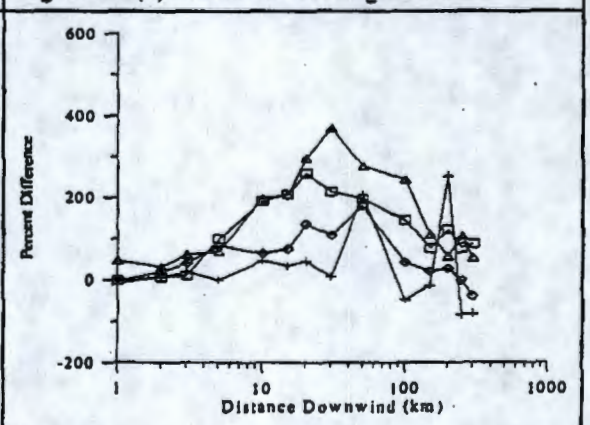


Figure L-6(d). Medford meteorological data.

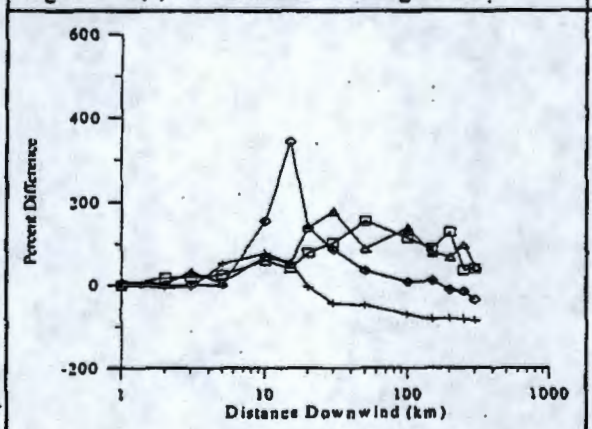


Figure L-6(e). Pittsburgh meteorological data.

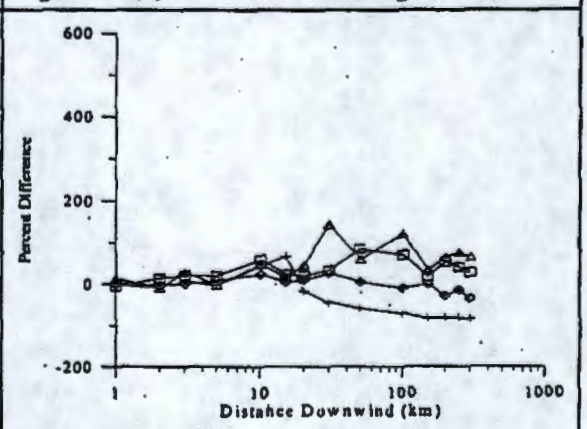


Figure L-6(f). Pittsburgh meteorological data.

Figure L-6. Highest of the second highest 3-hour average concentrations by distance. Figures a, c, & e show CALPUFF *puffs*, whereas figures b, d, & f show *slugs*.
Note: $\% \ Difference = 100 \left(\frac{\chi_{CALPUFF} - \chi_{ISC3}}{\chi_{ISC3}}\right)$.

Puff vs. ISC3 | *Slug* vs. ISC3

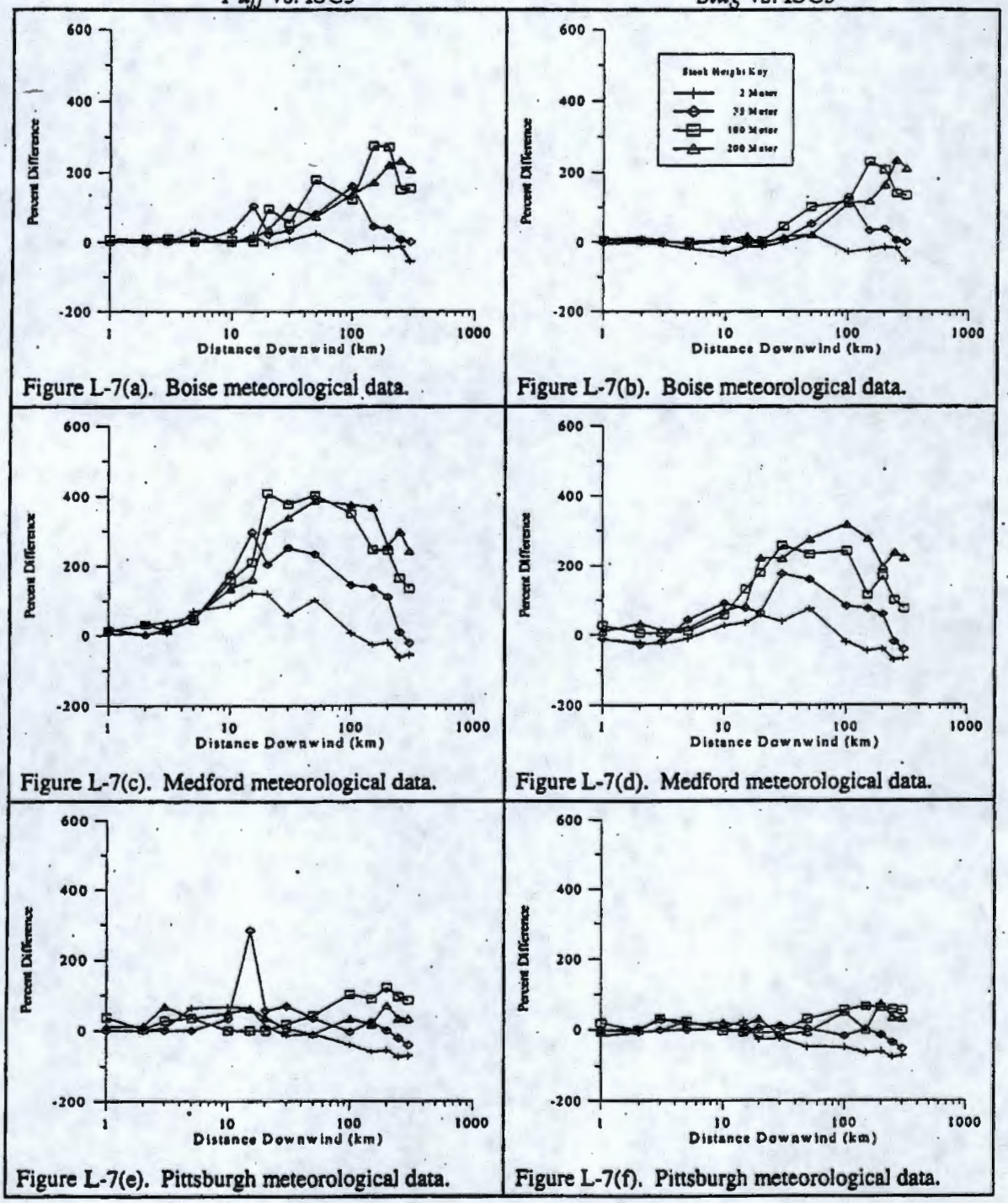


Figure L-7(a). Boise meteorological data.

Figure L-7(b). Boise meteorological data.

Figure L-7(c). Medford meteorological data.

Figure L-7(d). Medford meteorological data.

Figure L-7(e). Pittsburgh meteorological data.

Figure L-7(f). Pittsburgh meteorological data.

Figure L-7. Highest of the second highest 24-hour average concentrations by distance. Figures a, c, & e show CALPUFF *puffs*, whereas figures b, d, & f show *slugs*. Note: $\%\ Difference = 100\left(\frac{\chi_{CALPUFF} - \chi_{ISC3}}{\chi_{ISC3}}\right)$.

TECHNICAL REPORT DATA

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		6. PERFORMING ORGANIZATION CODE
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9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Environmental Protection Agency Office of Air Quality Planning and Standards Emissions, Monitoring, and Analysis Division Research Triangle Park, NC 27711		10. PROGRAM ELEMENT NO.
		11. CONTRACT/GRANT NO.
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15. SUPPLEMENTARY NOTES		

16. ABSTRACT

We examined CALPUFF for equivalency to ISC3, both in a steady-state mode, as well as non-steady-state (i.e., meteorological conditions were allowed to vary hourly). For 4 standard point sources, an array of persistent "screening" meteorological conditions and all 6 P-G categories, we completed 432 CALPUFF runs (216 for Z_i = 3000m; 216 for Z_i = 500m to assess reflection) and 108 ISC3 runs (54 for Z_i = 3000m; 54 for Z_i = 500m) for receptors out to 100km. Using a simple custom FORTRAN postprocessor, we analyzed paired residuals in a systematic way to characterize the two models' equivalence. Results were reduced and expressed in a tabular form. CALPUFF was seen to mimic ISC3 to a substantial degree. In non-steady state conditions, we ran CALPUFF and ISC3 to estimate impacts from standard point sources and results compared using meteorological data from Boise, ID, Medford, OR, and Pittsburgh, PA. Occurrences of calms and recirculations resulted in higher source impacts with CALPUFF than for ISC3 for most comparisons made.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Air Pollution Atmospheric Dispersion Modeling		

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ATTACHMENT 2

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J. Reddick

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K Tsai	I175	1		3
R Voke	I122	1		3
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Acronyms and Abbreviations

ALARA	as low as reasonably achievable
DCG	derived concentration guideline
DOE	U.S. Department of Energy
Ecology	Washington State Department of Ecology
GAC	granulated activated charcoal
HEME	high-efficiency mist eliminator
HEMF	high-efficiency metal filter
HEPA	high-efficiency particulate air
HLW	high-level waste
HWVP	Hanford Waste Vitrification Plant
MtG	metric tons of glass
POG	process offgas
RFD	reverse flow diverter
RPP	River Protection Project
SAS	steam atomized scrubber
SB	standby offgas
SBS	submerged bed scrubber
SOG	secondary offgas
TOC	total organic carbon
VVOG	vessel ventilation offgas
WESP	wet electrostatic precipitator
WTP	Waste Treatment Plant

Symbols Definitions

Vitrification Melter

Film Cooler

Ejector Venturi Scrubber

Offgas Quencher

Quencher Sump

Submerged Bed Scrubber

Hydrosonic Scrubber

High Efficiency Mist Eliminator

Wet Electrostatic Precipitator

Electric Heater

High Efficiency Metal Filter

High Efficiency Particulate Air Filter

Heat Exchanger

Caustic Scrubbing Column

Column

Block Valve

Pressure Relief Valve

Vortex Amplifier

Rupture Disk

Offgas Check Valve

Vessel

Cooling Coils

Air Ejector

Steam Ejector

Centrifigual Pump or Fan

RFD

1. Introduction

The document purpose, scope, and objectives are provided in this section.

1.1 Purpose

The purpose of this document is to evaluate alternatives in order to recommend a process offgas (POG) treatment system for the River Protection Project (RPP) Waste Treatment Plant (WTP) high-level waste (HLW) vitrification facility design.

1.2 Scope

The document scope includes the following:

- Design bases (Sections 3.1.1 and 3.1.2)
- Study methodology (Sections 3.1.3 and 3.1.4)
- Descriptions (six systems are defined for study evaluation) (Section 3.2)
- Evaluations (Section 4)
- Recommendation for system selection (Section 4.7).

The POG treatment system can be divided into four systems, based on their functions:

- The primary melter offgas treatment system provides normal melter pressure control, prevents the melter offgas line from plugging, cools the melter offgas, removes aerosols from the melter offgas, and removes some noxious gasses.

- The secondary offgas (SOG) system removes noxious gases from the POG.

- The standby melter offgas system controls nonroutine melter offgas flow surges to control melter pressure and remove aerosols from the associated gas.

- The vessel ventilation system controls the pressure in process vessels and removes particulates from the associated offgas.

These systems may be designed to interact and perform dual roles, thus minimizing equipment needs such as using the primary offgas system to remove particulates from the vessel ventilation system. Figure 1.1 provides a functional diagram of the POG treatment system. The primary components of the six systems being compared are included in Table 1.1.

Figure 1.1. HLW Vitrification Alternatives Functional Diagram

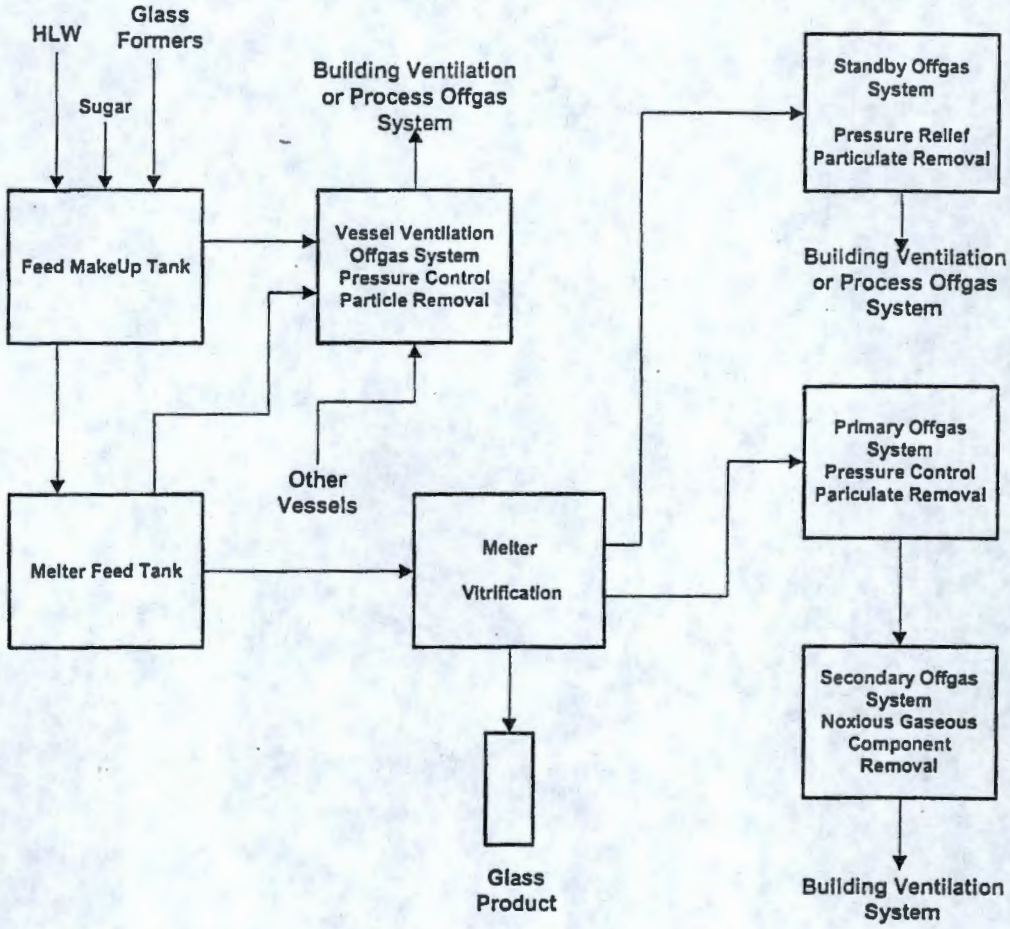

Table 1.1. Alternative Process Offgas Treatment System Primary Components

Components	Alternatives					
	A	B	C	D	E	F
Primary Offgas System	• Film Cooler • Eductor Venturi Scrubber • HEME (Parallel) • HEMF (Parallel) • Vortex Amplifier	• Film Cooler • Control Air • Eductor Venturi Scrubber • WESP • HEMF (Parallel)	• Film Cooler • Control Air • Quencher • Submerged Bed Scrubber • HEME (Parallel) • 2 HEPAs in Series (Parallel) • Vortex Amplifier	• Film Cooler • Control Air • Eductor Venturi Scrubber • 2 SAS in Series • Condenser • HEME (Parallel) • 2 HEPAs in Series (Parallel)	• Film Cooler • Control Air • Submerged Bed Scrubber • HEME (Parallel) • HEMF (Parallel)	• Film Cooler • Control Air • Submerged Bed Scrubber • WESP • HEME (Parallel) • 2 HEPAs in Series (Parallel)
Standby Offgas System	• Check Valve • HEMF • Vortex Amplifier • To SOG System	• Rupture Disk • Air Jet • HEMF • Check Valve • Bldg HEPA Filters	• Seal Pot • To Cell	• Seal Pot • To Cell	• Check Valve • Condenser • To Primary Offgas System	• Rupture Disk • Air Jet • HEMF • Check Valve • To Cell
Vessel Ventilation Offgas System	• HEME (Parallel) • To SOG System	• To Primary Offgas System HEMF	• HEMF • 2 HEPAs in Series • To SOG System	• To Primary Offgas System HEME	• To Standby Offgas System Condenser	• To Primary Offgas System HEME
Secondary Offgas System	• Fans (2) • Condenser • Caustic Scrubber • Iodine Sorber • 2 HEPAs in Series	• Fans (2) • Condenser • Caustic Scrubber • Catalytic Organic Oxidizer • 2 HEPAs in series	• Fans (3) • Condenser • Caustic Scrubber • Granular Activated Charcoal Sorber (organic) • Iodine Sorber • 2 HEPAs in series	• Fans (2) • 2 HEPAs in series	• Fans (3) • Condenser • Catalytic NO_x Reduction • 2 HEPAs in series	• Fans (3) • Condenser • Caustic Scrubber • Catalytic Organic Oxidizer

HEME = high-efficiency mist eliminator
HEMF = high-efficiency metal filter
WESP = wet electrostatic precipitator
SAS = steam atomized scrubber
SOG = secondary offgas
HEPA = high-efficiency particulate air (filter)

1.3 Objectives

The study objectives are to:

- Define system functions and requirements (Sections 3.1.1 and 3.1.2)
- Describe alternative systems and their features in terms amenable to comparative evaluations (Section 3.2)
- Comparatively evaluate the systems (Section 4)
- Recommend a POG treatment system for HLW vitrification facility design (Section 4.7).

2. Conclusions and Recommendations

Table 2.1 provides the results of the alternative systems evaluation. For an explanation of Table 2.1 scoring, see Section 3.1.3, Methodology; Section 3.1.4, Evaluation Approach; and Section 4.7, Alternative Selection. The highest total score indicates the most desirable alternative.

Table 2.1. Alternatives Evaluation

Criteria	Criteria Weight	Alternative Performance Rating (outstanding = 10, unacceptable = 0)											
		A		B		C		D		E		F	
		(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
Emissions Control													
Particulate (POG & VVOG)	10	10	100	10	100	10	100	10	100	10	100	10	100
Gaseous (SOG)	10	6	60	4	40	7	70	1	10	2	20	4	40
Safety	10	8	80	9	90	6	60	8	80	9	90	9	90
Secondary Offgas Area													
Maintenance Radiation/Contamination Hazard	7	2	14	1	7	5	35	9	63	2	14	9	63
Reliability/Availability	7	5	35	7	49	6	42	7	49	8	56	8	56
Technical Risk	5	7	35	7	35	7	35	9	45	8	40	6	30
Cost Elements													
Capital	4	7	28	7	28	8	32	9	36	8	32	7	28
Operating (equipment pieces)	3	5	15	6	18	6	18	9	27	9	27	9	27
Maintenance (failures/yr)	2	7	14	8	16	8	16	7	14	9	18	9	18
Research and Technology	1	7	7	7	7	7	7	9	9	8	8	6	6
TOTAL (Ranking)		388		390		415		433		405		458	

Notes:
(1) Source
(2) Weighted score
POG = process offgas
SOG = secondary offgas
VVOG = vessel ventilation offgas

The study conclusions are provided below:

- All alternatives meet "worst case" particulate radionuclide emissions requirements based on derived concentration guidelines (DCG) emission release limits.
- Alternatives A, B, C, and F meet gaseous radionuclide emissions requirements at the stack for the contract limit source term based on DCG emission limits.
- No alternative was found to have unacceptable safety hazards with appropriate engineering.
- Alternatives D and F met the requirement of being able to retain the SOG treatment area as a contact maintenance area.
- Only Alternative D approached exceeding the NO_x maximum emission criteria (excessive for HLW vitrification emissions) based on a maximized source term.
- Based on system reliability and availability, Alternative F ranked highest due to its relatively passive nature.
- All alternatives required some design data development and demonstration such as integrated system demonstration and solids mobilization to assure acceptable risk for system implementation.

The following recommendations are made:

- Alternative F is recommended for implementation based primarily on the ability to reliably and economically perform the required functions. This ability is based primarily on relative system simplicity and passivity.
- Some modifications to the recommended alternative may be appropriate to optimize system performance and minimize cost, as system requirements are more fully defined such as organic destruction and iodine removal.
- Allowable radionuclide plant emissions need to be determined using a licensing dose rate model, instead of DCGs, to assure system performance conclusions are valid.
- Design data development is required for component performance studies on the submerged bed scrubber (SBS), wet electrostatic precipitator (WESP), high-efficiency mist eliminator (HEME), and system demonstration studies on the recommended system to assure low risk of technology application.
- Research and technology studies are required to accurately define the sources and paths of organics, ^{129}I, ^{14}C, and ^{3}H through the pretreatment and vitrification plants to better assess the degree of process offgas treatment required.

3. Description of Alternatives

The description of alternatives provides the study bases and system descriptions to be evaluated. The study bases include the system design bases, functions and requirements, study methodology, and evaluation approach. Design bases information (HLW and melter feed compositions) are contained in Appendix A. Component descriptions of alternatives are provided in Appendix B. The flowsheets used to support the system evaluations are provided in Appendix C. Systems are compared instead of components due to the interactive nature of the components.

3.1 Study Bases

The study bases are provided in this section.

3.1.1 Design Bases

The design bases are provided by the contract (DOE 1998), BNFL basis of design document (BNFL 1998), and BNFL Inc. procedures, which include federal, state, and local regulations. The design bases represent a limiting envelope of conditions within which the components and systems must perform as intended.

3.1.1.1 High-Level Waste and Melter Feed

The HLW vitrification facility will process envelope D washed solids (DOE 1998) with added cesium/technetium concentrate, and strontium/transuranic solids. The limiting case for the POG system design is the HLW and associated melter feed that has the maximum concentration of feed components to challenge the functions and requirements of the POG treatment system. The design basis melter feed may never actually be processed in the plant.

The design basis HLW is defined as follows:

- The nominal composition of the envelope D melter feed identified for Phase 1 processing is HLW from tanks AZ-101, AZ-102, C-106, AY-102, and possibly C-102 and C-104. The solids from Tank AZ-101 have the highest HLW solids concentration of radioactive components, as shown in Appendix A. There is currently no evidence to indicate that any HLW to be processed in Phase 2 would have a higher radionuclide content.

- The contract maximum limits for envelope D generally exceed the Tank 101-AZ solids for chemicals and radionuclides. However, the maxima sum to more than 100 wt% and do not represent a real waste.

- The design basis melter feed is based on evaluation of both Tank 101-AZ and contract maxima information.

- The impact of pretreatment on the HLW solids compositions is discussed in Appendix A. The design basis HLW composition to the HLW vitrification facility assumes that pretreatment does not remove any components from the envelope D waste. (This assumption requires review as the WTP Project chemical flowsheet is developed).

- The design basis HLW is modified as shown in Appendix A to maximize volatile and radioactive components in the waste by assuming the greater of the content in the contract (Tables TS-8.1, TS-8.2, TS-8.3, and TS-8.4 of DOE 1998) or the Tank 101-AZ waste content.

- The organic (other than vitrification melter feed reductant additives) content of the feed is assumed to be the contract limit of total organic carbon (TOC) which is reacted in the melter to form CO_2. Organic compounds and their concentrations in the waste have not yet been fully characterized.

- The blended HLW received from pretreatment contains 20 wt% solids.

The design basis melter feed is defined as follows:

- The waste loading in the glass is 40 wt% on an oxide basis based on the contract, Table TS-1.1 (exclusive of sodium and silicon).

- Dry glass-forming materials are added directly to the blended HLW to make up the melter feed.

- The ^{137}Cs and ^{99}Tc concentrations in the melter feed are maximized to produce a glass filled (95 vol% full) canister producing 1,500 watts of radioactive decay heat. The ratio of ^{99}Tc to ^{137}Cs added to the feed in the concentrate is the highest value in the low-activity waste (LAW) feed envelopes.

- The nitrate content in the melter feed is based on ^{137}Cs product addition to the HLW feed (see Appendix A). The envelope D composition assumptions include minimal nitrate (this assumption requires review as the chemical flowsheet is developed).

- The sugar content in the melter feed is based on the correlation provided by R.D. Peters (see Appendix A).

- The feed is assumed not to be acidified.

- Based on stored waste tank experience at Hanford and Hanford Waste Vitrification Plant (HWVP) development work, the assumption is made that a minor amount of ammonium nitrate components are generated in the melter feed makeup and from the melter feed tank, and some ammonium nitrate is deposited on the feed and feed makeup tank demisters.

- No spent ion-exchange resin will be disposed of by HLW vitrification.

The HLW and associated melter feed compositions for this study is provided in Appendix A.

3.1.1.2 High-Level Waste Process Offgas Treatment System Throughput

The melter offgas treatment system will have the following capabilities:

- Accommodate maximum sustained POG flowrate from a melter operating at 1.5 metric tons glass/day (MtG/d).

- Normally handle intermittent POG flow surges of seven times for melter feed offgas normal flowrate.

- Handle a maximum credible gas flow surge of 20 times steam with the standby offgas system that is greater than anticipated to occur in the HLW vitrification facility lifetime (PNL 1989) without structural failure. The data used for this projection may not be fully applicable to Hanford HLW feeds with an air sparged melter. A 20 times surge was determined to have occurred in the Defense Waste Processing Facility (WSRC 1999).

- SOG treatment system processes offgas from one 1.5 MtG/d melter.

- Operate over a 40-yr period with appropriate maintenance and equipment replacement.

- An additional POG treatment system is provided for Phase 2 when the plant design capacity is increased from 1.5 MtG/d to 3 MtG/d by adding another melter system.

3.1.1.3 Process Offgas Treatment Requirements

For plant emissions, the POG will conform to applicable regulatory, contract, and BNFL design guideline requirements. The maximum dose rate to an exposed offsite individual will be maintained to less than 1.5 mrem/yr (DOE 1998, Interface Description 22). Because a model was not available for this study to assess the dose rate to the public, DCG limits (DOE 1993) were used for flowsheet performance evaluation. For "worst-case" assessments, credit is given for building filtration treatment, but no credit is given for building air dilution.

Worker doses at early design stages, when insufficient information is available regarding worker occupancy, is initially targeted at 2.5 mrem/hr for wide spread and static radiation fields and 25 mrem/hr maximum dose equivalent for average and maximum radiation areas (BNFL 1998, pg. 7). This guideline is used to assess the ability of alternatives to maintain the SOG treatment area dose rate to enable contact maintenance.

Organics in the waste will be destroyed or removed such that the overall emission limit of 0.375 Mt/yr (DOE 1998, Interface Description 22) is met. For this study, there was insufficient information on envelope D organic species and amounts to assess system organic destruction and removal efficiencies. The study assumes that all organic is converted to water and carbon dioxide.

Organic removal equipment may be needed for POG treatment and was included in several alternatives.

Radioactive materials removed from the process (liquid and solid waste) will conform to contract requirements for return to the U.S. Department of Energy (DOE).

A goal is to maintain HLW vitrification plants NO_x emissions at a limit (<40 tons/yr) that is not considered to be a significant increase as defined in 40 Code of Federal Regulations (CFR) 52.21(b)(23)(i)

3.1.2 Functions and Requirements

Functions and requirements that the POG treatment system performs are provided in this section.

The principle functions of the POG treatment system are as follows:

- Treat the process vessel offgas such that plant emissions requirements are met for release through the plant stack.
- Remove radionuclides from the POG to permit contact or semi-remote maintenance of the SOG treatment equipment using as low as reasonably achievable (ALARA) principles.
- Provide acceptable safety and hazard conditions.
- Provide Phase I contract glass production at minimum cost.
- Facilitate maximum Phase 2 glass production at minimum cost (maximum equipment reliability and availability for profitability).

Additional process requirements are utilized to implement the principle functions including the following:

- Prevent plugging of system elements to avoid loss of relative vacuum with potential associated loss of contents containment and plant production.
- Cool melter offgas to permit subsequent offgas treatment without equipment plugging or compromising the functionality of the treatment equipment.
- Remove airborne aerosols containing radionuclides from the POG to permit safe release to the environment.
- Remove pollutant gases (including ^{129}I, ^{14}C, ^{3}H, organic materials, NO_X, and acid gases) from the POG to permit safe release to the environment, and prevent impairing catalyst performance (catalyst poisoning).
- Maintain the melter at a vacuum relative to the cell.
- Prevent inadvertent glass pouring from the melter caused by melter pressure surges.
- Maintain the melter integrity during a credible gas generation surge.
- Route any liquid wastes generated in POG treatment to appropriate vessels for recycle into the process or return to DOE.
- Maintain the process vessels at negative pressure relative to the vessel host environment to contain the vessel contents.
- Implement the POG treatment process in an economical manner.
- Meet regulatory and safety requirements/guidelines.
- Meet the requirements of BNFL Inc. procedures.

3.1.3 Methodology

The following methodology is used in this study:

- Define study bases (Section 3.1)
- Define POG system functions and requirements to provide a comparative study bases (Section 3.1.2)
- Define study methodology (Section 3.1.3)
- Define systems evaluation approach (Section 3.1.4)
- Describe prospective system components to perform system element functions (Appendix B)
- Describe candidate systems (Section 3.2)
- Evaluate alternative systems according to the evaluation approach (Section 4)
- Recommend highest ranked system for the HLW vitrification facility design (Section 2.0).

3.1.4 Evaluation Approach

Each alternative system is relatively evaluated based on ability to perform functions and requirements in a cost-effective manner. System functions and requirements are provided in Section 3.1.2. Each function and requirement becomes an evaluation criterion, which is provided with numerical weighting from 0 (minimum) to 10 (maximum). The weighting states the relative importance of the criteria in regard to the evaluation. Any criterion that must be met has a weight of 10. The criteria and weights are defined to minimize repetitive rankings for a single system feature if not appropriate. For individual criteria, a score of 0 (minimum) to 10 (maximum) is made for each alternative. The score is multiplied by the weighting to provide a weighted score for a criteria. The weighted scores for all criteria are added for each alternative to provide a total score. The alternative with the highest overall score is considered to be the best alternative to perform the system functions and requirements. System functions and requirements with the associated weightings are shown in Table 2.1.

To provide a score for a criteria, a technical or cost assessment is performed in Section 4 to provide a quantitative basis for the score. Improved performance results in an increased score. For criteria where information is not available to provide a quantitative scoring assessment, the score is made on properties that quantitatively relate to determining the score value. For example, allowable radioactive releases from the plant stack are based on a maximum allowable exposure to a member of the public. However, an accepted exposure model was not available to support the study. Thus, DCGs used as release guidance in the past for DOE contractors were used as surrogate values for comparative analyses, realizing these values are usually conservative and will have to be subsequently verified. In other areas where information is not available, such as operating and maintenance costs, surrogate information such as equipment failure rates and downtimes are used, which should follow comparative cost trends for each system. See Section 4 for further discussion of the functions and requirements assessments and their rankings.

3.2 Alternatives

The alternative POG treatment systems are described in this section. Each system consists of components described and assessed in Appendix B.

3.2.1 Alternative A

A diagram of Alternative A is provided in Figure 3.1.

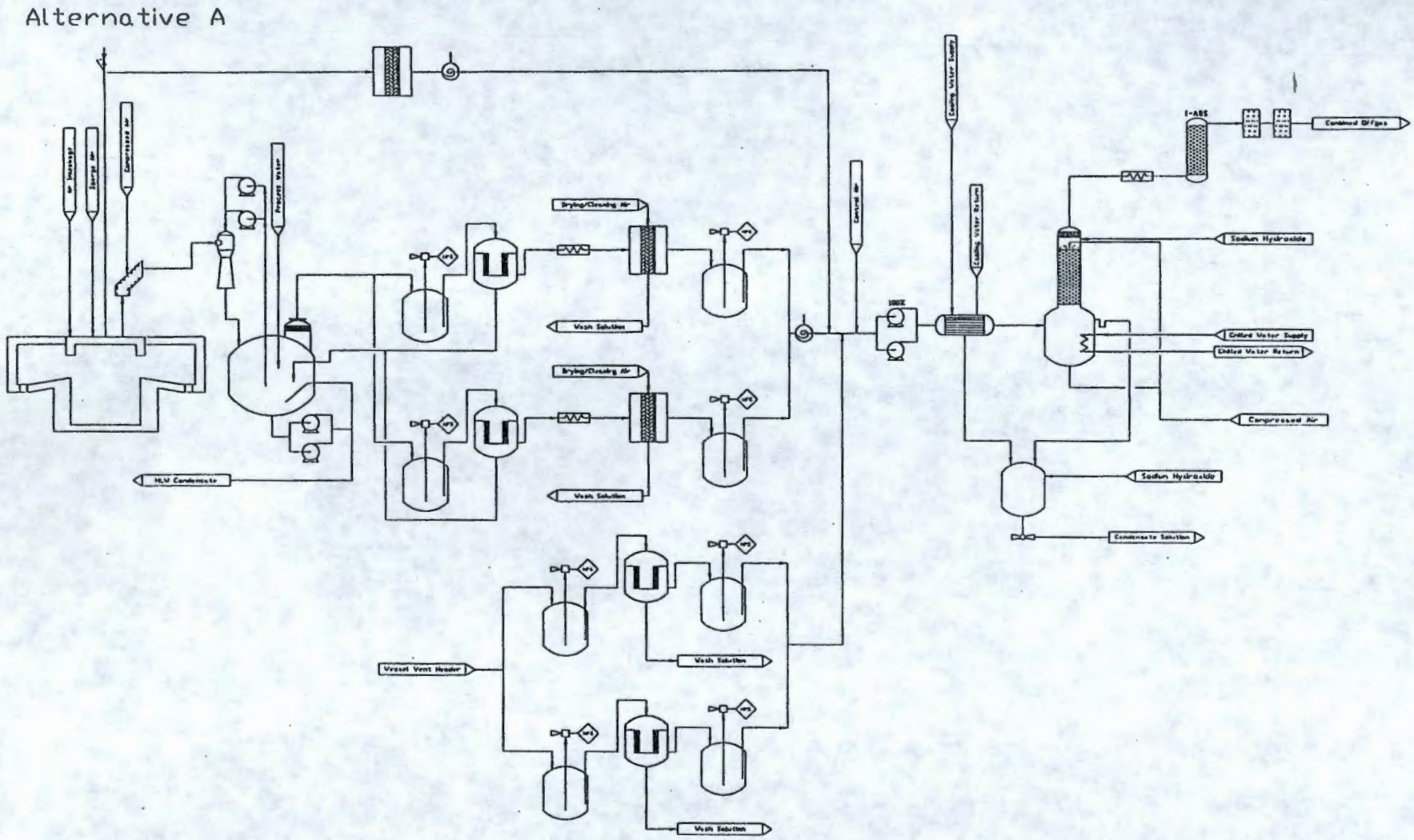

Figure 3.1. Flow Diagram – Alternative A

The melter offgas is 400 to 600 °C and flows through the film cooler where the gas is cooled to 300 to 350 °C by air injection. The cooling prevents particles from sticking to the offgas line and building up in the line. The melter offgas flows through an ejector venturi scrubber where the gas is further cooled to about 80 °C by contact with cooled circulating water from the scrubber. Solids are removed from the gas by impact with the water spray, and some noxious gases are partially absorbed. The solution temperature is maintained by adding water directly to the quench tank, and this solution is recycled through the scrubber by a pump. A built-in spare circulation pump is included to activate in case of primary circulation pump failure.

A pumping system is used to maintain solids in suspension in the tank to prevent solids buildup, and slurry is periodically transferred to the waste-handling system to prevent solids accumulation. The melter offgas is routed from a demister on the quencher tank through a seal pot to a high-efficiency mist eliminator (HEME) for mist (solids bearing) and solids removal. The mist collected by the HEME should facilitate self-cleaning; otherwise a water spray mist is periodically used for cleaning. The HEME cleaning water is drained to the quench tank. The gas flows through an electrical heater to evaporate any water drops that can partially plug a high efficiency metal filter (HEMF). The gas passes through a HEMF for efficient submicron particulate removal and another seal pot into a ventilation header. There is a standby system consisting of two seal pots, HEME, heater, and HEMF that is used if components in the primary system have to be flushed or serviced. Filtered air is available to facilitate HEMF drying after nitric acid washing. Water filling and removal from the seal pots are used to switch from one system to another. HEMF acid washes are routed to the waste system.

A vortex amplifier (flow control device) with a filter is used to normally control melter pressure by sensing the melter pressure and changing airflow through the primary offgas treatment system. The vessel ventilation air and the standby offgas system air join with the melter offgas in this header. An air inbleed system is used to control header pressure. A fan is incorporated into the system to provide a system vacuum. The fan has an installed back up.

If pressure increase is detected in the melter that the normal pressure control system cannot control, the standby melter pressure control system is activated. The system valve is opened to allow gas flow out of the melter. The air flow to a vortex amplifier is decreased to provide the gas flow motive force. The gas flows through a HEMF for solids removal and joins the primary system after the HEMFs.

The vessel ventilation offgas (VVOG), which contains air from reverse flow diverter (RFD) and pulsejet agitator operations, is routed through a seal pot, HEME, another seal pot, and into the primary offgas treatment system after the HEMFs. The HEME removes mists bearing solids and solids. The HEME is periodically washed with a water spray to remove solids. The wash solution is routed to the waste-handling system. There is a standby system consisting of two seal pots and a HEME that is used if components in the primary system have to be flushed or serviced. Water filling and removal from the seal pots are used to switch from one system to another.

In the SOG treatment system, the treated melter offgas, VVOG, and any standby system offgas are passed through a condenser. The water-cooled condenser reduces the gas temperature to about 40 °C for water condensation. Water condensation removes some tritium with the water and increases the size of solids (acts as nucleation sites for condensation) to facilitate removal in the caustic scrubbing column. Some NO_X and solids may be removed. The condensed water is routed to the waste-handling system. The gas passes through a packed scrubbing column. The gas contacts a chilled sodium hydroxide (NaOH) solution. An airlift is used to recirculate the solution in the column. Makeup 5M NaOH is provided to supplement the depleted NaOH. In the column, NO_X, CO_2 (^{14}C), water (^{3}H), ^{129}I, perhaps some volatile organic material, SO_X, and any other acid gases are partially scrubbed out. The scrubbing assures iodine

sorption media poisons are removed. The spent solution is routed to the waste-handling system. The column operates at about 30 °C. The gas is passed through a heater to increase the temperature to about 150 °C. The gas is passed through an iodine sorption column for contact with silver contained on a particle substructure for ^{129}I removal.

The treated offgas is finally routed through a fan, two sets of HEPA filters, and the plant stack.

3.2.2 Alternative B

A diagram of Alternative B is provided in Figure 3.2.

The melter offgas at 400 to 600 °C flows through the film cooler where the gas is cooled to 300 to 350 °C by air injection. The cooling prevents particles from sticking to the offgas line and building up in the line. Additional air is injected into the melter offgas line for normal melter pressure control by changing flowrate based on melter pressure. The melter offgas flows through an ejector venturi scrubber where the gas is further cooled to about 80 °C by contact with cooled water in the scrubber. Solids are also removed from the gas by impact with the water spray, and some noxious gases are partially removed by sorption.

The solution is maintained at about 80 °C by adding water directly to the quench tank, and this solution is recycled through the scrubber by a pump. A built-in spare circulation pump is activated in case of circulation pump failure. Another pumping system is used to maintain solids in suspension to prevent solids buildup in the tank, and slurry is periodically transferred to the waste-handling system for recycle to prevent solids accumulation.

The melter offgas is routed through a demister on the quencher tank to the WESP. The gas flows through a distributor system, through the collection tubes, and out of the WESP. In the tubes, the gas is subjected to about a 60,000 volt difference between the central electrode and the tube that electrically charges the particles and droplets. The charged aerosols collect on the tube and are washed by condensed water to the WESP bottom. The slurry is transported to the waste collection system for recycle. The WESP tubes are water cooled to facilitate water condensation for solids removal from the tubes. Process water can be used as necessary to wash the walls and bottom of the WESP.

The vessel ventilation air, containing air from RFD and pulsejet mixing operations, joins the melter offgas air on exiting the WESP for subsequent treatment. The gas flows through a seal pot followed by an electrical heater to evaporate any water drops that can partially plug a HEMF. The gas passes through a HEMF for efficient submicron particle removal and another seal pot into a ventilation header. There is a standby system consisting of a two seal pots, a heater, and HEMF which is used if components in the primary system have to be flushed or serviced. Filtered air is available to facilitate HEMF drying after washing. Water filling and removal from the seal pots is used to switch from one system to another. HEMF acid washes are routed to the waste system. An air inbleed system is used to control header pressure. A fan is incorporated into the system to provide a system vacuum. The fan has an installed back up.

If a low vacuum is detected in the melter that the normal pressure control system cannot control, the standby melter pressure control is activated. An air jet is opened to provide motive force for melter gas flow and the motive air cools the melter offgas to about 300 to 350 °C to prevent solids from sticking on the filter and blinding the filter. The gas flows through a HEMF for solids removal. The gas flows through a flapper valve into the building offgas treatment system, where the gas is further filtered by two sets of HEPA filters prior to being released to the stack.

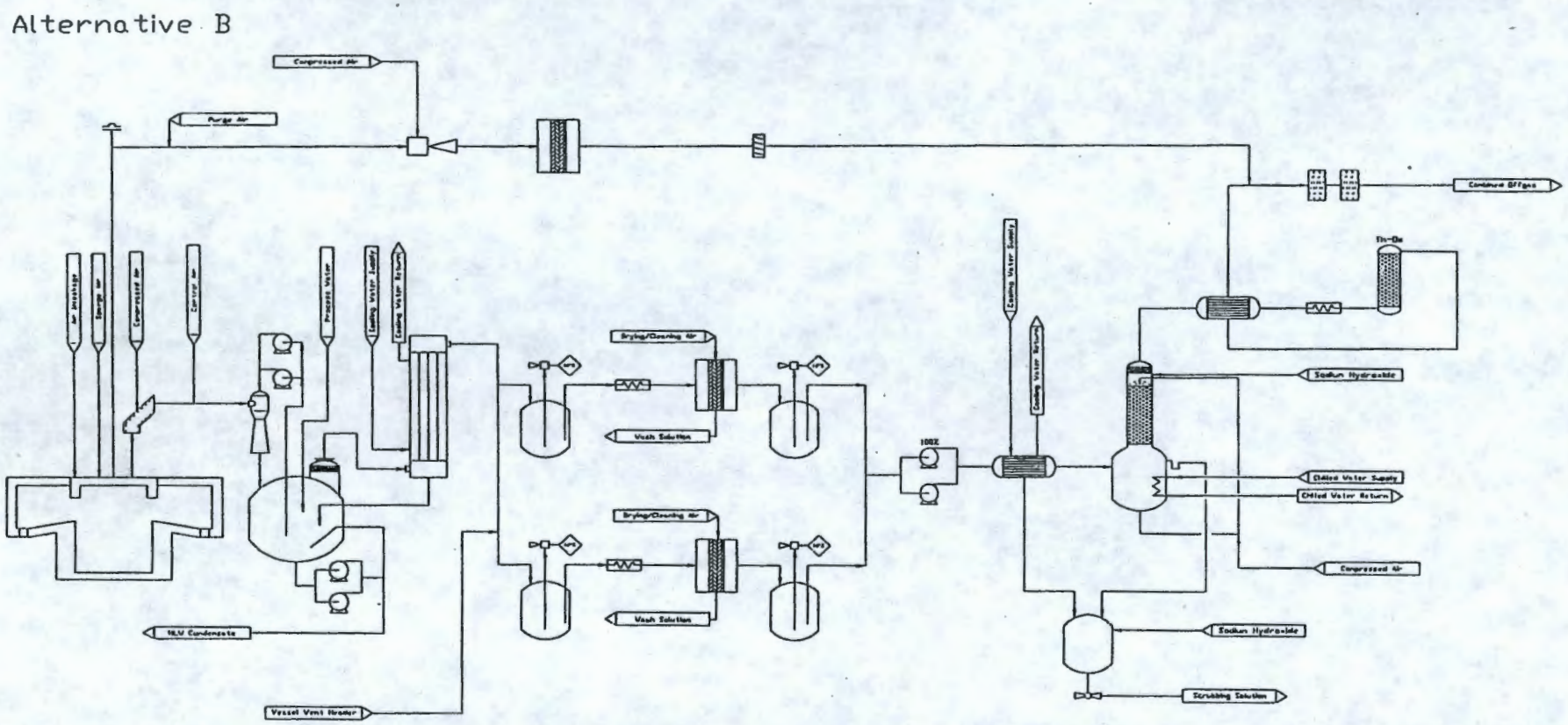

Figure 3.2. Flow Diagram – Alternative B

In the SOG treatment system, the primary melter offgas and the VVOG are passed through a condenser. The water-cooled condenser reduces the gas temperature to about 40 °C for water condensation. Water condensation removes some tritium as water and increases the size of solids (acts as nucleation sites for condension) to facilitate removal in the caustic scrubbing column. Some NO_X and solids may be removed. The condensed water is routed to the waste-handling system. The gas passes through a packed scrubbing column. The gas contacts a chilled NaOH solution. An airlift is used to recirculate the solution in the column. Makeup 5M NaOH is provided to supplement the depleted NaOH. In the column, NO_X, CO_2 (^{14}C), water (^{3}H), ^{129}I, perhaps some organic material, SO_X, and any other acid gases are partially scrubbed out. The scrubbing assures the catalyst poisons are removed from the offgas. The spent solution is routed to the waste-handling system. The column operates at about 30 °C. The gas is passed through a heat exchanger and heater to increase the temperature to about 300 °C. The gas is passed through a catalyzed organic oxidation column for contact with the packed bed catalyst. The organic materials react to form carbon dioxide and water. The gas leaving the column passes through the heat exchanger for heat recovery.

The treated offgas is finally routed through a fan, two sets of HEPA filters, and out of the plant stack.

3.2.3 Alternative C

A diagram of Alternative C is provided in Figure 3.3.

The melter offgas at 400 to 600 °C flows through the film cooler where the gas is cooled to 300 to 350 °C by steam injection. Cooling prevents particles from sticking to the offgas line and building up in the line. Additional air is injected into the melter offgas line for normal control of melter pressure by changing flowrate based on melter pressure. The melter offgas flows through a quencher where the gas is further cooled to about 80 °C by contact with water recirculated from the scrubber tank. Some small amounts of solids are also removed from the gas by impact with the water spray, and some noxious gases are partially removed by sorption. The solution is maintained at about 80 °C by addition of water directly to the quencher and the quench tank, and this solution is recycled through the quencher by a pump. A built-in spare circulation pump is included to activate in case of pump failure. The solids in the quench tank are maintained in suspension using a pulsejet agitator. Slurry is periodically transferred from the quench tank with a RFD to prevent solids accumulation. The quencher system has enough turndown to accommodate a 10X surge without the melter going positive pressure. The melter offgas is routed through a demister on the quench tank to the SBS.

The gas flows down through the SBS inlet pipe and across the distributor plate to form a bubble. The steam is rapidly condensed in the vicinity of the distributor plate. The gas rises through the packed column above the plate together with the scrub solution. The intimate contact of the gas and scrub solution in the bed facilitates removal of solids and soluble gas from the melter offgas. The gas and solution disengage above the column, and the solution continues circulation by natural convection past the cooling coils to control the solution temperature to about 50 °C. The scrubbed solids are suspended in the scrub tank with a pulsejet agitator. The solids slurry from the scrub tank overflows to the quench tank. The slurry from the quench tank is transported to the waste collection system for recycle.

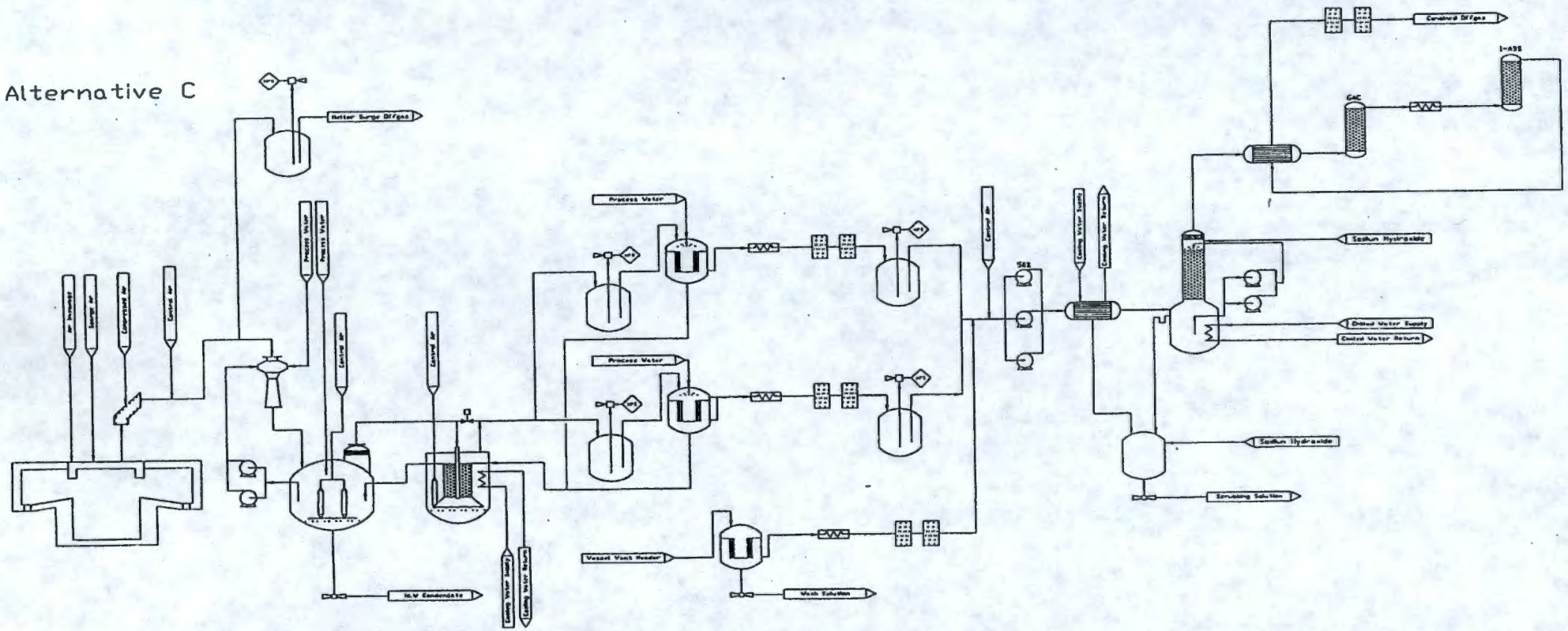

Figure 3.3. Flow Diagram – Alternative C

The melter offgas is routed through a seal pot, followed by a HEME for mist (solids bearing) and solids removal. The mist collected by the HEME should facilitate self-cleaning; otherwise a water spray mist is periodically provided for cleaning. The cleaning solution is drained to the quench tank. The gas flows through an electrical heater to evaporate any water drops, which can partially plug a high-efficiency particulate air (HEPA) filter. The gas passes through two HEPA filters in series for efficient submicron particle removal and another seal pot into a ventilation header. There is a standby system consisting of two seal pots, a HEME, a heater, and two HEPA filters, which is used if components in the primary system have to be flushed or serviced. Water filling and removal from the seal pots is used to switch from one system to another. A vortex amplifier is incorporated into the system to provide system vacuum control. The treated POG including the VVOG is moved by fans into the SOG treatment system.

The emergency pressure relief from the melter is through a seal pot into the melter cell.

The VVOG is routed through a HEME, heater, and two HEPA filters in series to efficiently remove aerosols from the VVOG. The HEME removes mists bearing solids and solids. The HEME is periodically washed with a water spray to remove solids. The wash solution is routed to the SBS. The treated VVOG is combined with the melter offgas after primary treatment after the second seal pot.

In the SOG treatment system, the primary melter offgas and the VVOG are passed through a condenser. The water-cooled condenser cools the gas to about 40 °C for water condensation. The water condensation removes some tritium with the water and increases the size of solids (acts as nucleation sites for condension) to facilitate removal in the caustic scrubbing column. Some NO_X and solids may be removed. The condensed water is routed to the waste-handling system. The gas passes through a packed scrubbing column. The gas contacts chilled NaOH solution in the packed column. A pump is used to recirculate the solution in the column. Makeup 5M NaOH is provided to make up the depleted NaOH. In the column, NO_X, CO_2 (^{14}C), water (^{3}H), ^{129}I, perhaps some organic material, SO_X, and any other acid gases are partially scrubbed out. The scrubbing assures that catalyst poisons do not reach the subsequent processes. The spent solution is routed to the waste-handling system. The column operates at about 30 °C.

The gas is passed through a heat exchanger to increase the temperature to about 100 °C. The gas is passed through a granulated activated charcoal (GAC) column for volatile organic materials sorption. The gas is passed through a heater to increase the temperature to about 150 °C. The gas is passed through an iodine sorption column for contact with silver contained on a particle substructure and ^{129}I removal. The gas leaving the column passes through a heat exchanger for heat recovery.

The treated offgas is finally routed through two sets of HEPA filters, a fan, and out the stack.

3.2.4 Alternative D

A diagram of Alternative D is provided in Figure 3.4.

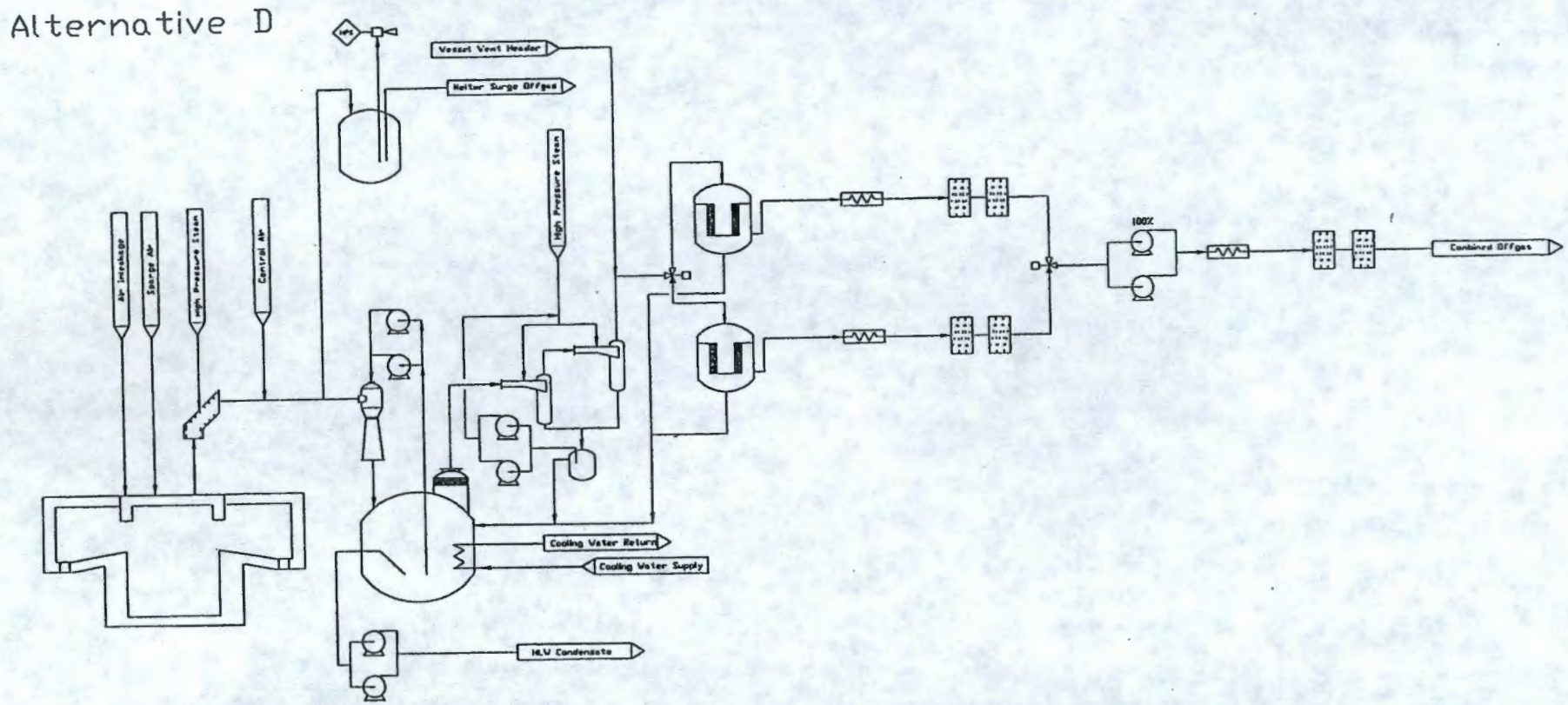

Figure 3.4. Flow Diagram – Alternative D

The melter offgas at 400 to 600 °C flows through the film cooler where the gas is cooled to 300 to 350 °C by steam injection. The cooling prevent particles from sticking to the offgas line and building up in the line. Additional air is injected into the melter offgas line for normal control of melter pressure by changing flowrate based on melter pressure. The melter offgas flows through an ejector venturi scrubber where the gas is further cooled to about 80 °C by contact with cooled water recirculated from the scrubber. Solids are removed from the gas by impact with the water spray, and some noxious gases are partially removed by sorption. The solution is maintained at about 80 °C by use of cooling coils/jacket on the quench tank and quench solution is recycled through the scrubber by a pump. A built-in spare circulation pump is included to activate in case of pump failure. A second pumping system is used to maintain solids in suspension in the tank to prevent solids buildup. Slurry is periodically transferred to the waste-handling system to prevent solids accumulation. This second pumping system also has a built-in backup pump.

The melter offgas is routed through a demister on the on the quencher tank through two steam atomized scrubbers (SAS) in series for aerosol removal. The steam aspirated wet scrubbers are effective for reducing the concentration of submicron particles. Particulate scrubbing is accomplished by injecting a liquid stream into the wake of an expanding supersonic free jet. The scrub solution is provided by pumping quench solution from the quench tank for combination with the melter offgas in the SASs. A backup pump is available if the primary pump fails. The flowrate is controlled with valves. Rapid acceleration of the liquid phase results in complete atomization. Fragmentation and acceleration of the liquid phase and the resulting high relative velocity created between the expanding flow and the entrained offgas flow results in efficient particulate scrubbing. The scrubbed particles are then effectively grown by agglomeration and separated from the gas phase by inertial means. The separated slurry flows into the quencher tank.

The melter offgas is routed through a diverter valve to a HEME for mist (solids bearing) and solids removal. The mist collected by the HEME should facilitate self-cleaning; otherwise a water spray mist is periodically provided for cleaning. The cleaning water is drained to the quench tank. The gas flows through an electrical heater to evaporate any water drops that can partially plug a HEPA filter. The gas passes through two HEPA filters in series for efficient submicron particle removal and another diverter valve into a ventilation header. There is a standby system consisting of a HEME, a heater, and two HEPA filters, which is used if components in the primary system have to be flushed or serviced. The VVOG is combined with the melter offgas for treatment after the second SAS. The treated offgas is moved through the primary treatment system with a 100% capacity fan into the SOG treatment system. A second 100% capacity fan is retained as backup.

The emergency pressure relief from the melter is through a seal pot into the melter cell.

The treated offgas is finally routed through two sets of HEPA filters and out the stack.

3.2.5 Alternative E

A diagram of Alternative E is provided in Figure 3.5.

Alternative E

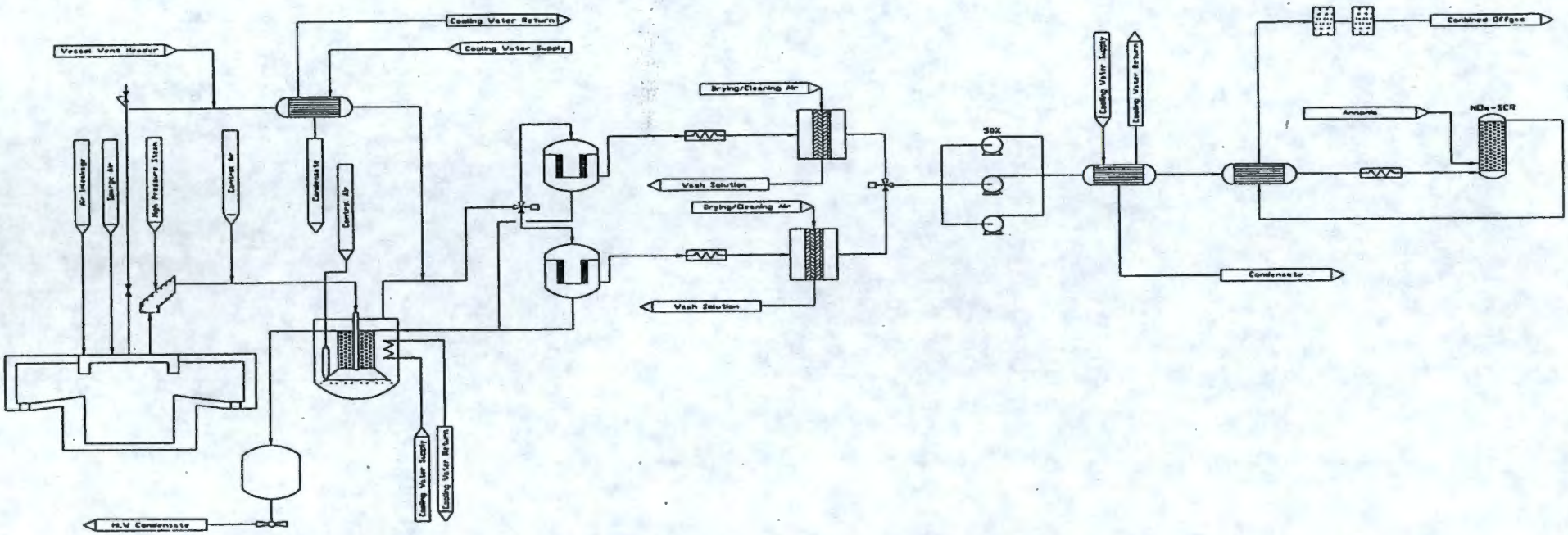

Figure 3.5. Flow Diagram – Alternative E

The melter offgas at 400 to 600 °C flows through the film cooler where the gas is cooled to 300 to 350 °C by steam injection. Cooling prevent particles from sticking to the offgas line and building up in the line. Additional air is injected into the melter offgas line for normal control of melter pressure by changing flowrate based on melter pressure. The melter offgas flows through a SBS. The gas flows down through the inlet pipe and across the distributor plate to form a bubble. The gas rises through the packed column above the plate together with the scrub solution. The steam is rapidly condensed in the vicinity of the distributor plate. The intimate contact of the gas and scrub solution in the bed facilitates removal of solids and some soluble gas from the melter offgas. The gas and solution disengage above the packed column, and the solution continues circulation by natural convection past the cooling coils to control the solution temperature to about 50 °C. The scrubbed solids are suspended off of the tank bottom with a pulsejet agitator. The solids slurry from the scrub tank overflows to the receiver tank for holding. The slurry from the holding tank is periodically transported using a RFD to the waste collection system for recycle.

The melter offgas is routed through a diverter valve followed by a HEME for mist (solids bearing) and solids removal. The mist collected by the HEME should facilitate self-cleaning; otherwise a water spray mist is periodically provided for cleaning. The cleaning water is drained to the SBS. The gas flows through an electrical heater to evaporate any water drops that can partially plug a HEMF. The gas passes through a HEMF for efficient submicron particle removal and another diverter valve into a ventilation header. There is a standby system consisting of an HEME, heater, and HEMF, which is used if components in the primary system have to be flushed or serviced. Filtered air is available to facilitate HEMF drying after washing. HEMF acid washes are routed to the waste system. Two 50% capacity fans are incorporated into the system to provide a system vacuum. There is a 50% capacity fan installed for backup. An air inbleed system is used to control header pressure. The treated POG including the VVOG is moved by fans into the SOG treatment system.

The vessel ventilation system and the emergency pressure relief from the melter are combined into one system and exhaust into the primary melter offgas for treatment directly upstream of the initial diverter valve. The emergency melter offgas system is activated by low vacuum in the melter by opening a valve. The high steam and gas flow through the valve and a condenser. The majority of the surge flow is steam, which condenses and flows to the SBS. The noncondensable gas from the condenser flows into the primary offgas system for treatment. The vessel ventilation system joins the emergency offgas treatment system directly upstream of the condenser.

In the SOG treatment system, the primary melter offgas, and the VVOG are passed through a condenser. The water-cooled condenser reduces the gas temperature to about 40 °C for water condensation. The water condensation removes some tritium with the water. Some NO_X and solids are removed. The condensed water is routed to the waste-handling system. The gas passes through a heat exchanger to heat the gas for NO_X destruction reaction. The gases are heated by the hot reaction gases from the NO_X destruction column. The heated gas passes through an electric heater to further increase the temperature to about 300 °C for reaction. The gas is mixed with ammonia gas and enters the reaction column. The gas is passed through a catalyzed reduction column for contact with the packed bed catalyst. The NO_X reacts with the ammonia to form nitrogen and water at a reaction temperature of about 300 °C. The reaction is highly exothermic. The gas leaving the column passes through a heat exchanger for cooling.

The treated offgas is finally routed through a fan, two sets of HEPA filters, and out the stack.

3.2.6 Alternative F

A diagram of Alternative F is provided in Figure 3.6.

The melter offgas at 400 to 600 °C flows through the film cooler where the gas is cooled 300 to 350 °C by air injection. The cooling prevents particles from sticking to the offgas line and building up in the line. Additional air is injected into the melter offgas line for normal melter pressure control by changing flowrate based on melter pressure. The melter offgas flows through a SBS. The gas flows down through the inlet pipe and across the distributor plate to form a bubble. The gas rises through the packed bed above the plate together with the scrub solution. The steam rapidly condenses in the vicinity of the distributor plate. The intimate contact of the gas and scrub solution in the bed facilitates removal of solids and some soluble gas from the melter offgas. The gas and solution disengage above the packed bed. The solution continues circulation by natural convection past the cooling coils to control the solution temperature to about 50 °C. The removed solids are suspended off of the tank bottom with a pulsejet agitator. The solids slurry from the scrub tank overflows to the receiver tank for holding. The slurry from the holding tank is transported to the scrub tank, and slurry from the scrub tank is transported to the waste collection system for recycle. This system maintains a constant pressure head over the SBS and facilitates removing the highest concentration solids from the system.

The melter offgas from the SBS is routed to the WESP. In the WESP the offgas passes through a distributor plate which assures uniform gas flow across the column. The gas then passes through a number of tubes. Each tube contains a rod down the tube center as a cathode with about a 60,000-volt DC charge. Through a corona discharge effect, the aerosols in the gas are negatively charged and deposited on the aniode tube. Cooling water is used on the tubes to cool the gas and facilitate water condensation on the tubes together with collecting water drops from the gas. The water flows down the tube and washes the solids to the WESP bottom. The solids slurry from the WESP bottom drains into the SBS. Process water can be used as necessary to wash the walls and bottom of the WESP. The VVOG is combined with the WESP offgas for combined treatment.

The melter offgas is routed through a diverter valve to a HEME for mist (solids bearing) and solids removal. The mist collected by the HEME should facilitate self-cleaning; otherwise a water spray mist is periodically provided for cleaning. The cleaning water is drained to the receiver tank. The gas flows through an electrical heater to evaporate any water drops, which can partially plug a HEPA filter. The gas passes through two HEPA filters in series for efficient submicron particle removal and another diverter valve into a ventilation header. There is a standby system consisting of a HEME, heater, and two HEPA filters, which is used if components in the primary system have to be flushed or serviced. The VVOG is combined with the melter offgas for treatment prior to entering the HEME. The treated offgas is moved through the primary treatment system with two 50% capacity fans into the SOG treatment system. A third 50% capacity fan is retained as backup.

If high pressure is detected in the melter that the normal pressure control system cannot control, the standby melter pressure control is activated. An air jet is opened to provide motive force for gas flow and cool the melter offgas to about 300 to 350 °C to prevent solids from sticking on the filter and binding the filter. The gas flows through a HEMF for solids removal. The gas flows through a flapper valve into the building offgas treatment system for filtration by two additional HEPA filters in series before release to the building stack.

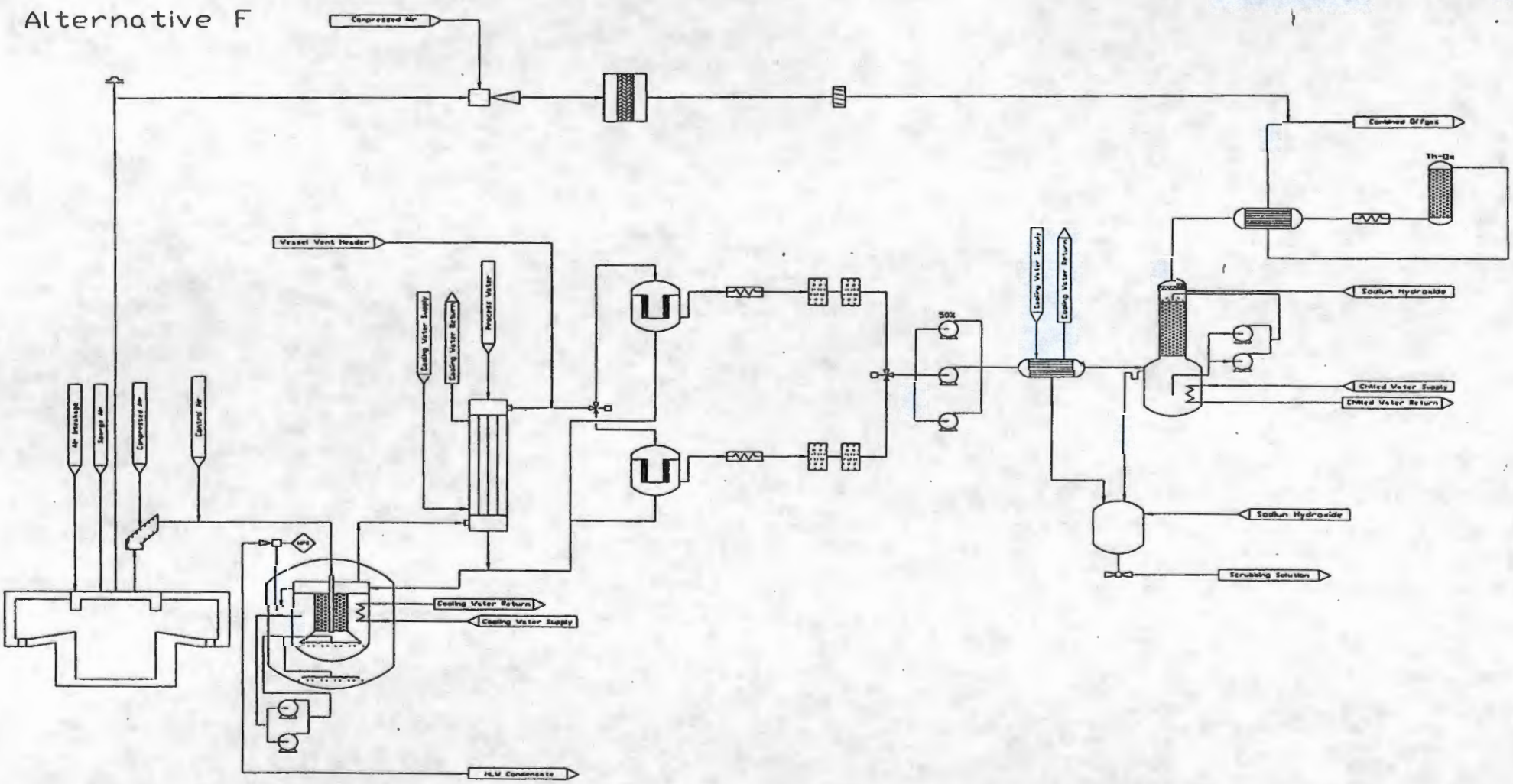

Figure 3.6. Flow Diagram – Alternative F

In the SOG treatment system, the treated melter offgas, the VVOG, and any standby system offgas is passed through a condenser. The water-cooled condenser cools the gas to about 40 °C for water condensation. The water condensation removes some tritium with the water and increases the size of solids (acts as nucleation sites for condension) to facilitate removal in the caustic scrubbing column. Some NO_X and solids may be removed. The condensed water is routed to the waste-handling system. The gas passes through a packed scrubbing column. The gas contacts a chilled NaOH solution. A pump is used to recirculate the solution in the column. Makeup 5M NaOH is provided to make up the depleted NaOH. In the column, NO_X, CO_2 (^{14}C), water (^{3}H), ^{129}I, perhaps some organic material, SO_X, and any other acid gases are partially scrubbed out. The scrubbing assures the catalyst poisons do not reach the subsequent processes. The spent solution is routed to the waste-handling system. The column operates at about 30 °C. The gas is passed through a heat exchanger and heater to increase the temperature to about 300 °C. The gas is passed through a catalyzed organic oxidation for organic destruction.

The treated offgas is finally routed back through the heat exchanger and through a fan for release out the stack.

4. Discussion of Recommended Alternative

The systems described in Section 3.2 are compared and evaluated in this section. The alternative system evaluations are relative to the study functions and requirements.

4.1 Process Offgas Emissions Control

The ability of each alternative to treat the POG for conformance to gaseous release requirements was evaluated. A material balance for each alternative process was developed for similar melter processing conditions using the design bases feed. A description of the design basis feed and how the composition was developed are contained in Appendix A. The material balance for each of the alternatives is contained in Appendix C. To compare the ability of each alternative to suitably treat the POG, the concentration of the radioisotopes in the offgas exiting the POG treatment system is divided by the DCG for that isotope (DOE 1993). The sum of fractions, converted to a percentage, is determined for comparison between alternatives. The radionuclide emissions and the DCGs for radioisotopes together with the sum of fractions are contained in Tables 4.1 through 4.6. See Section 3.1.1 for rationale in using DCGs as the bases for emissions comparison.

Table 4.1. Continuous Inhaled Air Derived Concentration Guides (Worst Case) – Alternative A

Temperature 25 °C
Offgas Flowrate 3,190 m^3/hr

Radionuclides	HEPA Filter Offgas Concentration Bq/m^3	µCi/ml	Individual DCGs µCi/ml	DCG Meet?	Concentration DCG (%)
^{3}H	2.46E+04	6.64E-07	1.00E-07	FALSE	664.2
^{14}C	1.78E+03	4.81E-08	5.00E-07	TRUE	9.6
^{60}Co	2.98E-07	8.06E-18	4.00E-10	TRUE	0.0
^{90}Sr	2.09E-04	5.65E-15	5.00E-11	TRUE	0.0
^{90}Y	2.09E-04	5.65E-15	2.00E-09	TRUE	0.0
^{99}Tc	7.08E-05	1.91E-15	1.00E-08	TRUE	0.0
^{129}I	4.58E+01	1.24E-09	7.00E-11	FALSE	1768.7
^{137}Cs	1.19E-02	3.22E-13	4.00E-10	TRUE	0.1
^{137m}Ba	1.13E-02	3.05E-13			
^{154}Eu	1.85E-06	5.01E-17	5.00E-11	TRUE	0.0
^{155}Eu	2.31E-06	6.25E-17	3.00E-10	TRUE	0.0
^{235}U	1.46E-12	3.94E-23	5.00E-12	TRUE	0.0
^{238}U	3.03E-11	8.18E-22	5.00E-12	TRUE	0.0
^{238}Pu	0.00E+00	0.00E+00	3.00E-14	TRUE	0.0
^{239}Pu	4.81E-08	1.30E-18	2.00E-14	TRUE	0.0
^{240}Pu	8.78E-09	2.37E-19	2.00E-14	TRUE	0.0
^{241}Pu	3.23E-07	8.72E-18	1.00E-12	TRUE	0.0
^{241}Am	7.29E-07	1.97E-17	2.00E-14	TRUE	0.1
Sum	2.64E+04	7.14E-07	6.13E-07		2442.7

Table 4.2. Continuous Inhaled Air Derived Concentration Guides (Worst Case) – Alternative B

Temperature 25 °C
Offgas Flowrate 3,190 m^3/hr

Radionuclides	HEPA Filter Offgas Concentration Bq/m^3	µCi/ml	Individual DCGs µCi/ml	DCG Meet?	Concentration DCG (%)
^{3}H	2.49E+04	6.73E-07	1.00E-07	FALSE	672.6
^{14}C	1.78E+03	4.81E-08	5.00E-07	TRUE	9.6
^{60}Co	1.49E-08	4.03E-19	4.00E-10	TRUE	0.0
^{90}Sr	2.05E-05	5.54E-16	5.00E-11	TRUE	0.0
^{90}Y	2.05E-05	5.54E-16	2.00E-09	TRUE	0.0
^{99}Tc	1.21E-04	3.26E-15	1.00E-08	TRUE	0.0
^{129}I	2.29E+03	6.19E-08	7.00E-11	FALSE	88436.9
^{137}Cs	3.71E-02	1.00E-12	4.00E-10	TRUE	0.3
^{137m}Ba	3.52E-02	9.50E-13			
^{154}Eu	1.85E-07	5.01E-18	5.00E-11	TRUE	0.0
^{155}Eu	2.31E-07	6.25E-18	3.00E-10	TRUE	0.0
^{235}U	1.46E-13	3.94E-24	5.00E-12	TRUE	0.0
^{238}U	3.03E-12	8.18E-23	5.00E-12	TRUE	0.0
^{238}Pu	0.00E+00	0.00E+00	3.00E-14	TRUE	0.0
^{239}Pu	3.26E-09	8.81E-20	2.00E-14	TRUE	0.0
^{240}Pu	8.78E-10	2.37E-20	2.00E-14	TRUE	0.0
^{241}Pu	3.23E-08	8.72E-19	1.00E-12	TRUE	0.0
^{241}Am	7.29E-08	1.97E-18	2.00E-14	TRUE	0.0
Sum	2.90E+04	7.83E-07	6.13E-07		89119.4

Table 4.3. Continuous Inhaled Air Derived Concentration Guides (Worst Case) – Alternative C

Temperature 25 °C
Offgas Flowrate 2,431 m^3/hr

Radionuclides	HEPA Filter Offgas Concentration Bq/m^3	µCi/ml	Individual DCGs µCi/ml	DCG Meet?	Concentration DCG (%)
^{3}H	5.68E+03	1.53E-07	1.00E-07	FALSE	153.5
^{14}C	2.33E+03	6.31E-08	5.00E-07	TRUE	12.6
^{60}Co	9.79E-09	2.64E-19	4.00E-10	TRUE	0.0
^{90}Sr	2.24E-06	6.05E-17	5.00E-11	TRUE	0.0
^{90}Y	2.24E-06	6.05E-17	2.00E-09	TRUE	0.0
^{99}Tc	2.54E-06	6.85E-17	1.00E-08	TRUE	0.0
^{129}I	6.01E+01	1.62E-09	7.00E-11	FALSE	2320.9
^{137}Cs	6.50E-04	1.76E-14	4.00E-10	TRUE	0.0
^{137m}Ba	6.15E-04	1.66E-14			
^{154}Eu	2.03E-08	5.48E-19	5.00E-11	TRUE	0.0
^{155}Eu	2.53E-08	6.83E-19	3.00E-10	TRUE	0.0
^{235}U	1.60E-14	4.31E-25	5.00E-12	TRUE	0.0
^{238}U	3.31E-13	8.94E-24	5.00E-12	TRUE	0.0
^{238}Pu	0.00E+00	0.00E+00	3.00E-14	TRUE	0.0
^{239}Pu	3.38E-10	9.14E-21	2.00E-14	TRUE	0.0
^{240}Pu	9.60E-11	2.59E-21	2.00E-14	TRUE	0.0
^{241}Pu	3.53E-09	9.54E-20	1.00E-12	TRUE	0.0
^{241}Am	7.97E-09	2.15E-19	2.00E-14	TRUE	0.0
Sum	8.07E+03	2.18E-07	6.13E-07		2487.0

Table 4.4. Continuous Inhaled Air Derived Concentration Guides (Worst Case) – Alternative D

Temperature 25 °C
Offgas Flowrate 3,532 m^3/hr

Radionuclides	HEPA Filter Offgas Concentration Bq/m^3	µCi/ml	Individual DCGs µCi/ml	DCG Meet?	Concentration DCG (%)
^{3}H	1.28E+04	3.46E-07	1.00E-07	FALSE	346.4
^{14}C	1.61E+04	4.34E-07	5.00E-07	TRUE	86.9
^{60}Co	1.08E-09	2.91E-20	4.00E-10	TRUE	0.0
^{90}Sr	7.39E-07	2.00E-17	5.00E-11	TRUE	0.0
^{90}Y	7.39E-07	2.00E-17	2.00E-09	TRUE	0.0
^{99}Tc	2.62E-06	7.08E-17	1.00E-08	TRUE	0.0
^{129}I	2.07E+04	5.59E-07	7.00E-11	FALSE	798857.0
^{137}Cs	4.03E-05	1.09E-15	4.00E-10	TRUE	0.0
^{137m}Ba	3.81E-05	1.03E-15			
^{154}Eu	6.70E-09	1.81E-19	5.00E-11	TRUE	0.0
^{155}Eu	8.35E-09	2.26E-19	3.00E-10	TRUE	0.0
^{235}U	5.27E-15	1.43E-25	5.00E-12	TRUE	0.0
^{238}U	1.09E-13	2.95E-24	5.00E-12	TRUE	0.0
^{238}Pu	0.00E+00	0.00E+00	3.00E-14	TRUE	0.0
^{239}Pu	1.12E-10	3.03E-21	2.00E-14	TRUE	0.0
^{240}Pu	3.17E-11	8.57E-22	2.00E-14	TRUE	0.0
^{241}Pu	1.17E-09	3.15E-20	1.00E-12	TRUE	0.0
^{241}Am	2.63E-09	7.12E-20	2.00E-14	TRUE	0.0
Sum	4.96E+04	1.34E-06	6.43E-07		799290.2

Table 4.5. Continuous Inhaled Air Derived Concentration Guides (Worst Case) – Alternative E

Temperature 25 °C
Offgas Flowrate 2,311 m^3/hr

Radionuclides	HEPA Filter Offgas Concentration Bq/m^3	µCi/ml	Individual DCGs µCi/ml	DCG Meet?	Concentration DCG (%)
^{3}H	1.74E+04	4.69E-07	1.00E-07	FALSE	469.2
^{14}C	2.46E+04	6.64E-07	5.00E-07	FALSE	132.7
^{60}Co	4.12E-07	1.11E-17	4.00E-10	TRUE	0.0
^{90}Sr	9.41E-05	2.54E-15	5.00E-11	TRUE	0.0
^{90}Y	9.41E-05	2.54E-15	2.00E-09	TRUE	0.0
^{99}Tc	7.81E-05	2.11E-15	1.00E-08	TRUE	0.0
^{129}I	3.16E+04	8.54E-07	7.00E-11	FALSE	1220686.4
^{137}Cs	1.93E-02	5.22E-13	4.00E-10	TRUE	0.1
^{137m}Ba	1.83E-02	4.94E-13			
^{154}Eu	8.53E-07	2.31E-17	5.00E-11	TRUE	0.0
^{155}Eu	1.06E-06	2.87E-17	3.00E-10	TRUE	0.0
^{235}U	6.72E-13	1.81E-23	5.00E-12	TRUE	0.0
^{238}U	1.39E-11	3.76E-22	5.00E-12	TRUE	0.0
^{238}Pu	0.00E+00	0.00E+00	3.00E-14	TRUE	0.0
^{239}Pu	1.42E-08	3.84E-19	2.00E-14	TRUE	0.0
^{240}Pu	4.04E-09	1.09E-19	2.00E-14	TRUE	0.0
^{241}Pu	1.49E-07	4.01E-18	1.00E-12	TRUE	0.0
^{241}Am	3.35E-07	9.06E-18	2.00E-14	TRUE	0.0
Sum	7.35E+04	1.99E-06	6.13E-07		1221288.6

Table 4.6. Continuous Inhaled Air Derived Concentration Guides (Worst Case) – Alternative F

Temperature 25 °C
Offgas Flowrate 3,190 m^3/hr

Radionuclides	HEPA Filter Offgas Concentration Bq/m^3	HEPA Filter Offgas Concentration µCi/ml	Individual DCGs µCi/ml	DCG Meet?	Concentration DCG (%)
^{3}H	3.49E+04	9.44E-07	1.00E-07	FALSE	944.0
^{14}C	1.78E+03	4.81E-08	5.00E-07	TRUE	9.6
^{60}Co	1.49E-06	4.03E-17	4.00E-10	TRUE	0.0
^{90}Sr	3.45E-04	9.33E-15	5.00E-11	TRUE	0.0
^{90}Y	3.45E-04	9.33E-15	2.00E-09	TRUE	0.0
^{99}Tc	9.67E-03	2.61E-13	1.00E-08	TRUE	0.0
^{129}I	2.29E+03	6.19E-08	7.00E-11	FALSE	88443.9
^{137}Cs	2.48E+00	6.69E-11	4.00E-10	TRUE	16.7
^{137m}Ba	2.34E+00	6.34E-11			
^{154}Eu	3.09E-06	8.35E-17	5.00E-11	TRUE	0.0
^{155}Eu	3.85E-06	1.04E-16	3.00E-10	TRUE	0.0
^{235}U	2.43E-12	6.56E-23	5.00E-12	TRUE	0.0
^{238}U	5.04E-11	1.36E-21	5.00E-12	TRUE	0.0
^{238}Pu	0.00E+00	0.00E+00	3.00E-14	TRUE	0.0
^{239}Pu	6.87E-08	1.86E-18	2.00E-14	TRUE	0.0
^{240}Pu	1.46E-08	3.95E-19	2.00E-14	TRUE	0.0
^{241}Pu	5.38E-07	1.45E-17	1.00E-12	TRUE	0.0
^{241}Am	1.21E-06	3.28E-17	2.00E-14	TRUE	0.2
Sum	3.90E+04	1.05E-06	6.13E-07		89414.5

None of the alternatives met all of the emissions requirements based on "worst case" conditions. All alternatives met the study emissions requirements for radionuclides contained in particulates. None of the alternative processes conform to all gaseous radionuclide emissions (^{3}H, ^{14}C, ^{129}I) requirements. None of the alternatives met the ^{129}I or ^{3}H emission limits. If the Tank 101-AZ ^{3}H and ^{14}C contents are used in the study versus the contract limit or the ^{3}H and ^{14}C are washed from the solids by a factor of 10, the individual DCG limit for ^{3}H and ^{14}C are not exceeded in any case. If the contract limit were used for ^{129}I instead of the Tank 101-AZ content and caustic column and high efficiency ^{129}I removal employed then the ^{129}I DCG limit may not be exceeded if the technologies operate effectively for the low I_2 concentration involved. The ^{129}I nonconformance is much lower where treated by a heated silver mordenite column (alternatives A and C). If the caustic scrubber were not utilized, the ^{14}C would be above a DCG of one for Alternative D.

A case was assessed to determine if the DCG limits would be exceeded at the HLW vitrification plant stack (air flow = 300,000 cfm) using a contract limit envelope D feed. The contract limit ^{129}I feed rate to the HLW vitrification plant is 29 times less than the tank 101-AZ feed. Table 4.7 shows that under these conditions the ^{129}I concentration at the release point (stack) is substantially lower than for the "worst case". Alternatives A and C have the lowest ^{129}I emissions followed by B and F. All four of these alternatives meet the DCG limits at the stack. Also, the concentrations of ^{3}H and ^{14}C are reduced well below the DCG limits at the stack release points (concentration reduced by factor of about 100). The scoring for all alternatives were relatively decreased for this criteria since "worst case" conditions lead to criteria not compliance.

Table 4.7. Continuous Inhaled Air Derived Concentration Guide Ratio for ^{129}I at Stack

Alternative	$\frac{^{129}I \text{ Concentration}}{^{129}I \text{ DCG}} \times 100$, %
A	0.38
B	19
C	0.38
D	190
E	190
F	19

A preliminary assessment was performed (BNFL Inc. 1999) to determine if the study releases for ^{3}H, ^{14}C, ^{129}I, and radionuclides associated with aerosols would result in radiation exposure to a maximum exposed offsite person in excess of 1.5 mrem/yr at the site boundary. The assessment indicated that exposure due to ^{3}H and ^{14}C was well below 1.5 mrem/yr, and exposure due to ^{129}I was likely below 1.5 mrem/yr for "worst case" conditions. The exposure due to radionuclides associated with aerosols was well below the exposure limit.

Additional study is required on the amount of ^{129}I in the feed and its pathway through the WTP processing facilities to determine if an emission concern actually exists and any related treatment requirements (see Appendix A). A system analysis is required based on permitting radiation dose models. On the basis of this study, best available radionuclide control technology may need to be employed on the system selected for ^{129}I control. Use of a silver mordenite column for ^{129}I removal is the best available technology. The spent ^{129}I removal column would be disposed as a mixed waste.

NO_X removal was specifically designed only into Alternative E. There is moderate NO_X removal (88% to 98%) in each alternative, except Alternative D (6.5%) as part of the quenching process and where the caustic scrubber is employed. The NO_X in the HLW feed to the vitrification plant was not deemed sufficient to warrant removal. The annual release of NO_X by each alternative together with the removal efficiency is shown in Appendix C. The amount of NO_X annually released by each alternative is well below the site limit of 40 tons a year (< 5 tons/yr) except Alternative D = 37 tons/yr. The amount released by HLW vitrification needs to be considered in context with other site plant releases. For this study the releases for the alternatives are deemed acceptable, except for Alternative D.

Organic removal in the POG treatment system was considered in this study. However, adequate quantitative information was not available to perform comparative performance assessments. Inclusion of technology for organic destruction (catalytic oxidation) provides substantial incentive to include caustic scrubbing to prevent rapid catalyst poisoning. An organic destruction assessment was only partially included in this study (Appendix B) because of uncertainties in plant feed amounts and speciation. Additional study is required as to the need for specific organic destruction equipment. Inclusion of this equipment is considered positive for pollution control.

4.2 Secondary Offgas Treatment Area Radiation Level

The SOG treatment area facility design requires manned entry for maintenance. The radiation dose rate in the area needs to be controlled to permit manned entry.

A conservative rough order of magnitude (ROM) shielding assessment was performed to determine the dose rate in the SOG treatment area after 10 yr of continuous operation at nominal operation conditions.

With upset conditions, these calculations may be less conservative. The assumptions were made that the plant operated 365 d/yr and 24 hr/d. All particulate material in the POG passing through the primary system is assumed to continuously and uniformly accumulate on a duct wall, 4-ft length and 10-in. diameter. The steel duct was assumed to have a wall thickness of 0.2 in. The vitrification production rate was 1.5 MtG/d, and the accumulation on the duct wall after 10 yr was decayed for 5 yr. The results of these analyses are shown in Table 4.8.

Table 4.8. Secondary Offgas Treatment Area Alternative Dose Rate Evaluation

Alternative	Dose Rate mR / hr
Alternative A	16,000
Alternative B	54,000
Alternative C	720
Alternative D	32
Alternative E	11,000
Alternative F	36

Virtually all of the dose rate at 12 in. from the duct comes from the gamma radiation of ^{137m}Ba, which is the daughter product of ^{137}Cs. The results show that the alternatives with low dose rates from the pipe have highly efficient submicron particulate removal capability with which the ^{137}Cs is normally primarily associated.

The criteria require the allowable dose rate to be 2.5 mrem/hr for wide spread and static radiation fields and 25 mrem/hr maximum dose equivalent for average and maximum radiation areas (BNFL 1998, pg. 7). The calculations are likely conservative by 1 to 2 orders of magnitude. Only alternatives D and F pass this screening test, within accuracy of the results, unless additional submicron filtration capability is added to other alternatives.

4.3 Safety

A two-day seminar was conducted to perform a process and hazards design review for the study alternatives, as described in Appendix D. The multidiscipline review was intended to identify failure modes, frequency, consequences, and mitigation strategies for the alternatives.

All alternative processes and associated equipment systems could be safely implemented with the use of appropriate design and control strategies.

Particular unit operations and equipment requiring particular design attention due to the consequences of the failure/event mode are identified in Table 4.9.

There is a particular concern with a fire hazard by using GAC in Alternative C for organic sorption. Venting the standby offgas system to the SOG system causing excessive maintenance radiation exposure was a concern for Alternative A. Venting the standby offgas system to the melter cell without any particulate removal may increase the hazard potential of staff radiation exposure in adjacent areas for Alternative D.

Table 4.9. Equipment and Process Safety

Alternative	Event / Failure Mode	Consequences	Control Strategy
General	Failure of major vessel, filled with radioactive slurry and permanently installed	• Major facility contamination/ recovery • Difficult equipment changeout • Long lost production • Administrative recovery	• Conservative vessel design (materials and corrosion allowance) • Remote installation/removal • Design for recovery
	POG treatment system not adequately designed to maintain radiation level in SOG area low enough to allow contact maintenance	• Frequent SOG area decontamination • High staff exposure during maintenance	• Installation of additional filtration between primary and SOG systems
	Pluggage of vessel drain lines/ RFDs with solids	• Process shutdown • Use innovative methods to clean lines/RFD	• Design with specific cleaning methods engineered in system
	Melter gas relief system (valve, seal pot, rupture disc) fails to open for pressure relief	• Melter integrity could be damaged • Glass could overflow from pour area to cell floor and unplanned area • Plant downtime • Administrative recovery • Release of contaminated gases to cell	• Include redundant design
A	Solids accumulation in quencher sump	• Inability to remove solids from tank • Melter shutdown • Ad hoc solids removal	• Provide reliable solids removal approach • Replace tank
	Solids accumulation in seal pot	• Inability to switch/operate filter systems • Melter shutdown • Ad hoc solids removal	• Provide reliable solids removal approach • Replace tank
	Standby system venting to SOG system could raise dose rate in SOG treatment area to unacceptable level	• High dose rate to maintenance workers • Increased decontamination frequency with system shutdowns • Increased contamination potential	• Change venting route • Add additional standby system filtration
B	Solids accumulation in quench tank	• Inability to remove solids from tank • Melter shutdown • Ad hoc solids removal	• Provide reliable solids removal approach • Replace tank
	WESP shorts out	• WESP particulate decontamination ability becomes substantially lower • Shut down melter • Replace WESP	• Assure WESP design and flushing avoids shorting • Design with replaceable electrodes
C	Activated charcoal catches fire	• Filter system plugs from smoke • Melter shuts down • Bypass SOG system	• Install fire suppression system • Ensure low inlet gas temperature
	Solids accumulation in quench tank	• Inability to remove solids from tank • Melter shutdown • Ad hoc solids removal	• Provide reliable solids removal approach • Replace tank
	Solids accumulation in SBS	• Inability to remove solids from tank • Melter shutdown • Ad hoc solids removal	• Provide reliable solids removal approach • Replace tank

Table 4.9. Equipment and Process Safety

Alternative	Event / Failure Mode	Consequences	Control Strategy
	Cooling coils in SBS fail	• SBS fills at abnormal rate • Shut off cooling water • Clean out and replace tank	• Design tank with cooling coil conservative corrosion allowance and materials
D	Solids accumulation in quench tank	• Inability to remove solids from tank • Melter shutdown • Ad hoc solids removal	• Provide reliable solids removal approach • Replace tank
	Cooling coils in quench tank fail	• SBS fills at abnormal rate • Shut off cooling water • Clean out and replace tank	• Design tank with cooling coil conservative corrosion allowance and materials
	Melter pressurization	• Releases of highly contaminated and nontreated melter offgas to cell • Increase potential for spread of radioactive contamination to building	• Further treat melter offgas before release to cell
E	Solids accumulation in SBS	• Inability to remove solids from tank • Melter shutdown • Ad hoc solids removal	• Provide reliable solids removal approach • Replace tank
	Cooling coils in SBS fail	• SBS fills at abnormal rate • Shut off cooling water • Clean out and replace tank	• Design tank with cooling coil conservative corrosion allowance and materials
F	Solids accumulation in SBS	• Inability to remove solids from tank • Melter shutdown • Ad hoc solids removal	• Provide reliable solids removal approach • Replace tank
	Cooling coils in SBS fail	• SBS fills at abnormal rate • Shut off cooling water • Clean out and replace tank	• Design tank with cooling coil conservative corrosion allowance and materials
	WESP shorts out	• WESP particulate decontamination ability becomes substantially lower • Shut down melter • Replace WESP	• Assure WESP design and flushing avoids shorting • Design with replaceable electrodes

4.4 Reliability and Availability

Increased reliability is represented in this study by the decrease in the number of system failures per year. Increased availability is represented by the decrease in plant downtime caused by system failures per year. Reliability and availability indicate the ability to have the plant available to operate when desired. Reliability and availability are also a measure of the ability to increase profit by being able to maximize/increase production not limited by feed availability. This feature becomes important during Phase 2 of the WTP Project.

The safety seminar, indicated in Section 4.3, identified process and equipment failure rates by equipment group (i.e., pumps, agitators, electric heaters) as described in Appendix D. Failure frequency by group was identified as once a month, year, 10 yr, or life of plant (40 yr). This frequency classification is a semi-quantitative judgement of the review team. A life of plant designation means that with proper design and engineering, the process/equipment group is expected to last the life of the plant without

failure. There was also a classification of "not credible", which indicates no significant probability of the event happening.

Appendix E provides an equipment/process failure frequency by equipment type and frequency per year if less than life of plant (40 yr) and credible. In Appendix E, an effort was made in some areas to define equipment component failure frequency in closer increments than in the seminar. Appendix E indicates if there is installed spare equipment, spare equipment onsite, and plant down time per event based on the author's judgement. Appendix E indicates the failure frequency and projected plant down time per year caused by comparable system offgas equipment failure based on the author's judgement. The downtime per failure is considered a minimum.

Appendix E assumes that the process is shut down to a standby condition on equipment failure even where installed spare equipment is available, because there is then no backup equipment, and the consequences of additional equipment failure.

For project Part B-2, there is no plant cost penalty associated with equipment downtime as long as contract production requirements can be met; however, the most reliable process is desired. Maintenance cost increases with equipment failure rate due to the cost of equipment, materials, and waste disposal. This is discussed further in Section 4.6.

In comparing the entire POG treatment systems, Table 4.10 indicates that Alternative F has the maximum reliability (minimum failures) per year followed closely by alternatives E, B, and D. Alternative E has the maximum availability (minimum plant downtime) followed closely by alternatives F and B.

Table 4.10. Projected Plant Downtime Due to Melter Offgas Treatment Process and Equipment Failures

Alternative	Failures per Year	Plant Downtime (d/yr)	Number of Major Equipment Pieces
A	26.8	34	50
B	24.2	29	35
C	25.1	30	43
D	24.4	31	23
E	24.2	26	22
F	23.8	28	25

Another measure of system reliability and availability is to compare the alternatives without including the SOG (includes remote maintenance areas only) and standby (SB) treatment systems. Thus, if the SOG and/or SB systems are deleted from the alternatives, Table 4.11 shows the most reliable systems to be alternatives E and F, and the most available system to be Alternative E followed by alternatives F and C. The high relative reliability and availability is based on the relative passive nature of the system achieved by minimizing components, particularly those that have a relatively high failure rate such as pumps.

Table 4.11. Projected Plant Downtime Due to Melter Offgas Treatment Process and Equipment Failures Excluding Secondary Offgas Treatment (Appendix F)

Alternative	Failures per Year		Plant Downtime (d/yr)		Number of Major Equipment Pieces	
Without	SOG	SOG and SB	SOG	SOG and SB	SOG	SOG and SB
A	24.8	23.1	29.7	20.3	37	34
B	22.2	20.8	25.1	21.8	24	22
C	23	23	24.6	24.6	27	25
D	24.3	24.3	25.4	25.4	18	17
E	21.7	21.3	23.5	21.7	13	12
F	21.8	20.5	24.4	21.3	14	12

SOG = secondary offgas treatment equipment.

SB = standby treatment equipment.

4.5 Technical Risk

For this study technical risk is defined as the likelihood that a process or equipment item will not operate as intended by design. This failure to perform may result in the inability of the plant to operate at designed production or at all. Design data development and demonstrations to assure performance can reduce risk. Based on input from the seminar described in Section 4.3 and the authors' judgement, the technical risk by alternative and process/equipment are categorized as high or medium. If not included, the risk is categorized as low. The projected cost to mitigate risk is a research and technology cost to perform a process/equipment development effort to assure achievement of intended performance at low risk.

The alternative technical risks are provided in Table 4.12.

Table 4.12. Equipment and Process Technical Risk

Alternative	Process / Equipment	Risk Description	Risk Category[1]	Projected Cost to Mitigate, $K
A	Quench sump	Ability to suspend solids	2	200
	Seal pot (initial)	Plugging and ability to clean seal pots	2	200
	HEMF	Ability to clean HEMFs	3	500
	Vortex amplifier	Ability to control melter pressure	Not acceptable	300
	I sorption	Ability to remove required ^{129}I	3	400
	Caustic scrubber (& Condenser)	Ability to remove required ^{14}C, ^{3}H, Organics	3	500
	System Demonstration	Ability of system to operate as designed	2	2,000
			Total:	4,100
B	Quench sump	Ability to suspend solids	2	200
	WESP	Demonstrate technology and operability on specific waste stream	3	600
	HEMF	Ability to clean HEMF	3	500
	Caustic scrubber (& Condenser)	Ability to remove required ^{14}C, ^{3}H, Organics	3	500
	Organic thermal oxidizer	Demonstrate technology and operability on specific waste stream	2	700
	System Demonstration	Ability of system to operate as designed	2	2,000

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Attachment 3

GHOST LETTER TO WASHINGTON DEPARTMENT OFECOLOGY AND U.S. ENVIRONMENTAL PROTECTION AGENCY

Consisting of 3 pages
including cover page

Suzanne Dahl, Project Manager
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Post Office Box 47600
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Dear Addresses:

Reference: Meeting held between DOE/ORP, CHG, U.S. Environmental Protection Agency, and the Washington Department of Ecology, November 1 and 2, 2000.

During the meeting referenced above, DOE was asked to provide the following documents:

- *Evaluation of Alternatives for the LAW Melter Offgas System* (RPT-W375LV-TE00008)

- *HLW Vitrification Process Offgas System Evaluation* (RPT-W375HV-PR00001)

Evaluation of Alternatives for the LAW Melter Offgas System is attached in its entirety. The text portion of *HLW Vitrification Process Offgas System Evaluation* is also provided.

If you have any questions or comments, please contact Ms. Lori Huffman on (509) 376-0104

Sincerely,

W. J. Taylor, Assistant Manager
Systems Acquisition
U. S. Department of Energy
Office of River Protection

ES:

Enclosure