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Risk-Based Systems Analysis of Emerging High-Level Waste Tank Remediation Technologies

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CONTENTS

1.0 INTRODUCTION 1-1
1.1 BACKGROUND 1-1
1.2 OBJECTIVES 1-1
1.3 QUESTIONS AND ANSWERS 1-6
1.4 REPORT ORGANIZATION 1-8

2.0 SYSTEM ANALYSIS MODEL 2-1
2.1 SYSTEM CHARACTERIZATION 2-2
2.1.1 Approach and Assumptions 2-2
2.1.2 Methods and Data 2-2
2.2 RISK EVALUATIONS 2-4
2.2.1 Approach 2-5
2.2.2 Methods, Data, and Assumptions 2-6
2.3 COST CALCULATIONS 2-22
2.3.1 Approach and Assumptions 2-22
2.3.2 Methods and Data 2-23
2.4 SYSTEM ANALYSIS MODEL SOFTWARE 2-24

3.0 BASELINE AND TRIAL APPLICATIONS 3-1
3.1 BASE CASE 3-1
3.1.1 Description 3-1
3.1.2 Case-Specific Assumptions 3-6
3.1.3 Results 3-9
3.2 TEST CASE I 3-18
3.2.1 Description 3-18
3.2.2 Case-Specific Assumptions 3-19
3.2.3 Results 3-21
3.3 TEST CASE II 3-26
3.3.1 Description 3-26
3.3.2 Case-Specific Assumptions 3-30
3.3.3 Results 3-31
3.4 COMPARISON SUMMARY AND MODULE UNCERTAINTY ANALYSIS 3-36
3.4.1 Major Risk Uncertainties 3-39
3.4.2 Cost Uncertainties 3-43

4.0 SUMMARY AND CONCLUSIONS 4-1

5.0 REFERENCES 5-1

APPENDIXES

A Module Descriptions A-1
B Module Schematics B-1
C Module Equipment List C-1
D Unit Operation Description Sheets D-1
E Stream Descriptions E-1
F Module Mass Balances F-1
G Mass Percent of Constituents of Concern G-1

CONTENTS (cont.)

APPENDIXES (cont.)

H Assumptions and Conversions Regarding Radionuclides H-1
I Assumptions Made In the Mass Balances I-1
J Module/Unit Operation Work Force Worker-Hours J-1
K MEPAS Code Input K-1
L Failure Risk Factor Sheets L-1
M Module Cost Summary M-1
N System Risk Analysis Model Software Printouts N-1
O Model Software O-1

LIST OF FIGURES

1-1 Technology Funding Decision-Making Process 1-3

1-2 System Analysis Model Risk and Cost Evaluations 1-4

1-3 Additional Stakeholder Values 1-5

2-1 System Analysis Model Software Flow Chart 2-25

3-1 Tank Waste Remediation System New Technical Strategy
Top-Level Flow Diagram 3-2

3-2 Base Case Top-Level Flow Diagram 3-3

3-3 Comparison of UST-ID Funding to Selected Risks Evaluated
for Base Case Modules 3-17

3-4 Close-Coupled Chemical Barrier 3-19

3-5 Robotic Sluicing 3-29

3-6 Base Case Costs (Percentage of Overall System Costs) 3-44

3-7 Test Case I Costs (Percentage of Overall System Costs) 3-45

3-8 Test Case II Costs (Percentage of Overall System Costs) 3-47

LIST OF TABLES

2-1 Unit Operation Descriptions 2-3

2-2 Comparison of Contaminant Rankings 2-7

2-3 Contaminants of Concern Evaluated in the Risk Model 2-8

2-4 Effective Dose Rates for Routine Worker Risks 2-9

2-5 Format for Failure Risks for Accident and Nonroutine Maintenance Events 2-16

2-6 Consequence Ranks and Relative Consequence Values 2-17

2-7 Consequence Ranks for Accident Event and General Indicator Conditions 2-18

2-8 Frequency Values for Accident Failure and General Indicator Conditions 2-20

2-9 Frequency Values for Nonroutine Maintenance Failure and General Indicator Conditions 2-21

2-10 System Analysis Model Cost Categories 2-23

3-1 Module Names 3-4

3-2 Risk Summary for the Base Case 3-10

3-3 Base Case Cost Summary 3-15

3-4 Base Case Cost and Risk Analyses Summary 3-16

3-5 Risk Summary for Test Case I 3-23

3-6 Test Case I Cost Summary 3-27

3-7 Test Case I Cost and Risk Analyses Summary 3-28

3-8 Risk Summary for Test Case II 3-33

3-9 Test Case II Cost Summary 3-37

3-10 Test Case II Cost and Risk Analyses Summary 3-38

3-11 Test Case Changes to System Risk and Cost from the Base Case 3-39

LIST OF TERMS

BVOG	bin vessel offgas
CENRTC	capital equipment not related to construction
COC	contaminant of concern
CVOG	condensed vessel offgas
D&D	decontamination and decommissioning
DOE	U.S. Department of Energy
DST	double-shell tank
EDTA	ethylenediaminetetraacetic acid
EPA	U.S. Environmental Protection Agency
GPP	general plant processes
HDW-EIS	Hanford Defense Waste Environmental Impact Statement
HEPA	high-efficiency particulate air (filter)
HI	hazard index
HLW	high-level waste
LLW	low-level waste
MEI	maximally exposed individual
MEPAS	Multimedia Environmental Pollutant Assessment System
NEPA	National Environmental Policy Act (1969)
OTD	Office of Technology Development
PPE	personal protective equipment
PPG	Priority Planning Grid
R&D	research and development
RfD	reference dose
RWTRTFA	Radioactive Waste Tank Remediation Technology Focus Area
SST	single-shell tank
TBP	tributyl phosphate
TNPW	total net present worth
TOC	total organic carbon
TRUEX	transuranic extraction
TWRS	Tank Waste Remediation System
UST-ID	Underground Storage Tank - Integrated Demonstration
VOG	vessel offgas

Metric Conversion Chart

The following chart is provided to the reader as a tool to aid in converting to metric units.

Into Metric Units

If You Know	Multiply By	To Get
Length		
inches	25.4	millimeters
inches	2.54	centimeters
feet	0.305	meters
yards	0.914	meters
miles	1.609	kilometers
Area		
sq. inches	6.452	sq. centimeters
sq. feet	0.093	sq. meters
sq. yards	0.0836	sq. meters
sq. miles	2.6	sq. kilometers
acres	0.405	hectares
Mass (weight)		
ounces	28.35	grams
pounds	0.454	kilograms
short ton	0.907	metric ton
Volume		
teaspoons	5	milliliters
tablespoons	15	milliliters
fluid ounces	30	milliliters
cups	0.24	liters
pints	0.47	liters
quarts	0.95	liters
gallons	3.8	liters
cubic feet	0.028	cubic meters
cubic yards	0.765	cubic meters
Temperature		
Fahrenheit	subtract 32, then multiply by 5/9	Celsius
Pressure		
inches of H_2O	0.00246	atmospheres
inches of Hg	0.03332	atmospheres

Out of Metric Units

If You Know	Multiply	To Get
Length		
millimeters	0.039	inches
centimeters	0.394	inches
meters	3.281	feet
meters	1.094	yards
kilometers	0.621	miles
Area		
sq. centimeters	0.155	sq. inches
sq. meters	10.76	sq. feet
sq. meters	1.196	sq. yards
sq. kilometers	0.4	sq. miles
hectares	2.47	acres
Mass (weight)		
grams	0.035	ounces
kilograms	2.205	pounds
metric ton	1.102	short ton
Volume		
milliliters	0.033	fluid ounces
liters	2.1	pints
liters	1.057	quarts
liters	0.264	gallons
cubic meters	35.315	cubic feet
cubic meters	1.308	cubic yards
Temperature		
Celsius	multiply by 9/5, then add 32	Fahrenheit
Pressure		
atmospheres	406.5	inches of H_2O
atmospheres	30.005	inches of Hg

RISK-BASED SYSTEMS ANALYSIS OF EMERGING HIGH-LEVEL WASTE TANK REMEDIATION TECHNOLOGIES

1.0 INTRODUCTION

This report describes a System Analysis Model developed under the U.S. Department of Energy (DOE) Office of Technology Development (OTD) Underground Storage Tank - Integrated Demonstration (UST-ID) program. The report identifies the project objectives and provides a description of the model. Development of the first "demonstration" version of this model and a trial application have been completed and the results are presented. This model will continue to evolve as it undergoes additional user review and testing.

1.1 BACKGROUND

The objective of DOE's Radioactive Waste Tank Remediation Technology Focus Area (RWTRTFA) is to identify and develop new technologies that will reduce the risk and/or cost of remediating DOE underground waste storage tanks and tank contents. There are, however, many more technology investment opportunities than the current budget can support. Current technology development selection methods evaluate new technologies in isolation from other components of an overall tank waste remediation system. These methods do not show the relative effect of new technologies on tank remediation systems as a whole. Consequently, DOE may spend its resources on technologies that promise to improve a single function but have a small, or possibly negative, impact on the overall system, or DOE may overlook a technology that does not address a high priority problem in the system but that does, if implemented, offer sufficient overall improvements. Systems engineering and detailed analyses often conducted under the National Environmental Policy Act (NEPA 1969) use a "whole system" approach but are costly, too time-consuming, and often not sufficiently focused to support the needs of the technology program decision-makers. An alternative approach is required to evaluate these system impacts but still meet the budget and schedule needs of the technology program.

1.2 OBJECTIVES

The approach demonstrated in this report is based on a limited systems analysis. This System Analysis Model combines elements of cost-effectiveness and systems analysis. The premise underlying the development of this model is that technology development decisions should be based on a disciplined assessment of the overall risks associated with a total remediation system and that the value of new technologies is their potential to reduce those overall risks at a reasonable cost. At the same time, the importance of quick turnaround and flexibility is acknowledged. It is not in the scope of the System Analysis Model to establish or recreate systems analysis on a scale that may be undertaken by programs responsible for implementing technologies for tank remediation. The objective of the model is instead to provide comparative risk and cost assessment data for baseline and alternate tank remediation cases, where alternate cases are created by substituting or adding emerging demonstration technologies to the baseline. This baseline originates from the Hanford Site Tank Waste Remediation System (TWRS) reference system[1] and is referred to as the Base Case throughout this document.

The key to a successful assessment is to conduct (1) sufficient systems modeling to provide a reliable basis for overall system performance assessments, (2) sufficient cost analysis to measure significant variations in costs, and (3) sufficient risk analysis to estimate significant variations of worker and public risk. Only a minimum set of critical variables can be assessed to support the limited budget and time constraints for decision-making.

Another important objective in the development of the model was to make it "user friendly" so that it can be used online in discussions with stakeholders. In the application, the model could be used to quickly examine the relative value of alternate technologies in the context of a complete remediation system. Feedback from the stakeholders will allow technology brokers to identify performance issues they must address to show that the technology would have a positive net benefit to the system.

In this version (Rev. 0), a "demonstration model" for system analysis is presented. It addresses worker and public health risks (Volume 2, Section 2.2) and costs (Volume 2, Section 2.3). Later versions would include other programmatic risks, such as schedule, compliance, and environmental risk. The risk assessments provided by the model will, ideally, be considered with other important decision-making criteria, including a set of stakeholder values that might discriminate among technical options. In a real decision-making context, it should be possible to combine the assessments of all criteria, examine different weighting factors for the criteria, and generate summary assessments for different configurations of an overall tank remediation system given alternate technologies. This process is shown in Figure 1-1. The steps involved in the System Analysis Model are shown in Figure 1-2. Figure 1-3 illustrates one set of additional stakeholder values that might be applied to technology development funding decisions.

The ultimate value of this model is to provide decision-makers with a tool for identifying development efforts that, if successful, would provide significant overall benefit in terms of system cost and risk and thus have high priority for funding. The scope of the work described in this report was to develop and demonstrate this decision tool. The decision tool demonstration focuses on one baseline configuration and two alternate configurations using new technologies. The new technologies are robotic sluicing instead of traditional sluicing and subsurface barriers instead of no barrier during sluicing. Time and budget limitations constrained the choice of analytic tools applied to this demonstration version; as additional risk parameters are added, more sophisticated tools for assessing their value may also be added. The near-term objective was to demonstrate a type of analysis that could be

[1]Formerly known as "Case Beta".

Figure 1-1. Technology Funding Decision-Making Process.

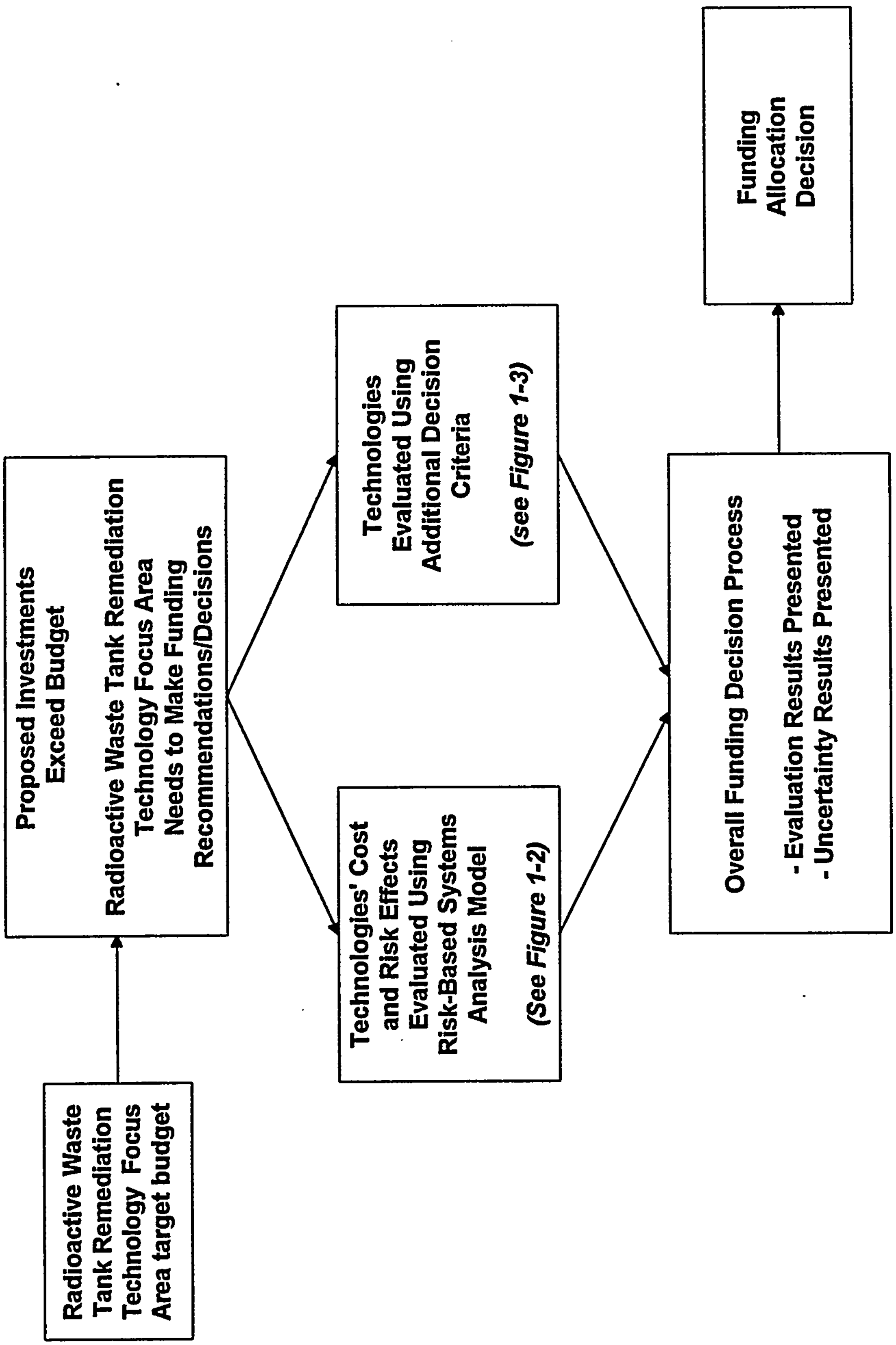


Figure 1-2. System Analysis Model Risk and Cost Evaluations.

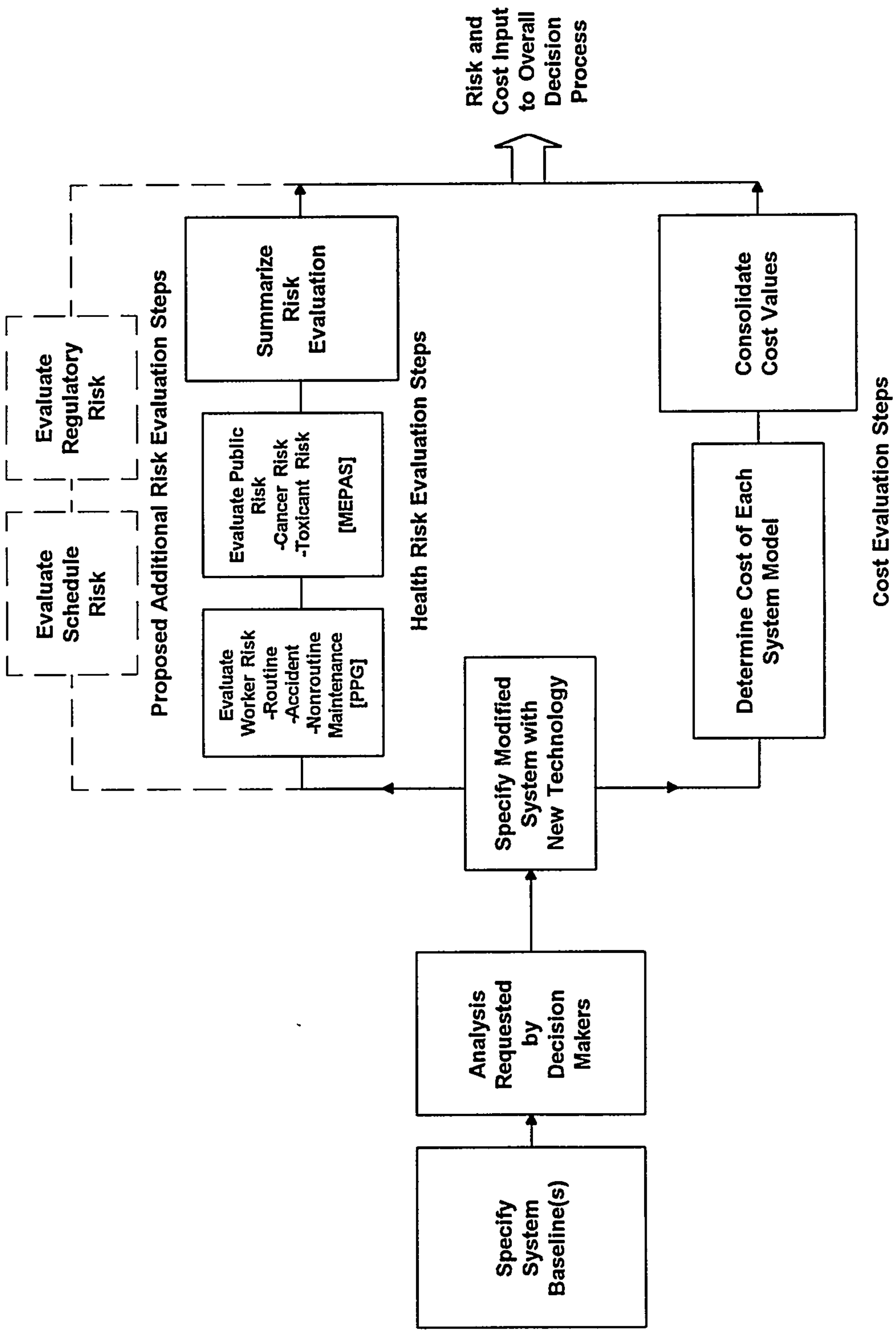
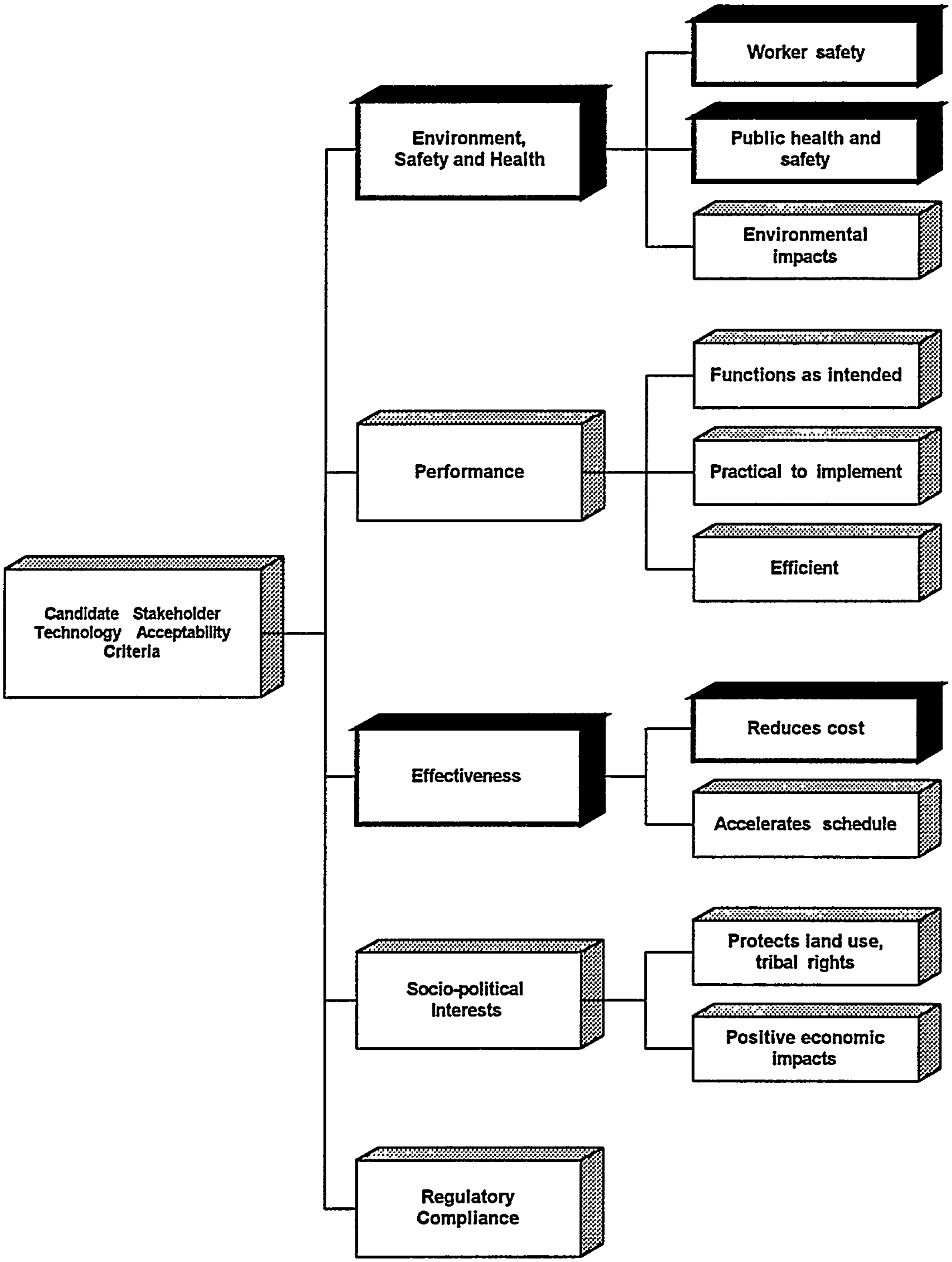


Figure 1-3. Additional Stakeholder Values.



applied to selected technologies to determine whether funding should be initiated or continued. Good candidate technologies for analysis include (1) subsurface barriers (demonstrated here), (2) robotic sluicing (demonstrated here), (3) full-scale retrieval of tanks and tank waste (e.g., mining), (4) advanced processing concepts (e.g., transuranic extraction [TRUEX]), (5) alternative low-level waste (LLW) forms (e.g., ceramics), and (6) alternative closure technologies (e.g., surface barriers).

1.3 QUESTIONS AND ANSWERS

This section provides answers to common questions that have arisen during previous reviews of this project.

What type of decisions does this model support?

This model supports resource allocation decisions for technology development. Specifically, it will help to evaluate and prioritize selected, high-cost items that are being funded because they promise to either reduce the health risks or costs of tank remediation systems. Example technologies are: subsurface barriers, robotic sluicing, full tank and tank waste retrieval, advanced separations processes, alternative LLW forms, and alternate closure scenarios.

How are stakeholder values incorporated?

At this time, the model can be used to evaluate the impact of new technologies on selected risks and the cost of the overall remediation system. Stakeholder values definition studies being performed simultaneously for TWRS can be incorporated into the model as additional decision criteria. The risk and cost data produced by this model would be incorporated into the larger set of stakeholder values that discriminate among technology investments (not all stakeholder values will be relevant).

How much will a model run cost and how long will it take?

After the model has been fully developed, it is anticipated that the evaluation of a new technology will take from 1 to 3 months and cost from $10,000 to $100,000 depending on the complexity of the technology's impacts to the overall system. If the model works as expected, significant saving of time and cost will occur by avoiding investments in new technologies that offer no advantage in improving cost-effectiveness. In addition, the model may identify areas where additional technology development may be needed to improve the overall cost-effectiveness of the system.

What is MEPAS and what are its uses?

The Multimedia Environmental Pollutant Assessment System (MEPAS) is a computer tool used to estimate concentrations in environmental media and chronic human health impacts from contaminants released to the environment. It is one of several tools that could be used to produce specific assessments incorporated into the system analyses reported here. It has the benefit of being broadly tested at the Hanford Site and generally familiar to users, although it also has critics within the system.

What is the PPG and what are its uses?

The Priority Planning Grid (PPG) is a system developed for ranking potentially hazardous conditions to determine a priority for corrective actions. It has been used in applications at the Hanford Site for several years and provides a ready, practical tool for evaluating nonroutine risks; however, it too has critics. In particular, the levels incorporated into the grid for determining priorities were not broadly elicited or reviewed before application of the grid, and there has been no effort to scale levels of the attributes so that they reflect real preferences. Subsequent applications of this model should replace the PPG with a more valid assessment method if one is identified.

Are the risk values in the model the only ones that can be used?

The MEPAS and the PPG are currently used to determine risk values but they are separate from the model. Any risk assessment tool could be interchanged with MEPAS and the PPG; however these tools would have to include contaminant transport and fate, carcinogenic and toxicant risk analysis, and accident/worker risk analysis.

Why was public risk expressed as the maximum exposed individual rather than as a population exposure?

Routine risks to the public are evaluated for the maximally exposed individual (MEI) rather than a collective population for the following reasons: (1) risks and hazard index (HI) for an MEI are a standard measure for human health effects, (2) there is no established method for computing population risks for noncarcinogenic chemicals that provides meaningful results, (3) all risk and noncancer hazard values should be based on the same receptor characteristics for comparative purposes, and (4) individual and population risks associated with exposure to radionuclides, chemical carcinogens, and chemical noncarcinogens are expected to be consistent.

Why was no evaluation of routine risk during the implementation, decommissioning, or waste disposal phases performed?

As a result of schedule and budget constraints, risks associated with implementation, decontamination and decommissioning (D&D), and routine risk during waste disposal operations were not included in this initial demonstration of the model. These potential risks will be addressed in the future development of the model.

How was the evaluation of liquid discharge to the ground under conditions of failure performed?

Under failure conditions, the risk associated with exposure to released radiological and chemical contaminants was not explicitly evaluated. Instead, the PPG methodology was used, which combines the operational and post-operational hazards from many different categories of risk into a single representation of risk. This decision may be revisited in subsequent versions.

Why does the model assume that an evaluation of human health risk from exposure to radionuclides are protective of ecosystems? In many instances an exposure pathway exists for wildlife and vegetation when one does not exist for human receptors.

It was not the intent to imply similarity between human health and ecological exposure pathways. An ecological risk assessment was not included in this model because (1) the purpose was to demonstrate the technology assessment tool and (2) an ecological risk assessment is considered to be too complex for evaluation at this time. It would be possible to add a measure of ecological risk in future applications; however, this would receive lower priority than other programmatic risks such as schedule and regulatory compliance.

Why were physical risk to workers not included in the model?

Physical injuries are an integral element of potential technology risks; however, due to schedule and budget constraints, physical injuries were not included in this initial version of the model. Quantification of potential physical injuries associated with remediation technologies will be included in the future development and application of the System Analysis Model.

1.4 REPORT ORGANIZATION

The System Analysis Model is intended to be a tool that can be applied to a multitude of different alternatives, and its approach to system characterization, risk calculation, and cost calculation should be considered independently of the specific technologies being assessed. Accordingly, the report has been organized in a step-wise fashion to facilitate review and understanding of the System Analysis Model and its envisioned role in the UST-ID program, and to demonstrate its applications to the TWRS technologies.

The System Analysis Model is described in detail in Section 2. A discussion of the purpose and objectives of the model are presented, along with a description of methodologies used to develop the system characterization, risk calculations, and cost calculations. In addition, the computer system software used to implement the System Analysis Model is described.

Section 3 describes the trial applications of the System Analysis Model. Included in the discussion of the Base Case, Test Case I, and Test Case II are descriptions of the case-specific assumptions and the results of the risk and cost evaluations. Additionally, a comparison of the results of the Base Case and test cases are presented, along with an uncertainty analysis of the assumptions and data associated with the development of the cost and risk values.

The conclusions of the System Analysis Model and its trial applications are presented in Section 4. References used in preparing the model and this document are listed in Section 5. Several appendixes are included in the report, which contain the supporting documentation for the System Analysis Model. These appendixes contain the data and discussions for module descriptions, schematics, equipment, mass balances, work force manhours, and cost summaries; unit operation description sheets; stream descriptions; assumptions; the MEPAS code; failure risk factors; and software printouts.

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2.0 SYSTEM ANALYSIS MODEL

As discussed in Section 1, a number of factors should be considered when making decisions to provide funding for further development of candidate waste tank remediation technologies. Two important factors are the potential human health risks associated with a technology, and the potential costs associated with implementing, operating, and decommissioning it. Measuring these factors is complicated by the fact that initial funding decisions must be made at a point early in the technology development process, often before there are sufficient design and process data to support quantitative analyses of potential risks or costs. In addition, because tank waste remediation will be accomplished by a complex system of interlinked technologies, the performance of individual technology modules within the system will influence overall system risks and costs.

A System Analysis Model has been developed to demonstrate that it is possible to review the characteristics of candidate technologies early in their development, and to perform systematic qualitative evaluations of their potential influence on overall tank waste remediation system human health risks and costs. The model was developed to provide a structured and objective method that can be applied in a consistent and cost-effective manner in these technology evaluations.

Rather than evaluating individual technologies in isolation, the technologies are evaluated in the context of a complete, multi-technology remediation system. As indicated previously, waste tank remediation will require a complex system of linked technology modules, and alternative technologies implemented within these modules will influence overall system performance. As such, an isolated evaluation may overlook impacts on costs and risks elsewhere in the system, which should be accounted for in the evaluation of a technology's merits. To address these potential impacts, the System Analysis Model can be used to (1) develop a baseline evaluation of full-scope remediation system risks and costs, and (2) then reevaluate the full-scope risks and costs with the alternative technology substituted into the system. In this way, alternative technologies are evaluated in light of their costs and benefits to the overall waste tank remediation effort.

Section 2.1 describes the characterization, or definition, element of the System Analysis Model. It discusses the development of flowsheets and material balances for all stages of the remediation system from waste tank retrieval to final waste disposal. The current TWRS reference system has provided the framework for the System Analysis Model. Although the TWRS reference system and the System Analysis Model are not intended to be dependent upon each other, they are closely related, and descriptions of the model assumptions and approach rely heavily on descriptions of the TWRS. The trial application of the System Analysis Model to the Base Case is discussed separately in Section 3.1.

Section 2.2 describes the health risk element of the System Analysis Model. It discusses the interfaces between the system characterization material balances and technology descriptions, and the qualitative health risk calculations. This section also discusses the range of potential health risks to workers and members of the public, identifies those that are addressed at this stage in the model development, and describes the general risk factors implemented in the calculations.

Section 2.3 describes the cost calculation element of the System Analysis Model. It discusses the direct interfaces with the system characterization element of the model, and the application of best engineering judgement.

Section 2.4 describes the computer software system used to implement the System Analysis Model. It describes the general system characteristics and defines the spreadsheet data links that perform the risk and cost calculations.

2.1 SYSTEM CHARACTERIZATION

System characterization is the first step in implementing the System Analysis Model. This step identifies all of the process specific data that feed into the risk and cost assessments.

2.1.1 Approach and Assumptions

System characterization requires that all of the major processes and process streams be identified and that an overall material balance be established. The major processes are labeled as unit operations and are grouped into functional groups labeled as modules. An example unit operation is the High-Level Waste (HLW) Evaporator which is part of the HLW Glass Cullet (module M.8).

Once the modules have been organized into an overall flow diagram, stream flows between modules are identified and labeled. All streams entering a module from outside the process (not within any module) and all streams leaving a module are labeled according to the module number. All streams entering a module from another module retain the label given upon leaving their original module. When two or more streams originate and conclude in the same unit operation as one another, they are combined under the same label for clarity.

Streams are designated as high activity, low activity, or nonradioactive, based on the radionuclide concentration. Streams with activity of 0.13 Ci/kg (0.06 Ci/lb) or greater have been designated as high activity waste and streams with an activity less than 0.13 Ci/kg (0.06 Ci/lb) have been designated as low activity waste. Streams with no possibility of radionuclide contamination are designated as nonradioactive.

2.1.2 Methods and Data

After the detailed flow diagram is established, a material balance is completed for all streams entering and leaving each module in terms of the total liquid mass, total solids mass, total water mass, and mass of contaminants of concern (identified in Section 2.2). The masses are expressed as kilograms processed during the life of the process. The total mass in each stream is obtained by adding the liquid and solids masses. The solids mass (excluding dissolved solids) is needed for selection of material transport equipment (e.g., pumps).

It is particularly important that all process streams that discharge to the environment be characterized, because they are the primary contributors to the public risk values. In addition, each unit operation is described in terms of the categories of information shown in Table 2-1. This information is used to estimate routine worker radiation exposure and potential for and severity of accidents associated with each unit operation.

Table 2-1. Unit Operation Descriptions.

Required information
General Description
Number of Individual Components (tanks, pumps, filters etc.)
Size/Capacity of Each Component (m, m^2, m^3)
Unit Operation Lifetime (years)
Operating Efficiency (%)
Radiation Level (High, Low, Cold)
Total Direct Labor Man-hours (hours)
Temperature (°C)
Pressure (psi)
pH/Acidity/Alkalinity
Energetic Reaction Potential (seven categories from Very Low to Very High)
Process Stability (High, Medium, Low)
Waste Form (solid, liquid, gas)
Solids in Waste (%)
Organics in Waste (%)
Flammability (seven categories from Very Low to Very High)
Number of (HL[a], LL[b], & Cold) Mechanized Parts per Unit
Number of (HL[a], LL[b], & Cold) Isolated Process Steps per Unit
Number of Installation Activities (e.g. install 20 mixer pumps)
Number of Items Requiring Decontamination
Number of Items Requiring Decommissioning and Disposal

[a]HL = High-level, assumed to require remote handling.
[b]LL = Low-level, assumed to allow contact handling.

The System Analysis Model's modular format provides a mechanism by which new modules can be added or modules can be modified to form test cases. This allows the impacts of new technologies to be implemented into the model and compared to the baseline.

2.2 RISK EVALUATIONS

The objective of the risk calculation in the System Analysis Model is to provide a consistent basis for qualitatively evaluating the potential influence that alternative technology modules may have on overall health risks associated with the remediation system. Calculation methods have been selected to be consistent with the fact that they will be applied early in the technology evaluation process, when limited or only qualitative information will be available regarding technology characteristics. The calculation methods that have been implemented are based on an interim selection process, and are subject to further review and modification. However, the System Analysis Model and associated risk calculations are sufficiently complete to permit their trial application (Section 3) and evaluation as a mechanism for supporting future assessments of candidate tank waste remediation technologies.

Although the term "health risk" has been used to describe the product of the risk calculations, several different products are actually calculated. In the case of technology module workers, health related impact is evaluated in the context of collective routine radiation dose to the members of the module work force. Radiation dose was selected because it is a common measure of worker impact, is thoroughly addressed by DOE criteria, and is well-documented in the records of past facility operations of a similar nature. In the case of the public, health related impact is addressed in the context of an MEI's (1) incremental increase in risk (probability) of death from cancer and (2) HI, which is the ratio of calculated toxic material exposure to the toxic material reference doses (RfD). An individual receptor and these quantities were selected because they are standard measures of public health impact, are adequately addressed in DOE and U.S. Environmental Protection Agency (EPA) criteria, and are applicable to both radiological and hazardous material.

An alternative approach was selected to address worker and public health related impact associated with potential failure conditions. Standard safety analysis procedures exist for the identification and evaluation of potential failure events. However, to be useful, these procedures require a reasonably detailed level of facility and process information. Because this information will not be available for emerging technology evaluations, a subjective approach was selected which relies on expert judgement. As discussed further in Section 2.2.2.2, for the purpose of this trial application and model evaluation, the results of failure condition evaluations are expressed as unitless relative risk values derived from selected elements of the PPG (WHC 1993).

The System Analysis Model risk calculations qualitatively address worker and public health risks based on the system characterization discussed in Section 2.1, which currently addresses the installation and operational phases of each technology module. As additional information is developed describing D&D of the modules, and more fully describing waste disposal, the risk calculations will be expanded to address worker and public health risks during those phases. Risks are calculated separately for near-term exposures associated with the active installation and operational phases, and for future exposures associated with residual contamination and disposed wastes following completion of the active operations.

The risk calculations address worker and public health risks associated with exposure to the radiological and hazardous materials processed or handled within the technology modules. The specific approaches and assumptions used in these calculations are discussed in Section 2.2.1. The risk calculations do not currently address the risks of physical injuries that can occur during construction or other industrial activities associated with the installation or operation of the technology modules. However, because these risks can be significant, they will be addressed in future revisions of the model.

Results generated by the risk calculations, while given as discrete numerical quantities, should not be viewed as estimates of actual or potential human health risk associated with the tank waste remediation technologies. The calculation results are intended to support consistent comparative evaluations of the influence that alternative technologies may have on overall system risk, and should be viewed as qualitative estimates only. Further, the calculational methods themselves are general, and are not the methods that would be used when performing a quantitative human health risk assessment based on more complete and quantitative inputs.

Implementation and operation of the tank waste remediation technologies may also produce risks to the wildlife and vegetation (ecological risks), in addition to potential human health risks. However, the evaluation of ecological risks is a complex process that is more directly dependent on the specific location and nature of remediation operations than evaluations of human health risks. Based on the purpose and timing of the risk calculations associated with the System Analysis Model, ecological risk calculations have not been included. The differences in ecological risk from different technologies is expected to be minimal, and including ecological risk in the model may be a less valuable enhancement than including schedule or regulatory risk indicators. Nevertheless, if important to stakeholders or decision-makers, the model could be expanded to include a measure of ecological risk.

2.2.1 Approach

The risk calculations provide the capability to qualitatively evaluate health risks for both workers and individual members of the public from tank waste remediation systems. The calculations currently encompass the installation and operational phases of remediation technology modules, and address potential risks associated with both routine and failure conditions during those phases.

Risks are calculated separately for near-term exposures associated with the active installation and operational phases, and for future public exposures associated with residual contamination and disposed wastes following completion of the active operations. The risk calculations therefore span both operational and post-operational phases. The analytical approach involves calculation of risks at the technology module and unit operation level, which are then summed to arrive at overall system risks. Results are described in terms of both a single risk index and its component parts.

2.2.2 Methods, Data, and Assumptions

Various analytic methods and assumptions were required to calculate health risks associated with the waste tank remediation technologies. The calculations address the risks associated with design basis routine operations and the risks associated with potential system failure conditions. Worker risks are only relevant to the active installation and operational phases, whereas public risks are relevant to both operational and post-operational phases. The methods used to address risks during routine operational conditions are discussed in Section 2.2.2.1. Risk calculation methods for risk calculations associated with failure conditions are discussed in Section 2.2.2.2.

Prior to evaluating worker and public risks, a list of more than 150 chemicals and radionuclides was screened and shortened to simplify the risk calculations. This condensed list of contaminants of concern (COC) includes only those contaminants that constitute most of the risk to human health. For the purposes of developing the condensed list of COCs, the Droppo et al. (1991) was reviewed. This report provided an analysis and ranking of tank waste constituents, based on risk to human health. Droppo et al. (1991) evaluated the risks, based on leakage and transport to groundwater and human health exposure through ingestion and use of groundwater for irrigation. Table 2-2 lists the carcinogenic and noncarcinogenic contaminants that were determined to result in a risk greater than 10^{-6} or an HI greater than 1 (Droppo et al. 1991).

Because Droppo et al. (1991) did not evaluate exposure from airborne releases, the MEPAS computer code was used to rank tank contaminants based on exposure to potential airborne effluents. Groundwater effluents were also evaluated using the MEPAS code. The results of this second evaluation are also presented in Table 2-2 and are consistent with the results obtained by Droppo et al. (1991).

Neither of these two evaluations addressed organic contaminants that are known or suspected to be present within the tank wastes, except for ethylenediaminetetraacetic acid (EDTA). The organic constituents in the tanks were evaluated in the Hanford Defense Waste Environmental Impact Statement (HDW-EIS) (DOE-RL 1987). Included in the HDW-EIS evaluation were approximately 40 organic chemicals in neutralized cladding removal wastes, double-shell slurry wastes, and organic complexant wastes. The types of organic chemicals identified include solvents, volatiles, chelating complexing agents, and acids. However, inspection of the identified chemicals reveals that many of these constituents may no longer be present in the identified form because they have combined with each other or with the inorganic materials within the tanks to form solid salts. From the list of organic contaminants identified in tank wastes above the detection limit, only EDTA and tributyl phosphate (TBP) have documented toxicity values. Therefore, only these two contaminants were included in the list of COCs for this model.

Organic contaminants are tracked through the system model mass balance relationships only as total organic carbon (TOC). Therefore, when applying risk factors for organics, an approach was developed that allowed the risk factors of EDTA and TBP to be combined and applied based on the amount of TOC.

Table 2-2. Comparison of Contaminant Rankings.

Contaminant Rankings			
Droppo et al. (1991)		MEPAS computations	
Carcinogens[a]	Noncarcinogens[b]	Carcinogens	Noncarcinogens
As	Sb	Be	Sb
^{238}U	EDTA	^{14}C	NO_3
^{99}Tc	Hg	^{99}Tc	V
^{14}C	NO_2	^{238}U	NO_2
^{129}I	V	^{129}I	Cr
^{235}U	Cr	^{90}Sr	Ni
^{242}Am	Be	^{137}Cs	Fluoride
^{240}Pu	NO_3	^{241}Am	--
^{239}Pu	Na	As	--
^{238}Pu	Fluoride	--	--
^{234}Pu	SO_4	--	--
^{241}Am	--	--	--
^{242}Cm	--	--	--
^{237}Np	--	--	--
^{233}U	--	--	--
^{241}Pu	--	--	--
^{93m}Nb	--	--	--

[a]Only contaminants that were determined to have a risk greater than 1×10^{-6} are included on this list.
[b]Only contaminants with a hazard index of greater than 1 are included on this list.
EDTA = ethylenediaminetetraacetic acid.
MEPAS = Multimedia Environmental Pollution Assessment System.

From these evaluations, the final list of COCs to be evaluated in this study was developed and is presented in Table 2-3. The COCs selected include all of those that ranked in the top 90% risk contributors from the MEPAS evaluations in addition to several others from the Droppo et al. (1991) study that may not have ranked high, but are common contaminants evaluated at the Hanford Site.

Table 2-3. Contaminants of Concern Evaluated in the Risk Model.

Radionuclides	Chemicals
^{241}Am	As
^{14}C	Be
^{137}Cs	Cr
^{129}I	F
^{239}Pu	Hg
^{90}Sr	Na
^{99}Tc	Ni
^{238}U	NO_2
	NO_3
	Sb
	SO_4
	V
	TOC

TOC = total organic carbon.

2.2.2.1 Routine Operations. Health risks for workers and members of the public can occur during routine operations associated with remediation activities. Exposures during routine operations can include exposure to design basis emissions to the environment and direct exposures to external radiation during planned operations. Risks associated with routine operations are limited to exposures to radiological or chemical contaminants. The risk calculations do not currently address the risks of physical injuries that can occur during construction or other industrial activities associated with the installation or operation of the technology modules. Because these risks can be significant, they will be addressed in future revisions of the model.

During the active operational phases, it is anticipated that contaminants, including airborne effluents, and liquid effluents discharged to the ground, will be released to the working environment and the environment outside of the facility. Post-operational exposures may result following the transport of contaminants released during the operational phase, including liquid effluents that were discharged to the ground and were subsequently transported to the groundwater and offsite.

2.2.2.1.1 Workers. Worker exposures may include external exposure to radiation fields, inhalation or ingestion of radiological or chemical contaminants, and dermal contact with chemical contaminants during the operational phase. However, only external radiation exposures are evaluated, based on the assumption that dermal contact and internal exposures (inhalation and ingestion) would be negligible under controlled normal operating conditions. The selection of routine operational worker exposure pathways is based on the following assumptions.

- All high-level operations will be conducted remotely, except for routine sampling and maintenance activities.
- Workers will wear appropriate personal protective equipment (PPE) (including respirators, coveralls, gloves, etc.) when performing contact-handled activities.
- Workers will not use groundwater for drinking, showering, or other potable purposes.

Worker risk is evaluated in terms of collective routine radiation dose to the workforce. Radiation dose was selected because it is a common measure of worker impact, is thoroughly addressed by DOE criteria, and is well documented in the records of past facility operations of a similar nature. Collective radiation dose is estimated for each of the unit operations, modules, and total system as the product of exposure dose-rate (R/hr) and worker hours.

Two categories of radiation dose rates are considered for the purpose of estimating total manrem dose during operations. The first is defined as an operational "routine occupancy" radiation zone dose rate assumed to be present throughout the workplace, where a portion of the workers spend a significant fraction of time. The second is defined as an intermittent occupancy zone of elevated dose rate assumed to be associated with process sample collection and/or routine maintenance activities. The dose rates assumed for these two zones within the three types of module/unit operations are presented in Table 2-4. The thresholds for the two zones are based on criteria presented in the DOE Radiological Controls Manual (DOE 1992). Occupancy factors (i.e., the percentage of time the zone will be occupied by workers) are based on operational experience and best engineering judgement. The zone dose rate levels and occupancy factors are subject to additional ongoing review by operations and radiation protection staff.

Table 2-4. Effective Dose Rates for Routine Worker Risks.

Unit	Intermittent dose rate		Operational dose rate	
	Dose rate (rem/hr)	Occupancy factor	Dose rate (rem/hr)	Occupancy factor
High-level	2	0.0001	0.002	0.5
Low-level	0.5	0.001	0.002	0.5
Cold	0	0.001	0	0.5

The collective average radiation dose is determined for the population of workers associated with each module over the lifetime of the operation. The worker risk for each module is computed from the following relationship.

$$\text{Collective } Dose_i = \sum_{j=1}^{n} T_{i,j}[(DR_{low,i,j})\ (RF_{low}) + (DR_{high,i,j})\ (RF_{high})]$$

where:

Collective $Dose_i$ = Total external radiation dose to workforce.

$DR_{low,i,j}$ = Low dose rate for unit operation j within module i (rem per hour).

$DR_{high,i,j}$ = High dose rate for unit operation j within module i (rem per hour).

RF_{low} = Low dose rate occupancy factor.

RF_{high} = High dose rate occupancy factor.

$T_{i,j}$ = Worker hours for unit operation j within module i (i.e., total manhours for unit operation j within module i) (hours).

2.2.2.1.2 Public. The evaluation of routine operational exposures to members of the public is based on potential exposure to contaminants that may be released to the environment and transported offsite. The determination of exposure is based on (1) the selection of COCs, (2) the selection of receptor characteristics, and (3) the methodology used to compute exposure and risk.

Exposure to members of the public can occur during the operational phase and the post-operational phase as a result of contaminants released to the environment. Based on the assumption that current active post-operational access restrictions will be relaxed over the long-term phase, separate receptors were evaluated. The characteristics of these two receptors are described below, followed by a description of the computational methodology and exposure pathways.

Operational Phase

The operational phase public receptor is assumed to be an individual located at the nearest Hanford Site boundary, which is 26 km (16 mi) east southeast of the 200 Areas. This individual is assumed to be a farmer who grows the majority of his or her own food. During the operational phase, this receptor can be exposed to airborne effluents released from the remediation activities. Effluents can take the form of a gas containing volatile compounds or particulates dispersed in air. Once radiological or chemical contaminants have been released to the atmosphere, they can be transported downwind where they can be inhaled directly or deposited on the ground and vegetation. Members of the public may be exposed through the following pathways: inhalation; ingestion of vegetation, meat, and milk products grown in contaminated soils; and external exposure through submersion in a contaminated plume or directly from the ground. Members of the public are not assumed to be exposed to groundwater contaminants during the operational phase because it is unlikely that contaminants released will be transported offsite during the operational phase.

Post-Operational Phase

The post-operational public receptor is assumed to be an individual located at the nearest future site boundary, as determined by the Hanford Future Site Uses Working Group, which is 3 km (1.9 mi) east of the 200 Area (HFSUWG 1992). This individual is assumed to be a farmer who grows the majority of his or her own food. During the post-operational phase, this receptor can be exposed to effluents released to the groundwater during earlier routine operations. Members of the public may be exposed to contaminated groundwater through direct ingestion of drinking water, showering, and ingestion of vegetation, meat, and milk products grown with the contaminated irrigation water.

Routine risks to the public are evaluated for the maximally exposed individual (MEI) rather than a collective population for the following reasons: (1) risks and HI for an MEI are a standard measure for human health effects, (2) there is no established method for computing population risks for noncarcinogenic chemicals that provides meaningful results, (3) all risk and noncancer hazard values should be based on the same receptor characteristics for comparative purposes, and (4) individual and population risks associated with exposure to radionuclides, chemical carcinogens, and chemical noncarcinogens are expected to be consistent.

Computational Methodology

Routine risks to members of the public were determined using the MEPAS computer code (Droppo et al. 1989). MEPAS is a software system that evaluates human health risk from radiological and chemical contaminants in the environment, including the computation of exposure and transport through the environment.

MEPAS is used to compute risk factors (for carcinogens) or RfD ratios (for noncarcinogens). The risk factor or RfD ratio values are then applied to the appropriate effluent stream from a module. Risk values and RfD ratios are computed directly by the MEPAS, through the input of calculated flux rates and release durations for the different streams released to the ground or atmosphere.

The formula for measuring EDTA and TBP is the only calculation not determined by directly applying the risk factor or RfD ratios. Because the system model only tracks total TOC through the mass balance of the system, a combined EDTA and TBP risk factor was developed that could be applied based on TOC. The representative TOC unit risk factor was computed by summing the risk factors computed for EDTA and TBP by MEPAS, multiplied by the weight fractions of each. This computation is demonstrated using the following equation.

$$RF_{TOC} = RF_{EDTA} \left(\frac{Inv_{EDTA}}{Inv_{TOC}}\right) + RF_{TBP} \left(\frac{Inv_{TBP}}{Inv_{TOC}}\right)$$

where:

RF_{TOC} = Risk factor for TOC.
RF_{EDTA} = Risk factor for EDTA.
RF_{TBP} = Risk factor for TBP.
Inv_{EDTA} = Inventory of EDTA in the stream of interest (μg/g).
Inv_{TBP} = Inventory of TBP in the stream of interest (μg/g).
Inv_{TOC} = Inventory of TOC in the stream of interest (μg/g).

The MEPAS code, along with the inputs used in the code, are described in detail in Appendix K. The output product from the MEPAS code includes risk factors or RfD ratios over a 70-year lifetime for each contaminant. Because these contaminants transport through the vadose zone and aquifer at different rates, exposure to the COCs will not necessarily occur during the same period of time. However, because of the comparative nature of this evaluation, summing the risks can provide a consistent point of comparison for cumulative risks. As stated previously, these results, as well as the other risk quantities discussed in this report should not be viewed as estimates of actual or potential cumulative risk. The methodology used to compute the flux rates and release durations for the groundwater pathways and atmospheric pathways are detailed below.

Groundwater Pathways: The methodology used to compute contaminant-specific flux rates and release durations for constituents released to the ground are consistent with the methodologies used to mitigate tank leakage. Contaminants are assumed to be released during routine operations. The contaminants are assumed to be mobilized by the recharge water that filters through the soils from natural precipitation at the site. The contaminants are mobilized and transported through the vadose zone to the groundwater and downgradient, where they are subsequently withdrawn from a groundwater well.

The constituent contained within the tank waste with the highest inventory and highest solubility limit is nitrate. The solubility of nitrate within tank waste is assumed to be 360 g/L (3 lb/gal) (Serne and Wood 1990). It is assumed in this analysis that all COCs leach congruently with nitrate. This assumption is conservative in some cases (e.g., where relatively insoluble species have been formed, such as uranium phosphate). However, data presented in Serne and Wood (1990) support the conservatism of the congruent leaching assumption. Based on an assumed recharge rate of 0.05 cm/yr, which corresponds to recharge through the Hanford Permanent Isolation Surface Barrier, and the assumed recharge area, the total dissolution rate of nitrate can be computed. This dissolution rate is applied as the flux rate for nitrate. From the total inventory of nitrate known to exist in the stream of interest, the duration of release can be computed as follows.

$$RD = \frac{Inv}{Flux}$$

where:

RD = Release duration (years).
Inv = Inventory (grams or curies).
Flux = Flux rate (grams or curies per year).

From the computed nitrate flux rate, the flux rates and release durations for all other COCs can be calculated as follows.

$$Flux_{COC} = \frac{Inv_{COC}}{Inv_{NO3}} \times Flux_{NO3}$$

where:

$Flux_{COC}$ = Flux rate for COC other than nitrate (grams per year).
Inv_{COC} = Inventory of COC other than nitrate (grams).
Inv_{NO3} = Inventory of nitrate (grams).
$Flux_{NO3}$ = Flux rate of nitrate (grams per year).

For radionuclides the flux rate is then multiplied by the appropriate specific activity (curies per gram) to obtain flux rate values in units of curies per year. The assumptions used to compute the nitrate flux rates and release durations for each of the groundwater pathway streams are described in Section 3 for each of the three cases evaluated.

Atmospheric Pathways: The methodology used to calculate the flux rates and release durations of COCs for the atmospheric pathways is a simple computational model. The release duration of each COC is equivalent to the duration of operation for the appropriate unit operation. The flux rate is then equal to the total inventory of each COC released to the air from a waste stream divided by the total time of operation for the unit operation.

$$Flux = \frac{Inv}{RD \times Eff \times 2.5E{+}08\ s/yr}$$

where:

Flux = Flux rate (grams or curies per second)
Inv = Inventory (grams or curies)
RD = Release duration (years)
Eff = Operating efficiency (unitless fraction).

The assumptions for each stream evaluated are detailed in Section 3 for each of the three cases analyzed.

2.2.2.2 Failure Conditions. Past experience with the type of remote handling operations associated with the TWRS indicates that nonroutine maintenance operations conducted in response to unanticipated equipment failures can be a significant component of overall worker exposures. In extreme situations, equipment or procedural failures have led to accident sequences that resulted in the loss of hazardous material containment, in turn resulting in acute exposure of workers and/or release of contaminants to the environment. System design criteria generally address the prevention of such failures and/or the mitigation of their consequences. However, a residual risk of equipment or procedural failures leading to accident sequences remains, and will vary between different technologies, system configurations, and environments.

Unlike the calculation of risks associated with routine operations, risks associated with potential failure conditions include the probability of failure conditions occurring, in addition to the probability that exposures and health impact will result. Standard system safety and safety analysis procedures exist to identify and evaluate potential failure events. To be useful, these procedures require that a reasonably detailed facility and process information be available. However, this demonstration will not be available for emerging technologies. An alternative approach relies on expert judgement, and, for the limited purpose of this trial application and model demonstration, the results are expressed as unitless relative risk values derived from selected elements of the PPG (WHC 1993). Because these elements of the PPG are being used outside their original application their use here is subject to ongoing review.[2]

Qualitative failure risk factors for each of the system modules are developed separately for "Accident Event" failures, and for failure events leading to "Nonroutine Maintenance" activities. Accident event failures are defined as those that release energy with the potential to release contamination within the facility and into the environment. Potential acute exposures dominate these types of events. Nonroutine maintenance failures are low energy events with limited potential for releasing contaminants. Worker external radiation exposures associated with corrective maintenance dominate these events. The development of qualitative risk factors for accident and nonroutine maintenance failures is described in the sections that follow.

2.2.2.2.1 Accident Events. Accident event risk factors are developed as the product of unitless qualitative consequence values and estimated frequencies of occurrence. Risk factors are first developed at the unit operation level within each module, then evaluated for the module as a whole. For accident failure events, the unit operation with the highest maximum accident event risk is designated as the limiting event for the module. This recognizes the fact that it is extremely unlikely that energetic accident

[2]We have additional methodological concerns with the PPG. These center on the selection of attributes, levels of consequence, and weights given to these levels. Nevertheless, the grid provides a standard for measuring failure conditions across modules and system configurations. Should failure have significant impact on a technology's evaluation, an uncertainty analysis can be performed on the PPG ratings to determine how robust the results are to these preestablished judgements.

events, which are themselves generally associated with a sequence of precursor events, will occur within multiple unit operations in a module. Table 2-5 presents the failure risk factor worksheet formats from the System Analysis Model for accident events.

Qualitative Consequence Values

Qualitative consequence values (unitless) have been derived from selected elements of the relative ranking system implemented in the PPG (WHC 1993). The PPG has established eight levels of consequence (ranks), within which nine impact attributes are compared. The attributes of interest for the System Analysis Model risk evaluation are public safety, worker safety, environmental contamination, and cost. Within each of the eight ranks, the PPG provides consequence descriptions for each of the attributes, and assigns a relative consequence value. The eight consequence values from the PPG for failure events are presented in Table 2-6. (Due to similarities in their general indicator descriptions, Rank 5 and 6 were combined to Rank 5/6.)

A relative consequence value is selected for each unit operation based on expert judgement and comparisons of the unit operation's baseline (or test) conditions to general indicator conditions established for each consequence rank. The potential magnitude of acute exposures for failure events are dependent on the general indicators listed in Table 2-7.

General indicator conditions have been developed that address the following: (1) waste inventory characteristics, (2) containment characteristics, and (3) the energetic reaction potential. The waste inventory characteristics rankings were based on: (1) the waste radiation (high-level, low-level, or cold), (2) the waste toxicity (high, low), and (3) the quantity and physical form of the waste for each unit within the modules. The containment characteristics were ranked from the internal container level to the facility level. The energetic reaction potential is the probability of an energetic event (e.g., explosion, fire) to release relatively large quantities of contaminants. The characteristics that contribute to increased potential for energetic events include system pressure and temperature, the presence of volatile or flammable liquids or gases, and reactive or unstable material.

These indicator conditions are not applied as absolute predictors of potential consequence level, but are used as guides for qualified staff in performing a systematic and consistent review of each unit operation's baseline conditions.

Frequency Categories

The PPG has established four frequency categories for consideration within each of the consequence ranks for both accident and nonroutine maintenance failure events. These categories are defined as follows:

- Very Low
  - Highly unlikely to occur within the facility lifetime
  - Frequency value 0.0001

Table 2-5. Format for Failure Risks for Accident and Nonroutine Maintenance Events.

Module Name

FAILURE RISK PARAMETERS Designation:	Component / Unit Operation Name Waste Desig.	Component / Unit Operation Name Waste Desig.	Component / Unit Operation Name Waste Desig.	Component / Unit Operation Name Waste Desig.	Component / Unit Operation Name Waste Desig.	Component / Unit Operation Name Waste Desig.	Component / Unit Operation Name Waste Desig.	Module Number
MAXIMUM ACCIDENT FAILURE EVENT Consequence: Frequency: Relative Risk:								LIMITING EVENT
NONROUTINE MAINTENANCE FAILURE EVENTS								SUM OF EVENTS
Electrical Instrumentation Consequence: Frequency: Relative Risk:								
Mechanized Equipment Consequence: Frequency: Relative Risk:								
Pluggage/Caking Consequence: Frequency: Relative Risk:								
Corrosion Consequence: Frequency: Relative Risk:								
Physical Operation Consequence: Frequency: Relative Risk:								
TOTAL NONROUTINE MAINTENANCE RISK Relative Risk:								

Notes:

Accident failure events are energy release events with the potential to 1) release contamination within the facility and into the environment, 2) damage the equipment and facility, and 3) physically injure workers. These events could include explosion, fire, pressure release, etc.

Nonroutine maintenance failure events are low energy events with limited potential for releasing contaminants from process systems These events will lead to increased worker exposures resulting from nonroutine corrective maintenance.

Table 2-6. Consequence Ranks and Relative Consequence Values.

DEVELOPMENT OF CONSEQUENCE VALUES FOR FAILURE EVENTS							
Rank	**8**	**7**	**5\6**	**4**	**3**	**2**	**1**
Attribute							
Public Safety:	No impact on Public health and safety	Public Inconvenience	Low-level radiation or chemical exposure	Exposures near Limits Moderate injuries	Multiple exposures >100 rem or >>IDLH		Single loss of life
Worker Safety:	No impact on Worker health and safety	Minor injuries requiring first aid Exposure below limits Removable skin contamination	Exposure >DOE limit Injury with 7 to 70 days lost time	Exposures of 100 rem or >>IDLH Injury with > 70 days lost time		Single loss of life (1500) Permanent disability and degraded lifestyle	
Environmental:	No releases affecting environment	Reportable releases to environment with no impact	Environmental damage that exceeds regulatory limits Cleanup costs approx $250K	Cleanup costs >$1M	Environmental cleanup >$100M onsite Cleanup >$25M offsite	Offsite cleanup >$100M, long recovery time	
Cost:	Equip/facility damage <<$1M Incr. operating cost <<$200K		Equip/facility damage $1M to $25M Incr. operating cost $200K to $5M/yr	Equip/facility damage >$25M (40) Incr. operating cost >$5M/yr (40)			
Relative Consequence Values	1	5	25	100	300	1000	3000

Table 2-7. Consequence Ranks for Accident Event and General Indicator Conditions.

Attribute / Rank	8	7	5\6	4	3	2	1
Waste Inventory							
- Type	LLW or Low Tox Waste	LLW or High Tox Waste	LLW, HLW, or High Tox Wastes	LLW, HLW, or High Tox Wastes	HLW or Extremely Tox Wastes	HLW or Extremely Tox Wastes	HLW or Extremely Tox Wastes
- Quantity	Small quantity	Small quantity	Moderate quantity	Large quantity	Large quantity		
- Physical form	Liquid or non-dispersable solid* * e.g. monolithic solid	Liquid or non-dispersible solid	Any form** LLW or Tox, liquid or ** except monolithic solid	Any form LLW, HLW or Tox	Any form HLW or Tox	Any form HLW or Tox	Any form HLW or Tox
Containment Characteristics							
- Container	High integrity container	Moderate integrity container	Moderate integrity container	Low integrity container	Low integrity container	No container	No container
- Primary containment	High integrity primary containment area	Moderate integrity primary containment area	Low integrity primary containment area	No primary containment area	No primary containment area	No primary containment area	No primary containment area
- Facility containment	High integrity structure	High integrity structure	Moderate integrity structure	Moderate integrity structure	Moderate integrity structure	Low integrity structure	no structure
Energetic Release Potential							
- Temperature	Ambient	Ambient	T up to 100 C	T up to 100 C	T > 100 C	T > 100 C	T > 100 C
- Pressure	Ambient	Ambient	P up to 100 psi	P up to 100 psi	P > 100 psi	P > 100 psi	P > 100 psi
- Reactive/ unstable	Nonreactive & stable	Low reactivity & stable	Low reactivity & instability	Moderately reactive	Moderately reactive	Highly reactive	Highly reactive
- Flammable	Nonflammable	Nonflammable	Flammable	Flammable	Flammable	Highly flammable	Highly flammable

- Low
  - Possible to occur within the facility lifetime
  - Frequency value 0.01
- Medium
  - Likely to occur within the facility lifetime
  - Frequency value 0.1
- High
  - Anticipated to occur within 2 years
  - Frequency value 1.

A frequency value is selected for each unit operation based on comparisons of the unit operation's baseline conditions to general indicator conditions established for each frequency category. As shown in Table 2-8, general indicator conditions have been developed for accident failures that address (1) flammable materials, (2) energetic reaction potentials, and (3) system temperature and pressure. These indicator conditions are not applied as absolute predictors of potential frequency category, but are used by qualified staff as guides in performing a systematic and consistent review of each unit operation's baseline conditions.

2.2.2.2.2 Nonroutine Maintenance. Nonroutine maintenance risk factors are developed as the product of unitless qualitative consequence values and estimated frequencies of occurrence. This is shown in Table 2-9, where the failure risk factors worksheet from the System Analysis Model are also shown for nonroutine maintenance failure events. These risk factors are developed separately for failures associated with (1) electrical equipment and instrumentation, (2) mechanized equipment, (3) plugging and caking, (4) corrosion, and (5) physical operations.

Risk factors are first developed at the unit operation level within each module, then combined for the module as a whole. Unlike accident failure events, the nonroutine maintenance failure risks are summed across all unit operations within a module because they are simple independent hardware failures.

<u>Qualitative Consequence Values</u>

Qualitative consequence values (unitless) for nonroutine maintenance failures are also developed based on the relative ranking system implemented in the PPG. However, in the case of nonroutine maintenance failures, consequences are assumed to be associated with increased worker exposures during the performance of maintenance procedures initiated following the failure event. As such, maintenance operations would be controlled activities, and exposures limited to acceptable levels through monitoring, radiation work procedures, and worker training. Therefore, consequences for nonroutine maintenance failures are assumed to be limited to Rank 7 for high-level and low-level unit operations, and Rank 8 for cold unit operations.

Table 2-8. Frequency Values for Accident Failure and General Indicator Conditions.

Rank / Attribute	8	7	5\6	4	3	2	1
Public Safety:	No impact on Public health and safety	Public Inconvenience	Low-level radiation or chemical exposure	Exposures near Limits Moderate injuries	Multiple exposures >100 rem or >>IDLH		Single loss of life
Worker Safety:	No impact on Worker health and safety	Minor injuries requiring first aid Exposure below limits Removable skin contamination	Exposure >DOE limit Injury with 7 to 70 days lost time	Exposures of 100 rem or >>IDLH Injury with > 70 days lost time		Single loss of life (1500) Permanent disability and degraded lifestyle	
Environmental:	No releases affecting environment	Reportable releases to environment with no impact	Environmental damage that exceeds regulatory limits Cleanup costs approx $250K	Cleanup costs >$1M	Environmental cleanup >$100M onsite Cleanup >$25M offsite	Offsite cleanup >$100M, long recovery time	
Cost:	Equip/facility damage <<$1M Incr. operating cost <<$200K		Equip/facility damage $1M to $25M Incr. operating cost $200K to $5M/yr	Equip/facility damage >$25M (40) Incr. operating cost >$5M/yr (40)			
Relative Consequence Values	1	5	25	100	300	1000	3000

Table 2-9. Frequency Values for Nonroutine Maintenance Failure and General Indicator Conditions.

Rank / Parameter	VERY LOW	LOW	MEDIUM	HIGH
Probability - Frequency of happening	Highly unlikely to occur	Possible to occur within facility lifetime	Likely to occur within facility lifetime	Anticipated to occur within 2 years
Frequency Values:	0.0001	0.01	0.1	1
GENERAL INDICATORS				
Nonroutine Maintenance Failures:	-No mechanical equipment -Minimal control requirements -Low suspended solids -Neutral pH/ corrosivity	-Moderate quantity of mechanical equipment of routine complexity -Moderate control requirements and instrumentation -Up to 10 percent suspended solids -Low pH/ moderate corrosivity	-Moderate quantity of mechanical equipment of routine complexity -Moderate control requirements and instrumentation -Up to 10 percent suspended solids -Low pH/ moderate corrosivity	-Extensive mechanical equipment, unique without operating history, highly complex -Extensive control requirements and instrumentation -Greater than 20 percent suspended solids -Low pH/ high corrosivity

These two rankings are summarized below:

- Rank 7
  - Minor injuries requiring first aid (consequence value 5)
  - Exposures below limits
  - Removable skin contamination

- Rank 8
  - No impact on worker health and safety (consequence value 1).

A relative consequence value is selected for each unit operation based on its baseline condition waste handling designation.

Frequency Categories

As described in Section 2.2.2.2.1, the PPG has established four frequency categories for consideration within each of the consequence ranks. A frequency value is selected for each of the five failure events within a unit operation based on comparison of the unit operation's baseline conditions to general indicator conditions established for each frequency category. As shown in Table 2-7, general indicator conditions have been developed that address (1) level and complexity of electrical instrumentation/control requirements, (2) level and complexity of mechanical equipment, (3) percent suspended solids, (4) level of corrosivity, and (5) number and complexity of physical operations. The low frequency category, which possibly can occur within a facility's lifetime (frequency value 0.01), is applied as the default value from which adjustments upward or downward are made based on evaluation of the indicator conditions.

These indicator conditions are not applied as absolute predictors of potential frequency category, but are used by qualified staff as guides in performing a systematic and consistent review of each unit operation's baseline conditions.

2.3 COST CALCULATIONS

Cost information is required to provide a basis for direct comparison of alternatives in terms of overall cost and cost-benefit. Benefit can be measured in terms of risk reduction. In general, reduction of risk is obtained at an increased overall cost. Conversely, a system change that results in a reduction in cost will usually increase the inherent risk of the overall system.

2.3.1 Approach and Assumptions

Due to the nature of the RWTRTFA, technologies that need to be evaluated are usually at some preliminary stage in their development. For this reason, system characterization and cost data are usually minimal or may be nonexistent. The data required for cost and risk analysis of new technologies must be estimated using best engineering judgement, which often results in order-of-magnitude quality estimates. Relatively simple risk and cost estimating software, coupled with an uncertainty analysis or evaluation, is appropriate considering the high uncertainties in risk and cost input data.

All costs are converted into Total Net Present Worth (TNPW) and 1994 dollars. The complete waste retrieval, treatment, and D&D process is assumed to take 13 years (10 years processing and 3 years D&D). A 10% discount rate was assumed for conversion of costs to TNPW.

2.3.2 Methods and Data

Costs are estimated for each module using available information and best engineering judgement, where required. Costs are broken out in the categories shown in Table 2-10.

Table 2-10. System Analysis Model Cost Categories.

Cost	Definition
Capital	All costs for facility design, purchase and construction, and equipment purchase and installation
Chemical	Cost of bulk chemicals added to the system
Labor	All labor costs for exempt, nonexempt, and bargaining unit personnel
Utilities	Steam and electricity only
CENRTC and GPP	Capital equipment not related to construction and general plant processes
R&D	Costs to develop and bring a technology to full implementation
Disposal	Costs for the low-level and high-level waste only
D&D	Decontamination and decommissioning of all the tanks and facilities at the completion of tank waste remediation work

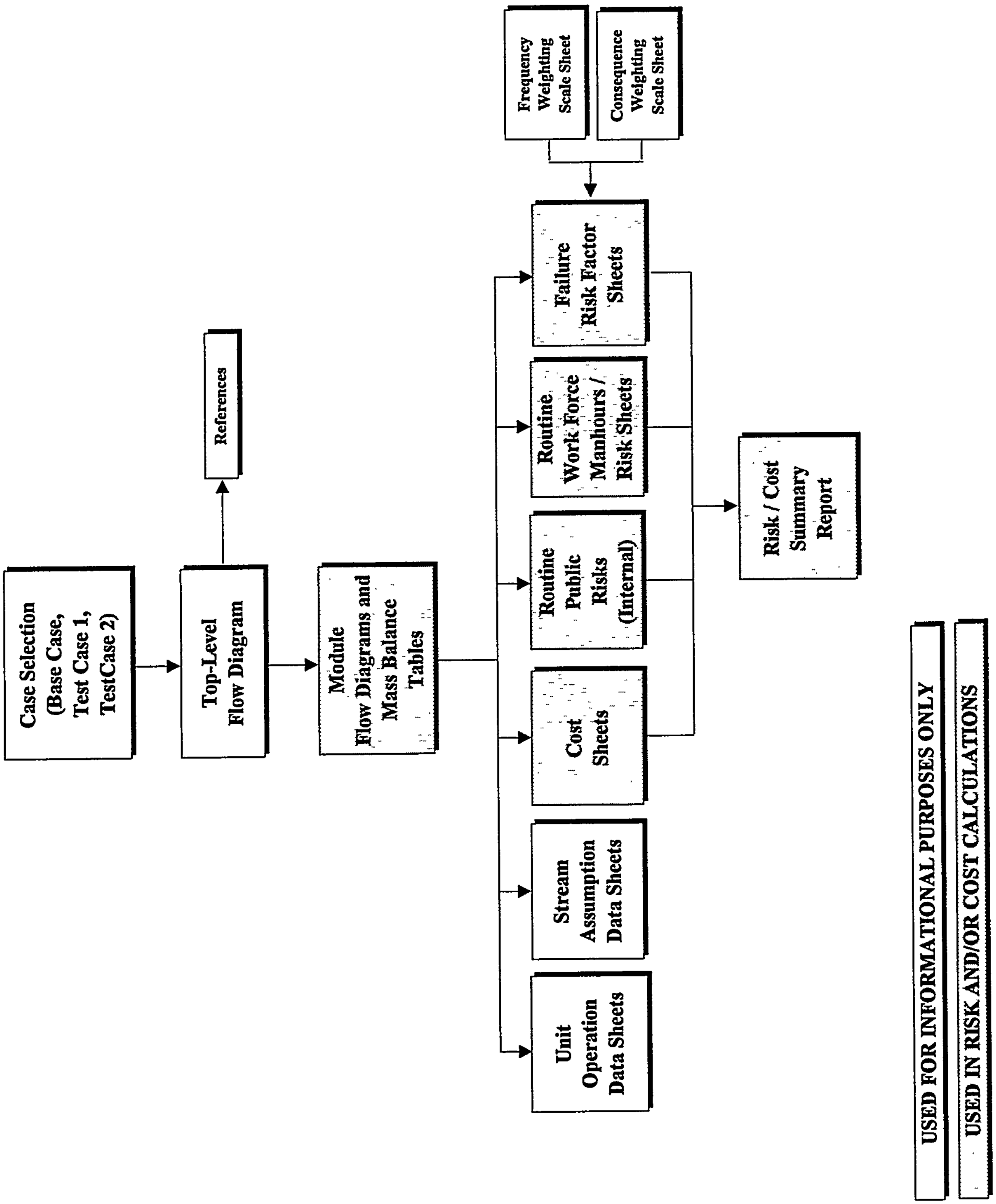
CENRTC = capital equipment not related to construction.
D&D = decontamination and decommissioning.
GPP = general plant processes.
R&D = research and development.

2.4 SYSTEM ANALYSIS MODEL SOFTWARE

The UST-ID System Analysis Model Software is a linked system of Microsoft Excel 4.0[3] spreadsheets that provide the user with a computerized directory of the flow processes (i.e., cases) being evaluated by the System Analysis Model for Tank Technologies. By using the mouse to click on a series of buttons or menu items, the user can call up a particular case (i.e., the Base Case, Test Case I, or Test Case II), display a complete flow diagram of any module within the given case, and then find out more information on the module and any unit operations within the module. Available information also includes the results of the risk analysis (discussed in Section 2.2) and the cost analysis (discussed in Section 2.3). This layered information system, which displays only as much information as required by the user, will allow the user to easily compare modules, unit operations, and risk/cost analyses results for a given test case with those of the Base Case. All that is needed to use the System Analysis Model Software is a basic knowledge of computers and of Microsoft Windows[4]. The software flow chart is provided as Figure 2-1.

[3]Microsoft Excel 4.0 is a trademark of Microsoft Corporation.
[4]Microsoft Windows is a trademark of Microsoft Corporation.

Figure 2-1. System Analysis Model Software Flow Chart.



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3.0 BASELINE AND TRIAL APPLICATIONS

The System Analysis Model, described in Sections 1 and 2, was used to establish a baseline assessment for the TWRS. Two test cases were also assessed to provide examples of how this model can be used as a decision-making tool.

3.1 BASE CASE

A Base Case was established that incorporates technologies currently planned for removing, treating, and disposing of the tank wastes, including the D&D of the tanks and associated facilities into a complete remediation system. This system provides the baseline for comparing the relative costs and risks of alternative technologies.

3.1.1 Description

Results from ASPEN[5] were used to develop the TWRS reference system. ASPEN is a computer modeling tool for the design of processing plants. The ASPEN results (ASPEN file run dated January 21, 1994) and TWRS reference system flowsheets from early 1994 were used to develop a simplified analysis similar to the ASPEN process that will run on a personal computer (PC)-based spreadsheet. This simplified process was used to develop the Base Case. Assumptions made to simplify the ASPEN process and develop the Base Case are described in Section 3.1.2.

The TWRS new technical strategy top-level flow diagram (Figure 3-1) was the basis for determining the modules within the Base Case. This flow diagram was organized into 13 modules as depicted in the Base Case top-level flow diagram (Figure 3-2). The names of these 13 modules are provided in Table 3-1.

Module M.1, *SST Waste Retrieval*, includes three unit operations: (1) single-shell tank (SST) waste retrieval, (2) cleanup and backfill, and (3) capping. The waste retrieval is accomplished by traditional sluicing without the aid of subsurface barriers. Following retrieval, each SST is filled with gravel and grout and capped with a Hanford Protective Barrier.

Module M.2, *DST Waste Retrieval*, includes six unit operations: (1) double-shell tank (DST) general waste retrieval, (2) complex concentrate waste retrieval, (3) dilute noncomplexed waste retrieval, (4) evaporation of dilute noncomplexed waste, (5) cleanup and backfill, and (6) capping. A mixer pump system is used in a two-step process for retrieving the waste. The noncomplexed waste stream is processed by the 242-A Evaporator. Following retrieval, the DSTs are filled and capped in the same manner as the SSTs in module M.1.

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[5]ASPEN is a trademark of Aspen Technology, Inc.

Figure 3-1. Tank Waste Remediation System New Technical Strategy Top-Level Flow Diagram.

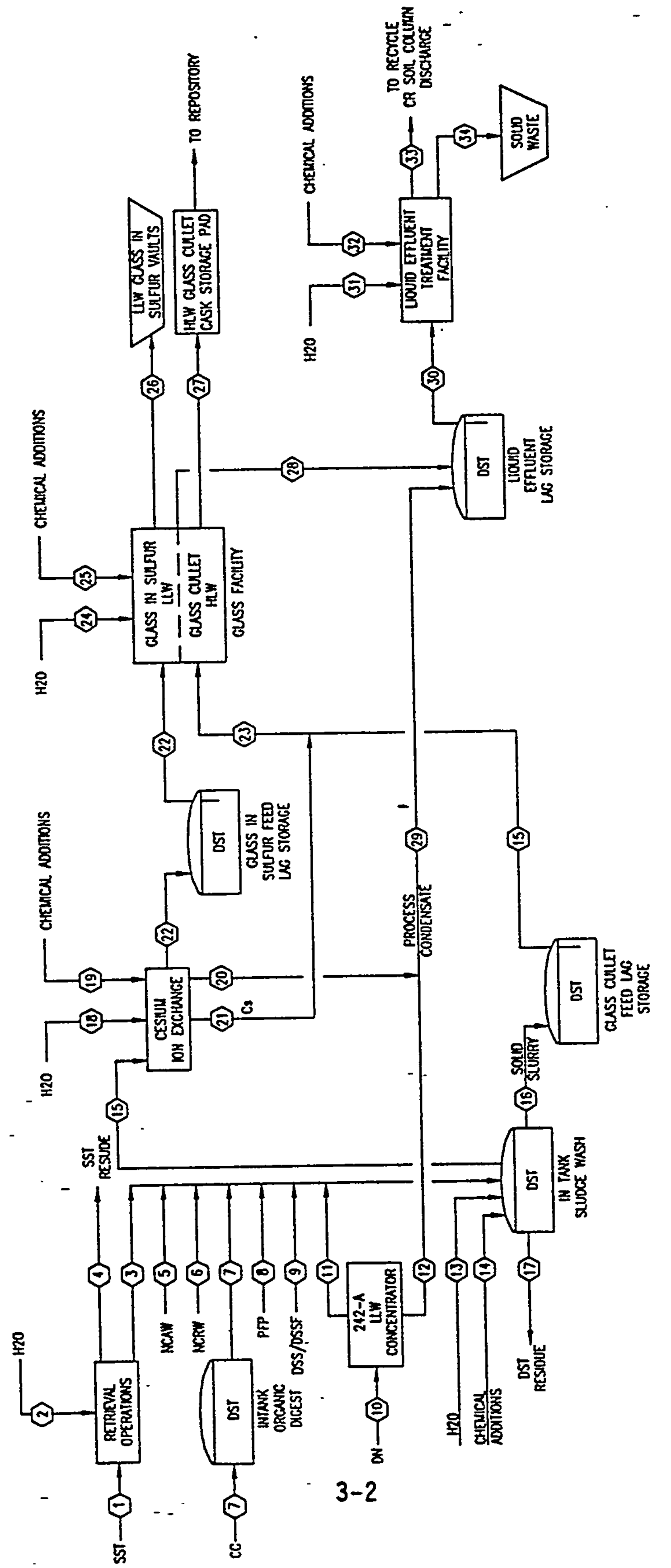


Figure 3-2. Base Case Top-Level Flow Diagram.

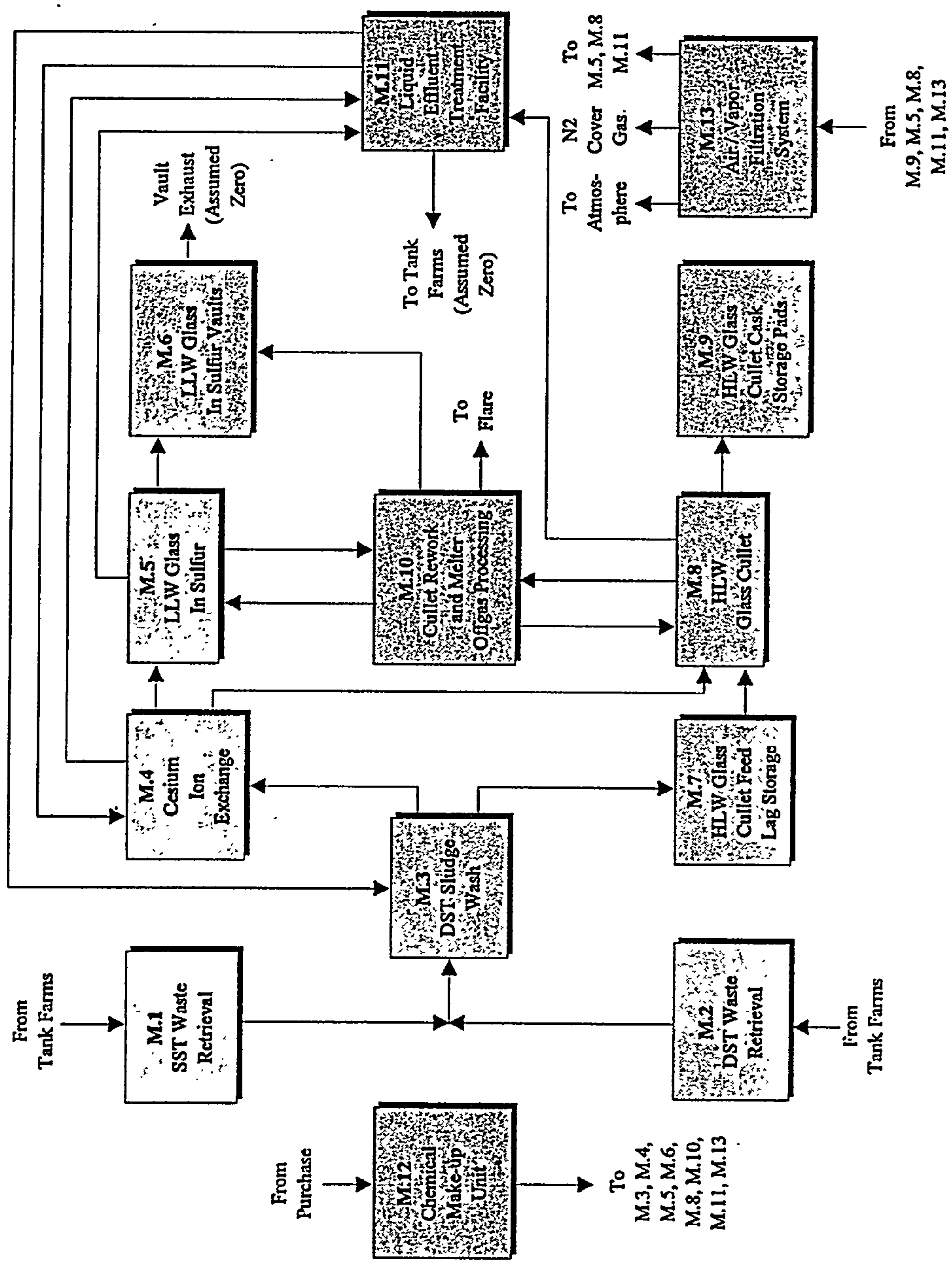


Table 3-1. Module Names.

Module	Name
M.1	SST Waste Retrieval
M.2	DST Waste Retrieval
M.3	DST Sludge Wash
M.4	Cesium Ion Exchange System
M.5	LLW Glass In Sulfur System
M.6	LLW Glass in Sulfur Vaults
M.7	HLW Glass Cullet Feed Lag Storage
M.8	HLW Glass Cullet System
M.9	HLW Glass Cullet Cask Storage
M.10	Cullet Rework and Melter Offgas Processing
M.11	Liquid Effluent Treatment Facility
M.12	Chemical Make-up Unit
M.13	Air/Vapor Filtration System

DST = double-shell tank.
HLW = high-level waste.
LLW = low-level waste.
SST = single-shell tank.

Module M.3, *DST Sludge Wash*, includes four processes of tank sludge wash as unit operations: (1) feed, (2) settling, (3) wash, and (4) transfer. The SST and DST waste feed from retrieval is decanted to 50 vol% solids in the settling process before being washed. The washed decant is sampled and then transferred to module M.4. The solids are transferred to module M.7.

Module M.4, *Cesium Ion Exchange*, includes five unit operations: (1) accumulation system, (2) supernatant evaporation system, (3) ion-exchange feed, (4) cesium ion-exchange concentration, and (5) eluent/regeneration system. The decant from module M.3 is concentrated by evaporation before being fed to the cesium ion-exchange process. After an assumed 99% removal of the cesium, the supernatant is fed to module M.5. The cesium product is concentrated to a bottoms concentration of 5*M* nitrate.

Module M.5, *LLW Glass in Sulfur*, includes five LLW unit operations: (1) evaporator, (2) melter, (3) glass quencher, (4) glass cullet drying, and (5) cyclone system. The LLW from the cesium ion-exchange system is concentrated and adjusted to specifications before being melted down into glass. The molten glass is cooled rapidly, forming cullet. The cullet is screened to filter out fines and oversized cullet. The screened cullet is fed to module M.6.

Module M.6, *LLW Glass in Sulfur Vaults*, includes four unit operations: (1) sulfur cement mixing, (2) LLW glass/sulfur mixer, (3) glass in sulfur disposal vault, and (4) decanted molten sulfur vault. The glass cullet from module M.5 is mixed with sulfur polymer cement to form a sulfur polymer concrete that is pumped to disposal vaults. Molten sulfur is decanted from the vaults and recycled.

Module M.7, *HLW Lag Storage*, includes an HLW feed accumulation and a HLW feed transfer tank. These unit operations, utilizing two 1 Mgal tanks, work as an overflow feed storage for the HLW Glass Cullet process module M.8.

Module M.8, *HLW Glass Cullet*, includes six HLW unit operations: (1) centrifuge system, (2) melter system, (3) evaporator, (4) glass quencher, (5) glass cullet drying, and (6) cyclone system. The HLW from the lag storage module M.7 and cesium ion-exchange module M.4 is pumped to module M.8 for vitrification. After adjustment, the melter feed stream is melted down into glass. The glass cullet, formed from rapid cooling, is screened to produce uniform sizes.

Module M.9, *HLW Glass Storage Pad*, includes air pallets and a repository for the HLW glass cullet. The HLW glass cullet is placed in modular iron casks on air pallets for storage.

Module M.10, *Rework and Offgas*, includes five unit operations: (1) cyclone system, (2) HLW separator, (3) NO_x/SO_2 separator, (4) LLW separator, and (5) Claus reactor system. The offgasses from the cyclone separators in modules M.5 and M.8 are sent through a quench tower, separator, and demister to remove the remaining fines. The gasses are also passed through high-efficiency particulate air (HEPA) filters. Sulfur dioxide is captured and processed into hydrogen sulfide, which is passed through a combustion chamber and two Claus reactors. The glass cullet from modules M.5 and M.8 are separated in a cyclone and recycled back to the melters.

Module M.11, *Liquid Effluent Treatment*, includes three unit operations: (1) process condensate recycle, (2) pH adjustment tank, and (3) retention basin. All condensate from the modules is sent to this module. Some condensate is recycled for cesium ion exchange while the remainder is pumped to a tank for pH adjustment and treatment or storage.

Module M.12, *Chemical Make-up Unit*, contains five unit operations: (1) dry storage, (2) bulk liquid storage, (3) bulk water storage, (4) bulk combustible liquid storage, and (5) batch mixer. All of the unit operations represent the cold chemical feeds into the other modules. The batch mixers are also included in this module to mix the glass formers used in the glass melters.

Module M.13, *Air/Vapor Filtration System*, includes six unit operations: (1) condenser vessel offgas (CVOG)/vessel offgas (VOG) system, (2) VOG/CVOG/process stack filter system, (3) bin vessel offgas (BVOG) system, (4) BVOG air supply system, (5) storage stack filter system, and (6) oxygen supply system. Vapors from all modules are sent through metal HEPA filters. Oxygen and nitrogen are recovered from air and the nitrogen is used as a cover gas where required. Oxygen is used in the combustion processes in modules M.5, M.8, and M.10.

More detailed descriptions of each module are provided in Appendix A, the module schematics are provided in Appendix B, and the module equipment lists are provided in Appendix C.

The unit operations are described in Appendix D. Information for the process descriptions of the unit operations has been taken from the *Tank Waste Technical Options Report* (Boomer et al. 1993).

Appendix E lists the individual module streams. It also details the module and unit operation from which each stream originated, the module and unit operation destination of the stream, and any assumptions for the stream. Mass balances around the modules are shown in Appendix F.

3.1.2 Case-Specific Assumptions

General methodologies and assumptions associated with the System Analysis Model were described in Section 2. Assumptions specific to the Base Case are identified below.

3.1.2.1 Risk Assumptions. Risks were computed for the Base Case using the methodologies described in Section 2.2. The following case-specific assumptions were used in computing the routine risks to the public.

- Releases of COCs to the ground with subsequent transport to the groundwater only occur in modules M.1 and M.2.
- Nitrate flux rates and durations for past leakage and leakage during retrieval are based on the total mass of nitrate, the assumed depth to the plume (30.2 m [99 ft]), the assumed depth to the aquifer (79 m [259 ft]), and the assumed time for recharge to travel to the aquifer (19,000 years). The resulting flux rate is calculated to be 2.15×10^6 g/yr (4,740 lb/yr) and 9.61×10^5 g/yr (2,119 lb/yr) for past leakage and leakage during retrieval, respectively.
- Nitrate flux rates and durations for SST residue and pipe leakage are based on an assumed solubility rate for nitrate of 360 g/L (3 lb/gal) and a recharge rate of 0.05 cm/yr (0.02 in./yr), resulting in a flux rate of 1.08×10^7 g/yr (2.4×10^4 lb/yr).
- Releases of COCs to the atmosphere with significant quantities of COCs only occur in module M.13, which operates for a total of 13 years at an efficiency of 60%.

3.1.2.2 Cost Assumptions. Several simplifying assumptions were made to develop the system costs.

3.1.2.2.1 Capital Costs. Capital costs for the 13 modules that comprise the Base Case were determined using information from Boomer et al. (1993) and best engineering judgement. These cost determinations are listed by module below. Detailed module descriptions, module schematics, and module equipment lists may be found in Appendixes A, B, and C, respectively.

- Capital costs for modules M.1 through M.3 were taken directly from Boomer et al. (1993), Appendix R.
- Capital costs for module M.4 were calculated as the difference in capital costs for the Sludge Wash B option and the Sludge Wash A option from Boomer et al. (1993).
- Capital costs for module M.5 and parts of modules M.10, M.11, and M.13 were taken from Boomer et al. (1993), Appendix H-8. Best engineering judgement was used to determine the cost of parts of modules M.10, M.11, and M.13. The difference was determined to be the capital cost of module M.5.
- Capital costs for module M.6 were taken from Boomer et al. (1993), Appendix H-8.
- Capital costs for module M.7 were taken from Boomer et al. (1993), Appendix G-15.
- Capital costs for module M.8 were calculated as three times the capital cost of module M.5.
- Capital costs for module M.9 were calculated as three times the capital cost of module M.6.
- Capital costs for module M.10 were calculated using best engineering judgement, taking into account the number of units, the complexity of the process, and the radioactivity level of the waste.
- Capital costs for modules M.11 and M.12 were determined using best engineering judgement.
- Capital costs for module M.13 were calculated using best engineering judgement, taking into account the number of units, the complexity of the process, and the radioactivity level of the waste.

3.1.2.2.2 Chemical Costs. The bulk chemical costs were allocated to the module into which each chemical flows. The bulk chemicals in module M.13 do not incur any cost within that module. This approach was taken to properly allocate the costs to modules requiring their use. The costs for the bulk chemicals were based on the unit costs in Boomer et al. (1993), Table R-110, and the system mass balance.

3.1.2.2.3 Labor Costs. Labor costs were derived for each module using Boomer et al. (1993) as a guideline for the labor positions needed to operate the system. Processes outlined in Boomer et al. (1993) were aligned with each module, using best engineering judgement, to extract the type and number of positions needed per module. Several of the processes were related to a specific module, while other processes were related to more than one module.

Some of the position titles outlined in Boomer et al. (1993) provided enough information to assign the position to a specific module, whereas the remaining titles securing an overhead function were divided and assigned evenly among the remaining modules.

Each of the labor positions fell into one of three categories: exempt, nonexempt, and bargaining unit. The annual cost for these categories was an average provided by Table R-110 from Boomer et al. (1993). Exempt was figured at $130,000 per man year, nonexempt at $50,000 per man year, and bargaining unit at $90,000 per man year in 1993 dollars. This average was based on 219 operating days per year for 8 hours per day per position. The average annual cost per module was multiplied by the appropriate factors in order to present the costs in 1994 dollars and to include interest for the total 13 years of operation.

3.1.2.2.4 Utilities. The utilities cost for the modules include steam and electricity only.

- Steam is used in module M.10 only and incurs an annual cost of $478,000/yr (Boomer et al. 1993).

- Electricity incurs an annual cost of $122,000/yr (Boomer et al. 1993) for modules M.4 through M.13 and is spread throughout these modules based on the amount of electrical equipment and best engineering judgement.

3.1.2.2.5 Capital Equipment Not Related To Construction and General Plant Processes. Capital equipment not related to construction (CENRTC) and general plant processes (GPP) annual costs for modules M.4 through M.13 are $26,100,000 (Boomer et al. 1993). The costs were distributed throughout the modules based on the number of components and the complexities of the processes using best engineering judgement.

3.1.2.2.6 Research and Development. The research and development (R&D) costs were developed using best engineering judgement, with consideration given to complexity of the process, previous industry use, previous development work, and the radiation level of the process.

3.1.2.2.7 Disposal. Disposal costs are only incurred in modules M.6 and M.9 (LLW and HLW disposal). These disposal costs are described below.

- Disposal costs for the Glass Cullet/Glass in Sulfur Process (encompassing the LLW and HLW) are $3,222,090,000 (Boomer et al. 1993, Appendix H-10)

- Disposal cost for LLW Glass in Sulfur (module M.6) is $331,200,000 (Boomer et al. 1993, Appendix H-8).

- Disposal cost for HLW Glass Cullet (module M.9) is $2,890,890,000, figured as the difference in the two former costs.

- These disposal costs were adjusted assuming a 13-year operation and 10% annual discount rate.

3.1.2.2.8 Decontamination and Decommissioning. The D&D cost for modules M.4 through M.13 is $627,840,000 (Boomer et al. 1993). The cost was distributed throughout the modules based on the number of components and weighting regarding the radiation levels as follows:

- Module M.7 is $12,000,000 (Boomer et al. 1993)
- Low-level is 1/3 of high-level
- Cold is 1/5 of low-level.

3.1.3 Results

Risks and costs associated with the Base Case are discussed in the following sections.

3.1.3.1 Risks. The results of the risk assessment are a compilation of the values computed for routine worker and public risks and nonroutine failure events. For each module, the following summary data have been computed for the operational and disposal phases:

- Incremental lifetime cancer risks from exposure to radioactive materials and chemicals released to the environment during routine operations
- Toxic material exposure HI from exposure to toxic chemicals released to the environment during routine operations
- Collective routine worker radiation dose from worker exposure to external radiation during routine operations
- Qualitative risks due to accidents and nonroutine maintenance activities.

Table 3-2 presents the risk values and TNPW costs for all modules and the overall system. The risk values within each module are further divided into operational and disposal phases. The total system risk and cost indices are presented first followed by the separation of risk into operational and disposal phases for the total system and each module moving across the table.

The following points summarize the results of the risk assessment.

- All risk associated with operational phase public exposure (carcinogen and noncarcinogen) occurs in the Air/Vapor Filtration System (module M.13). This is a result of the assumption that any fugitive leaks from the equipment are sent through the filtration system before discharge to the atmosphere.
- All risk associated with disposal phase public exposure occurs in SST and DST Waste Retrieval (modules M.1 and M.2). This is due to past leakage to the soil from the tanks and assumed leakage during retrieval. The DST Waste Retrieval (module M.2) shows a slightly lower cancer risk and a lower toxic HI than the SST Waste Retrieval (module M.1). Other modules are assumed to have no COC leakage and therefore no public risk.

Table 3-2. Risk Summary for the Base Case. (sheet 1 of 4)

	System Indices	System Indices		M.1, SST Waste Retrieval		M.2, DST Waste Retrieval	
		Operational Phase	Disposal Phase	Operational Phase	Disposal Phase	Operational Phase	Disposal Phase
Public							
Cancer Risk	2.51E-05	3.63E-15	2.51E-05	0.00E+00	1.98E-05	0.00E+00	5.36E-06
Toxicant HI	4.75E-01	7.10E-05	4.75E-01	0.00E+00	4.33E-01	0.00E+00	4.26E-02
Worker							
Collective Radiation Dose (man-rem)	16,991	16,991	NA	3,018	NA	696	NA
Failure Events Qualitative Risk							
Accidents	2.50	2.50	NA	2.50	NA	0.25	NA
Nonroutine Maintenance	58.92	58.92	NA	2.15	NA	2.05	NA
Costs	$13,431,080,000	$13,431,080,000		$1,451,620,000		$503,770,000	

Table 3-2. Risk Summary for the Base Case. (sheet 2 of 4)

	M.3, DST Sludge Wash		M.4, Cesium Ion Exchange		M.5, LLW Glass in Sulfur		M.6, LLW Glass in Sulfur Vaults	
	Operational Phase	Disposal Phase	Operational Phase	Disposal Phase	Operational Phase	Disposal Phase	Operational Phase	Disposal Phase
Public								
Cancer Risk	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Toxicant HI	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Worker								
Collective Radiation Dose (man-rem)	1,467	NA	1,742	NA	1,449	NA	1,260	NA
Failure Events Qualitative Risk								
Accidents	0.05	NA	0.25	NA	2.50	NA	0.05	NA
Nonroutine Maintenance	0.53	NA	0.83	NA	16.55	NA	5.41	NA
Costs	$352,940,000		$605,240,000		$1,627,590,000		$537,930,000	

Table 3-2. Risk Summary for the Base Case. (sheet 3 of 4)

	M.7, HLW Glass Cullet Feed Lag Storage		M.8, HLW Glass Cullet		M.9, HLW Glass Cullet Cask Storage Pad		M.10, Cullet Rework and Melter Off-Gas Processing	
	Operational Phase	Disposal Phase	Operational Phase	Disposal Phase	Operational Phase	Disposal Phase	Operational Phase	Disposal Phase
Public								
Cancer Risk	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Toxicant HI	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Worker								
Collective Radiation Dose (man-rem)	1,031	NA	1,932	NA	1,716	NA	1,055	NA
Failure Events Qualitative Risk								
Accidents	0.25	NA	2.50	NA	0.05	NA	0.05	NA
Nonroutine Maintenance	1.20	NA	22.06	NA	0.30	NA	5.97	NA
Costs	$119,280,000		$3,733,780,000		$3,315,820,000		$710,690,000	

Table 3-2. Risk Summary for the Base Case. (sheet 4 of 4)

	M.11, Liquid Effluent Treatment Facility		M.12, Chemical Make-up Unit		M.13, Air/Vapor Filtration System	
	Operational Phase	Disposal Phase	Operational Phase	Disposal Phase	Operational Phase	Disposal Phase
Public						
Cancer Risk	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.63E-15	0.00E+00
Toxicant HI	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.10E-05	0.00E+00
Worker						
Collective Radiation Dose (man-rem)	1,092	NA	0	NA	534	NA
Failure Events Qualitative Risk						
Accidents	0.05	NA	0.10	NA	0.01	NA
Nonroutine Maintenance	0.12	NA	1.16	NA	0.57	NA
Costs	$107,070,000		$94,350,000		$271,000,000	

- The greatest collective routine worker radiation doses are associated with the SST Waste Retrieval (module M.1), the DST Waste Retrieval (module M.2), DST Sludge Wash (module M.3), HLW Glass Cullet Feed Lag Storage (module M.7), HLW Glass Cullet (module M.8), and HLW Glass Cullet Cask Storage Pad (module M.9) due to the radiation levels associated with these operations and the greater number of direct contact worker-hours.

- Accident risks are concentrated in SST Waste Retrieval (module M.1), LLW Glass in Sulfur System (module M.5), and HLW Glass Cullet System (module M.8) due to the radiation levels and the number of worker-hours associated with these modules.

- Nonroutine maintenance risks are concentrated in the LLW Glass in Sulfur System (module M.5) and the HLW Glass Cullet System (module M.8), due to the radiation levels and equipment requirements associated with these modules.

3.1.3.2 Costs. The TNPW costs were determined from Boomer et al. (1993) and the assumptions described in Section 3.1.2. These costs are summarized in Table 3-3. A more detailed cost summary is included in Appendix M. As shown, the capital costs and the disposal costs represent the largest impacts to cost.

The relative contribution of each module to the system risk and cost are shown in Table 3-4.

The breakout of risk by system module allows for at least two preliminary analyses. Figure 3-3 also shows current (fiscal year 1994) technology funding levels plotted against these risks, to demonstrate the correlation between funding and remediation risk, which shows where the greatest relative health risks are across modules in the system. Three primary risks are included in this figure: disposal phase cancer risk, disposal phase toxicant HI, and accident risk. These three risks were chosen as representative of public and worker risk because they likely are the primary contributors to public exposure and catastrophic worker exposure, regardless of the technology. Operations associated with SST Waste Retrieval (module M.1), LLW glass formation (module M.5), and HLW glass formation (module M.8) have the greatest change of accident risks. Operations associated with SST and DST Waste Retrieval (module M.1 and M.2) carry the greatest cancer risks.

The risks are presented as a percentage of the total of each risk and are graphed against the UST-ID funding levels for projects related to each module. The UST-ID program is currently investing heavily in the development of characterization and safety (tank surveillance) technologies, including leak detection, in-tank waste characterization, and tank waste and structure surveillance (the Light-Duty Utility Arm). These technologies cannot be assessed using the current model. Future development would be necessary to expand the Base Case to include these "pre-processing" modules. Systems studies, such as the advanced processing assessment ("clean option") and this modeling activity, are also not included.

Table 3-3. Base Case Cost Summary (Total Net Present Worth).

BASE CASE	Capital Cost	Labor Cost	Utilities	CENRTC & GPP (a)	Chemical Cost	R & D (b)	Disposal	D&D (c)	Total	Percent of Total
Module 1	$814,000,000	$242,930,000	$390,000	$130,100,000	$0	$20,000,000	$0	$244,200,000	$1,451,620,000	10.81%
Module 2	$298,100,000	$25,250,000	$100,000	$30,790,000	$0	$20,000,000	$0	$129,530,000	$503,770,000	3.75%
Module 3	$110,000,000	$79,780,000	$80,000	$17,580,000	$46,680,000	$5,000,000	$0	$93,820,000	$352,940,000	2.63%
Module 4	$405,900,000	$72,890,000	$80,000	$20,390,000	$28,240,000	$10,000,000	$0	$67,740,000	$605,240,000	4.51%
Module 5	$1,105,500,000	$70,090,000	$160,000	$20,390,000	$263,710,000	$100,000,000	$0	$67,740,000	$1,627,590,000	12.12%
Module 6	$5,450,000	$64,450,000	$80,000	$4,060,000	$55,700,000	$10,000,000	$364,320,000	$33,870,000	$537,930,000	4.01%
Module 7	$44,000,000	$53,910,000	$80,000	$6,090,000	$0	$2,000,000	$0	$13,200,000	$119,280,000	0.89%
Module 8	$3,316,500,000	$53,910,000	$80,000	$51,020,000	$9,040,000	$100,000,000	$0	$203,230,000	$3,733,780,000	27.80%
Module 9	$16,340,000	$71,490,000	$80,000	$4,060,000	$0	$10,000,000	$3,179,980,000	$33,870,000	$3,315,820,000	24.69%
Module 10	$385,000,000	$56,720,000	$3,910,000	$61,180,000	$4,520,000	$30,000,000	$0	$169,360,000	$710,690,000	5.29%
Module 11	$5,500,000	$59,530,000	$80,000	$6,090,000	$0	$2,000,000	$0	$33,870,000	$107,070,000	0.80%
Module 12	$6,110,000	$64,450,000	$80,000	$10,160,000	$0	$0	$0	$13,550,000	$94,350,000	0.70%
Module 13	$139,700,000	$53,910,000	$230,000	$20,390,000	$2,570,000	$0	$0	$54,200,000	$271,000,000	2.02%
Total	$6,652,100,000	$969,310,000	$5,430,000	$382,300,000	$410,460,000	$309,000,000	$3,544,300,000	$1,158,180,000	$13,431,080,000	
Percent of Total	49.53%	7.22%	0.04%	2.85%	3.06%	2.30%	26.39%	8.62%		

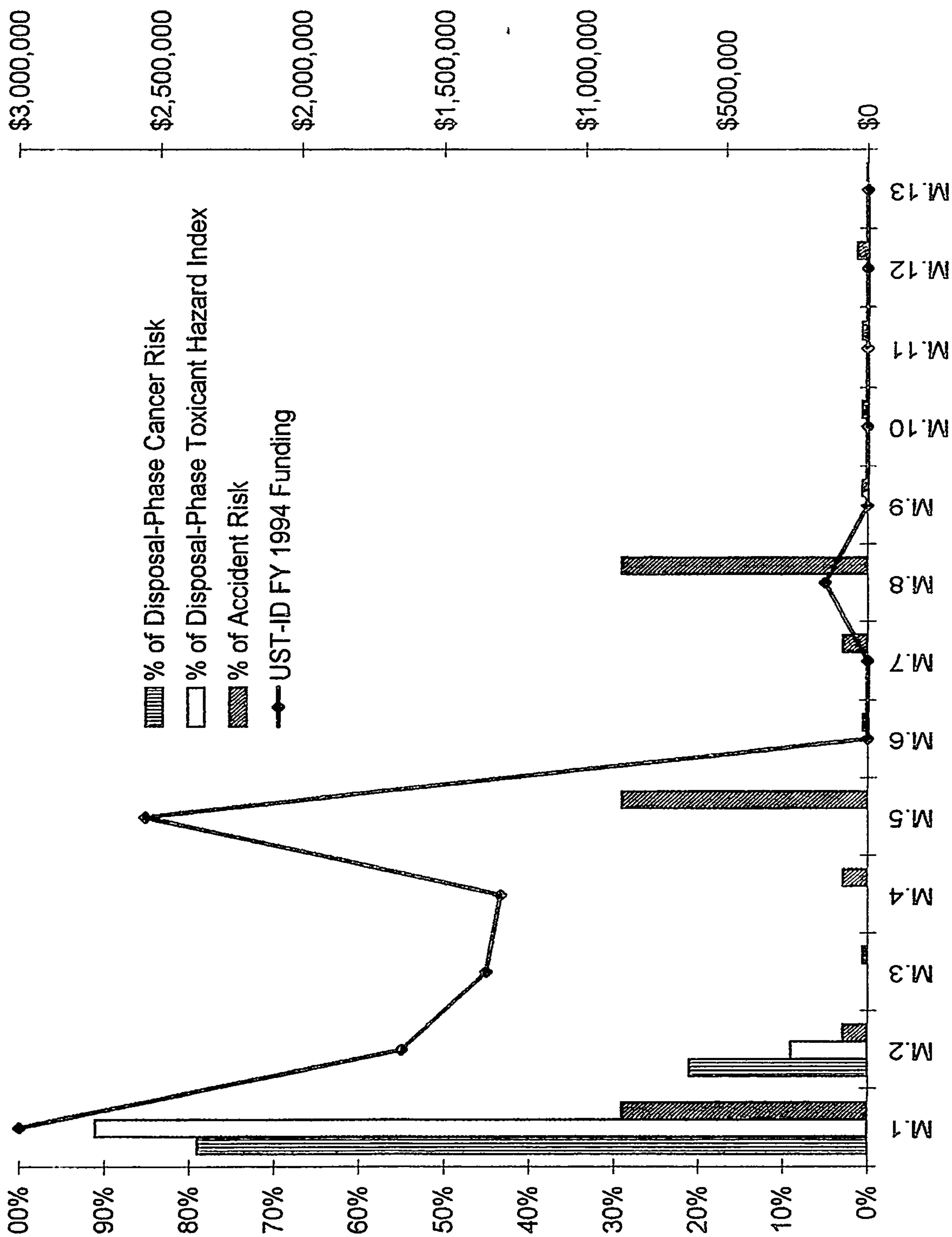
(a) CENRTC & GPP - capital equipment not related to construction and general plant processes
(b) R&D - research and development
(c) D&D - decontamination and decommissioning

Table 3-4. Base Case Cost and Risk Analyses Summary.

Risk and Cost Elements \ Modules		M.1 SST Waste Retrieval	M.2 DST Waste Retrieval	M.3 DST Sludge Wash	M.4 Cesium Ion Exchange	M.5 LLW Glass in Sulfur	M.6 LLW Glass in Sulfur Vaults	M.7 HLW Lag Storage	M.8 HLW Glass Cullet	M.9 HLW Glass Storage Pad	M.10 Rework and Offgas	M.11 Liquid Effluent Treatment	M.12 Chemical Make-up Unit	M.13 Air/Vapor Filtration System	Total Contribution by Element
Risk Element	Operational Phase Public Cancer Risk	—	—	—	—	—	—	—	—	—	—	—	—	100%	100%
	Disposal Phase Public Cancer Risk	79%	21%	—	—	—	—	—	—	—	—	—	—	—	100%
	Operational Phase Public Toxicant Hazard Index	—	—	—	—	—	—	—	—	—	—	—	—	100%	100%
	Disposal Phase Public Toxicant Hazard Index	91%	9%	—	—	—	—	—	—	—	—	—	—	—	100%
	Collective Routine Worker Radiation Dose	18%	4%	9%	10%	9%	7%	6%	11%	10%	6%	6%	—	3%	100%
	Accident Risk	29%	3%	< 1%	3%	29%	<1%	3%	29%	<1%	<1%	<1%	1%	<1%	100%
	Nonroutine Maintenance Risk	4%	4%	< 1%	1%	28%	9%	2%	38%	<1%	10%	<1%	2%	1%	100%
Cost Element	Total Net Present Worth	11%	4%	3%	5%	12%	4%	<1%	28%	25%	5%	<1%	<1%	2%	100%

— Non Contributor

Figure 3-3. Comparison of UST-ID Funding to Selected Risks Evaluated for Base Case Modules.



Remaining investments map relatively well against level of expected risk in the system. The UST-ID is investing heavily in remote retrieval technologies, where the greatest proportion of disposal phase cancer risk and toxic hazard lies. (These investments are also driven by regulatory compliance criteria addressing the level of waste that must be removed from the tank.) The UST-ID investment in retrieval technologies will increase in fiscal year 1995. If characterization and safety investments were graphed, Figure 3-3 would show an even greater amount directed at reducing retrieval risk indirectly through accurate tank surveillance and mapping technologies.

Innovations in LLW processing (module M.4), while correlated with accident risk in the graph, are actually intended to reduce the cost and long-term public health hazard associated with the current LLW glass form. Process modifications in other modules (M.3 and M.4), however, will affect not only the risk and cost of those modules, but also the risk and costs of successive modules. Specifically, the cost spent on cesium removal technologies (module M.4) will directly reduce the risk of LLW processing (module M.5), where a significant portion of accident risk resides (by increasing the extent to which the LLW stream may be contact handled). The dollars spent on sludge washing technologies (module M.3) may significantly reduce overall cost of the system by reducing the amount of HLW that must be processed and stored.

When fully developed, an output of this model would show correlations in spending with a full range of investment drivers, including cost, schedule, and regulatory risks associated with each module.

3.2 TEST CASE I

A modification of the Base Case is made by substituting or adding one or more alternative UST-ID remediation technologies for an existing technology unit and/or module(s). The resultant modified Base Case is a test case. In this report, overall risk and cost of Test Cases I and II were compared to overall risk and cost of the Base Case system. Using the relative risks and costs of both the Base Case and the test cases, a comparative assessment of the test cases was made. Test Case I is evaluated in the following sections.

3.2.1 Description

Test Case I involves an alternative module M.1 in place of the Base Case module M.1, SST Waste Retrieval. All other modules remain the same as the Base Case (Section 3.1.1). Traditional sluicing is the method of retrieval evaluated for the Base Case module M.1. For Test Case I, module M.1 a close-coupled chemical subsurface barrier would be added as a unit within the module. Barrier studies have been funded by the OTD, primarily through the In Situ Remediation Integrated Program, for the last three years. The Hanford Site's TWRS is also evaluating this technology. This addition would impact both the cost and risk of Test Case I in comparison to the Base Case.

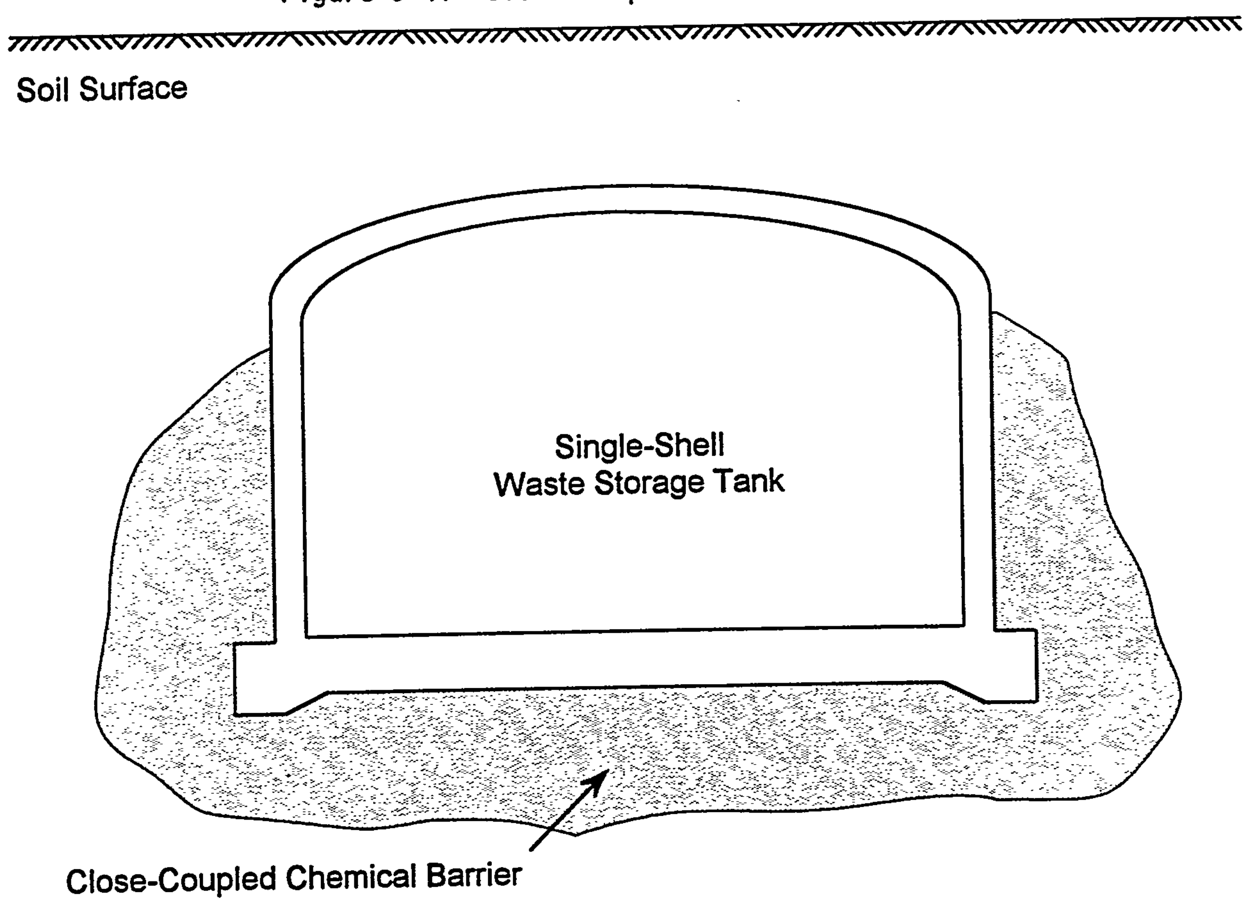
A close-coupled barrier was selected because it was identified in a draft feasibility study as the most cost-effective subsurface barrier system. The close-coupled chemical subsurface barrier would be positioned next to the tank to prevent further leakage. Chemicals used to create the close-coupled subsurface barrier (Figure 3-4) would be injected through vertical and horizontal pipes jacked into the soil. The horizontal pipes would be installed in two separate planes beneath the tanks. The horizontal pipes are perforated to allow the barrier-forming chemical to flow into the soil. A similar approach would be used at the tank walls. Injection pipes would be jacked vertically from the surface to the base of the tank footings. Injection of the chemical would be made through the end of the pipe at this level to tie into the barrier emplaced beneath the tank. Injections would then be made working upward from the base of the walls of the tank until a sealed, close-coupled basin about 3.3-m (10-ft) thick is created around the tank.

3.2.2 Case-Specific Assumptions

Assumptions specific to Test Case I are identified in the following sections.

3.2.2.1 System Characterization Assumptions. Material balance and stream assumptions remain unchanged from the Base Case except for changes to

Figure 3-4. Close-Coupled Chemical Barrier.



stream 1.7 and the addition of unit operation M.1.D Subsurface Barrier. The masses associated with stream 1.7 are assumed to be 0.1% those of the Base Case values, as barriers are assumed to reduce waste leakage to groundwater during retrieval by 99.9%.

3.2.2.2 Risk Assumptions. Risks were computed for the Test Case I using the methodologies described in Section 2.2. The following case-specific assumptions were used in computing the routine risks to the public.

- Releases of COCs to the ground with subsequent transport to the groundwater only occur in modules M.1 and M.2.
- Leakage during retrieval is assumed to be absorbed by the close-coupled barrier and subsequently released from the barrier materials, because the barriers are not designed to maintain their integrity following the active phase of the retrieval operations.
- Nitrate flux rates and durations for past leakage are based on the total mass of nitrate, the assumed depth of the plume (23.8 m [78 ft]), the assumed depth to the aquifer (79 m [259 m]), and the assumed time for recharge to travel to the aquifer (19,000 years). The resulting flux rate is calculated to be 1.17×10^6 g/yr (2,579 lb/yr).
- Nitrate flux rates and durations for SST residue and pipe leakage are based on an assumed solubility rate for nitrate of 360 g/L (3 lb/gal) and a recharge rate of 0.05 cm/yr (0.02 in./yr), resulting in a flux rate of 1.08×10^7 g/yr (2.4×10^4 lb/yr).
- Nitrate flux rates and durations for leakage during retrieval into the close-coupled barrier are based on assumed advection rate of 0.4 cm/yr (0.16 in./yr) and the total nitrate inventory assumed to be released to the barrier. The resulting flux rate is calculated to be 3.32×10^4 g/yr (73 lb/yr).
- Releases of COCs to the atmosphere with significant quantities of COCs only occur in module M.13, which operates for a total of 13 years at an efficiency of 60%.

3.2.2.3 Cost Assumptions. The Test Case I cost assumptions remain unchanged from the Base Case (Section 3.1.2.3). However, the following assumptions are added for the costing of the close-coupled chemical subsurface barrier.

- Barriers are required around the 67 SSTs assumed to have leaked, and barriers will also be placed around 30% of the remaining SSTs for a total of 92 subsurface barriers.
- Costs for design, inspection, escalation, and contingency are 82% of construction costs.
- Personnel costs are 2% per year of capital costs.

- Pipe drilling and jacking costs are $180/m ($540/ft).
- The injected chemical volume is 10 ft^3/ft of pipe and $0.90/$m^3$ ($32/$ft^3$).

3.2.3 Results

Risks and costs associated with Test Case I are discussed in the following sections.

3.2.3.1 Risks. The results of the risk assessment for the Base Case with a close-coupled barrier are a compilation of the values computed for routine worker and public risks and nonroutine failure events. For each module, the following summary data have been computed for the operational and disposal phases:

- Incremental lifetime cancer risks from exposure to radioactive materials and chemicals released to the environment during routine operations
- Toxic material exposure HI from exposure to toxic chemicals released to the environment during routine operations
- Collective routine worker radiation dose from worker exposure to external radiation during routine operations
- Qualitative risks due to accidents and nonroutine maintenance activities.

Table 3-5 presents these values for all modules. In addition, the risk values for the overall system model are presented for the operational and disposal phases, along with the total system indices.

The following points summarize the results of the risk analysis for Test Case I.

- As in the Base Case, all risk associated with operational phase public exposure (carcinogen and noncarcinogen) occurs in the Air/Vapor Filtration System (module M.13). This is a result of the assumption that any fugitive leaks from the equipment are sent through the filtration system before discharge to the atmosphere.
- As in the Base Case, all risk associated with disposal phase public exposure occurs in SST and DST Waste Retrieval (modules M.1 and M.2). This is due to past leakage to the soil from the tanks and leakage during retrieval. The DST Waste Retrieval (module M.2) shows a slightly lower cancer risk and a lower toxic HI than the SST Waste Retrieval (module M.1). Other modules are assumed to have no leakage and therefore no public risk.

Table 3-5. Risk Summary for Test Case I. (sheet 1 of 4)

		System Indices		M.1, SST Waste Retrieval		M.2, DST Waste Retrieval	
	System Indices	Operational Phase	Disposal Phase	Operational Phase	Disposal Phase	Operational Phase	Disposal Phase
Public							
Cancer Risk	1.49E-05	3.63E-15	1.49E-05	0.00E+00	9.55E-06	0.00E+00	5.36E-06
Toxicant HI	2.52E-01	7.10E-05	2.52E-01	0.00E+00	2.09E-01	0.00E+00	4.26E-02
Worker							
Collective Radiation Dose (man-rem)	17,300	17,300	NA	3,327	NA	696	NA
Failure Events Qualitative Risk							
Accidents	2.50	2.50	NA	2.50	NA	0.25	NA
Nonroutine Maintenance	59.03	59.03	NA	2.26	NA	2.05	NA
Costs	$16,692,950,000	$16,692,950,000		$4,713,490,000		$503,770,000	

Table 3-5. Risk Summary for Test Case I. (sheet 2 of 4)

	M.3, DST Sludge Wash		M.4, Cesium Ion Exchange		M.5, LLW Glass in Sulfur		M.6, LLW Glass in Sulfur Vaults	
	Operational Phase	Disposal Phase	Operational Phase	Disposal Phase	Operational Phase	Disposal Phase	Operational Phase	Disposal Phase
Public								
Cancer Risk	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Toxicant HI	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Worker								
Collective Radiation Dose (man-rem)	1,467	NA	1,742	NA	1,449	NA	1,260	NA
Failure Events Qualitative Risk								
Accidents	0.05	NA	0.25	NA	2.50	NA	0.05	NA
Nonroutine Maintenance	0.53	NA	0.83	NA	16.55	NA	5.41	NA
Costs	$352,940,000		$605,240,000		$1,627,590,000		$537,930,000	

Table 3-5. Risk Summary for Test Case I. (sheet 3 of 4)

	M.7, HLW Glass Cullet Feed Lag Storage		M.8, HLW Glass Cullet		M.9, HLW Glass Cullet Cask Storage Pad		M.10, Cullet Rework and Melter Off-Gas Processing	
	Operational Phase	Disposal Phase	Operational Phase	Disposal Phase	Operational Phase	Disposal Phase	Operational Phase	Disposal Phase
Public								
Cancer Risk	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Toxicant HI	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Worker								
Collective Radiation Dose (man-rem)	1,031	NA	1,932	NA	1,716	NA	1,055	NA
Failure Events Qualitative Risk								
Accidents	0.25	NA	2.50	NA	0.05	NA	0.05	NA
Nonroutine Maintenance	1.20	NA	22.06	NA	0.30	NA	5.97	NA
Costs	$119,280,000		$3,733,780,000		$3,315,820,000		$710,690,000	

Table 3-5. Risk Summary for Test Case I. (sheet 4 of 4)

	M.11, Liquid Effluent Treatment Facility		M.12, Chemical Make-up Unit		M.13, Air/Vapor Filtration System	
	Operational Phase	Disposal Phase	Operational Phase	Disposal Phase	Operational Phase	Disposal Phase
Public						
Cancer Risk	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.63E-15	0.00E+00
Toxicant HI	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.10E-05	0.00E+00
Worker						
Collective Radiation Dose (man-rem)	1,092	NA	0	NA	534	NA
Failure Events Qualitative Risk						
Accidents	0.05	NA	0.10	NA	0.01	NA
Nonroutine Maintenance	0.12	NA	1.16	NA	0.57	NA
Costs	$107,070,000		$94,350,000		$271,000,000	

- In contrast to the Base Case, the greatest collective routine worker radiation doses are associated with the DST Waste Retrieval (module M.2), DST Sludge Wash (module M.3), HLW Glass Cullet Feed Lag Storage (module M.7), HLW Glass Cullet (module M.8), and HLW Glass Cullet Cask Storage Pad (module M.9) due to the radiation levels associated with these operations and the greater number of direct contact worker-hours. In the Base Case, the greatest nonroutine worker risk is associated with SST Waste Retrieval (Module M.1), with additional risk stemming from the modules listed here.

- As in the Base Case, accident risks are concentrated in SST Waste Retrieval (module M.1), LLW Glass in Sulfur System (module M.5), and HLW Glass Cullet System (module M.8) due to the radiation levels and the number of worker-hours associated with these modules.

- As in the Base Case, nonroutine maintenance risks are concentrated in the LLW Glass in Sulfur System (module M.5) and the HLW Glass Cullet System (module M.8), due to the radiation levels and equipment requirements associated with these modules.

3.2.3.2 Costs. The costs for Test Case I, module M.1 is the cost of the Base Case, module M.1 plus costs for the addition of close-coupled chemical subsurface barriers. The TNPW costs are summarized in Table 3-6. The capital costs for SST Waste Retrieval (module M.1) and HLW Glass Cullet (module M.8) are the largest single costs and together account for 40% of the total system cost. The relative contribution of each module to the system risks and costs are shown in Table 3-7.

3.3 TEST CASE II

As previously stated, a modification of the Base Case is made by substituting or adding one or more alternative UST-ID remediation technologies for an existing technology and/or module(s). The second modification of the Base Case analyzed in this report is also made by substituting an alternative UST-ID remediation technology for Base Case module M.1.

3.3.1 Description

Test Case II remains the same as the Base Case with the exception of module M.1 (Section 3.1.1). Traditional sluicing is no longer the method of waste retrieval used in the SSTs. Test Case II would affect tank waste retrieval using robotic sluicing with a bridge-mounted confinement structure in place of module M.1. No subsurface barriers would be used in this test case.

Robotic sluicing is a variation of robotic arm-based retrieval systems that were first investigated at the Hanford Site in the mid-1970s (Figure 3-5). The system described in this report is best-suited for retrieval of hardened sludge from SSTs (Wallace 1993) and has been funded by the OTD through the UST-ID and Robotics Program for the last three years. The robotic arm is mounted on the bridge-mounted confinement structure.

Table 3-6. Test Case I Cost Summary (Total Net Present Worth).

TEST CASE 1	Capital Cost	Labor Cost	Utilities	CENRTC & GPP (a)	Chemical Cost	R & D (b)	Disposal	D&D (c)	Total	Percent of Total
Module 1	$3,402,000,000	$483,300,000	$390,000	$386,700,000	$0	$186,000,000	$0	$255,100,000	$4,713,490,000	28.24%
Module 2	$298,100,000	$25,250,000	$100,000	$30,790,000	$0	$20,000,000	$0	$129,530,000	$503,770,000	3.02%
Module 3	$110,000,000	$79,780,000	$80,000	$17,580,000	$46,680,000	$5,000,000	$0	$93,820,000	$352,940,000	2.11%
Module 4	$405,900,000	$72,890,000	$80,000	$20,390,000	$28,240,000	$10,000,000	$0	$67,740,000	$605,240,000	3.63%
Module 5	$1,105,500,000	$70,090,000	$160,000	$20,390,000	$263,710,000	$100,000,000	$0	$67,740,000	$1,627,590,000	9.75%
Module 6	$5,450,000	$64,450,000	$80,000	$4,060,000	$55,700,000	$10,000,000	$364,320,000	$33,870,000	$537,930,000	3.22%
Module 7	$44,000,000	$53,910,000	$80,000	$6,090,000	$0	$2,000,000	$0	$13,200,000	$119,280,000	0.71%
Module 8	$3,316,500,000	$53,910,000	$80,000	$51,020,000	$9,040,000	$100,000,000	$0	$203,230,000	$3,733,780,000	22.37%
Module 9	$16,340,000	$71,490,000	$80,000	$4,060,000	$0	$10,000,000	$3,179,980,000	$33,870,000	$3,315,820,000	19.86%
Module 10	$385,000,000	$56,720,000	$3,910,000	$61,180,000	$4,520,000	$30,000,000	$0	$169,360,000	$710,690,000	4.26%
Module 11	$5,500,000	$59,530,000	$80,000	$6,090,000	$0	$2,000,000	$0	$33,870,000	$107,070,000	0.64%
Module 12	$6,110,000	$64,450,000	$80,000	$10,160,000	$0	$0	$0	$13,550,000	$94,350,000	0.57%
Module 13	$139,700,000	$53,910,000	$230,000	$20,390,000	$2,570,000	$0	$0	$54,200,000	$271,000,000	1.62%
Total	$9,240,100,000	$1,209,680,000	$5,430,000	$638,900,000	$410,460,000	$475,000,000	$3,544,300,000	$1,169,080,000	$16,692,950,000	
Percent of Total	55.35%	7.25%	0.03%	3.83%	2.46%	2.85%	21.23%	7.00%		

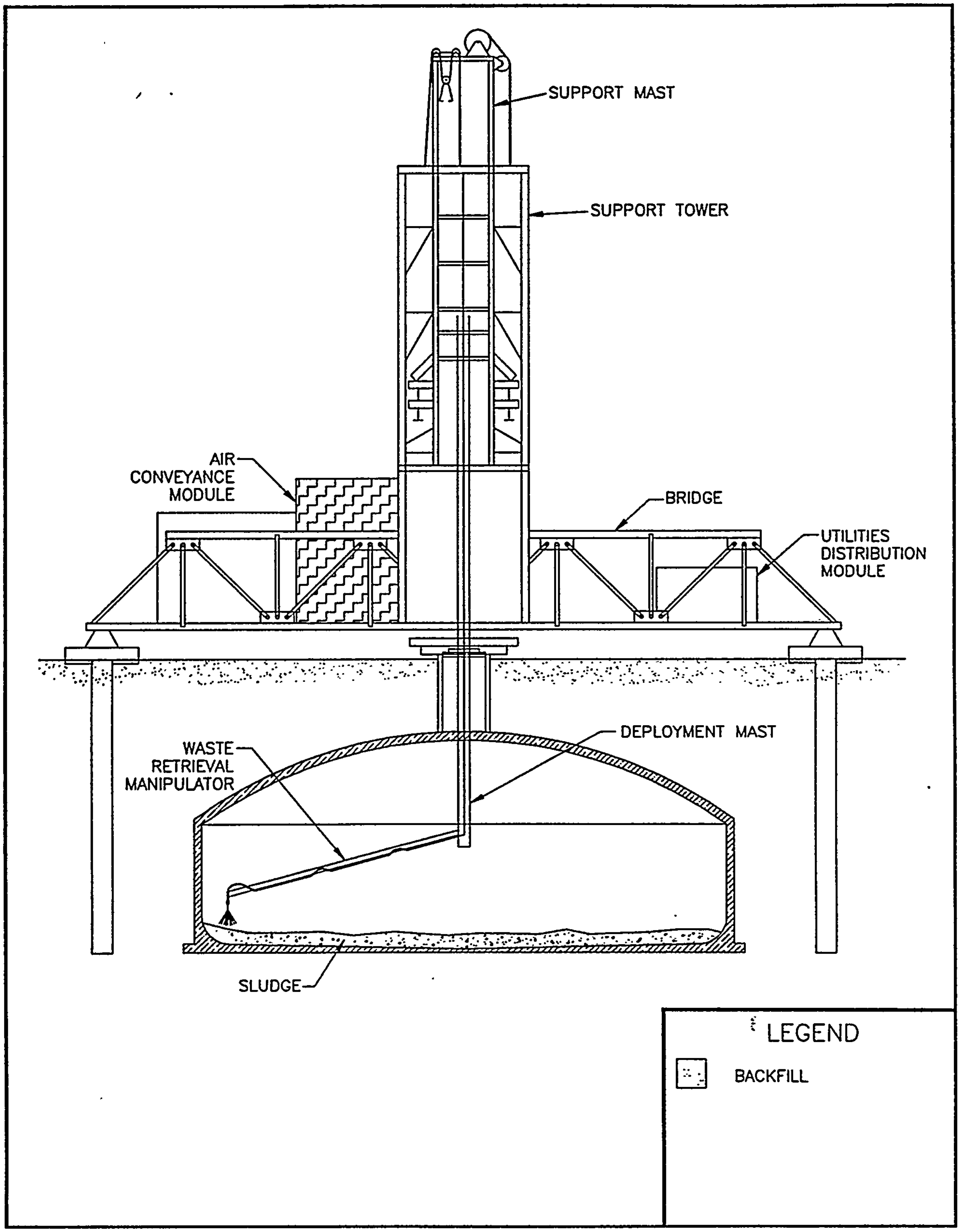
(a) CENRTC & GPP - capital equipment not related to construction and general plant processes
(b) R&D - research and development
(c) D&D - decontamination and decommissioning

Table 3-7. Test Case I Cost and Risk Analyses Summary.

Risk and Cost Elements \ Modules		M.1 SST Waste Retrieval	M.2 DST Waste Retrieval	M.3 DST Sludge Wash	M.4 Cesium Ion Exchange	M.5 LLW Glass In Sulfur	M.6 LLW Glass In Sulfur Vaults	M.7 HLW Lag Storage	M.8 HLW Glass Cullet	M.9 HLW Glass Storage Pad	M.10 Rework and Offgas	M.11 Liquid Effluent Treatment	M.12 Chemical Make-up Unit	M.13 Air/Vapor Filtration System	Total Contribution by Element
Risk Element	Operational Phase Public Cancer Risk	—	—	—	—	—	—	—	—	—	—	—	—	100%	100%
	Disposal Phase Public Cancer Risk	48%	52%	—	—	—	—	—	—	—	—	—	—	—	100%
	Operational Phase Public Toxicant Hazard Index	—	—	—	—	—	—	—	—	—	—	—	—	100%	100%
	Disposal Phase Public Toxicant Hazard Index	72%	28%	—	—	—	—	—	—	—	—	—	—	—	100%
	Collective Routine Worker Radiation Dose	19%	4%	8%	10%	8%	7%	6%	11%	10%	6%	6%	—	3%	100%
	Accident Risk	29%	3%	< 1%	3%	29%	<1%	3%	29%	<1%	<1%	<1%	1%	<1%	100%
	Nonroutine Maintenance Risk	4%	4%	< 1%	1%	28%	9%	2%	37%	<1%	10%	<1%	2%	1%	100%
Cost Element	Total Net Present Worth	28%	3%	2%	4%	10%	3%	<1%	22%	20%	4%	<1%	<1%	2%	100%

— Non Contributor

Figure 3-5. Robotic Sluicing.



The robotic arm end effectors use water jets for dislodging the waste. After the sludge is dislodged, the slurried mixture is immediately vacuumed through a hose to an air separation system. Following separation the waste proceeds to the waste processing system via the air conveyance module.

3.3.2 Case-Specific Assumptions

Assumptions specific to Test Case II are identified in the following sections.

3.3.2.1 System Characterization Assumptions. Material balance and stream assumptions remain unchanged from the Base Case except for changes to streams 1.7 and 1.8. Constituent masses associated with stream 1.7, waste leakage during retrieval, stream 1.8, residual in tank after retrieval, are assumed to be 10% those of the Base Case values. The robotic sluicing is assumed to reduce tank leakage by 90% by minimizing the addition of water. The residual in the tanks is assumed to be reduced from 1% in the Base Case to 0.1% in this test case.

3.3.2.2 Risk Assumptions. Risks were computed for Test Case II using the methodologies described in Section 2.2. The following case-specific assumptions were used in computing the routine risks to the public.

- Robotic sluicing removes an additional 0.9% of the COCs from the USTs.
- Releases of COCs to the ground with subsequent transport to the groundwater only occur in modules M.1 and M.2.
- Nitrate flux rates and durations for past leakage and leakage during retrieval are based on the total mass of nitrate, the assumed depth to the plume (24.4 m [80 ft]), the assumed depth to the aquifer (79 m [259 ft]), and the assumed time for recharge to travel to the aquifer (19,000 years). The resulting flux rate is calculated to be 2.15×10^6 g/yr (4,740 lb/yr) and 2.15×10^5 g/yr (474 lb/yr) for past leakage and leakage during retrieval, respectively.
- Nitrate flux rates and durations for SST residue and pipe leakage are based on an assumed solubility rate for nitrate of 360 g/L (3 lb/gal) and a recharge rate of 0.05 cm/yr (0.02 in./yr), resulting in a flux rate of 8.77×10^5 g/yr (1,933 lb/yr).
- Releases of COCs to the atmosphere with significant quantities of COCs only occur in module M.13, which operates for a total of 13 years at an efficiency of 60%.

3.3.2.3 Cost Assumptions. The Test Case II cost assumptions remain unchanged from the Base Case (Section 3.1.2.3) for modules M.2 through M.13. However, the robotic sluicing used in module M.1 of Test Case II requires much more equipment than the traditional sluicing used in the Base Case. The following assumptions were made for the costing of robotic sluicing in module M.1.

- More R&D must be performed to make robotic sluicing technically ready for implementation as compared to traditional sluicing.
- Costs for design, inspection, escalation, and contingency are 82% of construction costs.
- Costs of operating personnel are 4.2% per year of capital costs.
- The D&D costs are significantly higher because there is much more equipment used with robotic sluicing as compared to traditional sluicing.

3.3.3 Results

Risks and costs associated with Test Case II are discussed in the following sections.

3.3.3.1 Risks. The results of the risk analysis for the Base Case with robotic sluicing are a compilation of the values computed for routine worker and public risks and nonroutine failure events. For each module, the following summary data have been computed for the operational and disposal phases:

- Incremental lifetime cancer risks from exposure to radioactive materials and chemicals released to the environment during routine operations
- Toxic material exposure HI from exposure to toxic chemicals released to the environment during routine operations
- Collective routine worker radiation dose from worker exposure to external radiation during routine operations
- Qualitative risks due to accidents and nonroutine maintenance activities.

Table 3-8 presents these values for all modules. In addition, the risk values for the overall system model are presented for the operational and disposal phases, along with the total system indices.

The following points summarize the results of the risk analysis for Test Case II.

- As in the Base Case, all risk associated with operational phase public exposure (carcinogen and noncarcinogen) occurs in the Air/Vapor Filtration System (module M.13). This is a result of the assumption that any fugitive leaks from the equipment are sent through the filtration system before discharge to the atmosphere.

Table 3-8. Risk Summary for Test Case II. (sheet 1 of 4)

		System Indices		M.1, SST Waste Retrieval		M.2, DST Waste Retrieval	
	System Indices	Operational Phase	Disposal Phase	Operational Phase	Disposal Phase	Operational Phase	Disposal Phase
Public							
Cancer Risk	1.20E-05	3.63E-15	1.20E-05	0.00E+00	6.62E-06	0.00E+00	5.36E-06
Toxicant HI	1.87E-01	7.10E-05	1.87E-01	0.00E+00	1.45E-01	0.00E+00	4.26E-02
Worker							
Collective Radiation Dose (man-rem)	21,530	21,530	NA	7,558	NA	696	NA
Failure Events Qualitative Risk							
Accidents	2.50	2.50	NA	2.50	NA	0.25	NA
Nonroutine Maintenance	60.27	60.27	NA	3.50	NA	2.05	NA
Costs	$15,937,950,000	$15,937,950,000		$3,958,490,000		$503,770,000	

Table 3-8. Risk Summary for Test Case II. (sheet 2 of 4)

	M.3, DST Sludge Wash		M.4, Cesium Ion Exchange		M.5, LLW Glass in Sulfur		M.6, LLW Glass in Sulfur Vaults	
	Operational Phase	Disposal Phase	Operational Phase	Disposal Phase	Operational Phase	Disposal Phase	Operational Phase	Disposal Phase
Public								
Cancer Risk	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Toxicant HI	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Worker								
Collective Radiation Dose (man-rem)	1,467	NA	1,742	NA	1,449	NA	1,260	NA
Failure Events Qualitative Risk								
Accidents	0.05	NA	0.25	NA	2.50	NA	0.05	NA
Nonroutine Maintenance	0.53	NA	0.83	NA	16.55	NA	5.41	NA
Costs	$352,940,000		$605,240,000		$1,627,590,000		$537,930,000	

Table 3-8. Risk Summary for Test Case II. (sheet 3 of 4)

	M.7, HLW Glass Cullet Feed Lag Storage		M.8, HLW Glass Cullet		M.9, HLW Glass Cullet Cask Storage Pad		M.10, Cullet Rework and Melter Off-Gas Processing	
	Operational Phase	Disposal Phase	Operational Phase	Disposal Phase	Operational Phase	Disposal Phase	Operational Phase	Disposal Phase
Public								
Cancer Risk	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Toxicant HI	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Worker								
Collective Radiation Dose (man-rem)	1,031	NA	1,932	NA	1,716	NA	1,055	NA
Failure Events Qualitative Risk								
Accidents	0.25	NA	2.50	NA	0.05	NA	0.05	NA
Nonroutine Maintenance	1.20	NA	22.06	NA	0.30	NA	5.97	NA
Costs	$119,280,000		$3,733,780,000		$3,315,820,000		$710,690,000	

Table 3-8. Risk Summary for Test Case II. (sheet 4 of 4)

	M.11, Liquid Effluent Treatment Facility		M.12, Chemical Make-up Unit		M.13, Air/Vapor Filtration System	
	Operational Phase	Disposal Phase	Operational Phase	Disposal Phase	Operational Phase	Disposal Phase
Public						
Cancer Risk	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.63E-15	0.00E+00
Toxicant HI	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.10E-05	0.00E+00
Worker						
Collective Radiation Dose (man-rem)	1,092	NA	0	NA	534	NA
Failure Events Qualitative Risk						
Accidents	0.05	NA	0.10	NA	0.01	NA
Nonroutine Maintenance	0.12	NA	1.16	NA	0.57	NA
Costs	$107,070,000		$94,350,000		$271,000,000	

- As in the Base Case, all risk associated with disposal phase public exposure occurs in SST and DST Waste Retrieval (modules M.1 and M.2). This is due to past leakage to the soil from the tanks and leakage during retrieval. The DST Waste Retrieval (module M.1) shows a slightly lower cancer risk and toxic HI than the SST Waste Retrieval (module M.1). Other modules are assumed to have no leakage and therefore no public risk.

- As in the Base Case, the greatest collective routine worker radiation doses are associated with the SST Waste Retrieval (module M.1), the DST Waste Retrieval (module M.2), DST Sludge Wash (module M.3), HLW Glass Cullet Feed Lag Storage (module M.7), HLW Glass Cullet (module M.8), and HLW Glass Cullet Cask Storage Pad (module M.9) due to the radiation levels associated with these operations and the greater number of direct contact worker-hours.

- As in the Base Case, accident risks are concentrated in SST Waste Retrieval (module M.1), LLW Glass in Sulfur System (module M.5), and HLW Glass Cullet System (module M.8) due to the radiation levels and the number of worker-hours associated with these modules.

- As in the Base Case, nonroutine maintenance risks are concentrated in the LLW Glass in Sulfur System (module M.5) and the HLW Glass Cullet System (module M.8), due to the radiation levels and equipment requirements associated with these modules.

3.3.3.2 Costs. The TNPW costs are summarized in Table 3-9. The capital cost for HLW Glass Cullet (module M.8) and disposal cost for HLW Glass Cullet Cask Storage (module M.9) are the largest single costs and together account for 41% of the total system cost. The relative contribution of each module to the system risk and cost are shown in Table 3-10.

3.4 COMPARISON SUMMARY AND MODULE UNCERTAINTY ANALYSIS

The individual results from analysis of the Base Case, Test Case I, and Test Case II were given in Sections 3.1.3, 3.2.3, and 3.3.3, respectively. The changes in the test case risks and costs relative to the Base Case are shown in Table 3-11.

Table 3-11 shows the percentage change for both test cases relative to the total Base Case system risks and costs. A general observation is that both test cases increase the total system cost by approximately 20% while decreasing the public disposal phase risk by 40% to 60%. Test Case II, Robotic Sluicing, however shows a 27% increase in worker risk. Table 3-11 shows that Test Case I (subsurface barriers) promises to reduce by 41% the chance that the MEI will get cancer, reduce by 47% the chance that the MEI will be harmed by toxicants, increase by 2% the collective routine worker radiation dose, and increase by <1% the accident risks and nonroutine maintenance risk. These reductions are achieved at a 24% increase in cost, or an addition of $3,300,000,000. In contrast, at slightly less cost increase (19% or $2,500,000,000), Test Case II (robotic sluicing)) may provide relatively similar public risk reductions, but adds to the collective routine worker radiation dose.

Table 3-9. Test Case II Cost Summary (Total Net Present Worth).

TEST CASE 2	Capital Cost	Labor Cost	Utilities	CENRTC & GPP (a)	Chemical Cost	R & D (b)	Disposal	D&D (c)	Total	Percent of Total
Module 1	$2,334,000,000	$663,200,000	$390,000	$373,000,000	$0	$236,000,000	$0	$351,900,000	$3,958,490,000	24.84%
Module 2	$298,100,000	$25,250,000	$100,000	$30,790,000	$0	$20,000,000	$0	$129,530,000	$503,770,000	3.16%
Module 3	$110,000,000	$79,780,000	$80,000	$17,580,000	$46,680,000	$5,000,000	$0	$93,820,000	$352,940,000	2.21%
Module 4	$405,900,000	$72,890,000	$80,000	$20,390,000	$28,240,000	$10,000,000	$0	$67,740,000	$605,240,000	3.80%
Module 5	$1,105,500,000	$70,090,000	$160,000	$20,390,000	$263,710,000	$100,000,000	$0	$67,740,000	$1,627,590,000	10.21%
Module 6	$5,450,000	$64,450,000	$80,000	$4,060,000	$55,700,000	$10,000,000	$364,320,000	$33,870,000	$537,930,000	3.38%
Module 7	$44,000,000	$53,910,000	$80,000	$6,090,000	$0	$2,000,000	$0	$13,200,000	$119,280,000	0.75%
Module 8	$3,316,500,000	$53,910,000	$80,000	$51,020,000	$9,040,000	$100,000,000	$0	$203,230,000	$3,733,780,000	23.43%
Module 9	$16,340,000	$71,490,000	$80,000	$4,060,000	$0	$10,000,000	$3,179,980,000	$33,870,000	$3,315,820,000	20.80%
Module 10	$385,000,000	$56,720,000	$3,910,000	$61,180,000	$4,520,000	$30,000,000	$0	$169,360,000	$710,690,000	4.46%
Module 11	$5,500,000	$59,530,000	$80,000	$6,090,000	$0	$2,000,000	$0	$33,870,000	$107,070,000	0.67%
Module 12	$6,110,000	$64,450,000	$80,000	$10,160,000	$0	$0	$0	$13,550,000	$94,350,000	0.59%
Module 13	$139,700,000	$53,910,000	$230,000	$20,390,000	$2,570,000	$0	$0	$54,200,000	$271,000,000	1.70%
Total	$8,172,100,000	$1,389,580,000	$5,430,000	$625,200,000	$410,460,000	$525,000,000	$3,544,300,000	$1,265,880,000	$15,937,950,000	
Percent of Total	51.27%	8.72%	0.03%	3.92%	2.58%	3.29%	22.24%	7.94%		

(a) CENRTC & GPP - capital equipment not related to construction and general plant processes
(b) R&D - research and development
(c) D&D - decontamination and decommissioning

Table 3-10. Test Case II Cost and Risk Analyses Summary.

Risk and Cost Elements / Modules		M.1 SST Waste Retrieval	M.2 DST Waste Retrieval	M.3 DST Sludge Wash	M.4 Cesium Ion Exchange	M.5 LLW Glass in Sulfur	M.6 LLW Glass in Sulfur Vaults	M.7 HLW Lag Storage	M.8 HLW Glass Cullet	M.9 HLW Glass Storage Pad	M.10 Rework and Offgas	M.11 Liquid Effluent Treatment	M.12 Chemical Make-up Unit	M.13 Air/Vapor Filtration System	Total Contribution by Element
Risk Element	Operational Phase Public Cancer Risk	—	—	—	—	—	—	—	—	—	—	—	—	100%	100%
	Disposal Phase Public Cancer Risk	18%	83%	—	—	—	—	—	—	—	—	—	—	—	100%
	Operational Phase Public Toxicant Hazard Index	—	—	—	—	—	—	—	—	—	—	—	—	100%	100%
	Disposal Phase Public Toxicant Hazard Index	37%	63%	—	—	—	—	—	—	—	—	—	—	—	100%
	Collective Routine Worker Radiation Dose	35%	3%	7%	8%	7%	6%	5%	9%	8%	5%	5%	—	2%	100%
	Accident Risk	29%	3%	< 1%	3%	29%	<1%	3%	29%	<1%	<1%	<1%	1%	<1%	100%
	Nonroutine Maintenance Risk	6%	3%	< 1%	1%	28%	9%	2%	37%	<1%	10%	<1%	2%	<1%	100%
Cost Element	Total Net Present Worth	25%	3%	2%	4%	10%	3%	<1%	23%	21%	5%	<1%	<1%	2%	100%

— Non Contributor

Table 3-11. Test Case Changes to System Risk and Cost from the Base Case.

Element	Test Case I	Test Case II
Risk element		
Operational phase public cancer risk	--	--
Disposal phase public cancer risk	-41%	-52%
Operational phase public toxicant hazard index	--	--
Disposal phase public toxicant hazard index	-47%	-61%
Collective routine worker radiation dose	+2%	+27%
Accident risk	<1%	<1%
Nonroutine maintenance risk	<1%	+2%
Cost element		
Total net present worth	+24%	+19%

Note that the model does not currently provide a method for directly comparing cost to unit of risk reduction. That is, it is not possible to directly answer the question "is this reduction in risk worth the cost of technology development?" First, because the measured risks are relative and not absolute, the question lacks external validity. A conclusion is not possible from the level of analysis in the model that barriers will reduce the incidence of cancer by a specific amount, only that it will do so to a greater or lesser extent than will the baseline. Second, the model does not currently incorporate utility functions for cost and risk such that the two can be directly related. Instead, the model provides useful guidance regarding the relative benefit of alternative investments and helps answer the following question: given several investment opportunities, which appear to reduce risk at the least cost? Once other decision variables are incorporated into the model or into the decision process more generally and the uncertainty surrounding the values is addressed, this information should help to prioritize technology investment options in a manner that is both systematic and defensible.

3.4.1 Major Risk Uncertainties

As discussed in Section 1.1, an objective of the OTD and the RWTRTFA is to employ a reliable and cost-effective mechanism for evaluating candidate technologies based on their ability to reduce health risks associated with tank waste remediation. Because these evaluations must be made at the beginning of the technology development process, the range and quality of design data to support quantitative analyses of potential risks will not be available, and it is necessary to apply qualitative approaches in the evaluation of possible risk reduction. These qualitative approaches rely on a number of best estimates regarding technology characteristics, and a range of assumptions regarding contaminants, receptors and exposure conditions.

Comparative evaluations have been performed in the trial applications of the System Analysis Model to the Base Case remediation system and Test Cases I and II (Section 3). The results from these trial applications reveal that the key risk measures were disposal phase public health risks (cancer risk and HI), routine worker risk, and accident risks. However, the System Analysis Model is not currently complete, and certain relevant risk measures are not yet incorporated in the model. Therefore, at the present time caution must be exercised in reaching conclusions regarding the range and magnitude of potential risks associated with tank waste remediation systems.

The identified key risk measures were influenced to varying degrees by the alternative technologies evaluated in Test Cases I and II. In the sections that follow, qualitative uncertainty analyses are discussed that evaluate the effects that uncertainties in several model and technology parameters may have on the key health risk measures.

3.4.1.1 Public Disposal Phase Risks. An evaluation of the model and technology parameters' uncertainties associated with the disposal phase public health risks were conducted either through (1) varying parameter values within the System Analysis Model or (2) extrapolating results from a related study funded by the UST-ID, (a feasibility study of tank leakage mitigation using subsurface barriers), which are directly applicable to the disposal phase risks evaluated in this model.

The parameters for which uncertainty is evaluated as follows: (1) the inventories of COCs in the sources of potential groundwater contamination, (2) the initial tank waste inventory, (3) the geology underlying the tanks, and (4) the solubilities of different COCs. The overall conclusion of the uncertainty analysis is that the range in estimated health risks between the Base Case (traditional sluicing) and the highest risk test case (Test Case II, robotic sluicing) approximates the range of uncertainty in the parameters evaluated. The risk results are most sensitive to technologies that change the amount of residual waste remaining in the tanks following retrieval.

<u>Uncertainty in Source Inventories and Release Rates</u>

The Base Case and Test Cases I and II provide the bases for evaluating the sensitivity of risk results to source inventory and release rate. Sources of contaminant release to groundwater are tank residues (all cases), old leaks to soil (all cases), new leaks to soil (Base Case and Test Case II), and contaminated subsurface barriers (Test Case I).

The Base Case and Test Case I exhibit the same COC inventory levels in the tank residues (the primary source of risk), because each uses traditional sluicing. However, Test Case II uses robotic sluicing, which removes an additional 0.9% of tank waste, resulting in tank residue inventories that are 1/10th those for the Base Case. The computed risks for Test Case II, from the tank residue source, were determined to be approximately 33% of those for the Base Case and Test Case I.

The Base Case, Test Case I, and Test Case II exhibit the same amount of past leakage to the soil; however, each case has differing assumptions regarding the quantity of waste materials that leak to soil during retrieval.

For Test Case I, it is assumed that a close-coupled barrier is installed, which eliminates leaks into the soil. Waste is still assumed to leak from the tank and absorb into the barrier. The release rate of waste materials out of the barrier is assumed to be about 3% of the release rate of the waste from the soils in the Base Case. These combined differences result in risk values for Test Case I from tank leakage sources that are approximately 48% of the Base Case and Test Case II.

High and Low COC Inventory Cases

Uncertainty also exists in the overall inventory of COCs in the SSTs. The uncertainty results from the range of inventory estimates presented in different sources of inventory information, and varying levels of conservatism applied in those sources. Inventories used in this evaluation were based primarily on estimates provided in Boomer et al. (1993). Except for nitrate, Boomer et al. (1993) inventories are 0 to 40% lower than those used by other studies of the SSTs. Thus uncertainty in initial inventory of the waste adds slightly to the overall uncertainty in projecting risk.

In the related draft TWRS subsurface barrier feasibility evaluations, the sensitivity of risk results to high and low COC inventory estimates was analyzed. The impact of high versus low inventory of COCs on HI was determined to be small (about 25%). For relative cancer risk, the impact was determined to be high (about a factor of five). This also reflects the dominance of tank residues over other sources in contributing to risk.

High and Low Vadose Zone Travel Rate Cases

The geologic stratigraphy at the Hanford Site is varied. For this evaluation, the stratigraphy was assumed to be that of the 200 West Area, because these geological strata produced the highest risks. Based on the location of the tanks under remediation, the transport of contaminants through the vadose zone to the aquifer can vary significantly and impact the risk results.

Two cases involving different geologies beneath tank farms were evaluated in the related draft TWRS subsurface feasibility study. One resulted in a projected higher vadose zone travel rate and the other in a lower rate. The rate of travel affects the level of diffusion and dispersion that would occur in the vadose zone and hence, the peak concentrations of COCs and corresponding risks. A high vadose zone travel rate would yield relative risks and HI about five times greater than risks and HI associated with slow vadose zone travel rates.

Solubility-Limited Case

A final case involving solubility-limited release and leaching of tank waste was conducted. Contaminant solubility limits the concentration of COCs that leak from the tank. Previous analyses in this evaluation were based on the conservative assumption that all COCs would leak and leach congruently with nitrate. It can be inferred from the solubilities of the COCs that some COCs will dissolve at rates several orders of magnitude lower than assumed in this analyses. Lower solubilities would result in lower release rates of COCs and lower relative risk. There would be little effect on HI since HI results are dominated by nitrate.

The case was evaluated in the related draft TWRS subsurface feasibility study to determine the impact of solubility limited leaching. The use of solubility limits to model releases of COCs would reduce relative risk by about a factor of 20 times from levels estimated using congruent leaching with nitrate, but would have no impact on HI.

3.4.1.2 Accident Risks. The assessment of potential accident risks addresses the probability that a failure condition occurs, in addition to the risk of individual exposure and health impact. Standard system safety and safety analysis procedures exist for the identification and evaluation of potential failure events; however, to be useful, these procedures require that a reasonably detailed level of facility and process information be available. This information was not available during these trial applications, nor is it expected to be available during future technology evaluations. As a result, the accident risks were developed based on expert judgement and evaluation of anticipated technology baseline conditions. As such, the accident risks are extremely sensitive to the identification and evaluation of technology characteristics, and the approach implemented within the System Analysis Model.

Technology Characteristics

Accident event risk factors have been developed as the product of unitless qualitative consequence values and estimated frequencies of occurrence. Consequence values are determined for a unit operation based on expert judgement and evaluation of the unit operation's anticipated baseline conditions. Relevant baseline conditions include (1) waste inventory characteristics, (2) containment characteristics, and (3) the energetic reaction potential. Waste inventory characteristics include the activity of waste (high-level, low-level, or cold), the toxicity (high, low), and the quantity and physical form of the waste for each technology unit. To the extent that these conditions are not known, they must be assumed, which creates the potential for significant differences in consequence values.

Frequency values are also based on expert judgement and evaluation of unit operation baseline conditions. Relevant baseline conditions include (1) the presence of flammable materials, (2) conditions that could lead to energetic reactions, (3) the level of system temperature and pressure, (4) level and complexity of electrical instrumentation/control requirements, (5) level and complexity of mechanical equipment, (6) level of corrosivity, and (7) number and complexity of physical operations. To the extent that these conditions are not known, they must be assumed, which creates the potential for significant differences in frequency values.

The range of potential differences in assumed technology characteristics can be reasonably expected to be large. The degree to which accident risks are sensitive to differences in these assumptions is determined by the model's approach in calculating risk values.

<u>Model Approach</u>

The approach currently implemented within the System Analysis Model to address worker and public health related impact associated with potential accident conditions uses eight qualitative consequence categories and four frequency levels to compute relative risk values (consequence times frequency). For the purpose of this trial application and model evaluation, the results are expressed as unitless relative risk values derived from selected elements of the PPG (WHC 1993).

The selection of consequence values from a limited number of defined categories affords a degree of simplicity and consistency in developing accident relative risk values for technology operations. However, the fewer number of categories available to select from, the larger the steps will be between categories in order to encompass the range of consequences from nonexistent to catastrophic. In the case of the eight categories used in these trial applications, the unitless consequence values are 1, 5, 10, 25, 100, 300, 1,000, and 3,000. Differences in professional judgement during the evaluation of baseline conditions could reasonably result in a one-category difference in assigned consequence category. Depending upon the category, this would result in a two- to five-fold difference in consequence value and accident risk.

Frequency levels are selected from four categories that span a range from High (occurs within two years) to Very Low (highly unlikely to occur). The four frequency values used in these trial applications were 1 (High), 0.1 (Medium), 0.01 (Low), and 0.0001 (Very Low). Differences in professional judgement during the evaluation of baseline conditions could reasonably result in a one-category difference in assigned frequency level. Depending upon the level, this would result in a one- to two-order-of-magnitude difference in frequency level and accident risk.

3.4.2 Cost Uncertainties

Costs for the Base Case and Test Cases I and II in the primary cost categories for all modules are shown in Figures 3-6, 3-7, and 3-8, respectively. These figures show the capital cost, labor cost, and disposal costs for each module as a percentage of the total system cost. The primary differentiation between the Base Case and the test cases is the module M.1 SST Waste Retrieval capital costs. Any assumptions that impact the SST Waste Retrieval capital cost estimates will directly impact the evaluation. The module M.1 capital costs for the two test cases are approximately three times larger than the Base Case. Therefore it is unlikely that changing some of the capital cost assumptions will alter the conclusion that the use of subsurface barriers or robotic sluicing is significantly more expensive than the base case traditional sluicing.

The other cost categories represent only a small portion of the total cost and even major changes in these assumptions would not significantly alter the final results.

Figure 3-6. Base Case Costs (Percentage of Overall System Costs).

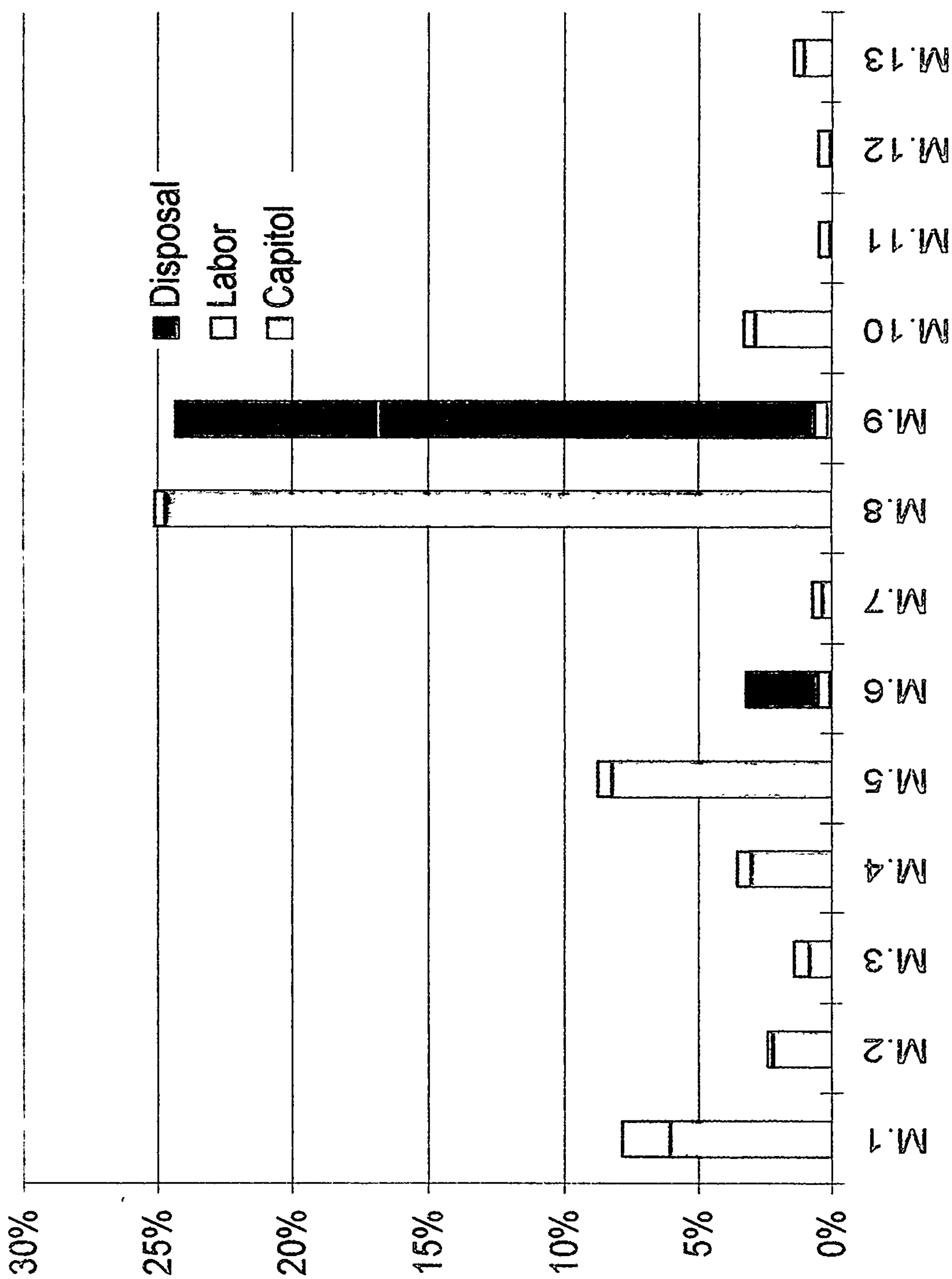


Figure 3-7. Test Case I Costs (Percentage of Overall System Costs).

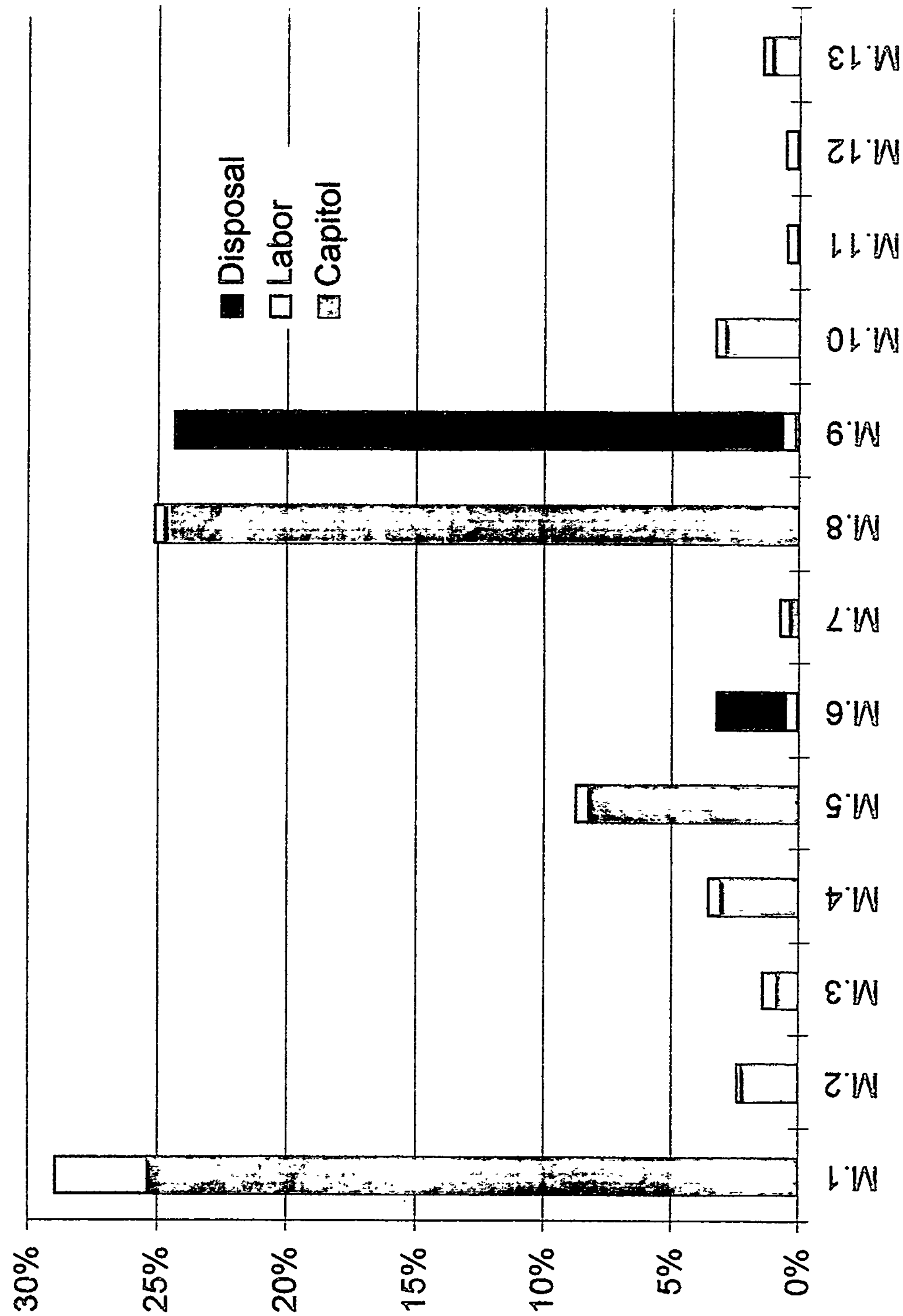


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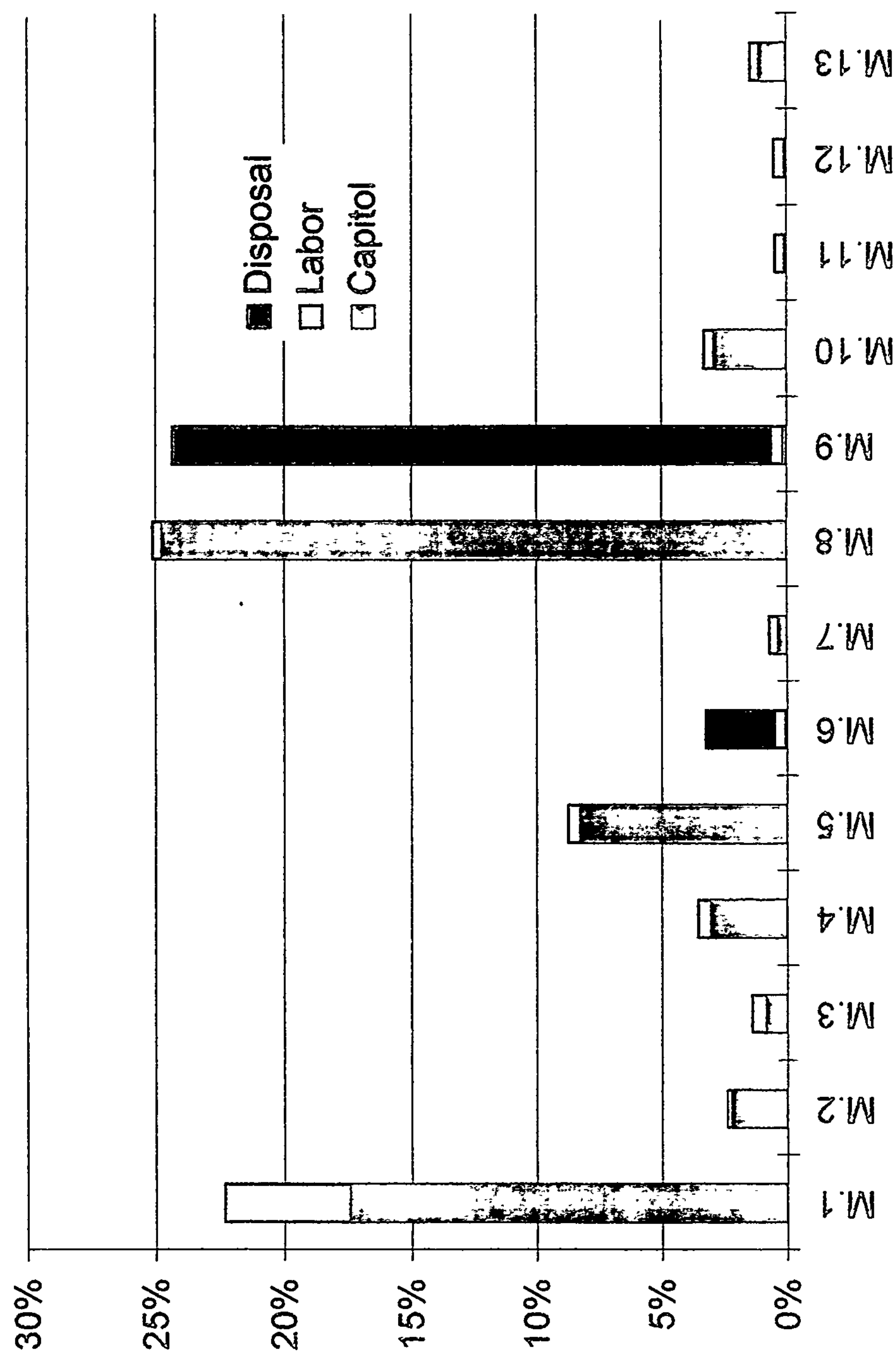
Figure 3-8. Test Case II Costs (Percentage of Overall System Costs).



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4.0 SUMMARY AND CONCLUSIONS

The System Analysis Model provides the framework for evaluating the risk and cost of new technologies relative to a baseline plan. The general approach incorporates new technologies into complete remediation systems to allow a disciplined assessment of overall system risk and cost.

The specific model reported here uses a structured methodology for estimating risks and costs of a baseline remediation plan for HLW tanks. The same methodology can be applied to alternative technologies to yield comparative costs and risks. A flowsheet and material balance for all stages of the Base Case from retrieval though disposal were first established. The risks and life-cycle costs of each stage were then defined. All risk element values and costs were summed to provide cumulative system risk and cost. Test Cases I and II were assessed by establishing a modified flowsheet and material balance for each test system. All test case risks and costs were assigned for the full system to arrive at a cumulative risk and cost which was compared against the Base Case.

The System Analysis Model provides a flexible, practical tool for decision makers in the RWTRTFA. It is intended to bridge a gap between very complex (or nonexistent) system models developed by site remediation programs and the information needs for the RWTRTFA decision makers. The model and supporting software are designed to support online discussions of the relative added value of alternate remediation technologies. In that way, it should be a practical tool for building consensus among users, technologists, stakeholders, and final decision-makers.

Some constraints associated with this approach include the following.

- Cost and risk values are relative so there is the potential for misinterpretation as rigorous quantitative costs and risks. Figures shown here should not be considered absolute; however, the analyses are practical for comparing competing investments.

- Detailed resolution is not provided at the unit operation level. The model requires the addition or substitution of complete unit operations and/or system modules.

- Activities that do not directly impact cost or worker/public risk or that have impacts that can't be quantified within the current system configuration are not specifically addressed (e.g., characterization methods).

- A limited set of exposure scenarios were included in the System Risk Analysis Model.

Some specific recommendations regarding the further development and use of the System Analysis Model are as follows.

1. Incorporate physical injury, D&D, and routine waste disposal operational risks.

2. Incorporate a decision analysis framework that includes all important decision factors and associated weightings to be used in addition to the risk and cost impacts of technologies to facilitate technology screening and prioritization. Schedule, regulatory compliance, ecological impact, and socioeconomic impacts should be considered as an initial set of factors.

3. Perform and expand the uncertainty analyses to facilitate the evaluation and determination of critical model parameters. Translate risk reductions into meaningful, comparable units.

4. Implement a more formal "method selection" process for the various risk assessment elements implemented in the model. The selection process would document functional objectives and criteria for the methods, and evaluate available analytical methods relative to those criteria and objectives. The end result would be documented bases for each of the methods implemented in the model. It is likely that this process would result in some changes to the current model risk methods.

5. Expand the number of model variables that the user can change online. This should improve the usefulness of the software.

6. Revise the Baseline System Characterization material balance to link the waste streams. The current mass balance does not provide for automatically maintaining a closed material balance. The user is currently allowed to change the masses of individual stream constituents but these changes are not automatically reflected downstream. The user is required to make all the appropriate changes to maintain a closed material balance. This process can be automated to force a closed material balance.

7. Evaluate whether nonprocess technologies such as characterization and safety can be incorporated into the current assessment methodology. Such technologies which currently cannot be assessed include tank leak detection, in-tank waste characterization, and tank waste and structure surveillance (Light-Duty Utility Arm). If found to be feasible, incorporate characterization modules or operations to allow evaluation of characterization technologies.

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APPENDIX A

MODULE DESCRIPTIONS

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Metric Conversion Chart

The following chart is provided to the reader as a tool to aid in converting to metric units.

Into Metric Units

If You Know	Multiply By	To Get
Length		
inches	25.4	millimeters
inches	2.54	centimeters
feet	0.305	meters
yards	0.914	meters
miles	1.609	kilometers
Area		
sq. inches	6.452	sq. centimeters
sq. feet	0.093	sq. meters
sq. yards	0.0836	sq. meters
sq. miles	2.6	sq. kilometers
acres	0.405	hectares
Mass (weight)		
ounces	28.35	grams
pounds	0.454	kilograms
short ton	0.907	metric ton
Volume		
teaspoons	5	milliliters
tablespoons	15	milliliters
fluid ounces	30	milliliters
cups	0.24	liters
pints	0.47	liters
quarts	0.95	liters
gallons	3.8	liters
cubic feet	0.028	cubic meters
cubic yards	0.765	cubic meters
Temperature		
Fahrenheit	subtract 32, then multiply by 5/9	Celsius
Pressure		
inches of H_2O	0.00246	atmospheres
inches of Hg	0.03332	atmospheres

Out of Metric Units

If You Know	Multiply	To Get
Length		
millimeters	0.039	inches
centimeters	0.394	inches
meters	3.281	feet
meters	1.094	yards
kilometers	0.621	miles
Area		
sq. centimeters	0.155	sq. inches
sq. meters	10.76	sq. feet
sq. meters	1.196	sq. yards
sq. kilometers	0.4	sq. miles
hectares	2.47	acres
Mass (weight)		
grams	0.035	ounces
kilograms	2.205	pounds
metric ton	1.102	short ton
Volume		
milliliters	0.033	fluid ounces
liters	2.1	pints
liters	1.057	quarts
liters	0.264	gallons
cubic meters	35.315	cubic feet
cubic meters	1.308	cubic yards
Temperature		
Celsius	multiply by 9/5, then add 32	Fahrenheit
Pressure		
atmospheres	406.5	inches of H_2O
atmospheres	30.005	inches of Hg

Module Descriptions

The Base Case Top-Level Flow Diagram was presented as Figure 3-1. This figure shows the 13 modules that make up the base case. The boundaries of a module are defined as starting at the first piece of equipment within the module and ending at the beginning of the next module. Any equipment required to move waste from one module to another is defined as being within the module from which it originates.

The remainder of this appendix provides descriptions of the modules. The descriptions are based extensively on information provided in Boomer et al. (1993). Module schematics are included as Appendix B.

Base Case Module M.1

Single-Shell Tank Waste Retrieval

Hydraulic retrieval by sluicing has been modeled for the base case for single-shell tank (SST) waste retrieval. Hydraulic retrieval uses the action of water jet to dislodge and mobilize waste. The jet action breaks down larger sludge and salt cake formations and accelerates the dissolution of the soluble waste forms. The solids, dissolved wastes, and free liquid form a slurry. The slurry is then directed to the inlet of the slurry transfer pump. The pump carries waste from the sluiced tank to an accumulation tank. Recirculation of the sluice feed continues until a solids concentration of 10% and a 5 *M* sodium solution is reached.

Following retrieval of waste, each tank will be partially filled with exhumed SST waste transfer piping, contaminated soil, and other associated stable solid waste, resulting from Tank Waste Remediation System (TWRS) waste recovery operations. The tank space will then be filled with gravel to the greatest degree practical, followed by injection of grout to completely fill the tank head space. The grout is a pumpable mixture of sand, portland cement, and water. The tank filling action is intended to provide a physically stable base on which to install caps.

Each of the 12 SST tank farms will be capped with a Hanford Protective Barrier. Dimensions of the barrier are assumed to be 415 x 530 ft with a minimum thickness of 5.67 ft. The barrier is comprised of the following materials: silt with pea gravel (29%), compacted silt (29%), filter sand (9%), filter gravel (9%), drainage gravel (9%), asphalt (9%), asphalt base (6%), and grading fill (variable %).

The unit operations defined for module M.1 are as follows:

- M.1.A - SST Waste Retrieval System
- M.1.B - SST Cleanup & Backfill
- M.1.C - Capping.

Test Case I Module M.1 Single-Shell Tank Waste Retrieval

Hydraulic retrieval by sluicing has been modeled for test case I for single-shell tank (SST) waste retrieval. Hydraulic retrieval uses the action of water jet to dislodge and mobilize waste. The jet action breaks down larger sludge and salt cake formations and accelerates the dissolution of the soluble waste forms. The solids, dissolved wastes, and free liquid form a slurry. The slurry is then directed to the inlet of the slurry transfer pump. The pump carries waste from the sluiced tank to an accumulation tank. Recirculation of the sluice feed continues until a solids concentration of 10% and a 5 *M* sodium solution is reached.

A close-coupled chemical subsurface barrier is positioned next to half of the tanks to prevent further leakage during retrieval. Chemicals used to create the close-coupled subsurface barrier will be injected through vertical and horizontal pipes jacked into the soil. Horizontal pipes used to flush the soil will also be used for injection of barrier-forming chemicals, which are installed in the open areas between tanks. The horizontal pipes will be installed in two separate planes beneath the tanks. The horizontal pipes are perforated to allow the barrier-forming chemical to flow into the soil.

A similar approach will be used at the tank walls. Injection pipes will be jacked vertically from the surface to the base of the tank footings. Injection of the chemical will be made through the end of the pipe at this level to tie into the barrier emplaced beneath the tank. Injections will then be made working upward from the base of the walls of the tank until a sealed, close-coupled basin about 10-ft thick is created around the tank.

Following retrieval of waste, each tank will be partially filled with exhumed SST waste transfer piping, contaminated soil, and other associated stable solid waste, resulting from Tank Waste Remediation System (TWRS) waste recovery operations. The tank space will then be filled with gravel to the greatest degree practical, followed by injection of grout to completely fill the tank head space. The grout is a pumpable mixture of sand, portland cement, and water. The tank filling action is intended to provide a physically stable base on which to install caps.

Each of the 12 SST tank farms will be capped with a Hanford Protective Barrier. Dimensions of the barrier are assumed to be 415 x 530 ft with a minimum thickness of 5.67 ft. The barrier is comprised of the following materials: silt with pea gravel (29%), compacted silt (29%), filter sand (9%), filter gravel (9%), drainage gravel (9%), asphalt (9%), asphalt base (6%), and grading fill (variable %).

The unit operations defined for test case I module M.1 are as follows:

- M.1.A - SST Waste Retrieval System
- M.1.B - SST Cleanup & Backfill
- M.1.C - Capping.
- M.1.D - Subsurface Barrier

Test Case II Module M.1
Single-Shell Tank Waste Retrieval

Robotic retrieval has been modeled for test case II SST waste retrieval. It is a variation of robotic armed-based retrieval systems that were first investigated at the Hanford Site in the mid-1970s. The system described is best-suited for retrieval of hardened sludge from SSTs (Wallace 1993). The robotic arm is mounted on the bridge-mounted confinement structure. The robotic arm end effectors use water jets for dislodging the waste. After the sludge is dislodged, the slurried mixture is immediately vacuumed through a hose to an air separation system. Following separation the waste proceeds to the waste processing system via the air conveyance module.

Following retrieval of waste, each tank will be partially filled with exhumed SST waste transfer piping, contaminated soil, and other associated stable solid waste, resulting from Tank Waste Remediation System (TWRS) waste recovery operations. The tank space will then be filled with gravel to the greatest degree practical, followed by injection of grout to completely fill the tank head space. The grout is a pumpable mixture of sand, portland cement, and water. The tank filling action is intended to provide a physically stable base on which to install caps.

Each of the 12 SST tank farms will be capped with a Hanford Protective Barrier. Dimensions of the barrier are assumed to be 415 x 530 ft with a minimum thickness of 5.67 ft. The barrier is comprised of the following materials: silt with pea gravel (29%), compacted silt (29%), filter sand (9%), filter gravel (9%), drainage gravel (9%), asphalt (9%), asphalt base (6%), and grading fill (variable %).

The unit operations defined for test case I module M.1 are as follows:

- M.1.A - SST Waste Retrieval System
- M.1.B - SST Cleanup & Backfill
- M.1.C - Capping.

Module M.2
Double-Shell Tank Waste Retrieval

Mixer pump waste retrieval has been modeled for the base case double-shell tank (DST) waste retrieval. Retrieval with mixer pumps is a two-step process. The sludges or solids located on the bottom of the tank are first mobilized and suspended in the supernatant. Once in suspension the solids are distributed throughout the supernatant and are pumped from the tank. Pumping operations are expected to remove 99.97% of tank waste contents.

A mixer pump system consisting of two to four mixer pumps will be installed in concrete pits above the DSTs and will extend down through riser pipes. The waste will then be pumped out of tanks by a waste transfer pump (Wodrich 1993). It is assumed that 10 miles of new 6 in. encased buried piping and associated equipment is installed to support retrieval operations.

Three waste streams flow into module M.2 and are described as follows:

Stream 2.1 contains concentrated phosphate waste originating from the decontamination of the N Reactor in the 100 N Area. It also includes the solids portion of the Plutonium/Uranium Extraction (PUREX) Plant neutralized cladding removal waste (NCRW). The NCRW solids are classified as transuranic (TRU) waste. This waste also includes TRU solids from Plutonium Finishing Plant operations (Hanlon 1994). The waste is contained in 12 tanks located in the 241-AN, 241-AP, 241-AW, 241-AZ, and 241-SY Tank Farms. Tanks 241-AW-101, 241-AN-103, -104, and -105 are identified as Watch List Tanks due to potential for hydrogen gas accumulation above the flammability limit (Hanlon 1994). Typical tank waste contains an average of 19% solids. Waste inventories range from 22,000 to 1,147,000 gal.

Stream 2.2 contains a concentrated waste product from the evaporation of dilute complexed waste. The dilute complexed waste is characterized by a high content of organic carbon including organic complexants. Salt well liquid from the SSTs is the main source of the dilute complexed waste (Hanlon 1994). The waste is contained in five DSTs, located in the 241-AN, 241-AY, and 241-SY Tank Farms. Tanks 241-SY-101 and 241-SY-103 are identified as Watch List

Tanks due to a potential for hydrogen gas accumulation above the flammability limit. Typical tank waste contains an average of 9% solids. Waste inventories range from 748,000 to 1,115,000 gal.

Stream 2.3 contains low activity liquid waste originating from T Plant and S Plant, the 300 and 400 Areas, the PUREX facility (decladding supernatant and miscellaneous waste), B Plant, 100 N Area (sulfate waste), salt wells, and Plutonium Finishing Plant supernate (Hanlon 1994). This waste is contained in 11 tanks, located in the 241-AN, 241-AP, 241-AW, and 241-AY Tank Farms. Typical tank waste contains an average of 3% solids. Waste inventories range from 18,000 to 1,061,000 gal.

Also included in module M.2 is the 242-A Evaporator. This evaporator processes dilute DST non-complexed waste from a number of operations including salt well pumping, PUREX Plant, and N Reactor operations. The 242-A Evaporator produces six streams (primarily stream condensate) which are collected in a condensate collection tank. After filtration, the collected waste becomes the 242-A Evaporator process condensate which is subsequently pumped to the Liquid Effluent Process and Recycle Discharge (LEPRD) facility for treatment. This process is continuous with typical flow rates of 90 to 140 gal/min from the feed tank, to 20 to 60 gal/min for condensate and 43 to 90 gal/min for the slurry discharge (Triplett 1991).

Following retrieval of waste, each tank will be partially filled with exhumed DST waste transfer piping, contaminated soil, and other associated stable solid waste resulting from TWRS waste recovery operations. The tank space will then be filled with gravel to the greatest degree practical, followed by injection of grout to completely fill the tank head space. The grout is a pumpable mixture of sand, portland cement, and water. The tank filling action is intended to provide a physically stable base on which to install caps.

Each of the six DST tank farms will be capped with a Hanford Protective Barrier. The barrier is comprise of the following materials: silt with pea gravel (29%), compacted silt (29%), filter sand (9%), filter gravel (9%), drainage gravel (9%), asphalt (9%), asphalt base (6%), and grading fill (variable %).

The unit operations defined for module M.2 are as follows:

- M.2.A - General Waste Retrieval System
- M.2.B - Complex Concentrate (CC) Waste Retrieval System
- M.2.C - Dilute Noncomplexed (DN) Waste Retrieval System
- M.2.D - DN Waste Evaporator
- M.2.E - DST Cleanup & Backfill
- M.2.F - Capping.

Module M.3
Double-Shell Tank Sludge Wash

In-Tank Sludge Wash A (ITSW) has been modeled as the base case for the DST Tank Sludge Wash. The ITSW operation uses existing DSTs to separate water soluble salts from water insoluble solids through a decant step and a series of wash-decant steps. The solid slurry from ITSW is sampled and then sent to High-Level Waste (HLW) DST Glass Cullet Feed Lag Storage (module M.7) while the liquid is sent to the Cesium Ion Exchange System (module M.4).

The SST and DST waste feed from retrieval is mixed in-line with a polyelectrolyte before it enters the first stage settling tanks. The polyelectrolyte coagulates colloidal solids thereby increasing the solids recovery. After settling, the waste is decanted to 50 wt% solids. The decant is again mixed in-line with a polyelectrolyte and is sent to the second stage settling tanks. The solid slurry is washed in tank with a 0.11 *M* sodium hydroxide - 0.1 *M* sodium nitrate solution. The washed slurry is then mixed in-line with the polyelectrolyte while being pumped to the first wash tank.

After settling in the first wash tank, the decant from the first stage settling tanks is again decanted to remove any solids that were accidently decanted in the first decant. The decant is pumped to supernatant accumulation tanks before being pumped to the supernatant sample and transfer tanks where it is sampled. After sampling, the decant is pumped to the Cesium Ion Exchange System (module M.4).

The slurry in the second stage settling tanks is washed with wash solution and is pumped to the first wash tank where it is mixed with the slurry from the first stage settling tanks. The mixture is allowed to settle and then is decanted. The decant is pumped to the wash solution accumulation tank. The slurry is then washed with wash solution, mixed in-line with polyelectrolyte, and pumped to the second wash tank where it is allowed to settle.

The slurry in the second wash tank is again decanted. The decant is pumped to the wash solution accumulation tank where it is mixed with the decant from the first wash tank. The remaining slurry is combined with water until a slurry that is 25 wt% solids is achieved. This slurry is pumped to HLW Feed Accumulation (module M.7.A).

The unit operations defined for module M.3 are as follows:

- M.3.A - Feed Process
- M.3.B - Settling Process
- M.3.C - Wash Process
- M.3.D - Transfer Process.

Module M.4
Cesium Ion Exchange System

In the cesium ion exchange and waste concentration process, the decant from the sludge wash process (module M.3) is concentrated in existing tank farm evaporators before cesium ion exchange. The clarified centrate is processed through the first cycle ion exchange system where 99% of the cesium is removed. After regeneration, the first cycle cesium product is concentrated and then processed through the second cycle ion exchange where again the bulk of the cesium is removed. After regeneration, the second cycle cesium product is concentrated, sampled, neutralized with sodium hydroxide, and the sent to HLW Glass Cullet Lag Storage (module M.7).

The clarified centrate from the supernatant evaporator serves as the feed to the cesium ion exchange columns. The feed stream is sampled in the cesium ion exchange sample tank before being jetted to the ion exchange feed tank. The cesium ion exchange column system consists of three columns of Duolite CS-100 resin that operate on a 24 hour cycle. While two of the columns are being loaded in series, the third column is being regenerated.

The feed enters the cesium ion exchange columns and essentially all of the incoming cesium is captured with the remainder of the solution flowing to the ion exchange waste tank. After 24 hours of loading, the primary column in the series is removed, the secondary column becomes the primary column, and the newly regenerated column becomes the secondary column.

During regeneration, a water flush stream is used to displace from the column any of the cesium solution that remained. The effluent is sent to the cesium ion exchange waste tank. Next, a 0.1 *M* nitric acid - sodium scrub stream removes 63% of the columns resident sodium and 0.39% of the captured cesium and flows to the cesium ion exchange waste tank. A 0.3 *M* nitric acid - cesium eluent stream then removes the remainder of the resident sodium and cesium and flows to the cesium ion exchange eluent catch tank. An eluent flush stream is them used to rinse the column to remove any remaining acid. The initial 25% of the flush stream flows to the cesium ion exchange eluent catch tank and the remaining 75% flows to the cesium ion exchange waste tank.

Next, a 0.5 *M* sodium hydroxide stream is used to regenerate approximately 25% of the resin back to the sodium loaded condition. A 2.0 *M* sodium hydroxide stream is used to convert the balance of the resin to the sodium loaded condition. Both of the effluent regeneration streams are sent to the cesium ion exchange waste tank.

From the cesium ion exchange eluent catch tank, the product stream flows to the cesium ion exchange concentrator where it is concentrated to a bottoms concentration of 5 *M* nitrate. The bottoms are then sent to the concentrator catch tank where it is neutralized with sodium hydroxide to a final concentration of 0.1 *M* hydroxide in preparation for recycling back to the cesium ion exchange columns and pumping to the HLW Glass Cullet System (module M.8).

The waste stream from the cesium ion exchange column is sampled and the solution is sent to the LLW Glass In Sulfur System (module M.5)

The unit operations defined for module M.4 are as follows:

- M.4.A - Accumulation System
- M.4.B - Supernatant Evaporation System
- M.4.C - Ion Exchange Feed
- M.4.D - Cesium Ion Exchange
- M.4.E - Cesium Ion Exchange Concentrator
- M.4.F - Eluent/Regeneration System.

Module M.5
Low-Level Waste Glass In Sulfur System

The LLW Glass In Sulfur process is based on applying new technology in glass making and work by BNL in developing a sulfur concrete waste form for U.S. Nuclear Regulatory Commission (NRC) approval. The principle process criteria is to make a durable glass aggregate that can be pumped in molten sulfur cement and later embedded in sulfur cement at a bulk disposal site.

Waste from the Cesium Ion Exchange System waste sample tank (module M.4) is pumped to the LLW evaporator feed tank before being pumped to the LLW evaporator where it is concentrated to a bottoms concentration of 5 *M* sodium. The waste is then sent to the LLW melter feed adjust tank where it is adjusted to hydroxide and nitrite specifications as necessary.

The melter feed stream is injected into a high temperature combustion chamber where a turbulent regime of convective heat transfer is maintained with a high intensity gas burner. Exhaust from the combustion chamber is sent to a cyclonic collection tank where the glass is separated from the gasses and the glass-forming reactions occur. The glass and gasses exit the cyclone melter and are separated in what is essentially a small refining tank. The offgas from the separator is sent to Cullet Rework and Melter Offgas Processing (module M.10).

Molten glass from the separator flows into a water filled quench tank where the glass stream is rapidly cooled, forming gravel sized glass chunks (cullet). The glass cullet is removed from the water filled receiver tank and dried as use as aggregate in sulfur polymer concrete. The glass is screened to control fines and oversized cullet and the glass aggregate is sent to the LLW Glass/Sulfur Mixer (module M.6.B).

The unit operations defined for module M.5 are as follows:

- M.5.A - LLW Evaporator
- M.5.B - LLW Melter
- M.5.C - LLW Glass Quencher

- M.5.D - LLW Glass Cullet Drying
- M.5.E - LLW Cyclone System.

Module M.6
Low-Level Waste Glass In Sulfur Vaults

The glass aggregate from the LLW Glass In Sulfur System (module M.5) is mixed with molten sulfur polymer cement to make a sulfur polymer concrete that is pumped through heated pipelines to disposal vaults. Because sulfur polymer concretes can be recycled or reworked by heating, concerns over permanent solidification of the waste form in transfer lines as with cement grouts are not relevant.

The unit operations defined for module M.6 are as follows:

- M.6.A - Sulfur Cement Mixing
- M.6.B - LLW Glass/Sulfur Mixer
- M.6.C - Glass In Sulfur Disposal Vault
- M.6.D - Decanted Molten Sulfur Vault.

Module M.7
High-Level Waste Glass Cullet Feed Lag Storage

The HLW Glass Cullet Feed Lag Storage utilizes two 1-Mgal tanks to provide capacity when retrieval startup precedes HLW treatment, retrieval rates exceed HLW processing rates, or separations rates exceed retrieval rates.

The unit operations defined for module M.7 are as follows:

- M.7.A - HLW Feed Accumulation
- M.7.B - HLW Feed Transfer Tank.

Module M.8
High-Level Waste Glass Cullet System

Waste from the cesium ion exchange concentrator catch tank is pumped to the HLW centrifuge receipt/sample tank before being pumped to the HLW centrifuge and on to the HLW evaporator where it is concentrated and sent to the HLW melter feed adjust tank where it is adjusted to hydroxide and nitrite specifications as necessary.

The melter feed stream is injected into a high temperature combustion chamber where a turbulent regime of convective heat transfer is maintained with a high intensity gas burner. Exhaust from the combustion chamber is sent to a cyclonic collection tank where the glass is separated from the gasses and the glass-forming reactions occur. The glass and gasses exit the cyclone melter and are separated in what is essentially a small refining tank. The offgas from the separator is sent to Cullet Rework and Melter Offgas Processing (module M.10).

Molten glass from the separator flows into a water filled quench tank where the glass stream is rapidly cooled, forming gravel sized glass chunks (cullet). The glass cullet is removed from the water filled receiver tank, dried, and screened to control fines and oversized cullet, thereby producing a product with a higher packing density and thus reducing storage volume. The graded cullet is then sent to HLW Glass Cullet Cask Storage (module M.9).

The unit operations defined for module M.8 are as follows:

- M.8.A - HLW Centrifuge System
- M.8.B - HLW Melter System
- M.8.C - HLW Evaporator
- M.8.D - HLW Glass Quencher
- M.8.E - HLW Glass Cullet Drying
- M.8.F - HLW Cyclone System.

Module M.9
High-Level Waste Glass Cullet Cask Storage

The graded cullet from the HLW Glass Cullet System (module M.8) is loaded into self-shielded, modular iron casks for disposal. The casks are approximately 7 ft in diameter by 19 ft long with a wall thickness of 8 in. to provide adequate shielding. Waste loading of the glass is 25 wt% total waste oxides, so that the process campaign generates 1.2 M ft^3 of glass cullet. This results in the production of 3,900 casks filled with cullet for the 13 year campaign.

The unit operations defined for module M.9 are as follows:

- M.9.A - Air Pallets
- M.9.B - Repository.

Module M.10
Cullet Rework and Melter Offgas Processing

Offgas from the HLW and LLW separators (modules M.5 and M.8) is sent to Cullet Rework and Melter Offgas Processing. The gasses are first sent through a quench tower, separator, and demister to remove the fines. The gasses are then passed through metal high-efficiency particulate air (HEPA) filters and passed through a limestone bed to capture sulfur dioxide as calcium sulfate. The gas train is then catalytically reacted with ammonia to destroy NOS after which it is sent to the Air/Vapor Filtration System (module M.13). Hydrogen gas is passed through the limestone beds to remove the sulfur as hydrogen sulfide. The hydrogen sulfide is passed through a combustion chamber and two Claus reactors, removing the sulfur for recycle. The excess gasses from the Claus reactors are sent to a tail gas incinerator and discharged to a flare.

The fines and oversized cullet from the HLW and LLW melter systems (modules M.5 and M.8) are sent to a cyclone where they are removed from the gas streams and recycled back to the melters. The offgasses from the cyclone are sent through metal HEPA filters and on to the Air/Vapor Filtration System (module M.13).

The unit operations defined for module M.10 are as follows:

- M.10.A - Cyclone System
- M.10.B - HLW Separator
- M.10.C - NO_x/SO_2 Separator
- M.10.D - LLW Separator
- M.10.E - Claus Reactor System.

Module M.11
Liquid Effluent Treatment Facility

The supernatant evaporator condensate (module M.4), the LLW evaporator condensate (module M.5), the HLW evaporator condensate (module M.8), the HLW cullet drying condensate, and the LLW cullet drying condensate enter the Liquid Effluent Treatment Facility. Some of the condensate is recycled to the cesium ion exchange feed adjust tank (module M.4) and the frit filter prior to the cesium ion exchange columns (module M.4). The remainder of the condensate is pumped to a pH adjustment tank where sodium hydroxide is added to neutralize the liquid.

After pH adjustment, off-specification condensate it pumped to the tank farms. The other liquids are recycled into the DST Sludge Wash (module M.3) or sent to the LEPRD facility for further treatment.

The unit operations defined for module M.11 are as follows:

- M.11.A - Process Condensate Recycle
- M.11.B - pH Adjustment Tank
- M.11.C - Retention Basin.

Module M.12
Chemical Make-up Unit

This module represents the cold chemical feed into the process. Also included are the batch mixers to mix the glass formers used in the glass melters.

The unit operations defined for module M.12 are as follows:

- M.12.A - Dry Storage
- M.12.B - Bulk Liquid Storage
- M.12.C - Bulk Water Storage
- M.12.D - Bulk Combustible Liquid Storage
- M.12.E - Batch Mixer.

Module M.13
Air/Vapor Filtration System

Vapors from the process are sent to the Air/Vapor Filtration System where they are sent through a series of metal HEPA filters and discharged out of the facility stack.

Vapors from the HLW storage bin vents and the LLW storage bin vents are sent to the Air/Vapor Filtration System where they are sent through a series of metal HEPA filters and discharged out of the cullet storage facility stack.

Oxygen requirements for the combustion processes (modules M.5 and M.8) are met through use of an air separator. Air is compressed to 125 lb/in^2 (gauge), sent through a filter, and dried. The pressurized air is then run through a CMS bed, separating the nitrogen from the air. The remaining oxygen is then sent to the LLW melter (module M.5), the HLW melter (module M.8), and Cullet Rework and Melter Offgas Processing (module M.10). The nitrogen from this process is used as a cover gas where required.

The unit operations defined for module M.13 are as follows:

- M.13.A - Condenser Vessel Offgas (CVOG)/Vessel Offgas (VOG) System
- M.13.B - VOG/CVOG/Process Offgas (PVOG) Air Supply System
- M.13.C - Process Stack Filter System
- M.13.D - Bin Offgas (BVOG) System
- M.13.E - BVOG Air Supply System
- M.13.F - Storage Stack Filter System
- M.13.G - Oxygen Supply System.

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APPENDIX B

MODULE SCHEMATICS

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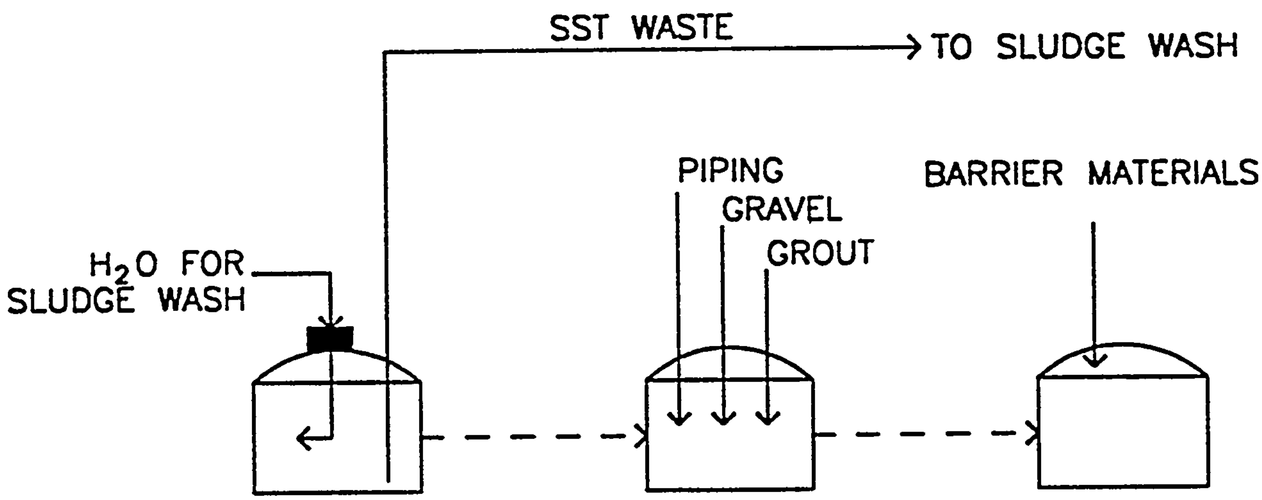
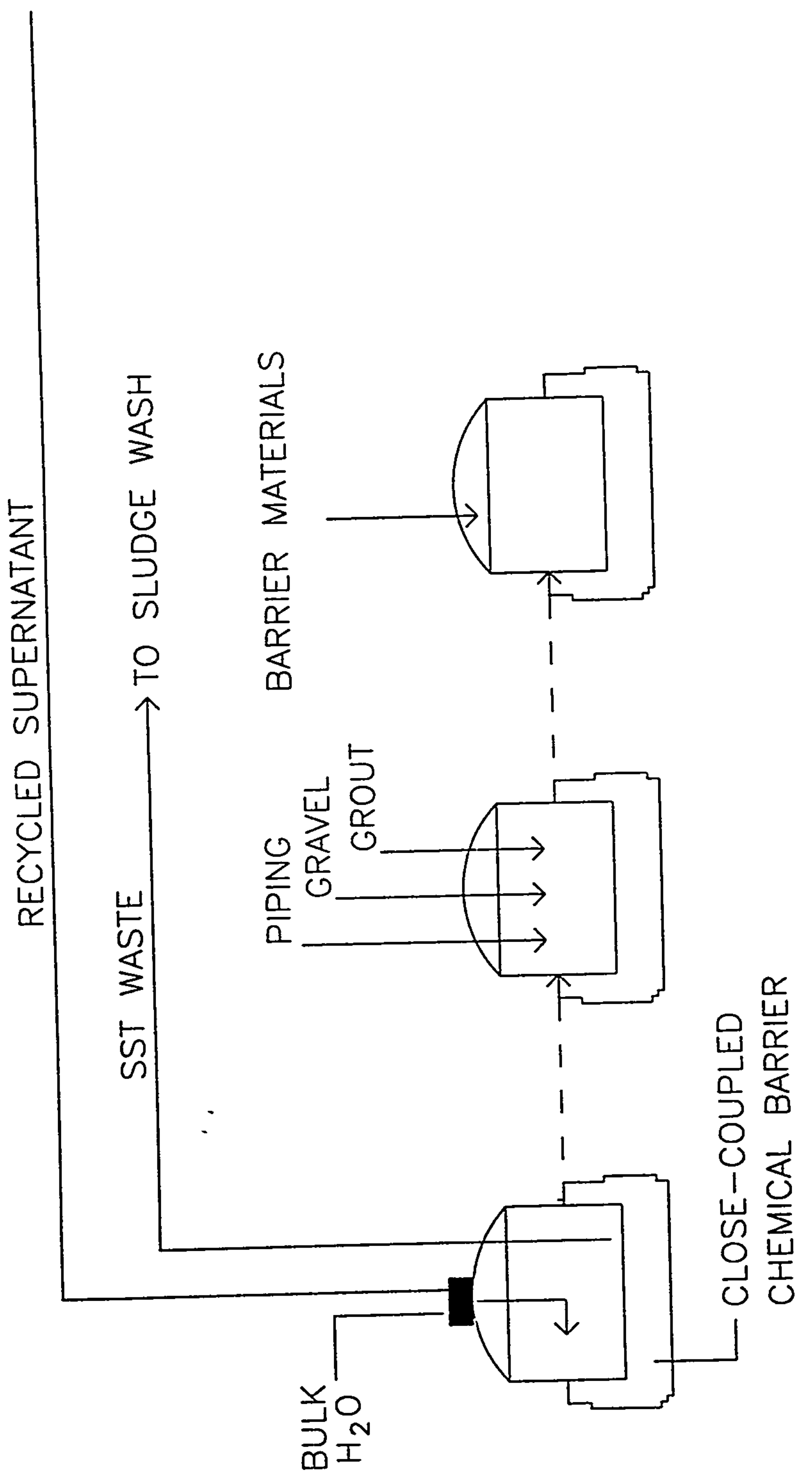
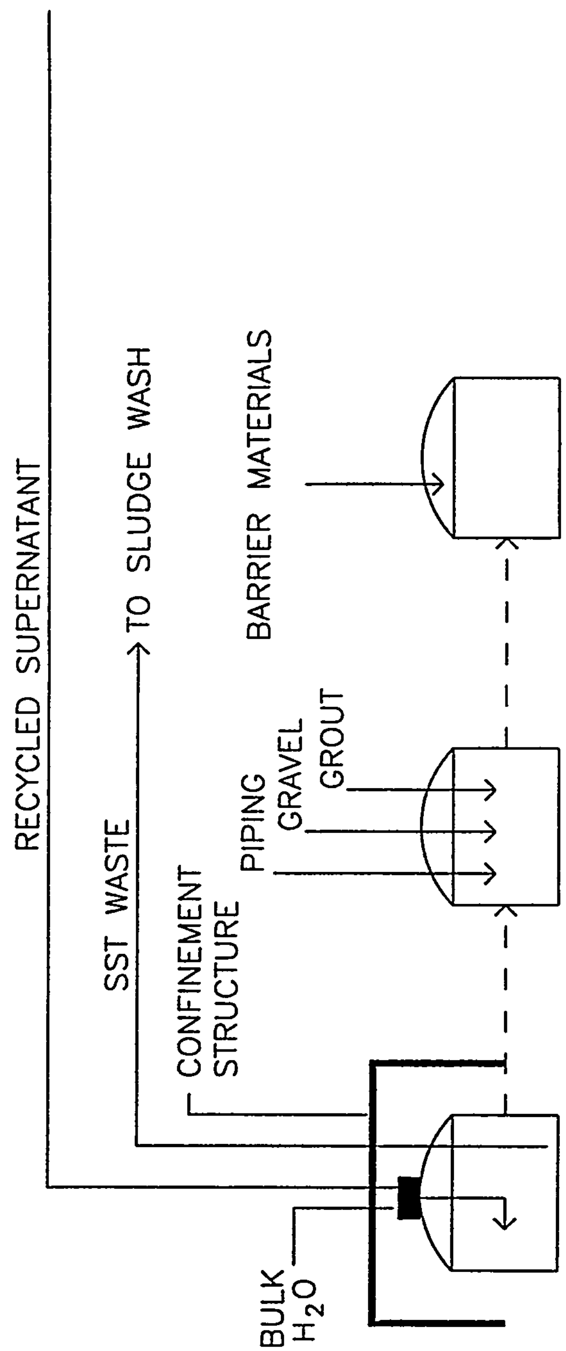
Base Case Module M.1 — Single-Shell Tank Waste Retrieval.



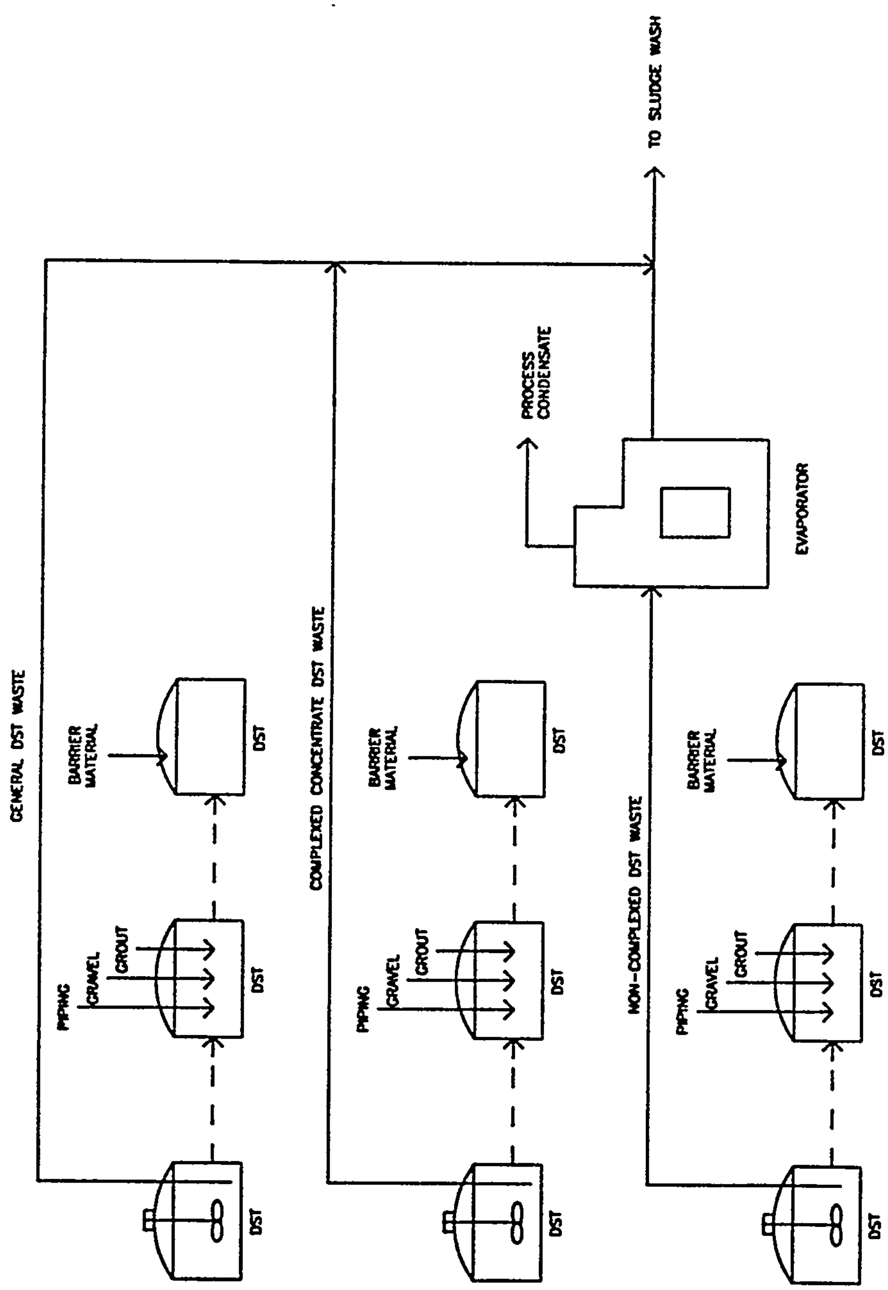
Test Case I Module M.1 — Single-Shell Tank Waste Retrieval.

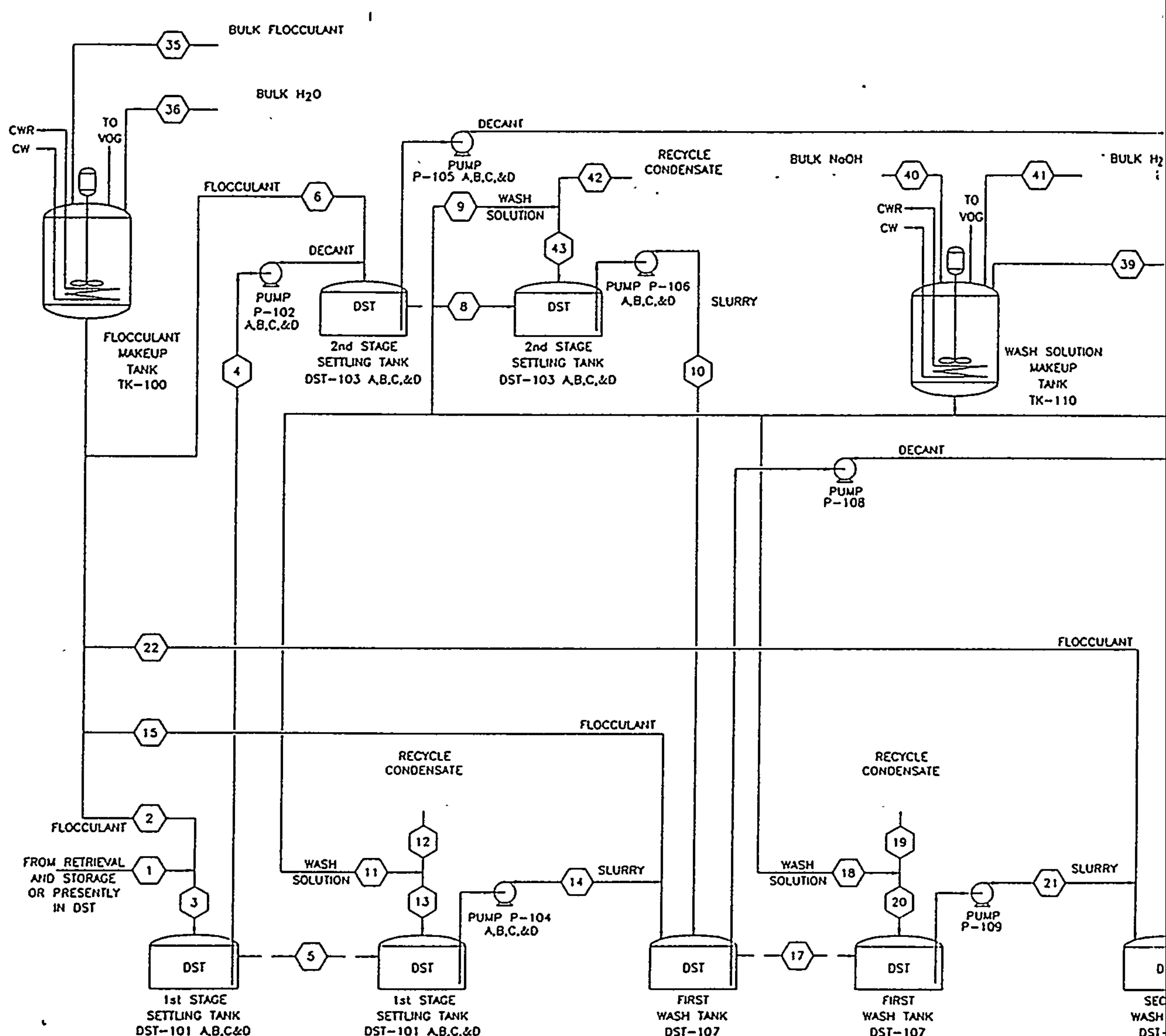


Test Case II Module M.1 — Single-Shell Tank Waste Retrieval.

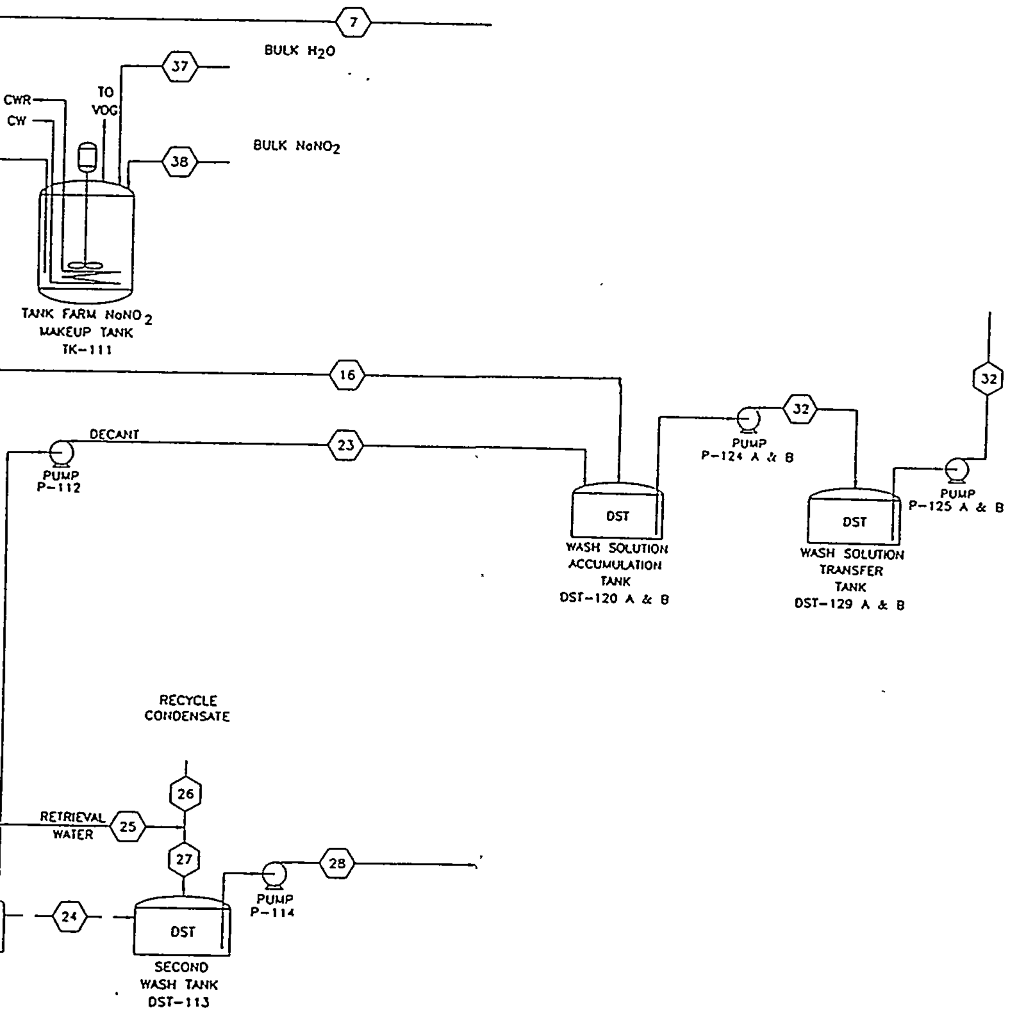


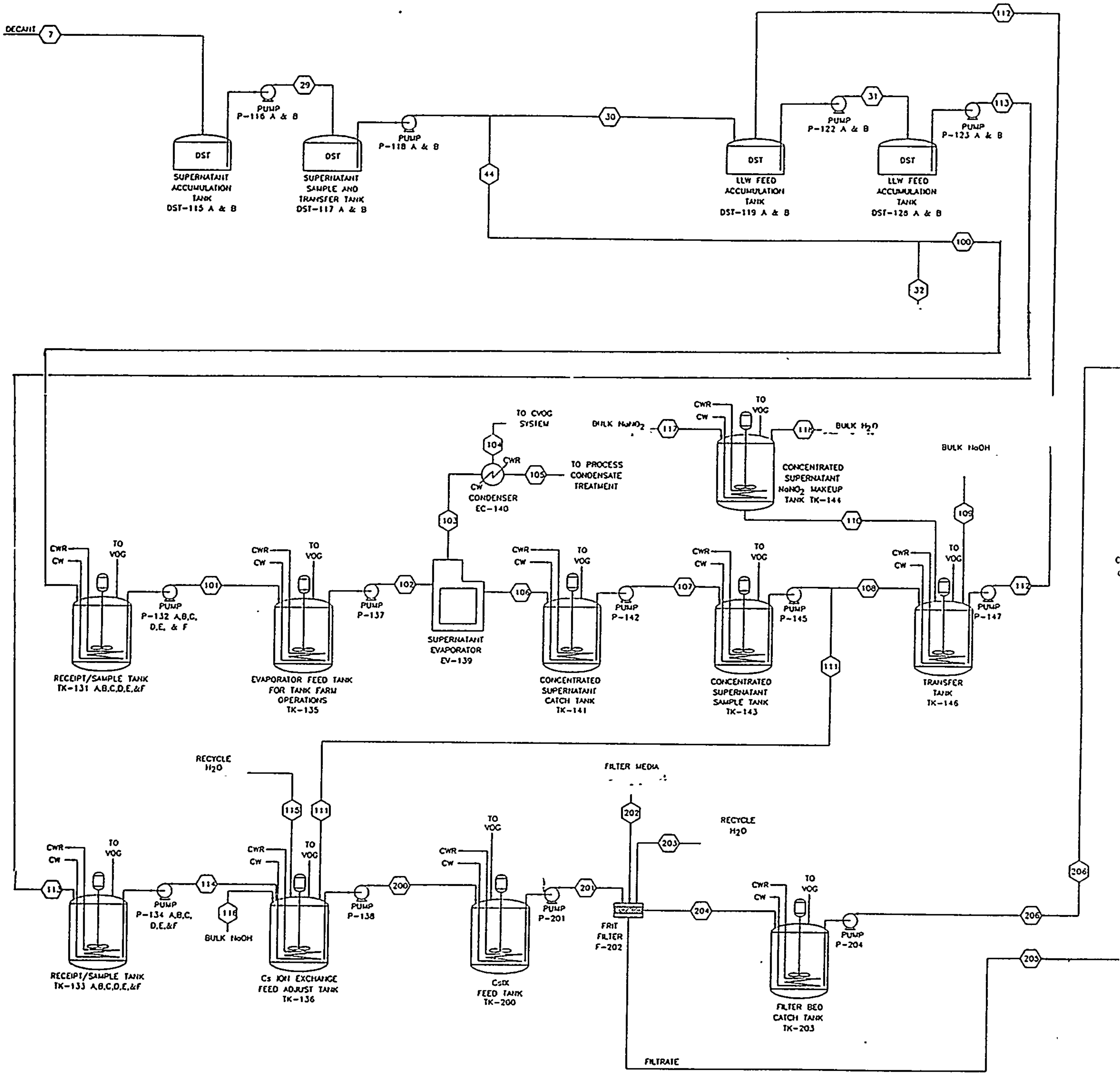
Module M.2 — Double-Shell Tank Retrieval.




BULK FLOCCULANT
BULK H2O
CWR
CW
TO VOG
DECANT
PUMP P-105 A,B,C,&D
RECYCLE CONDENSATE
BULK NaOH
BULK H2
FLOCCULANT
WASH SOLUTION
DECANT
PUMP P-102 A,B,C,&D
DST
2nd STAGE SETTLING TANK DST-103 A,B,C,&D
PUMP P-106 A,B,C,&D
SLURRY
FLOCCULANT MAKEUP TANK TK-100
WASH SOLUTION MAKEUP TANK TK-110
DECANT
PUMP P-108
FLOCCULANT
RECYCLE CONDENSATE
FLOCCULANT
FROM RETRIEVAL AND STORAGE OR PRESENTLY IN DST
WASH SOLUTION
SLURRY
PUMP P-104 A,B,C,&D
PUMP P-109
1st STAGE SETTLING TANK DST-101 A,B,C&D
1st STAGE SETTLING TANK DST-101 A,B,C,&D
FIRST WASH TANK DST-107

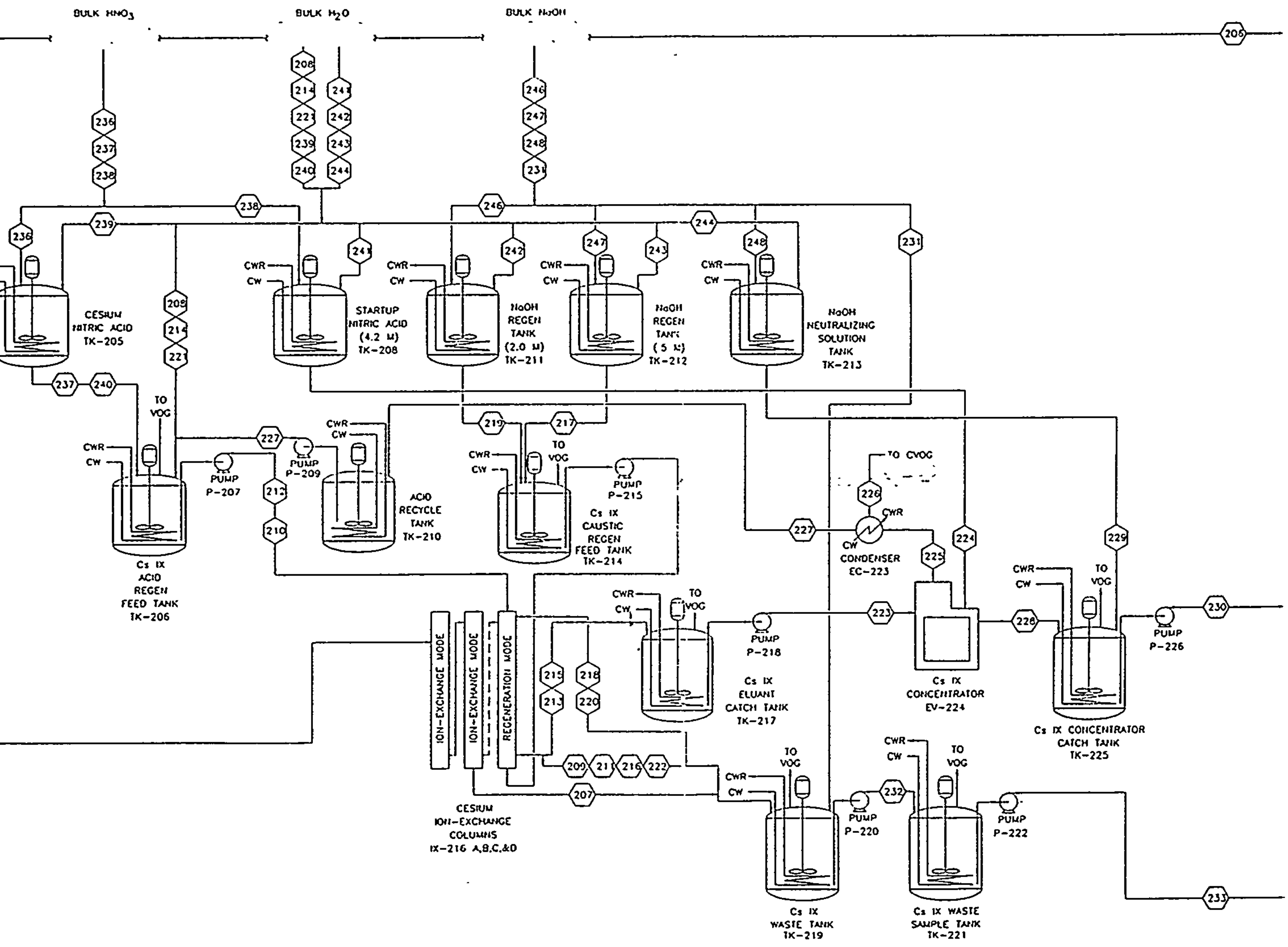
Module M.3 — In-Tank Sludge Wash.

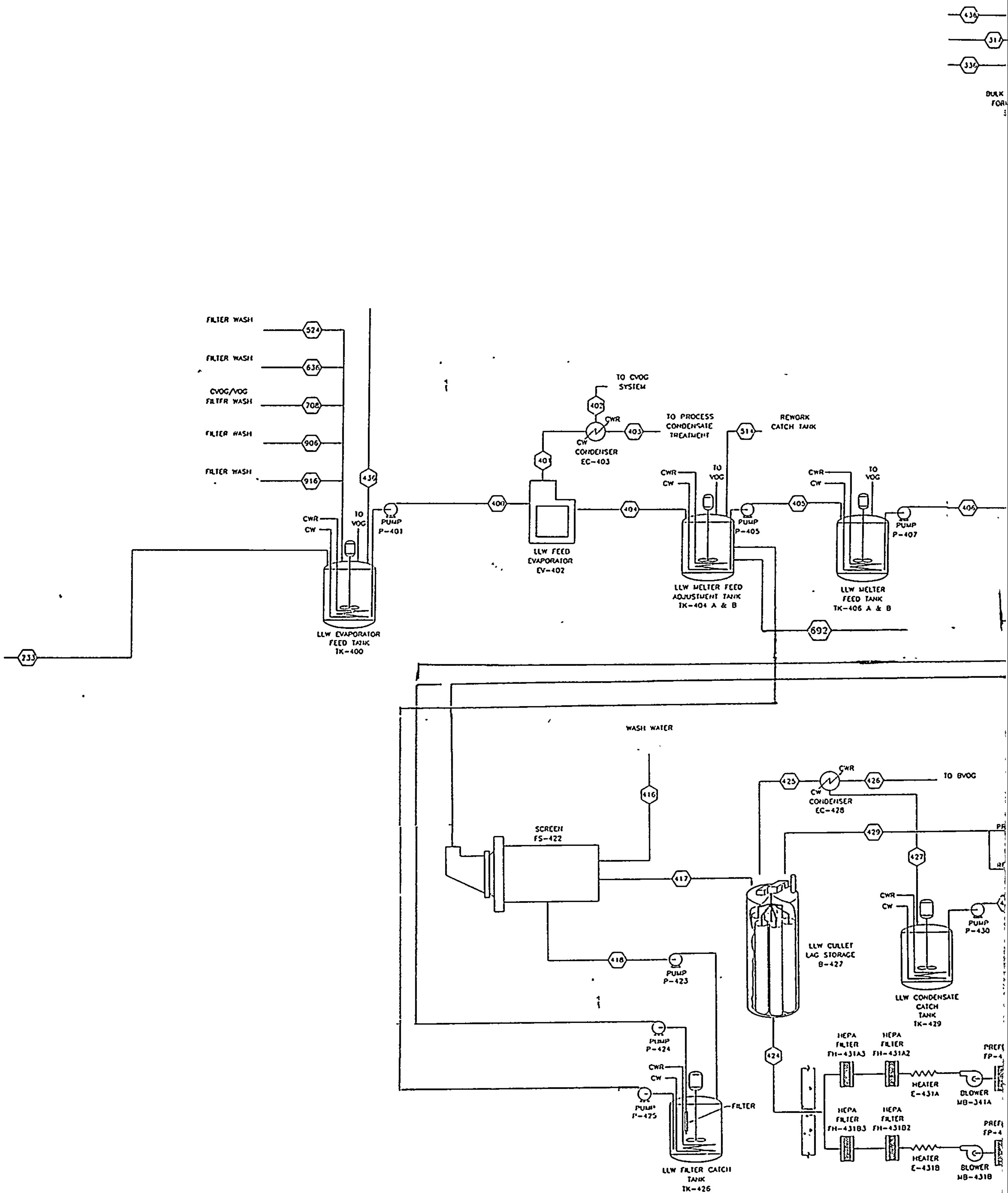




DECANT
PUMP P-116 A & B
PUMP P-118 A & B
PUMP P-122 A & B
PUMP P-123 A & B
DST
SUPERNATANT ACCUMULATION TANK DST-115 A & B
SUPERNATANT SAMPLE AND TRANSFER TANK DST-117 A & B
LLW FEED ACCUMULATION TANK DST-119 A & B
LLW FEED ACCUMULATION TANK DST-125 A & B
TO CVOG SYSTEM
CWR
CW
CONDENSER EC-140
TO PROCESS CONDENSATE TREATMENT
BULK $NaNO_2$
BULK H_2O
CONCENTRATED SUPERNATANT $NaNO_2$ MAKEUP TANK TK-144
BULK NaOH
TO VOG
PUMP P-132 A,B,C, D,E, & F
PUMP P-137
PUMP P-142
PUMP P-145
PUMP P-147
RECEIPT/SAMPLE TANK TK-131 A,B,C,D,E,&F
EVAPORATOR FEED TANK FOR TANK FARM OPERATIONS TK-135
SUPERNATANT EVAPORATOR EV-139
CONCENTRATED SUPERNATANT CATCH TANK TK-141
CONCENTRATED SUPERNATANT SAMPLE TANK TK-143
TRANSFER TANK TK-146
RECYCLE H_2O
FILTER MEDIA
PUMP P-134 A,B,C, D,E,&F
BULK NaOH
PUMP P-138
PUMP P-201
PUMP P-204
RECEIPT/SAMPLE TANK TK-133 A,B,C,D,E,&F
Cs ION EXCHANGE FEED ADJUST TANK TK-136
CsIX FEED TANK TK-200
FRIT FILTER F-202
FILTER BED CATCH TANK TK-203
FILTRATE

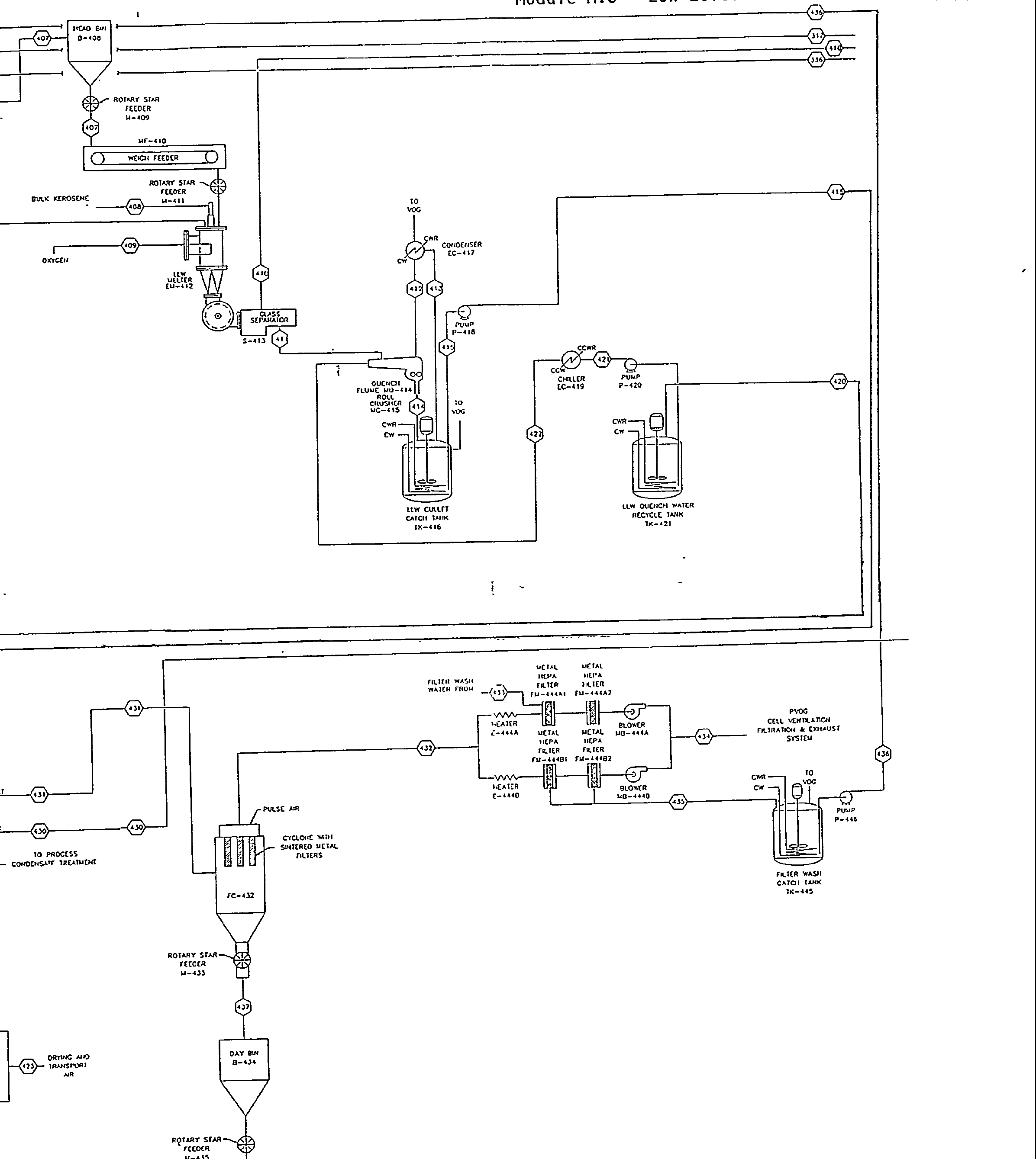
Module M.4 — Cesium Ion Exchange.

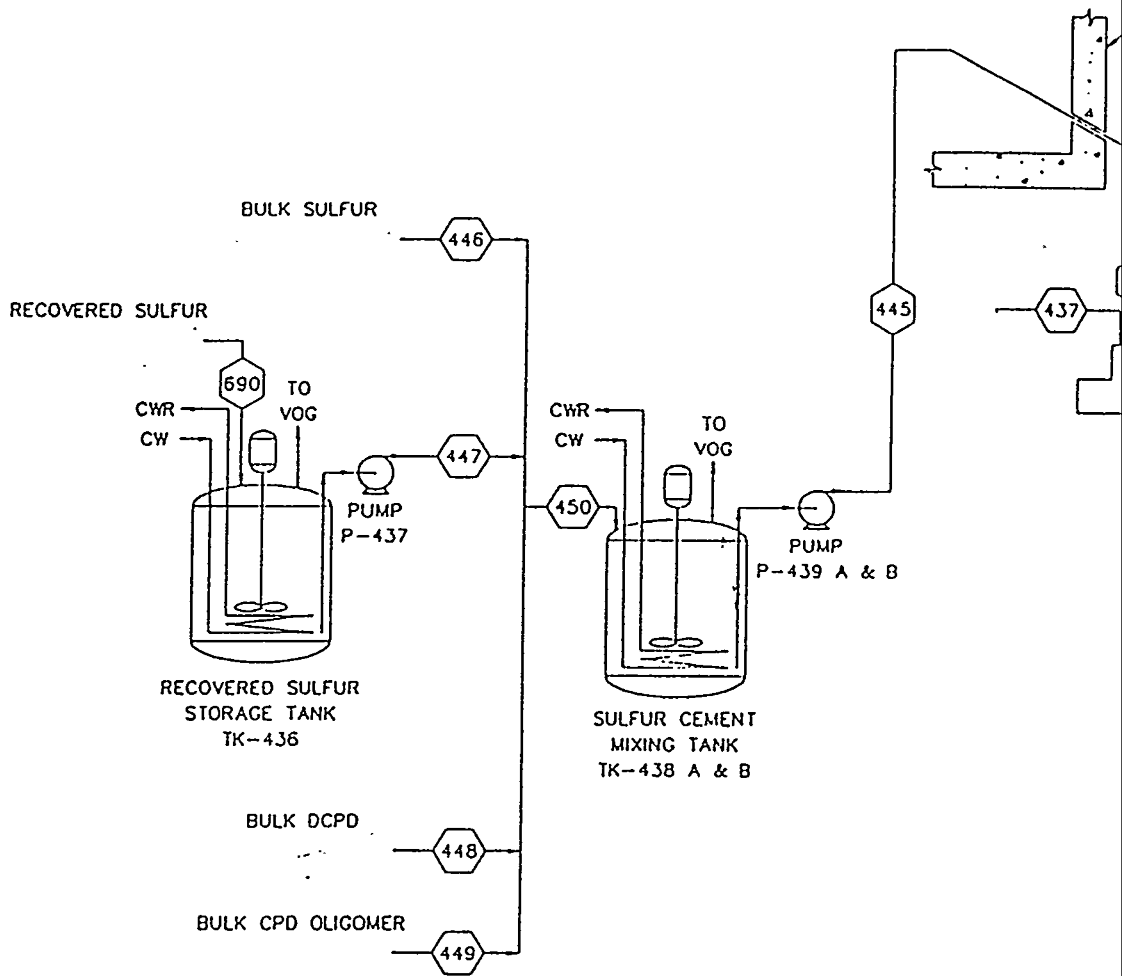




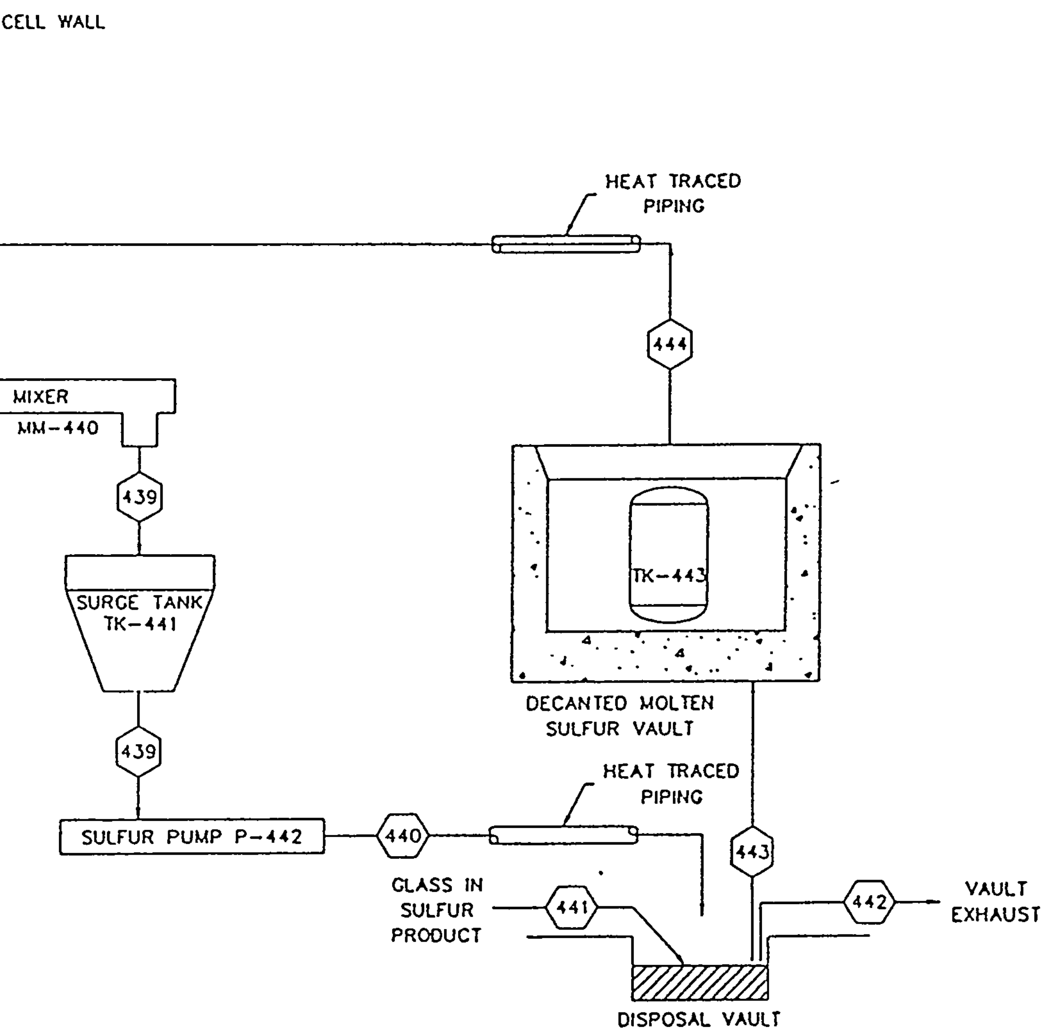
FILTER WASH
524
FILTER WASH
636
CVOG/VOG FILTER WASH
708
FILTER WASH
906
FILTER WASH
916
430
CWR
CW
TO VOG
PUMP P-401
LLW EVAPORATOR FEED TANK TK-400
233
400
LLW FEED EVAPORATOR EV-402
401
402
TO CVOG SYSTEM
CWR
CW
CONDENSER EC-403
403
TO PROCESS CONDENSATE TREATMENT
404
LLW MELTER FEED ADJUSTMENT TANK TK-404 A & B
PUMP P-405
REWORK CATCH TANK
405
LLW MELTER FEED TANK TK-406 A & B
PUMP P-407
406
692
WASH WATER
416
SCREEN FS-422
417
418
PUMP P-423
PUMP P-424
PUMP P-475
LLW FILTER CATCH TANK TK-426
FILTER
425
CONDENSER EC-428
426
TO BVOG
429
427
LLW CULLET LAG STORAGE B-427
LLW CONDENSATE CATCH TANK TK-429
PUMP P-430
424
HEPA FILTER FH-431A3
HEPA FILTER FH-431A2
HEATER E-431A
BLOWER HB-341A
HEPA FILTER FH-431B3
HEPA FILTER FH-431B2
HEATER E-431B
BLOWER HB-431B
436
336
BULK

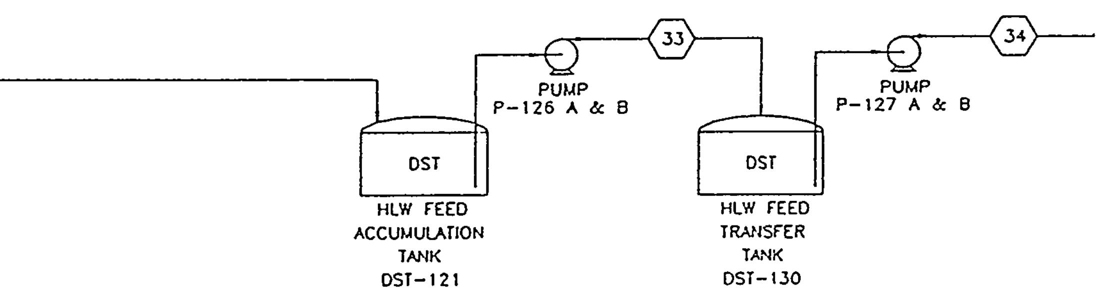
Module M.5 — Low-Level Waste Glass in Sulfur.

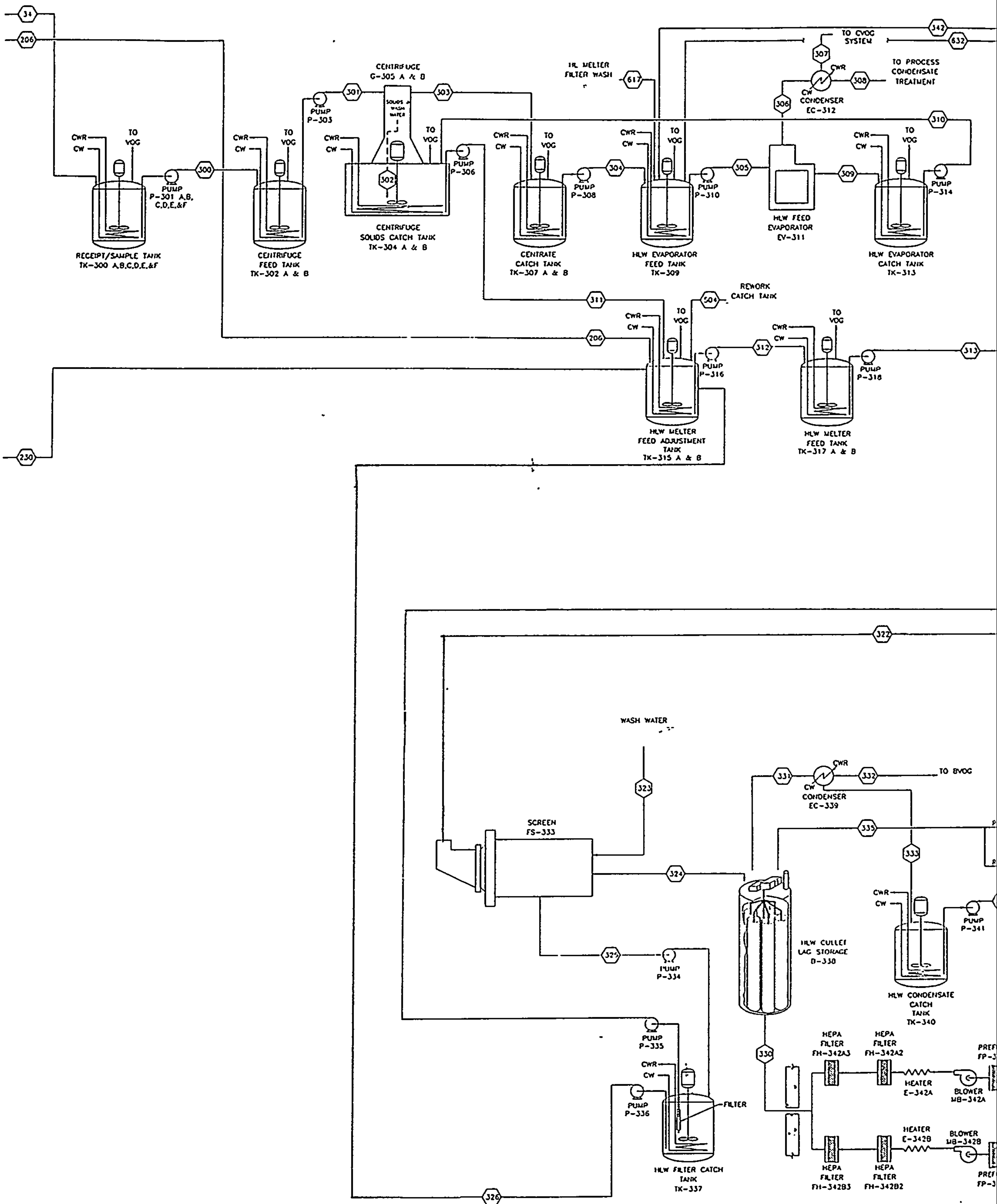



BULK SULFUR
446
RECOVERED SULFUR
590
TO VOG
CWR
CW
447
PUMP
P-437
450
CWR
CW
TO VOG
PUMP
P-439 A & B
445
437
RECOVERED SULFUR
STORAGE TANK
TK-436
SULFUR CEMENT
MIXING TANK
TK-438 A & B
BULK DCPD
448
BULK CPD OLIGOMER
449

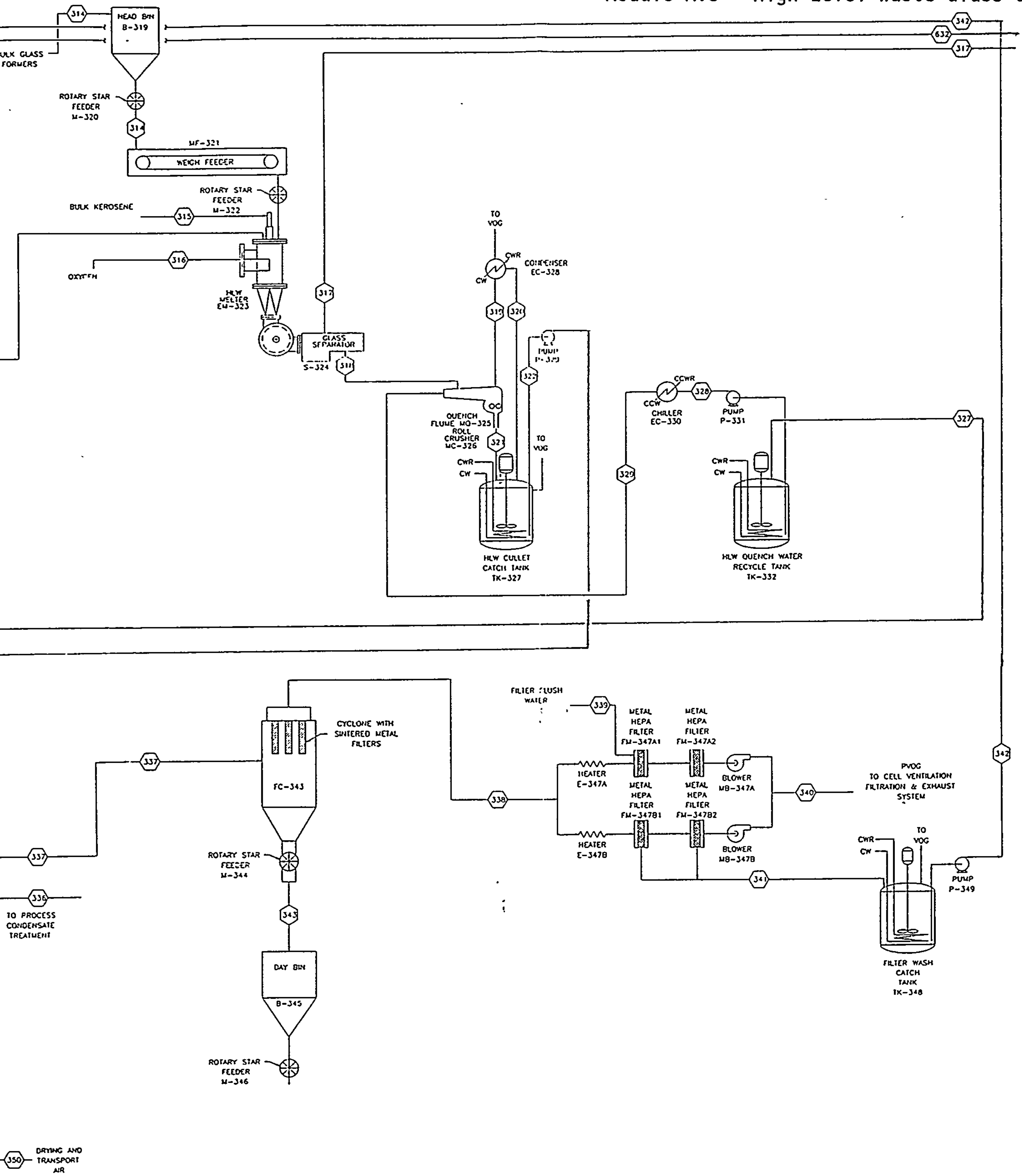
Module M.6 — Low-Level Waste Glass in Sulfur Vaults.

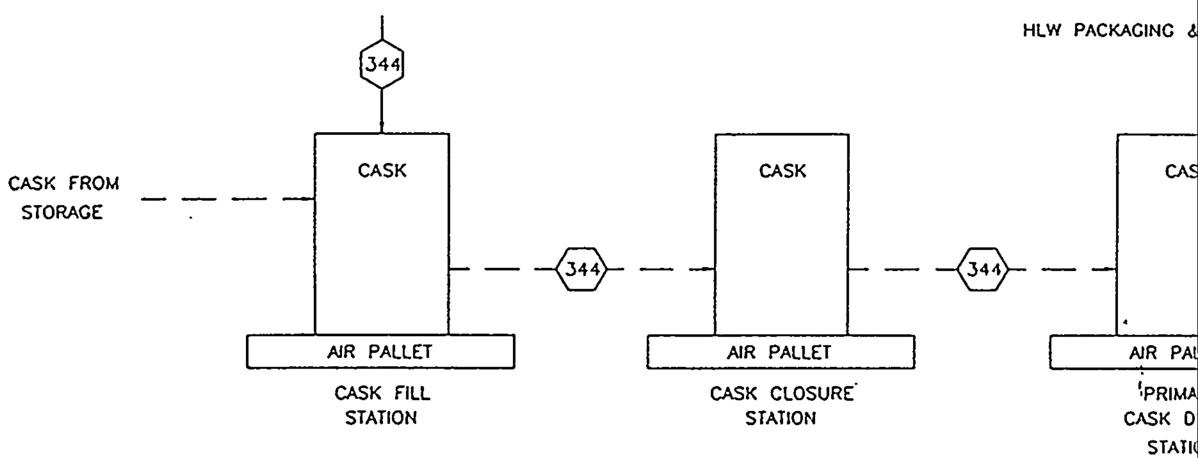



33
34
PUMP
P-126 A & B
PUMP
P-127 A & B
DST
DST
HLW FEED
ACCUMULATION
TANK
DST-121
HLW FEED
TRANSFER
TANK
DST-130



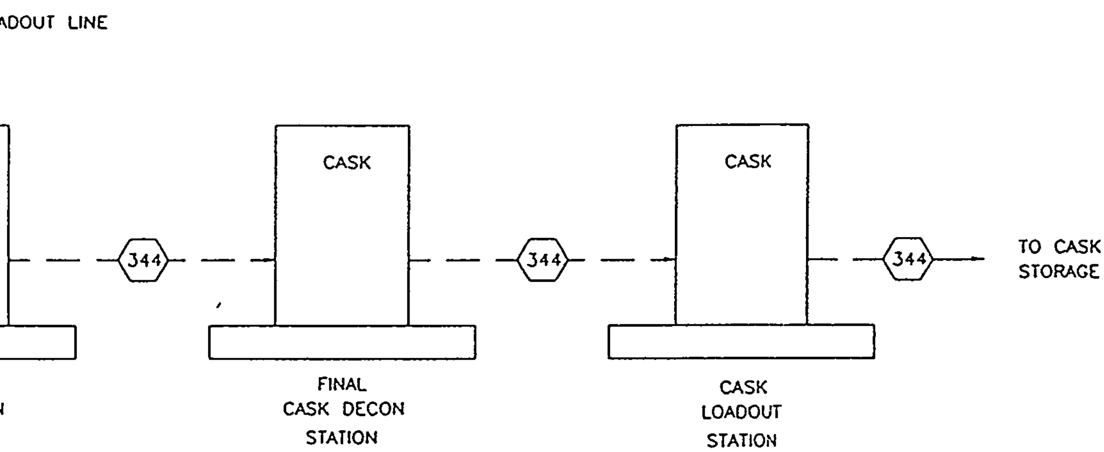
CENTRIFUGE
G-305 A & B
SOLIDS & WASH WATER
IHL MELTER FILTER WASH
TO CVOG SYSTEM
TO PROCESS CONDENSATE TREATMENT
CONDENSER
EC-312
CWR
CW
TO VOG
PUMP
P-301 A,B, C,D,E,&F
RECEIPT/SAMPLE TANK
TK-300 A,B,C,D,E,&F
PUMP
P-303
CENTRIFUGE FEED TANK
TK-302 A & B
PUMP
P-306
CENTRIFUGE SOLIDS CATCH TANK
TK-304 A & B
PUMP
P-308
CENTRATE CATCH TANK
TK-307 A & B
PUMP
P-310
HLW EVAPORATOR FEED TANK
TK-309
HLW FEED EVAPORATOR
EV-311
PUMP
P-314
HLW EVAPORATOR CATCH TANK
TK-313
REWORK CATCH TANK
PUMP
P-316
HLW MELTER FEED ADJUSTMENT TANK
TK-315 A & B
PUMP
P-318
HLW MELTER FEED TANK
TK-317 A & B
WASH WATER
SCREEN
FS-333
TO BVOG
CONDENSER
EC-339
PUMP
P-334
HLW CULLET LAG STORAGE
B-338
PUMP
P-341
HLW CONDENSATE CATCH TANK
TK-340
PUMP
P-335
PUMP
P-336
FILTER
HLW FILTER CATCH TANK
TK-337
HEPA FILTER
FH-342A3
HEPA FILTER
FH-342A2
HEATER
E-342A
BLOWER
MB-342A
HEATER
E-342B
BLOWER
MB-342B
HEPA FILTER
FH-342B3
HEPA FILTER
FH-342B2
34
206
300
301
302
303
304
305
306
307
308
309
310
311
312
313
342
632
617
504
206
230
322
323
324
325
326
330
331
332
333
335

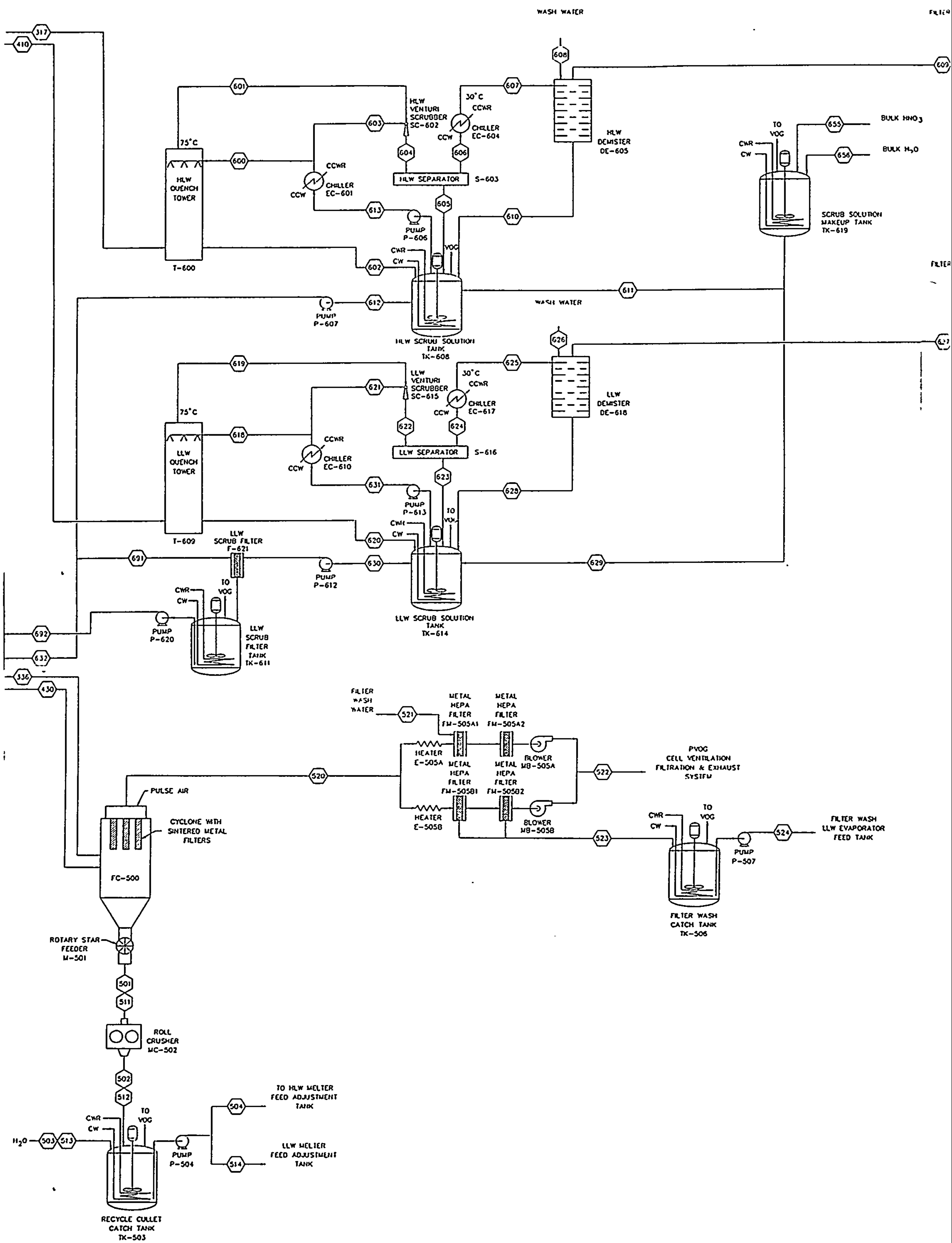

HEAD BIN B-319
BULK GLASS FORMERS
ROTARY STAR FEEDER M-320
MF-321
WEIGH FEEDER
ROTARY STAR FEEDER M-322
BULK KEROSENE
OXYGEN
HLW MELTER EM-323
GLASS SEPARATOR
S-324
TO VOG
CWR
CW
CONDENSER EC-328
PUMP P-329
QUENCH FLUME MQ-325
ROLL CRUSHER MC-326
TO VOG
CWR
CW
HLW CULLET CATCH TANK TK-327
CCWR
CCW
CHILLER EC-330
PUMP P-331
HLW QUENCH WATER RECYCLE TANK TK-332
FILTER FLUSH WATER
CYCLONE WITH SINTERED METAL FILTERS
FC-343
ROTARY STAR FEEDER M-344
TO PROCESS CONDENSATE TREATMENT
DAY BIN
B-345
ROTARY STAR FEEDER M-346
METAL HEPA FILTER FM-347A1
METAL HEPA FILTER FM-347A2
HEATER E-347A
BLOWER MB-347A
METAL HEPA FILTER FM-347B1
METAL HEPA FILTER FM-347B2
HEATER E-347B
BLOWER MB-347B
PVOG TO CELL VENTILATION FILTRATION & EXHAUST SYSTEM
FILTER WASH CATCH TANK TK-348
PUMP P-349
DRYING AND TRANSPORT AIR
314
315
316
317
318
319
320
321
322
323
327
328
329
336
337
338
339
340
341
342
343
350
632



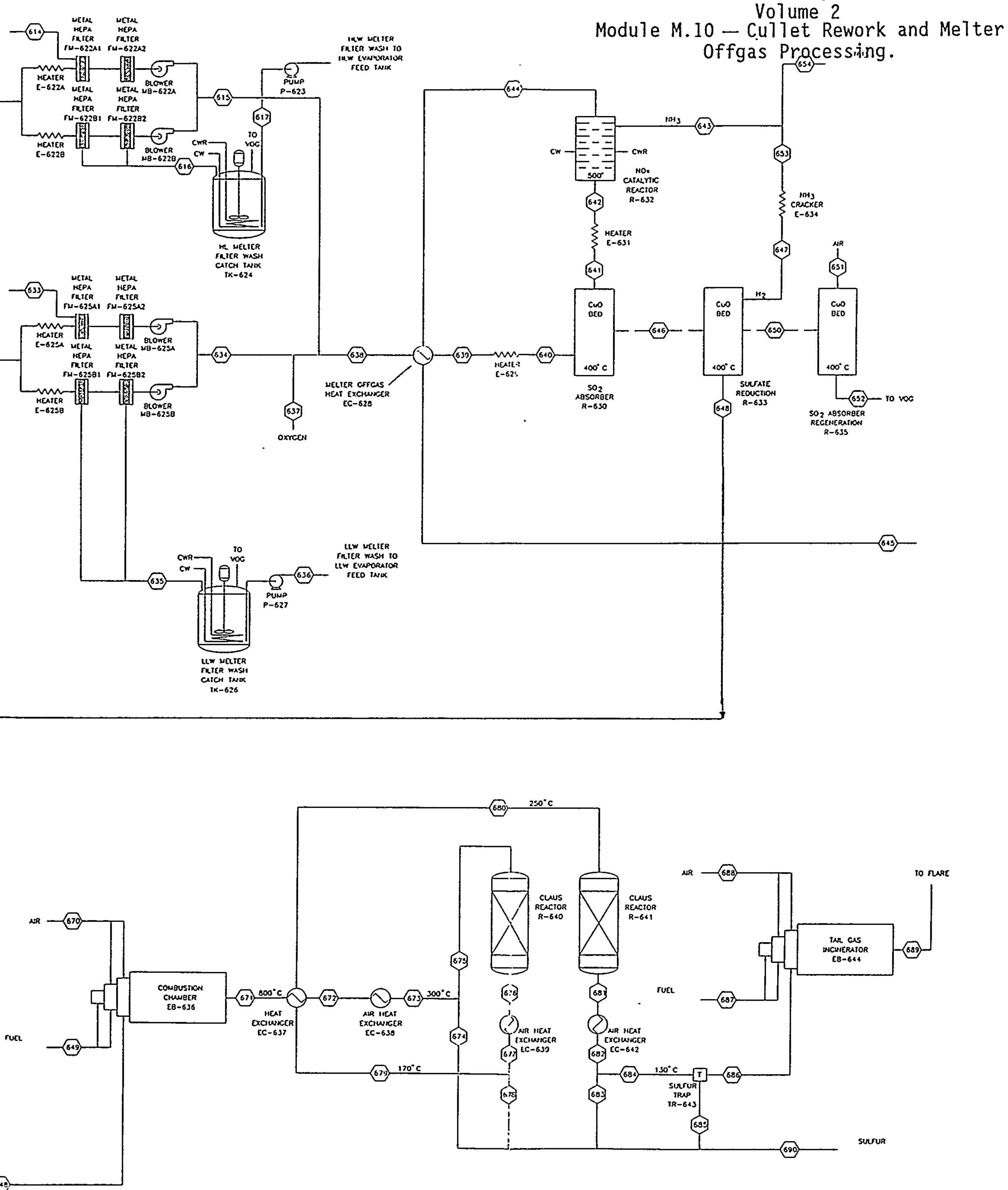
HLW PACKAGING &
CASK FROM
STORAGE
344
CASK
AIR PALLET
CASK FILL
STATION
CASK
AIR PALLET
CASK CLOSURE
STATION

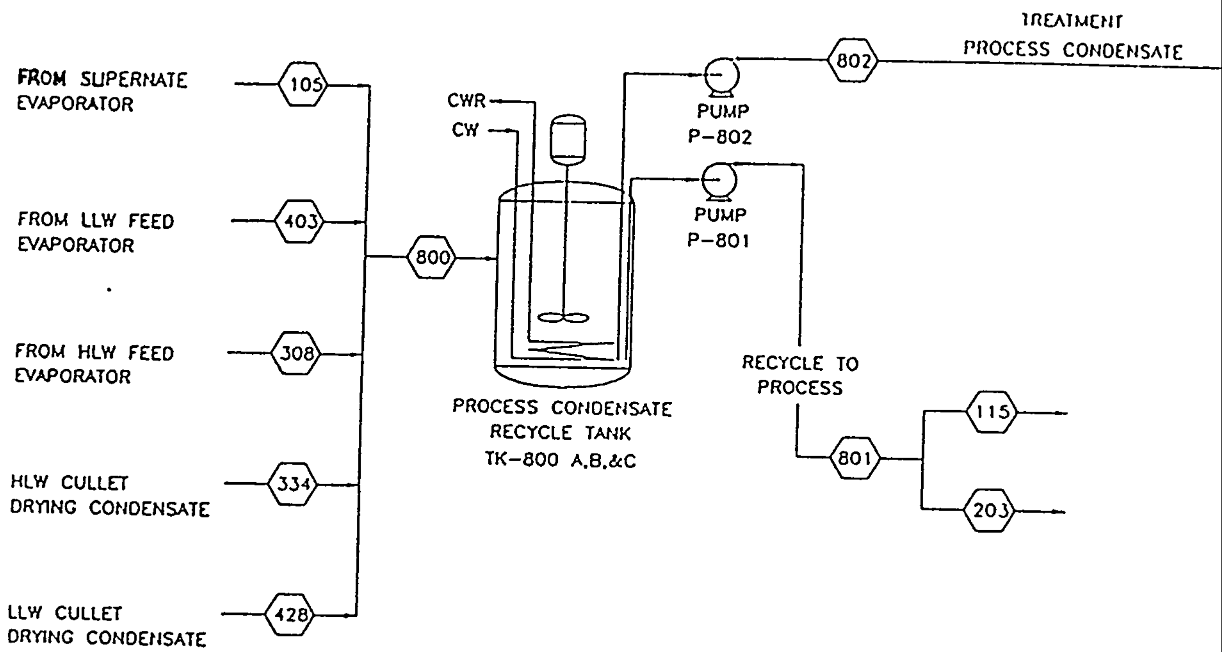
Module M.9 — High-Level Waste Glass Cullet Cask Storage.



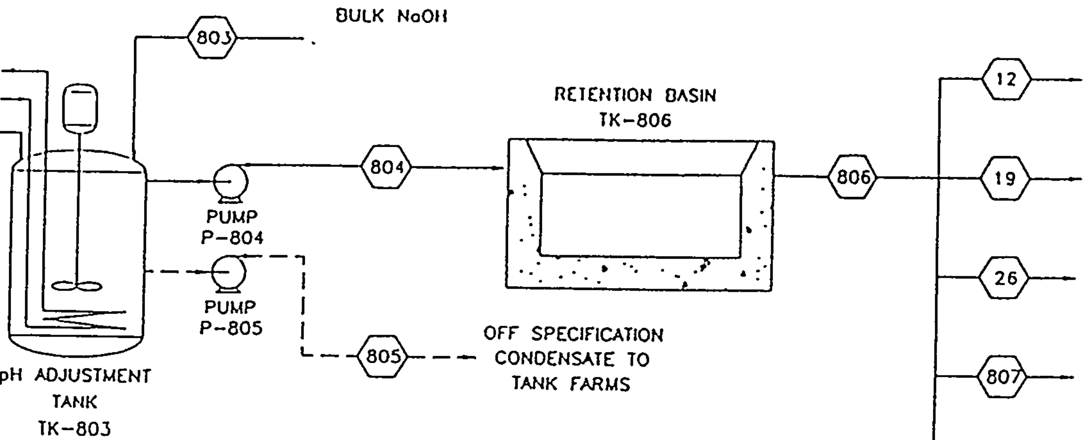


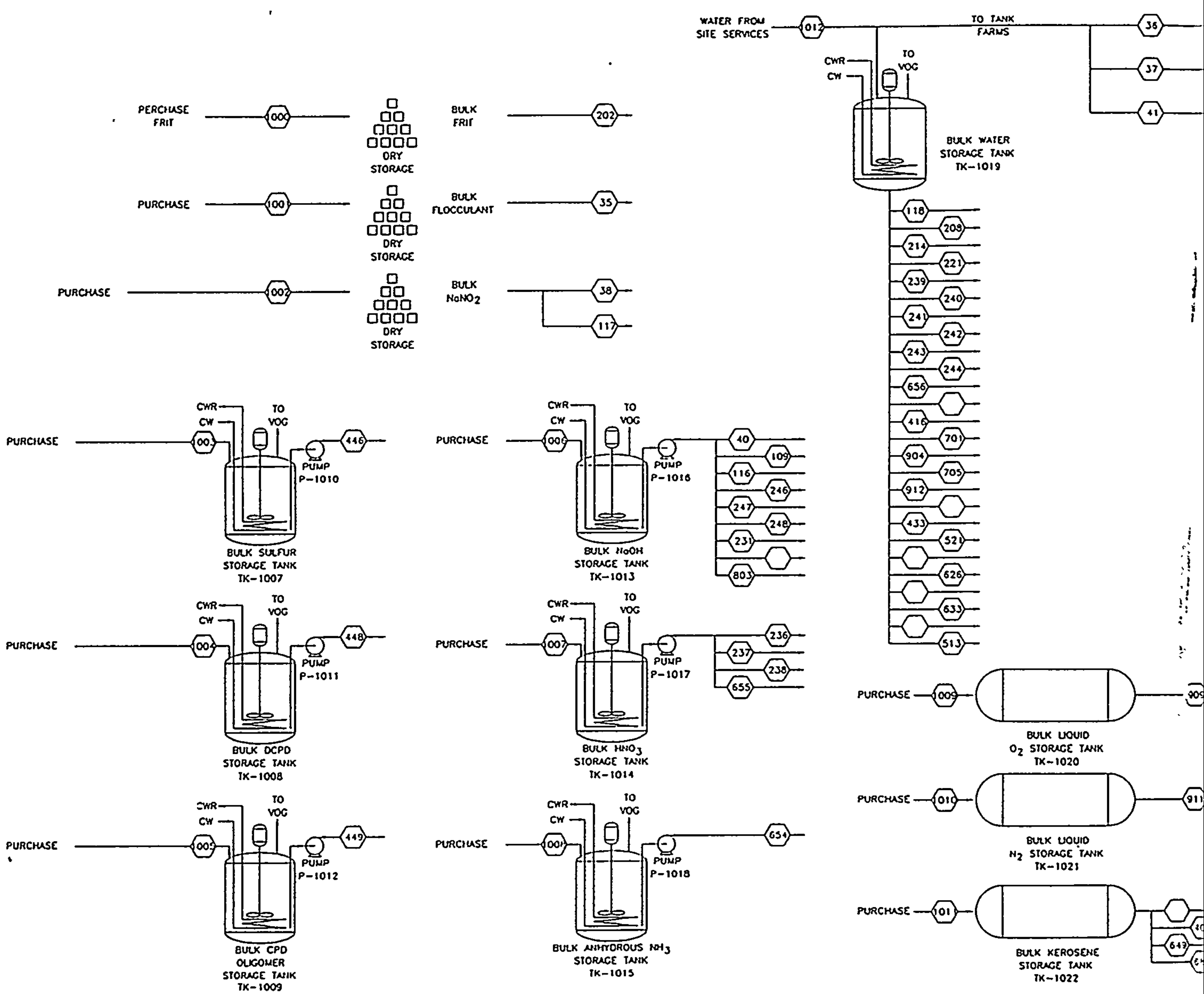
WASH WATER
HLW VENTURI SCRUBBER SC-602
30°C
CCWR
CHILLER EC-604
CCW
HLW DEMISTER DE-605
HLW QUENCH TOWER
75°C
T-600
CHILLER EC-601
HLW SEPARATOR
S-603
PUMP P-606
TO VOG
CWR
CW
PUMP P-607
HLW SCRUB SOLUTION TANK TK-608
BULK HNO_3
BULK H_2O
SCRUB SOLUTION MAKEUP TANK TK-619
LLW VENTURI SCRUBBER SC-615
CHILLER EC-617
LLW DEMISTER DE-618
LLW QUENCH TOWER
T-609
CHILLER EC-610
LLW SEPARATOR
S-616
PUMP P-613
LLW SCRUB FILTER F-621
PUMP P-612
LLW SCRUB SOLUTION TANK TK-614
PUMP P-620
LLW SCRUB FILTER TANK TK-611
FILTER WASH WATER
METAL HEPA FILTER FM-505A1
METAL HEPA FILTER FM-505A2
HEATER E-505A
BLOWER MB-505A
METAL HEPA FILTER FM-505B1
METAL HEPA FILTER FM-505B2
HEATER E-505B
BLOWER MB-505B
PVOG CELL VENTILATION FILTRATION & EXHAUST SYSTEM
PULSE AIR
CYCLONE WITH SINTERED METAL FILTERS
FC-500
FILTER WASH CATCH TANK TK-506
PUMP P-507
FILTER WASH LLW EVAPORATOR FEED TANK
ROTARY STAR FEEDER M-501
ROLL CRUSHER MC-502
TO HLW MELTER FEED ADJUSTMENT TANK
LLW MELTER FEED ADJUSTMENT TANK
H_2O
PUMP P-504
RECYCLE CULLET CATCH TANK TK-503


METAL HEPA FILTER FM-622A1
METAL HEPA FILTER FM-622A2
HEATER E-622A
BLOWER MB-622A
METAL HEPA FILTER FM-622B1
METAL HEPA FILTER FM-622B2
HEATER E-622B
BLOWER MB-622B
HLW MELTER FILTER WASH TO HLW EVAPORATOR FEED TANK
PUMP P-623
HL MELTER FILTER WASH CATCH TANK TK-624
METAL HEPA FILTER FM-625A1
METAL HEPA FILTER FM-625A2
HEATER E-625A
BLOWER MB-625A
METAL HEPA FILTER FM-625B1
METAL HEPA FILTER FM-625B2
HEATER E-625B
BLOWER MB-625B
OXYGEN
MELTER OFFGAS HEAT EXCHANGER EC-628
LLW MELTER FILTER WASH TO LLW EVAPORATOR FEED TANK
PUMP P-627
LLW MELTER FILTER WASH CATCH TANK TK-626
NOx CATALYTIC REACTOR R-632
HEATER E-631
CuO BED
SO2 ABSORBER R-630
SULFATE REDUCTION R-633
SO2 ABSORBER REGENERATION R-635
NH3 CRACKER E-634
TO VOG
COMBUSTION CHAMBER EB-636
HEAT EXCHANGER EC-637
AIR HEAT EXCHANGER EC-638
CLAUS REACTOR R-640
CLAUS REACTOR R-641
AIR HEAT EXCHANGER EC-639
AIR HEAT EXCHANGER EC-642
SULFUR TRAP TR-643
TAIL GAS INCINERATOR EB-644
TO FLARE
SULFUR



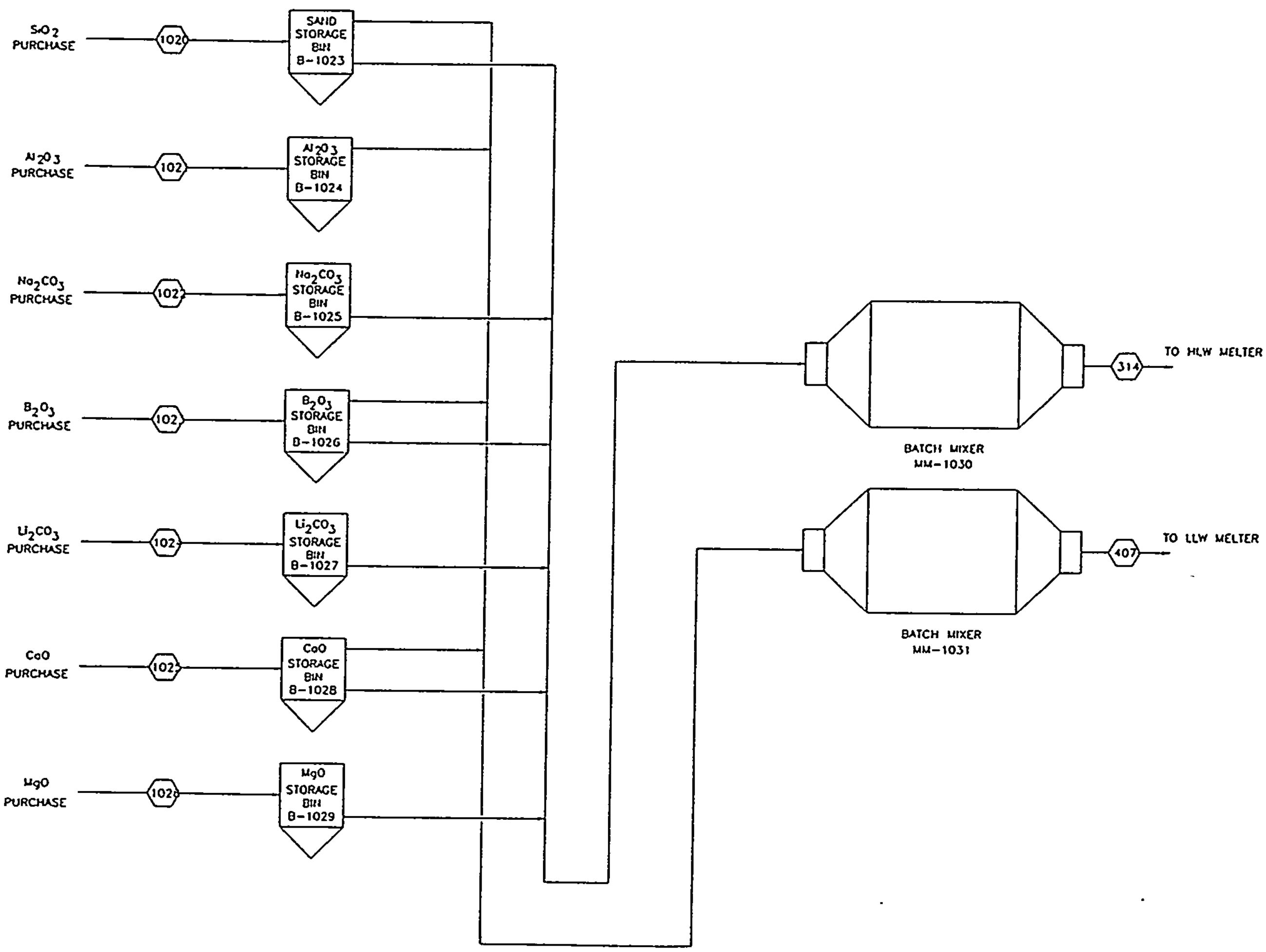
TREATMENT
PROCESS CONDENSATE
FROM SUPERNATE EVAPORATOR
105
802
CWR
CW
PUMP P-802
FROM LLW FEED EVAPORATOR
403
800
PUMP P-801
FROM HLW FEED EVAPORATOR
308
RECYCLE TO PROCESS
PROCESS CONDENSATE RECYCLE TANK TK-800 A,B,&C
115
HLW CULLET DRYING CONDENSATE
334
801
203
LLW CULLET DRYING CONDENSATE
428

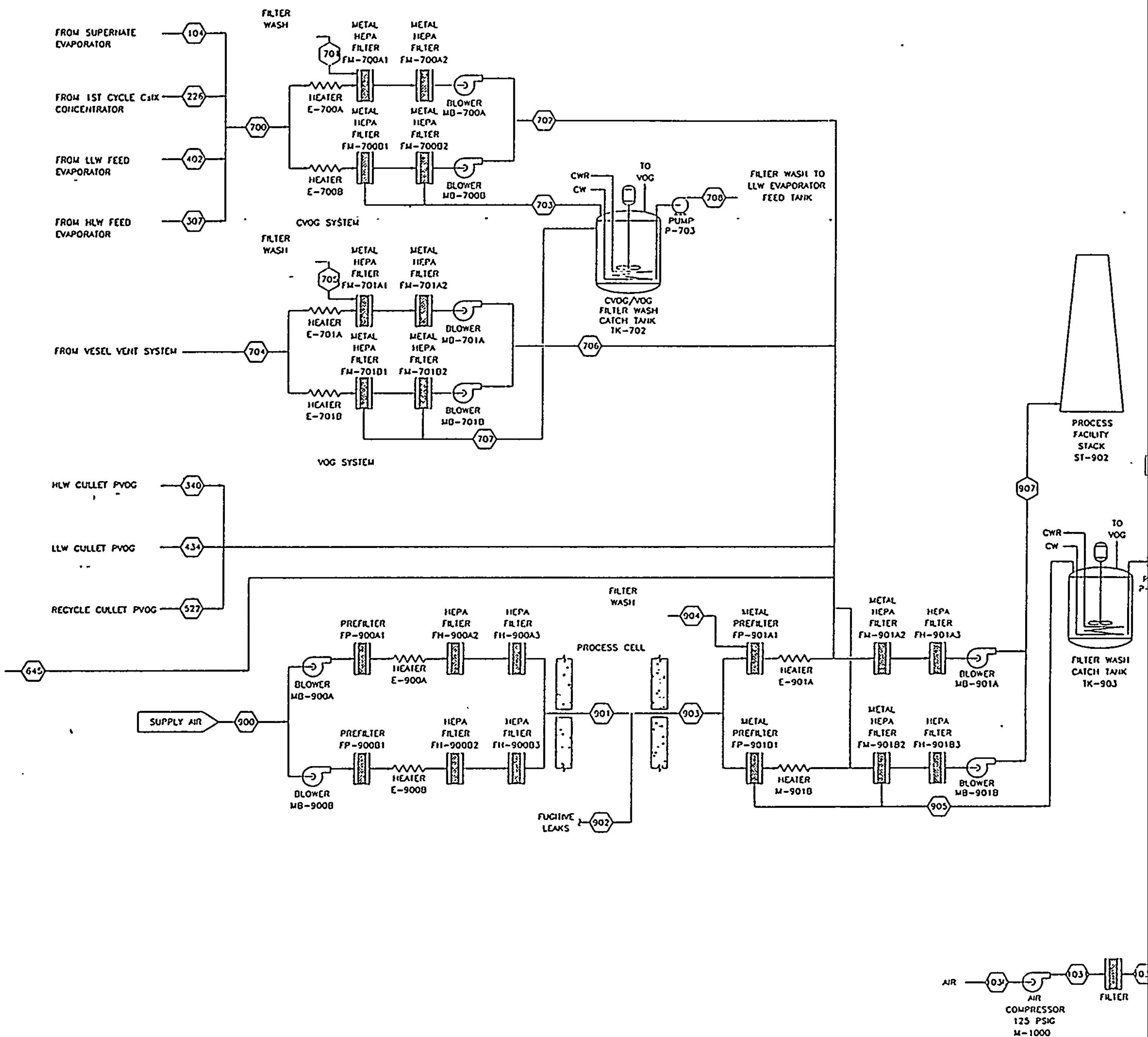

BULK NaOH
803
RETENTION BASIN
TK-806
804
PUMP
P-804
806
12
19
26
807
42
PUMP
P-805
805
OFF SPECIFICATION
CONDENSATE TO
TANK FARMS
pH ADJUSTMENT
TANK
TK-803



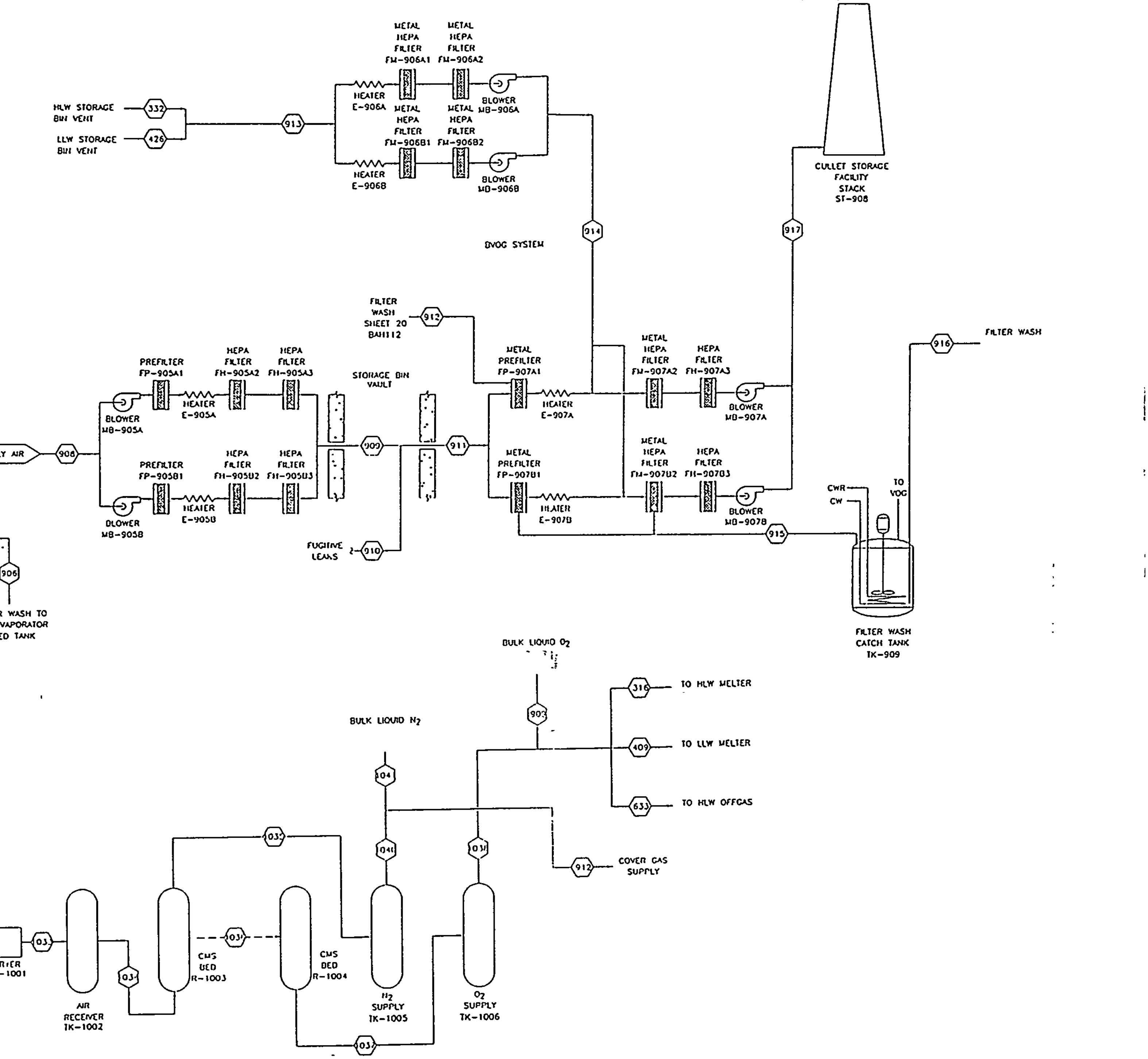
PERCHASE FRIT
000
DRY STORAGE
BULK FRIT
202
PURCHASE
100
DRY STORAGE
BULK FLOCCULANT
35
PURCHASE
002
DRY STORAGE
BULK NaNO2
38
117
WATER FROM SITE SERVICES
012
TO TANK FARMS
36
37
41
CWR
CW
TO VOG
BULK WATER STORAGE TANK TK-1019
118
208
214
221
239
240
241
242
243
244
656
416
701
904
705
912
433
521
626
633
513
PURCHASE
003
CWR
CW
TO VOG
PUMP P-1010
446
BULK SULFUR STORAGE TANK TK-1007
PURCHASE
006
CWR
CW
TO VOG
PUMP P-1016
40
109
116
246
247
248
231
803
BULK NaOH STORAGE TANK TK-1013
PURCHASE
004
CWR
CW
TO VOG
PUMP P-1011
448
BULK DCPD STORAGE TANK TK-1008
PURCHASE
007
CWR
CW
TO VOG
PUMP P-1017
236
237
238
655
BULK HNO3 STORAGE TANK TK-1014
PURCHASE
009
909
BULK LIQUID O2 STORAGE TANK TK-1020
PURCHASE
005
CWR
CW
TO VOG
PUMP P-1012
449
BULK CPD OLIGOMER STORAGE TANK TK-1009
PURCHASE
008
CWR
CW
TO VOG
PUMP P-1018
654
BULK ANHYDROUS NH3 STORAGE TANK TK-1015
PURCHASE
010
911
BULK LIQUID N2 STORAGE TANK TK-1021
PURCHASE
011
643
BULK KEROSENE STORAGE TANK TK-1022

Module M.12 — Chemical Make-Up Unit.




FROM SUPERNATE EVAPORATOR
104
FROM 1ST CYCLE CsIX CONCENTRATOR
226
FROM LLW FEED EVAPORATOR
402
FROM HLW FEED EVAPORATOR
307
700
FILTER WASH
701
METAL HEPA FILTER FM-700A1
METAL HEPA FILTER FM-700A2
HEATER E-700A
BLOWER MB-700A
METAL HEPA FILTER FM-700B1
METAL HEPA FILTER FM-700B2
HEATER E-700B
BLOWER MB-700B
707
703
CVOG SYSTEM
CWR
CW
TO VOG
PUMP P-703
708
FILTER WASH TO LLW EVAPORATOR FEED TANK
CVOG/VOG FILTER WASH CATCH TANK TK-702
FILTER WASH
702
METAL HEPA FILTER FM-701A1
METAL HEPA FILTER FM-701A2
HEATER E-701A
BLOWER MB-701A
FROM VESEL VENT SYSTEM
704
706
METAL HEPA FILTER FM-701B1
METAL HEPA FILTER FM-701B2
HEATER E-701B
BLOWER MB-701B
707
VOG SYSTEM
PROCESS FACILITY STACK ST-902
907
HLW CULLET PVOG
340
LLW CULLET PVOG
434
RECYCLE CULLET PVOG
522
645
FILTER WASH
904
PREFILTER FP-900A1
HEPA FILTER FH-900A2
HEPA FILTER FH-900A3
HEATER E-900A
BLOWER MB-900A
PROCESS CELL
SUPPLY AIR
900
901
903
PREFILTER FP-900B1
HEPA FILTER FH-900B2
HEPA FILTER FH-900B3
HEATER E-900B
BLOWER MB-900B
FUGITIVE LEAKS
902
METAL PREFILTER FP-901A1
HEATER E-901A
METAL HEPA FILTER FM-901A2
HEPA FILTER FH-901A3
BLOWER MB-901A
METAL PREFILTER FP-901B1
HEATER M-901B
METAL HEPA FILTER FM-901B2
HEPA FILTER FH-901B3
BLOWER MB-901B
905
CWR
CW
TO VOG
FILTER WASH CATCH TANK TK-903
AIR
1031
AIR COMPRESSOR 125 PSIG M-1000
1032
FILTER

Module M.13 — Air/Vapor Filtration System.



APPENDIX C

MODULE EQUIPMENT LIST

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MODULE EQUIPMENT LIST

MODULE	accumulation tanks	air compressors	air/heat exchangers	air pallets	air receivers	barriers	batch mixers	blowers	casks	catalytic reactors	catch tanks	centrifuges	cesium ion exchange columns	chemical storage bins	chemical storage tanks
1						0+0+12									
2						0+0+8									
3															
4											0+0+4		0+0+4		
5								0+4+0			0+4+0				
6															
7															
8								4+0+0			9+0+0	2+0+0			
9				0+0+5					5+0+0						
10			0+0+3					4+2+0		0+0+1	2+2+0				
11															
12							0+0+2							0+0+7	0+0+7
13		0+0+1			0+0+1			0+0+14			0+2+1				

Some of the third place numbers are not actual cold numbers. They have not yet been determined to be high, low, or cold. The list will be updated.

NOTE: The first number indicates number of high radiation equipment, the second indicates low radiation, and the third indicates cold.

MODULE EQUIPMENT LIST

MODULE	chemical supply tanks	chillers	claus reactors	cms beds	combustion chambers	concentrators	condensors	cracker	CuO beds	cyclones	day bins	decanted molten sulfur vault	demisters	disposal vaults	double shell accumulation tanks
1															
2															
3															0+0+2
4						0+0+1	0+0+2								0+4+2
5							0+4+0			0+1+0	0+1+0				
6												0+1+0		0+1+0	
7															1+0+0
8		1+0+0					3+0+0			1+0+0	1+0+0				
9															
10		2+2+0	0+0+2		0+0+1			0+0+1	0+0+3	0+0+1			1+1+0		
11															
12															
13	0+0+2			0+0+2											

MODULE EQUIPMENT LIST

MODULE	double shell settling tanks	double shell transfer tanks	double shell wash tanks	dry chemical storage barrels (?)	dryers	evaporators	facility stacks	feed tanks	feed adjustment tanks	filters	frit filters	glass cullet lag storage	glass separators	gravel washers/crushers	gravel distributors
1														0+0+1	0+0+149
2														0+0+1	0+0+28
3	0+0+16	0+0+2	0+0+4												
4		0+0+2				0+0+1		0+0+4	0+0+1		0+0+1				
5						0+1+0		0+3+0	0+2+0			0+1+0	0+1+0		
6															
7		1+0+0													
8						1+0+0		4+0+0	2+0+0			1+0+0	1+0+0		
9															
10															
11															
12				0+0+3											
13					0+0+1		0+0+2			0+0+1					

MODULE EQUIPMENT LIST

MODULE	grout mixers	head bins	heat traced piping (ft)	heaters	heat exchangers	heat traced piping	HEPA filters	in-tank mixers	liquid chemical storage tanks	makeup tanks	melters	metal HEPA filters	metal prefilters	neutralizing solution tanks	nitric acid tanks
1	0+0+149							0+0+149							
2	0+0+28							0+0+88							
3								0+0+3		0+0+3					
4								0+0+32		0+0+1				0+0+1	0+0+2
5		0+0+1		0+4+0			0+4+0	0+10+0			0+1+0	0+4+0			
6								0+3+0							
7															
8		0+0+1		4+0+0			4+0+0	23+0+0			1+0+0	4+0+0			
9															
10				6+2+0	0+0+2			3+4+1		0+0+1		8+4+0			
11								0+0+4							
12								0+0+7	0+0+3						
13				0+0+14			0+0+12	0+2+1				0+0+16	0+0+4		

MODULE EQUIPMENT LIST

MODULE	pH adjustment tanks	pipe waste unloading stations	piping (ft)	prefilters	pumps	quench flume	quench towers	receipt/sample tanks	recovered sulfur storage tanks	recycle tanks	regeneration tanks	retention basin	roll crushers	rotary star feeders	sample tanks
1		0+0+149													
2		0+0+28													
3					0+0+24										
4					0+4+30			0+0+12		0+0+1	0+0+2				0+0+2
5				0+2+0	0+10+0	0+1+0				0+1+0			0+1+0	0+1+2	
6					0+3+0				0+1+0						
7					4+0+0										
8				2+0+0	20+0+0	1+0+0		6+0+0		1+0+0			1+0+0	2+0+2	
9															
10					4+5+0		1+1+0						0+0+1	0+0+1	
11	0+0+1				0+0+4					0+0+1		0+0+1			
12					0+0+7										
13				0+0+4	0+2+0										

MODULE EQUIPMENT LIST

MODULE	screens	scrub filters	scrub filter tanks	solution tanks	sulfur cement mixing tanks	sulfur mixer	sulfur pump	sulfur traps	surge tanks	tail gas incinerators	transfer tanks	venturi scrubbers	waste separators	waste tanks	weigh feeders
1															
2															
3															
4											0+0+1			0+0+1	
5	0+1+0														0+0+1
6					0+2+0	0+1+0	0+1+0		0+1+0						
7															
8	1+0+0														0+0+1
9															
10		0+0+1	0+0+1	0+0+2				0+0+1		0+0+1		0+0+2	0+0+2		
11															
12															
13															

APPENDIX D

UNIT OPERATION DESCRIPTION SHEETS

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Metric Conversion Chart

The following chart is provided to the reader as a tool to aid in converting to metric units.

Into Metric Units

If You Know	Multiply By	To Get
Length		
inches	25.4	millimeters
inches	2.54	centimeters
feet	0.305	meters
yards	0.914	meters
miles	1.609	kilometers
Area		
sq. inches	6.452	sq. centimeters
sq. feet	0.093	sq. meters
sq. yards	0.0836	sq. meters
sq. miles	2.6	sq. kilometers
acres	0.405	hectares
Mass (weight)		
ounces	28.35	grams
pounds	0.454	kilograms
short ton	0.907	metric ton
Volume		
teaspoons	5	milliliters
tablespoons	15	milliliters
fluid ounces	30	milliliters
cups	0.24	liters
pints	0.47	liters
quarts	0.95	liters
gallons	3.8	liters
cubic feet	0.028	cubic meters
cubic yards	0.765	cubic meters
Temperature		
Fahrenheit	subtract 32, then multiply by 5/9	Celsius
Pressure		
inches of H_2O	0.00246	atmospheres
inches of Hg	0.03332	atmospheres

Out of Metric Units

If You Know	Multiply	To Get
Length		
millimeters	0.039	inches
centimeters	0.394	inches
meters	3.281	feet
meters	1.094	yards
kilometers	0.621	miles
Area		
sq. centimeters	0.155	sq. inches
sq. meters	10.76	sq. feet
sq. meters	1.196	sq. yards
sq. kilometers	0.4	sq. miles
hectares	2.47	acres
Mass (weight)		
grams	0.035	ounces
kilograms	2.205	pounds
metric ton	1.102	short ton
Volume		
milliliters	0.033	fluid ounces
liters	2.1	pints
liters	1.057	quarts
liters	0.264	gallons
cubic meters	35.315	cubic feet
cubic meters	1.308	cubic yards
Temperature		
Celsius	multiply by 9/5, then add 32	Fahrenheit
Pressure		
atmospheres	406.5	inches of H_2O
atmospheres	30.005	inches of Hg

Module: Base Case M.1, SST Waste Retrieval
Component / Unit Operation: M.1.A, SST Waste Retrieval System

General Description: High-level waste is contained in 149 SSTs. The typical tank contains about 40 wt% sludge and 60 wt% saltcake (Boomer 1993). The average mass of waste in each tank is about 1,500 metric tonnes (Boomer 1993). Each tank is assumed to require installation of onenew pump and one new mixer-sluicer. It is estimated that ___ of the tanks will require installation of ___ new sluice/pump pits. Recycled water is added to the tanks via the sluicer to dissolve and/or entrain tank waste, which is pumped from the tank. I is assumed that 9.6 miles of new 6: encased buried piping and associated equipment is installed to support retrieval operations. Some waste previously leaked from the tanks and more leakage during sluicing is expected to occur. Some leakage from the slurry transfer piping will also occur. Sluicing is assumed to remove 99% of the tank waste contents (Boomer 1993).

Number of Units: 149 SSTs (Boomer 1993)
Unit Size: 55,000 to 1,000,000 gal (Boomer 1993)
Operational Duration (yrs): 37
Operating Efficiency: 70%
Radiation Level: High
Temp: 25 - 90 C, decreasing to 20 C during retrieval (Boomer 1993)
Pressure: tanks, ambient: pumps/sluicers, 150 psi
pH/Acidity/Alkalinity: pH 14, decreasing to pH 8 during retrieval (BEJ)
Energetic Reaction Potential: Low
Process Stability: moderate (some plugging potential exists)
% Solids in Waste: 0.8, decreasing to <1% during sluicing (Boomer 1993)
Waste Form: Slurry
% Organics in Waste: 0.001 (Boomer 1993)
Flammability: Low

Mechanized Parts / Unit
High-level: 2 (1 pump, 1 mixer-sluicer)
Low-level: 0
Cold: 0

Isolated Process Steps / Unit
High-level: 0
Low-level: 0
Cold: 0

Combined Installation Activities: 149 pumps, 149 mixer-sluicers, ___ pits, 12 pipeline systems (one for each tank farm)

Combined Decontamination/ Decommissioning Disposal/Activities
Decontaminations: 0 (See M.1.B and M.1.C)
Decommissioning & Disposal: 0 (See M.1.B and M.1.C)

Module: Base Case M.1, SST Waste Retrieval
Component / Unit Operation: M.1.B, SST Cleanup & Backfill

General Description: Following retrieval of waste, each tank will be partially filled with exhumed SST waste transfer piping, contaminated soil and other associated stable solid waste, resulting from TWRS waste recovery operations. The tank space will then be filled with gravel to the greatest degree practical, followed by injection of grout to completely fill the tank head space. The grout is a pumpable mixture of sand, portland cement, and water. The tank filling action is intended to provide a physically stable base on which to install caps. (M.1.C).

Number of Units: 179 SSTs (Boomer 1993)
Unit Size: 630,000 gal (average)
Operational Duration (yrs): 45
Operating Efficiency: 25%
Radiation Level: High (tanks and pipe)
Temp: ambient
Pressure: ambient
pH/Acidity/Alkalinity: neutral
Energetic Reaction Potential: very low
Process Stability: high
% Solids in Waste: 100%
Waste Form: Solid
% Organics in Waste: 0%
Flammability: very low

Mechanized Parts / Unit
High-level: 0.01 Soil Excavators, 0.03 Trucks, 0.01 Pipe Cutters/Loaders, 0.03 Pipe Waste Unloading Stations
Low-level: 0
Cold: 0.03 Gravel distributors, 0.03 Portable Grout Mixing/Pumping Systems

Isolated Process Steps / Unit
High-level: 545,500 - 0.5 yd soil scoops, 10 pipe cuts, 5,070 pipe waste loadings, 20 truck pipe waste hauls
Low-level: 0
Cold: 0 - 0.5 yd soil scoops, 0 truck soil hauls, 171,000 truck gravel hauls, 3,100 SST gravel loadings, 13,000 concrete truck hauls.

Combined Installation Activities: 149 Pipe Waste Unloading Stations, 1 Gravel Washer/Crusher, 149 Gravel Distributors, 149 Grout Mixer/Pumpers

Combined Decontamination/ Decommissioning Disposal/Activities:
Decontaminations: Soil Excavator (__), Trucks (__), Pipe Cutter/Loaders (__), Gravel Distributors (__)
Decommissioning & Disposal: 2 Soil Excavators, 4 Trucks, 2 Pipe Cutters/Loaders, 4 Pipe Waste Unloading Stations.

Module: Base Case M.1, SST Waste Retrieval
Component / Unit Operation: M.1.C, Capping

General Description: Following retrieval of the waste from the tanks (M.1.A) and stabilization of the tanks (M.1.B), each of the 12 SST tank farms will be capped with a Hanford Protective Barrier. Dimensions of the barrier are assumed to be 415 ft x 530 ft with a minimum thickness of 5.67 ft. The barrier comprises the following materials: silt with pea gravel (29%), compacted silt (29%), filter sand (9%), filter gravel (9%), drainage gravel (9%), asphalt (9%), asphalt base (6%), and grading fill (variable %). The barrier is assumed to limit recharge to ___ cm/yr.

Number of Units: 12 SST Tank Farms/Barriers
Unit Size: 1,247,120 ft^3 (9,328,430 gal)
Operational Duration (yrs): N/A
Operating Efficiency: N/A
Radiation Level: cold
Temp: ambient
Pressure: ambient
pH/Acidity/Alkalinity: neutral
Energetic Reaction Potential: very low, except for blasting to produce rip rap
Process Stability: very high
% Solids in Waste: N/A
Waste Form: N/A
% Organics in Waste: N/A
Flammability: very low

Mechanized Parts / Unit
High-level: 0
Low-level: 0
Cold: ___ 20-yd trucks, (etc.)

Isolated Process Steps / Unit
High-level: 0
Low-level: 0
Cold: (TBD)

Combined Installation Activities: (TBD)

Combined Decontamination/ Decommissioning Disposal/Activities
Decontaminations: 0
Decommissioning & Disposal: Recontouring of borrow pits; disposal of failed cold equipment.

Module: Test Case 1 M.1, SST Waste Retrieval
Component / Unit Operation: M.1.A, SST Waste Retrieval System

General Description: High-level waste is contained in 149 SSTs. The typical tank contains about 40 wt% sludge and 60 wt% saltcake (Boomer 1993). The average mass of waste in each tank is about 1,500 metric tonnes (Boomer 1993). Each tank is assumed to require installation of one new pump and one new mixer-sluicer. It is estimated that ___ of the tanks will require installation of ___ new sluice/pump pits. Recycled water is added to the tanks via the sluicer to dissolve and/or entrain tank waste, which is pumped from the tank. It is assumed that 9.6 miles of new 6" encased buried piping and associated equipment is installed to support retrieval operations. Some waste has previously leaked from the tanks. Some leakage from the slurry transfer piping will also occur. No leaking during sluicing is expected to occur due to the subsurface barrier. Sluicing is assumed to remove 99% of the tank waste contents (Boomer 1993).

Number of Units: 149 SSTs (Boomer 1993)
Unit Size: 55,000 to 1,000,000 gal (Boomer 1993)
Operational Duration (yrs): 37.25
Operating Efficiency: 100%
Radiation Level: High
Temp: 25 - 90 C, decreasing to 20 C during retrieval (Boomer 1993)
Pressure: tanks, ambient: pumps/sluicers, 150 psi
pH/Acidity/Alkalinity: pH 14, decreasing to pH 8 during retrieval (BEJ)
Energetic Reaction Potential: Moderately Low (ferrocyanides, organic phases, H2) (BEJ)
Process Stability: Moderate (some plugging potential exists)
% Solids in Waste: 80%, decreasing to <1% during sluicing (Boomer 1993)
Waste Form: Slurry
% Organics in Waste: 0.1% (Boomer 1993)
Flammability: Very low, except moderate for 1 tank containing floating organics

Mechanized Parts / Unit
High-level: 2 (1 pump, 1 mixer-sluicer)
Low-level: 0
Cold: 0

Isolated Process Steps / Unit
High-level: 0
Low-level: 0
Cold: 0

Combined Installation Activities: 149 pumps, 149 mixer-sluicers, ___ pits, 12 pipeline systems (one for each tank farm)

Combined Decontamination/ Decommissioning Disposal/Activities
Decontaminations: 0 (See M.1.B and M.1.C)
Decommissioning & Disposal: 0 (See M.1.B and M.1.C)

Module: Test Case 1 M.1, SST Waste Retrieval
Component / Unit Operation: M.1.B, SST Cleanup & Backfill

General Description: Following retrieval of waste, each tank will be partially filled with exhumed SST waste transfer piping, contaminated soil and other associated stable solid waste, resulting from TWRS waste recovery operations. The tank space will then be filled with gravel to the greatest degree practical, followed by injection of grout to completely fill the tank head space. The grout is a pumpable mixture of sand, portland cement, and water. The tank filling action is intended to provide a physically stable base on which to install caps. (M.1.C).

Number of Units: 179 SSTs (Boomer 1993)
Unit Size: 630,000 gal (average)
Operational Duration (yrs): 45
Operating Efficiency: 25%
Radiation Level: High (tanks and pipe)
Temp: ambient
Pressure: ambient
pH/Acidity/Alkalinity: neutral
Energetic Reaction Potential: very low
Process Stability: high
% Solids in Waste: 100%
Waste Form: Solid
% Organics in Waste: 0%
Flammability: very low

Mechanized Parts / Unit
High-level: 0.01 Soil Excavators, 0.03 Trucks, 0.01 Pipe Cutters/Loaders, 0.03 Pipe Waste Unloading Stations
Low-level: 0
Cold: 0.03 Gravel distributors, 0.03 Portable Grout Mixing/Pumping Systems

Isolated Process Steps / Unit
High-level: 545,500 - 0.5 yd soil scoops, 10 pipe cuts, 5,070 pipe waste loadings, 20 truck pipe waste hauls
Low-level: 0
Cold: 0 - 0.5 yd soil scoops, 0 truck soil hauls, 171,000 truck gravel hauls, 3,100 SST gravel loadings, 13,000 concrete truck hauls.

Combined Installation Activities: 149 Pipe Waste Unloading Stations, 1 Gravel Washer/Crusher, 149 Gravel Distributors, 149 Grout Mixer/Pumpers
Combined Decontamination/ Decommissioning Disposal/Activities:
Decontaminations: Soil Excavator (___), Trucks (___), Pipe Cutter/Loaders (___), Gravel Distributors (___)
Decommissioning & Disposal: 2 Soil Excavators, 4 Trucks, 2 Pipe Cutters/Loaders, 4 Pipe Waste Unloading Stations.

Module: Test Case 1 M.1, SST Waste Retrieval
Component / Unit Operation: M.1.C, Capping

General Description: Following retrieval of the waste from the tanks (M.1.A) and stabilization of the tanks (M.1.B), each of the 12 SST tank farms will be capped with a Hanford Protective Barrier. Dimensions of the barrier are assumed to be 415 ft x 530 ft with a minimum thickness of 5.67 ft. The barrier comprises the following materials: silt with pea gravel (29%), compacted silt (29%), filter sand (9%), filter gravel (9%), drainage gravel (9%), asphalt (9%), asphalt base (6%), and grading fill (variable %). The barrier is assumed to limit recharge to ___ cm/yr.

Number of Units: 12 SST Tank Farms/Barriers
Unit Size: 1,247,120 ft^3 (9,328,430 gal)
Operational Duration (yrs): N/A
Operating Efficiency: N/A
Radiation Level: cold
Temp: ambient
Pressure: ambient
pH/Acidity/Alkalinity: neutral
Energetic Reaction Potential: very low, except for blasting to produce rip rap
Process Stability: very high
% Solids in Waste: N/A
Waste Form: N/A
% Organics in Waste: N/A
Flammability: very low

Mechanized Parts / Unit
High-level: 0
Low-level: 0
Cold: ___ 20-yd trucks, (etc.)

Isolated Process Steps / Unit
High-level: 0
Low-level: 0
Cold: (TBD)

Combined Installation Activities: (TBD)

Combined Decontamination/ Decommissioning Disposal/Activities
Decontaminations: 0
Decommissioning & Disposal: Recontouring of borrow pits; disposal of failed cold equipment.

Module: Test Case 1 M.1, SST Waste Retrieval
Component / Unit Operation: M.1.D, Close-Coupled Barrier

General Description: A close-coupled chemical subsurface barrier is positioned around each tank to prevent further leakage. Chemicals used to create the close-coupled subsurface barrier will be injected through vertical and horizontal pipes jacked into the soil. It is assumed that the horizontal pipes will be installed from inside vertical 15-ft. diameter caissons, which are installed in the open areas between tanks. Alternately, coffered trenches can be constructed at the boundary of the tank farm and used as the location for installation of the jacked pipes. Injections will be made working upward from the base of the walls of the tank until a sealed, close-coupled basin about 10 ft. thick is created around the tank.

Number of Units: 92 Subsurface Barriers
Unit Size: 8,000 cu. yd.
Operational Duration (yrs): 15.30
Operating Efficiency: 100%
Radiation Level: Low
Temp: 20 C (BEJ)
Pressure: during placement: 150 psia, after placement: ambient (BEJ
pH/Acidity/Alkalinity: neutral (BEJ)
Energetic Reaction Potential: low (BEJ)
Process Stability: high
% Solids in Waste: N/A
Waste Form: N/A
% Organics in Waste: N/A
Flammability: Very low

Mechanized Parts / Unit
High-level: 0.03 Soil Excavators
Low-level: 0
Cold: 0.03 Portable Chemical Mixing/Pumping Systems

Isolated Process Steps / Unit
High-level: TBD
Low-level: TBD
Cold: TBD

Combined Installation Activities: TBD

Combined Decontamination/ Decommissioning Disposal/Activities
Decontaminations: 0 (See M.1.B and M.1.C)
Decommissioning & Disposal: 0 (See M.1.B and M.1.C)

Module: Test Case 2 M.1, SST Waste Retrieval
Component / Unit Operation: M.1.A, SST Waste Retrieval System

General Description: High-level waste is contained in 149 SSTs. The typical tank contains about 40 wt% sludge and 60 wt% saltcake (Boomer 1993). The average mass of waste in each tank is about 1,500 metric tonnes (Boomer 1993). It is assumed that one robotic system including a confinement structure is required for each set of 4 waste tanks. it is assumed that 9.6 miles of new 6" encased buried piping and associated equipment is installed to support retrieval operations. Some waste previously leaked from the tanks and more leakage during robotic retrieval is expected to occur. Some leakage from the slurry transfer piping will also occur. Robotic retrieval is assumed to remove 99.9% of the tank waste contents.

Number of Units: 149 SSTs (Boomer 1993)
Unit Size: 55,000 to 1,000,000 gal (Boomer 1993)
Operational Duration (yrs): 37.25
Operating Efficiency: 100%
Radiation Level: High
Temp: 25 - 90 C, decreasing to 20 C during retrieval (Boomer 1993)
Pressure: tanks, ambient: air conveyance system -5 psig; robotic arm end effectors, 1000 psig (BEJ)
pH/Acidity/Alkalinity: pH 14, decreasing to pH 8 during retrieval (BEJ)
Energetic Reaction Potential: moderately low (ferrocyanides, organic phases, H2) (BEJ)
Process Stability: moderate (some plugging potential exists)
% Solids in Waste: 80% (Boomer 1993)
Waste Form: Slurry
% Organics in Waste: 0.1% (Boomer 1993)
Flammability: very low, except moderate for 1 tank containing floating organics

Mechanized Parts / Unit
High-level: 2 (1 robotic arm, 1 air conveyance module)
Low-level: 0
Cold: 0

Isolated Process Steps / Unit
High-level: 0
Low-level: 0
Cold: 0

Combined Installation Activities: 36 robotic arm systems, 36 confinement structures, 12 pipeline systems (one for each tank farm)

Combined Decontamination/ Decommissioning Disposal/Activities
Decontaminations: 0 (See M.1.B and M.1.C)
Decommissioning & Disposal: 0 (See M.1.B and M.1.C)

Module: Test Case 2 M.1, SST Waste Retrieval
Component / Unit Operation: M.1.B, SST Cleanup & Backfill

General Description: Following retrieval of waste, each tank will be partially filled with exhumed SST waste transfer piping, contaminated soil and other associated stable solid waste, resulting from TWRS waste recovery operations. The tank space will then be filled with gravel to the greatest degree practical, followed by injection of grout to completely fill the tank head space. The grout is a pumpable mixture of sand, portland cement, and water. The tank filling action is intended to provide a physically stable base on which to install caps. (M.1.C).

Number of Units: 179 SSTs (Boomer 1993)
Unit Size: 630,000 gal (average)
Operational Duration (yrs): 45
Operating Efficiency: 25%
Radiation Level: High (tanks and pipe)
Temp: ambient
Pressure: ambient
pH/Acidity/Alkalinity: neutral
Energetic Reaction Potential: very low
Process Stability: high
% Solids in Waste: 100%
Waste Form: Solid
% Organics in Waste: 0%
Flammability: very low

Mechanized Parts / Unit
High-level: 0.01 Soil Excavators, 0.03 Trucks, 0.01 Pipe Cutters/Loaders, 0.03 Pipe Waste Unloading Stations
Low-level: 0
Cold: 0.03 Gravel distributors, 0.03 Portable Grout Mixing/Pumping Systems

Isolated Process Steps / Unit
High-level: 545,500 - 0.5 yd soil scoops, 10 pipe cuts, 5,070 pipe waste loadings, 20 truck pipe waste hauls
Low-level: 0
Cold: 0 - 0.5 yd soil scoops, 0 truck soil hauls, 171,000 truck gravel hauls, 3,100 SST gravel loadings, 13,000 concrete truck hauls.

Combined Installation Activities: 149 Pipe Waste Unloading Stations, 1 Gravel Washer/Crusher, 149 Gravel Distributors, 149 Grout Mixer/Pumpers
Combined Decontamination/ Decommissioning Disposal/Activities:
Decontaminations: Soil Excavator (__), Trucks (__), Pipe Cutter/Loaders (__), Gravel Distributors (__)
Decommissioning & Disposal: 2 Soil Excavators, 4 Trucks, 2 Pipe Cutters/Loaders, 4 Pipe Waste Unloading Stations.

Module: Test Case 2 M.1, SST Waste Retrieval
Component / Unit Operation: M.1.C, Capping

General Description: Following retrieval of the waste from the tanks (M.1.A) and stabilization of the tanks (M.1.B), each of the 12 SST tank farms will be capped with a Hanford Protective Barrier. Dimensions of the barrier are assumed to be 415 ft x 530 ft with a minimum thickness of 5.67 ft. The barrier comprises the following materials: silt with pea gravel (29%), compacted silt (29%), filter sand (9%), filter gravel (9%), drainage gravel (9%), asphalt (9%), asphalt base (6%), and grading fill (variable %). The barrier is assumed to limit recharge to ___ cm/yr.

Number of Units: 12 SST Tank Farms/Barriers
Unit Size: 1,247,120 ft³ (9,328,430 gal)
Operational Duration (yrs): N/A
Operating Efficiency: N/A
Radiation Level: cold
Temp: ambient
Pressure: ambient
pH/Acidity/Alkalinity: neutral
Energetic Reaction Potential: very low, except for blasting to produce rip rap
Process Stability: very high
% Solids in Waste: N/A
Waste Form: N/A
% Organics in Waste: N/A
Flammability: very low

Mechanized Parts / Unit
High-level: 0
Low-level: 0
Cold: ___ 20-yd trucks, (etc.)

Isolated Process Steps / Unit
High-level: 0
Low-level: 0
Cold: (TBD)

Combined Installation Activities: (TBD)

Combined Decontamination/ Decommissioning Disposal/Activities
Decontaminations: 0
Decommissioning & Disposal: Recontouring of borrow pits; disposal of failed cold equipment.

Module: M.2, DST Waste Retrieval
Component / Unit Operation: M.2.A, DST Miscellaneous Waste Retrieval System

General Description: This waste stream contains concentrated phosphate waste originating from the decontamination of the N Reactor in the 100 N Area. It also includes the solids portion of the PUREX Neutralized Cladding Removal Waste (NCRW). NCRW solids are classified as transuranic (TRU) waste. This waste also includes TRU solids from Plutonium Finishing Plant (PFP) operations (Halon 1994). The waste is contained in 12 tanks located in the 241-AN, 241-AP, 241-AW, 241-AZ and 241-SY tank farm areas. Tanks 241-AW-101, 241-AN-103, 104, and 105 are identified as Watch List Tanks due to potential for hydrogen gas accumulation above the flammability limit (Halon 1994). Typical tank waste contains an average of 19% solids. Sluicing operations are expected to remove 99.97% of tank waste contents (______________). Waste inventories range from 22,000 to 1,147,000 gallons. A mixer pump system consisting of two to four mixer pumps will be installed in concrete pits above the DSTs and will extend down through riser pipes. The waste will then be pumped out of tank by a waste transfer pump (Wodrich 1993). It is assumed that 10 miles
Number of Units: 12 DSTs (Halon 1993)
Unit Size: 1,000,000 to 1,160,000 gallons (Boomer 1993)
Unit Utilization (yrs): 3
Operating Efficiency: 70%
Radiation Level: High
Temp: 25 - 90 C, decreasing to 20 C during retrieval (Boomer 1993)
Pressure: tanks, ambient: pumps/sluicers, 150 psi
pH/Acidity/Alkalinity: pH 14, decreasing to pH 8 during retrieval (BEJ)
Energetic Reaction Potential: Low
Process Stability: moderate (some plugging potential exists)
% Solids in Waste: 19% (Halon 1994)
Waste Form: Slurry
% Organics in Waste: 0.3% (Boomer 1993)
Flammability: Low, except for the 4 tanks that contain hydrogen gas

Mechanized Parts / Unit
High-level: 2 to 4 mixer pumps, 1 transfer pump (Wodrich 1993)
Low-level: 0
Cold: 0

Isolated Process Steps / Unit
High-level: 0
Low-level: 0
Cold: 0

ombined Installation Activities: 12 to24 mixer pumps, 12 transfer pumps

Combined Decontamination/
ommissioning Disposal/Activities
Decontaminations: 0 (see M.2.E and M.2.F)
Decommissioning & Disposal: 0 (see M.2.E and M.2.F)

Module: M.2, DST Waste Retrieval
Component / Unit Operation: M.2.B Concentrated Complexant Waste Retrieval System

General Description: This waste is a concentrated waste product from the evaporation of dilute complexed waste. The dilute complexed waste is characterized bya high content oforganic carbon including organic complexants. Saltwell liquid from the SSTs is the main source of the dilute complexed waste (Halon 1994). The waste is contained in five DSTs, located in the 241-AN, 241-AY and 241-SY tank farm areas. Tanks 241-SY-101 and 241-SY-103 are identified as Watch List Tanks due to a potential for hydrogen gas accumulation above the flammability limit. Typical tank waste contains an average of 9% solids. Sluicing operations are expected to remove 99.97% of tank waste contents (______). Waste inventories range from 748,000 to 1,115,000 gallons. A mixer pump system consisting of two to four mixer pumps will be installed in concrete pits above the DSTs and will extend down through riser pipes.. The waste will then be pumped out of the tank by a waste transfer pump (Wodrich 1993). It is assumed that 10 miles of new 6" encased buried piping and associated equipment
Number of Units: 5 DST (Halon 1993)
Unit Size: 1,000,000 to 1,160,000 gallons (Boomer 1993)
Unit Utilization (yrs): 1
Operating Efficiency: 70%
Radiation Level: High
Temp: 25 - 90 C, decreasing to 20 C during retrieval (Boomer 1993)
Pressure: tanks, ambient: pumps/sluicers, 150 psi
pH/Acidity/Alkalinity: pH 14, decreasing to pH 8 during retrieval (BEJ)
Energetic Reaction Potential: Low (organic phases, H2) (BEJ)
Process Stability: moderate (some plugging potential exists)
% Solids in Waste: 9% (Halon, 1994)
Wasten Form: Slurry
% Organics in Waste: 1.4% (Boomer 1993)
Flammability: Very Low, except for the 2 tanks that contain hydrogen gas

Mechanized Parts / Unit
High-level: 2 to 4 mixer pumps, 1 transfer pump (Wodrich 1993)
Low-level: 0
Cold: 0

Isolated Process Steps / Unit
High-level: 0
Low-level: 0
Cold: 0

ombined Installation Activities: 10 to 20 mixer pumps, 5 transfer pumps

Combined Decontamination/
ommissioning Disposal/Activities
Decontaminations: 0 (see M.2.E and M.2.F)
Decommissioning & Disposal: 0 (see M.2.E and M.2.F)

Module: M.2, DST Waste Retrieval
Component / Unit Operation: M.2.C, Dilute Non-Complexed Waste Retrieval System

General Description: Low activity luquid waste originating from T and S plants, the 300 and 400 Areas, PUREX facility (decladding supernatant and miscellaneous waste), 100 N Area (sulfate waste) B Plant, saltwells, and PFP (Plutonium Finishing Plant) supernate (Halon 1994). This waste is contained in 11 tanks, located in the 241-AN, 241-AP, 241-AW and 241-AY tank farm areas. Typical tank waste contains an average of 3% solids. Sluicing operations are expected to remove 99.97% of tank waste contents. Waste inventories range from 18,000 to 1,061,000 gallons. A mixer pump system consisting of two to four mixer pumps will be installed in concrete pits above the DSTs and will extend down throug riser pipes. The waste will then be pumped out of the tank by a waste transfer pump (Wodrich 1993). It is assumed that 10 miles of new 6" encased buried piping and associated equipment is installed to support

Number of Units: 11 DSTs (Halon 1994)
Unit Size: 1,000,000 to 1,160,000 gallons (Boomer 1993)
Unit Utilization (yrs): 2.75
Operating Efficiency: 70%
Radiation Level: High
Temp: 25 - 90 C, decreasing to 20 C during retrieval (Boomer 1993)
Pressure: tanks, ambient: pumps/sluicers, 150 psig
pH/Acidity/Alkalinity: pH 14, decreasing to pH 8 during retrieval (BEJ)
Energetic Reaction Potential: Very Low
Process Stability: moderate (some plugging potential exists)
% Solids in Waste: 3%, (Halon 1994)
Waste Form: Slurry
% Organics in Waste: 0.1% (Boomer 1993)
Flammability: Very Low

Mechanized Parts / Unit
High-level: 2 to 4 mixer pumps, 1 transfer pump (Wodrich 1993)
Low-level: 0
Cold: 0

Isolated Process Steps / Unit
High-level: 0
Low-level: 0
Cold: 0

ombined Installation Activities: 22 to 44 mixer pumps, 11 transfer pumps

Combined Decontamination/ ommissioning Disposal/Activities
Decontaminations: 0 (see M.2.E and M.2.F)
Decommissioning & Disposal: 0 (see M.2.E and M.2.F)

Module: M.2, DST Waste Retrieval
Component / Unit Operation: M.2.D 242-A Evaporator

General Description: This evaporator processed dilute DST non-complexed waste from a number of operations including saltwell pumping, purex Plant and N Reactor operations. The 242-A Evaporator produces six streams (primarily stream condensate) which are collected in a condensate collection tank. After filtration, the collected waste becomes the 242-A Evaporator process condensate which is subsequently treated. This process is continuous with typical flow rates of 90 to 140 gpm from the feed tank, to 20 to 60 gpm for condensate and 43 to 90 for the slurry discharge (Tripplet, 1991).

Number of Units: 1 Evaporator (242-A)
Unit Size: 1,000,000 to 1,160,000 gal.
Unit Utilization (yrs): 0.25
Operating Efficiency: 70%
Radiation Level: High
Temp: ~110 degrees C
Pressure: 0.68 - 1.64 psig
pH/Acidity/Alkalinity: pH 2 to 12.5
Energetic Reaction Potential: Low
Process Stability: moderate (some plugging potential exists)
% Solids in Waste: 15% (Halon 1994)
Waste Form: Slurry
% Organics in Waste: 0.1% (Boomer 1993)
Flammability: Moderately Low

Mechanized Parts / Unit
High-level: 11 transfer pumps
Low-level: 0
Cold: 0

Isolated Process Steps / Unit
High-level: 3 (vapor-liquid separation, condensation, liquid transfer)
Low-level: 0
Cold: 0

ombined Installation Activities: 11 transfer pumps and piping systems

**Combined Decontamination/
ommissioning Disposal/Activities**
Decontaminations: 1
Decommissioning & Disposal:

Module: M.2, DST Waste Retrieval
Component / Unit Operation: M.2.E, DST Cleanup & Backfill

General Description: Following retrieval of waste, each tank will be partially filled with exhumed DST waste transfer piping, contaminated soil and other associated stable solid waste, resulting from TWRS waste recovery operations. The tank space will then be filled with gravel to the greatest degree practical, followed by injection of grout to completely fill the tank head space. The grout is a pumpable mixture of sand, portland cement, and water. The tank filling action is intended to provide a physically stable base on which to install caps (M.1.F).

Number of Units: 28 DSTs (Boomer 1993)
Unit Size: 1,000,000 to 1,160,000 gallons
Unit Utilization (yrs): 7
Operating Efficiency: 25%
Radiation Level: High (tanks and pipe)
Temp: Ambient
Pressure: Ambient
pH/Acidity/Alkalinity: Neutral
Energetic Reaction Potential: Very Low
Process Stability: High
% Solids in Waste: 100%
Waste Form: Solid
% Organics in Waste: 0%
Flammability: Very Low

Mechanized Parts / Unit
High-level: 0.01 Soil Excavators, 0.03 Trucks, 0.01 Pipe Cutters/Loaders, 0.03 Pipe Waste Unloading Stations
Low-level: 0
Cold: 0.03 Gravel distributors, 0.03 Portable Grout Mixing/Pumping Systems

Isolated Process Steps / Unit
High-level: ______ - 0.5 yd soil scoops, 10' pipe cuts, _____ pipe waste loadings, 20 truck pipe waste hauls.
Low-level: 0
Cold: 0 - 0.5 yd soil scoops, 0 truck soil hauls, _______ truck gravel hauls, _____ DST gravel loadings, 13,000 concrete truck hauls.

ombined Installation Activities: 28 Pipe Waste Unloading Stations, 1 Gravel Washer/Crusher, 28 Gravel Distributors, 28 Grout Mixer/Pumpers
Combined Decontamination/ ommissioning Disposal/Activities
Decontaminations: Soil Excavator (__), Trucks (__), Pipe Cutter/Loaders (__),Gravel Distributors (__)
Decommissioning & Disposal: 2 Soil Excavators, 4 Trucks, 2 Pipe Cutters/Loaders, 4 Pipe Waste Unloading Stations.

Module: M.2, DST Waste Retrieval
Component / Unit Operation: M.2.F, Capping

General Description: Following retrieval of the waste from the tanks (M.1.A) and stabilization of the 6 DST tank farms will be capped with a Hanford Protective Barrier. Dimensions of the barrier are assumed to be ____x____ with a minimum thickness of 5.67 ft. The barrier comprises the following materials: silt with pea gravel (29%), compacted silt (29%), filter sand (9%), filter gravel (9%), drainage gravel (9%), asphalt (9%), asphalt base (6%), and grading fill (variable %). The barrier is assumed to limit recharge to _____ cm/yr.

Number of Units: 6 DST Tank Farms/Barriers
Unit Size: 1,000,000 to 1,160,000
Unit Utilization (yrs): N/A
Operating Efficiency: N/A
Radiation Level: Cold
Temp: Ambient
Pressure: Ambient
pH/Acidity/Alkalinity: Neutral
Energetic Reaction Potential: Very Low, except for blasting to produce rip rap
Process Stability: Very High
% Solids in Waste: N/A
Waste Form: N/A
% Organics in Waste: N/A
Flammability: Very Low

Mechanized Parts / Unit
High-level: 0
Low-level: 0
Cold: ___ 20-yd trucks, (etc.)

Isolated Process Steps / Unit
High-level: 0
Low-level: 0
Cold: (TBD)

ombined Installation Activities: (TBD)

**Combined Decontamination/
ommissioning Disposal/Activities**
Decontaminations: 0
Decommissioning & Disposal: Recontouring of borrow pits, disposal of failed cold equipment.

Module: M.3, DST Sludge Wash
Component / Unit Operation: M.3.A, Chemical Feed System

General Description: This feed stream distributes bulk water, flocculant, NaOH, and NaNO2 to the settling and wshing unit operations for Module 4. Chemical addition in the Sludge Washing process is used for the formation of a wash solution. Bulk flocculant is utilized to enhance the settling properties of the waste.

Number of Units: 4 (conveyance systems)
Unit Size: 3 to 6" pipes
Unit Utilization (yrs): N/A
Operating Efficiency: 60%
Radiation Level: Cold
Temp: Ambient
Pressure: 0.04 psig
pH/Acidity/Alkalinity: ~ 7 - 8
Energetic Reaction Potential: Very Low - Low
Process Stability: High
% Solids in Waste: 0%
Waste Form: Liquid
% Organics in Waste: 0%
Flammability: Very Low

Mechanized Parts / Unit
High-level: 0
Low-level: 0
Cold: 0

Isolated Process Steps / Unit
High-level: 0
Low-level: 0
Cold: 0

ombined Installation Activities: 3 to 6" pipes

Combined Decontamination/ ommissioning Disposal/Activities
Decontaminations:
Decommissioning & Disposal:

Module: M.3, DST Sludge Wash
Component / Unit Operation: M. 3.B, Sludge Settling Process

General Description: This multi-step operation involves the settling of sludge formed by the in-line conditioning of DST and SST waste. Conditioning is done by mixing the waste with a polyelectrolyte flocculant solution before it enters the First Stage Settling Tanks. The polyelectrolyte coagulates colloidal solids thereby increasing solids recovery (Boomer 1993). The settled material is pumped as a slurry to a wash tank. Decant from the First Stage Settling Tank is again mixed in-line with a flocculant solution and sent to the Secondary Settling Tanks. The slurry from this process is sent to a wash tank and the supernatant is routed to an accumulation tank.

Number of Units: 8 Double Shell Settling Tanks, 3 pumps
Unit Size:
Unit Utilization (yrs): 13 (Boomer 1993)
Operating Efficiency: 75%
Radiation Level: High
Temp: Ambient
Pressure: 0.04 psig
pH/Acidity/Alkalinity: 8 - 14
Energetic Reaction Potential: Very Low
Process Stability: High
% Solids in Waste: 2% (first stage), 20% (second stage)
Waste Form: Slurry
% Organics in Waste: 0% (both)
Flammability: Low

Mechanized Parts / Unit
High-level: 3 transfer pumps
Low-level: 0
Cold: 0

Isolated Process Steps / Unit
High-level: 2
Low-level: 0
Cold: 0

ombined Installation Activities: 3 pumps, piping

Combined Decontamination/
ommissioning Disposal/Activities
Decontaminations:
Decommissioning & Disposal:

Module: M.3, DST Sludge Wash
Component / Unit Operation: M.3.C, Sludge Wash Process

General Description: The slurry from the sludge settling operation is washed with the wash solution and is mixed with the slurry from the Second Stage Settling Tanks. The mixture is allowed to settle and then is decanted. The decant is pumped to Wash Solution Accumulation Tanks. The slurry is then washed, mixed in-line with a polyelectrolyte, and pumped to a Second Wash Tank where it is allowed to settle. The decant from the Second Wash Tank is also pumped to the Wash Solution Accumulation Tank. This slurry is pumped to HLW Accumulation Tanks (Boomer 1993).

Number of Units: 2 Double Shell Settling Tanks, 2 Accumulation Tanks, 4 pumps
Unit Size:
Unit Utilization (yrs): 13 (Boomer 1993)
Operating Efficiency: 75%
Radiation Level: High
Temp: Ambient
Pressure: 0.04 psig
pH/Acidity/Alkalinity: 8 - 12
Energetic Reaction Potential: Very Low
Process Stability: High
% Solids in Waste: 0.1% (decant), 20% (slurry)
Waste Form: Decant, slurry
% Organics in Waste: 0.02% (decant), 0.07% (slurry)
Flammability: Low

Mechanized Parts / Unit
High-level: 4 transfer pumps
Low-level: 0
Cold: 0

Isolated Process Steps / Unit
High-level: 2
Low-level: 0
Cold: 0

ombined Installation Activities: 4 pumps, piping

Combined Decontamination/ ommissioning Disposal/Activities
Decontaminations:
Decommissioning & Disposal:

Module: M.3, DST Sludge Wash
Component / Unit Operation: M.3.D, Wash Transfer Process

General Description: This processes involves pumping the decant from the wash solution accumulation tanks to the wash solution transfer tanks where they are sampled before being fed to the evaporator (Boomer 1993).

Number of Units: 2 double shell transfer tanks, 2 pumps
Unit Size:
Unit Utilization (yrs): 13 (Boomer 1993)
Operating Efficiency: 75%
Radiation Level: High
Temp: Ambient
Pressure: 0.04 psig
pH/Acidity/Alkalinity: 8 - 10
Energetic Reaction Potential: Very Low
Process Stability: High
% Solids in Waste: 0.1%
Waste Form: Liquid
% Organics in Waste: 0.02%
Flammability: Low

Mechanized Parts / Unit
High-level: 2 transfer pumps
Low-level: 0
Cold: 0

Isolated Process Steps / Unit
High-level: 1
Low-level: 0
Cold: 0

ombined Installation Activities: 2 pumps, piping

Combined Decontamination/
ommissioning Disposal/Activities
Decontaminations:
Decommissioning & Disposal:

Module: M.4, Cesium Ion Exchange
Component / Unit Operation: M.4.A, Accumulation System

General Description: This system accumulated decant from the sludge washing system. Decant from sludge washing operations is transferred to the Supernatant Accumulation Tanks. Then the decant stream is pumped into the Supernatant Transfer Tank where it is divided into two waste streams. The first portion of the stream is sent to a LLW Feed Accumulation Tank. The second is a liquid stream sent to a receipt/sample tank.

Number of Units: 8 accumulation tanks, 6 receipt./sample tanks, 14 pumps
Unit Size:
Unit Utilization (yrs): 13 (Boomer 1993)
Operating Efficiency: 75%
Radiation Level: High
Temp: Ambient
Pressure: 0.04 psig
pH/Acidity/Alkalinity: 8 - 14
Energetic Reaction Potential: Very Low
Process Stability:
% Solids in Waste: 0.01% (accumulation stream), 0% (sample stream)
Waste Form: liquid
% Organics in Waste: 0.1% (accumulation stream), 0% (sample stream)
Flammability: Very Low

Mechanized Parts / Unit
High-level: 0
Low-level: 14 pumps
Cold: 0

Isolated Process Steps / Unit
High-level:
Low-level:
Cold:

ombined Installation Activities:

Combined Decontamination/
ommissioning Disposal/Activities
Decontaminations:
Decommissioning & Disposal:

Module: M.4, Cesium Ion Exchange
Component / Unit Operation: M.4.B, Supernatant Evaporator System

General Description: This system receives a liquid stream from the accumulation system Receipt/Sample Tank, and bulk NaNO2, bulk H2O and bulk NaOH streams. The liquid stream enters the Evaporator Feed Tank and is pumped into the Supernatant Evaporator where the supernatant is concentrated and the vapors are sent to the cooling condensor and treated. The remaining supernatant in the Supernatant Evaporator flows into a catch tank and is then pumped into a Sample Tank where the bottoms are sampled. The concentrated supernatant is then pumped out into two streams; one proceeding to the Cs IX Feed Adjust Tank and the other to the Transfer Tank. In addition, the bulk NaNO2 and bulk water streams each flow into a Concentrated Supernatant NaNO2 Makeup Tank. The liquid stream from this tank also flows into the Transfer Tank with the concentrated supernatant. A third stream of bulk NaOH flows into the Transfer Tank before all LLW is pumped back out to the LLW Feed
Number of Units: 1 makeup tank, 1 catch tank, 1 sample tank, 1 transfer tank, 1evaporator, 1 condensor, 3 pumps
Unit Size:
Unit Utilization (yrs): 13 (Boomer 1993)
Operating Efficiency: 60%
Radiation Level: High
Temp: Ambient - 110 degrees Celsius
Pressure: 0.04 psig
pH/Acidity/Alkalinity: 8 - 14
Energetic Reaction Potential: Very Low - Low
Process Stability:
% Solids in Waste: 0% (LLW stream), 0.01% (Cs IX stream)
Waste Form: Liquid solution
% Organics in Waste: 0% (LLW stream), 0.13% (Cs IX stream)
Flammability: Very Low

Mechanized Parts / Unit
High-level: 3 pumps
Low-level: 0
Cold: 0

Isolated Process Steps / Unit
High-level:
Low-level:
Cold:

ombined Installation Activities:

Combined Decontamination/ ommissioning Disposal/Activities
Decontaminations:
Decommissioning & Disposal:

Module: M.4, Cesium Ion Exchange
Component / Unit Operation: M.4.C, Ion Exchange Feed

General Description: This system takes the liquid stream from the LLW Feed Accumulation Tank into the Receipt/Sample Tanks to be sampled. Then the liquid is pumped into the Cs IX Feed Adjust Tank. Recycled water, bulk NaOH, and concentrated supernatant from the Concentrated Supernatant Tank also enter the Cs IX Feed Adjust Tank. After adjustment, the liquid stream is pumped into the Cs IX Feed Tank before being pumped through the frit filter. Recycled water and filter media are also sent through the filter, with the filtrate being sent to the Cs IX System. The filtered liquid (4.67% solids) waste stream enters the Filter Bed Catch Tank before being pumped to the HLW melter.
Number of Units: 9 pumps, 5 sample tanks, 1 feed adjust tank, 1 feed tank, 1catch tank, 1 frit filter
Unit Size:
Unit Utilization (yrs): 13 (Boomer 1993)
Operating Efficiency: 60%
Radiation Level: High
Temp: Ambient
Pressure: 0.04 psig
pH/Acidity/Alkalinity: 8 - 14
Energetic Reaction Potential: Very Low - Low
Process Stability:
% Solids in Waste: 4.67% (HLW stream), 0% (filtrate stream)
Waste Form: Liquid
% Organics in Waste: 0.02% (HLW stream), 0.13% (filtrate stream)
Flammability: Very Low

Mechanized Parts / Unit
High-level: 9 pumps
Low-level: 0
Cold: 0

Isolated Process Steps / Unit
High-level:
Low-level:
Cold:

ombined Installation Activities:

Combined Decontamination/ ommissioning Disposal/Activities
Decontaminations:
Decommissioning & Disposal:

Module: M.4, Cesium Ion Exchange
Component / Unit Operation: M.4.D, Cesium Ion Exchange

General Description: The filtered stream from the Ce IX Feed System flows into the Ce IX columns, loaded with Duolite resin, where almost all of the cesium is captured. The first two columns are loaded in series while the third column is regenerated. the remainder of the solution flows into the Cesium Waste Tank and is then pumped into the Cesium Waste Sample Tank for sampling. During regeneration of the third column, a water flush stream is used to remove the remaining cesium solution. A sodium scrub stream removes a large portion of the resident sodium and Ce and flows to the Cesium Waste Tank. The cesium eluent stream removes the remaining sodium and cesium flows to the Cs IX Eluent Catch Tank, where the stream is pumped to the Cs IX Concentrator system. The eluent from the flush stream is used to rinse the column of acid, sending 25% to the Eluent Catch Tank and 75% to the Waste Tank. Two effluent regeneration streams also enter the third column, with the stream flowing into the Waste Tank (Boomer 1993).
Number of Units: 3 Cs IX columns, 3 pumps, 1 catch tank, 1 sample tank, 1 waste tank
Unit Size: 57 m3 (eluant tank), 204 m3 (waste and sample tanks), 4.88 m x 4.88 m (columns)
Unit Utilization (yrs): 13 (Boomer 1993)
Operating Efficiency: 60%
Radiation Level: High
Temp: Ambient
Pressure: 0.04 to 50 psig
pH/Acidity/Alkalinity: <1 - >14
Energetic Reaction Potential: Very Low - Moderate
Process Stability: Medium
% Solids in Waste: 0% (waste stream), 0% (eluant stream)
Waste Form: Liquid
% Organics in Waste: 0.08% (waste stream), 0% (eluant stream)
Flammability: Very Low - Low

Mechanized Parts / Unit
High-level: 0
Low-level: 3 pumps
Cold: 0

Isolated Process Steps / Unit
High-level:
Low-level:
Cold:

ombined Installation Activities:

Combined Decontamination/ ommissioning Disposal/Activities
Decontaminations:
Decommissioning & Disposal:

Module: M.4, Cesium Ion Exchange
Component / Unit Operation: M.4.E, Cs IX Concentrator

General Description: The concentrator system concentrates the liquid stream pumped from the Cs IX Eluent Catch Tank. The bottoms are sent to the Concentrator Catch Tank awaiting neutralization. The vapors from the concentrator are condensed and released to their appropriate systems (Boomer 1993).

Number of Units: 1 concentrator, 1 catch tank, 1 condensor, 1 pump
Unit Size:
Unit Utilization (yrs): 13 (Boomer 1993)
Operating Efficiency: 60%
Radiation Level: High
Temp: 60 - 110 degrees Celsius
Pressure: 0.04 psig
pH/Acidity/Alkalinity: Neutral - <1
Energetic Reaction Potential: Very Low - Low
Process Stability: Medium
% Solids in Waste: 0%
Waste Form: Liquid
% Organics in Waste: 0%
Flammability: Low

Mechanized Parts / Unit
High-level: 0
Low-level: 1 pump
Cold: 0

Isolated Process Steps / Unit
High-level:
Low-level:
Cold:

ombined Installation Activities:

Combined Decontamination/ ommissioning Disposal/Activities
Decontaminations:
Decommissioning & Disposal:

Module: M.4, Cesium Ion Exchange
Component / Unit Operation: M.4.F, Eluent/Regeneration System

General Description: This system receives bulk water, bulk HNO3, bulk NaOH, and liquid streams from the Cs IX Waste Tank and the Concentrator for Cs IX. The bulk water is distributed to six tanks: Cesium Nitric Acid, Cs IX Acid Regeneration Feed, Startup Nitric Acid (4.2m), NaOH Regeneration (2.0m), NaOH Regeneration (0.5m), and NaOH Neutralizing Solution. Bulk HNO3 is sent to the Cesium Nitric Acid and Startup Nitric Acid Tanks and to the Cs IX System for neutralization. The liquid stream from the Cesium Nitric Acid Tank flows into the Cs IX Regeneration Feed Tank. The Acid Recycle Tank stream, fed by the concentrator system, is pumped into the Acid Regeneration Feed Tank to mix with the cesium citric acid and bulk water streams. The combined stream is then pumped to the Cs IX regeneration column. The Startup Nitric Acid Tank is sent to the Concentrator System for concentration, while the NaOH Neutralizing Solution Tank stream is sent to the Concentrator Catch Tank for neutralization of the concentrate. The two NaOH Regeneration Tanks flow into the Cs IX Caustic Regeneration Feed Tank. The stream from this tank is also pumped into the regeneration column of the Cs IX System.
Number of Units: 3 pumps, 2 feed tanks, 2 nitric acid tanks, 2 regeneration tanks, 1 solution tank, 1 recycle tank
Unit Size:
Unit Utilization (yrs): 13 (Boomer 1993)
Operating Efficiency: 60%
Radiation Level: Low
Temp: Ambient
Pressure: 0.04 psig to Ambient
pH/Acidity/Alkalinity: <1 - >14
Energetic Reaction Potential: Very Low - Low
Process Stability: Medium
% Solids in Waste: 0%
Waste Form: Liquid
% Organics in Waste: 0%
Flammability: Very Low

Mechanized Parts / Unit
High-level: 0
Low-level: 3 pumps
Cold: 0

Isolated Process Steps / Unit
High-level: 0
Low-level: 0
Cold: 0

ombined Installation Activities: 3 pumps, piping

Combined Decontamination/ ommissioning Disposal/Activities
Decontaminations:
Decommissioning & Disposal:

Module: M.5, LLW Glass in Sulfur
Component / Unit Operation: M.5.A, LLW Evaporator

General Description: In this unit the LLW Evaporator Feed Tank is fed by seven streams, six of which are filter washes. The liquid stream is pumped from the tank to the LLW Feed Evaporator. The vapors from the evaporator are condensed and sent to other systems. A liquid waste stream also exits the LLW Feed Evaporator to the LLW Melter.

Number of Units: 1 feed tank, 1 evaporator, 1 condensor
Unit Size:
Unit Utilization (yrs): 13 (Boomer 1993)
Operating Efficiency: 60%
Radiation Level: Low
Temp: Ambient - 110 degrees Celsius
Pressure: 0.04 psig
pH/Acidity/Alkalinity: 10 - 14
Energetic Reaction Potential: Low
Process Stability: Medium
% Solids in Waste: 0.0009%
Waste Form: Liquid
% Organics in Waste: 0.17%
Flammability: Very Low

Mechanized Parts / Unit
High-level: 0
Low-level: 0
Cold: 0

Isolated Process Steps / Unit
High-level:
Low-level:
Cold:

ombined Installation Activities:

Combined Decontamination/
ommissioning Disposal/Activities
Decontaminations:
Decommissioning & Disposal:

Module: M.5, LLW Glass in Sulfur
Component / Unit Operation: M.5.B, LLW Melter

General Description: The LLW Melter Feed Adjustment Tanks Receive two LLW slurry streams and one LLW liquid stream. Following adjustment, the liquid stream is pumped from the tanks to the LLW Melter Feed Tanks before being pumped to the LLW Melter. Bulk glass enters the Head Bin, is fed through the Rotary Star Feeder, then the Weigh Feeder, and then another Rotary Star Feeder before entering the LLW Melter. Bulk kerosene and oxygen are the third and fourth streams to flow into the LLW melter. The final step incorporates the melted material into the glass separator with two steams (one slurry, one liquid) flowing to new locations.

Number of Units: 1 feed adjustment tank, 1 feed tank, 1 head bin, 2 Rotary Star feeders, 1 weigh feeder, 1 LLW melter, 1 glass separator
Unit Size: 102 m3 (feed adjustment and feed tanks), 3.57 kg/s (head bin and weigh feeder), 1,268 kg/s (melter)
Unit Utilization (yrs): 13 (Boomer 1993)
Operating Efficiency: 60%
Radiation Level: Low
Temp: Ambient - 1300 degrees Celsius
Pressure: 0.04 psig
pH/Acidity/Alkalinity: 10 - 14
Energetic Reaction Potential: Very Low - Moderately High
Process Stability: Medium
% Solids in Waste: 100% (slurry stream), 0.5% (liquid stream)
Waste Form: Slurry, liquid
% Organics in Waste: 0% (slurry stream), 0% (liquid stream)
Flammability: Very Low - Moderately High

Mechanized Parts / Unit
High-level: 0
Low-level: 3 feeders, 1 glass separator
Cold: 0

Isolated Process Steps / Unit
High-level:
Low-level:
Cold:

ombined Installation Activities:

Combined Decontamination/ ommissioning Disposal/Activities
Decontaminations:
Decommissioning & Disposal:

Module: M.5, LLW Glass in Sulfur
Component / Unit Operation: M.5.C, LLW Glass Quencher

General Description: The molten glass flows through the water filled Quench Flume and produces cullet stored in the LLW Cullet Catch Tank. The vapor from the Quench Flume flows through a condenser and is rerouted back into the catch tank. The glass cullet is pumped through a screen to remove fines and oversize cullet before being sent to dry. A liquid waste stream is pumped from the screen into the LLW Filter Catch Tank before returning to the LLW Quench Water Recycle Tank. The stream is pumped through a chiller for cooling and then back into the quench flume. The unusable waste stream from the LLW Filter Catch Tank flows back to the LLW Melter Feed Adjustment Tank in the LLW Melter system (Boomer 1993).

Number of Units: 5 pumps, 2 catch tanks, 1 recycle tank, 1 quench flume, 1 roll crusher, 1 screen, 1 condenser, 1 chiller
Unit Size:
Unit Utilization (yrs): 13 (Boomer 1993)
Operating Efficiency: 60%
Radiation Level: Low
Temp: 40 - 100 degrees Celsius
Pressure: 0.04 psig
pH/Acidity/Alkalinity: 8 - 10
Energetic Reaction Potential: Very Low - Moderately Low
Process Stability:
% Solids in Waste: 98%
Waste Form: Solid
% Organics in Waste: 0%
Flammability: Very Low

Mechanized Parts / Unit
High-level: 5 pumps, 1 roll crusher, 1 chiller
Low-level: 0
Cold: 0

Isolated Process Steps / Unit
High-level:
Low-level:
Cold:

ombined Installation Activities:

Combined Decontamination/ ommissioning Disposal/Activities
Decontaminations:
Decommissioning & Disposal:

Module: M.5, LLW Glass in Sulfur
Component / Unit Operation: M.5.D, LLW Glass Cullet Drying

General Description: The LLW Cullet Lag Storage Receives cullet from the LLW Glass Quencher screen and air for drying and transport purposes. The air is circulated through two prefilters, then blown through two heaters and four HEPA filters before reaching the LLW Cullet Lag Storage. The vapors from the storage are sent through a condenser, with the condensate flowing back into a LLW Condensate Catch Tank. The condensate is pumped from this tank to process condensate treatment. The product from the LLW Cullet Lag Storage is sent to the LLW Cyclone System for further processing.

Number of Units: 1 LLW cullet lag storage, 1 catch tank, 4 HEPA filters, 2 prefilters, 2 heaters, 2 blowers, 1 condenser, 1 pump
Unit Size:
Unit Utilization (yrs): 13 (Boomer 1993)
Operating Efficiency: 60%
Radiation Level: Low
Temp: Ambient - 80 degrees C
Pressure: -4 to +4 psig
pH/Acidity/Alkalinity: 8 - 10
Energetic Reaction Potential: Very Low
Process Stability:
% Solids in Waste: 0.02% (condensed stream), 0% (condensate treatment stream), 19% (product stream)
Waste Form: liquid (condensed and condensate treatment streams), slurry (product stream)
% Organics in Waste: 0% (all streams)
Flammability: Very Low

Mechanized Parts / Unit
High-level: 0
Low-level: 2 blowers, 2 heaters, 1 pump
Cold: 0

Isolated Process Steps / Unit
High-level:
Low-level:
Cold:

ombined Installation Activities:

Combined Decontamination/
ommissioning Disposal/Activities
Decontaminations:
Decommissioning & Disposal:

Module: M.5, LLW Glass in Sulfur
Component / Unit Operation: M.5.E, LLW Cyclone System

General Description: The Cyclone with sintered metal filters receives the product stream from the LLW Cullet Lag Storage. Pulse air is added to the filter with the solid product flowing out through a Rotary Star Feeder into a day bin. Another Rotary Star Feeder sends the solids to be mixed with sulfur cement. The filter wash stream also exits the Cyclone. This stream passes through two heaters, four metal HEPA filters, and two blowers. A filter wash water stream also enters the metal HEPA filter process. The liquid stream is sent to the PVOG Cell Ventilation Filtration and Exhaust system, while the solids are sent to the Filter Wash Catch Tank. The filter wash stream is then pumped back to the LLW Evaporator Feed Tank in the LLW Evaporator system.

Number of Units: 4 metal HEPA filters, 2 heaters, 2 blowers, 2 Rotary Star Feeders, 1 cyclone (with 3 sintered metal filters), 1 day bin, 1 catch tank, 1 pump
Unit Size:
Unit Utilization (yrs): 13 (Boomer 1993)
Operating Efficiency: 60%
Radiation Level: Low
Temp: Ambient to -80 degrees Celsius
Pressure: -4 to +4 psig
pH/Acidity/Alkalinity: 8 - 10
Energetic Reaction Potential: Very Low
Process Stability:
% Solids in Waste: 100% (product stream), 0% (PVOG stream)
Waste Form: Solid (product stream), liquid (PVOG stream)
% Organics in Waste: 0%
Flammability: Very Low

Mechanized Parts / Unit
High-level: 0
Low-level: 2 feeders, 2 blowers, 1 pump
Cold: 0

Isolated Process Steps / Unit
High-level:
Low-level:
Cold:

ombined Installation Activities:

Combined Decontamination/ ommissioning Disposal/Activities
Decontaminations:
Decommissioning & Disposal:

Module: M.6, LLW Glass in Sulfur Vaults
Component / Unit Operation: M.6.A, Sulfur Cement Mixing

General Description: This system receives recovered sulfur and stores it in the Recovered Sulfur Storage Tank. This stream, along with bulk sulfur, bulk DCPD, and bulk CPD Oligomer, is pumped into two Sulfur Cement Mixing Tanks for mixing. The combined streams are then pumped through a cell wall and into the LLW Glass/Sulfur Mixer Unit to mix with the glass cullet.

Number of Units: 3 pumps, 2 mixing tanks, 1 storage tank
Unit Size:
Unit Utilization (yrs): 13 (Boomer 1993)
Operating Efficiency: 60%
Radiation Level: Low
Temp: ~130 degrees Celsius
Pressure: 0.04 psig
pH/Acidity/Alkalinity: NA
Energetic Reaction Potential: Low - Moderately Low
Process Stability:
% Solids in Waste: 0.01%
Waste Form: Liquid
% Organics in Waste: 0%
Flammability: Low - Moderately Low

Mechanized Parts / Unit
High-level: 0
Low-level: 3 pumps
Cold: 0

Isolated Process Steps / Unit
High-level:
Low-level:
Cold:

ombined Installation Activities:

Combined Decontamination/ ommissioning Disposal/Activities
Decontaminations:
Decommissioning & Disposal:

Module: M.6, LLW Glass in Sulfur Vaults
Component / Unit Operation: M.6.B, LLW Glass/Sulfur Mixer

General Description: The sulfur cement liquid stream from the Sulfur Cement Mixing System, in combination with the glass aggregate, flows into the mixer in the LLW Glass/Sulfur Mixer System. The mixing of the two forms a sulfur polymer cement that flows into the Surge Tank and then to the Sulfur Pump. From there, the cement is pumped through a heated pipeline into the disposal vault (Boomer 1993).

Number of Units: 1 mixer, 1 surge tank, 1 sulfur pump
Unit Size: 4.42E-3 m3/s (mixer), 0.26 m3 (surge tank), 4.42E-3 m3/s (sulfur pump)
Unit Utilization (yrs): 13 (Boomer 1993)
Operating Efficiency: 60%
Radiation Level: Low
Temp: ~130 degrees Celsius
Pressure: 0.04 - 50 psig
pH/Acidity/Alkalinity: NA
Energetic Reaction Potential: Low
Process Stability:
% Solids in Waste: 50%
Waste Form: Slurry
% Organics in Waste: 0%
Flammability: Low

Mechanized Parts / Unit
High-level: 0
Low-level: 1 mixer, 1pump
Cold: 0

Isolated Process Steps / Unit
High-level:
Low-level:
Cold:

ombined Installation Activities:

Combined Decontamination/ ommissioning Disposal/Activities
Decontaminations:
Decommissioning & Disposal:

Module: M.6, LLW Glass in Sulfur Vaults
Component / Unit Operation: M.6.C, Glass In Sulfur Disposal Vault

General Description: The disposal vault is filled with decanted molten sulfur polymer cement pumped from the sulfur pump. The glass in sulfur product stream also empties into this vault. Exhaust exits the vault and the decanted molten sulfur is decanted and sent to the Decanted Molten Sulfur Vault.

Number of Units: 1 disposal vault
Unit Size:
Unit Utilization (yrs): 13 (Boomer 1993)
Operating Efficiency: 60%
Radiation Level: Low
Temp: ~130 degrees Celsius
Pressure: 0.04 psig
pH/Acidity/Alkalinity: N/A
Energetic Reaction Potential: Low
Process Stability:
% Solids in Waste: 0% (exhaust), 0.01% (decanted molten sulfur)
Waste Form: Gas, liquid
% Organics in Waste: 0%
Flammability: Low

Mechanized Parts / Unit
High-level: 0
Low-level: 0
Cold: 0

Isolated Process Steps / Unit
High-level:
Low-level:
Cold:

ombined Installation Activities:

Combined Decontamination/ ommissioning Disposal/Activities
Decontaminations:
Decommissioning & Disposal:

Module: M.6, LLW Glass in Sulfur Vaults
Component / Unit Operation: M.6.D, Decanted Molten Sulfur Vault

General Description: The Decanted Molten Sulfur Vault receives the decanted molten sulfur from the disposal vault and stores it. The remaining gasses are released through heat traced piping out into the LLW Glass/Sulfur Mixer System.

Number of Units: 1 decanted molten sulfur vault
Unit Size:
Unit Utilization (yrs): 13 (Boomer 1993)
Operating Efficiency: 60%
Radiation Level: Low
Temp: ~130 degrees Celsius
Pressure: 0.04 psig
pH/Acidity/Alkalinity: N/A
Energetic Reaction Potential: Low
Process Stability:
% Solids in Waste: 0.01%
Waste Form: Gas
% Organics in Waste: 0%
Flammability: Low

Mechanized Parts / Unit
High-level: 0
Low-level: 0
Cold: 0

Isolated Process Steps / Unit
High-level:
Low-level:
Cold:

ombined Installation Activities:

Combined Decontamination/ ommissioning Disposal/Activities
Decontaminations:
Decommissioning & Disposal:

Module: M.7, HLW Glass Cullet Feed Lag Storage
Component / Unit Operation: M.7.A, HLW Feed Accumulation

General Description: This process receives HLW slurry waste from the Sludge Wash operation. This HLW is contained in a HLW Accumulation Tank until it is transferred to a HLW Feed Transfer Tank for further processing. The lag storage provides capacity when retrieval startup precedes separations or when retrieval rates exceed separation processing rates (Boomer 1993).

Number of Units: 1 accumulation tank, 2 pumps
Unit Size:
Unit Utilization (yrs): 13 (Boomer 1993)
Operating Efficiency: 60%
Radiation Level: High
Temp: Ambient
Pressure: 0.04 psig
pH/Acidity/Alkalinity: 8 - 10
Energetic Reaction Potential: Very Low
Process Stability:
% Solids in Waste: 20%
Waste Form: Slurry
% Organics in Waste: 0.07%
Flammability: Low

Mechanized Parts / Unit
High-level: 2 pumps
Low-level: 0
Cold: 0

Isolated Process Steps / Unit
High-level:
Low-level:
Cold:

ombined Installation Activities: 2 pumps, piping

Combined Decontamination/
ommissioning Disposal/Activities
Decontaminations:
Decommissioning & Disposal:

Module: M.7, HLW Glass Cullet Feed Lag Storage
Component / Unit Operation: M.7.B, HLW Feed Transfer Tank

General Description: This process receives waste from the HLW Feed Accumulation Tank. The waste is then pumped to a HLW Centrifuge System for further processing.

Number of Units: 1 transfer tank, 2 pumps
Unit Size: 56.8 m3 (feed transfer tank)
Unit Utilization (yrs): 13 (Boomer 1993)
Operating Efficiency: 60%
Radiation Level: High
Temp: Ambient
Pressure: 0.04 psig
pH/Acidity/Alkalinity: 8 - 10
Energetic Reaction Potential: Very Low
Process Stability:
% Solids in Waste: 20%
Waste Form: Slurry
% Organics in Waste: 0.07%
Flammability: Low

Mechanized Parts / Unit
High-level: 2 pumps
Low-level: 0
Cold: 0

Isolated Process Steps / Unit
High-level:
Low-level:
Cold:

ombined Installation Activities:

Combined Decontamination/
ommissioning Disposal/Activities
Decontaminations:
Decommissioning & Disposal:

Module: M.8, HLW Glass Cullet
Component / Unit Operation: M.8.A, HLW Centrifuge System

General Description: This process initially receives slurry waste from the HLW Feed Transfer Tank to Receipt/Sample Tanks. The slurry is then pumped to Centrifuge Feed Tanks for final processing before entering the centrifuge system. Centrate from the centrifuge is then pumped to HLW Evaporator Feed Tanks. The slurry from the Centrifuge Solids Catch Tank is pumped to HLW Melter Feed Adjustment Tanks.

Number of Units: 9 pumps, 6 receipt/sample tanks, 4 catch tanks, 2 feed tanks, 2 centrifuges
Unit Size: 56.8 m3 (feed tanks), 28.8 m3 (catch tanks)
Unit Utilization (yrs): 13 (Boomer 1993)
Operating Efficiency: 60%
Radiation Level: High
Temp: Ambient
Pressure: 0.04 psi
pH/Acidity/Alkalinity: 8 - 10
Energetic Reaction Potential: Very Low - Low
Process Stability:
% Solids in Waste: 0.1% (centrate), 23% (slurry)
Waste Form: Slurry
% Organics in Waste: 0% (centrate), 0.07% (slurry)
Flammability: Very Low - Low

Mechanized Parts / Unit
High-level: 9 pumps
Low-level: 0
Cold: 0

Isolated Process Steps / Unit
High-level:
Low-level:
Cold:

ombined Installation Activities: 9 pumps, piping

Combined Decontamination/ ommissioning Disposal/Activities
Decontaminations:
Decommissioning & Disposal:

Module: M.8, HLW Glass Cullet
Component / Unit Operation: M.8.B, HLW Melter System

General Description: The HLW Melter Feed Adjustment Tanks receive slurries from the Centrifuge Solids Catch Tank, the Rework Catch Tank, Cs IX Concentration Catch Tank, and the filter bed. Oxygen and kerosene are added to aid in combustion. The LLW melter also receives bulk glass formers from a weigh feeder equipped with a rotary feeder. The vapors from the melter are separated from the stream by a glass separator. The lag is then introduced to the quench flume roll crusher along with recycle condensate to produce HLW glass cullets.

Number of Units: 4 feed tanks, 2 feeders, 1 head bin, 1 HLW melter, 1 glass separator
Unit Size:
Unit Utilization (yrs): 13 (Boomer 1993)
Operating Efficiency: 60%
Radiation Level: High
Temp: Ambient - 1300
Pressure: 0.04 psi
pH/Acidity/Alkalinity: 8 - 12
Energetic Reaction Potential: Very Low - Moderately High
Process Stability:
% Solids in Waste: 100% (solid stream), 0% (vapor stream)
Waste Form: solid and vapor
% Organics in Waste: 0%
Flammability: Very Low - Moderately Low

Mechanized Parts / Unit
High-level: 2 pumps, 2 feeders, 1 separator
Low-level: 0
Cold: 0

Isolated Process Steps / Unit
High-level:
Low-level:
Cold:

ombined Installation Activities: 2 pumps and piping, bin and feeders

Combined Decontamination/ ommissioning Disposal/Activities
Decontaminations:
Decommissioning & Disposal:

Module: M.8, HLW Glass Cullet
Component / Unit Operation: M.8.C, HLW Evaporator

General Description: High level waste streams from the Centrate Catch Tank and HLW Melter Filter Wash are contained in the HLW Evaporator Feed Tank. This stream is then pumped to the HLW evaporator where the water vapor is condensed and the HLW is transferred to a HLW Evaporator Catch Tank. The condensate is treated and the HLW portion is pumped back to the centrifuge for further treatment.

Number of Units: 2 pumps, 1 feed tank, 1 catch tank, 1 evaporator, 1 condenser
Unit Size: 204.4 m3 (feed tank), 204.4 m3 (catch tank)
Unit Utilization (yrs): 13 (Boomer 1993)
Operating Efficiency: 60%
Radiation Level: High
Temp: Ambient - 110
Pressure: 0.04 psi
pH/Acidity/Alkalinity: 8 - 10
Energetic Reaction Potential: Very Low - Low
Process Stability:
% Solids in Waste: 0%
Waste Form: Water vapor
% Organics in Waste: 0%
Flammability: Low - Moderately Low

Mechanized Parts / Unit
High-level: 2 pumps
Low-level: 0
Cold: 0

Isolated Process Steps / Unit
High-level:
Low-level:
Cold:

ombined Installation Activities:

Combined Decontamination/ ommissioning Disposal/Activities
Decontaminations:
Decommissioning & Disposal:

Module: M.8, HLW Glass Cullet
Component / Unit Operation: M.8.D, HLW Glass Quencher

General Description: The lag from the HLW Melter is introduced to the Quench Flume Roll Crusher along with recycle condensate to produce HLW cullets. The HLW cullets are contained in a catch tank where they are pumped then screened. The filtrate is reprocessed and the lag is distributed to a HLW Cullet Lag Storage.

Number of Units: 5 pumps, 2 catch tanks, 2 condensers, 1 recycle tank, 1 screen, 1 quencher
Unit Size: 204.4 m3 (catch tanks), 5.67 Kg/s (condensers)
Unit Utilization (yrs): 13 (Boomer 1993)
Operating Efficiency: 60%
Radiation Level: High
Temp: 40 - 100 degrees C
Pressure: 0.04 psig
pH/Acidity/Alkalinity: 8 - 10
Energetic Reaction Potential: Very Low - Moderately Low
Process Stability:
% Solids in Waste: 98%
Waste Form: solid
% Organics in Waste: 0%
Flammability: Very Low - Low

Mechanized Parts / Unit
High-level: 5 pumps, quencher
Low-level: 0
Cold: 0

Isolated Process Steps / Unit
High-level:
Low-level:
Cold:

ombined Installation Activities: pumps, condenser, piping

Combined Decontamination/ ommissioning Disposal/Activities
Decontaminations:
Decommissioning & Disposal:

Module: M.8, HLW Glass Cullet
Component / Unit Operation: M.8.E, HLW Glass Cullet Drying

General Description: This process introduces drying and transport air to the HLW Cullet Lag Storage tank. A vapor and a solid stream exit the storage tanks. The vapor is condensed and subsequently contained in a catch tank. The solid stream is divided into a product stream, that is routed to a separations process, and a rework stream that is routed for condensate treatment.

Number of Units: 4 HEPA filters, 2 prefilters, 2 blowers, 1 pump, 1 catch tank, 1 condenser, 1 lag storage tank.
Unit Size: 204.4 m3 (catch tank), 5.67 Kg/s (condenser)
Unit Utilization (yrs): 13 (Boomer 1993)
Operating Efficiency: 60%
Radiation Level: High
Temp: 30 - 200 degrees Celsius
Pressure: -4 to +4 psig
pH/Acidity/Alkalinity: 8 - 10
Energetic Reaction Potential: Very Low
Process Stability:
% Solids in Waste: 12% (product and rework streams)
Waste Form: Slurry
% Organics in Waste: 0%
Flammability: Very Low

Mechanized Parts / Unit
High-level: 1 pump
Low-level: 0
Cold: 2 blowers

Isolated Process Steps / Unit
High-level:
Low-level:
Cold:

ombined Installation Activities: blower, filters, piping

Combined Decontamination/ ommissioning Disposal/Activities
Decontaminations:
Decommissioning & Disposal:

Module: M.8, HLW Glass Cullet
Component / Unit Operation: M.8.F, HLW Cyclone System

General Description: Solids from the HLW cullet slurry are separated by a cyclone with sintered metal filters. The slurry is fed to the next system, the day bin, via a Rotary Star Feeder. The filtered material is sent through two heaters, four metal HEPA filters, and two blowers. Filter flush water is run through the filters and collected in the Filter Wash Catch Tank before being pumped to the evaporator feed tank in a previous system. The remaining stream is released to cell ventilation filtration and exhaust sytem.

Number of Units: 4 HEPA filters, 2 blowers, 1 cyclone, 2 rotary star feeders, 1 day bin
Unit Size:
Unit Utilization (yrs): 13 (Boomer 1993)
Operating Efficiency: 60%
Radiation Level: High
Temp: ambient - 200 C
Pressure: -4 to +4
pH/Acidity/Alkalinity: 8 - 10
Energetic Reaction Potential: Very low
Process Stability:
% Solids in Waste: 100% (solid stream), 1% (liquid stream)
Waste Form Solid, liquid
% Organics in Waste: 0% (both)
Flammability: Very low

Mechanized Parts / Unit
High-level: 3 feeders, 2 blowers
Low-level: 0
Cold: 0

Isolated Process Steps / Unit
High-level:
Low-level:
Cold:

ombined Installation Activities:

Combined Decontamination/ ommissioning Disposal/Activities
Decontaminations:
Decommissioning & Disposal:

Module: M.9, HLW Glass Cullet Cask Storage Pad
Component / Unit Operation: M.9.A, Air Pallets

General Description: This unit is the HLW packaging and loadout line made up of five air pallets. The air pallets are: cask fill station, cask closure station, primary cask decontamination station, final cask decontamination station, and cask loadout station. Casks are positioned on top of these air pallets.

Number of Units: 5 air pallets
Unit Size:
Unit Utilization (yrs): 13 (Boomer 1993)
Operating Efficiency: 60%
Radiation Level: High
Temp: 50 - 200 C
Pressure: 0.04 psi
pH/Acidity/Alkalinity: N/A
Energetic Reaction Potential: Very low
Process Stability: 100%
% Solids in Waste: Solid
% Organics in Waste: 0%
Flammability: Very low

Mechanized Parts / Unit
High-level: 0
Low-level: 0
Cold: 0

Isolated Process Steps / Unit
High-level:
Low-level:
Cold:

ombined Installation Activities:

Combined Decontamination/
ommissioning Disposal/Activities
Decontaminations:
Decommissioning & Disposal:

Module: M.9, HLW Glass Cullet Cask Storage Pad
Component / Unit Operation: M.9.B, Repository

General Description: This unit receives HLW glass cullets, stored in casks, from the Cask Storage Pads, and stores them.

Number of Units:
Unit Size:
Unit Utilization (yrs): 13 (Boomer 1993)
Operating Efficiency: 60%
Radiation Level: High
Temp: 50 - 200 C
Pressure: 0.04 psi
pH/Acidity/Alkalinity: N/A
Energetic Reaction Potential: Very low
Process Stability:
% Solids in Waste: 100%
Waste Form: Solid
% Organics in Waste: 0%
Flammability: Very low

Mechanized Parts / Unit
High-level:
Low-level:
Cold:

Isolated Process Steps / Unit
High-level:
Low-level:
Cold:

ombined Installation Activities:

Combined Decontamination/
ommissioning Disposal/Activities
Decontaminations:
Decommissioning & Disposal:

Module: M.10, Cullet Rework and Melter Off-Gas Processing
Component / Unit Operation: M.10.A, Cyclone System

General Description: This system receives LLW and HLW glass cullet from lag storage and sends it through the cyclone with sintered metal filters. A Rotary Star Feeder sends the cullet through a roll crusher and into a Recycle Cullet Catch Tank. The LLW and HLW streams are then pumped to the appropriate Melter Feed Adjustment Tank. The waste flows through a filter system consisting of two heaters, four metal HEPA filters and two blowers. A filter wash water stream flows through the filters and is collected in the filter wash catch tank before being pumped to the Filter Wash LLW Evaporator Feed Tank. The remaining waste flows to the PVOG Cell
Number of Units: 4 metal HEPA filters, 2 heaters, 2 blowers, 2 catch tanks, 2 pumps, 1 cyclone, 1 Rotary Star Feeder, 1 roll crusher
Unit Size:
Unit Utilization (yrs): 13 (Boomer 1993)
Operating Efficiency: 60%
Radiation Level: High
Temp: ambient - 200 C
Pressure: -4 to +4
pH/Acidity/Alkalinity: 8 - 10
Energetic Reaction Potential: Very low
Process Stability:
% Solids in Waste: 0% (PVOG stream), 1% (filter wash)
Waste Form: Liquid
% Organics in Waste: 0%
Flammability: Very Low - Low

Mechanized Parts / Unit
High-level: 1 pump, 1 feeder, 1 roll crusher
Low-level: 2 blowers, 1 pump
Cold: 0

Isolated Process Steps / Unit
High-level:
Low-level:
Cold:

ombined Installation Activities:

Combined Decontamination/
ommissioning Disposal/Activities
Decontaminations:
Decommissioning & Disposal:

Module: M.10, Cullet Rework and Melter Off-Gas Processing
Component / Unit Operation: M.10.B, HLW Separator

General Description: The HLW Quench Tower receives a gas stream which is sprayed with HLW scrub solution from the HLW Scrub Solution Tank. The gas stream then is sent through the HLW Venturi Scrubber, while the scrub solution is sent back to the HLW Scrub Solution Tank. The Venturi Scrubber also uses HLW scrub solution that is pumped through a chiller. The waste stream from the HLW Venturi Scrubber is separated, with the gas stream sent through a chiller and HLW demister and the liquid sent back to the HLW Scrub Solution Tank. The HLW demister is fed from a separate wash water stream. Again, the liquid and gas streams are separated. The Scrub Solution Makeup Tank feeds the HLW Scrub Solution Tank and the LLW tank in the LLW system. The HLW from the Scrub Solution Tank is pumped out for further treatment. The gas stream is sent through two heaters, four metal HEPA filters, and two blowers. The gas flows to the next system and the filter wash flows to the HLW Melter Filter Wash Catch Tank before being pumped to another system for evaporation.

Number of Units: 4 metal HEPA filters, 3 pumps, 2 heaters, 2 blowers, 2 solution tanks, 2 chillers, 1 HLW quench tower, 1 catch tank, 1 HLW Venturi Scrubber, 1 HLW separator, 1 HLW demister
Unit Size:
Unit Utilization (yrs): 13 (Boomer 1993)
Operating Efficiency: 60%
Radiation Level: High
Temp: ambient - 75 C
Pressure: 0.04 psi
pH/Acidity/Alkalinity: <1 - 10
Energetic Reaction Potential: Very Low - Moderately Low
Process Stability:
% Solids in Waste: 0% (gas stream), 0.1% (liquid stream), 0.9% (filter wash)
Waste Form: Gas, liquid
% Organics in Waste: 0%
Flammability: Very low

Mechanized Parts / Unit
High-level: 3 pumps, 2 blowers, 1 scrubber
Low-level: 0
Cold: 0

Isolated Process Steps / Unit
High-level:
Low-level:
Cold:

ombined Installation Activities:

Combined Decontamination/ ommissioning Disposal/Activities
Decontaminations:
Decommissioning & Disposal:

Module: M.10, Cullet Rework and Melter Off-Gas Processing
Component / Unit Operation: M.10.C, NOx/SO2 Separator

General Description: The gas stream entering this system is a combination of two gas streams from the LLW and HLW separator systems and an oxygen stream. The stream passes through a melter offgas heat exchanger and splits into two streams. One stream flows through a heater and into an SO2 absorber (one of three CuO beds). Another gas stream exits the SO2 absorber, flows through another heater and enters the NOx catalytic reactor. The gas stream that exits this reactor flows back to the original heat exchanger. NH3 also enters the system, breaking into two streams. One of the streams flows into theNOx catalytic reactor and the other flows through the NH3 cracker. H2 is the resulting gas stream of the NH3 cracker and flows into the CuO bed for sulfate reduction. The sulfate reduced gas stream exits this CuO bed and is sent to the Claus Reactor System. The

Number of Units: 3 CuO beds, 2 heaters, 1 heat exchanger, 1 catalytic reactor, 1 cracker
Unit Size:
Unit Utilization (yrs): 13 (Boomer 1993)
Operating Efficiency: 60%
Radiation Level: Low (traces of nuclides exist)
Temp: 400 - 500 C
Pressure: 1 - 2 psig
pH/Acidity/Alkalinity: N/A
Energetic Reaction Potential: Moderately Low - Moderate
Process Stability:
% Solids in Waste: 0%
Waste Form: Gas
% Organics in Waste: 0%
Flammability: Very Low - Moderate

Mechanized Parts / Unit
High-level: 0
Low-level: 0
Cold: 0

Isolated Process Steps / Unit
High-level:
Low-level:
Cold:

ombined Installation Activities:

Combined Decontamination/ ommissioning Disposal/Activities
Decontaminations:
Decommissioning & Disposal:

Module: M.10, Cullet Rework and Melter Off-Gas Processing
Component / Unit Operation: M.10.D, LLW Separator

General Description: The LLW quench tower receives a gas stream which is sprayed with LLW scrub solution from the LLW Scrub Solution Tank. The gas stream then is sent through the LLW Venturi Scrubber, while the scrub solution is sent back to the LLW Scrub Solution Tank. The Venturi Scrubber also uses LLW scrub solution that is pumped through a chiller. The waste stream from the LLW Venturi Scrubber is separated, with the gas stream sent through a chiller and LLW demister and the liquid sent back to the LLW Scrub Solution Tank. The LLW demister is fed from a separate wash water stream. Again, the liquid and gas streams are separated. The Scrub Solution Makeup Tank feeds the LLW Scrub Solution Tank. The LLW from the Scrub Solution Tank is pumped out and filtered, with the LLW scrub filter entering the LLW Scrub Filter Tank. The gas stream is sent through a filtration system including four metal HEPA filters. The gas flows to the next system and the filter wash slurry flows to the LLW Melter Filter Wash Catch Tank before being pumped to another system for evaporation.
Number of Units: 4 metal HEPA filters, 3 pumps, 2 heaters, 2 blowers, 2 solution tanks, 2 chillers, 1 LLW quench tower, 1 catch tank, 1 filter tank, 1 LLW Venturi Scrubber, 1 LLW separator, 1 LLW demister
Unit Size:
Unit Utilization (yrs): 13 (Boomer 1993)
Operating Efficiency: 60%
Radiation Level: Low
Temp: ambient - 75 C
Pressure: 0.04 psi
pH/Acidity/Alkalinity: 3 - 10
Energetic Reaction Potential: Very Low - Moderately Low
Process Stability:
% Solids in Waste: 0% (gas stream), 14% (slurry stream), 100% (filter wash)
Waste Form: Gas, slurry, solid
% Organics in Waste: 0% (all streams)
Flammability: Very low

Mechanized Parts / Unit
High-level: 4 pumps, 2 blowers
Low-level: 0
Cold: 0

Isolated Process Steps / Unit
High-level:
Low-level:
Cold:

ombined Installation Activities:

Combined Decontamination/ ommissioning Disposal/Activities
Decontaminations:
Decommissioning & Disposal:

Module: M.10, Cullet Rework and Melter Off-Gas Processing
Component / Unit Operation: M.10.E, Claus Reactor System

General Description: This system receives air, fuel, and a gas stream from the NOx/SO2 separator into a combustion chamber at various entry points. The resulting stream flows through a heat exchanger and splits into two streams. One flows through another air heat exchanger andjoins a gas stream entering one of two Claus Reactors. The gas stream may flow out of the system. The other gas stream flows into the second Claus reactor The gas exiting each of the two reactors flow through air heat exchangers for cooling. The first reactor gas stream either flows back into the original heat exchanger for further processing or out of the system. The gas stream from the second reactor either flows out of the system or flows through a sulfur trap and to a tail gas incinerator. The stream from the sulfur trap flows out of the system. The tail gas incinerator also takes in air and fuel for incineration. The resulting gas stream is sent to flare.
Number of Units: 3 air heat exchangers, 2 Claus Reactors, 1 combustion chamber, 1 tail gas incinerator, 1 heat exchanger, 1 sulfur trap
Unit Size:
Unit Utilization (yrs): 13 (Boomer 1993)
Operating Efficiency: 60%
Radiation Level: Low (traces of nuclides exist)
Temp: 250 - 800 C
Pressure: 1 - 2 psig
pH/Acidity/Alkalinity: N/A
Energetic Reaction Potential: Low to Moderate
Process Stability:
% Solids in Waste: 0%
Waste Form: Gas
% Organics in Waste: 0%
Flammability: Low to Moderately Low

Mechanized Parts / Unit
High-level:
Low-level: 0
Cold: 0

Isolated Process Steps / Unit
High-level:
Low-level:
Cold:

ombined Installation Activities: piping

Combined Decontamination/ ommissioning Disposal/Activities
Decontaminations:
Decommissioning & Disposal:

Module: M.11, Liquid Effluent Treatment Facility
Component / Unit Operation: M.11.A, Process Condensate Recycle

General Description: The Process Condensate Recycle Tanks receive a combination stream made up of five streams: supernate evaporator, LLW feed evaporator, HLW feed evaporator, HLW cullet drying condensate, and LLW cullet drying condensate. The treatment process condensate and the recycled stream are pumped out of the tanks.

Number of Units: 3 recycle tanks, 2 pumps
Unit Size:
Unit Utilization (yrs): 13 (Boomer 1993)
Operating Efficiency: 60%
Radiation Level: Low (traces of nuclides exist)
Temp: ambient - 40
Pressure: 0.04 psi
pH/Acidity/Alkalinity: 8 - 10
Energetic Reaction Potential: Very low
Process Stability:
% Solids in Waste: 0% (recycled stream), 0% (condensate stream)
Waste Form: Liquid
% Organics in Waste: 0% (recycled stream), 0% (condensate stream)
Flammability: Very low

Mechanized Parts / Unit
High-level: 0
Low-level: 0
Cold: 2 pumps

Isolated Process Steps / Unit
High-level:
Low-level:
Cold:

ombined Installation Activities: 2 pumps, piping

Combined Decontamination/ ommissioning Disposal/Activities
Decontaminations:
Decommissioning & Disposal:

Module: M.11, Liquid Effluent Treatment Facility
Component / Unit Operation: M.11.B, pH Adjustment Tank

General Description: The treatment process condensate stream and bulk NaOH enter the pH Adjustment Tank for adjustmient. Two streams are then pumped out of the tank. One is off specification condensate going to the tank farms. The other enters the Retention Basin.

Number of Units: 2 pumps, 1 adjustment tank
Unit Size:
Unit Utilization (yrs): 13 (Boomer 1993)
Operating Efficiency: 60%
Radiation Level: Low (traces of nuclides exist)
Temp: ambient
Pressure: 0.04 psi
pH/Acidity/Alkalinity: 8 - 10
Energetic Reaction Potential: Low
Process Stability:
% Solids in Waste: 0% (both streams)
Waste Form: Liquid (both streams)
% Organics in Waste: 0% (both streams)
Flammability: Very low

Mechanized Parts / Unit
High-level: 2 pumps
Low-level: 0
Cold: 0

Isolated Process Steps / Unit
High-level:
Low-level:
Cold:

ombined Installation Activities:

Combined Decontamination/ ommissioning Disposal/Activities
Decontaminations:
Decommissioning & Disposal:

Module: M.11, Liquid Effluent Treatment Facility
Component / Unit Operation: M.11.C, Retention Basin

General Description: This unit consists of a retention basin for adjusted treatment process condensate.
Number of Units: 1 retention basin
Unit Size:
Unit Utilization (yrs): 13 (Boomer 1993)
Operating Efficiency: 60%
Radiation Level: Low (traces of nuclides exist)
Temp: ambient
Pressure: 0.04 psi
pH/Acidity/Alkalinity: 8 - 10
Energetic Reaction Potential: Very low
Process Stability:
% Solids in Waste: 0%
Waste Form: Liquid
% Organics in Waste: 0%
Flammability: Very low

Mechanized Parts / Unit
High-level: 0
Low-level: 0
Cold: 0

Isolated Process Steps / Unit
High-level:
Low-level:
Cold:

ombined Installation Activities:

Combined Decontamination/
ommissioning Disposal/Activities
Decontaminations:
Decommissioning & Disposal:

Module: M.12, Chemical Make-up Unit
Component / Unit Operation: M.12.A, Dry Storage

General Description: This unit contains three separate dry storage areas with barrels containing bulk frit, bulk flocculent, and bulk NaNO2. From these areas the solids are sent to their appropriate tanks for use.

Number of Units: 3 storage areas
Unit Size:
Unit Utilization (yrs): N/A
Operating Efficiency: 60%
Radiation Level: Cold
Temp: Ambient
Pressure: Ambient
pH/Acidity/Alkalinity: 7 - 8
Energetic Reaction Potential: Very Low
Process Stability:
% Solids in Waste: 100%
Waste Form: Solid
% Organics in Waste: 0%
Flammability: Very Low

Mechanized Parts / Unit
High-level: 0
Low-level: 0
Cold: 0

Isolated Process Steps / Unit
High-level: 0
Low-level: 0
Cold: 0

ombined Installation Activities: piping

Combined Decontamination/ ommissioning Disposal/Activities
Decontaminations:
Decommissioning & Disposal:

Module: M.12, Chemical Make-up Unit
Component / Unit Operation: M.12.B, Bulk Liquid Storage

General Description: This unit is made up of six storage tanks containing bulk liquids to be used in various processes. The tanks are the Bulk Sulfur Storage Tank, the bulk DCPD Storage Tank, the Bulk CPD Oligomer Storage Tank, the Bulk NaOH Storage Tank, the Bulk HNO3 Storage Tank, and the Bulk Anhydrous NH3 Storage Tank.
Number of Units: 6 storage tanks, 6 pumps
Unit Size: 5.68 m3
Unit Utilization (yrs): N/A
Operating Efficiency: 60%
Radiation Level: Cold
Temp: Ambient - 120 degrees C
Pressure: 0.04 - 120 psig
pH/Acidity/Alkalinity: <1 to >14
Energetic Reaction Potential: Low - Moderate
Process Stability:
% Solids in Waste: 0%
Waste Form: Liquid
% Organics in Waste: 0%
Flammability: Very Low - Moderately High

Mechanized Parts / Unit
High-level: 0
Low-level: 0
Cold: 6 pumps

Isolated Process Steps / Unit
High-level: 0
Low-level: 0
Cold: 0

ombined Installation Activities:

Combined Decontamination/ ommissioning Disposal/Activities
Decontaminations:
Decommissioning & Disposal:

Module: M.12, Chemical Make-up Unit
Component / Unit Operation: M.12.C, Bulk H2O Storage

General Description: This unit contains one Bulk H2O Storage Tank filled by water from site services to be used in various processes.

Number of Units: 1 storage tank
Unit Size: 568 m3
Unit Utilization (yrs): N/A
Operating Efficiency: 60%
Radiation Level: Cold
Temp: Ambient
Pressure: 0.04 psi
pH/Acidity/Alkalinity: Neutral
Energetic Reaction Potential: Very Low
Process Stability:
% Solids in Waste: 0%
Waste Form: Liquid
% Organics in Waste: 0%
Flammability: Very Low

Mechanized Parts / Unit
High-level: 0
Low-level: 0
Cold: 0

Isolated Process Steps / Unit
High-level: 0
Low-level: 0
Cold: 0

ombined Installation Activities:

Combined Decontamination/
ommissioning Disposal/Activities
Decontaminations:
Decommissioning & Disposal:

Module: M.12, Chemical Make-up Unit
Component / Unit Operation: M.12.D, Bulk Combustible Liquid Storage

General Description: This unit is made up of three bulk liquid tanks containing O2, N2, and kerosene respectively. These liquids will be piped to various locations.

Number of Units: 3 storage tanks
Unit Size:
Unit Utilization (yrs): N/A
Operating Efficiency: 60%
Radiation Level: Cold
Temp: Low - Ambient
Pressure: Ambient - High
pH/Acidity/Alkalinity: Neutral
Energetic Reaction Potential: Very Low - Moderate
Process Stability:
% Solids in Waste: 0%
Waste Form: Liquid
% Organics in Waste: 0%
Flammability: Very Low - Moderate

Mechanized Parts / Unit
High-level: 0
Low-level: 0
Cold: 0

Isolated Process Steps / Unit
High-level: 0
Low-level: 0
Cold: 0

ombined Installation Activities:

Combined Decontamination/
ommissioning Disposal/Activities
Decontaminations:
Decommissioning & Disposal:

Module: M.12, Chemical Make-up Unit
Component / Unit Operation: M.12.E, Glass Melter Batch Mixers

General Description: This unit has seven storage bins containing sand, Al2O3, Na2O3, Na2CO3, B2O3, Li2CO3, CaO, and MgO respectively. Sand, Al2O3, B2O3, and CaO flow into one of two batch mixers and sand, Na2CO3, B2O3, Li2CO3, CaO, and MgO flow into the other.

Number of Units: 7 storage bins, 2 batch mixers
Unit Size:
Unit Utilization (yrs): N/A
Operating Efficiency: 60%
Radiation Level: Cold
Temp: ambient
Pressure: ambient
pH/Acidity/Alkalinity: ~10 - 12
Energetic Reaction Potential: Very low
Process Stability:
% Solids in Waste: 100%
Waste Form: Solid
% Organics in Waste: 0%
Flammability: Very low

Mechanized Parts / Unit
High-level: 0
Low-level: 0
Cold: 2 batch mixers

Isolated Process Steps / Unit
High-level: 0
Low-level: 0
Cold: 0

ombined Installation Activities:

Combined Decontamination/
ommissioning Disposal/Activities
Decontaminations:
Decommissioning & Disposal:

Module: M.13, Air/Vapor Filtration System
Component / Unit Operation: M.13.A, CVOG/VOG System

General Description: This system filters CVOG and VOG using metal HEPA filters. The first stream received is a combination of streams from the supernate evaporator, first cycle Cs IX concentrator, LLW feed evaporator, and HLW feed evaporator. This stream is heated, filtered, and blown out to the Process Stack Filter system. The resulting filter wash flows into the CVOG/VOG Filter Wash Catch Tank before being pumped out of the system. The second filter system receives a stream from the Vessel Vent System. It also passes through heaters, metal HEPA filters, and blowers before exiting. The filter wash from this process flows to the catch tank.

Number of Units: 8 metal HEPA filters, 4 heaters, 4 blowers, 1 catch tank, 1 pump
Unit Size:
Unit Utilization (yrs): 13 (Boomer 1993)
Operating Efficiency: 60%
Radiation Level: Low
Temp: ambient
Pressure: 0.04 psi
pH/Acidity/Alkalinity: 8 - 10
Energetic Reaction Potential: Very low
Process Stability:
% Solids in Waste: 0%
Waste Form: Gas
% Organics in Waste: 0%
Flammability: Very low

Mechanized Parts / Unit
High-level: 4 blowers
Low-level: 1 pump
Cold: 0

Isolated Process Steps / Unit
High-level: 0
Low-level: 0
Cold: 0

ombined Installation Activities: 1 pump, piping

Combined Decontamination/
ommissioning Disposal/Activities
Decontaminations:
Decommissioning & Disposal:

Module: M.13, Air/Vapor Filtration System
Component / Unit Operation: M.13.B, VOG/CVOG/PVOG Air Supply System

General Description: Supply air is blown through two prefilters, two heaters, four HEPA filters, and a process cell. The air is filtered for use in the Process Stack Filter System.

Number of Units: 4 HEPA filters, 2 prefilters, 2 blowers, 2 heaters
Unit Size:
Unit Utilization (yrs): N/A
Operating Efficiency: 60%
Radiation Level: Cold
Temp: 25 - 35 degrees C
Pressure: <1 psig
pH/Acidity/Alkalinity: NA
Energetic Reaction Potential: Very low
Process Stability:
% Solids in Waste: 0%
Waste Form: Gas
% Organics in Waste: 0%
Flammability: Very low

Mechanized Parts / Unit
High-level: 0
Low-level: 0
Cold: 2 blowers, 2 heaters

Isolated Process Steps / Unit
High-level:
Low-level:
Cold:

ombined Installation Activities: piping

Combined Decontamination/
ommissioning Disposal/Activities
Decontaminations:
Decommissioning & Disposal:

Module: M.13, Air/Vapor Filtration System
Component / Unit Operation: M.13.C, Process Stack Filter System

General Description: A fugitive leak stream and filtered supply air combine and flow through metal prefilters and heaters before being joined by PVOG/VOG streams. The combined stream flows through metal HEPA filters and HEPA filters and is blown to the process facility stack for processing. The filter wash from the filters flows to the Filter Wash Catch Tank.

Number of Units: 2 metal prefilters, 2 metal HEPA filters, 2 HEPA filters, 2 heaters, 2 blowers, 1 catch tank, 1 process facility stack, 1 pump
Unit Size:
Unit Utilization (yrs): 13 (Boomer 1993)
Operating Efficiency: 60%
Radiation Level: Low
Temp: ambient
Pressure: 0.04 psig
pH/Acidity/Alkalinity: 8 - 10
Energetic Reaction Potential: Very low
Process Stability:
% Solids in Waste: 1%
Waste Form: Liquid
% Organics in Waste: 0%
Flammability: Very low

Mechanized Parts / Unit
High-level: 2 blowers, 1 pump
Low-level: 0
Cold: 0

Isolated Process Steps / Unit
High-level:
Low-level:
Cold:

ombined Installation Activities:

Combined Decontamination/
ommissioning Disposal/Activities
Decontaminations:
Decommissioning & Disposal:

Module: M.13, Air/Vapor Filtration System
Component / Unit Operation: M.13.D, BVOG System

General Description: One gas stream from HLW and LLW storage bin vents enters this filtration system. The stream passes through two heaters, four metal HEPA filters, and two blowers before entering the Storage Stack System.

Number of Units: 4 metal HEPA filters, 2 heaters, 2 blowers
Unit Size:
Unit Utilization (yrs): 13 (Boomer 1993)
Operating Efficiency: 60%
Radiation Level: High
Temp: 25 - 35 degrees C
Pressure: 0.04 psig
pH/Acidity/Alkalinity: NA
Energetic Reaction Potential: Very low
Process Stability:
% Solids in Waste: 0.02%
Waste Form: Gas
% Organics in Waste: 0%
Flammability: Very low

Mechanized Parts / Unit
High-level: 2 blowers
Low-level: 0
Cold: 0

Isolated Process Steps / Unit
High-level:
Low-level:
Cold:

ombined Installation Activities:

Combined Decontamination/
ommissioning Disposal/Activities
Decontaminations:
Decommissioning & Disposal:

Module: M.13, Air/Vapor Filtration System
Component / Unit Operation: M.13.E, BVOG Air Supply System

General Description: Supply air is blown through two prefilters, two heaters, four HEPA filters and the storage bin vault. The air is filtered for use in the Storage Stack System.

Number of Units: 4 HEPA filters, 2 prefilters, 2 blowers, 2 heaters
Unit Size:
Unit Utilization (yrs): N/A
Operating Efficiency: 60%
Radiation Level: Cold
Temp: 25 - 35 degrees C
Pressure: <1 psig
pH/Acidity/Alkalinity: NA
Energetic Reaction Potential: Very low
Process Stability:
% Solids in Waste: 0%
Waste Form: Gas
% Organics in Waste: 0%
Flammability: Very low

Mechanized Parts / Unit
High-level: 0
Low-level: 0
Cold: 2 blowers

Isolated Process Steps / Unit
High-level:
Low-level:
Cold:

ombined Installation Activities: piping

Combined Decontamination/
ommissioning Disposal/Activities
Decontaminations:
Decommissioning & Disposal:

Module: M.13, Air/Vapor Filtration System
Component / Unit Operation: M.13.F, Storage Stack Filter System

General Description: A fugitive leak stream and filtered supply air combine and flow through metal prefilters and heaters before being joined by the BVOG stream.. The combined stream then flows through metal HEPA filters and HEPA filters before being blown to the cullet storage facility stack. The filter wash from the filters flows to the Filter Wash Catch Tank.

Number of Units: 2 metal prefilters, 2 metal HEPA filters, 2 HEPA filters, 2 heaters, 2 blowers, 1 catch tank, 1 cullet storage facility stack
Unit Size:
Unit Utilization (yrs): 13 (Boomer 1993)
Operating Efficiency: 60%
Radiation Level: Low
Temp: ambient
Pressure: 0.04 psig
pH/Acidity/Alkalinity: 8 - 10
Energetic Reaction Potential: Very low
Process Stability:
% Solids in Waste: 1%
Waste Form: Liquid
% Organics in Waste: 0%
Flammability: Very low

Mechanized Parts / Unit
High-level: 2 blowers
Low-level: 0
Cold: 0

Isolated Process Steps / Unit
High-level:
Low-level:
Cold:

ombined Installation Activities:

Combined Decontamination/ ommissioning Disposal/Activities
Decontaminations:
Decommissioning & Disposal:

Module: M.13, Air/Vapor Filtration System
Component / Unit Operation: M.13.G, Oxygen Supply System

General Description: An air stream enters a compressor and is forced through a filter. The air then passes through a dryer and into an air receiver before flowing into one of two CMS beds for separation. The appropriate streams flow into the N2 supply or the O2 supply. Bulk N2 and bulk O2 are added to their respective streams before flowing to their destination for further use.

Number of Units: 2 air receiver tanks, 2 supply tanks, 1 air compressor, 1 filter, 1 dryer
Unit Size:
Unit Utilization (yrs): N/A
Operating Efficiency: 60%
Radiation Level: Cold
Temp: ambient
Pressure: 125 psig
pH/Acidity/Alkalinity: NA
Energetic Reaction Potential: Low
Process Stability:
% Solids in Waste: 0%
Waste Form: Liquid
% Organics in Waste: 0%
Flammability: Very low

Mechanized Parts / Unit
High-level: 0
Low-level: 0
Cold: 1 air compressor

Isolated Process Steps / Unit
High-level:
Low-level:
Cold:

ombined Installation Activities: piping

Combined Decontamination/
ommissioning Disposal/Activities
Decontaminations:
Decommissioning & Disposal:

APPENDIX E

STREAM DESCRIPTIONS

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Metric Conversion Chart

The following chart is provided to the reader as a tool to aid in converting to metric units.

Into Metric Units

If You Know	Multiply By	To Get
Length		
inches	25.4	millimeters
inches	2.54	centimeters
feet	0.305	meters
yards	0.914	meters
miles	1.609	kilometers
Area		
sq. inches	6.452	sq. centimeters
sq. feet	0.093	sq. meters
sq. yards	0.0836	sq. meters
sq. miles	2.6	sq. kilometers
acres	0.405	hectares
Mass (weight)		
ounces	28.35	grams
pounds	0.454	kilograms
short ton	0.907	metric ton
Volume		
teaspoons	5	milliliters
tablespoons	15	milliliters
fluid ounces	30	milliliters
cups	0.24	liters
pints	0.47	liters
quarts	0.95	liters
gallons	3.8	liters
cubic feet	0.028	cubic meters
cubic yards	0.765	cubic meters
Temperature		
Fahrenheit	subtract 32, then multiply by 5/9	Celsius
Pressure		
inches of H_2O	0.00246	atmospheres
inches of Hg	0.03332	atmospheres

Out of Metric Units

If You Know	Multiply	To Get
Length		
millimeters	0.039	inches
centimeters	0.394	inches
meters	3.281	feet
meters	1.094	yards
kilometers	0.621	miles
Area		
sq. centimeters	0.155	sq. inches
sq. meters	10.76	sq. feet
sq. meters	1.196	sq. yards
sq. kilometers	0.4	sq. miles
hectares	2.47	acres
Mass (weight)		
grams	0.035	ounces
kilograms	2.205	pounds
metric ton	1.102	short ton
Volume		
milliliters	0.033	fluid ounces
liters	2.1	pints
liters	1.057	quarts
liters	0.264	gallons
cubic meters	35.315	cubic feet
cubic meters	1.308	cubic yards
Temperature		
Celsius	multiply by 9/5, then add 32	Fahrenheit
Pressure		
atmospheres	406.5	inches of H_2O
atmospheres	30.005	inches of Hg

Stream Descriptions

Mass Flow Values

Mass flows for modules M.1 and M.2 were obtained from the *Tank Waste Technical Options Report* (Boomer et al. 1993). Mass flows for modules M.3 through M.13 were obtained from the WHC ASPEN[1] Combined Separations, Parallel HLW and LLW Vitrification, 50 to 20% Solids, 45% HLW WO Loading run dated January 21, 1994.

Fugitive Emissions

The processes and facilities are designed to run at a slightly negative pressure and there are extensive vapor systems designed for the processes. It has therefore been assumed that all fugitive emissions from the processes are zero.

Decontamination and Decommissioning (D&D) Waste

It has been assumed that the average size of a piece of equipment within any process is 1,000 gal and that 0.1% of the inventory within each piece of equipment will be leaked during D&D (determined by best engineering judgement [BEJ]). The estimated mass of D&D waste has been calculated as 0.1% of the mass of each stream multiplied by the number of pieces of equipment within the module, and the assumed 1,000 gal volume of each piece of equipment, divided by the density of the stream.

Radiation Level

Streams have been designated as high activity, low activity, or nonradioactive, based on the radionuclide concentration. Streams with 0.13 Ci/kg or greater have been designated as high activity waste and streams with less than 0.13 Ci/kg have been designated as low activity waste. Streams behind fed into the process are designated as nonradioactive.

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[1]ASPEN is a trademark of Aspen Technology, Inc.

Stream 1.1

This stream represents the amount of pure water needed to dissolve the single-shell tank (SST) salt cake to an approximate concentration of 5 *M* $NaNO_3$ and to create a 10% solids slurry from the SST sludge.

Stream 1.2

This stream is defined as the total SST waste inventory. This stream is equivalent to the total chemical inventory shown in Table 4-2 of Boomer et al. (1993), and the total radionuclide inventory shown in Table 4-5 of Boomer et al. (1993).

Stream 1.3

This stream represents the retrieved SST waste. This stream is equal to the initial inventory (Stream 1.2) plus the sluicing water (Stream 1.1) minus the amount of waste lost through the system (Streams 1.4, 1.8, 1.7, and 1.9).

Stream 1.4

This stream represents fugitive emissions from the SST retrieval process. It is assumed to be zero.

Stream 1.5

This stream represents fugitive emissions from the SST cleanup and backfill process. It is assumed to be zero.

Stream 1.6

This stream represents past leakage to the soil. It is assumed to be equal to 1% of Stream 1.2. To maintain the mass balance, this stream is identified as an input and output from the module.

Base Case Stream 1.7

This stream represents leakage to the soil that occurs during sluicing, assuming 66 tanks will leak once sluicing activities begin (Lowe 1993). Analyses have shown that leakage of up to 140 m^3 (40,000 gal) per tank may occur during sluicing operations (Lowe 1993); therefore, a total of 2,640,000 gal of liquid waste is estimated to have been released to the ground. Stream 1.7 is obtained by assuming that the new leakage induced by sluicing is equal to 3.52 (2,640,000 divided by 750,000 gal) times the total past leakage (Stream 1.6).

Test Case I Stream 1.7

This stream represents leakage to the soil that occurs during sluicing. It is assumed that the close-coupled barrier reduces the leakage by 99.9% relative to the base case.

Test Case II Stream 1.7

This stream represents leakage to the soil that occurs during sluicing. It is assumed that robotic retrieval reduces this leakage to 1/10th of the base case leakage.

Base Case Stream 1.8

This stream is equal to 1% of Stream 1.2 (Boomer et al. 1993). It represents the residual waste that is distributed over the internal tank surfaces as well as on the resident in-tank hardware.

Test Case I Stream 1.8

This stream is equal to 1% of Stream 1.2 (Boomer et al. 1993). It represents the residual waste that is distributed over the internal tank surfaces as well as on the resident in-tank hardware.

Test Case II Stream 1.8

Robotic retrieval is assumed to remove 99.9% of the tank waste. This stream is equal to 0.1% of Stream 1.2 (Boomer et al. 1993). It represents the residual waste that is distributed over the internal tank surfaces as well as on the resident in-tank hardware.

Stream 1.9

This stream represents contaminated SST waste transfer piping, ancillary equipment and associated soils from newly completed SST waste retrieval operations. Boomer et al. (1993) assumes that total contamination from Resource Conservation and Recovery Act (RCRA) past-practice units (PPUs) represents 0.1% of Stream 1.2. Assume that newly created leakage waste is the same; therefore, Stream 1.9 is 0.1% of Stream 1.2.

Stream 2.1

This stream consists of miscellaneous waste from 12 DSTs. This waste is composed of neutralized cladding removal waste (NCRW), concentrated phosphate (CP), neutralized current acid waste (NCAW), and double-shell slurry/double-shell slurry feed (DSS/DSSF) (Hanlon 1994).

Stream 2.2

This stream represents the complexed concentrate (CC) waste from five double-shell tanks (DSTs).

Stream 2.3

This stream represents the dilute noncomplexed (DN) waste from 11 DSTs.

Stream 2.4

This stream represents the DST waste that goes to the sludge washing process.

Stream 2.5

This low activity stream represents condensate flowing from the DST Waste retrieval evaporator out of the system to the Liquid Effluent Process Recycle and Discharge (LEPRD). It is assumed to contain 0.1% of the evaporator feed (Stream 2.3) contaminants and 90% of the feed water.

Stream 2.6

This stream represents the release of emissions during cleanup and backfilling activities.

Stream 2.7

This stream represents fugitive emissions from the DST retrieval process. It is assumed to be zero.

Stream 2.8

This stream represents the residual waste after retrieval that is distributed over the internal tank surfaces as well as on the resident in-tank hardware. It is assumed to be 1% of the summation of Streams 2.1, 2.2, and 2.3.

Stream 2.9

This stream represents contaminated DST waste transfer piping, ancillary equipment and associated soils from newly completed DST waste retrieval operations. Boomer et al. (1993) assumes that total contamination from RCRA PPUs represents 0.1% of Streams 2.1, 2.2, and 2.3. It is assumed that newly created leakage waste is the same, therefore Stream 2.9 is 0.1% of Streams 2.1, 2.2, and 2.3.

Stream 1.6, 2.7

This high activity stream flows from the SST and DST waste retrieval systems into the DST sludge wash settling tanks.

Stream 3.1

This high activity stream flows from the DST sludge wash settling tanks to the cesium ion exchange accumulation system.

Stream 3.2

This high activity stream flows from the DST sludge wash system into the HLW feed lag storage feed accumulation tanks.

Stream 3.3

This high activity stream flows from the DST sludge wash transfer tanks into the cesium ion exchange accumulation system.

Stream 3.4

This stream represents fugitive emissions from the sludge wash process. It is assumed to be zero.

Stream 3.5

This high activity stream represents D&D waste from the sludge wash process. The sludge wash process contains 37 pieces of equipment.

Stream 4.1

This nonradioactive stream flows from the cesium ion exchange supernatant evaporation system into the Liquid Effluent Treatment Facility process condensate recycle system.

Stream 4.2

This nonradioactive stream flows from the cesium ion exchange supernatant evaporation system into the air/vapor filtration condenser vessel offgas (CVOG)/vessel offgas (VOG) system.

Stream 4.3

This high activity stream flows from the cesium ion exchange feed system into the HLW glass cullet melter system.

Stream 4.4

This low activity stream flows from the cesium ion exchange system into the LLW glass in sulfur evaporator system.

Stream 4.5

This high activity stream flows from the cesium ion exchange concentrator system into the HLW glass cullet melter system.

Stream 4.6

This low activity stream flows from the cesium ion exchange concentrator system into the air/vapor filtration CVOG/VOG system.

Stream 4.7

This stream represents fugitive emissions from the cesium ion exchange process. It is assumed to be zero.

Stream 4.8

This high activity stream represents D&D waste from the cesium ion exchange process. The cesium ion exchange process contains 67 pieces of equipment.

Stream 5.1

This nonradioactive stream flows from the LLW glass in sulfur evaporator system into the Liquid Effluent Treatment Facility process condensate recycle system.

Stream 5.2

This nonradioactive stream flows from the LLW glass in sulfur evaporator system into the air/vapor filtration CVOG/VOG system.

Stream 5.3

This low activity stream flows from the LLW glass in sulfur melter system into the cullet rework and melter offgas processing LLW separator system.

Stream 5.4

This nonradioactive stream flows from the LLW glass in sulfur cullet drying system into the Liquid Effluent Treatment Facility process condensate recycle system.

Stream 5.5

This low activity stream flows from the LLW glass in sulfur cullet drying system into the cullet rework and melter offgas processing cyclone system.

Stream 5.6

This stream flows from the LLW glass in sulfur cullet drying system into the air/vapor filtration bin vessel offgas (BVOG) system.

Stream 5.7

This low activity stream flows from the LLW glass in sulfur cyclone system into the LLW glass in sulfur vault sulfur cement mixing.

Stream 5.8

This low activity stream flows from the LLW glass in sulfur cyclone system into the air/vapor filtration process stack filter system.

Stream 5.9

This stream represents fugitive emissions from the LLW glass in sulfur process. It is assumed to be zero.

Stream 5.10

This high activity stream represents D&D waste from the LLW glass in sulfur process. The LLW glass in sulfur process contains 57 pieces of equipment.

Stream 5.11

This stream represents drying and transport air flowing into the LLW glass in sulfur glass cullet drying system. The ASPEN file run used as the basis for this model showed this stream as zero.

Stream 6.1

This stream flows from the LLW glass in sulfur disposal vault and is discharged into the atmosphere. The ASPEN file run used as the basis for this model showed this stream as zero.

Stream 6.2

This stream represents fugitive emissions from the LLW glass in sulfur disposal vault. It is assumed to be zero.

Stream 6.3

This low activity stream represents D&D waste from the LLW glass in sulfur disposal vault. The LLW glass in sulfur disposal vault contains nine pieces of equipment.

Stream 7.1

This high activity stream flows from the HLW glass cullet feed lag storage feed transfer tank into the HLW glass cullet centrifuge system.

Stream 7.2

This stream represents fugitive emissions from the HLW glass cullet feed lag storage. It is assumed to be zero.

Stream 7.3

This high activity stream represents D&D waste from the HLW glass cullet feed lag storage. The HLW glass cullet feed lag storage contains four pieces of equipment.

Stream 8.1

This nonradioactive stream represents air flowing into the HLW glass cullet drying system.

Stream 8.2

This high activity stream flows from the HLW glass cullet melter system into the cullet rework and melter offgas processing HLW separator system.

<u>Stream 8.3</u>

This nonradioactive stream flows from the HLW glass cullet evaporator system into the Liquid Effluent Treatment Facility process condensate recycle system.

<u>Stream 8.4</u>

This nonradioactive stream flows from the HLW glass cullet evaporator system into the air/vapor filtration CVOG/VOG system.

<u>Stream 8.5</u>

This nonradioactive stream flows from the HLW glass cullet drying system into the Liquid Effluent Treatment Facility process condensate recycle system.

<u>Stream 8.6</u>

This high activity stream flows from the HLW glass cullet drying system into the cullet rework and melter offgas processing cyclone system.

<u>Stream 8.7</u>

This high activity stream flows from the HLW glass cullet drying system into the air/vapor filtration BVOG system.

<u>Stream 8.8</u>

This high activity stream flows from the HLW glass cullet cyclone system into the HLW glass cullet cask storage pad air pallets.

<u>Stream 8.9</u>

This high activity stream flows from the HLW glass cullet cyclone system into the air/vapor filtration process stack filter system.

Stream 8.10

This stream represents fugitive emissions from the HLW glass cullet process. It is assumed to be zero.

Stream 8.11

This high activity stream represents D&D waste from the HLW glass cullet process. The HLW glass cullet process contains 74 pieces of equipment.

Stream 9.1

This stream represents fugitive emissions from the HLW glass cullet storage pad. It is assumed to be zero.

Stream 9.2

This high activity stream represents D&D waste from the HLW glass cullet storage pad. The HLW glass cullet storage pad contains six pieces of equipment.

Stream 10.1

This nonradioactive stream represents air flowing into the cullet rework and melter offgas processing No_x/SO_2 separator system.

Stream 10.2

This nonradioactive stream represents air flowing into the cullet rework and melter offgas processing Claus reactor system.

Stream 10.3

This low activity stream flows from the cullet rework and melter offgas processing cyclone system into the air/vapor filtration process stack filter system.

Stream 10.4

This low activity stream flows from the cullet rework and melter offgas processing cyclone system into the LLW glass in sulfur evaporator system.

Stream 10.5

This low activity stream flows from the cullet rework and melter offgas processing cyclone system into the LLW glass in sulfur melter system.

Stream 10.6

This high activity stream flows from the cullet rework and melter offgas processing cyclone system into the HLW glass cullet melter system.

Stream 10.7

This high activity stream flows from the cullet rework and melter offgas processing HLW separator system into the HLW glass cullet evaporator system.

Stream 10.8

This nonradioactive stream flows from the cullet rework and melter offgas processing NO_x/SO_2 separator system into the air/vapor filtration process stack filter system.

Stream 10.9

This low activity stream flows from the cullet rework and melter offgas processing LLW separator system into the LLW glass in sulfur evaporator system.

Stream 10.10

This low activity stream flows from the cullet rework and melter offgas processing LLW separator system into the LLW glass in sulfur melter system.

Stream 10.11

This nonradioactive stream flows from the cullet rework and melter offgas processing Claus reactor system into the LLW glass in sulfur vault sulfur cement mixing.

Stream 10.12

This nonradioactive stream represents steam flowing from the cullet rework and melter offgas processing Claus reactor system and discharged into the atmosphere.

Stream 10.13

This stream represents fugitive emissions from the cullet rework and melter offgas process. It is assumed to be zero.

Stream 10.14

This high activity stream represents D&D waste from the cullet rework and melter offgas process. The cullet rework and melter offgas process contains 64 pieces of equipment.

Stream 11.1

This nonradioactive stream flows from the Liquid Effluent Treatment Facility process condensate recycle system into the cesium ion exchange feed.

Stream 11.2

This stream flows from the Liquid Effluent Treatment Facility pH adjustment tank into the tank farms. The ASPEN file run used as the basis for this model showed this stream as zero.

Stream 11.3

This nonradioactive stream flows from the Liquid Effluent Treatment Facility retention basin into the DST sludge wash settle tanks.

Stream 11.4

This nonradioactive stream flows from the Liquid Effluent Treatment Facility retention basin into the DST sludge wash.

Stream 11.5

This nonradioactive stream flows from the Liquid Effluent Treatment Facility retention basin to the LEPRD.

Stream 11.6

This stream represents fugitive emissions from the Liquid Effluent Treatment Facility. It is assumed to be zero.

Stream 11.7

This nonradioactive stream represents D&D waste from the Liquid Effluent Treatment Facility. The Liquid Effluent Treatment Facility contains 10 pieces of equipment.

Stream 12.1

This nonradioactive stream represents purchased chemicals into the chemical make-up unit dry storage.

Stream 12.2

This nonradioactive stream represents purchased chemicals into the chemical make-up unit bulk liquid storage.

Stream 12.3

This nonradioactive stream represents purchased chemicals into the chemical make-up unit bulk H_2O storage.

Stream 12.4

This nonradioactive stream represents purchased chemicals into the chemical make-up unit bulk combustible liquid storage.

Stream 12.5

This nonradioactive stream represents purchased chemicals into the chemical make-up unit glass melter batch mixers.

Stream 12.6

This nonradioactive stream flows from the chemical make-up unit dry storage into the DST sludge wash feed.

Stream 12.7

This nonradioactive stream flows from the chemical make-up unit dry storage into the cesium ion exchange supernatant evaporation system.

Stream 12.8

This nonradioactive stream flows from the chemical make-up unit dry storage into the cesium ion exchange feed.

Stream 12.9

This nonradioactive stream flows from the chemical make-up unit bulk liquid storage into the DST sludge wash feed.

Stream 12.10

This nonradioactive stream flows from the chemical make-up unit bulk liquid storage into the cesium ion exchange supernatant evaporation system.

Stream 12.11

This nonradioactive stream flows from the chemical make-up unit bulk liquid storage into the cesium ion exchange feed.

Stream 12.12

This nonradioactive stream flows from the chemical make-up unit bulk liquid storage into the cesium ion exchange eluent/regeneration system.

Stream 12.13

This nonradioactive stream flows from the chemical make-up unit bulk liquid storage into the LLW glass in sulfur vault sulfur cement mixing.

Stream 12.14

This stream flows from the chemical make-up unit bulk liquid storage into the Liquid Effluent Treatment Facility Ph adjustment tank. The ASPEN file run used as the basis for this model showed this stream as zero.

Stream 12.15

This nonradioactive stream flows from the chemical make-up unit bulk liquid storage into the cullet rework and melter offgas processing No_x/SO_2 separator system.

Stream 12.16

This stream flows from the chemical make-up unit bulk liquid storage into the cullet rework and melter offgas processing HLW separator system. The ASPEN file run used as the basis for this model showed this stream as zero.

Stream 12.17

This nonradioactive stream flows from the chemical make-up unit bulk H_2O storage into the DST sludge wash feed.

Stream 12.18

This nonradioactive stream flows from the chemical make-up unit bulk H_2O storage into the cesium ion exchange supernatant evaporation system.

Stream 12.19

This nonradioactive stream flows from the chemical make-up unit bulk H_2O storage into the cesium ion exchange eluent/regeneration system.

Stream 12.20

This nonradioactive stream flows from the chemical make-up unit bulk H_2O storage into the LLW glass in sulfur quenching system.

Stream 12.21

This nonradioactive stream flows from the chemical make-up unit bulk H_2O storage into the LLW glass in sulfur cyclone system.

Stream 12.22

This nonradioactive stream flows from the chemical make-up unit bulk H_2O storage into the cullet rework and melter offgas processing cyclone system.

Stream 12.23

This nonradioactive stream flows from the chemical make-up unit bulk H_2O storage into the cullet rework and melter offgas processing HLW separator system.

Stream 12.24

This nonradioactive stream flows from the chemical make-up unit bulk H_2O storage into the cullet rework and melter offgas processing LLW separator system.

Stream 12.25

This nonradioactive stream flows from the chemical make-up unit bulk H_2O storage into the air/vapor filtration CVOG/VOG system.

Stream 12.26

This nonradioactive stream flows from the chemical make-up unit bulk H_2O storage into the air/vapor filtration process stack filter system.

Stream 12.27

This nonradioactive stream flows from the chemical make-up unit bulk H_2O storage into the air/vapor filtration storage stack filter system.

Stream 12.28

This nonradioactive stream flows from the chemical make-up unit bulk combustible liquid storage into the LLW glass in sulfur melter system.

Stream 12.29

This nonradioactive stream flows from the chemical make-up unit bulk combustible liquid storage into the HLW glass cullet melter system.

Stream 12.30

This stream flows from the chemical make-up unit bulk combustible liquid storage into the cullet rework and melter offgas processing Claus reactor system. The ASPEN file run used as the basis for this model showed this stream as zero.

Stream 12.31

This stream flows from the chemical make-up unit bulk combustible liquid storage into the air/vapor filtration oxygen supply system. The ASPEN file run used as the basis for this model showed this stream as zero.

Stream 12.32

This nonradioactive stream flows from the chemical make-up unit glass melter batch mixers into the LLW glass in sulfur melter system.

Stream 12.33

This nonradioactive stream flows from the chemical make-up unit glass melter batch mixers into the HLW glass cullet melter system.

Stream 12.34

This nonradioactive stream flows from the chemical make-up unit bulk H_2O storage into the HLW glass cullet cyclone system.

Stream 12.35

This stream represents fugitive emissions from the chemical make-up system. It is assumed to be zero.

Stream 13.14

This nonradioactive stream represents D&D waste from the chemical make-up system. The chemical make-up system contains 28 pieces of equipment.

Stream 13.1

This stream represents air flowing into the air/vapor filtration CVOG/VOG/PVOG air supply system. The ASPEN file run used as the basis for this model showed this stream as zero.

Stream 13.2

This stream represents air flowing into the air/vapor filtration BVOG air supply system. The ASPEN file run used as the basis for this model showed this stream as zero.

Stream 13.3

This stream represents air flowing into the air/vapor filtration oxygen supply system. The ASPEN file run used as the basis for this model had not achieved a mass balance around the air/vapor filtration oxygen supply system. This stream was determined by calculating a mass balance of the streams around the unit:

$$13.3 = 13.9 + 13.10 + 13.11 + 13.12 - 12.31.$$

Stream 13.4

This stream flows from the air/vapor filtration CVOG/VOG System into the LLW Glass in sulfur evaporator system. The ASPEN file run used as the basis for this model showed this stream as zero.

Stream 13.5

This low activity stream flows from the air/vapor filtration process stack filter system into the LLW Glass in sulfur evaporator system.

Stream 13.6

This low activity stream flows from the air/vapor filtration process stack filter system and is discharged into the atmosphere.

Stream 13.7

This low activity stream flows from the air/vapor filtration storage stack filter system into the LLW glass in sulfur evaporator system.

Stream 13.8

This low activity stream flows from the air/vapor filtration storage stack filter system and is discharged into the atmosphere.

Stream 13.9

This nonradioactive stream flows from the air/vapor filtration oxygen supply system into the cullet rework and melter offgas processing NO_x/SO_2 separator system.

Stream 13.10

This nonradioactive stream flows from the air/vapor filtration oxygen supply system into the LLW glass in sulfur melter system.

Stream 13.11

This nonradioactive stream flows from the air/vapor filtration oxygen supply system into the HLW glass cullet melter system.

Stream 13.12

This nonradioactive stream represents a nitrogen cover-gas flowing from the air/vapor filtration oxygen supply system. The ASPEN file run that was the basis for this model did not utilize this stream elsewhere in the system model.

Stream 13.13

This stream represents fugitive emissions from the air/vapor filtration oxygen supply system. It is assumed to be zero.

Stream 13.14

This low activity stream represents D&D waste from the air/vapor filtration oxygen supply system. The air/vapor filtration oxygen supply system contains 51 pieces of equipment.

Stream 13.15

This stream represents flow from the vessel vent system to the air/vapor filtration CVOG/VOG System. The ASPEN file run used as the basis for this model showed this stream as zero.

Stream 13.16

This stream represents fugitive leaks to the air/vapor filtration storage stack filter system. The ASPEN file run used as the basis for this model showed this stream as zero.

APPENDIX F

MODULE MASS BALANCES

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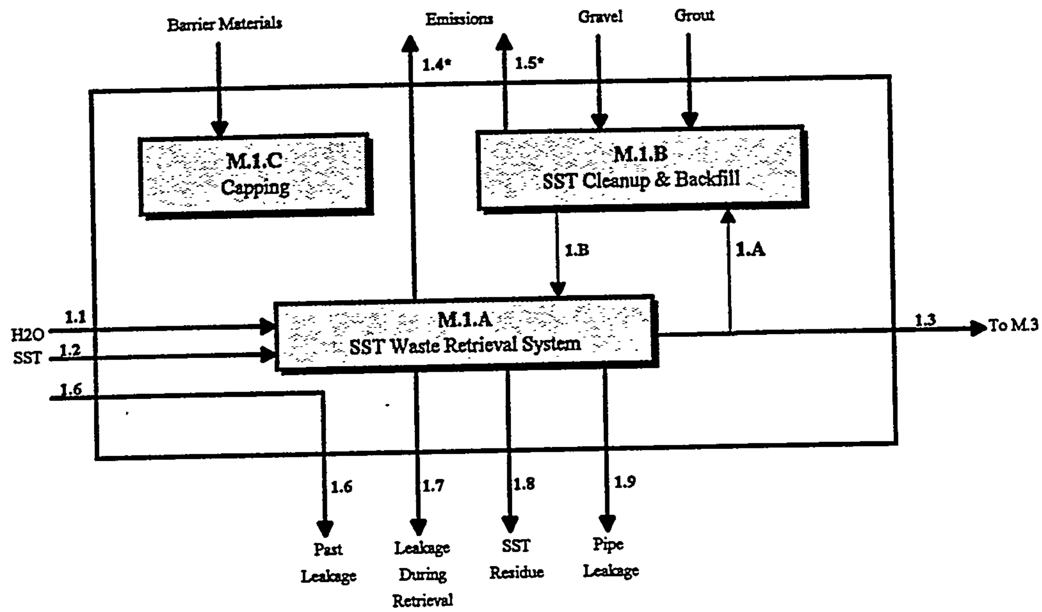
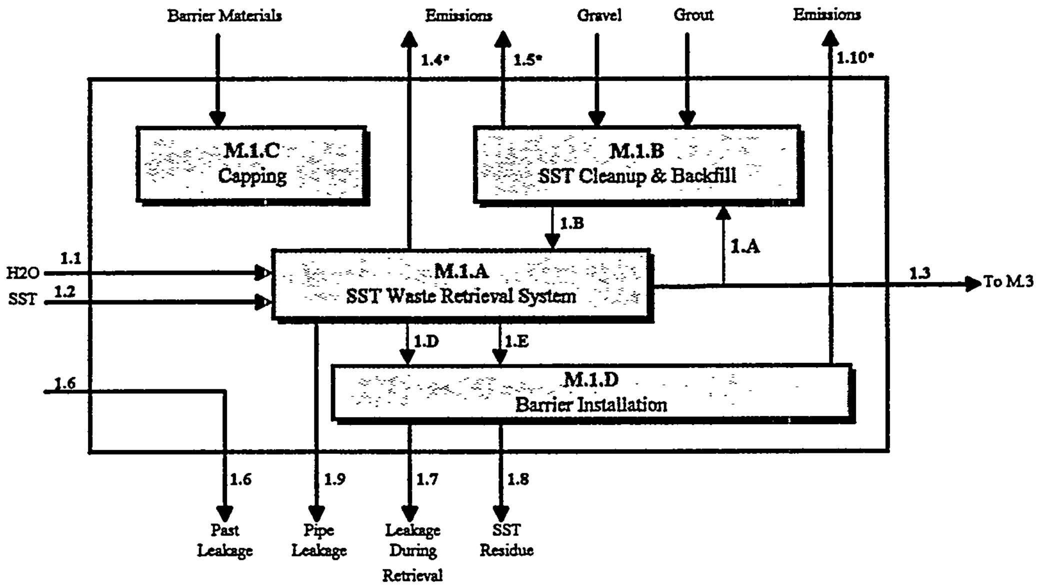


Base Case M.1, SST Waste Retrieval

	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9
Tot. Liquid Mass Flow (kg)	4.22E+08	1.67E+08	5.82E+08	0.00E+00	0.00E+00	1.67E+06	5.89E+06	1.67E+06	1.67E+05
Tot. Solid Mass Flow(kg)	0.00E+00	5.58E+07	5.52E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.58E+05	0.00E+00
% Solid Mass	0.00%	25.00%	8.67%	0.00%	0.00%	0.00%	0.00%	25.00%	0.00%
H2O (kg)	4.22E+08	4.48E+07	4.65E+08	0.00E+00	0.00E+00	4.48E+05	1.58E+06	4.48E+05	4.48E+04
Chemicals (kg)									
As	0.00E+00	4.63E+01	4.42E+01	0.00E+00	0.00E+00	4.63E-01	1.63E+00	4.63E-01	4.63E-02
Be	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cr	0.00E+00	9.60E+04	9.16E+04	0.00E+00	0.00E+00	9.60E+02	3.38E+03	9.60E+02	9.60E+01
F	0.00E+00	8.00E+05	7.63E+05	0.00E+00	0.00E+00	8.00E+03	2.82E+04	8.00E+03	8.00E+02
Hg	0.00E+00	1.00E+03	9.54E+02	0.00E+00	0.00E+00	1.00E+01	3.52E+01	1.00E+01	1.00E+00
Na	0.00E+00	5.13E+07	4.89E+07	0.00E+00	0.00E+00	5.13E+05	1.81E+06	5.13E+05	5.13E+04
Ni	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NO2	0.00E+00	4.80E+06	4.58E+06	0.00E+00	0.00E+00	4.80E+04	1.69E+05	4.80E+04	4.80E+03
NO3	0.00E+00	9.68E+07	9.23E+07	0.00E+00	0.00E+00	9.68E+05	3.41E+06	9.68E+05	9.68E+04
Sb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SO4	0.00E+00	1.60E+06	1.53E+06	0.00E+00	0.00E+00	1.60E+04	5.63E+04	1.60E+04	1.60E+03
V	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TOC	0.00E+00	2.00E+05	1.91E+05	0.00E+00	0.00E+00	2.00E+03	7.04E+03	2.00E+03	2.00E+02
Radionuclides (Ci)									
Am-241	0.00E+00	4.60E+04	4.38E+04	0.00E+00	0.00E+00	4.60E+02	1.62E+03	4.60E+02	4.60E+01
C-14	0.00E+00	3.00E+03	2.86E+03	0.00E+00	0.00E+00	3.00E+01	1.06E+02	3.00E+01	3.00E+00
Cs-137	0.00E+00	3.50E+07	3.34E+07	0.00E+00	0.00E+00	3.50E+05	1.23E+06	3.50E+05	3.50E+04
I-129	0.00E+00	2.40E+01	2.29E+01	0.00E+00	0.00E+00	2.40E-01	8.45E-01	2.40E-01	2.40E-02
Pu-239	0.00E+00	1.50E+04	1.43E+04	0.00E+00	0.00E+00	1.50E+02	5.28E+02	1.50E+02	1.50E+01
Sr-90	0.00E+00	1.13E+08	1.08E+08	0.00E+00	0.00E+00	1.13E+06	3.98E+06	1.13E+06	1.13E+05
Tc-99	0.00E+00	1.60E+04	1.53E+04	0.00E+00	0.00E+00	1.60E+02	5.63E+02	1.60E+02	1.60E+01
U	0.00E+00	4.60E+02	4.39E+02	0.00E+00	0.00E+00	4.60E+00	1.62E+01	4.60E+00	4.60E-01

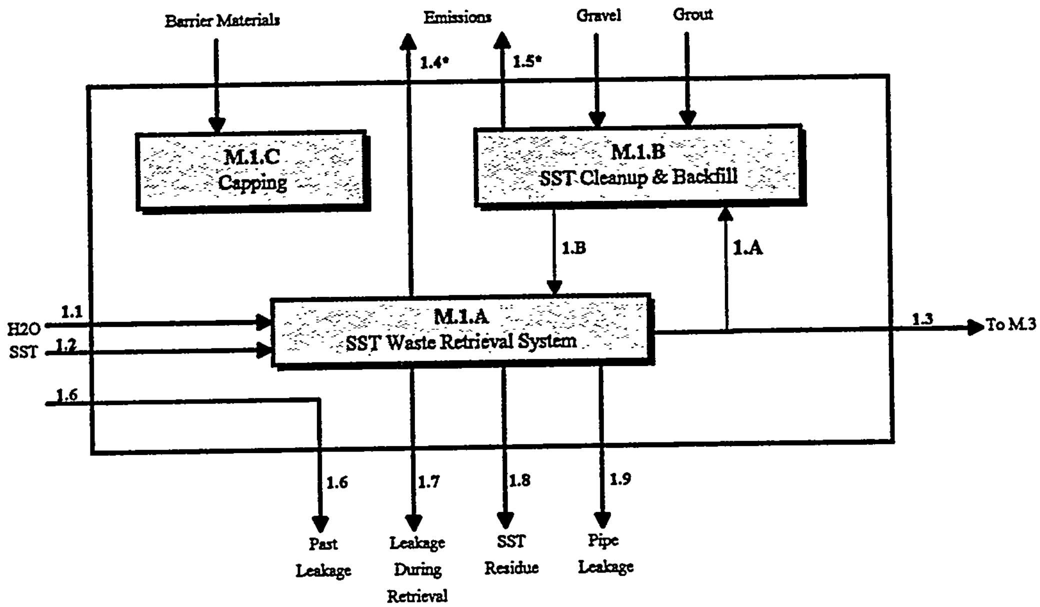
* This stream contains trace amounts of radioactive materials which have not been tracked by the Aspen run. Therefore, all values are zero.



Test Case 1 M.1, SST Waste Retrieval

	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	1.10
Tot. Liquid Mass Flow (kg)	4.22E+08	1.67E+08	5.82E+08	0.00E+00	0.00E+00	1.67E+06	5.89E+03	1.67E+06	1.67E+05	0.00E+00
Tot. Solid Mass Flow(kg)	0.00E+00	5.58E+07	5.52E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.58E+05	0.00E+00	0.00E+00
% Solid Mass	0.00%	25.00%	8.67%	0.00%	0.00%	0.00%	0.00%	25.00%	0.00%	0.00%
H2O (kg)	4.22E+08	4.48E+07	4.65E+08	0.00E+00	0.00E+00	4.48E+05	1.58E+03	4.48E+05	4.48E+04	0.00E+00
Chemicals (kg)										
As	0.00E+00	4.63E+01	4.42E+01	0.00E+00	0.00E+00	4.63E-01	1.63E-03	4.63E-01	4.63E-02	0.00E+00
Be	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cr	0.00E+00	9.60E+04	9.16E+04	0.00E+00	0.00E+00	9.60E+02	3.38E+00	9.60E+02	9.60E+01	0.00E+00
F	0.00E+00	8.00E+05	7.63E+05	0.00E+00	0.00E+00	8.00E+03	2.82E+01	8.00E+03	8.00E+02	0.00E+00
Hg	0.00E+00	1.00E+03	9.54E+02	0.00E+00	0.00E+00	1.00E+01	3.52E-02	1.00E+01	1.00E+00	0.00E+00
Na	0.00E+00	5.13E+07	4.89E+07	0.00E+00	0.00E+00	5.13E+05	1.81E+03	5.13E+05	5.13E+04	0.00E+00
Ni	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NO2	0.00E+00	4.80E+06	4.58E+06	0.00E+00	0.00E+00	4.80E+04	1.69E+02	4.80E+04	4.80E+03	0.00E+00
NO3	0.00E+00	9.68E+07	9.23E+07	0.00E+00	0.00E+00	9.68E+05	3.41E+03	9.68E+05	9.68E+04	0.00E+00
Sb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SO4	0.00E+00	1.60E+06	1.53E+06	0.00E+00	0.00E+00	1.60E+04	5.63E+01	1.60E+04	1.60E+03	0.00E+00
V	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TOC	0.00E+00	2.00E+05	1.91E+05	0.00E+00	0.00E+00	2.00E+03	7.04E+00	2.00E+03	2.00E+02	0.00E+00
Radionuclides (Ci)										
Am-241	0.00E+00	4.60E+04	4.38E+04	0.00E+00	0.00E+00	4.60E+02	1.62E+00	4.60E+02	4.60E+01	0.00E+00
C-14	0.00E+00	3.00E+03	2.86E+03	0.00E+00	0.00E+00	3.00E+01	1.06E-01	3.00E+01	3.00E+00	0.00E+00
Cs-137	0.00E+00	3.50E+07	3.34E+07	0.00E+00	0.00E+00	3.50E+05	1.23E+03	3.50E+05	3.50E+04	0.00E+00
I-129	0.00E+00	2.40E+01	2.29E+01	0.00E+00	0.00E+00	2.40E-01	8.45E-04	2.40E-01	2.40E-02	0.00E+00
Pu-239	0.00E+00	1.50E+04	1.43E+04	0.00E+00	0.00E+00	1.50E+02	5.28E-01	1.50E+02	1.50E+01	0.00E+00
Sr-90	0.00E+00	1.13E+08	1.08E+08	0.00E+00	0.00E+00	1.13E+06	3.98E+03	1.13E+06	1.13E+05	0.00E+00
Tc-99	0.00E+00	1.60E+04	1.53E+04	0.00E+00	0.00E+00	1.60E+02	5.63E-01	1.60E+02	1.60E+01	0.00E+00
U	0.00E+00	4.60E+02	4.39E+02	0.00E+00	0.00E+00	4.60E+00	1.62E-02	4.60E+00	4.60E-01	0.00E+00

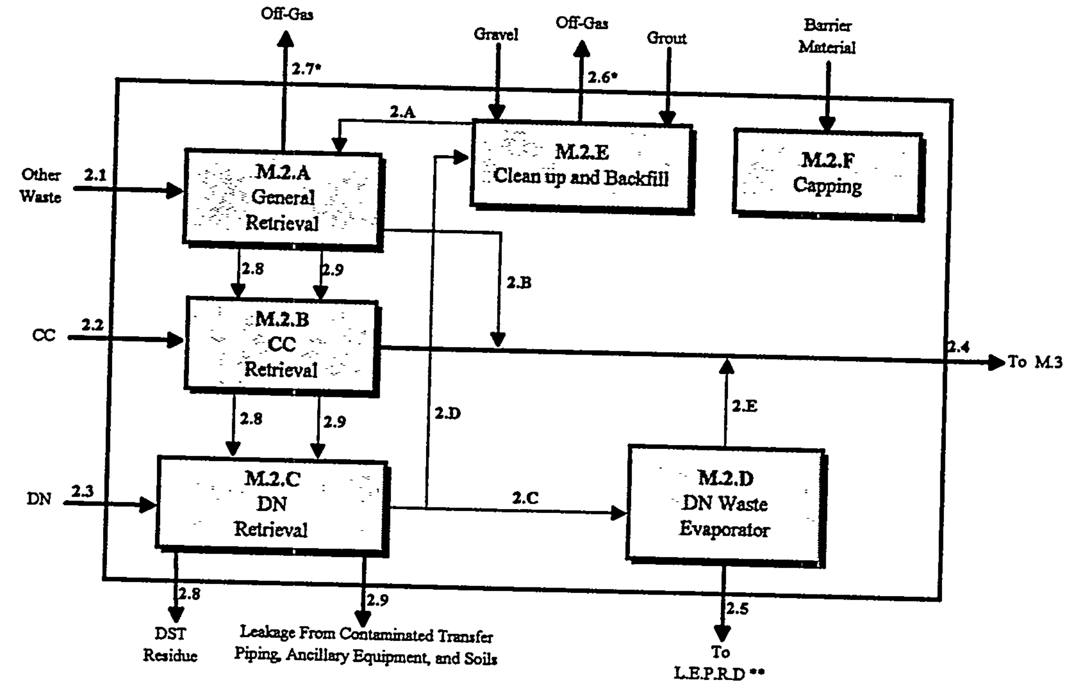
* This stream contains trace amounts of radioactive materials which have not been tracked by the Aspen run. Therefore, all values are zero.



Test Case 2 M.1, SST Waste Retrieval

	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9
Tot. Liquid Mass Flow (kg)	4.22E+08	1.67E+08	5.82E+08	0.00E+00	0.00E+00	1.67E+06	5.89E+05	1.67E+05	1.67E+05
Tot. Solid Mass Flow(kg)	0.00E+00	5.58E+07	5.52E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.58E+04	0.00E+00
% Solid Mass	0.00%	25.00%	8.67%	0.00%	0.00%	0.00%	0.00%	2.50%	0.00%
H2O (kg)	4.22E+08	4.48E+07	4.65E+08	0.00E+00	0.00E+00	4.48E+05	1.58E+05	4.48E+04	4.48E+04
Chemicals (kg)									
As	0.00E+00	4.63E+01	4.42E+01	0.00E+00	0.00E+00	4.63E-01	1.63E-01	4.63E-02	4.63E-02
Be	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cr	0.00E+00	9.60E+04	9.16E+04	0.00E+00	0.00E+00	9.60E+02	3.38E+02	9.60E+01	9.60E+01
F	0.00E+00	8.00E+05	7.63E+05	0.00E+00	0.00E+00	8.00E+03	2.82E+03	8.00E+02	8.00E+02
Hg	0.00E+00	1.00E+03	9.54E+02	0.00E+00	0.00E+00	1.00E+01	3.52E+00	1.00E+00	1.00E+00
Na	0.00E+00	5.13E+07	4.89E+07	0.00E+00	0.00E+00	5.13E+05	1.81E+05	5.13E+04	5.13E+04
Ni	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NO2	0.00E+00	4.80E+06	4.58E+06	0.00E+00	0.00E+00	4.80E+04	1.69E+04	4.80E+03	4.80E+03
NO3	0.00E+00	9.68E+07	9.23E+07	0.00E+00	0.00E+00	9.68E+05	3.41E+05	9.68E+04	9.68E+04
Sb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SO4	0.00E+00	1.60E+06	1.53E+06	0.00E+00	0.00E+00	1.60E+04	5.63E+03	1.60E+03	1.60E+03
V	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TOC	0.00E+00	2.00E+05	1.91E+05	0.00E+00	0.00E+00	2.00E+03	7.04E+02	2.00E+02	2.00E+02
Radionuclides (Ci)									
Am-241	0.00E+00	4.60E+04	4.38E+04	0.00E+00	0.00E+00	4.60E+02	1.62E+02	4.60E+01	4.60E+01
C-14	0.00E+00	3.00E+03	2.86E+03	0.00E+00	0.00E+00	3.00E+01	1.06E+01	3.00E+00	3.00E+00
Cs-137	0.00E+00	3.50E+07	3.34E+07	0.00E+00	0.00E+00	3.50E+05	1.23E+05	3.50E+04	3.50E+04
I-129	0.00E+00	2.40E+01	2.29E+01	0.00E+00	0.00E+00	2.40E-01	8.45E-02	2.40E-02	2.40E-02
Pu-239	0.00E+00	1.50E+04	1.43E+04	0.00E+00	0.00E+00	1.50E+02	5.28E+01	1.50E+01	1.50E+01
Sr-90	0.00E+00	1.13E+08	1.08E+08	0.00E+00	0.00E+00	1.13E+06	3.98E+05	1.13E+05	1.13E+05
Tc-99	0.00E+00	1.60E+04	1.53E+04	0.00E+00	0.00E+00	1.60E+02	5.63E+01	1.60E+01	1.60E+01
U	0.00E+00	4.60E+02	4.39E+02	0.00E+00	0.00E+00	4.60E+00	1.62E+00	4.60E-01	4.60E-01

* This stream contains trace amounts of radioactive materials which have not been tracked by the Aspen run. Therefore, all values are zero.

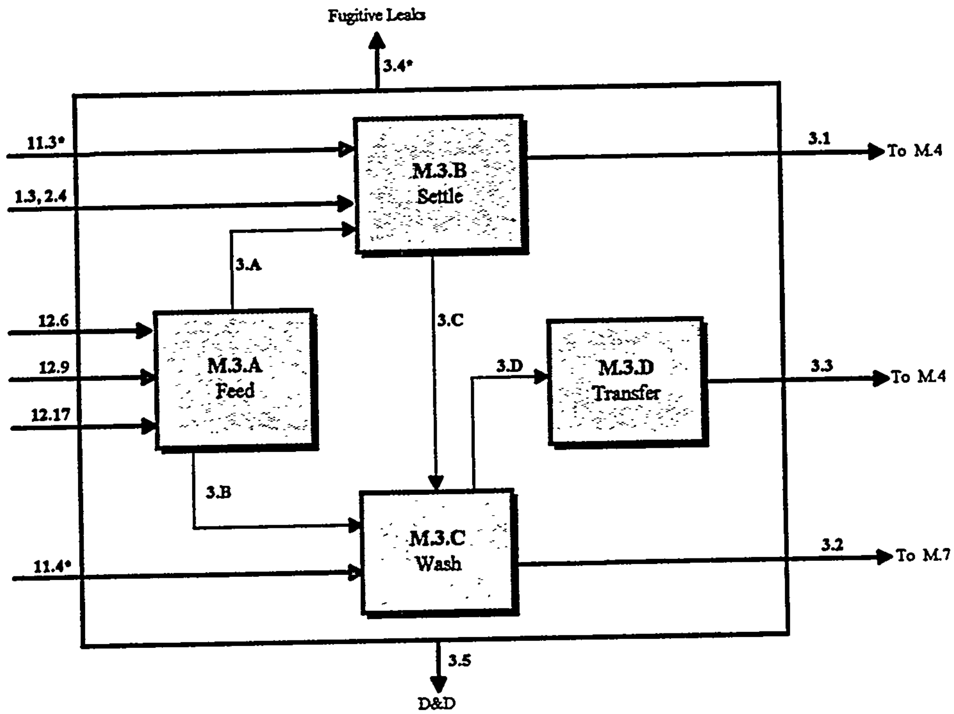


M.2, DST Waste Retrieval

	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9
Tot. Liquid Mass Flow (kg)	6.37E+07	6.03E+07	4.82E+07	1.52E+08	1.79E+07	0.00E+00	0.00E+00	1.72E+06	1.72E+05
Tot. Solid Mass Flow(kg)	1.53E+07	9.65E+06	1.93E+06	2.44E+07	0.00E+00	0.00E+00	0.00E+00	2.69E+05	2.69E+04
% Solid Mass	24.00%	16.00%	4.00%	16.00%	0.00%	NA	NA	13.49%	13.49%
H2O (kg)	2.62E+07	2.48E+07	1.99E+07	5.23E+07	1.79E+07	0.00E+00	0.00E+00	7.09E+05	7.09E+04
Chemicals (kg)									
As	2.98E+02	2.82E+02	2.26E+02	7.97E+02	2.26E-01	0.00E+00	0.00E+00	8.06E+00	8.06E-01
Be	3.72E+00	3.52E+00	2.82E+00	9.94E+00	2.82E-03	0.00E+00	0.00E+00	1.01E-01	1.01E-02
Cr	2.73E+04	2.59E+04	2.07E+04	7.30E+04	2.07E+01	0.00E+00	0.00E+00	7.39E+02	7.39E+01
F	1.51E+05	1.43E+05	1.14E+05	4.03E+05	1.14E+02	0.00E+00	0.00E+00	4.08E+03	4.08E+02
Hg	8.05E+01	7.61E+01	6.09E+01	2.15E+02	6.09E-02	0.00E+00	0.00E+00	2.17E+00	2.17E-01
Na	7.24E+06	6.85E+06	5.48E+06	1.93E+07	5.48E+03	0.00E+00	0.00E+00	1.96E+05	1.96E+04
Ni	8.52E+04	8.06E+04	6.45E+04	2.28E+05	6.45E+01	0.00E+00	0.00E+00	2.30E+03	2.30E+02
NO2	2.24E+06	2.12E+06	1.70E+06	5.99E+06	1.70E+03	0.00E+00	0.00E+00	6.06E+04	6.06E+03
NO3	6.62E+06	6.26E+06	5.01E+06	1.77E+07	5.01E+03	0.00E+00	0 00E+00	1.79E+05	1.79E+04
Sb	6.98E+02	6.61E+02	5.28E+02	1.87E+03	5.28E-01	0.00E+00	0.00E+00	1.89E+01	1.89E+00
SO4	1.92E+05	1.82E+05	1.45E+05	5.13E+05	1.45E+02	0.00E+00	0.00E+00	5.19E+03	5.19E+02
V	1.80E+01	1.70E+01	1.36E+01	4.81E+01	1.36E-02	0.00E+00	0.00E+00	4.86E-01	4.86E-02
TOC	2.33E+05	2.20E+05	1.76E+05	6.22E+05	1.76E+02	0.00E+00	0.00E+00	6.30E+03	6.30E+02
Radionuclides (Ci)									
Am-241	3.51E+04	3.32E+04	2.65E+04	9.37E+04	2.65E+01	0.00E+00	0.00E+00	9.48E+02	9.48E+01
C-14	7.83E+02	7.41E+02	5.93E+02	2.09E+03	5.93E-01	0.00E+00	0.00E+00	2.12E+01	2.12E+00
Cs-137	2.70E+07	2.55E+07	2.04E+07	7.21E+07	2.04E+04	0.00E+00	0.00E+00	7.29E+05	7.29E+04
I-129	5.82E+00	5.51E+00	4.41E+00	1.56E+01	4.41E-03	0.00E+00	0.00E+00	1.57E-01	1.57E-02
Pu-239	1.74E+03	1.64E+03	1.32E+03	4.64E+03	1.32E+00	0.00E+00	0.00E+00	4.70E+01	4.70E+00
Sr-90	1.96E+09	1.86E+09	1.49E+09	5.25E+09	1.49E+06	0.00E+00	0.00E+00	5.30E+07	5.30E+06
Tc-99	9.21E+03	8.71E+03	6.97E+03	2.46E+04	6.97E+00	0.00E+00	0.00E+00	2.49E+02	2.49E+01
U									

* This stream contains trace amounts of radioactive materials which have not been tracked by the Aspen run. Therefore, all values are zero.

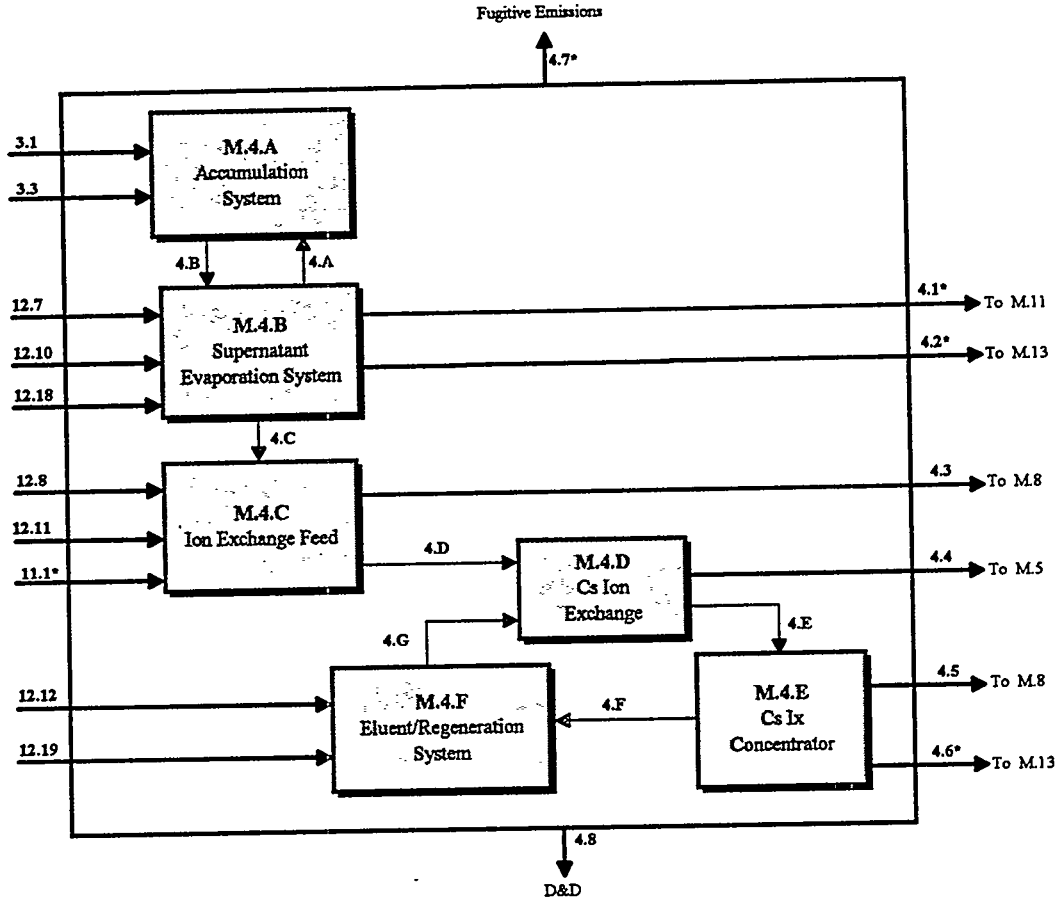
** Liquid Effluent Processing for Recycle or Discharge



M.3, DST Sludge Wash

	12.6	12.9	12.17	11.3	1.3 & 2.4	11.4	3.1	3.2	3.3	3.4	3.5
Tot. Liquid Mass Flow (kg)	1.13E+05	1.61E+07	6.67E+05	7.67E+06	7.34E+08	3.11E+07	7.19E+08	4.17E+07	6.52E+07	0.00E+00	1.39E+02
Tot. Solid Mass Flow(kg)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.55E+07	0.00E+00	1.84E+02	1.04E+07	6.90E+04	0.00E+00	2.73E+00
% Solid Mass	0.00%	0.00%	0.00%	0.00%	2.07%	0.00%	0.00%	19.96%	0.11%	NA	1.93%
H2O (kg)	0.00E+00	8.05E+06	6.67E+05	7.67E+06	5.17E+08	3.11E+07	5.06E+08	4.05E+07	4.87E+07	0.00E+00	9.94E+01
Chemicals (kg)											
As	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.41E+02	0.00E+00	1.85E+02	6.48E+02	8.05E+00	0.00E+00	1.48E-04
Be	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.94E+00	0.00E+00	7.25E-01	9.14E+00	7.53E-02	0.00E+00	1.75E-06
Cr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.65E+05	0.00E+00	4.07E+04	2.49E+04	9.92E+04	0.00E+00	2.90E-02
F	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.17E+06	0.00E+00	1.09E+06	5.75E+04	2.24E+04	0.00E+00	2.05E-01
Hg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.17E+03	0.00E+00	1.14E+03	1.02E+01	2.31E+01	0.00E+00	2.06E-04
Na	1.47E+04	4.63E+06	0.00E+00	0.00E+00	6.83E+07	0.00E+00	6.57E+07	1.61E+06	5.63E+06	0.00E+00	1.28E+01
Ni	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.28E+05	0.00E+00	5.66E+02	2.26E+05	1.51E+03	0.00E+00	4.01E-02
NO2	2.94E+04	0.00E+00	0.00E+00	0.00E+00	1.06E+07	0.00E+00	1.03E+07	9.58E+04	2.21E+05	0.00E+00	1.87E+00
NO3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.10E+08	0.00E+00	1.07E+08	1.16E+06	2.18E+06	0.00E+00	1.94E+01
Sb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.87E+03	0.00E+00	5.47E+01	1.80E+03	1.30E+01	0.00E+00	3.29E-04
SO4	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.04E+06	0.00E+00	1.95E+06	4.16E+04	3.99E+04	0.00E+00	3.59E-01
V	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.81E+01	0.00E+00	9.36E+00	3.83E+01	4.44E-01	0.00E+00	8.46E-06
TOC	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.13E+05	0.00E+00	7.64E+05	3.40E+04	1.57E+04	0.00E+00	1.43E-01
Radionuclides (Ci)											
Am-241	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.38E+05	0.00E+00	6.22E+03	1.31E+05	9.91E+02	0.00E+00	2.42E-02
C-14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.96E+03	0.00E+00	4.82E+03	5.47E+01	9.80E+01	0.00E+00	8.72E-04
Cs-137	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.06E+08	0.00E+00	9.18E+07	1.17E+07	1.94E+06	0.00E+00	1.86E+01
I-129	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.85E+01	0.00E+00	3.72E+01	5.17E-01	7.58E-01	0.00E+00	6.77E-06
Pu-239	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.90E+04	0.00E+00	5.86E+02	1.82E+04	1.33E+02	0.00E+00	3.34E-03
Sr-90	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.35E+09	0.00E+00	5.26E+07	5.27E+09	3.61E+07	0.00E+00	9.43E+02
Tc-99	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.99E+04	0.00E+00	3.00E+04	9.16E+03	6.71E+02	0.00E+00	7.02E-03
U	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.52E-01	0.00E+00	2.60E-02	4.23E-01	3.33E-03	0.00E+00	7.96E-08

* This stream contains trace amounts of radioactive materials which have not been tracked by the Aspen run. Therefore, all values are zero.

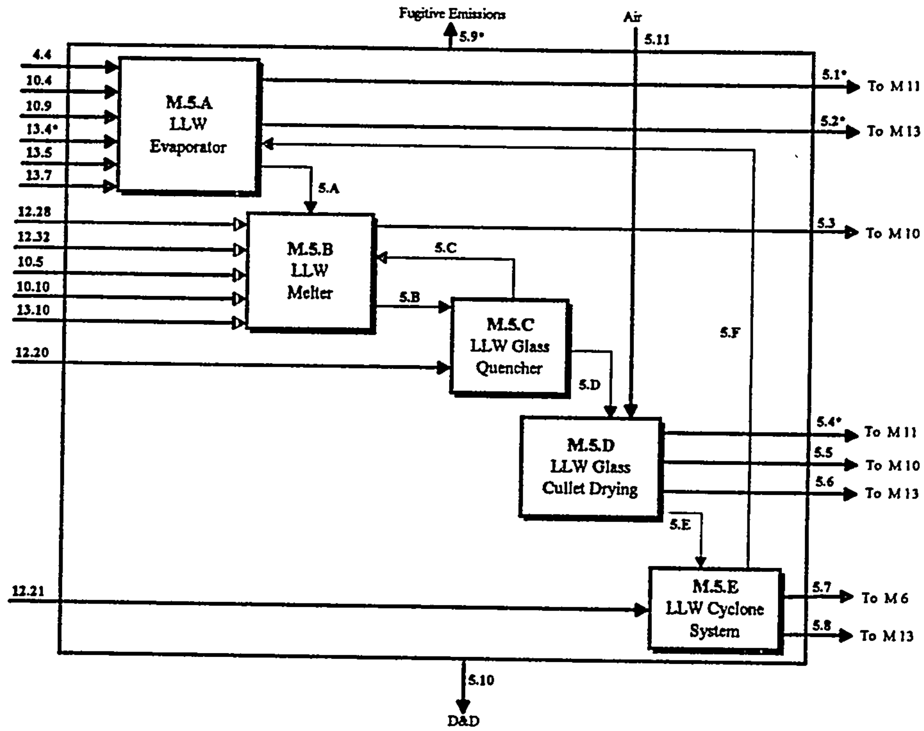


M.4, Cesium Ion Exchange

	3.1	3.3	12.7	12.10	12.18	12.8	12.11	11.1	12.12	12.19	4.1	4.2
Tot. Liquid Mass Flow (kg)	7.19E+08	6.52E+07	1.10E-01	2.19E-01	1.10E-01	0.00E+00	2.19E-02	2.19E+06	1.26E+07	4.05E+08	1.90E+08	1.91E+06
Tot. Solid Mass Flow(kg)	1.84E+02	6.90E+04	0.00E+00	0.00E+00	0.00E+00	5.31E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
% Solid Mass	0.00%	0.11%	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
H2O (kg)	5.06E+08	4.87E+07	0.00E+00	1.10E-01	1.10E-01	0.00E+00	1.10E-02	2.19E+06	5.72E+06	4.05E+08	1.90E+08	1.91E+06
Chemicals (kg)												
As	1.85E+02	8.05E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Be	7.25E-01	7.53E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0 00E+00
Cr	4.07E+04	9.92E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
F	1.09E+06	2.24E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0 00E+00
Hg	1.14E+03	2.31E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Na	6.57E+07	5.63E+06	3.66E-02	6.30E-02	0.00E+00	0.00E+00	6.30E-03	0.00E+00	2.38E+06	0.00E+00	0.00E+00	0.00E+00
Ni	5.66E+02	1.51E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NO2	1.03E+07	2.21E+05	7.30E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NO3	1.07E+08	2.18E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.69E+06	0.00E+00	0.00E+00	0.00E+00
Sb	5.47E+01	1.30E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SO4	1.95E+06	3.99E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
V	9.36E+00	4.44E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TOC	7.64E+05	1.57E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Radionuclides (Ci)												
Am-241	6.22E+03	9.91E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
C-14	4.82E+03	9.80E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs-137	9.18E+07	1.94E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-129	3.72E+01	7.58E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pu-239	5.86E+02	1.33E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr-90	5.26E+07	3.61E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tc-99	3.00E+04	6.71E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0 00E+00
U	2.60E-02	3.33E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

* This stream contains trace amounts of radioactive materials which have not been tracked by the Aspen run. Therefore, all values are zero.

4.3	4.4	4.5	4.6	4.7	4.8
2.49E+06	1.00E+09	3.74E+06	2.10E+06	0.00E+00	2.54E+02
1.22E+05	6.92E+02	0.00E+00	0.00E+00	0.00E+00	2.58E-02
4.67%	0.00%	0.00%	0.00%	NA	0.01%
2.37E+06	7.70E+08	2.10E+06	2.08E+06	0.00E+00	2.04E+02
4.35E+00	1.89E+02	0.00E+00	0.00E+00	0.00E+00	4.07E-05
6.05E-02	7.41E-01	0.00E+00	0.00E+00	0.00E+00	1.69E-07
1.94E+02	1.40E+05	0.00E+00	0.00E+00	0.00E+00	2.95E-02
9.23E+02	1.11E+06	0.00E+00	0.00E+00	0.00E+00	2.35E-01
6.37E-01	1.16E+03	0.00E+00	0.00E+00	0.00E+00	2.45E-04
4.33E+04	7.35E+07	1.93E+05	0.00E+00	0.00E+00	1.55E+01
1.49E+03	5.90E+02	0.00E+00	0.00E+00	0.00E+00	4.37E-04
5.70E+03	1.05E+07	0.00E+00	0.00E+00	0.00E+00	2.22E+00
6.12E+04	1.10E+08	1.43E+06	2.09E+04	0.00E+00	2.36E+01
1.18E+01	5.59E+01	0.00E+00	0.00E+00	0.00E+00	1.43E-05
1.25E+03	1.99E+06	0.00E+00	0.00E+00	0.00E+00	4.20E-01
2.57E-01	9.54E+00	0.00E+00	0.00E+00	0.00E+00	2.07E-06
6.07E+02	7.79E+05	0.00E+00	0.00E+00	0.00E+00	1.64E-01
8.62E+02	6.36E+03	0.00E+00	0.00E+00	0.00E+00	1.52E-03
2.77E+00	4.91E+03	0.00E+00	0.00E+00	0.00E+00	1.04E-03
1.23E+05	7.40E+05	9.29E+07	0.00E+00	0.00E+00	1.98E+01
2.20E-02	3.80E+01	0.00E+00	0.00E+00	0.00E+00	8.00E-06
1.20E+02	5.99E+02	0.00E+00	0.00E+00	0.00E+00	1.52E-04
3.47E+07	4.86E+07	5.30E+06	0.00E+00	0.00E+00	1.87E+01
7.53E+01	3.06E+04	0.00E+00	0.00E+00	0.00E+00	6.47E-03
2.80E-03	2.66E-02	0.00E+00	0.00E+00	0.00E+00	6.20E-09

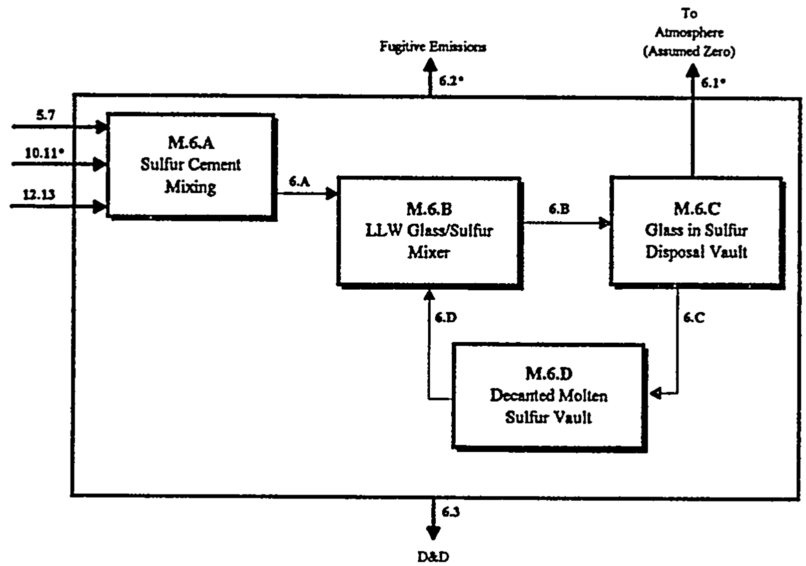


M.5, LLW Glass in Sulfur

	5.11	4.4	10.4	10.9	13.4	13.5	13.7	12.28	12.32	10.5	10.10	13.10
Tot Liquid Mass Flow (kg)	3 37E+09	1.00E+09	4 17E+03	0 00E+00	0 00E+00	2 25E+02	4 18E+07	6 79E+07	0 00E+00	2 00E+07	2 44E+07	2 29E+08
Tot. Solid Mass Flow(kg)	0 00E+00	6 92E+02	4.21E+01	3.15E+02	0 00E+00	2 27E+00	4.22E+05	0 00E+00	2 84E+08	4 00E+06	4 00E+06	0 00E+00
% Solid Mass	0 00%	0.00%	1.00%	100 00%	NA	1.00%	1.00%	0 00%	100 00%	16 67%	14 08%	0 00%
H2O (kg)	3 74E+07	7.70E+08	4.17E+03	0 00E+00	0.00E+00	2.25E+02	4 18E+07	0 00E+00	0 00E+00	2 00E+07	2 44E+07	0 00E+00
Chemicals (kg)												
As	0 00E+00	1.89E+02	8 47E-05	1 51E-04	0 00E+00	4 24E-06	8 47E-01	0 00E+00	0 00E+00	1.90E+00	1.90E+00	0 00E+00
Be	0 00E+00	7.41E-01	1 00E-06	5 91E-07	0 00E+00	5 01E-08	1.01E-02	0 00E+00	0 00E+00	7 46E-03	7.49E-03	0 00E+00
Cr	0 00E+00	1.40E+05	1.66E-02	1.12E-01	0 00E+00	8.97E-04	1.66E+02	0.00E+00	0 00E+00	1 41E+03	1 41E+03	0 00E+00
F	0 00E+00	1.11E+06	0 00E+00	0 00E+00	0 00E+00	0 00E+00	0 00E+00	0 00E+00	0 00E+00	0 00E+00	0 00E+00	0 00E+00
Hg	0 00E+00	1.16E+03	0 00E+00	0 00E+00	0 00E+00	0 00E+00	0 00E+00	0 00E+00	0 00E+00	0 00E+00	6 09E+01	0 00E+00
· Na	0 00E+00	7.35E+07	7 60E+00	5 87E+01	0 00E+00	4 10E-01	7.60E+04	0 00E+00	0 00E+00	7 41E+05	7.42E+05	0 00E+00
Ni	0 00E+00	5.90E+02	1.90E-02	9 35E-06	0 00E+00	1.02E-03	1 90E+02	0 00E+00	0 00E+00	5.92E+00	5.93E+00	0 00E+00
NO2	0 00E+00	1.05E+07	0 00E+00	0 00E+00	0 00E+00	0 00E+00	0 00E+00	0 00E+00	0 00E+00	0 00E+00	0 00E+00	0 00E+00
NO3	0 00E+00	1 10E+08	0.00E+00	0 00E+00	0 00E+00	0.00E+00	0 00E+00	0 00E+00	0 00E+00	0 00E+00	0 00E+00	0 00E+00
Sb	0 00E+00	5.59E+01	1.88E-04	4 47E-05	0 00E+00	9.41E-06	1 88E+00	0.00E+00	0 00E+00	5 65E-01	5 65E-01	0 00E+00
SO4	0 00E+00	1.99E+06	0 00E+00	0 00E+00	0 00E+00	n 00E+00	0.00E+00	0 00E+00	0 00E+00	0 00E+00	0 00E+00	0 00E+00
V	0 00E+00	9.54E+00	4 85E-06	7 62E-06	0 00E+00	` 11E-07	4 85E-02	0 00E+00	0 00E+00	9 64E-02	9.64E-02	0 00E+00
TOC	0 00E+00	7.79E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0 00E+00	0 00E+00	0.00E+00	0.00E+00	0.00E+00
Radionuclides (Ci)												
Am-241	0 00E+00	6.36E+03	1.39E-02	0 00E+00	0 00E+00	6.95E-04	1 39E+02	0 00E+00	0 00E+00	6 42E+01	6 39E+01	0 00E+00
C-14	0 00E+00	4.91E+03	0.00E+00	0.00E+00	0 00E+00	0 00E+00	0 00E+00	0 00E+00	0 00E+00	0 00E+00	0 00E+00	0 00E+00
Cs-137	0 00E+00	7.40E+05	1.06E+01	5.90E-01	0 00E+00	5.31E-01	1 06E+05	0 00E+00	0 00E+00	7 45E+03	7 45E+03	0 00E+00
I-129	0.00E+00	3 80E+01	0 00E+00	0 00E+00	0 00E+00	0 00E+00	0 00E+00	0 00E+00	0 00E+00	0 00E+00	0.00E+00	0 00E+00
Pu-239	0 00E+00	5 99E+02	1.91E-03	4.79E-04	0.00E+00	9.60E-05	1.91E+01	0 00E+00	0 00E+00	6 05E+00	6 05E+00	0 00E+00
Sr-90	0.00E+00	4 86E+07	5 40E+02	3 89E+01	0 00E+00	0 00E+00	0 00E+00	0 00E+00	0 00E+00	4 90E+05	4 90E+05	0 00E+00
Tc-99	0 00E+00	3 06E+04	4.00E-03	1.25E-02	0 00E+00	2 00E-04	4 00E+01	0 00E+00	0 00E+00	1 58E+02	9 44E+02	0 00E+00
U	0.00E+00	2 66E-02	4.57E-08	2.12E-08	0 00E+00	2.46E-09	4.57E-04	0 00E+00	0 00E+00	2 68E-04	2 68E-04	0 00E+00

* This stream contains trace amounts of radioactive materials which have not been tracked by the Aspen run. Therefore, all values are zero.

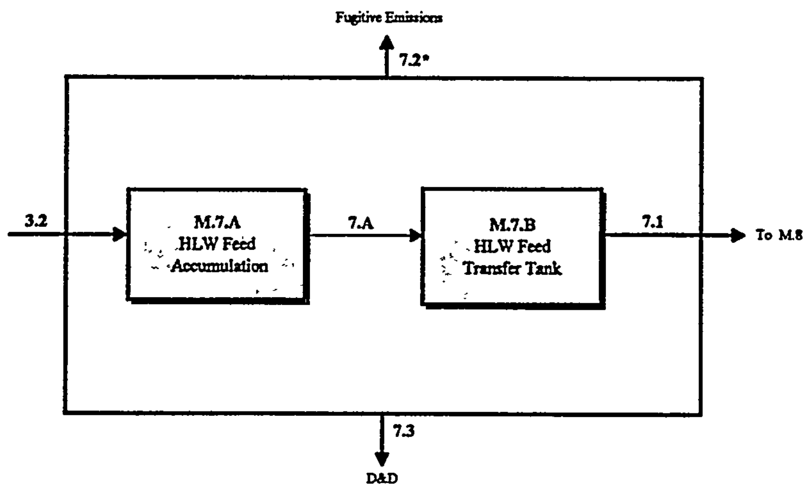
12.20	12.21	5.1	5.2	5.3	5.4	5.5	5.6	5.7	5.8	5.9	5.10
4.84E+07	3.91E+05	5.27E+08	5.32E+06	7.50E+08	2.66E+07	1.68E+07	1.67E+09	0.00E+00	1.67E+09	0.00E+00	2.10E+02
0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.08E+06	0.00E+00	4.00E+06	4.00E+05	3.96E+08	1.98E+00	0.00E+00	1.28E+01
0.00%	0.00%	0.00%	0.00%	0.54%	0.00%	19.23%	0.02%	100.00%	0.00%	NA	5.74%
4.84E+07	3.91E+05	5.27E+08	5.32E+06	4.89E+08	2.66E+07	1.88E+05	0.00E+00	0.00E+00	1.86E+07	0.00E+00	3.97E+01
0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.94E+00	0.00E+00	1.90E+00	1.90E-01	1.88E+02	9.45E-07	0.00E+00	8.49E-06
0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.64E-03	0.00E+00	7.46E-03	7.49E-04	7.39E-01	3.71E-09	0.00E+00	3.36E-08
0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.44E+03	0.00E+00	1.41E+03	1.41E+02	1.40E+05	6.98E-04	0.00E+00	6.27E-03
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.86E-02
0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.22E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.35E-05
0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.57E+05	0.00E+00	7.41E+05	7.42E+04	7.34E+07	3.67E-01	0.00E+00	3.29E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.05E+00	0.00E+00	5.92E+00	5.93E-01	5.87E+02	2.93E-06	0.00E+00	3.47E-05
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.60E-01
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.82E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.77E-01	0.00E+00	5.65E-01	5.65E-02	5.59E+01	2.79E-07	0.00E+00	2.58E-06
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.72E-02
0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.86E-02	0.00E+00	9.64E-02	9.64E-03	9.52E+00	4.77E-08	0.00E+00	4.29E-07
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.41E-02
0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.54E+01	0.00E+00	6.42E+01	6.42E+00	6.33E+03	3.18E-05	0.00E+00	2.90E-04
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.15E-04
0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.60E+03	0.00E+00	7.45E+03	7.45E+02	7.37E+05	3.69E-03	0.00E+00	3.77E-02
0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.80E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.66E-06
0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.18E+00	0.00E+00	6.05E+00	6.05E-01	5.99E+02	2.99E-06	0.00E+00	2.76E-05
0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.01E+05	0.00E+00	4.90E+05	4.92E+04	4.85E+07	2.43E-01	0.00E+00	2.17E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.58E+04	0.00E+00	1.58E+02	1.58E+01	1.56E+04	7.80E-05	0.00E+00	1.39E-03
0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.74E-04	0.00E+00	2.68E-04	2.68E-05	2.65E-02	1.33E-10	0.00E+00	1.21E-09



M.6, LLW Glass in Sulfur Vaults

	5.7	10.11	12.13	6.1	6.2	6.3
Tot. Liquid Mass Flow (kg)	0.00E+00	3.67E+05	1.37E+08	0.00E+00	0.00E+00	1.51E+01
Tot. Solid Mass Flow(kg)	3.96E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.36E+01
% Solid Mass	100.00%	0.00%	0.00%	NA	NA	74.26%
H2O (kg)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Chemicals (kg)						
As	1.88E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.08E-05
Be	7.39E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.14E-08
Cr	1.40E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.54E-02
F	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Na	7.34E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.09E+00
Ni	5.87E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.46E-05
NO2	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NO3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sb	5.59E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.15E-06
SO4	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
V	9.52E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.05E-06
TOC	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Radionuclides (Ci)						
Am-241	6.33E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.98E-04
C-14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs-137	7.37E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.12E-02
I-129	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pu-239	5.99E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.60E-05
Sr-90	4.85E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.35E+00
Tc-99	1.56E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.72E-03
U	2.65E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.93E-09

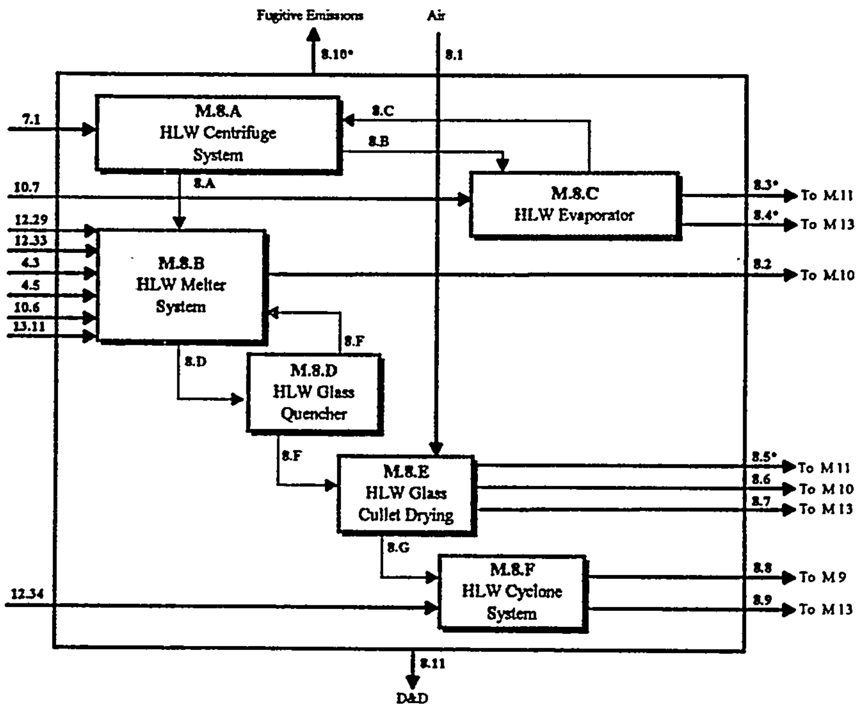
* This stream contains trace amounts of radioactive materials which have not been tracked by the Aspen run. Therefore, all values are zero.



M.7, HLW Glass Cullet Feed Lag Storage

	3.2	7.1	7.2	7.3
Tot. Liquid Mass Flow (kg)	4.17E+07	4.17E+07	0.00E+00	1.37E+01
Tot Solid Mass Flow(kg)	1.04E+07	1.04E+07	0.00E+00	3.41E+00
% Solid Mass	19.96%	19.96%	NA	19.96%
H2O (kg)	4.05E+07	4.05E+07	0.00E+00	1.33E+01
Chemicals (kg)				
As	6.48E+02	6.48E+02	0.00E+00	2.13E-04
Be	9.14E+00	9.14E+00	0.00E+00	3.00E-06
Cr	2.49E+04	2.49E+04	0.00E+00	8.16E-03
F	5.75E+04	5.75E+04	0.00E+00	1.88E-02
Hg	1.02E+01	1.02E+01	0.00E+00	3.34E-06
Na	1.61E+06	1.61E+06	0.00E+00	5.26E-01
Ni	2.26E+05	2.26E+05	0.00E+00	7.40E-02
NO2	9.58E+04	9.58E+04	0.00E+00	3.14E-02
NO3	1.16E+06	1.16E+06	0.00E+00	3.79E-01
Sb	1.80E+03	1.80E+03	0.00E+00	5.90E-04
SO4	4.16E+04	4.16E+04	0.00E+00	1.36E-02
V	3.83E+01	3.83E+01	0.00E+00	1.26E-05
TOC	3.40E+04	3.40E+04	0.00E+00	1.11E-02
Radionuclides (Ci)				
Am-241	1.31E+05	1.31E+05	0.00E+00	4.28E-02
C-14	5.47E+01	5.47E+01	0.00E+00	1.79E-05
Cs-137	1.17E+07	1.17E+07	0.00E+00	3.84E+00
I-129	5.17E-01	5.17E-01	0.00E+00	1.69E-07
Pu-239	1.82E+04	1.82E+04	0.00E+00	5.97E-03
Sr-90	5.27E+09	5.27E+09	0.00E+00	1.73E+03
Tc-99	9.16E+03	9.16E+03	0.00E+00	3.00E-03
U	4.23E-01	4.23E-01	0.00E+00	1.39E-07

* This stream contains trace amounts of radioactive materials which have not been tracked by the Aspen run. Therefore, all values are zero.

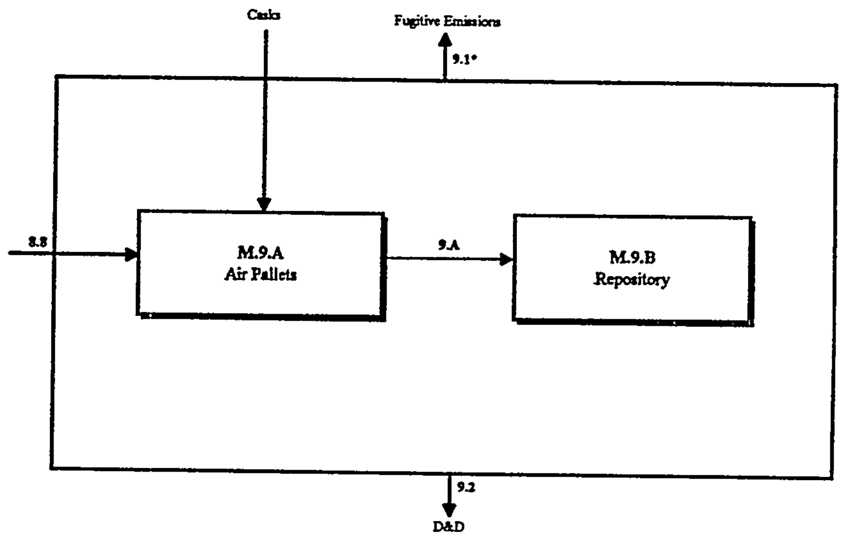


M.8, HLW Glass Cullet

	8.1	7.1	12.29	12.33	4.3	4.5	10.6	13.11	10.7	12.34	8.2	8.3
Tot Liquid Mass Flow (kg)	1.85E+08	4.17E+07	5.50E+06	0.00E+00	2.49E+06	3.74E+06	1.10E+06	2.35E+07	5.20E+08	2.15E+04	7.52E+07	5.20E+08
Tot Solid Mass Flow(kg)	0.00E+00	1.04E+07	0.00E+00	1.12E+07	1.22E+05	0.00E+00	2.19E+05	0.00E+00	3.05E+05	0.00E+00	2.24E+05	0.00E+00
% Solid Mass	0.00%	19.96%	0.00%	100.00%	4.67%	0.00%	16.60%	0.00%	0.06%	0.00%	0.30%	0.00%
H2O (kg)	2.05E+06	4.05E+07	0.00E+00	0.00E+00	2.37E+06	2.10E+06	1.10E+06	0.00E+00	5.20E+08	2.15E+04	5.57E+07	5.20E+08
Chemicals (kg)												
As	0.00E+00	6.48E+02	0.00E+00	0.00E+00	4.35E+00	0.00E+00	6.58E+00	0.00E+00	6.78E+00	0.00E+00	6.71E+00	0.00E+00
Be	0.00E+00	9.14E+00	0.00E+00	0.00E+00	6.05E-02	0.00E+00	9.30E-02	0.00E+00	9.51E-02	0.00E+00	9.48E-02	0.00E+00
Cr	0.00E+00	2.49E+04	0.00E+00	0.00E+00	1.94E+02	0.00E+00	2.53E+02	0.00E+00	2.88E+02	0.00E+00	2.59E+02	0.00E+00
F	0.00E+00	5.75E+04	0.00E+00	0.00E+00	9.23E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hg	0.00E+00	1.02E+01	0.00E+00	0.00E+00	6.37E-01	0.00E+00	0.00E+00	0.00E+00	2.73E+03	0.00E+00	2.74E+03	0.00E+00
Na	0.00E+00	1.61E+06	0.00E+00	0.00E+00	4.33E+04	1.93E+05	1.87E+04	0.00E+00	[illegible]	0.00E+00	1.91E+04	0.00E+00
Ni	0.00E+00	2.26E+05	0.00E+00	0.00E+00	1.49E+03	0.00E+00	1.89E+03	0.00E+00	1.93E+03	0.00E+00	1.93E+03	0.00E+00
NO2	0.00E+00	9.58E+04	0.00E+00	0.00E+00	5.70E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NO3	0.00E+00	1.16E+06	0.00E+00	0.00E+00	6.12E+04	1.43E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sb	0.00E+00	1.80E+03	0.00E+00	0.00E+00	1.18E+01	0.00E+00	1.83E+01	0.00E+00	1.87E+01	0.00E+00	1.87E+01	0.00E+00
SO4	0.00E+00	4.16E+04	0.00E+00	0.00E+00	1.25E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
V	0.00E+00	3.83E+01	0.00E+00	0.00E+00	2.57E-01	0.00E+00	3.89E-01	0.00E+00	3.99E-01	0.00E+00	3.97E-01	0.00E+00
TOC	0.00E+00	3.40E+04	0.00E+00	0.00E+00	6.07E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Radionuclides (Ci)												
Am-241	0.00E+00	1.31E+05	0.00E+00	0.00E+00	8.62E+02	0.00E+00	1.32E+03	0.00E+00	1.35E+03	0.00E+00	1.35E+03	0.00E+00
C-14	0.00E+00	5.47E+01	0.00E+00	0.00E+00	2.77E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs-137	0.00E+00	1.17E+07	0.00E+00	0.00E+00	1.23E+05	9.29E+07	1.06E+06	0.00E+00	1.08E+06	0.00E+00	1.08E+06	0.00E+00
I-129	0.00E+00	5.17E-01	0.00E+00	0.00E+00	2.20E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.40E-01	0.00E+00
Pu-239	0.00E+00	1.82E+04	0.00E+00	0.00E+00	1.20E+02	0.00E+00	1.85E+02	0.00E+00	1.89E+02	0.00E+00	1.89E+02	0.00E+00
Sr-90	0.00E+00	5.27E+09	0.00E+00	0.00E+00	3.47E+07	5.30E+06	5.36E+07	0.00E+00	5.48E+07	0.00E+00	5.48E+07	0.00E+00
Tc-99	0.00E+00	9.16E+03	0.00E+00	0.00E+00	7.53E+01	0.00E+00	2.42E+02	0.00E+00	3.94E+04	0.00E+00	2.42E+04	0.00E+00
U	0.00E+00	4.23E-01	0.00E+00	0.00E+00	2.80E-03	0.00E+00	4.30E-03	0.00E+00	4.41E-03	0.00E+00	4.38E-03	0.00E+00

* This stream contains trace amounts of radioactive materials which have not been tracked by the Aspen run. Therefore, all values are zero.

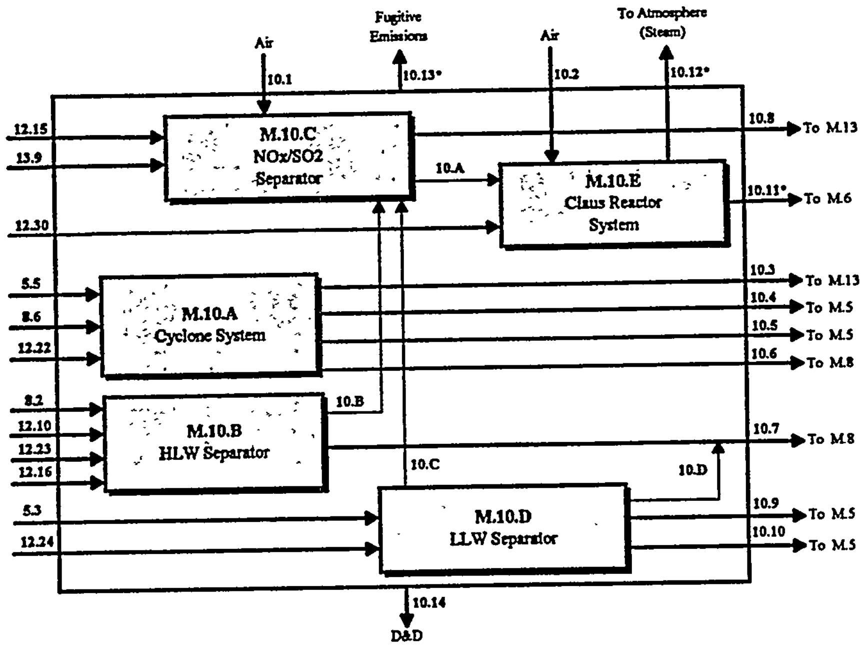
8.4	8.5	8.6	8.7	8.8	8.9	8.10	8.11
5.26E+06	7.40E+05	1.57E+06	2.73E+07	0.00E+00	1.55E+08	0.00E+00	2.77E+02
0.00E+00	0.00E+00	2.19E+05	2.19E+04	2.17E+07	1.08E-01	0.00E+00	7.87E+00
0.00%	0.00%	12.24%	0.08%	100.00%	0.00%	NA	2.76%
5.26E+06	7.40E+05	1.75E+04	0.00E+00	0.00E+00	1.73E+06	0.00E+00	2.01E+02
0.00E+00	0.00E+00	6.58E+00	6.58E-01	6.52E+02	3.26E-06	0.00E+00	2.36E-04
0.00E+00	0.00E+00	9.30E-02	9.30E-03	9.19E+00	4.61E-08	·0.00E+00	3.32E-06
0.00E+00	0.00E+00	2.53E+02	2.54E+01	2.51E+04	1.25E-04	0.00E+00	9.06E-03
0.00E+00	.0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.07E-02
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.70E-04
0.00E+00	0.00E+00	1.87E+04	1.87E+03	1.85E+06	9.27E-03	0.00E+00	6.70E-01
0.00E+00	0.00E+00	1.89E+03	1.89E+02	1.88E+05	9.38E-04	0.00E+00	8.17E-02
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.59E-02
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.36E-01
0.00E+00	0.00E+00	1.83E+01	1.83E+00	1.81E+03	9.03E-06	0.00E+00	6.54E-04
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.52E-02
0.00E+00	0.00E+00	3.89E-01	3.89E-02	3.85E+01	1.92E-07	0.00E+00	1.39E-05
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.22E-02
0.00E+00	0.00E+00	1.32E+03	1.33E+02	1.31E+05	6.54E-04	0.00E+00	4.74E-02
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.03E-05
0.00E+00	0.00E+00	1.06E+06	1.06E+05	1.05E+08	5.22E-01	0.00E+00	3.78E+01
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.91E-07
0.00E+00	0.00E+00	1.85E+02	1.85E+01	1.83E+04	9.21E-05	0.00E+00	6.62E-03
0.00E+00	0.00E+00	5.36E+07	5.37E+06	5.31E+09	2.65E+01	0.00E+00	1.92E+03
0.00E+00	0.00E+00	2.42E+02	2.43E+01	2.40E+04	1.20E-04	0.00E+00	1.73E-02
0.00E+00	0.00E+00	4.30E-03	4.30E-04	4.27E-01	2.13E-09	0.00E+00	1.54E-07



M.9, HLW Glass Cullet Cask Storage Pad

	8.8	9.1	9.2
Tot Liquid Mass Flow (kg)	0.00E+00	0 00E+00	0 00E+00
Tot. Solid Mass Flow(kg)	2.17E+07	0 00E+00	5 23E+01
% Solid Mass	100.00%	NA	100.00%
H2O (kg)	0 00E+00	0.00E+00	0 00E+00
Chemicals (kg)			
As	6 52E+02	0.00E+00	1.57E-03
Be	9 19E+00	0 00E+00	2 21E-05
Cr	2 51E+04	0.00E+00	6 04E-02
F	0.00E+00	0 00E+00	0 00E+00
Hg	0 00E+00	0 00E+00	0 00E+00
Na	1.85E+06	0 00E+00	4 46E+00
Ni	1.88E+05	0 00E+00	4 52E-01
NO2	0 00E+00	0.00E+00	0 00E+00
NO3	0 00E+00	0 00E+00	0 00E+00
Sb	1.81E+03	0 00E+00	4 35E-03
SO4	0 00E+00	0 00E+00	0 00E+00
V	3 85E+01	0 00E+00	9 27E-05
TOC	0.00E+00	0 00E+00	0 00E+00
Radionuclides (Ci)			
Am-241	1.31E+05	0.00E+00	3 16E-01
C-14	0.00E+00	0 00E+00	0 00E+00
Cs-137	1 05E+08	0 00E+00	2 53E+02
I-129	0 00E+00	0 00E+00	0 00E+00
Pu-239	1.83E+04	0 00E+00	4 42E-02
Sr-90	5 31E+09	0.00E+00	1.28E+04
Tc-99	2 40E+04	0 00E+00	5.78E-02
U	4.27E-01	0.00E+00	1.03E-06

* This stream contains trace amounts of radioactive materials which have not been tracked by the Aspen run. Therefore, all values are zero.

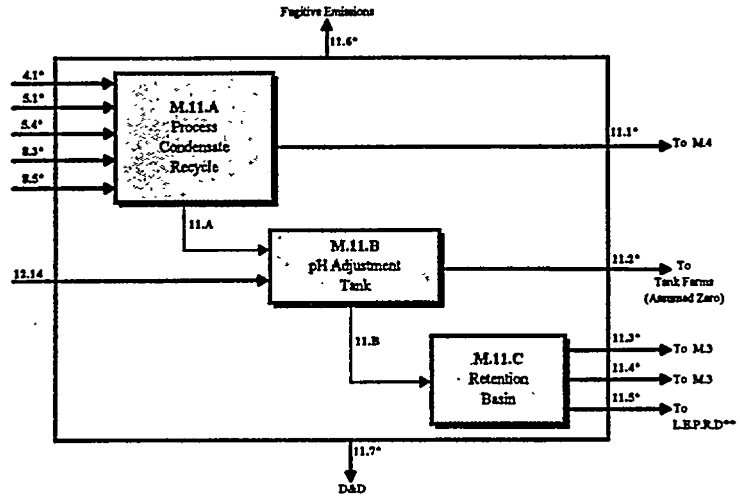


M.10, Cullet Rework and Melter Off-Gas Processing

	10.1	10.2	5.5	8.6	12.22	8.2	12.10	12.23	12.16	12.15	13.19	5.3
Tot. Liquid Mass Flow (kg)	9.23E+07	2.78E+06	1.68E+07	1.57E+06	2.11E+07	7.52E+07	2.19E-01	1.72E+03	0 00E+00	8.38E+06	5 46E+05	7.50E+08
Tot. Solid Mass Flow(kg)	0 00E+00	0 00E+00	4.00E+06	2.19E+05	0.00E+00	2.24E+05	0.00E+00	0.00E+00	0 00E+00	0.00E+00	0.00E+00	4.08E+06
% Solid Mass	0.00%	0 00%	19.23%	12.24%	0.00%	0.30%	0.00%	0.00%	NA	0.00%	0.00%	0.54%
H2O (kg)	0 00E+00	0 00E+00	1.88E+05	1.75E+04	2.11E+07	5.57E+07	1.10E-01	3.44E+03	0.00E+00	0.00E+00	0 00E+00	4.89E+08
Chemicals (kg)												
As	0 00E+00	0.00E+00	1.90E+00	6 58E+00	0.00E+00	6.71E+00	0.00E+00	0 00E+00	0 00E+00	0.00E+00	0 00E+00	1 94E+00
Be	0 00E+00	0 00E+00	7.46E-03	9.30E-02	0 00E+00	9.48E-02	0 00E+00	0 00E+00	0 00E+00	0 00E+00	0 00E+00	7 64E-03
Cr	0.00E+00	0 00E+00	1.41E+03	2.53E+02	0 00E+00	2 59E+02	0 00E+00	0 00E+00	0 00E+00	0 00E+00	0 00E+00	1 44E+03
F	0 00E+00	0 00E+00	0 00E+00	0 00E+00	0 00E+00	0 00E+00	0 00E+00	0 00E+00	0 00E+00	0 00E+00	0 00E+00	0 00E+00
Hg	0 00E+00	0 00E+00	0 00E+00	0 00E+00	0 00E+00	2 74E+03	0.00E+00	0 00E+00	0 00E+00	0 00E+00	0.00E+00	1.22E+03
Na	0 00E+00	0 00E+00	7.41E+05	1.87E+04	0 00E+00	1.91E+04	6.30E-02	0.00E+00	0 00E+00	0 00E+00	0 00E+00	7.57E+05
Ni	0.00E+00	0.00E+00	5.92E+00	1.89E+03	0.00E+00	1.93E+03	0.00E+00	0 00E+00	0 00E+00	0 00E+00	0 00E+00	6.05E+00
NO2	0 00E+00	0 00E+00	0 00E+00	0 00E+00	0 00E+00	0 00E+00	0.00E+00	0 00E+00	0 00E+00	0 00E+00	0 00E+00	0 00E+00
NO3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0 00E+00	0 00E+00	0.00E+00	0 00E+00
Sb	0.00E+00	0.00E+00	5.65E-01	1.83E+01	0.00E+00	1.87E+01	0.00E+00	0 00E+00	0 00E+00	0 00E+00	0 00E+00	5.77E-01
SO4	0 00E+00	0.00E+00	0 00E+00	0.00E+00	0 00E+00	0 00E+00	0 00E+00	0 00E+00	0 00E+00	0 00E+00	0 00E+00	0 00E+00
V	0.00E+00	0 00E+00	9.64E-02	3.89E-01	0.00E+00	3.97E-01	0.00E+00	0.00E+00	0.00E+00	0 00E+00	0 00E+00	9.86E-02
TOC	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0 00E+00	0.00E+00	0.00E+00	0 00E+00
Radionuclides (Ci)												
Am-241	0.00E+00	0.00E+00	6 42E+01	1.32E+03	0 00E+00	1.35E+03	0.00E+00	0.00E+00	0 00E+00	0.00E+00	0.00E+00	6 54E+01
C-14	0.00E+00	0.00E+00	0 00E+00	0.00E+00	0 00E+00	0 00E+00	0.00E+00	0.00E+00	0 00E+00	0 00E+00	0 00E+00	0 00E+00
Cs-137	0.00E+00	0.00E+00	7.45E+03	1.06E+06	0 00E+00	1.08E+06	0.00E+00	0.00E+00	0.00E+00	0 00E+00	0 00E+00	7 60E+03
I-129	0 00E+00	0 00E+00	0.00E+00	0.00E+00	0 00E+00	5.40E-01	0.00E+00	0 00E+00	0 00E+00	0.00E+00	0 00E+00	3 80E+01
Pu-239	0 00E+00	0 00E+00	6.05E+00	1.85E+02	0 00E+00	1.89E+02	0 00E+00	0.00E+00	0 00E+00	0.00E+00	0 00E+00	6 18E+00
Sr-90	0.00E+00	0.00E+00	4.90E+05	5.36E+07	0 00E+00	5 48E+07	0 00E+00	0 00E+00	0 00E+00	0.00E+00	0 00E+00	5 01E+05
Tc-99	0 00E+00	0 00E+00	1.58E+02	2.42E+02	0 00E+00	2.42E+04	0 00E+00	0.00E+00	0 00E+00	0.00E+00	0.00E+00	1.58E+04
U	0.00E+00	0.00E+00	2.68E-04	4.30E-03	0.00E+00	4.38E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.74E-04

* This stream contains trace amounts of radioactive materials which have not been tracked by the Aspen run. Therefore, all values are zero.

12.24	12.30	10.3	10.4	10.5	10.6	10.7	10.8	10.9	10.10	10.11	10.12	10.13	10.14
2.19E-07	0.00E+00	1.84E+07	4.17E+03	2.00E+07	1.10E+06	5.20E+08	3.80E+08	0.00E+00	2.44E+07	3.67E+05	4.44E+06	0.00E+00	2.42E+02
0.00E+00	0.00E+00	2.11E-02	4.21E+01	4.00E+06	2.19E+05	3.05E+05	1.66E-01	3.15E+02	4.00E+06	0.00E+00	0.00E+00	0.00E+00	2.13E+00
0.00%	NA	0.00%	1.00%	16.67%	16.60%	0.06%	0.00%	100.00%	14.08%	0.00%	0.00%	NA	0.87%
2.19E-07	0.00E+00	2.05E+05	4.17E+03	2.00E+07	1.10E+06	5.20E+08	1.18E+07	0.00E+00	2.44E+07	0.00E+00	1.72E+06	0.00E+00	1.41E+02
0.00E+00	0.00E+00	4.24E-08	8.47E-05	1.90E+00	6.58E+00	6.78E+00	0.00E+00	1.51E-04	1.90E+00	0.00E+00	0.00E+00	0.00E+00	4.28E-06
0.00E+00	0.00E+00	5.01E-10	1.00E-06	7.46E-03	9.30E-02	9.51E-02	0.00E+00	5.91E-07	7.49E-03	0.00E+00	0.00E+00	0.00E+00	5.06E-08
0.00E+00	0.00E+00	8.32E-06	1.66E-02	1.41E+03	2.53E+02	2.88E+02	6.59E-05	1.12E-01	1.41E+03	0.00E+00	0.00E+00	0.00E+00	8.39E-04
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.73E+03	0.00E+00	0.00E+00	6.09E+01	0.00E+00	0.00E+00	0.00E+00	9.88E-04
0.00E+00	0.00E+00	3.80E-03	7.60E+00	7.41E+05	1.87E+04	3.43E+04	3.01E-02	5.87E+01	7.42E+05	0.00E+00	0.00E+00	0.00E+00	3.83E-01
0.00E+00	0.00E+00	9.49E-06	1.90E-02	5.92E+00	1.89E+03	1.93E+03	7.10E-05	9.35E-06	5.93E+00	0.00E+00	0.00E+00	0.00E+00	9.57E-04
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.00E+00	0.00E+00	9.41E-08	1.88E-04	5.65E-01	1.83E+01	1.87E+01	0.00E+00	4.47E-05	5.65E-01	0.00E+00	0.00E+00	0.00E+00	9.50E-06
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.00E+00	0.00E+00	2.43E-09	4.85E-06	9.64E-02	3.89E-01	3.99E-01	0.00E+00	7.62E-06	9.64E-02	0.00E+00	0.00E+00	0.00E+00	2.45E-07
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.00E+00	0.00E+00	6.95E-06	1.39E-02	6.42E+01	1.32E+03	1.35E+03	0.00E+00	0.00E+00	6.39E+01	0.00E+00	0.00E+00	0.00E+00	7.00E-04
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.00E+00	0.00E+00	5.31E-03	1.06E+01	7.45E+03	1.06E+06	1.08E+06	0.00E+00	5.90E-01	7.45E+03	0.00E+00	0.00E+00	0.00E+00	5.38E-01
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.85E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.61E-06
0.00E+00	0.00E+00	9.60E-07	1.91E-03	6.05E+00	1.85E+02	1.89E+02	0.00E+00	4.79E-04	6.05E+00	0.00E+00	0.00E+00	0.00E+00	9.65E-05
0.00E+00	0.00E+00	2.70E-01	5.40E+02	4.90E+05	5.36E+07	5.48E+07	0.00E+00	3.89E+01	4.90E+05	0.00E+00	0.00E+00	0.00E+00	2.73E+01
0.00E+00	0.00E+00	2.00E-06	4.00E-03	1.58E+02	2.42E+02	3.94E+04	0.00E+00	1.25E-02	9.44E+02	0.00E+00	0.00E+00	0.00E+00	1.01E-02
0.00E+00	0.00E+00	2.28E-11	4.57E-08	2.68E-04	4.30E-03	4.41E-03	1.81E-10	2.12E-08	2.68E-04	0.00E+00	0.00E+00	0.00E+00	2.30E-09

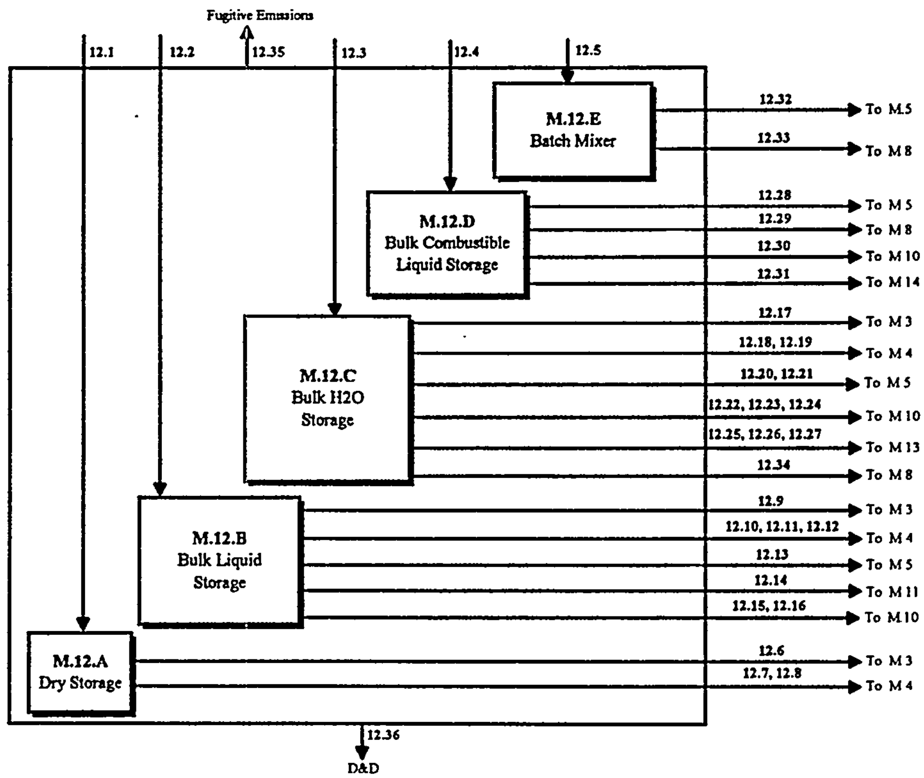


M.11, Liquid Effluent Treatment Facility

	4.1	5.1	5.4	8.3	8.5	12.14	11.1	11.2	11.3	11.4	11.5	11.6	11.7
Tot. Liquid Mass Flow (kg)	1.90E+08	5.27E+08	2.66E+07	5.20E+08	7.40E+05	0.00E+00	2.19E+06	0.00E+00	7.67E+06	3.11E+07	1.19E+09	0.00E+00	3.79E+01
Tot. Solid Mass Flow(kg)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
% Solid Mass	0.00%	0.00%	0.00%	0.00%	0.00%	NA	0.00%	NA	0.00%	0.00%	0.00%	NA	0.00%
H2O (kg)	1.90E+08	5.27E+08	2.66E+07	5.20E+08	7.40E+05	0.00E+00	2.19E+06	0.00E+00	7.67E+06	3.11E+07	1.19E+09	0.00E+00	3.79E+01
Chemicals (kg)													
As	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Be	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
F	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Na	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ni	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NO2	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NO3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SO4	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
V	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TOC	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Radionuclides (Ci)													
Am-241	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
C-14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs-137	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-129	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pu-239	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr-90	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tc-99	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
U	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

* This stream contains trace amounts of radioactive materials which have not been tracked by the Aspen run. Therefore, all values are zero.

** Liquid Effluent Processing for Recycle or Discharge

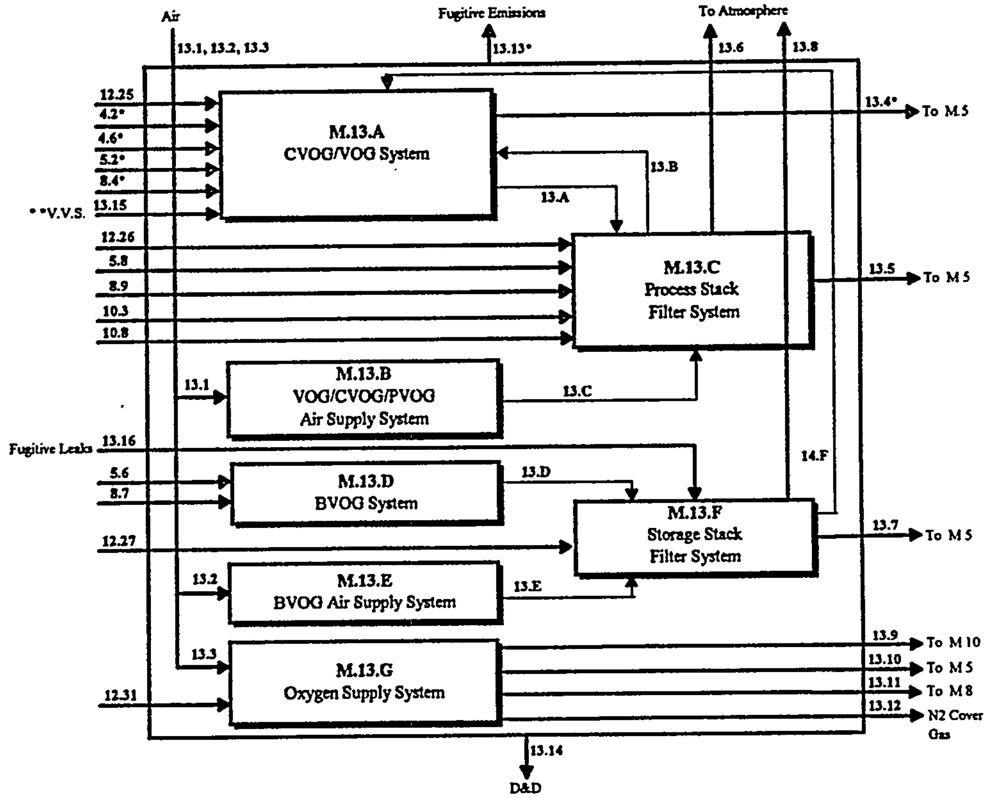


M.12, Chemical Make-up Unit

	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	12.9	12.10	12.11	12.12
Tot Liquid Mass Flow (kg)	1.13E+05	1.74E+08	4.98E+08	7.34E+07	0.00E+00	1.13E+05	1.10E-01	0.00E+00	1.61E+07	2.19E-01	2.19E-02	1.26E+07
Tot Solid Mass Flow(kg)	2.95E+08	0.00E+00	0.00E+00	0.00E+00	2.95E+08	0.00E+00	0.00E+00	5.31E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
% Solid Mass	99.96%	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%
H2O (kg)	0.00E+00	1.38E+07	4.98E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.05E+06	1.10E-01	1.10E-02	5.72E+06
Chemicals (kg)												
As	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Be	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
F	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Na	1.47E+04	7.01E+06	0.00E+00	0.00E+00	0.00E+00	1.47E+04	3.66E-02	0.00E+00	4.63E+06	6.30E-02	6.30E-03	2.38E+06
Ni	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NO2	2.94E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.94E+04	7.30E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NO3	0.00E+00	2.68E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.69E+06
Sb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SO4	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
V	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TOC	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Radionuclides (Ci)												
Am-241	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
C-14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs-137	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-129	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pu-239	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr-90	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tc-99	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
U	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

12.13	12.14	12.15	12.16	12.17	12.18	12.19	12.20	12.21	12.22	12.23	12.24	12.25	12.26
1.37E+08	0.00E+00	8.38E+06	0.00E+00	6.67E+05	1.10E-01	4.05E+08	4.84E+07	3.91E+05	2.11E+07	1.72E+03	2.19E-07	4.38E-07	2.25E+02
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.00%	NA	0.00%	NA	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.67E+05	1.10E-01	4.05E+08	4.84E+07	3.91E+05	2.11E+07	1.72E+03	2.19E-07	4.38E-07	2.25E+02
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

12.27	12.28	12.29	12.30	12.31	12.32	12.33	12.34	12.35	12.36
4.18E+07	6.79E+07	5.50E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.15E+04	0.00E+00	7.89E+01
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.84E+08	1.12E+07	0.00E+00	0.00E+00	6.25E+01
0.00%	0.00%	0.00%	NA	NA	100.00%	100.00%	0.00%	NA	44.19%
4.18E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.15E+04	0.00E+00	5.42E+01
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.44E-01
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.11E-03
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.84E-01
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00



M.13, Air/Vapor Filtration System

	13.1	13.2	13.3	13.15	13.16	4.2	4.6	5.2	8.4	12.25	5.8	8.9
Tot Liquid Mass Flow (kg)	0.00E+00	0.00E+00	1.20E+09	0.00E+00	0.00E+00	1.91E+06	2.10E+06	5.32E+06	5.26E+06	4.38E-07	1.67E+09	1.55E+08
Tot Solid Mass Flow(kg)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.98E+00	1.08E-01
% Solid Mass	NA	NA	0.00%	NA	NA	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
H2O (kg)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.91E+06	2.08E+06	5.32E+06	5.26E+06	4.38E-07	1.86E+07	1.73E+06
Chemicals (kg)												
As	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.45E-07	3.26E-06
Be	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.71E-09	4.61E-08
Cr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.98E-04	1.25E-04
F	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Na	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.67E-01	9.27E-03
Ni	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.93E-06	9.38E-04
NO2	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NO3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.09E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.79E-07	9.03E-06
SO4	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
V	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.77E-08	1.92E-07
TOC	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Radionuclides (Ci)												
Am-241	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.18E-05	6.54E-04
C-14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs-137	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.69E-03	5.22E-01
I-129	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pu-239	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.99E-06	9.21E-05
Sr-90	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.43E-01	2.65E+01
Tc-99	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.80E-05	1.20E-04
U	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.33E-10	2.13E-09

* This stream contains trace amounts of radioactive materials which have not been tracked by the Aspen run. Therefore, all values are zero.

** Vessel Vent System

10.3	10.8	12.26	5.6	8.7	12.27	12.31	13.4	13.5	13.6	13.7	13.8	13.9	13.10
1.84E+07	3.80E+08	2.25E+02	1.67E+09	2.73E+07	4.18E+07	0.00E+00	0.00E+00	2.25E+02	2.14E+09	4.18E+07	1.69E+09	5.46E+05	2.29E+08
2.11E-02	1.66E-01	0.00E+00	4.00E+05	2.19E+04	0.00E+00	0.00E+00	0.00E+00	2.27E+00	1.14E-03	4.22E+05	2.11E+02	0.00E+00	0.00E+00
0.00%	0.00%	0.00%	0.02%	0.08%	0.00%	NA	NA	1.00%	0.00%	1.00%	0.00%	0.00%	0.00%
2.05E+05	1.18E+07	2.25E+02	0.00E+00	0.00E+00	4.18E+07	0.00E+00	0.00E+00	2.25E+02	4.69E+07	4.18E+07	0.00E+00	0.00E+00	0.00E+00
4.24E-08	0.00E+00	0.00E+00	1.90E-01	6.58E-01	0.00E+00	0.00E+00	0.00E+00	4.24E-06	2.12E-09	8.47E-01	4.25E-04	0.00E+00	0.00E+00
5.01E-10	0.00E+00	0.00E+00	7.49E-04	9.30E-03	0.00E+00	0.00E+00	0.00E+00	5.01E-08	2.51E-11	1.01E-02	5.01E-06	0.00E+00	0.00E+00
8.32E-06	6.59E-05	0.00E+00	1.41E+02	2.54E+01	0.00E+00	0.00E+00	0.00E+00	8.97E-04	4.49E-07	1.66E+02	8.33E-02	0.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
3.80E-03	3.01E-02	0.00E+00	7.42E+04	1.87E+03	0.00E+00	0.00E+00	0.00E+00	4.10E-01	2.05E-04	7.60E+04	3.80E+01	0.00E+00	0.00E+00
9.49E-06	7.10E-05	0.00E+00	5.93E-01	1.89E+02	0.00E+00	0.00E+00	0.00E+00	1.02E-03	5.10E-07	1.90E+02	9.49E-02	0.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.09E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
9.41E-08	0.00E+00	0.00E+00	5.65E-02	1.83E+00	0.00E+00	0.00E+00	0.00E+00	9.41E-06	4.70E-09	1.88E+00	9.41E-04	0.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2.43E-09	0.00E+00	0.00E+00	9.64E-03	3.89E-02	0.00E+00	0.00E+00	0.00E+00	2.43E-07	1.21E-10	4.85E-02	2.43E-05	0.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
6.95E-06	0.00E+00	0.00E+00	6.42E+00	1.33E+02	0.00E+00	0.00E+00	0.00E+00	6.95E-04	3.48E-07	1.39E+02	6.95E-02	0.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
5.31E-03	0.00E+00	0.00E+00	7.45E+02	1.06E+05	0.00E+00	0.00E+00	0.00E+00	5.31E-01	2.66E-04	1.06E+05	5.32E+01	0.00E+00	0.00E+00
0.00E+00	3.85E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.85E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
9.60E-07	0.00E+00	0.00E+00	6 05E-01	1.85E+01	0.00E+00	0.00E+00	0.00E+00	9.60E-05	4.79E-08	1.91E+01	9.60E-03	0.00E+00	0.00E+00
2.70E-01	0.00E+00	0.00E+00	4.92E+04	5.37E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2.00E-06	0.00E+00	0.00E+00	1.58E+01	2.43E+01	0.00E+00	0.00E+00	0.00E+00	2.00E-04	1.00E-07	4.00E+01	2.00E-02	0.00E+00	0.00E+00
2.28E-11	1.81E-10	0.00E+00	2.68E-05	4.30E-04	0.00E+00	0.00E+00	0.00E+00	2.46E-09	1.23E-12	4.57E-04	2.29E-07	0.00E+00	0.00E+00

13.11	13.12	13.13	13.14
2.35E+07	9.51E+08	0.00E+00	1.93E+02
0.00E+00	0.00E+00	0.00E+00	1.57E-02
0.00%	0.00%	NA	0.01%
0.00E+00	0.00E+00	0.00E+00	3.31E+00
0.00E+00	0.00E+00	0.00E+00	3.17E-08
0.00E+00	0.00E+00	0.00E+00	3.75E-10
0.00E+00	0.00E+00	0.00E+00	6.21E-06
0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	2.84E-03
0.00E+00	0.00E+00	0.00E+00	7.08E-06
0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	7.80E-04
0.00E+00	0.00E+00	0.00E+00	7.03E-08
0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	1.81E-09
0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	5.19E-06
0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	3.98E-03
0.00E+00	0.00E+00	0.00E+00	1.43E-06
0.00E+00	0.00E+00	0.00E+00	7.14E-07
0.00E+00	0.00E+00	0.00E+00	2.02E-01
0.00E+00	0.00E+00	0.00E+00	1.50E-06
0.00E+00	0.00E+00	0.00E+00	1.70E-11

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APPENDIX G

MASS PERCENT OF CONSTITUENTS OF CONCERN

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Table G-1 shows the assumed mass percentage of constituents of concern (COC) that were used to convert material inventory data from compound and isotope specific to element mass. This is necessary because the material balance used in the model generally shows only the individual elements.

Table G-1. Mass Percent of Constituents of Concern.

COC	Mass% of COCs	
As	100%	As
^{205}As	65.19%	As
Be	100%	Be
BeO	36.03%	Be
Ni	100%	Ni
Ni_2FeC_6	43.60%	Ni
Ni_2O_3	70.98%	Ni
NiO	78.58%	Ni
Sb	100%	Sb
^{205}Sb	75.27%	Sb
V	100%	V
V^{205}	56.02%	V
Am	100%	Am
Am^{203}	90.94%	Am
Pu	100%	Pu
PuO_2	88.24%	Pu
Sr	100%	Sr
SrO	84.91%	Sr
UO_2	88.15%	U
UO_3	83.22%	U

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APPENDIX H

ASSUMPTIONS AND CONVERSIONS REGARDING RADIONUCLIDES

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Radiation Level

Streams have been designated as high activity, low activity, or nonradioactive, based on the radionuclide concentration. Streams with 0.13 Ci/kg or greater have been designated as high activity waste and streams with less than 0.13 Ci/kg have been designated as low activity waste. Streams fed into the process from outside the modules (e.g., bulk chemicals) are designated as nonradioactive.

Isotopes

^{241}Am It was assumed that all americium reported in the ASPEN file was ^{241}Am. The percent mass conversion shown in the table above was used to determine ^{241}Am in compounds. Americium was reported on a mass basis. To convert to curies, the following conversion was used: 3,240 Ci/kg.

^{14}C Carbon was reported in the ASPEN file was ^{14}C on a mass basis. To convert to curies, the following conversion was used: 4460 Ci/kg.

^{137}Cs Cesium was reported in the ASPEN file as cesium and barium. It was assumed that all the cesium and barium was ^{137}Cs.

^{129}I It was assumed that all iodine reported in the ASPEN file was ^{129}I. Iodine was reported on a mass basis. To convert to curies, the following conversion was used: 0.163 Ci/kg.

^{239}Pu It was assumed that all plutonium reported in the ASPEN file was ^{239}Pu. The percent mass conversion shown in the table above was used to determine ^{239}Pu in compounds. Plutonium was reported on a mass basis. To convert to curies, the following conversion was used: 74 Ci/kg

^{90}Sr Strontium was reported in the ASPEN file as strontium and yttrium. It was assumed that all the strontium and yttrium was ^{90}Sr.

^{99}Tc It was assumed that all technetium reported in the ASPEN file was ^{99}Tc.

Uranium The percent mass conversion shown in Appendix G, Table G-1, was used to determine uranium in compounds. Uranium was reported on a mass basis. To convert to curies, the following conversion was used: 3.3×10^{-4} Ci/kg.

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APPENDIX I

ASSUMPTIONS MADE IN THE MASS BALANCES

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Metric Conversion Chart

The following chart is provided to the reader as a tool to aid in converting to metric units.

Into Metric Units

If You Know	Multiply By	To Get
Length		
inches	25.4	millimeters
inches	2.54	centimeters
feet	0.305	meters
yards	0.914	meters
miles	1.609	kilometers
Area		
sq. inches	6.452	sq. centimeters
sq. feet	0.093	sq. meters
sq. yards	0.0836	sq. meters
sq. miles	2.6	sq. kilometers
acres	0.405	hectares
Mass (weight)		
ounces	28.35	grams
pounds	0.454	kilograms
short ton	0.907	metric ton
Volume		
teaspoons	5	milliliters
tablespoons	15	milliliters
fluid ounces	30	milliliters
cups	0.24	liters
pints	0.47	liters
quarts	0.95	liters
gallons	3.8	liters
cubic feet	0.028	cubic meters
cubic yards	0.765	cubic meters
Temperature		
Fahrenheit	subtract 32, then multiply by 5/9	Celsius
Pressure		
inches of H_2O	0.00246	atmospheres
inches of Hg	0.03332	atmospheres

Out of Metric Units

If You Know	Multiply	To Get
Length		
millimeters	0.039	inches
centimeters	0.394	inches
meters	3.281	feet
meters	1.094	yards
kilometers	0.621	miles
Area		
sq. centimeters	0.155	sq. inches
sq. meters	10.76	sq. feet
sq. meters	1.196	sq. yards
sq. kilometers	0.4	sq. miles
hectares	2.47	acres
Mass (weight)		
grams	0.035	ounces
kilograms	2.205	pounds
metric ton	1.102	short ton
Volume		
milliliters	0.033	fluid ounces
liters	2.1	pints
liters	1.057	quarts
liters	0.264	gallons
cubic meters	35.315	cubic feet
cubic meters	1.308	cubic yards
Temperature		
Celsius	multiply by 9/5, then add 32	Fahrenheit
Pressure		
atmospheres	406.5	inches of H_2O
atmospheres	30.005	inches of Hg

Fugitive Emissions

The processes and facilities are designed to run at a slightly negative pressure and there are extensive vapor systems designed for the processes. It has therefore been assumed that all fugitive emissions from the processes go out of the air/vapor filtration system (module M.13).

Decontamination and Decommissioning (D&D) Waste

It has been assumed that the average size of a piece of equipment within any process is 1,000 gal and that 0.1% of the inventory within each piece of equipment will be leaked during D&D (determined using best engineering judgement [BEJ]). The estimated mass of D&D waste has been calculated as 0.1% of the mass of each stream multiplied by the number of pieces of equipment within the module, and the assumed 1,000 gal volume of each piece of equipment, divided by the density of the stream.

Stream 1.6

This stream represents past leakage to the soil. It also includes 1% of other soluble species in the salt cake and interstitial liquid (Boomer et al. 1993).

Base Case Stream 1.7

This stream represents leakage to the soil that occurs during sluicing, assuming 66 tanks will leak once sluicing activities begin (Lowe 1993). Analyses have shown that leakage of up to 140 m^3 (40,000 gal) per tank may occur during sluicing operations (Lowe 1993), therefore, a total of 2,640,000 gal of liquid waste is estimated to have been released to the ground. Stream 1.7 is obtained by assuming that the new leakage induced by sluicing is equal to 3.52 (2,640,000 divided by 750,000 gal) times the total past leakage (Stream 1.6).

Test Case I Stream 1.7

This stream represents leakage to the soil that occurs during sluicing. It is assumed that the close-coupled barrier reduces this leakage by 99.9% relative to the base case.

Test Case II Stream 1.7

This stream represents leakage to the soil that occurs during sluicing. It is assumed that robotic retrieval reduces this leakage to 1/10th of the base case leakage.

Base Case Stream 1.8

This stream is equal to 1% of Stream 1.2 (Boomer et al. 1993). It represents the residual waste that is distributed over the internal tank surfaces as well as on the resident in-tank hardware.

Test Case II Stream 1.8

Robotic retrieval is assumed to remove 99.9% of the tank waste. This stream is equal to 0.1% of Stream 1.2 (Boomer et al. 1993). It represents the residual waste that is distributed over the internal tank surfaces as well as on the resident in-tank hardware.

Stream 1.9

This stream represents contaminated single-shell tank (SST) waste transfer piping, ancillary equipment, and associated soils from newly completed SST waste retrieval operations. Boomer et al. (1993) assumes that total contamination from Resource Conservation and Recovery Act (RCRA) past-practice units (PPUs) represents 0.1% of Stream 1.2. Assume that newly created leakage waste is the same, therefore Stream 1.9 is 0.1% of Stream 1.2.

Stream 2.1

This stream consists of miscellaneous waste from 12 double-shell tanks (DSTs). This waste is composed of neutralized cladding removal waste (NCRW), concentrated phosphate (CP), neutralized current acid waste (NCAW), and double-shell slurry/double-shell slurry feed (DSS/DSSF) (Hanlon 1994).

Stream 2.5

This low activity stream represents condensate flowing from the DST waste retrieval evaporator out of the system to the Liquid Effluent Process Recycle and Discharge (LEPRD). It is assumed to contain 0.1% of the evaporator feed (Stream 2.3) contaminants and 90% of the feed water.

Stream 2.8

This stream represents the residual waste after retrieval that is distributed over the internal tank surfaces as well as on the resident in-tank hardware. It is assumed to be 1% of the summation of Streams 2.1, 2.2, and 2.3.

Stream 2.9

This stream represents contaminated DST waste transfer piping, ancillary equipment and associated soils from newly completed DST waste retrieval operations. Boomer et al. (1993) assumes that total contamination from RCRA PPUs represents 0.1% of Streams 2.1, 2.2, and 2.3. It is assumed that newly created leakage waste is the same, therefore Stream 2.9 is 0.1% of Streams 2.1, 2.2, and 2.3.

Stream 13.3

This stream represents air flowing into the air/vapor filtration oxygen supply system. The ASPEN file run used as the basis for this model had not achieved a mass balance around the air/vapor filtration oxygen supply system. This stream was determined by calculating a mass balance around the unit:

$$13.3 = 13.9 + 13.10 + 13.11 + 13.12 - 12.31.$$

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APPENDIX J

MODULE/UNIT OPERATION WORK FORCE WORKER-HOURS

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This appendix includes spreadsheets containing the worker-hours and dose rates for each module and the corresponding routine worker risks.

Module Name: Base Case M.1, SST Waste Retrieval
Total Direct Man-Hours: 5,030,000

UNIT OPERATION WORKER DOSE	M.1.A, SST Waste Retrieval System	M.1.B, SST Cleanup & Backfill	M.1.C, Capping	
Designation:	HL	HL	Cold	TOTAL
MAN-HOUR FRACTION	0.20	0.30	0.50	1.00
UNIT OPERATION MAN-HRS	1,006,000	1,509,000	2,515,000	5,030,000
High Dose Rate (rem/hr)	2	2	0	
High Dose Rate Occupancy Factor	0.0001	0.0001	0.0001	
Low Dose Rate (rem/hr)	0.002	0.002	0	
Low Dose Rate Occupancy Factor	0.5	0.5	0.5	
Total Man-Rem	**1207.20**	**1810.80**	**0.00**	**3018.00**
Total Number of Operating Years	37.25	37.25	N/A	74.50
Annual Man-Rem	32.41	48.61	0.00	81.02
Total Number of Exposed Workers	15.41	23.12	0.00	38.54

Module Name: Test Case 1 M.1, SST Waste Retrieval
Total Direct Man-Hours: 5,324,400

UNIT OPERATION WORKER DOSE	M.1.A, SST Waste Retrieval System	M.1.B, SST Cleanup & Backfill	M.1.C, Capping	M.1.D, Close-Coupled Barrier	
Designation:	HL	HL	Cold	LL	TOTAL
MAN-HOUR FRACTION	0.19	0.28	0.47	0.06	1.00
UNIT OPERATION MAN-HRS	1,006,000	1,509,000	2,515,000	294,400	5,324,400
High Dose Rate (rem/hr)	2	2	0	0.5	
High Dose Rate Occupancy Factor	0.0001	0.0001	0.0001	0.0001	
Low Dose Rate (rem/hr)	0.002	0.002	0	0.002	
Low Dose Rate Occupancy Factor	0.5	0.5	0.5	0.5	
Total Man-Rem	**1207.20**	**1810.80**	**0.00**	**309.12**	**3327.12**
Total Number of Operating Years	37.25	37.25	N/A	15.30	89.80
Annual Man-Rem	32.41	48.61	0.00	20.20	101.22
Total Number of Exposed Workers	15.41	23.12	0.00	10.98	49.52

Module Name: M.2, DST Waste Retrieval
Total Direct Man-Hours: 966,000

UNIT OPERATION WORKER DOSE	M.2.A, DST Miscellaneous Waste Retrieval System	M.2.B Concentrated Complexant Waste Retrieval System	M.2.C, Dilute Non-Complexed Waste Retrieval System	M.2.D 242-A Evaporator	M.2.E, DST Cleanup & Backfill	M.2.F, Capping	TOTAL
Designation:	HL	HL	HL	HL	HL	Cold	
MAN-HOUR FRACTION	0.03	0.03	0.03	0.20	0.30	0.40	1.00
UNIT OPERATION MAN-HRS	32,200	32,200	32,200	193,200	289,800	386,400	966,000
High Dose Rate (rem/hr)	2	2	2	2	2	0	
High Dose Rate Occupancy Factor	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	
Low Dose Rate (rem/hr)	0.002	0.002	0.002	0.002	0.002	0	
Low Dose Rate Occupancy Factor	0.5	0.5	0.5	0.5	0.5	0.5	
Total Man-Rem	38.64	38.64	38.64	231.84	347.76	0.00	695.52
Total Number of Operating Years	3.00	1.25	2.75	0.25	7.00	N/A	14.25
Annual Man-Rem	12.88	30.91	14.05	927.36	49.68	0.00	1034.88
Total Number of Exposed Workers	6.13	14.70	6.68	441.10	23.63	0.00	492.24

Module Name: Test Case 2 M.1, SST Waste Retrieval
Total Direct Man-Hours: 8,813,000

UNIT OPERATION WORKER DOSE	M.1.A, SST Waste Retrieval System	M.1.B, SST Cleanup & Backfill	M.1.C, Capping	TOTAL
Designation:	HL	HL	Cold	
MAN-HOUR FRACTION	0.54	0.17	0.29	1.00
UNIT OPERATION MAN-HRS	4,789,000	1,509,000	2,515,000	8,813,000
High Dose Rate (rem/hr)	2	2	0	
High Dose Rate Occupancy Factor	0.0001	0.0001	0.0001	
Low Dose Rate (rem/hr)	0.002	0.002	0	
Low Dose Rate Occupancy Factor	0.5	0.5	0.5	
Total Man-Rem	5746.80	1810.80	0.00	7557.60
Total Number of Operating Years	37.25	37.25	N/A	74.50
Annual Man-Rem	154.28	48.61	0.00	202.89
Total Number of Exposed Workers	73.38	23.12	0.00	96.50

Module Name: M.3, DST Sludge Wash
Total Direct Man-Hours: 1,630,000

UNIT OPERATION WORKER DOSE	M.3.A, Chemical Feed System	M. 3.B, Sludge Settling Process	M.3.C, Sludge Wash Process	M.3.D, Wash Transfer Process	TOTAL
Designation:	Cold	HL	HL	HL	
MAN-HOUR FRACTION	0.25	0.25	0.25	0.25	1.00
UNIT OPERATION MAN-HRS	407,500	407,500	407,500	407,500	1,630,000
High Dose Rate (rem/hr)	0	2	2	2	
High Dose Rate Occupancy Factor	0.0001	0.0001	0.0001	0.0001	
Low Dose Rate (rem/hr)	0	0.002	0.002	0.002	
Low Dose Rate Occupancy Factor	0.5	0.5	0.5	0.5	
Total Man-Rem	0.00	489.00	489.00	489.00	1467.00
Total Number of Operating Years	N/A	13.00	13.00	13.00	39.00
Annual Man-Rem	0.00	37.62	37.62	37.62	112.85
Total Number of Exposed Workers	0.00	17.89	17.89	17.89	53.67

Module Name: M.4, Cesium Ion Exchange
Total Direct Man-Hours: 1,470,000

UNIT OPERATION WORKER DOSE	M.4.A, Accumulation System	M.4.B, Supernatant Evaporator System	M.4.C, Ion Exchange Feed	M.4.D, Cesium Ion Exchange	M.4.E, Cs IX Concentrator	M.4.F, Eluent/Regeneration System	TOTAL
Designation:	HL	HL	HL	HL	HL	LL	
MAN-HOUR FRACTION	0.25	0.15	0.25	0.20	0.05	0.10	1.00
UNIT OPERATION MAN-HRS	367,500	220,500	367,500	294,000	73,500	147,000	1,470,000
High Dose Rate (rem/hr)	2	2	2	2	2	0.5	
High Dose Rate Occupancy Factor	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	
Low Dose Rate (rem/hr)	0.002	0.002	0.002	0.002	0.002	0.002	
Low Dose Rate Occupancy Factor	0.5	0.5	0.5	0.5	0.5	0.5	
Total Man-Rem	441.00	264.60	441.00	352.80	88.20	154.35	1741.95
Total Number of Operating Years	13.00	13.00	13.00	13.00	13.00	13.00	78.00
Annual Man-Rem	33.92	20.35	33.92	27.14	6.78	11.87	134.00
Total Number of Exposed Workers	16.14	9.68	16.14	12.91	3.23	6.45	64.54

Module Name: M.5, LLW Glass in Sulfur
Total Direct Man-Hours: 1,380,000

UNIT OPERATION WORKER DOSE	M.5.A, LLW Evaporator	M.5.B, LLW Melter	M.5.C, LLW Glass Quencher	M.5.D, LLW Glass Cullet Drying	M.5.E, LLW Cyclone System	TOTAL
Designation:	LL	LL	LL	LL	LL	
MAN-HOUR FRACTION	0.15	0.35	0.15	0.15	0.20	1.00
UNIT OPERATION MAN-HRS	207,000	483,000	207,000	207,000	276,000	1,380,000
High Dose Rate (rem/hr)	0.5	0.5	0.5	0.5	0.5	
High Dose Rate Occupancy Factor	0.0001	0.0001	0.0001	0.0001	0.0001	
Low Dose Rate (rem/hr)	0.002	0.002	0.002	0.002	0.002	
Low Dose Rate Occupancy Factor	0.5	0.5	0.5	0.5	0.5	
Total Man-Rem	217.35	507.15	217.35	217.35	289.80	1449.00
Total Number of Operating Years	13.00	13.00	13.00	13.00	13.00	65.00
Annual Man-Rem	16.72	39.01	16.72	16.72	22.29	111.46
Total Number of Exposed Workers	9.09	21.21	9.09	9.09	12.12	60.59

Module Name: M.6, LLW Glass in Sulfur Vaults
Total Direct Man-Hours: 1,200,000

UNIT OPERATION WORKER DOSE	M.6.A, Sulfur Cement Mixing	M.6.B, LLW Glass/Sulfur Mixer	M.6.C, Glass In Sulfur Disposal Vault	M.6.D, Decanted Molten Sulfur Vault	TOTAL
Designation:	LL	LL	LL	LL	
MAN-HOUR FRACTION	0.25	0.50	0.15	0.10	1.00
UNIT OPERATION MAN-HRS	300,000	600,000	180,000	120,000	1,200,000
High Dose Rate (rem/hr)	0.5	0.5	0.5	0.5	
High Dose Rate Occupancy Factor	0.0001	0.0001	0.0001	0.0001	
Low Dose Rate (rem/hr)	0.002	0.002	0.002	0.002	
Low Dose Rate Occupancy Factor	0.5	0.5	0.5	0.5	
Total Man-Rem	315.00	630.00	189.00	126.00	1260.00
Total Number of Operating Years	13.00	13.00	13.00	13.00	52.00
Annual Man-Rem	24.23	48.46	14.54	9.69	96.92
Total Number of Exposed Workers	13.17	26.34	7.90	5.27	52.69

Module Name: M.7, HLW Glass Cullet Feed Lag Storage
Total Direct Man-Hours: 859,000

UNIT OPERATION WORKER DOSE	M.7.A, HLW Feed Accumulation	M.7.B, HLW Feed Transfer Tank	
Designation:	HL	HL	TOTAL
MAN-HOUR FRACTION	0.50	0.50	1.00
UNIT OPERATION MAN-HRS	429,500	429,500	859,000
High Dose Rate (rem/hr)	2	2	
High Dose Rate Occupancy Factor	0.0001	0.0001	
Low Dose Rate (rem/hr)	0.002	0.002	
Low Dose Rate Occupancy Factor	0.5	0.5	
Total Man-Rem	515.40	515.40	1030.80
Total Number of Operating Years	13.00	37.25	50.25
Annual Man-Rem	39.65	13.84	53.48
Total Number of Exposed Workers	18.86	6.58	25.44

Module Name: M.8, HLW Glass Cullet
Total Direct Man-Hours: 1,610,000

UNIT OPERATION WORKER DOSE	M.8.A, HLW Centrifuge System	M.8.B, HLW Melter System	M.8.C, HLW Evaporator	M.8.D, HLW Glass Quencher	M.8.E, HLW Glass Cullet Drying	M.8.F, HLW Cyclone System	
Designation:	HL	HL	HL	HL	HL	HL	TOTAL
MAN-HOUR FRACTION	0.30	0.35	0.05	0.10	0.10	0.10	1.00
UNIT OPERATION MAN-HRS	483,000	563,500	80,500	161,000	161,000	161,000	1,610,000
High Dose Rate (rem/hr)	2	2	2	2	2	2	
High Dose Rate Occupancy Factor	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	
Low Dose Rate (rem/hr)	0.002	0.002	0.002	0.002	0.002	0.002	
Low Dose Rate Occupancy Factor	0.5	0.5	0.5	0.5	0.5	0.5	
Total Man-Rem	579.60	676.20	96.60	193.20	193.20	193.20	1932.00
Total Number of Operating Years	13.00	13.00	13.00	13.00	13.00	13.00	78.00
Annual Man-Rem	44.58	52.02	7.43	14.86	14.86	14.86	148.62
Total Number of Exposed Workers	21.21	24.74	3.53	7.07	7.07	7.07	70.69

Module Name: M.9, HLW Glass Cullet Cask Storage Pad
Total Direct Man-Hours: 1,430,000

UNIT OPERATION WORKER DOSE	M.9.A, Air Pallets	M.9.B, Repository	
Designation:	HL	HL	TOTAL
MAN-HOUR FRACTION	0.90	0.10	1.00
UNIT OPERATION MAN-HRS	1,287,000	143,000	1,430,000
High Dose Rate (rem/hr)	2	2	
High Dose Rate Occupancy Factor	0.0001	0.0001	
Low Dose Rate (rem/hr)	0.002	0.002	
Low Dose Rate Occupancy Factor	0.5	0.5	
Total Man-Rem	**1544.40**	**171.60**	**1716.00**
Total Number of Operating Years	13.00	13.00	26.00
Annual Man-Rem	118.80	13.20	132.00
Total Number of Exposed Workers	56.51	6.28	62.79

Module Name: M.10, Cullet Rework and Melter Off-Gas Processing
Total Direct Man-Hours: 950,000

UNIT OPERATION WORKER DOSE	M.10.A, Cyclone System	M.10.B, HLW Separator	M.10.C, NOx/SO2 Separator	M.10.D, LLW Separator	M.10.E, Claus Reactor System	
Designation:	HL	HL	LL	LL	LL	TOTAL
MAN-HOUR FRACTION	0.20	0.20	0.20	0.20	0.20	1.00
UNIT OPERATION MAN-HRS	190,000	190,000	190,000	190,000	190,000	950,000
High Dose Rate (rem/hr)	2	2	0.5	0.5	0.5	
High Dose Rate Occupancy Factor	0.0001	0.0001	0.0001	0.0001	0.0001	
Low Dose Rate (rem/hr)	0.002	0.002	0.002	0.002	0.002	
Low Dose Rate Occupancy Factor	0.5	0.5	0.5	0.5	0.5	
Total Man-Rem	**228.00**	**228.00**	**199.50**	**199.50**	**199.50**	**1054.50**
Total Number of Operating Years	13.00	13.00	13.00	13.00	13.00	65.00
Annual Man-Rem	17.54	17.54	15.35	15.35	15.35	81.12
Total Number of Exposed Workers	8.34	8.34	8.34	8.34	8.34	41.71

Module Name: M.11, Liquid Effluent Treatment Facility
Total Direct Man-Hours: 1,040,000

UNIT OPERATION WORKER DOSE	M.11.A, Process Condensate Recycle	M.11.B, pH Adjustment Tank	M.11.C, Retention Basin	
Designation:	LL	LL	LL	TOTAL
MAN-HOUR FRACTION	0.33	0.33	0.33	1.00
UNIT OPERATION MAN-HRS	346,667	346,667	346,667	1,040,000
High Dose Rate (rem/hr)	0.5	0.5	0.5	
High Dose Rate Occupancy Factor	0.0001	0.0001	0.0001	
Low Dose Rate (rem/hr)	0.002	0.002	0.002	
Low Dose Rate Occupancy Factor	0.5	0.5	0.5	
Total Man-Rem	**364.00**	**364.00**	**364.00**	**1092.00**
Total Number of Operating Years	13.00	13.00	13.00	39.00
Annual Man-Rem	28.00	28.00	28.00	84.00
Total Number of Exposed Workers	15.22	15.22	15.22	45.66

Module Name: M.12, Chemical Make-up Unit
Total Direct Man-Hours: 1,200,000

UNIT OPERATION WORKER DOSE	M.12.A, Dry Storage	M.12.B, Bulk Liquid Storage	M.12.C, Bulk H2O Storage	M.12.D, Bulk Combustible Liquid Storage	M.12.E, Glass Melter Batch Mixers	
Designation:	Cold	Cold	Cold	Cold	Cold	TOTAL
MAN-HOUR FRACTION	0.20	0.20	0.20	0.20	0.20	1.00
UNIT OPERATION MAN-HRS	240,000	240,000	240,000	240,000	240,000	1,200,000
High Dose Rate (rem/hr)	0	0	0	0	0	
High Dose Rate Occupancy Factor	0.0001	0.0001	0.0001	0.0001	0.0001	
Low Dose Rate (rem/hr)	0	0	0	0	0	
Low Dose Rate Occupancy Factor	0.5	0.5	0.5	0.5	0.5	
Total Man-Rem	0.00	0.00	0.00	0.00	0.00	0.00
Total Number of Operating Years	N/A	N/A	N/A	N/A	N/A	0.00
Annual Man-Rem	0.00	0.00	0.00	0.00	0.00	0.00
Total Number of Exposed Workers	0.00	0.00	0.00	0.00	0.00	0.00

Module Name: M.13, Air/Vapor Filtration System

Total Direct Man-Hours: 859,000

UNIT OPERATION WORKER DOSE	M.13.A, CVOG/VOG System	M.13.B, VOG/CVOG/PVOG Air Supply System	M.13.C, Process Stack Filter System	M.13.D, BVOG System	M.13.E, BVOG Air Supply System	M.13.F, Storage Stack Filter System	M.13.G, Oxygen Supply System	TOTAL
Designation:	LL	Cold	LL	HL	Cold	LL	Cold	
MAN-HOUR FRACTION	0.14	0.14	0.14	0.14	0.14	0.14	0.14	**1.00**
UNIT OPERATION MAN-HRS	122,714	122,714	122,714	122,714	122,714	122,714	122,714	**859,000**
High Dose Rate (rem/hr)	0.5	0	0.5	2	0	0.5	0	
High Dose Rate Occupancy Factor	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	
Low Dose Rate (rem/hr)	0.002	0	0.002	0.002	0	0.002	0	
Low Dose Rate Occupancy Factor	0.5	0.5	0.5	0.5	0.5	0.5	0.5	
Total Man-Rem	**128.85**	0.00	**128.85**	**147.26**	0.00	**128.85**	0.00	**533.81**
Total Number of Operating Years	13.00	N/A	13.00	13.00	N/A	13.00	N/A	52.00
Annual Man-Rem	9.91	0.00	9.91	11.33	0.00	9.91	0.00	41.06
Total Number of Exposed Workers	5.39	0.00	5.39	5.39	0.00	5.39	0.00	21.55

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APPENDIX K

MEPAS CODE INPUT

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K.0 MEPAS CODE INPUT AND OUTPUT

The Multimedia Environmental Pollutant Assessment System (MEPAS) is a computer-based system used to quantify relative human health impact from radiological and chemical contaminants released to the environment (Droppo et. al 1989). The MEPAS code uses empirical, analytical, and semi-analytical mathematical algorithms and a pathway analysis to estimate the following processes:

- Potential release of contaminants into the environment
- Transport of contaminants through and between multiple environmental media, including subsurface or groundwater, surface water, overland, and atmospheric
- Exposure to surrounding human populations through the following exposure pathways: inhalation, ingestion of water and food products, dermal contact, and external radiation
- Human health effects associated with exposure to chemicals and radionuclides.

For the model, the MEPAS code was used to evaluate two exposure pathways for public health.

- Discharge of liquid effluents to the subsurface during tank remediation, resulting in transport to groundwater and through groundwater offsite, where this water is used by the public for drinking, showering, irrigation of crops, and animal water.
- Discharge of airborne effluents to the atmosphere during tank remediation and transport offsite, where the contaminants are inhaled by the public or deposited on the ground with uptake by plants and animals.

MEPAS Version 3.0g was used for the public human health risk evaluation. The input parameters required by the MEPAS code are described in the following sections for the groundwater and atmospheric pathways.

K.1 INPUT DATA

MEPAS requires a great deal of input data to execute the transport and exposure models. The input requirements for the groundwater and atmospheric pathways are described below.

K.1.1 Groundwater Pathway

The groundwater pathway requires the following types of data for execution.

- Contaminant release data
- Source characteristics
- Geologic media (partially saturated zone) characteristics
- Groundwater (saturated zone) characteristics
- Human exposure pathway selection
- Receptor location and exposure characteristics.

Table K-1 lists the input parameters required by the MEPAS code for the groundwater pathway. The values used in this evaluation for each of the input parameters are also listed in this table. In addition, Table K-2 lists the MEPAS input parameters used for the geologic media characteristics. These values were obtained directly from the data used for the Hanford Programmatic Environmental Impact Statement (Schramke et al. 1994), based on the 200 West Area. It is assumed for the purposes of this relative risk evaluation that this data is representative of the physical characteristics associated with Hanford Site geologic stratigraphy. Table K-3 lists the contaminant-specific K_d values used in the evaluation. In addition, certain MEPAS default parameter values are used for all cases evaluated, including receptor inhalation and ingestion

Table K-1. MEPAS Code Input Parameters for the Groundwater Pathway. Sheet 1 of 4

Parameter Type	Parameter Description	Value	Data Source or Justification
Contaminant Release Data	Contaminant-specific flux	See Tables K-4 through K-6	Dependent upon the waste stream under evaluation
	Discharge duration	1 yr	Assumption used to compute unit risk factors
	Starting date of release	03/94	Arbitrary assignment
	Starting date for risk calculations	03/94	Arbitrary assignment
	Waste liquid infiltration rate	4.5×10^{-6} ft/day	Based on an assumed recharge rate of 0.05 cm/yr
Source Characteristics	Area source dimensions (length and width)	50 ft long x 50 ft wide	Average of tank dimensions from DOE 1987
	Depth of release	44 ft	Average of depths to tank bottom from DOE 1987
Geologic Media Data	Medium types encountered moving from source to receptor (e.g., partially saturated zone to saturated zone to surface water or well)	6, see Table K-2	Schramke, 1994
	Soil classification associated with the media encountered from source to receptor (e.g., sand, clay, silt, etc.)	see Table K-2	Schramke 1994

Table K-1. MEPAS Code Input Parameters for the Groundwater Pathway. Sheet 2 of 4

Parameter Type	Parameter Description	Value	Data Source or Justification
Geologic Media Data (continued)	Percent sand, silt, and clay associated with each media classification encountered	see Table K-2	Schramke 1994
	Percent organic matter content in each media classification encountered	see Table K-2	Schramke 1994
	Percent iron and aluminum in each media classification encountered	see Table K-2	Schramke 1994
	pH of pore water in each media classification encountered	see Table K-2	Schramke 1994
	Thickness of media zone	see Table K-2	Schramke 1994
	Bulk density of media zone	see Table K-2	Schramke 1994
	Total porosity of media zone	see Table K-2	Schramke 1994
	Field capacity of media zone	see Table K-2	Schramke 1994
	Longitudinal dispersivity of media zone	see Table K-2	Schramke 1994
	Saturated hydraulic conductivity	see Table K-2	Schramke 1994
Groundwater Data	Effective porosity of the saturated zone	11%	Schramke 1994
	Pore water velocity of the saturated zone	0.6 ft/day	Schramke 1994
	Groundwater travel distance	9,800 ft	Schramke 1994
	Transverse dispersivity of the saturated zone	490 ft	Schramke 1994
	Vertical dispersivity of the saturated zone	1.14 ft	Schramke 1994
	Percent of contaminant flux to saturated zone	100%	Schramke 1994

Table K-1. MEPAS Code Input Parameters for the Groundwater Pathway. Sheet 3 of 4

Parameter Type	Parameter Description	Value	Data Source or Justification
Groundwater Data (continued)	Perpendicular distance to plume centerline	0 ft	Conservative assumption.
	Contaminant-specific subsurface adsorption coefficients (Kd) for each media zone	see Table K-3	Droppo, et al. 1991.
Exposure Pathway Selection	Exposure pathways considered - ingestion of groundwater - ingestion of vegetation - ingestion of meat and milk products - inhalation during showering - dermal contact during showering	None	Assumption
Receptor Exposure Characteristics	Location of public receptor	3 km E of the 200 Area	HFSUWG 1992
	Drinking population served	1	Assumption used for the computation of risks to maximally exposed individual.
	Selection of water treatment (Y or N)	N	Conservative assumption.
	Water distribution time	0.5 days	Droppo et. al 1989

Table K-1. MEPAS Code Input Parameters for the Groundwater Pathway. Sheet 4 of 4

Parameter Type	Parameter Description	Value	Data Source or Justification
Receptor Exposure Characteristics (cont.)	Type of irrigation usage selection	crops and animal feed and water	Assumption
	Irrigation rate	100 L/m^2-month	Droppo et al. 1989
	Human body weight	70 kg	EPA 1989
	Exposure duration	70 yrs	EPA 1989

Table K-2. MEPAS Input Parameters for Geologic Media Characteristics.

Parameter	Partially Saturated Zone					Saturated Zone
	Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	
Soil classification	Sand	Loam	Loamy sand	Sandy loam	Loamy sand	Loamy sand
Percent sand (%)	95	45	86	73	87	87
Percent silt (%)	3	55	12	25	11	11
Percent clay (%)	2	0	2	2	2	2
Percent organic matter content (%)	0	0	0	0	0	0
Percent iron and aluminum (%)	0	0	0	0	0	0
pH of pore water	8.5	7	7	7	7	7.9
Thickness (ft)	82	49.2	15	20	70	30
Bulk density (g/cm^3)	1.75	1.65	1.65	1.9	1.76	1.76
Total porosity (%)	36	40	40	31	36	36
Field capacity (%)	11	13	18	7.2	12	NA
Longitudinal dispersivity (ft)	0.82	0.492	0.15	0.2	0.7	980
Saturated hydraulic conductivity (cm/s)	34	6.46	193	5.67	5.95	NA

1. All values are from Schramke, 1994.

Table K-3. Contaminant Kd Values[1]

Contaminant	Kd (mL/g)
Antimony	0
Arsenic	0.6
Beryllium	0
Chromium	1.0
EDTA	0
Fluorene	0
Mercury	0
Nickel	1.2
Nitrate	0
Nitrite	0
Sodium	0
Sulfate	0
Tributyl phosphate	0
Vanadium	0
Am^{241}	8.2
C^{14}	0
Cs^{137}	51
I^{129}	0
Pu^{239}	10
Sr^{90}	24.3
Tc^{99}	0
U^{238}	0

1 Values based on Droppo et. al 1991.

rates and contaminant-specific reference doses and cancer slope factors, based on a risk level of 1E-06.

For the tank waste remediation evaluation, it is assumed that liquid releases to the ground occur in the subsurface partially saturated zone, located beneath the underground storage tanks. The source of release is assumed to be represented by an area configuration equal to the average area of a tank. Flux values and release durations are dependent upon the module, source and case under investigation and are listed in Tables K-4 through K-6 for each of the three cases. These values are computed as described in Section 2.2.

K.1.2 Atmospheric Pathway

The atmospheric pathway requires the following types of data for execution.

- Source characteristics
- Contaminant release data
- Climatological characteristics
- Joint frequency data
- Population data
- Human exposure pathway selection
- Receptor location and exposure characteristics.

Table K-7 lists the MEPAS input parameters required for the atmospheric pathway. The values used in this evaluation for each of the input parameters are also listed in this table.

For the purposes of the tank waste remediation evaluation, it is assumed that airborne effluents released to the atmosphere are released from a stack configuration. As described in Section 2.2, flux rates and durations were computed for each constituent. The flux rates and durations computed for each stream and constituent are presented in Table K-8.

Table K-4. Flux Rates and Release Durations for the Base Case Streams Releasing to Groundwater.

Contaminant	Module M.1 - Past Leakage Inventory (g)	Flux Rate (g/yr)	Flux Rate (Ci/yr)	Release Duration (yr)	Module M.1 - Leakage During Retrieval Inventory (g)	Flux Rate (g/yr)	Flux Rate (Ci/yr)	Release Duration (yr)
EDTA	1.68E+05	3.73E+02	NA	4.50E+02	5.91E+05	1.66E+02	NA	3.55E+03
Nitrate	9.68E+08	2.15E+06	NA	4.50E+02	3.41E+09	9.60E+05	NA	3.55E+03
Nitrite	4.79E+07	1.07E+05	NA	4.50E+02	1.69E+08	4.75E+04	NA	3.55E+03
TBP	1.46E+05	3.24E+02	NA	4.50E+02	5.13E+05	1.45E+02	NA	3.55E+03
Arsenic	4.59E+02	1.02E+00	NA	4.50E+02	1.62E+03	4.55E-01	NA	3.55E+03
Beryllium	0.00E+00	0.00E+00	NA	0.00E+00	0.00E+00	0.00E+00	NA	0.00E+00
Chromium	9.58E+05	2.13E+03	NA	4.50E+02	3.37E+06	9.50E+02	NA	3.55E+03
Fluoride	7.98E+06	1.78E+04	NA	4.50E+02	2.81E+07	7.92E+03	NA	3.55E+03
Mercury	9.98E+03	2.22E+01	NA	4.50E+02	3.52E+04	9.90E+00	NA	3.55E+03
Sodium	5.09E+08	1.13E+06	NA	4.50E+02	1.79E+09	5.05E+05	NA	3.55E+03
Nickel	0.00E+00	0.00E+00	NA	0.00E+00	0.00E+00	0.00E+00	NA	0.00E+00
Antimony	0.00E+00	0.00E+00	NA	0.00E+00	0.00E+00	0.00E+00	NA	0.00E+00
Sulfate	1.60E+07	3.55E+04	NA	4.50E+02	5.62E+07	1.58E+04	NA	3.55E+03
Vanadium	0.00E+00	0.00E+00	NA	0.00E+00	0.00E+00	0.00E+00	NA	0.00E+00
C-14	6.71E+00	1.49E-02	6.66E-02	4.50E+02	2.36E+01	6.66E-03	2.97E-02	3.55E+03
I-129	1.47E+03	3.27E+00	5.33E-04	4.50E+02	5.18E+03	1.46E+00	2.38E-04	3.55E+03
Tc-99	9.39E+03	2.09E+01	3.55E-01	4.50E+02	3.31E+04	9.32E+00	1.58E-01	3.55E+03
U-238	1.38E+07	3.07E+04	1.02E-02	4.50E+02	4.86E+07	1.37E+04	4.55E-03	3.55E+03
Am-241	1.42E+02	3.15E-01	1.02E+00	4.50E+02	4.99E+02	1.40E-01	4.55E-01	3.55E+03
Cs-137	4.01E+03	8.93E+00	7.77E+02	4.50E+02	1.41E+04	3.98E+00	3.46E+02	3.55E+03
Pu-239	4.40E+03	9.77E+00	5.99E-01	4.50E+02	1.55E+04	4.36E+00	2.67E-01	3.55E+03
Sr-90	7.79E+03	1.73E+01	2.44E+03	4.50E+02	2.74E+04	7.72E+00	1.09E+03	3.55E+03

Table K-4. Flux Rates and Release Durations for the Base Case Streams Releasing to Groundwater.

Contaminant	Module M.1 - SST Residue Inventory (g)	Flux Rate (g/yr)	Flux Rate (Ci/yr)	Release Duration (yr)	Module M.1 - Pipe Leakage Inventory (g)	Flux Rate (g/yr)	Flux Rate (Ci/yr)	Release Duration (yr)
EDTA	1.68E+05	1.86E+03	NA	9.00E+01	1.68E+04	1.86E+03	NA	9.00E+00
Nitrate	9.68E+08	1.08E+07	NA	9.00E+01	9.68E+07	1.08E+07	NA	9.00E+00
Nitrite	4.79E+07	5.33E+05	NA	9.00E+01	4.79E+06	5.33E+05	NA	9.00E+00
TBP	1.46E+05	1.62E+03	NA	9.00E+01	1.46E+04	1.62E+03	NA	9.00E+00
Arsenic	4.59E+02	5.10E+00	NA	9.00E+01	4.59E+01	5.10E+00	NA	9.00E+00
Beryllium	0.00E+00	0.00E+00	NA	0.00E+00	0.00E+00	0.00E+00	NA	0.00E+00
Chromium	9.58E+05	1.07E+04	NA	9.00E+01	9.58E+04	1.07E+04	NA	9.00E+00
Fluoride	7.98E+06	8.88E+04	NA	9.00E+01	7.98E+05	8.88E+04	NA	9.00E+00
Mercury	9.98E+03	1.11E+02	NA	9.00E+01	9.98E+02	1.11E+02	NA	9.00E+00
Sodium	5.09E+08	5.66E+06	NA	9.00E+01	5.09E+07	5.66E+06	NA	9.00E+00
Nickel	0.00E+00	0.00E+00	NA	0.00E+00	0.00E+00	0.00E+00	NA	0.00E+00
Antimony	0.00E+00	0.00E+00	NA	0.00E+00	0.00E+00	0.00E+00	NA	0.00E+00
Sulfate	1.60E+07	1.78E+05	NA	9.00E+01	1.60E+06	1.78E+05	NA	9.00E+00
Vanadium	0.00E+00	0.00E+00	NA	0.00E+00	0.00E+00	0.00E+00	NA	0.00E+00
C-14	6.71E+00	7.46E-02	3.33E-01	9.00E+01	6.71E-01	7.46E-02	3.33E-01	9.00E+00
I-129	1.47E+03	1.63E+01	2.66E-03	9.00E+01	1.47E+02	1.63E+01	2.66E-03	9.00E+00
Tc-99	9.39E+03	1.04E+02	1.78E+00	9.00E+01	9.39E+02	1.04E+02	1.78E+00	9.00E+00
U-238	1.38E+07	1.53E+05	5.10E-02	9.00E+01	1.38E+06	1.53E+05	5.10E-02	9.00E+00
Am-241	1.42E+02	1.57E+00	5.10E+00	9.00E+01	1.42E+01	1.57E+00	5.10E+00	9.00E+00
Cs-137	4.01E+03	4.46E+01	3.88E+03	9.00E+01	4.01E+02	4.46E+01	3.88E+03	9.00E+00
Pu-239	4.40E+03	4.89E+01	3.00E+00	9.00E+01	4.40E+02	4.89E+01	3.00E+00	9.00E+00
Sr-90	7.79E+03	8.66E+01	1.22E+04	9.00E+01	7.79E+02	8.66E+01	1.22E+04	9.00E+00

Table K-4. Flux Rates and Release Durations for the Base Case Streams Releasing to Groundwater. Page 3 of 3

Contaminant	Module M.2 - DST Residue: Inventory (g)	Flux Rate (g/yr)	Flux Rate (Ci/yr)	Release Duration (yr)	Module M.2 - Pipe Leakage: Inventory (g)	Flux Rate (g/yr)	Flux Rate (Ci/yr)	Release Duration (yr)
EDTA	5.28E+05	2.59E+03	NA	2.04E+02	5.28E+04	2.59E+03	NA	2.04E+01
Nitrate	1.79E+08	8.77E+05	NA	2.04E+02	1.79E+07	8.77E+05	NA	2.04E+01
Nitrite	6.06E+07	2.97E+05	NA	2.04E+02	6.06E+06	2.97E+05	NA	2.04E+01
TBP	4.59E+05	2.25E+03	NA	2.04E+02	4.59E+04	2.25E+03	NA	2.04E+01
Arsenic	8.06E+03	3.95E+01	NA	2.04E+02	8.06E+02	3.95E+01	NA	2.04E+01
Beryllium	1.01E+02	4.93E-01	NA	2.04E+02	1.01E+01	4.93E-01	NA	2.04E+01
Chromium	7.39E+05	3.62E+03	NA	2.04E+02	7.39E+04	3.62E+03	NA	2.04E+01
Fluoride	1.06E+06	5.20E+03	NA	2.04E+02	1.06E+05	5.20E+03	NA	2.04E+01
Mercury	7.74E+04	3.80E+02	NA	2.04E+02	7.74E+03	3.80E+02	NA	2.04E+01
Sodium	1.96E+08	9.60E+05	NA	2.04E+02	1.96E+07	9.60E+05	NA	2.04E+01
Nickel	2.30E+06	1.13E+04	NA	2.04E+02	2.30E+05	1.13E+04	NA	2.04E+01
Antimony	1.89E+04	9.26E+01	NA	2.04E+02	1.89E+03	9.26E+01	NA	2.04E+01
Sulfate	5.19E+06	2.55E+04	NA	2.04E+02	5.19E+05	2.55E+04	NA	2.04E+01
Vanadium	4.86E+02	2.38E+00	NA	2.04E+02	4.86E+01	2.38E+00	NA	2.04E+01
C-14	4.75E+00	2.33E-02	1.04E-01	2.04E+02	4.75E-01	2.33E-02	1.04E-01	2.04E+01
I-129	9.66E+02	4.74E+00	7.72E-04	2.04E+02	9.66E+01	4.74E+00	7.72E-04	2.04E+01
Tc-99	1.46E+04	7.18E+01	1.22E+00	2.04E+02	1.46E+03	7.18E+01	1.22E+00	2.04E+01
U-238	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Am-241	2.92E+02	1.43E+00	4.65E+00	2.04E+02	2.92E+01	1.43E+00	4.65E+00	2.04E+01
Cs-137	8.38E+03	4.11E+01	3.58E+03	2.04E+02	8.38E+02	4.11E+01	3.58E+03	2.04E+01
Pu-239	7.67E+02	3.76E+00	2.31E-01	2.04E+02	7.67E+01	3.76E+00	2.31E-01	2.04E+01
Sr-90	3.77E+05	1.85E+03	2.60E+05	2.04E+02	3.77E+04	1.85E+03	2.60E+05	2.04E+01

Table K-5. Flux Rates and Release Durations for Test Case I Streams Releasing to Groundwater.

Contaminant	Module M.1 - Past Leakage				Module M.1 - Leakage During Retrieval (Barrier)			
	Inventory (g)	Flux Rate (g/yr)	Flux Rate (Ci/yr)	Release Duration (yr)	Inventory (g)	Flux Rate (g/yr)	Flux Rate (Ci/yr)	Release Duration (yr)
EDTA	1.68E+05	2.04E+02	NA	8.23E+02	1.68E+04	5.73E+00	NA	2.92E+03
Nitrate	9.68E+08	1.18E+06	NA	8.23E+02	9.68E+07	3.31E+04	NA	2.92E+03
Nitrite	4.79E+07	5.82E+04	NA	8.23E+02	4.79E+06	1.64E+03	NA	2.92E+03
TBP	1.46E+05	1.77E+02	NA	8.23E+02	1.46E+04	4.98E+00	NA	2.92E+03
Arsenic	4.59E+02	5.57E-01	NA	8.23E+02	4.59E+01	1.57E-02	NA	2.92E+03
Beryllium	0.00E+00	0.00E+00	NA	0.00E+00	0.00E+00	0.00E+00	NA	0.00E+00
Chromium	9.58E+05	1.16E+03	NA	8.23E+02	9.58E+04	3.28E+01	NA	2.92E+03
Fluoride	7.98E+06	9.69E+03	NA	8.23E+02	7.98E+05	2.73E+02	NA	2.92E+03
Mercury	9.98E+03	1.21E+01	NA	8.23E+02	9.98E+02	3.41E-01	NA	2.92E+03
Sodium	5.09E+08	6.18E+05	NA	8.23E+02	5.09E+07	1.74E+04	NA	2.92E+03
Nickel	0.00E+00	0.00E+00	NA	0.00E+00	0.00E+00	0.00E+00	NA	0.00E+00
Antimony	0.00E+00	0.00E+00	NA	0.00E+00	0.00E+00	0.00E+00	NA	0.00E+00
Sulfate	1.60E+07	1.94E+04	NA	8.23E+02	1.60E+06	5.46E+02	NA	2.92E+03
Vanadium	0.00E+00	0.00E+00	NA	0.00E+00	0.00E+00	0.00E+00	NA	0.00E+00
C-14	6.71E+00	8.15E-03	3.64E-02	8.23E+02	6.71E-01	2.30E-04	1.02E-03	2.92E+03
I-129	1.47E+03	1.78E+00	2.91E-04	8.23E+02	1.47E+02	5.03E-02	8.19E-06	2.92E+03
Tc-99	9.39E+03	1.14E+01	1.94E-01	8.23E+02	9.39E+02	3.21E-01	5.46E-03	2.92E+03
U-238	1.38E+07	1.67E+04	5.57E-03	8.23E+02	1.38E+06	4.72E+02	1.57E-04	2.92E+03
Am-241	1.42E+02	1.72E-01	5.57E-01	8.23E+02	1.42E+01	4.84E-03	1.57E-02	2.92E+03
Cs-137	4.01E+03	4.88E+00	4.24E+02	8.23E+02	4.01E+02	1.37E-01	1.19E+01	2.92E+03
Pu-239	4.40E+03	5.34E+00	3.27E-01	8.23E+02	4.40E+02	1.50E-01	9.22E-03	2.92E+03
Sr-90	7.79E+03	9.45E+00	1.33E+03	8.23E+02	7.79E+02	2.66E-01	3.75E+01	2.92E+03

Table K-5. Flux Rates and Release Durations for Test Case I Streams Releasing to Groundwater.

	Module M.1 - SST Residue				Module M.1 - Pipe Leakage			
Contaminant	Inventory (g)	Flux Rate (g/yr)	Flux Rate (Ci/yr)	Release Duration (yr)	Inventory (g)	Flux Rate (g/yr)	Flux Rate (Ci/yr)	Release Duration (yr)
EDTA	1.68E+05	1.86E+03	NA	9.00E+01	1.68E+04	1.86E+03	NA	9.00E+00
Nitrate	9.68E+08	1.08E+07	NA	9.00E+01	9.68E+07	1.08E+07	NA	9.00E+00
Nitrite	4.79E+07	5.33E+05	NA	9.00E+01	4.79E+06	5.33E+05	NA	9.00E+00
TBP	1.46E+05	1.62E+03	NA	9.00E+01	1.46E+04	1.62E+03	NA	9.00E+00
Arsenic	4.59E+02	5.10E+00	NA	9.00E+01	4.59E+01	5.10E+00	NA	9.00E+00
Beryllium	0.00E+00	0.00E+00	NA	0.00E+00	0.00E+00	0.00E+00	NA	0.00E+00
Chromium	9.58E+05	1.07E+04	NA	9.00E+01	9.58E+04	1.07E+04	NA	9.00E+00
Fluoride	7.98E+06	8.88E+04	NA	9.00E+01	7.98E+05	8.88E+04	NA	9.00E+00
Mercury	9.98E+03	1.11E+02	NA	9.00E+01	9.98E+02	1.11E+02	NA	9.00E+00
Sodium	5.09E+08	5.66E+06	NA	9.00E+01	5.09E+07	5.66E+06	NA	9.00E+00
Nickel	0.00E+00	0.00E+00	NA	0.00E+00	0.00E+00	0.00E+00	NA	0.00E+00
Antimony	0.00E+00	0.00E+00	NA	0.00E+00	0.00E+00	0.00E+00	NA	0.00E+00
Sulfate	1.60E+07	1.78E+05	NA	9.00E+01	1.60E+06	1.78E+05	NA	9.00E+00
Vanadium	0.00E+00	0.00E+00	NA	0.00E+00	0.00E+00	0.00E+00	NA	0.00E+00
C-14	6.71E+00	7.46E-02	3.33E-01	9.00E+01	6.71E-01	7.46E-02	3.33E-01	9.00E+00
I-129	1.47E+03	1.63E+01	2.66E-03	9.00E+01	1.47E+02	1.63E+01	2.66E-03	9.00E+00
Tc-99	9.39E+03	1.04E+02	1.78E+00	9.00E+01	9.39E+02	1.04E+02	1.78E+00	9.00E+00
U-238	1.38E+07	1.53E+05	5.10E-02	9.00E+01	1.38E+06	1.53E+05	5.10E-02	9.00E+00
Am-241	1.42E+02	1.57E+00	5.10E+00	9.00E+01	1.42E+01	1.57E+00	5.10E+00	9.00E+00
Cs-137	4.01E+03	4.46E+01	3.88E+03	9.00E+01	4.01E+02	4.46E+01	3.88E+03	9.00E+00
Pu-239	4.40E+03	4.89E+01	3.00E+00	9.00E+01	4.40E+02	4.89E+01	3.00E+00	9.00E+00
Sr-90	7.79E+03	8.66E+01	1.22E+04	9.00E+01	7.79E+02	8.66E+01	1.22E+04	9.00E+00

Table K-6. Flux Rates and Release Durations for Test Case II Streams Releasing to Groundwater.

Contaminant	Module M.1 - Past Leakage Inventory (g)	Flux Rate (g/yr)	Flux Rate (Ci/yr)	Release Duration (yr)	Module M.1 - Leakage During Retrieval Inventory (g)	Flux Rate (g/yr)	Flux Rate (Ci/yr)	Release Duration (yr)
EDTA	1.68E+05	3.73E+02	NA	4.50E+02	5.91E+04	3.77E+01	NA	1.57E+03
Nitrate	9.68E+08	2.15E+06	NA	4.50E+02	3.41E+08	2.18E+05	NA	1.57E+03
Nitrite	4.79E+07	1.07E+05	NA	4.50E+02	1.69E+07	1.08E+04	NA	1.57E+03
TBP	1.46E+05	3.24E+02	NA	4.50E+02	5.13E+04	3.27E+01	NA	1.57E+03
Arsenic	4.59E+02	1.02E+00	NA	4.50E+02	1.62E+02	1.03E-01	NA	1.57E+03
Beryllium	0.00E+00	0.00E+00	NA	0.00E+00	0.00E+00	0.00E+00	NA	0.00E+00
Chromium	9.58E+05	2.13E+03	NA	4.50E+02	3.37E+05	2.15E+02	NA	1.57E+03
Fluoride	7.98E+06	1.78E+04	NA	4.50E+02	2.81E+06	1.79E+03	NA	1.57E+03
Mercury	9.98E+03	2.22E+01	NA	4.50E+02	3.52E+03	2.24E+00	NA	1.57E+03
Sodium	5.09E+08	1.13E+06	NA	4.50E+02	1.79E+08	1.14E+05	NA	1.57E+03
Nickel	0.00E+00	0.00E+00	NA	0.00E+00	0.00E+00	0.00E+00	NA	0.00E+00
Antimony	0.00E+00	0.00E+00	NA	0.00E+00	0.00E+00	0.00E+00	NA	0.00E+00
Sulfate	1.60E+07	3.55E+04	NA	4.50E+02	5.62E+06	3.59E+03	NA	1.57E+03
Vanadium	0.00E+00	0.00E+00	NA	0.00E+00	0.00E+00	0.00E+00	NA	0.00E+00
C-14	6.71E+00	1.49E-02	6.66E-02	4.50E+02	2.36E+00	1.51E-03	6.73E-03	1.57E+03
I-129	1.47E+03	3.27E+00	5.33E-04	4.50E+02	5.18E+02	3.30E-01	5.38E-05	1.57E+03
Tc-99	9.39E+03	2.09E+01	3.55E-01	4.50E+02	3.31E+03	2.11E+00	3.59E-02	1.57E+03
U-238	1.38E+07	3.07E+04	1.02E-02	4.50E+02	4.86E+06	3.10E+03	1.03E-03	1.57E+03
Am-241	1.42E+02	3.15E-01	1.02E+00	4.50E+02	4.99E+01	3.18E-02	1.03E-01	1.57E+03
Cs-137	4.01E+03	8.93E+00	7.77E+02	4.50E+02	1.41E+03	9.02E-01	7.85E+01	1.57E+03
Pu-239	4.40E+03	9.77E+00	5.99E-01	4.50E+02	1.55E+03	9.88E-01	6.06E-02	1.57E+03
Sr-90	7.79E+03	1.73E+01	2.44E+03	4.50E+02	2.74E+03	1.75E+00	2.47E+02	1.57E+03

Table K-6. Flux Rates and Release Durations for Test Case II Streams Releasing to Groundwater. Page 2 of 2

Contaminant	Module M.1 - SST Residue				Module M.1 - Pipe Leakage			
	Inventory (g)	Flux Rate (g/yr)	Flux Rate (Ci/yr)	Release Duration (yr)	Inventory (g)	Flux Rate (g/yr)	Flux Rate (Ci/yr)	Release Duration (yr)
EDTA	1.68E+04	1.86E+03	NA	9.00E+00	1.68E+04	1.86E+03	NA	9.00E+00
Nitrate	9.68E+07	1.08E+07	NA	9.00E+00	9.68E+07	1.08E+07	NA	9.00E+00
Nitrite	4.79E+06	5.33E+05	NA	9.00E+00	4.79E+06	5.33E+05	NA	9.00E+00
TBP	1.46E+04	1.62E+03	NA	9.00E+00	1.46E+04	1.62E+03	NA	9.00E+00
Arsenic	4.59E+01	5.10E+00	NA	9.00E+00	4.59E+01	5.10E+00	NA	9.00E+00
Beryllium	0.00E+00	0.00E+00	NA	0.00E+00	0.00E+00	0.00E+00	NA	0.00E+00
Chromium	9.58E+04	1.07E+04	NA	9.00E+00	9.58E+04	1.07E+04	NA	9.00E+00
Fluoride	7.98E+05	8.88E+04	NA	9.00E+00	7.98E+05	8.88E+04	NA	9.00E+00
Mercury	9.98E+02	1.11E+02	NA	9.00E+00	9.98E+02	1.11E+02	NA	9.00E+00
Sodium	5.09E+07	5.66E+06	NA	9.00E+00	5.09E+07	5.66E+06	NA	9.00E+00
Nickel	0.00E+00	0.00E+00	NA	0.00E+00	0.00E+00	0.00E+00	NA	0.00E+00
Antimony	0.00E+00	0.00E+00	NA	0.00E+00	0.00E+00	0.00E+00	NA	0.00E+00
Sulfate	1.60E+06	1.78E+05	NA	9.00E+00	1.60E+06	1.78E+05	NA	9.00E+00
Vanadium	0.00E+00	0.00E+00	NA	0.00E+00	0.00E+00	0.00E+00	NA	0.00E+00
C-14	6.71E-01	7.46E-02	3.33E-01	9.00E+00	6.71E-01	7.46E-02	3.33E-01	9.00E+00
I-129	1.47E+02	1.63E+01	2.66E-03	9.00E+00	1.47E+02	1.63E+01	2.66E-03	9.00E+00
Tc-99	9.39E+02	1.04E+02	1.78E+00	9.00E+00	9.39E+02	1.04E+02	1.78E+00	9.00E+00
U-238	1.38E+06	1.53E+05	5.10E-02	9.00E+00	1.38E+06	1.53E+05	5.10E-02	9.00E+00
Am-241	1.42E+01	1.57E+00	5.10E+00	9.00E+00	1.42E+01	1.57E+00	5.10E+00	9.00E+00
Cs-137	4.01E+02	4.46E+01	3.88E+03	9.00E+00	4.01E+02	4.46E+01	3.88E+03	9.00E+00
Pu-239	4.40E+02	4.89E+01	3.00E+00	9.00E+00	4.40E+02	4.89E+01	3.00E+00	9.00E+00
Sr-90	7.79E+02	8.66E+01	1.22E+04	9.00E+00	7.79E+02	8.66E+01	1.22E+04	9.00E+00

Table K-7. MEPAS Code Input Parameters for the Atmospheric Pathway. Sheet 1 of 3

Parameter Type	Parameter Description	Value	Data Source or Justification
Source Characteristics	Type of release	point source from stack	Assumption
	Duration of release	13 yr	Assumption used to compute unit risk factors, based on unit operation time
	Effluent exit temperature	68°F	Assumption that exit temperature is ambient
	Vertical exit velocity	2 m/s	Assumption
	Effluent exit radius	1 m	Assumption
	Effluent release height	20 m	Assumption
	Building height, if applicable	15 m	Assumption
Contaminant Release Data	Contaminant-specific release rate	dependent upon waste stream under evaluation	See Table K-8
Climatological Characteristics	Morning mixing height	300 m	Stone et al. 1983
	Afternoon mixing height	1800 m	Stone et al. 1983
	Number of annual thunderstorms	10	Stone et al. 1983
	Annual mean air temperature	53°F	Stone et al. 1983
	Annual precipitation	6.3 in	Stone et al. 1983
	Number of annual precipitation days	130 days	Stone et al. 1983

Table K-7. MEPAS Code Input Parameters for the Atmospheric Pathway. Sheet 2 of 3

Parameter Type	Parameter Description	Value	Data Source or Justification
Climatological Characteristics (cont.)	Selection of terrain type (flat or non-flat)	flat	Conservative assumption
	Local wind channeling index (modelled or not modelled)	not modelled	Assumption
Joint Frequency Data	Joint frequency data anemometer height	89 m	Napier et. al. 1988
	Joint frequency data roughness length	1 cm	Napier et. al. 1988
	Joint frequency data wind speed groups 1 - 6 midpoints	Group 1: 0.89 m/s Group 2: 2.65 m/s Group 3: 4.7 m/s Group 4: 7.15 m/s Group 5: 9.8 m/s Group 6: 12.7 m/s	Napier et. al. 1988
	Format of joint frequency summary data	Percentages	Napier et. al. 1988
	Joint frequency data file	HANFORD.JFD	Napier et. al. 1988, based on 1983 to 1987 averages
Population Data	Population distribution file	HANFORD.POP	Based on 1990 census data
Exposure Pathway Selection	Exposure pathways considered - inhalation - deposition followed by vegetation, meat, and milk ingestion	None	Assumption

Table K-7. MEPAS Code Input Parameters for the Atmospheric Pathway. Sheet 3 of 3

Parameter Type	Parameter Description	Value	Data Source or Justification
Receptor Exposure Characteristics	Location of public and worker receptor(s)	26 km ESE of the 200 Area	DOE 1987
	Irrigation rate	100 L/m^2-month	Droppo et. al. 1989
	Human body weight	70 kg	EPA 1989
	Exposure duration	70 yrs	EPA 1989

Table K-8. Flux Rates and Release Durations for Base Case Streams Releasing to Air.

	Module M.13 Air Filtration Process Stack			Module M.13 Air Filtration Storage Stack		
Contaminant	Inventory (g or Ci)	Flux Rate (g/s or Ci/s)	Release Duration (yr)	Inventory (g or Ci)	Flux Rate (g/s or Ci/s)	Release Duration (yr)
EDTA	0.00E+00	0.00E+00	1.30E+01	0.00E+00	0.00E+00	1.30E+01
Nitrate	2.09E+07	8.36E-02	1.30E+01	0.00E+00	0.00E+00	1.30E+01
Nitrite	0.00E+00	0.00E+00	1.30E+01	0.00E+00	0.00E+00	1.30E+01
TBP	0.00E+00	0.00E+00	1.30E+01	0.00E+00	0.00E+00	1.30E+01
Arsenic	2.12E-06	8.48E-15	1.30E+01	4.25E-01	1.70E-09	1.30E+01
Beryllium	2.51E-08	1.00E-16	1.30E+01	5.01E-03	2.00E-11	1.30E+01
Chromium	4.49E-04	1.80E-12	1.30E+01	8.33E+01	3.33E-07	1.30E+01
Fluoride	0.00E+00	0.00E+00	1.30E+01	0.00E+00	0.00E+00	1.30E+01
Mercury	0.00E+00	0.00E+00	1.30E+01	0.00E+00	0.00E+00	1.30E+01
Sodium	2.05E-01	8.20E-10	1.30E+01	3.80E+04	1.52E-04	1.30E+01
Nickel	5.10E-04	2.04E-12	1.30E+01	9.49E+01	3.80E-07	1.30E+01
Antimony	4.70E-06	1.88E-14	1.30E+01	9.41E-01	3.76E-09	1.30E+01
Sulfate	0.00E+00	0.00E+00	1.30E+01	0.00E+00	0.00E+00	1.30E+01
Vanadium	1.21E-07	4.84E-16	1.30E+01	2.43E-02	9.72E-11	1.30E+01
C-14	0.00E+00	0.00E+00	1.30E+01	0.00E+00	0.00E+00	1.30E+01
I-129	3.85E+01	1.54E-07	1.30E+01	0.00E+00	0.00E+00	1.30E+01
Tc-99	1.00E-07	4.00E-16	1.30E+01	2.00E-02	8.00E-11	1.30E+01
U-238	1.23E-12	4.92E-21	1.30E+01	2.29E-07	9.16E-16	1.30E+01
Am-241	3.48E-07	1.39E-15	1.30E+01	6.95E-02	2.78E-10	1.30E+01
Cs-137	2.66E-04	1.06E-12	1.30E+01	5.32E+01	2.13E-07	1.30E+01
Pu-239	4.79E-08	1.92E-16	1.30E+01	9.60E-03	3.84E-11	1.30E+01
Sr-90	0.00E+00	0.00E+00	1.30E+01	0.00E+00	0.00E+00	1.30E+01

K.2 OUTPUT DATA

The MEPAS code provides output data in the form of risk values for radionuclides and chemical carcinogens and reference (RfD) ratios for noncarcinogenic chemicals. For this evaluation, these output values will be applied directly as the risk or hazard index for each contaminant. There is one exception to the direct application of the risk factor or RfD ratios: ethylenediaminetetraacetic acid (EDTA) and tributyl phosphate (TBP). Because the system model only tracks total organic carbon (TOC) through the mass balance of the system, it is necessary to develop a representative unit risk factor for TOC. The representative TOC unit risk factor was computed by summing the risk factors computed for EDTA and TBP by MEPAS, as multiplied by the weight fractions of each. This computation is demonstrated using the following equation.

$$RF_{TOC} = RF_{EDTA} \left(\frac{Inv_{EDTA}}{Inv_{TOC}}\right) + RF_{TBP} \left(\frac{Inv_{TBP}}{Inv_{TOC}}\right)$$

where:

RF_{TOC} = unit risk factor for TOC $[(g/yr)^{-1}]$
RF_{EDTA} = unit risk factor for EDTA $[(g/yr)^{-1}]$
RF_{TBP} = unit risk factor for TBP $[(g/yr)^{-1}]$
Inv_{EDTA} = inventory of EDTA for the stream of interest (μg/g)
Inv_{TBP} = inventory of TBP for the stream of interest (μg/g)
Inv_{TOC} = inventory of TOC for the stream of interest (μg/g).

Table K-9 lists the risk factors for each contaminant of concern for the groundwater and atmospheric pathways. Also included in this table is the computed representative risk factor for TOC.

Table K-9. Summary of Constituent Risk and RfD Values for All Cases. Page 1 of 2

Constituent	Base Case - Traditional Sluicing Module M.1				Test Case 1 - Close-Coupled Barrier Module M.1			
	Past Leakage	Leakage During Retrieval	SST Residue	Pipe Leakage	Past Leakage	Leakage During Retrieval	SST Residue	Pipe Leakage
Chemicals:								
As	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
F	2.30E-03	5.35E-03	2.37E-03	7.16E-04	2.21E-03	1.68E-04	2.37E-03	1.46E-04
Hg	1.54E-03	3.60E-03	1.59E-03	4.82E-04	1.48E-03	1.13E-04	1.59E-03	9.83E-05
Na	1.67E-05	3.90E-05	1.72E-05	5.21E-06	1.61E-05	1.23E-06	1.72E-05	1.07E-06
NO3	8.78E-02	2.04E-01	9.09E-02	2.75E-02	8.49E-02	6.44E-03	9.09E-02	5.62E-03
S	3.43E-06	7.95E-06	3.55E-06	1.07E-06	3.30E-06	2.51E-07	3.55E-06	2.19E-07
NO2	5.40E-03	1.25E-02	5.56E-03	5.74E-03	5.16E-03	3.94E-04	5.56E-03	3.42E-04
Ni								
Be								
Sb								
V								
TOC	7.57E-04	1.76E-03	7.80E-04	2.37E-04	7.29E-04	5.54E-05	7.80E-04	4.80E-05
Radionuclides:								
C-14	1.62E-07	3.74E-07	1.67E-07	1.11E-08	1.56E-07	1.17E-08	1.67E-07	1.11E-08
I-129	4.41E-07	1.03E-06	4.55E-07	2.79E-08	4.25E-07	3.24E-08	4.55E-07	2.79E-08
Tc-99	2.81E-06	6.52E-06	2.91E-06	1.80E-07	2.71E-06	2.06E-07	2.91E-06	1.80E-07
U-238	1.06E-06	2.47E-06	1.09E-06	6.75E-08	1.02E-06	7.77E-08	1.09E-06	6.75E-08
Am-241	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs-137	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pu-239	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr-90	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table K-9. Summary of Constituent Risk and RfD Values for All Cases.

	Test Case 2 - Robotic Sluicing Module M.1				All Cases Module M.2		All Cases Module M.13	
Constituent	Past Leakage	Leakage During Retrieval	SST Residue	Pipe Leakage	DST Residue	Pipe Leakage	Process Stack	Storage Stack
Chemicals:								
As	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.76E-20	3.54E-15
Cr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.08E-10	2.00E-05
F	2.30E-03	7.16E-04	2.36E-04	1.46E-04	3.12E-04	3.16E-05	0.00E+00	0.00E+00
Hg	1.54E-03	4.82E-04	1.58E-04	9.83E-05	1.22E-02	1.24E-03	0.00E+00	0.00E+00
Na	1.67E-05	5.21E-06	1.71E-06	1.07E-06	6.58E-06	6.67E-07	3.38E-17	6.26E-12
NO3	8.78E-02	2.75E-02	9.02E-03	5.62E-03	1.66E-02	1.68E-03	5.10E-05	0.00E+00
S	3.43E-06	1.07E-06	3.53E-07	2.19E-07	1.14E-06	1.16E-07	0.00E+00	0.00E+00
NO2	5.40E-03	1.69E-03	5.50E-04	3.42E-04	6.95E-03	7.05E-04	0.00E+00	0.00E+00
Ni					0.00E+00	0.00E+00	1.96E-16	3.65E-11
Be					2.19E-09	2.22E-10	4.21E-22	8.39E-17
Sb					2.13E-04	2.16E-05	4.59E-17	9.17E-12
V					2.51E-07	2.55E-08	6.82E-20	1.37E-14
TOC	7.57E-04	2.37E-04	7.76E-05	4.80E-05	2.44E-03	2.47E-04	0.00E+00	0.00E+00
Radionuclides:								
C-14	1.62E-07	5.04E-08	1.66E-08	1.11E-08	1.17E-07	1.19E-08	0.00E+00	0.00E+00
I-129	4.41E-07	1.38E-07	4.51E-08	2.79E-08	2.96E-07	3.00E-08	2.49E-19	0.00E+00
Tc-99	2.81E-06	8.79E-07	2.89E-07	1.80E-07	4.45E-06	4.51E-07	1.62E-29	3.25E-24
U-238	1.06E-06	3.31E-07	1.09E-07	6.75E-08	0.00E+00	0.00E+00	0.00E+00	7.58E-29
Am-241	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.59E-28	1.12E-22
Cs-137	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.05E-25	4.12E-20
Pu-239	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.47E-29	1.49E-23
Sr-90	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

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APPENDIX L

FAILURE RISK FACTOR SHEETS

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Module Name: Base Case M.1, SST Waste Retrieval

FAILURE RISK PARAMETERS	M.1.A, SST Waste Retrieval System	M.1.B, SST Cleanup & Backfill	M.1.C, Capping	Module Number
Designation:	HL	HL	Cold	1
MAXIMUM ACCIDENT FAILURE EVENT				LIMITING EVENT
Consequence:	25	5	1	
Frequency:	0.1	0.01	0.0001	
Relative Risk:	2.5	0.05	0.0001	2.5
NONROUTINE MAINTENANCE FAILURE EVENTS				SUM OF EVENTS
Electrical Instrumentation				
Consequence:	5	5	1	
Frequency:	0.01	0.0001	0.0001	
Relative Risk:	0.05	0.0005	0.0001	0.0506
Mechanized Equipment				
Consequence:	5	5	1	
Frequency:	0.01	0.0001	0.0001	
Relative Risk:	0.05	0.0005	0.0001	0.0506
Pluggage/Caking				
Consequence:	5	5	1	
Frequency:	0.1	0.0001	0.0001	
Relative Risk:	0.5	0.0005	0.0001	0.5006
Corrosion				
Consequence:	5	5	1	
Frequency:	0.1	0.1	0.0001	
Relative Risk:	0.5	0.5	0.0001	1.0001
Physical Operation				
Consequence:	5	5	1	
Frequency:	0.01	0.1	0.0001	
Relative Risk:	0.05	0.5	0.0001	0.5501
TOTAL NONROUTINE MAINTENANCE RISK				
Relative Risk:	1.15	1.0015	0.0005	2.15

Notes:

Accident failure events are energy release events with the potential to 1) release contamination within the facility and into the environment, 2) damage the equipment and facility, and 3) physically injure workers. These events could include explosion, fire, pressure release, etc.

Nonroutine maintenance failure events are low energy events with limited potential for releasing contaminants from process systems. These events will lead to increased worker exposures resulting from nonroutine corrective maintenance.

Module Name: Test Case 1 M.1, SST Waste Retrieval

FAILURE RISK PARAMETERS	M.1.A, SST Waste Retrieval System	M.1.B, SST Cleanup & Backfill	M.1.C, Capping	M.1.D, Close-Coupled Barrier	Module Number
Designation:	HL	HL	Cold	LL	1
MAXIMUM ACCIDENT FAILURE EVENT					**LIMITING EVENT**
Consequence:	25	5	1	1	
Frequency:	0.1	0.01	0.0001	0.01	
Relative Risk:	2.5	0.05	0.0001	0.01	2.5
NONROUTINE MAINTENANCE FAILURE EVENTS					**SUM OF EVENTS**
Electrical Instrumentation					
Consequence:	5	5	1	1	
Frequency:	0.01	0.0001	0.0001	0.0001	
Relative Risk:	0.05	0.0005	0.0001	0.0001	0.0507
Mechanized Equipment					
Consequence:	5	5	1	1	
Frequency:	0.01	0.0001	0.0001	0.01	
Relative Risk:	0.05	0.0005	0.0001	0.01	0.0606
Pluggage/Caking					
Consequence:	5	5	1	1	
Frequency:	0.1	0.0001	0.0001	0.0001	
Relative Risk:	0.5	0.0005	0.0001	0.0001	0.5007
Corrosion					
Consequence:	5	5	1	1	
Frequency:	0.1	0.1	0.0001	0.0001	
Relative Risk:	0.5	0.5	0.0001	0.0001	1.0002
Physical Operation					
Consequence:	5	5	1	1	
Frequency:	0.01	0.1	0.0001	0.1	
Relative Risk:	0.05	0.5	0.0001	0.1	0.6501
TOTAL NONROUTINE MAINTENANCE RISK					
Relative Risk:	1.15	1.0015	0.0005	0.1103	2.2623

Notes:

Accident failure events are energy release events with the potential to 1) release contamination within the facility and into the environment, 2) damage the equipment and facility, and 3) physically injure workers. These events could include explosion, fire, pressure release, etc.

Nonroutine maintenance failure events are low energy events with limited potential for releasing contaminants from process systems. These events will lead to increased worker exposures resulting from nonroutine corrective maintenance.

Module Name: Test Case 2 M.1, SST Waste Retrieval

FAILURE RISK PARAMETERS	M.1.A, SST Waste Retrieval System	M.1.B, SST Cleanup & Backfill	M.1.C, Capping	Module Number
Designation:	HL	HL	Cold	1
MAXIMUM ACCIDENT FAILURE EVENT				**LIMITING EVENT**
Consequence:	25	5	1	
Frequency:	0.1	0.01	0.0001	
Relative Risk:	2.5	0.05	0.0001	2.5
NONROUTINE MAINTENANCE FAILURE EVENTS				**SUM OF EVENTS**
Electrical Instrumentation				
Consequence:	5	5	1	
Frequency:	0.1	0.0001	0.0001	
Relative Risk:	0.5	0.0005	0.0001	0.5006
Mechanized Equipment				
Consequence:	5	5	1	
Frequency:	0.1	0.0001	0.0001	
Relative Risk:	0.5	0.0005	0.0001	0.5006
Pluggage/Caking				
Consequence:	5	5	1	
Frequency:	0.1	0.0001	0.0001	
Relative Risk:	0.5	0.0005	0.0001	0.5006
Corrosion				
Consequence:	5	5	1	
Frequency:	0.1	0.1	0.0001	
Relative Risk:	0.5	0.5	0.0001	1.0001
Physical Operation				
Consequence:	5	5	1	
Frequency:	0.1	0.1	0.0001	
Relative Risk:	0.5	0.5	0.0001	1.0001
TOTAL NONROUTINE MAINTENANCE RISK				
Relative Risk:	2.5	1.0015	0.0005	3.502

Notes:

Accident failure events are energy release events with the potential to 1) release contamination within the facility and into the environment, 2) damage the equipment and facility, and 3) physically injure workers. These events could include explosion, fire, pressure release, etc.

Nonroutine maintenance failure events are low energy events with limited potential for releasing contaminants from process systems. These events will lead to increased worker exposures resulting from nonroutine corrective maintenance.

Module Name: M.2, DST Waste Retrieval

FAILURE RISK PARAMETERS	M.2.A, DST Miscellaneous Waste Retrieval System	M.2.B Concentrated Complexant Waste Retrieval System	M.2.C, Dilute Non-Complexed Waste Retrieval System	M.2.D 242-A Evaporator	M.2.E, DST Cleanup & Backfill	M.2.F, Capping	Module Number
Designation:	HL	HL	HL	HL	HL	Cold	2
MAXIMUM ACCIDENT FAILURE EVENT							**LIMITING EVENT**
Consequence:	25.0	25.0	25.0	25	5	1	
Frequency:	0.0	0.0	0.0	0.01	0.01	0.0001	
Relative Risk:	0.3	0.3	0.3	0.25	0.05	0.0001	0.3
NONROUTINE MAINTENANCE FAILURE EVENTS							**SUM OF EVENTS**
Electrical Instrumentation							
Consequence:	5	5	5	5	5	1	
Frequency:	0.0033	0.0033	0.0033	0.01	0.0001	0.0001	
Relative Risk:	0.0167	0.0167	0.0167	0.05	0.0005	0.0001	0.1
Mechanized Equipment							
Consequence:	5	5	5	5	5	1	
Frequency:	0.0033	0.0033	0.0033	0.01	0.0001	0.0001	
Relative Risk:	0.0167	0.0167	0.0167	0.05	0.0005	0.0001	0.1
Pluggage/Caking							
Consequence:	5	5	5	5	5	1	
Frequency:	0.0333	0.0033	0.0033	0.1	0.0001	0.0001	
Relative Risk:	0.1667	0.0167	0.0167	0.5	0.0005	0.0001	0.7
Corrosion							
Consequence:	5	5	5	5	5	1	
Frequency:	0.0033	0.0033	0.0033	0.01	0.0001	0.0001	
Relative Risk:	0.0167	0.0167	0.0167	0.05	0.0005	0.0001	0.1
Physical Operation							
Consequence:	5	5	5	5	5	1	
Frequency:	0.0333	0.0333	0.0333	0.01	0.1	0.0001	
Relative Risk:	0.1667	0.1667	0.1667	0.05	0.5	0.0001	1.1
TOTAL NONROUTINE MAINTENANCE RISK							
Relative Risk:	0.3833	0.2333	0.2333	0.7	0.502	0.0005	2.1

Notes:

Accident failure events are energy release events with the potential to 1) release contamination within the facility and into the environment, 2) damage the equipment and facility, and 3) physically injure workers. These events could include explosion, fire, pressure release, etc.

Nonroutine maintenance failure events are low energy events with limited potential for releasing contaminants from process systems. These events will lead to increased worker exposures resulting from nonroutine corrective maintenance.

Module Name: M.3, DST Sludge Wash

FAILURE RISK PARAMETERS	M.3.A, Chemical Feed System	M. 3.B, Sludge Settling Process	M.3.C, Sludge Wash Process	M.3.D, Wash Transfer Process	Module Number
Designation:	Cold	HL	HL	HL	3
MAXIMUM ACCIDENT FAILURE EVENT					**LIMITING EVENT**
Consequence:	1	5	5	5	
Frequency:	0.0001	0.01	0.01	0.01	
Relative Risk:	0.0001	0.05	0.05	0.05	0.05
NONROUTINE MAINTENANCE FAILURE EVENTS					**SUM OF EVENTS**
Electrical Instrumentation					
Consequence:	1	5	5	5	
Frequency:	0.01	0.01	0.01	0.01	
Relative Risk:	0.01	0.05	0.05	0.05	0.16
Mechanized Equipment					
Consequence:	1	5	5	5	
Frequency:	0.01	0.01	0.01	0.01	
Relative Risk:	0.01	0.05	0.05	0.05	0.16
Pluggage/Caking					
Consequence:	1	5	5	5	
Frequency:	0.01	0.01	0.01	0.0001	
Relative Risk:	0.01	0.05	0.05	0.0005	0.1105
Corrosion					
Consequence:	1	5	5	5	
Frequency:	0.0001	0.01	0.01	0.0001	
Relative Risk:	0.0001	0.05	0.05	0.0005	0.1006
Physical Operation					
Consequence:	1	5	5	5	
Frequency:	0.0001	0.0001	0.0001	0.0001	
Relative Risk:	0.0001	0.0005	0.0005	0.0005	0.0016
TOTAL NONROUTINE MAINTENANCE RISK					
Relative Risk:	0.0302	0.2005	0.2005	0.1015	0.5327

Notes:

Accident failure events are energy release events with the potential to 1) release contamination within the facility and into the environment, 2) damage the equipment and facility, and 3) physically injure workers. These events could include explosion, fire, pressure release, etc.

Nonroutine maintenance failure events are low energy events with limited potential for releasing contaminants from process systems These events will lead to increased worker exposures resulting from nonroutine corrective maintenance.

Module Name: M.4, Cesium Ion Exchange

FAILURE RISK PARAMETERS Designation:	M.4.A, Accumulation System HL	M 4.B, Supernatant Evaporator System HL	M 4.C, Ion Exchange Feed HL	M.4.D, Cesium Ion Exchange HL	M.4.E, Cs IX Concentrator HL	M.4.F, Eluent/Regeneration System LL	Module Number 4
MAXIMUM ACCIDENT FAILURE EVENT							**LIMITING EVENT**
Consequence:	5	25	5	5	5	1	
Frequency:	0.01	0.01	0 01	0.01	0.01	0 01	
Relative Risk:	0.05	0.25	0.05	0 05	0 05	0.01	0.25
NONROUTINE MAINTENANCE FAILURE EVENTS							**SUM OF EVENTS**
Electrical Instrumentation							
Consequence:	5	5	5	5	5	1	
Frequency:	0.01	0.01	0.01	0.01	0.01	0.01	
Relative Risk:	0.05	0.05	0 05	0.05	0.05	0 01	0.26
Mechanized Equipment							
Consequence:	5	5	5	5	5	1	
Frequency:	0.01	0.01	0.01	0.01	0.01	0 01	
Relative Risk:	0.05	0.05	0.05	0.05	0.05	0 01	0.26
Pluggage/Caking							
Consequence:	5	5	5	5	5	1	
Frequency:	0.0001	0.0001	0.01	0.0001	0.0001	0 0001	
Relative Risk:	0.0005	0.0005	0.05	0.0005	0.0005	0 0001	0 0521
Corrosion							
Consequence:	5	5	5	5	5	1	
Frequency:	0.01	0.01	0.01	0.01	0.01	0.01	
Relative Risk:	0.05	0.05	0.05	0.05	0.05	0 01	0.26
Physical Operation							
Consequence:	5	5	5	5	5	1	
Frequency:	0.0001	0.0001	0.0001	0.0001	0.0001	0 0001	
Relative Risk:	0.0005	0.0005	0 0005	0 0005	0 0005	0 0001	0 0026
TOTAL NONROUTINE MAINTENANCE RISK							
Relative Risk:	0.151	0.151	0.2005	0.151	0.151	0 0302	0.8347

Notes:

Accident failure events are energy release events with the potential to 1) release contamination within the facility and into the environment, 2) damage the equipment and facility, and 3) physically injure workers. These events could include explosion, fire, pressure release, etc.

Nonroutine maintenance failure events are low energy events with limited potential for releasing contaminants from process systems. These events will lead to increased worker exposures resulting from nonroutine corrective maintenance.

Module Name: M.5, LLW Glass in Sulfur

FAILURE RISK PARAMETERS	M.5.A, LLW Evaporator	M.5.B, LLW Melter	M.5.C, LLW Glass Quencher	M.5.D, LLW Glass Cullet Drying	M.5.E, LLW Cyclone System	Module Number
Designation:	LL	LL	LL	LL	LL	5
MAXIMUM ACCIDENT FAILURE EVENT						**LIMITING EVENT**
Consequence:	25	25	5	5	5	
Frequency:	0.01	0.1	0.01	0.0001	0.0001	
Relative Risk:	0.25	2.5	0.05	0.0005	0.0005	2.5
NONROUTINE MAINTENANCE FAILURE EVENTS						**SUM OF EVENTS**
Electrical Instrumentation						
Consequence:	5	5	5	5	5	
Frequency:	0.01	0.01	0.01	0.01	0.01	
Relative Risk:	0.05	0.05	0.05	0.05	0.05	0.25
Mechanized Equipment						
Consequence:	5	5	5	5	5	
Frequency:	0.01	0.01	0.01	0.01	0.1	
Relative Risk:	0.05	0.05	0.05	0.05	0.5	0.7
Pluggage/Caking						
Consequence:	5	5	5	5	5	
Frequency:	0.0001	1	1	0.1	1	
Relative Risk:	0.0005	5	5	0.5	5	15.5005
Corrosion						
Consequence:	5	5	5	5	5	
Frequency:	0.01	0.01	0.0001	0.0001	0.0001	
Relative Risk:	0.05	0.05	0.0005	0.0005	0.0005	0.1015
Physical Operation						
Consequence:	5	5	5	5	5	
Frequency:	0.0001	0.0001	0.0001	0.0001	0.0001	
Relative Risk:	0.0005	0.0005	0.0005	0.0005	0.0005	0.0025
TOTAL NONROUTINE MAINTENANCE RISK						
Relative Risk:	0.151	5.1505	5.101	0.601	5.551	16.5545

Notes:

Accident failure events are energy release events with the potential to 1) release contamination within the facility and into the environment, 2) damage the equipment and facility, and 3) physically injure workers. These events could include explosion, fire, pressure release, etc.

Nonroutine maintenance failure events are low energy events with limited potential for releasing contaminants from process systems. These events will lead to increased worker exposures resulting from nonroutine corrective maintenance.

Module Name: M.6, LLW Glass in Sulfur Vaults

FAILURE RISK PARAMETERS	M.6.A, Sulfur Cement Mixing	M.6.B, LLW Glass/Sulfur Mixer	M.6.C, Glass In Sulfur Disposal Vault	M.6.D, Decanted Molten Sulfur Vault	Module Number
Designation:	LL	LL	LL	LL	6
MAXIMUM ACCIDENT FAILURE EVENT					**LIMITING EVENT**
Consequence:	5	5	5	5	
Frequency:	0.01	0.01	0.01	0.01	
Relative Risk:	0.05	0.05	0.05	0.05	0.05
NONROUTINE MAINTENANCE FAILURE EVENTS					**SUM OF EVENTS**
Electrical Instrumentation					
Consequence:	5	5	5	5	
Frequency:	0.01	0.01	0.0001	0.0001	
Relative Risk:	0.05	0.05	0.0005	0.0005	0.101
Mechanized Equipment					
Consequence:	5	5	5	5	
Frequency:	0.01	0.01	0.0001	0.0001	
Relative Risk:	0.05	0.05	0.0005	0.0005	0.101
Pluggage/Caking					
Consequence:	5	5	5	5	
Frequency:	0.0001	1	0.0001	0.0001	
Relative Risk:	0.0005	5	0.0005	0.0005	5.0015
Corrosion					
Consequence:	5	5	5	5	
Frequency:	0.01	0.01	0.01	0.01	
Relative Risk:	0.05	0.05	0.05	0.05	0.2
Physical Operation					
Consequence:	5	5	5	5	
Frequency:	0.0001	0.0001	0.0001	0.0001	
Relative Risk:	0.0005	0.0005	0.0005	0.0005	0.002
TOTAL NONROUTINE MAINTENANCE RISK					
Relative Risk:	0.151	5.1505	0.052	0.052	5.4055

Notes:

Accident failure events are energy release events with the potential to 1) release contamination within the facility and into the environment, 2) damage the equipment and facility, and 3) physically injure workers These events could include explosion, fire, pressure release, etc.

Nonroutine maintenance failure events are low energy events with limited potential for releasing contaminants from process s These events will lead to increased worker exposures resulting from nonroutine corrective maintenance.

Module Name: M.7, HLW Glass Cullet Feed Lag Storage

FAILURE RISK PARAMETERS	M.7.A, HLW Feed Accumulation	M.7.B, HLW Feed Transfer Tank	Module Number
Designation:	HL	HL	7
MAXIMUM ACCIDENT FAILURE EVENT			LIMITING EVENT
Consequence:	25	25	
Frequency:	0.01	0.01	
Relative Risk:	0.25	0.25	0.25
NONROUTINE MAINTENANCE FAILURE EVENTS			SUM OF EVENTS
Electrical Instrumentation			
Consequence:	5	5	
Frequency:	0.01	0.01	
Relative Risk:	0.05	0.05	0.1
Mechanized Equipment			
Consequence:	5	5	
Frequency:	0.01	0.01	
Relative Risk:	0.05	0.05	0.1
Pluggage/Caking			
Consequence:	5	5	
Frequency:	0.1	0.1	
Relative Risk:	0.5	0.5	1
Corrosion			
Consequence:	5	5	
Frequency:	0.0001	0.0001	
Relative Risk:	0.0005	0.0005	0.001
Physical Operation			
Consequence:	5	5	
Frequency:	0.0001	0.0001	
Relative Risk:	0.0005	0.0005	0.001
TOTAL NONROUTINE MAINTENANCE RISK			
Relative Risk:	0.601	0.601	1.202

Notes:

Accident failure events are energy release events with the potential to 1) release con environment, 2) damage the equipment and facility, and 3) physically injure worker fire, pressure release, etc.

Nonroutine maintenance failure events are low energy events with limited potential These events will lead to increased worker exposures resulting from nonroutine corr

Module Name: M.8, HLW Glass Cullet

FAILURE RISK PARAMETERS	M.8.A, HLW Centrifuge System	M.8.B, HLW Melter System	M.8 C, HLW Evaporator	M.8.D, HLW Glass Quencher	M.8.E, HLW Glass Cullet Drying	M.8.F, HLW Cyclone System	Module Number
Designation:	HL	HL	HL	HL	HL	HL	8
MAXIMUM ACCIDENT FAILURE EVENT							**LIMITING EVENT**
Consequence:	25	25	25	5	5	5	
Frequency:	0.1	0.1	0.01	0 01	0.01	0 01	
Relative Risk:	2.5	2.5	0.25	0.05	0.05	0 05	2 5
NONROUTINE MAINTENANCE FAILURE EVENTS							**SUM OF EVENTS**
Electrical Instrumentation							
Consequence:	5	5	5	5	5	5	
Frequency:	0.01	0.01	0 01	0.01	0 01	0.01	
Relative Risk:	0.05	0 05	0.05	0.05	0.05	0.05	0.3
Mechanized Equipment							
Consequence:	5	5	5	5	5	5	
Frequency:	0.1	0.01	0.01	0.01	0.01	0.1	
Relative Risk:	0.5	0 05	0.05	0 05	0.05	0.5	1.2
Pluggage/Caking							
Consequence:	5	5	5	5	5	5	
Frequency:	1	1	0.0001	1	0 1	1	
Relative Risk:	5	5	0.0005	5	0 5	5	20.5005
Corrosion							
Consequence:	5	5	5	5	5	5	
Frequency:	0.0001	0.01	0.0001	0.0001	0.0001	0 0001	
Relative Risk:	0.0005	0.05	0.0005	0.0005	0.0005	0 0005	0 0525
Physical Operation							
Consequence:	5	5	5	5	5	5	
Frequency:	0 0001	0.0001	0 0001	0 0001	0 0001	0 0001	
Relative Risk:	0.0005	0 0005	0 0005	0.0005	0 0005	0 0005	0 003
TOTAL NONROUTINE MAINTENANCE RISK							
Relative Risk:	5.551	5.1505	0.1015	5.101	0.601	5 551	22 056

Notes:

Accident failure events are energy release events with the potential to 1) release contamination within the facility and into the environment, 2) damage the equipment and facility, and 3) physically injure workers. These events could include explosion, fire, pressure release, etc.

Nonroutine maintenance failure events are low energy events with limited potential for releasing contaminants from process systems. These events will lead to increased worker exposures resulting from nonroutine corrective maintenance.

Module Name: M.9, HLW Glass Cullet Cask Storage Pad

FAILURE RISK PARAMETERS	M.9.A, Air Pallets	M.9.B, Repository	Module Number
Designation:	HL	HL	9
MAXIMUM ACCIDENT FAILURE EVENT			**LIMITING EVENT**
Consequence:	5	5	
Frequency:	0.01	0.01	
Relative Risk:	0.05	0.05	0.05
NONROUTINE MAINTENANCE FAILURE EVENTS			**SUM OF EVENTS**
Electrical Instrumentation			
Consequence:	5	5	
Frequency:	0.01	0.01	
Relative Risk:	0.05	0.05	0.1
Mechanized Equipment			
Consequence:	5	5	
Frequency:	0.01	0.01	
Relative Risk:	0.05	0.05	0.1
Pluggage/Caking			
Consequence:	5	5	
Frequency:	0.0001	0.0001	
Relative Risk:	0.0005	0.0005	0.001
Corrosion			
Consequence:	5	5	
Frequency:	0.0001	0.0001	
Relative Risk:	0.0005	0.0005	0.001
Physical Operation			
Consequence:	5	5	
Frequency:	0.01	0.01	
Relative Risk:	0.05	0.05	0.1
TOTAL NONROUTINE MAINTENANCE RISK			
Relative Risk:	0.151	0.151	0.302

Notes:

Accident failure events are energy release events with the potential to 1) release con environment, 2) damage the equipment and facility, and 3) physically injure worker fire, pressure release, etc.

Nonroutine maintenance failure events are low energy events with limited potential These events will lead to increased worker exposures resulting from nonroutine corr

Module Name: M.10, Cullet Rework and Melter Off-Gas Processing

FAILURE RISK PARAMETERS	M.10.A, Cyclone System	M.10.B, HLW Separator	M.10.C, NOx/SO2 Separator	M.10.D, LLW Separator	M.10.E, Claus Reactor System	Module Number
Designation:	HL	HL	LL	LL	LL	10
MAXIMUM ACCIDENT FAILURE EVENT						**LIMITING EVENT**
Consequence:	5	5	1	5	5	
Frequency:	0.01	0.01	0.01	0.01	0 01	
Relative Risk:	0.05	0.05	0.01	0.05	0.05	0.05
NONROUTINE MAINTENANCE FAILURE EVENTS						**SUM OF EVENTS**
Electrical Instrumentation						
Consequence:	5	5	1	5	5	
Frequency:	0.01	0 01	0.01	0.01	0.01	
Relative Risk:	0.05	0.05	0.01	0.05	0.05	0.21
Mechanized Equipment						
Consequence:	5	5	1	5	5	
Frequency:	0.1	0.01	0.01	0.01	0.01	
Relative Risk:	0.5	0.05	0.01	0.05	0.05	0.66
Pluggage/Caking						
Consequence:	5	5	1	5	5	
Frequency:	0.0001	0.0001	0.0001	1	0 0001	
Relative Risk:	0.0005	0.0005	0.0001	5	0 0005	5.0016
Corrosion						
Consequence:	5	5	1	5	5	
Frequency:	0.0001	0.01	0.0001	0.01	0.0001	
Relative Risk:	0.0005	0.05	0.0001	0.05	0.0005	0.1011
Physical Operation						
Consequence:	5	5	1	5	5	
Frequency:	0.0001	0.0001	0.0001	0.0001	0.0001	
Relative Risk:	0.0005	0.0005	0.0001	0 0005	0.0005	0.0021
TOTAL NONROUTINE MAINTENANCE RISK						
Relative Risk:	0 5515	0.151	0 0203	5.1505	0 1015	5.9748

Notes:

Accident failure events are energy release events with the potential to 1) release contamination within the facility and into the environment, 2) damage the equipment and facility, and 3) physically injure workers. These events could include explosion, fire, pressure release, etc

Nonroutine maintenance failure events are low energy events with limited potential for releasing contaminants from process systems. These events will lead to increased worker exposures resulting from nonroutine corrective maintenance

Module Name: M.11, Liquid Effluent Treatment Facility

FAILURE RISK PARAMETERS	M.11.A, Process Condensate Recycle	M.11.B, pH Adjustment Tank	M.11.C, Retention Basin	Module Number
Designation:	LL	LL	LL	11
MAXIMUM ACCIDENT FAILURE EVENT				**LIMITING EVENT**
Consequence:	5	1	5	
Frequency:	0.01	0.01	0.01	
Relative Risk:	0.05	0.01	0.05	0.05
NONROUTINE MAINTENANCE FAILURE EVENTS				**SUM OF EVENTS**
Electrical Instrumentation				
Consequence:	5	1	5	
Frequency:	0.01	0.01	0.0001	
Relative Risk:	0.05	0.01	0.0005	0.0605
Mechanized Equipment				
Consequence:	5	1	5	
Frequency:	0.01	0.01	0.0001	
Relative Risk:	0.05	0.01	0.0005	0.0605
Pluggage/Caking				
Consequence:	5	1	5	
Frequency:	0.0001	0.0001	0.0001	
Relative Risk:	0.0005	0.0001	0.0005	0.0011
Corrosion				
Consequence:	5	1	5	
Frequency:	0.0001	0.0001	0.0001	
Relative Risk:	0.0005	0.0001	0.0005	0.0011
Physical Operation				
Consequence:	5	1	5	
Frequency:	0.0001	0.0001	0.0001	
Relative Risk:	0.0005	0.0001	0.0005	0.0011
TOTAL NONROUTINE MAINTENANCE RISK				
Relative Risk:	0.1015	0.0203	0.0025	0.1243

Notes:

Accident failure events are energy release events with the potential to 1) release contamination within th environment, 2) damage the equipment and facility, and 3) physically injure workers. These events coul fire, pressure release, etc.

Nonroutine maintenance failure events are low energy events with limited potential for releasing contami These events will lead to increased worker exposures resulting from nonroutine corrective maintenance.

Module Name: M.12, Chemical Make-up Unit

FAILURE RISK PARAMETERS	M.12.A, Dry Storage	M.12.B, Bulk Liquid Storage	M.12.C, Bulk H2O Storage	M.12.D, Bulk Combustible Liquid Storage	M.12.E, Glass Melter Batch Mixers	Module Number
Designation:	Cold	Cold	Cold	Cold	Cold	12
MAXIMUM ACCIDENT FAILURE EVENT						LIMITING EVENT
Consequence:	1	1	1	1	1	
Frequency:	0.0001	0.01	0.0001	0.1	0.0001	
Relative Risk:	0.0001	0.01	0.0001	0.1	0.0001	0.1
NONROUTINE MAINTENANCE FAILURE EVENTS						SUM OF EVENTS
Electrical Instrumentation						
Consequence:	1	1	1	1	1	
Frequency:	0.0001	0.01	0.0001	0.0001	0 01	
Relative Risk:	0.0001	0 01	0 0001	0.0001	0 01	0.0203
Mechanized Equipment						
Consequence:	1	1	1	1	1	
Frequency:	0 0001	0.01	0.0001	0.0001	0.01	
Relative Risk:	0.0001	0.01	0.0001	0.0001	0.01	0.0203
Pluggage/Caking						
Consequence:	1	1	1	1	1	
Frequency:	0.0001	0.0001	0.0001	0.0001	1	
Relative Risk:	0.0001	0.0001	0.0001	0.0001	1	1.0004
Corrosion						
Consequence:	1	1	1	1	1	
Frequency:	0.0001	0.1	0.0001	0.0001	0.01	
Relative Risk:	0.0001	0.1	0.0001	0.0001	0.01	0.1103
Physical Operation						
Consequence:	1	1	1	1	1	
Frequency:	0 01	0.0001	0.0001	0.0001	0 0001	
Relative Risk:	0.01	0.0001	0.0001	0.0001	0 0001	0 0104
TOTAL NONROUTINE MAINTENANCE RISK						
Relative Risk:	0.0104	0 1202	0.0005	0.0005	1 0301	1.1617

Notes:

Accident failure events are energy release events with the potential to 1) release contamination within the facility and into the environment, 2) damage the equipment and facility, and 3) physically injure workers. These events could include explosion, fire, pressure release, etc.

Nonroutine maintenance failure events are low energy events with limited potential for releasing contaminants from process systems These events will lead to increased worker exposures resulting from nonroutine corrective maintenance.

Module Name: M.13, Air/Vapor Filtration System

FAILURE RISK PARAMETERS	M.13.A, CVOG/VOG System	M.13.B, VOG/CVOG/PVOG Air Supply System	M.13.C, Process Stack Filter System	M.13.D, BVOG System	M.13.E, BVOG Air Supply System	M.13.F, Storage Stack Filter System	M.13.G, Oxygen Supply System	Module Number
Designation:	LL	Cold	LL	HL	Cold	LL	Cold	13
MAXIMUM ACCIDENT FAILURE EVENT								LIMITING EVENT
Consequence:	5	1	5	5	1	5	1	
Frequency:	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.01	
Relative Risk:	0.0005	0.0001	0.0005	0.0005	0.0001	0.0005	0.01	0.01
NONROUTINE MAINTENANCE FAILURE EVENTS								SUM OF EVENTS
Electrical Instrumentation								
Consequence:	5	1	5	5	1	5	1	
Frequency:	0 01	0.01	0.01	0.01	0.01	0.01	0.01	
Relative Risk:	0.05	0.01	0.05	0.05	0.01	0.05	0.01	0.23
Mechanized Equipment								
Consequence:	5	1	5	5	1	5	1	
Frequency:	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
Relative Risk:	0.05	0.01	0.05	0.05	0.01	0.05	0.01	0.23
Pluggage/Caking								
Consequence:	5	1	5	5	1	5	1	
Frequency:	0.0001	0.0001	0.01	0.0001	0.0001	0.01	0.0001	
Relative Risk:	0.0005	0.0001	0.05	0.0005	0.0001	0.05	0.0001	0.1013
Corrosion								
Consequence:	5	1	5	5	1	5	1	
Frequency:	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	
Relative Risk:	0.0005	0 0001	0.0005	0.0005	0.0001	0.0005	0.0001	0.0023
Physical Operation								
Consequence:	5	1	5	5	1	5	1	
Frequency:	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	
Relative Risk:	0.0005	0.0001	0.0005	0.0005	0.0001	0.0005	0.0001	0.0023
TOTAL NONROUTINE MAINTENANCE RISK								
Relative Risk:	0.1015	0.0203	0.151	0.1015	0.0203	0.151	0.0203	0 5659

Notes:

Accident failure events are energy release events with the potential to 1) release contamination within the facility and into the environment, 2) damage the equipment and facility, and 3) physically injure workers. These events could include explosion, fire, pressure release, etc.

Nonroutine maintenance failure events are low energy events with limited potential for releasing contaminants from process systems. These events will lead to increased worker exposures resulting from nonroutine corrective maintenance.

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APPENDIX M

MODULE COST SUMMARY

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Module Name: Test Case 1 M.1, SST Waste Retrieval

COST FACTORS	COST
Capital Cost	$3,402,000,000
Labor Cost	$483,300,000
Utilities	$390,000
CENTRC & GPP	$386,700,000
Chemical Cost	$0
R & D	$186,000,000
Disposal	$0
Decontamination & Decommissioning	$255,100,000
TOTAL	**$4,713,490,000**

Module Name: Base Case M.1, SST Waste Retrieval

COST FACTORS	COST
Capital Cost	$814,000,000
Labor Cost	$242,930,000
Utilities	$390,000
CENTRC & GPP	$130,100,000
Chemical Cost	$0
R & D	$20,000,000
Disposal	$0
Decontamination & Decommissioning	$244,200,000
TOTAL	**$1,451,620,000**

Module Name: Test Case 2 M.1, SST Waste Retrieval

COST FACTORS	COST
Capital Cost	$2,334,000,000
Labor Cost	$663,200,000
Utilities	$390,000
CENTRC & GPP	$373,000,000
Chemical Cost	$0
R & D	$236,000,000
Disposal	$0
Decontamination & Decommissioning	$351,900,000
TOTAL	**$3,958,490,000**

Module Name: M.2, DST Waste Retrieval

COST FACTORS	COST
Capital Cost	$298,100,000
Labor Cost	$25,250,000
Utilities	$100,000
CENTRC & GPP	$30,790,000
Chemical Cost	$0
R & D	$20,000,000
Disposal	$0
Decontamination & Decommissioning	$129,530,000
TOTAL	**$503,770,000**

Module Name: M.3, DST Sludge Wash

COST FACTORS	COST
Capital Cost	$110,000,000
Labor Cost	$79,780,000
Utilities	$80,000
CENTRC & GPP	$17,580,000
Chemical Cost	$46,680,000
R & D	$5,000,000
Disposal	$0
Decontamination & Decommissioning	$93,820,000
TOTAL	**$352,940,000**

Module Name: M.4, Cesium Ion Exchange

COST FACTORS	COST
Capital Cost	$405,900,000
Labor Cost	$72,890,000
Utilities	$80,000
CENTRC & GPP	$20,390,000
Chemical Cost	$28,240,000
R & D	$10,000,000
Disposal	$0
Decontamination & Decommissioning	$67,740,000
TOTAL	**$605,240,000**

Module Name: M.5, LLW Glass in Sulfur

COST FACTORS	COST
Capital Cost	$1,105,500,000
Labor Cost	$70,090,000
Utilities	$160,000
CENTRC & GPP	$20,390,000
Chemical Cost	$263,710,000
R & D	$100,000,000
Disposal	$0
Decontamination & Decommissioning	$67,740,000
TOTAL	**$1,627,590,000**

Module Name: M.6, LLW Glass in Sulfur Vaults

COST FACTORS	COST
Capital Cost	$5,450,000
Labor Cost	$64,450,000
Utilities	$80,000
CENTRC & GPP	$4,060,000
Chemical Cost	$55,700,000
R & D	$10,000,000
Disposal	$364,320,000
Decontamination & Decommissioning	$33,870,000
TOTAL	**$537,930,000**

Module Name: M.7, HLW Glass Cullet Feed Lag Storage

COST FACTORS	COST
Capital Cost	$44,000,000
Labor Cost	$53,910,000
Utilities	$80,000
CENTRC & GPP	$6,090,000
Chemical Cost	$0
R & D	$2,000,000
Disposal	$0
Decontamination & Decommissioning	$13,200,000
TOTAL	**$119,280,000**

Module Name: M.8, HLW Glass Cullet

COST FACTORS	COST
Capital Cost	$3,316,500,000
Labor Cost	$53,910,000
Utilities	$80,000
CENTRC & GPP	$51,020,000
Chemical Cost	$9,040,000
R & D	$100,000,000
Disposal	$0
Decontamination & Decommissioning	$203,230,000
TOTAL	**$3,733,780,000**

Module Name: M.9, HLW Glass Cullet Cask Storage Pad

COST FACTORS	COST
Capital Cost	$16,340,000
Labor Cost	$71,490,000
Utilities	$80,000
CENTRC & GPP	$4,060,000
Chemical Cost	$0
R & D	$10,000,000
Disposal	$3,179,980,000
Decontamination & Decommissioning	$33,870,000
TOTAL	**$3,315,820,000**

Module Name: M.10, Cullet Rework and Melter Off-Gas Processing

COST FACTORS	COST
Capital Cost	$385,000,000
Labor Cost	$56,720,000
Utilities	$3,910,000
CENTRC & GPP	$61,180,000
Chemical Cost	$4,520,000
R & D	$30,000,000
Disposal	$0
Decontamination & Decommissioning	$169,360,000
TOTAL	**$710,690,000**

Module Name: M.11, Liquid Effluent Treatment Facility

COST FACTORS	COST
Capital Cost	$5,500,000
Labor Cost	$59,530,000
Utilities	$80,000
CENTRC & GPP	$6,090,000
Chemical Cost	$0
R & D	$2,000,000
Disposal	$0
Decontamination & Decommissioning	$33,870,000
TOTAL	**$107,070,000**

Module Name: M.12, Chemical Make-up Unit

COST FACTORS	COST
Capital Cost	$6,110,000
Labor Cost	$64,450,000
Utilities	$80,000
CENTRC & GPP	$10,160,000
Chemical Cost	$0
R & D	$0
Disposal	$0
Decontamination & Decommissioning	$13,550,000
TOTAL	**$94,350,000**

Module Name: M.13, Air/Vapor Filtration System

COST FACTORS	COST
Capital Cost	$139,700,000
Labor Cost	$53,910,000
Utilities	$230,000
CENTRC & GPP	$20,390,000
Chemical Cost	$2,570,000
R & D	$0
Disposal	$0
Decontamination & Decommissioning	$54,200,000
TOTAL	**$271,000,000**

APPENDIX N

SYSTEM RISK ANALYSIS MODEL SOFTWARE PRINTOUT

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Metric Conversion Chart

The following chart is provided to the reader as a tool to aid in converting to metric units.

Into Metric Units

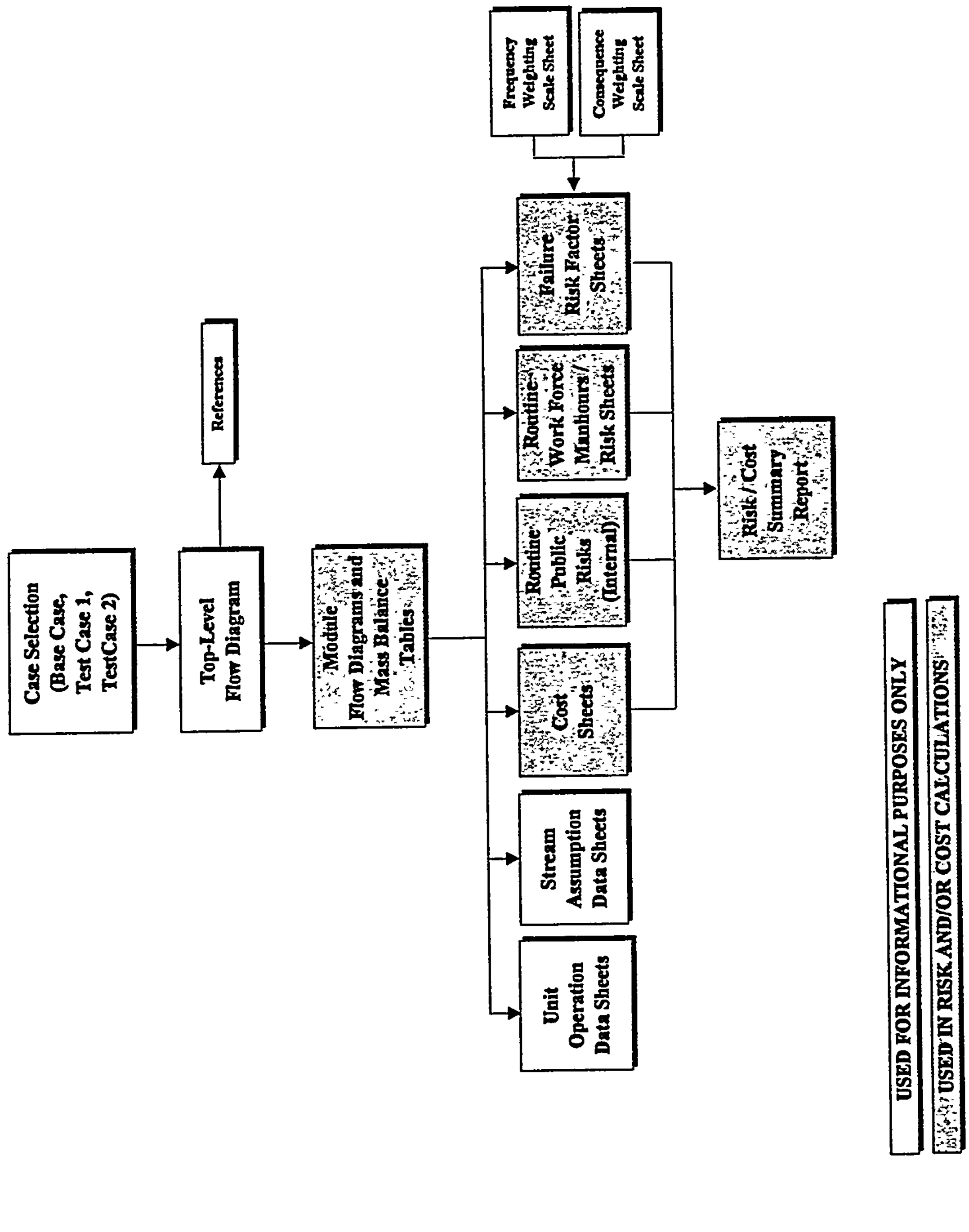
If You Know	Multiply By	To Get
Length		
inches	25.4	millimeters
inches	2.54	centimeters
feet	0.305	meters
yards	0.914	meters
miles	1.609	kilometers
Area		
sq. inches	6.452	sq. centimeters
sq. feet	0.093	sq. meters
sq. yards	0.0836	sq. meters
sq. miles	2.6	sq. kilometers
acres	0.405	hectares
Mass (weight)		
ounces	28.35	grams
pounds	0.454	kilograms
short ton	0.907	metric ton
Volume		
teaspoons	5	milliliters
tablespoons	15	milliliters
fluid ounces	30	milliliters
cups	0.24	liters
pints	0.47	liters
quarts	0.95	liters
gallons	3.8	liters
cubic feet	0.028	cubic meters
cubic yards	0.765	cubic meters
Temperature		
Fahrenheit	subtract 32, then multiply by 5/9	Celsius
Pressure		
inches of H_2O	0.00246	atmospheres
inches of Hg	0.03332	atmospheres

Out of Metric Units

If You Know	Multiply	To Get
Length		
millimeters	0.039	inches
centimeters	0.394	inches
meters	3.281	feet
meters	1.094	yards
kilometers	0.621	miles
Area		
sq. centimeters	0.155	sq. inches
sq. meters	10.76	sq. feet
sq. meters	1.196	sq. yards
sq. kilometers	0.4	sq. miles
hectares	2.47	acres
Mass (weight)		
grams	0.035	ounces
kilograms	2.205	pounds
metric ton	1.102	short ton
Volume		
milliliters	0.033	fluid ounces
liters	2.1	pints
liters	1.057	quarts
liters	0.264	gallons
cubic meters	35.315	cubic feet
cubic meters	1.308	cubic yards
Temperature		
Celsius	multiply by 9/5, then add 32	Fahrenheit
Pressure		
atmospheres	406.5	inches of H_2O
atmospheres	30.005	inches of Hg

Model Flow Chart

Model Software Flow Chart



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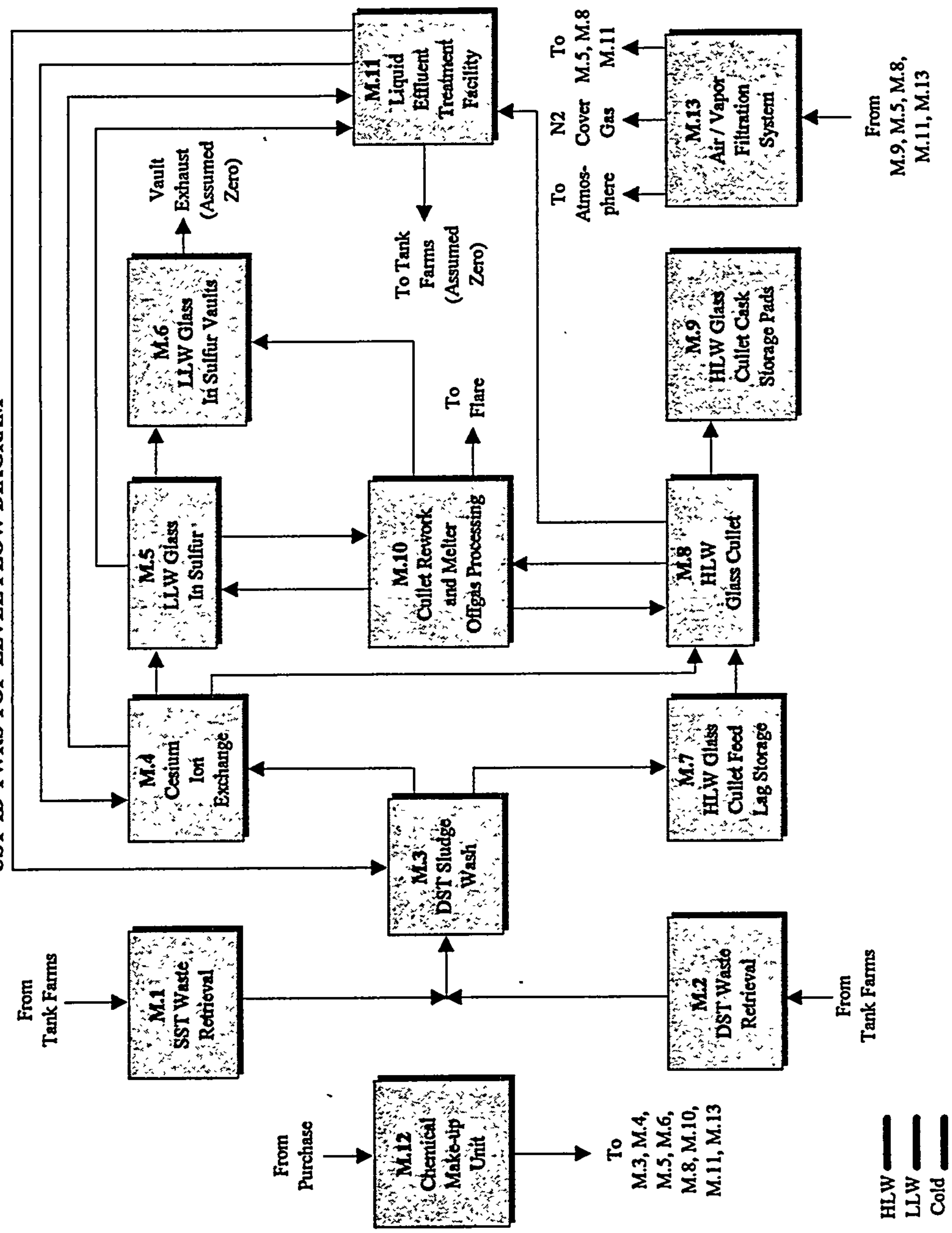
Top Level Flow Diagram

UST-ID TWRS TOP-LEVEL FLOW DIAGRAM



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Module Diagrams and Mass Balance Tables

The module diagrams and mass balance tables are found in Appendix B.

Unit Operation Description Sheets

The unit operation description sheets are found in Appendix D.

Stream Assumptions

Assumptions for Base Case, Module 1, SST Waste Retrieval

Radiation Level

Streams have been designated as high activity, low activity, or non-radioactive, based on the radionuclide concentration. Streams with 0.13 Ci/kg or greater have been designated as high activity waste and streams with less than 0.13 Ci/kg have been designated as low activity waste. Chemical additions to the process are designated as non-radioactive.

Stream 1.2:

This stream is defined as the total single shell Tank (SST) waste inventory. This stream is equivalent to the total chemical inventory shown in Table 4-2 of Boomer 1993, and the total radionuclide inventory shown in Table 4-5 of Boomer 1993.

Stream 1.1:

This stream represents the amount of pure water needed to dissolve the SST salt cake to an approximate concentration of 5M $NaNO_3$ and to create a 10% solids slurry from the SST sludge.

Stream 1.3:

This Stream represents the retrieved SST waste. This stream is equal to the initial inventory (Stream 1.2) plus the sluicing water (Stream 1.1) minus the amount waste lost through the system (Stream 1.8, 1.7, 1.9, 1.4, and 1.5).

Stream 1.8:

This stream is equal to 1% of Stream 1.2 (Boomer 1993). It represents the residual waste that is distributed over the internal tank surfaces as well as on the resident in-tank hardware.

Stream 1.6:

This stream represents past leakage to the soil. It is assumed to be equal to 1% of Stream 1.2. To maintain the mass balance, this stream is identified as an input and output from the module.

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Stream 1.7:

This stream represents leakage to the soil that occurs during sluicing. Assume 66 tanks will leak once sluicing activities begin (Lowe 1993). Analyses have shown that leakage of up to 140 m3 (40,000 gallons) per tank may occur during sluicing operations (Lowe 1993). therefore a total of 2,640,000 gallons of liquid waste is estimated to have been released to the ground. Stream 1.7 is obtained by assuming that the new leakage induced by sluicing is equal to 3.52 (2,640,000 divided by 750,000 gallons) times the total past leakage (Stream 1.6).

Stream 1.9:

This stream represents contaminated SST waste transfer piping, ancillary equipment and associated soils from newly completed SST waste retrieval operations. Boomer 1993 assumes that total contamination from RCRA past practice units (PPU) represents 0.1% of Stream 1.2. Assume that newly created leakage waste is the same, therefore Stream 1.9 is 0.1% of Stream 1.2.

Streams 1.4 and 1.5:

Previous studies have indicated that the release of off-gasses is very small during sluicing operations. Off-gas generation is insignificant, because continuous ventilation through a HEPA filter has been provided. Therefore, zero release is assumed However, due to the presence of trace amounts of radionuclides, these streams are designated as low activity.

Assumptions for Test Case 1, Module 1, SST Waste Retrieval

Radiation Level

Streams have been designated as high activity, low activity, or non-radioactive, based on the radionuclide concentration. Streams with 0.13 Ci/kg or greater have been designated as high activity waste and streams with less than 0.13 Ci/kg have been designated as low activity waste. Chemical additions to the process are designated as non-radioactive.

Stream 1.2:

This stream is defined as the total single shell Tank (SST) waste inventory. This stream is equivalent to the total chemical inventory shown in Table 4-2 of Boomer 1993, and the total radionuclide inventory shown in Table 4-5 of Boomer 1993.

Stream 1.1:

This stream represents the amount of pure water needed to dissolve the SST salt cake to an approximate concentration of 5M $NaNO_3$ and to create a 10% solids slurry from the SST sludge.

Stream 1.3:

This Stream represents the retrieved SST waste. This stream is equal to the initial inventory (Stream 1.2) plus the sluicing water (Stream 1.1) minus the amount waste lost through the system (Stream 1.8, 1.7, 1.9, 1.4,and 1.5).

Stream 1.8:

This stream is equal to 1% of Stream 1.2 (Boomer 1993). It represents the residual waste that is distributed over the internal tank surfaces as well as on the resident in-tank hardware.

Stream 1.6:

This stream represents past leakage to the soil. It is assumed to be equal to 1% of Stream 1.2. To maintain the mass balance, this stream is identified as an input and output from the module.

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Stream 1.7:

This stream represents leakage to the soil that occurs during sluicing. It is assumed that the close-coupled barrier reduces this leakage by 99.9% relative to the base case.

Stream 1.9:

This stream represents contaminated SST waste transfer piping, ancillary equipment and associated soils from newly completed SST waste retrieval operations. Boomer 1993 assumes that total contamination from RCRA past practice units (PPU) represents 0.1% of Stream 1.2. Assume that newly created leakage waste is the same, therefore Stream 1.9 is 0.1% of Stream 1.2.

Streams 1.4 and 1.5:

Previous studies have indicated that the release of off-gasses is very small during sluicing operations. Off-gas generation is insignificant, because continuous ventilation through a HEPA filter has been provided. Therefore, zero release is assumed. However, due to the presence of trace amounts of radionuclides, these streams are designated as low activity.

Assumptions for Module 1, SST Waste Retrieval

Radiation Level

Streams have been designated as high activity, low activity, or non-radioactive, based on the radionuclide concentration. Streams with 0.13 Ci/kg or greater have been designated as high activity waste and streams with less than 0.13 Ci/kg have been designated as low activity waste. Chemical additions to the process are designated as non-radioactive.

Stream 1.2:

This stream is defined as the total single shell Tank (SST) waste inventory. This stream is equivalent to the total chemical inventory shown in Table 4-2 of Boomer et al.(1993), and the total radionuclide inventory shown in Table 4-5 of Boomer et al.(1993).

Stream 1.1:

This stream represents the amount of pure water needed to dissolve the SST salt cake to an approximate concentration of 5M $NaNO_3$ and to create a 10% solids slurry from the SST sludge.

Stream 1.3:

This stream represents the retrieved SST waste. This stream is equal to the initial inventory (Stream 1.2) minus the amount waste lost through the system (Stream 1.8, 1.7, 1.9, 1.4,and 1.5).

Stream 1.8:

This stream is equal to 1% of Stream 1.2 (Boomer et al.1993). It represents the residual waste that is distributed over the internal tank surfaces as well as on the resident in-tank hardware.

Stream 1.6:

This stream represents past leakage to the soil. It also includes 1% of other soluble species in the salt cake and interstitial liquid (Boomer et al.1993).

Stream 1.7:

This stream represents leakage to the soil that occurs during sluicing. Assume 66 tanks will leak once sluicing activities begin (Lowe 1993). Analyses have shown that leakage of up to 140 m^3 (40,000 gallons) sluicing activities begin (Lowe 1993). Analyses have shown that leakage of up to 140 m3 (40,000 gallons) per tank may occur during sluicing operations (Lowe 1993). therefore a total of 2,640,000 gallons of liquid waste is estimated to be released to the ground. Hanlon 1993 indicates that an average of 750,000 gallons may have leaked during past sluicing operations. Stream 1.7 is obtained by assuming that the new leakage induced by sluicing is equal to 3.52 (2,640,000 divided by 750,000 gallons) times the total past leakage (Stream 1.6).

Stream 1.9:

This stream represents contaminated SST waste transfer piping, ancillary equipment and associated soils from newly completed SST waste retrieval operations. Boomer 1993 assumes that total contamination from RCRA past practice units (PPU) represents 0.1% of Stream 1.2. Assume that newly created leakage waste is the same, therefore Stream 1.9 is 0.1% of Stream 1.2.

Streams 1.4 and 1.5:

Previous studies have indicated that the release of off-gasses is very small during sluicing operations. Off-gas generation is insignificant, because continuous ventilation through a HEPA filter has been provided. Therefore, zero release is assumed. However, due to the presence of trace amounts of radionuclides, these streams are designated as low activity.

Assumptions for Module 2, DST Waste Retrieval

Radiation Level

Streams have been designated as high activity, low activity, or non-radioactive, based on the radionuclide concentration. Streams with 0.13 Ci/kg or greater have been designated as high activity waste and streams with less than 0.13 Ci/kg have been designated as low activity waste. Chemical additions to the process are designated as non-radioactive.

Stream 2.1:

This stream consists of miscellaneous waste from 12 DSTs. This waste is composed of NCRW (Neutralized cladding Removal Waste), CP (Concentrated Phosphate), NCAW (Neutralized Current Acid Waste), DSS/DSSF (Double Shell Slurry / Double Shell Slurry Feed) (Halon 1994).

Stream 2.2:

This stream represents the CC (Complexed Concentrate) waste from 5 DSTs.

Stream 2.3:

This stream represents the DN (Dilute non-complexed) waste from 11 DSTs.

Stream 2.8:

This stream represents the residual waste after retrieval that is distributed over the internal tank surfaces as well as on the resident in-tank hardware.

Stream 2.9:

This stream represents leakage from contaminated DST waste transfer piping, ancillary equipment, and associated soils from newly completed DST waste retrieval operations.

Stream 2.5:

This stream represents process condensate from the DN Waste Evaporator. This stream flows out of the system to the Liquid Effluent Processing for Recycle or Discharge (LEPARD).

Stream 2.4:

This stream is equal to the summation of Streams 2.A, 2.B, and 2.C. It represents the DST waste that goes to the sludge washing process.

Streams 2.6 and 2.7:

Previous studies have indicated that the release of emissions is very small during sluicing operations and backfill activities due to continuous ventilation through a HEPA filter. Therefore, zero release is assumed.

backfill activities due to continuous ventilation through a HEPA filter. Therefore, zero release is assumed. However, because of the presence of trace amounts of radionuclides, these streams are designated as low activity.

Assumptions for Module 3, In-Tank Sludge Washing

Mass Flow Values

Mass flows for modules 3 through 13 were obtained from a WHC ASPEN run dated January 21, 1994 (Combined Separations, Parallel HLW & LLW Vitrification, 50-20% Solids, 45% HLW WO Loading).

Fugitive Emissions

The processes and facilities are designed to run at a slightly negative pressure (Gail Allen, WHC), and there are extensive vapor recovery systems designed for the processes. It has therefore been assumed that there will be no fugitive emissions from the processes or the facilities.

Decontamination and Decommissioning (D&D) Waste

It has been assumed that the average size of a piece of equipment within any process is 1,000 gallons and that 0.1% of the inventory within each piece of equipment will be leaked during D&D (BEJ). The estimated mass of D&D waste has been calculated as 0.1% of the mass of each stream multiplied by the number of pieces of equipment within the module and the assumed 1000 gallon volume of each piece of equipment, and multiplying the total by the density of the stream.

Radiation Level

Streams have been designated as high activity, low activity, or non-radioactive, based on the radionuclide concentration. Streams with 0.13 Ci/kg or greater have been designated as high activity waste and streams with less than 0.13 Ci/kg have been designated as low activity waste. Chemical additions to the process are designated as non-radioactive.

Stream 12.6:

This non-radioactive stream flows from the Chemical Make-up Unit Dry Storage into the DST Sludge Wash Feed.

Stream 12.9:

This non-radioactive stream flows from the Chemical Make-up Unit Bulk Liquid Storage into the DST Sludge Wash Feed.

Stream 12.17:

This non-radioactive stream flows from the Chemical Make-up Unit Bulk H2O Storage into the DST Sludge Wash Feed.

Stream 1.6, 2.4:

This high activity stream flows from the SST and DST waste retrieval systems into the DST Sludge Wash Settling Tanks.

Stream 11.3:

This low activity stream flows from the Liquid Effluent Treatment Facility Retention Basin into the DST Sludge Wash Settle Tanks. Since this stream contains only trace amounts of radionuclides, all values are assumed to be zero.

Stream 11.4:

This low activity stream flows from the Liquid Effluent Treatment Facility Retention Basin into the DST Sludge Wash. Since this stream contains only trace amounts of radionuclides, all values are assumed to be zero.

Stream 3.1:

This high activity stream flows from the DST Sludge Wash Settling Tanks to the Cesium Ion Exchange Accumulation System.

Stream 3.2:

This high activity stream flows from the DST Sludge Wash System into the HLW Feed Lag Storage Feed Accumulation Tanks.

Stream 3.3:

This high activity stream flows from the DST Sludge Wash Transfer Tanks into the Cesium Ion Exchange Accumulation System.

Stream 3.4:

This stream represents fugitive emissions from the Sludge Wash Process. It is assumed to be zero. However, due to the presence of trace amounts of radionuclides, it is designated as low activity.

Stream 3.5:

This high activity stream represents D&D waste from the Sludge Wash Process. The Sludge Wash process contains 37 pieces of equipment.

Assumptions for Module 4, Cesium Ion Exchange

Mass Flow Values

Mass flows for modules 3 through 13 were obtained from a WHC ASPEN run dated January 21, 1994 (Combined Separations, Parallel HLW & LLW Vitrification, 50-20% Solids, 45% HLW WO Loading).

Fugitive Emissions

The processes and facilities are designed to run at a slightly negative pressure (Gail Allen, WHC), and there are extensive vapor recovery systems designed for the processes. It has therefore been assumed that there will be no fugitive emissions from the processes or the facilities.

Decontamination and Decommissioning (D&D) Waste

It has been assumed that the average size of a piece of equipment within any process is 1,000 gallons and that 0.1% of the inventory within each piece of equipment will be leaked during D&D (BEJ). The estimated mass of D&D waste has been calculated as 0.1% of the mass of each stream multiplied by the number of pieces of equipment within the module and the assumed 1,000 gallon volume of each piece of equipment, and multiplying the total by the density of the stream.

Radiation Level

Streams have been designated as high activity, low activity, or non-radioactive, based on the radionuclide concentration. Streams with 0.13 Ci/kg or greater have been designated as high activity waste and streams with less than 0.13 Ci/kg have been designated as low activity waste. Chemical additions to the process are designated as non-radioactive.

Stream 3.1:

This high activity stream flows from the DST Sludge Wash Settling Tanks to the Cesium Ion Exchange Accumulation System.

Stream 3.3:

This high activity stream flows from the DST Sludge Wash Transfer Tanks into the Cesium Ion Exchange Accumulation System.

Stream 12.7:

This non-radioactive stream flows from the Chemical Make-up Unit Dry Storage into the Cesium Ion Exchange Supernatant Evaporation System.

Stream 12.10:

This non-radioactive stream flows from the Chemical Make-up Unit Bulk Liquid Storage into the Cesium Ion Exchange Supernatant Evaporation System.

Stream 12.18:

This non-radioactive stream flows from the Chemical Make-up Unit Bulk H2O Storage into the Cesium Ion Exchange Supernatant Evaporation System.

Stream 12.8:

This non-radioactive stream flows from the Chemical Make-up Unit Dry Storage into the Cesium Ion Exchange Feed.

Stream 12.11:

This non-radioactive stream flows from the Chemical Make-up Unit Bulk Liquid Storage into the Cesium Ion Exchange Feed.

Stream 11.1:

This low activity stream flows from the Liquid Effluent Treatment Facility Process Condensate Recycle System into the Cesium Ion Exchange Feed. Since this stream contains only trace amounts of radionuclides, all values are assumed to be zero.

Stream 12.12:

This non-radioactive stream flows from the Chemical Make-up Unit Bulk Liquid Storage into the Cesium Ion Exchange Eluent/Regeneration System.

Stream 12.19:

This non-radioactive stream flows from the Chemical Make-up Unit Bulk H2O Storage into the Cesium Ion Exchange Eluent/Regeneration System.

Stream 4.1:

This low activity stream flows from the Cesium Ion Exchange Supernatant Evaporation System into the Liquid Effluent Treatment Facility Process Condensate Recycle System. Since this stream contains only trace amounts of radionuclides, all values are assumed to be zero.

Stream 4.2:

Stream 4.2:

This low activity stream flows from the Cesium Ion Exchange Supernatant Evaporation System into the Air/Vapor Filtration CVOG/VOG System. Since this stream contains only trace amounts of radionuclides, all values are assumed to be zero.

Stream 4.3:

This high activity stream flows from the Cesium Ion Exchange Feed System into the HLW Glass Cullet Melter System.

Stream 4.4:

This low activity stream flows from the Cesium Ion Exchange System into the LLW Glass in Sulfur Evaporator System.

Stream 4.5:

This high activity stream flows from the Cesium Ion Exchange Concentrator System into the HLW Glass Cullet Melter System.

Stream 4.6:

This low activity stream flows from the Cesium Ion Exchange Concentrator System into the Air/Vapor Filtration CVOG/VOG System. Since this stream contains only trace amounts of radionuclides, all values are assumed to be zero.

Stream 4.7:

This stream represents fugitive emissions from the Cesium Ion Exchange Process. It is assumed to be zero.

Stream 4.8:

This high activity stream represents D&D waste from the Cesium Ion Exchange Process. The Cesium Ion Exchange process contains 67 pieces of equipment.

Assumptions for Module 5, LLW Glass In Sulfur

Mass Flow Values

Mass flows for modules 3 through 13 were obtained from a WHC ASPEN run dated January 21, 1994 (Combined Separations, Parallel HLW & LLW Vitrification, 50-20% Solids, 45% HLW WO Loading).

Fugitive Emissions

The processes and facilities are designed to run at a slightly negative pressure (Gail Allen, WHC), and there are extensive vapor recovery systems designed for the processes. It has therefore been assumed that there will be no fugitive emissions from the processes or the facilities.

Decontamination and Decommissioning (D&D) Waste

It has been assumed that the average size of a piece of equipment within any process is 1,000 gallons and that 0.1% of the inventory within each piece of equipment will be leaked during D&D (BEJ). The estimated mass of D&D waste has been calculated as 0.1% of the mass of each stream multiplied by the number of pieces of equipment within the module and the assumed 1,000 gallon volume of each piece of equipment, and multiplying the total by the density of the stream.

Radiation Level

Streams have been designated as high activity, low activity, or non-radioactive, based on the radionuclide concentration. Streams with 0.13 Ci/kg or greater have been designated as high activity waste and streams with less than 0.13 Ci/kg have been designated as low activity waste. Chemical additions to the process are designated as non-radioactive.

Stream 4.4:

This low activity stream flows from the Cesium Ion Exchange System into the LLW Glass in Sulfur Evaporator System.

Stream 5.1:

This low activity stream flows from the LLW Glass in Sulfur Evaporator System into the Liquid Effluent Treatment Facility Process Condensate Recycle System. Since this stream contains only trace amounts of radionuclides, all values are assumed to be zero.

Stream 5.2:

This low activity stream flows from the LLW Glass in Sulfur Evaporator System into the Air/Vapor Filtration CVOG/VOG System. Since this stream contains only trace amounts of radionuclides, all values are assumed to be zero.

Stream 5.3:

This low activity stream flows from the LLW Glass in Sulfur Melter System into the Cullet Rework and Melter Off-gas Processing LLW Separator System.

Stream 5.4:

This low activity stream flows from the LLW Glass in Sulfur Cullet Drying System into the Liquid Effluent Treatment Facility Process Condensate Recycle System. Since this stream contains only trace amounts of radionuclides, all values are assumed to be zero.

Stream 5.5:

This low activity stream flows from the LLW Glass in Sulfur Cullet Drying System into the Cullet Rework and Melter Off-gas Processing Cyclone System.

Stream 5.6:

This low activity stream flows from the LLW Glass in Sulfur Cullet Drying System into the Air/Vapor Filtration BVOG System.

Stream 5.7:

This low activity stream flows from the LLW Glass in Sulfur Cyclone System into the LLW Glass in Sulfur Vault Sulfur Cement Mixing.

Stream 5.8:

This low activity stream flows from the LLW Glass in Sulfur Cyclone System into the Air/Vapor Filtration Process Stack Filter System.

Stream 5.9:

This stream represents fugitive emissions from the LLW Glass in Sulfur Process. It is assumed to be zero. However, due to the presence of trace amounts of radionuclides, it is designated as low activity.

Stream 5.10:

This low activity stream represents D&D waste from the LLW Glass in Sulfur Process. The LLW Glass in Sulfur process contains 57 pieces of equipment.

Stream 5.11:

This stream represents Drying and Transport Air flowing into the LLW Glass in Sulfur Glass Cullet Drying System. The ASPEN run used as the basis for this model showed this stream as zero.

Stream 10.4:

Stream 10.4:

This low activity stream flows from the Cullet Rework and Melter Off-gas Processing Cyclone System into the LLW Glass in Sulfur Evaporator System.

Stream 10.5:

This low activity stream flows from the Cullet Rework and Melter Off-gas Processing Cyclone System into the LLW Glass in Sulfur Melter System.

Stream 10.9:

This low activity stream flows from the Cullet Rework and Melter Off-gas Processing LLW Separator System into the LLW Glass in Sulfur Evaporator System.

Stream 10.10:

This low activity stream flows from the Cullet Rework and Melter Off-gas Processing LLW Separator System into the LLW Glass in Sulfur Melter System.

Stream 12.20:

This non-radioactive stream flows from the Chemical Make-up Unit Bulk H2O Storage into the LLW Glass in Sulfur Quenching System.

Stream 12.21:

This non-radioactive stream flows from the Chemical Make-up Unit Bulk H2O Storage into the LLW Glass in Sulfur Cyclone System.

Stream 12.28:

This non-radioactive stream flows from the Chemical Make-up Unit Bulk Combustible Liquid Storage into the LLW Glass in Sulfur Melter System.

Stream 12.32:

This non-radioactive stream flows from the Chemical Make-up Unit Glass Melter Batch Mixers into the LLW Glass in Sulfur Melter System.

Stream 13.4:

This stream flows from the Air/Vapor Filtration CVOG/VOG System into the LLW Glass in Sulfur Evaporator System. The ASPEN run used as the basis for this model showed this stream as zero. However, due to the presence of trace amounts of radionuclides, it is designated as low activity.

Stream 13.5:

This low activity stream flows from the Air/Vapor Filtration Process Stack Filter System into the LLW

This low activity stream flows from the Air/Vapor Filtration Process Stack Filter System into the LLW Glass in Sulfur Evaporator System.

Stream 13.7:

This low activity stream flows from the Air/Vapor Filtration Storage Stack Filter System into the LLW Glass in Sulfur Evaporator System.

Stream 13.10:

This non-radioactive stream flows from the Air/Vapor Filtration Oxygen Supply System into the LLW Glass in Sulfur Melter System.

Assumptions for Module 6, LLW Glass in Sulfur Vaults

Mass Flow Values

Mass flows for modules 3 through 13 were obtained from a WHC ASPEN run dated January 21, 1994 (Combined Separations, Parallel HLW & LLW Vitrification, 50-20% Solids, 45% HLW WO Loading).

Fugitive Emissions

The processes and facilities are designed to run at a slightly negative pressure (Gail Allen, WHC), and there are extensive vapor recovery systems designed for the processes. It has therefore been assumed that there will be no fugitive emissions from the processes or the facilities.

Decontamination and Decommissioning (D&D) Waste

It has been assumed that the average size of a piece of equipment within any process is 1,000 gallons and that 0.1% of the inventory within each piece of equipment will be leaked during D&D (BEJ). The estimated mass of D&D waste has been calculated as 0.1% of the mass of each stream multiplied by the number of pieces of equipment within the module and the assumed 1,000 gallon volume of each piece of equipment, and multiplying the total by the density of the stream.

Radiation Level

Streams have been designated as high activity, low activity, or non-radioactive, based on the radionuclide concentration. Streams with 0.13 Ci/kg or greater have been designated as high activity waste and streams with less than 0.13 Ci/kg have been designated as low activity waste. Chemical additions to the process are designated as non-radioactive.

Stream 5.7:

This low activity stream flows from the LLW Glass in Sulfur Cyclone System into the LLW Glass in Sulfur Vault Sulfur Cement Mixing.

Stream 6.1:

This stream flows from the LLW Glass in Sulfur Disposal Vault and is discharged into the atmosphere. The ASPEN run used as the basis for this model showed this stream as zero. However, due to the presence

The ASPEN run used as the basis for this model showed this stream as zero. However, due to the presence of trace amounts of radionuclides, it is designated as low activity.

Stream 6.2:

This stream represents fugitive emissions from the LLW Glass in Sulfur Disposal Vault. It is assumed to be zero. However, due to the presence of trace amounts of radionuclides, it is designated as low activity.

Stream 6.3:

This low activity stream represents D&D waste from the LLW Glass in Sulfur Disposal Vault. The LLW Glass in Sulfur Disposal Vault contains 9 pieces of equipment.

Stream 10.11:

This low activity stream flows from the Cullet Rework and Melter Off-gas Processing Claus Reactor System into the LLW Glass in Sulfur Vault Sulfur Cement Mixing. Since it contains only trace amounts of radionuclides, it is assumed to be zero.

Stream 12.13:

This non-radioactive stream flows from the Chemical Make-up Unit Bulk Liquid Storage into the LLW Glass in Sulfur Vault Sulfur Cement Mixing.

Assumptions for Module 7, HLW Glass Cullet Feed Lag Storage

Mass Flow Values

Mass flows for modules 3 through 13 were obtained from a WHC ASPEN run dated January 21, 1994 (Combined Separations, Parallel HLW & LLW Vitrification, 50-20% Solids, 45% HLW WO Loading).

Fugitive Emissions

The processes and facilities are designed to run at a slightly negative pressure (Gail Allen, WHC), and there are extensive vapor recovery systems designed for the processes. It has therefore been assumed that there will be no fugitive emissions from the processes or the facilities.

Decontamination and Decommissioning (D&D) Waste

It has been assumed that the average size of a piece of equipment within any process is 1,000 gallons and that 0.1% of the inventory within each piece of equipment will be leaked during D&D (BEJ). The estimated mass of D&D waste has been calculated as 0.1% of the mass of each stream multiplied by the number of pieces of equipment within the module and the assumed 1,000 gallon volume of each piece of equipment, and multiplying the total by the density of the stream.

Radiation Level

Streams have been designated as high activity, low activity, or non-radioactive, based on the radionuclide concentration. Streams with 0.13 Ci/kg or greater have been designated as high activity waste and streams with less than 0.13 Ci/kg have been designated as low activity waste. Chemical additions to the process are designated as non-radioactive.

Stream 3.2:

This high activity stream flows from the DST Sludge Wash System into the HLW Feed Lag Storage Feed Accumulation Tanks.

Stream 7.1:

This high activity stream flows from the HLW Glass Cullet Feed Lag Storage Feed Transfer Tank into the HLW Glass Cullet Centrifuge System.

Stream 7.2:

This stream represents fugitive emissions from the HLW Glass Cullet Feed Lag Storage. It is assumed to be zero. However, due to the presence of trace amounts of radionuclides, it is designated as low activity.

Stream 7.3:

This high activity stream represents D&D waste from the HLW Glass Cullet Feed Lag Storage. The HLW Glass Cullet Feed Lag Storage contains 4 pieces of equipment.

Assumptions for Module 8, HLW Glass Cullet

Mass Flow Values

Mass flows for modules 3 through 13 were obtained from a WHC ASPEN run dated January 21, 1994 (Combined Separations, Parallel HLW & LLW Vitrification, 50-20% Solids, 45% HLW WO Loading).

Fugitive Emissions

The processes and facilities are designed to run at a slightly negative pressure (Gail Allen, WHC), and there are extensive vapor recovery systems designed for the processes. It has therefore been assumed that there will be no fugitive emissions from the processes or the facilities.

Decontamination and Decommissioning (D&D) Waste

It has been assumed that the average size of a piece of equipment within any process is 1,000 gallons and that 0.1% of the inventory within each piece of equipment will be leaked during D&D (BEJ). The estimated mass of D&D waste has been calculated as 0.1% of the mass of each stream multiplied by the number of pieces of equipment within the module and the assumed 1,000 gallon volume of each piece of equipment, and multiplying the total by the density of the stream.

Radiation Level

Streams have been designated as high activity, low activity, or non-radioactive, based on the radionuclide concentration. Streams with 0.13 Ci/kg or greater have been designated as high activity waste and streams with less than 0.13 Ci/kg have been designated as low activity waste. Chemical additions to the process are designated as non-radioactive.

Stream 4.3:

This high activity stream flows from the Cesium Ion Exchange Feed System into the HLW Glass Cullet Melter System.

Stream 4.5:

This high activity stream flows from the Cesium Ion Exchange Concentrator System into the HLW Glass Cullet Melter System.

Stream 7.1:

This high activity stream flows from the HLW Glass Cullet Feed Lag Storage Feed Transfer Tank into the

This high activity stream flows from the HLW Glass Cullet Feed Lag Storage Feed Transfer Tank into the HLW Glass Cullet Centrifuge System.

Stream 8.1:

This non-radioactive stream represents air flowing into the HLW Glass Cullet Drying System.

Stream 8.2:

This high activity stream flows from the HLW Glass Cullet Melter System into the Cullet Rework and Melter Off-gas Processing HLW Separator System.

Stream 8.3:

This low activity stream flows from the HLW Glass Cullet Evaporator System into the Liquid Effluent Treatment Facility Process Condensate Recycle System. Since this stream contains only trace amounts of radionuclides, it is assumed to be zero.

Stream 8.4:

This low activity stream flows from the HLW Glass Cullet Evaporator System into the Air/Vapor Filtration CVOG/VOG System. Since it contains only trace amounts of radionuclides, it is assumed to be zero.

Stream 8.5:

This low activity stream flows from the HLW Glass Cullet Drying System into the Liquid Effluent Treatment Facility Process Condensate Recycle System. Since it contains only trace amounts of radionuclides, it is assumed to be zero.

Stream 8.6:

This high activity stream flows from the HLW Glass Cullet Drying System into the Cullet Rework and Melter Off-gas Processing Cyclone System.

Stream 8.7:

This high activity stream flows from the HLW Glass Cullet Drying System into the Air/Vapor Filtration BVOG System.

Stream 8.8:

This high activity stream flows from the HLW Glass Cullet Cyclone System into the HLW Glass Cullet

This high activity stream flows from the HLW Glass Cullet Cyclone System into the HLW Glass Cullet Cask Storage Pad Air Pallets.

Stream 8.9:

This low activity stream flows from the HLW Glass Cullet Cyclone System into the Air/Vapor Filtration Process Stack Filter System.

Stream 8.10:

This stream represents fugitive emissions from the HLW Glass Cullet Process. It is assumed to be zero. However, due to the presence of trace amounts of radionuclides, it is designated as low activity.

Stream 8.11:

This high activity stream represents D&D waste from the HLW Glass Cullet Process. The HLW Glass Cullet Process contains 74 pieces of equipment.

Stream 10.6:

This high activity stream flows from the Cullet Rework and Melter Off-gas Processing Cyclone System into the HLW Glass Cullet Melter System.

Stream 10.7:

This high activity stream flows from the Cullet Rework and Melter Off-gas Processing HLW Separator System into the HLW Glass Cullet Evaporator System.

Stream 12.29:

This non-radioactive stream flows from the Chemical Make-up Unit Bulk Combustible Liquid Storage into the HLW Glass Cullet Melter System.

Stream 12.33:

This non-radioactive stream flows from the Chemical Make-up Unit Glass Melter Batch Mixers into the HLW Glass Cullet Melter System.

Stream 12.34:

This non-radioactive stream flows from the Chemical Make-up Unit Bulk H2O Storage into the HLW Glass Cullet Cyclone System.

Stream 13.11:

This non-radioactive stream flows from the Air/Vapor Filtration Oxygen Supply System into the HLW Glass Cullet Melter System.

Assumptions for Module 9, HLW Glass Cullet Cask Storage

Mass Flow Values

Mass flows for modules 3 through 13 were obtained from a WHC ASPEN run dated January 21, 1994 (Combined Separations, Parallel HLW & LLW Vitrification, 50-20% Solids, 45% HLW WO Loading).

Fugitive Emissions

The processes and facilities are designed to run at a slightly negative pressure, and there are extensive vapor recovery systems designed for the processes. It has therefore been assumed that there will be no fugitive emissions from the processes or the facilities.

Decontamination and Decommissioning (D&D) Waste

It has been assumed that the average size of a piece of equipment within any process is 1000 gallons and that 0.1% of the inventory within each piece of equipment will be leaked during D&D (BEJ). The estimated mass of D&D waste has been calculated as 0.1% of the mass of each stream multiplied by the number of pieces of equipment within the module and the assumed 1000 gallon volume of each piece of equipment, and multiplying the total by the density of the stream.

Radiation Level

Streams have been designated as high activity, low activity, or non-radioactive, based on the radionuclide concentration. Streams with 0.13 Ci/kg or greater have been designated as high activity waste and streams with less than 0.13 Ci/kg have been designated as low activity waste. Chemical additions to the process are designated as non-radioactive.

Stream 8.8:

This high activity stream flows from the HLW Glass Cullet Cyclone System into the HLW Glass Cullet Cask Storage Pad Air Pallets.

Stream 9.1:

This stream represents fugitive emissions from the HLW Glass Cullet Storage Pad. It is assumed to be zero. However, due to the presence of trace amounts of radionuclides, it is designated as low activity.

Stream 9.2

This high activity stream represents D&D waste from the HLW Glass Cullet Storage Pad. The HLW Glass Cullet Storage Pad contains 6 pieces of equipment.

Module: M.10, Cullet Rework and Melter Off-Gas Processing
Component / Unit Operation: M.10.E, Claus Reactor System

General Description: This system receives air, fuel, and a gas stream from the NOx/SO2 separator into a combustion chamber at various entry points. The resulting stream flows through a heat exchanger and splits into two streams. One flows through another air heat exchanger and joins a gas stream entering one of two Claus Reactors. The gas stream may flow out of the system. The other gas stream flows into the second Claus reactor The gas exiting each of the two reactors flow through air heat exchangers for cooling. The first reactor gas stream either flows back into the original heat exchanger for further processing or out of the system. The gas stream from the second reactor either flows out of the system or flows through a sulfur trap and to a tail gas incinerator. The stream from the sulfur trap flows out of the system. The tail gas incinerator also takes in air and fuel for incineration. The resulting gas stream is sent to flare.

Number of Units: 3 air heat exchangers, 2 Claus Reactors, 1 combustion chamber, 1 tail gas incinerator, 1 heat exchanger, 1 sulfur trap
Unit Size:
Unit Utilization (yrs): 13 (Boomer 1993)
Operating Efficiency: 60%
Radiation Level: Low (traces of nuclides exist)
Temp: 250 - 800 C
Pressure: 1 - 2 psig
pH/Acidity/Alkalinity: N/A
Energetic Reaction Potential: Low to Moderate
Process Stability:
% Solids in Waste: 0%
Waste Form: Gas
% Organics in Waste: 0%
Flammability: Low to Moderately Low

Mechanized Parts / Unit
High-level:
Low-level: 0
Cold: 0

Isolated Process Steps / Unit
High-level:
Low-level:
Cold:

Combined Installation Activities: piping

Combined Decontamination/ Decommissioning Disposal/Activities
Decontaminations:
Decommissioning & Disposal:

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Assumptions for Module 10, Cullet Rework and Melter Off-gas Processing

Mass Flow Values

Mass flows for modules 3 through 13 were obtained from a WHC ASPEN run dated January 21, 1994 (Combined Separations, Parallel HLW & LLW Vitrification, 50-20% Solids, 45% HLW WO Loading).

Fugitive Emissions

The processes and facilities are designed to run at a slightly negative pressure (Gail Allen, WHC), and there are extensive vapor recovery systems designed for the processes. It has therefore been assumed that there will be no fugitive emissions from the processes or the facilities.

Decontamination and Decommissioning (D&D) Waste

It has been assumed that the average size of a piece of equipment within any process is 1,000 gallons and that 0.1% of the inventory within each piece of equipment will be leaked during D&D (BEJ). The estimated mass of D&D waste has been calculated as 0.1% of the mass of each stream multiplied by the number of pieces of equipment within the module and the assumed 1,000 gallon volume of each piece of equipment, and multiplying the total by the density of the stream.

Radiation Level

Streams have been designated as high activity, low activity, or non-radioactive, based on the radionuclide concentration. Streams with 0.13 Ci/kg or greater have been designated as high activity waste and streams with less than 0.13 Ci/kg have been designated as low activity waste. Chemical additions to the process are designated as non-radioactive.

Stream 5.3:

This low activity stream flows from the LLW Glass in Sulfur Melter System into the Cullet Rework and Melter Off-gas Processing LLW Separator System.

Stream 5.5:

This low activity stream flows from the LLW Glass in Sulfur Cullet Drying System into the Cullet Rework and Melter Off-gas Processing Cyclone System.

Stream 8.2:

This high activity stream flows from the HLW Glass Cullet Melter System into the Cullet Rework and Melter Off-gas Processing HLW Separator System.

Stream 8.6:

This high activity stream flows from the HLW Glass Cullet Drying System into the Cullet Rework and Melter Off-gas Processing Cyclone System.

Stream 10.1:

This non-radioactive stream represents air flowing into the Cullet Rework and Melter Off-gas Processing NOx/SO2 Separator System.

Stream 10.2:

This non-radioactive stream represents air flowing into the Cullet Rework and Melter Off-gas Processing Claus Reactor System.

Stream 10.3:

This low activity stream flows from the Cullet Rework and Melter Off-gas Processing Cyclone System into the Air/Vapor Filtration Process Stack Filter System.

Stream 10.4:

This low activity stream flows from the Cullet Rework and Melter Off-gas Processing Cyclone System into the LLW Glass in Sulfur Evaporator System.

Stream 10.5:

This low activity stream flows from the Cullet Rework and Melter Off-gas Processing Cyclone System into the LLW Glass in Sulfur Melter System.

Stream 10.6:

This high activity stream flows from the Cullet Rework and Melter Off-gas Processing Cyclone System into the HLW Glass Cullet Melter System.

Stream 10.7:

This high activity stream flows from the Cullet Rework and Melter Off-gas Processing HLW Separator System into the HLW Glass Cullet Evaporator System.

Stream 10.8:

This low activity stream flows from the Cullet Rework and Melter Off-gas Processing NOx/SO2 Separator System into the Air/Vapor Filtration Process Stack Filter System. It contains trace amounts of radionuclides.

Off-gas Processing HLW Separator System. The ASPEN run used as the basis for this model showed this stream as zero.

Stream 12.22:
This non-radioactive stream flows from the Chemical Make-up Unit Bulk H2O Storage into the Cullet Rework and Melter Off-gas Processing Cyclone System.

Stream 12.23:
This non-radioactive stream flows from the Chemical Make-up Unit Bulk H2O Storage into the Cullet Rework and Melter Off-gas Processing HLW Separator System.

Stream 12.24:
This non-radioactive stream flows from the Chemical Make-up Unit Bulk H2O Storage into the Cullet Rework and Melter Off-gas Processing LLW Separator System.

Stream 12.30:
This stream flows from the Chemical Make-up Unit Bulk Combustible Liquid Storage into the Cullet Rework and Melter Off-gas Processing Claus Reactor System. The ASPEN run used as the basis for this model showed this stream as zero.

Stream 13.9:
This non-radioactive stream flows from the Air/Vapor Filtration Oxygen Supply System into the Cullet Rework and Melter Off-gas Processing NOx/SO2 Separator System.

Assumptions for Module 11, Liquid Effluent Treatment Facility

Mass Flow Values

Mass flows for modules 3 through 13 were obtained from a WHC ASPEN run dated January 21, 1994 (Combined Separations, Parallel HLW & LLW Vitrification, 50-20% Solids, 45% HLW WO Loading).

Fugitive Emissions

The processes and facilities are designed to run at a slightly negative pressure (Gail Allen, WHC), and there are extensive vapor recovery systems designed for the processes. It has therefore been assumed that there will be no fugitive emissions from the processes or the facilities.

Decontamination and Decommissioning (D&D) Waste

It has been assumed that the average size of a piece of equipment within any process is 1000 gallons and that 0.1% of the inventory within each piece of equipment will be leaked during D&D (BEJ). The estimated mass of D&D waste has been calculated as 0.1% of the mass of each stream multiplied by the number of pieces of equipment within the module and the assumed 1000 gallon volume of each piece of equipment, and multiplying the total by the density of the stream.

Radiation Level

Streams have been designated as high activity, low activity, or non-radioactive, based on the radionuclide concentration. Streams with 0.13 Ci/kg or greater have been designated as high activity waste and streams with less than 0.13 Ci/kg have been designated as low activity waste. Chemical additions to the process are designated as non-radioactive.

Stream 4.1:

This low activity stream flows from the Cesium Ion Exchange Supernatant Evaporation System into the Liquid Effluent Treatment Facility Process Condensate Recycle System. Since this stream contains only trace amounts of radionuclides, all radionuclide values are assumed to be zero.

Stream 5.1:

This low activity stream flows from the LLW Glass in Sulfur Evaporator System into the Liquid Effluent Treatment Facility Process Condensate Recycle System. Since this stream contains only trace amounts of radionuclides, all radionuclide values are assumed to be zero.

Stream 5.4:

This low activity stream flows from the LLW Glass in Sulfur Cullet Drying System into the Liquid Effluent Treatment Facility Process Condensate Recycle System. Since this stream contains only trace amounts of

Treatment Facility Process Condensate Recycle System. Since this stream contains only trace amounts of radionuclides, all radionuclide values are assumed to be zero.

Stream 8.3:

This low activity stream flows from the HLW Glass Cullet Evaporator System into the Liquid Effluent Treatment Facility Process Condensate Recycle System. Since this stream contains only trace amounts of radionuclides, all radionuclide values are assumed to be zero.

Stream 8.5:

This low activity stream flows from the HLW Glass Cullet Drying System into the Liquid Effluent Treatment Facility Process Condensate Recycle System. Since this stream contains only trace amounts of radionuclides, all radionuclide values are assumed to be zero.

Stream 11.1:

This low activity stream flows from the Liquid Effluent Treatment Facility Process Condensate Recycle System into the Cesium Ion Exchange Feed. Since this stream contains only trace amounts of radionuclides, all radionuclide values are assumed to be zero.

Stream 11.2:

This stream flows from the Liquid Effluent Treatment Facility pH Adjustment Tank into the tank farms. The ASPEN run used as the basis for this model showed this stream as zero. However, due to the presence of trace amounts of radionuclides, it is designated as low activity.

Stream 11.3:

This low activity stream flows from the Liquid Effluent Treatment Facility Retention Basin into the DST Sludge Wash Settle Tanks. Since this stream contains only trace amounts of radionuclides, all radionuclide values are assumed to be zero.

Stream 11.4:

This low activity stream flows from the Liquid Effluent Treatment Facility Retention Basin into the DST Sludge Wash. Since this stream contains only trace amounts of radionuclides, all radionuclide values are assumed to be zero.

Stream 11.5:

This low activity stream flows from the Liquid Effluent Treatment Facility Retention Basin to the L.E.P.A.R.D. (Liquid Effluent Processing for Recycle or Discharge). Since this stream contains only trace amounts of radionuclides, all radionuclide values are assumed to be zero.

Stream 11.6:

This stream represents fugitive emissions from the Liquid Effluent Treatment Facility. It is assumed to be zero. However, due to the presence of trace amounts of radionuclides, it is designated as low activity.

Stream 11.7:

This low activity stream represents D&D waste from the Liquid Effluent Treatment Facility. The Liquid Effluent Treatment Facility contains 10 pieces of equipment. Since this stream contains only trace amounts of radionuclides, all radionuclide values are assumed to be zero.

Stream 12.14:

This non-radioactive stream flows from the Chemical Make-up Unit Bulk Liquid Storage into the Liquid Effluent Treatment Facility pH Adjustment Tank.

Assumptions for Module 11, Liquid Effluent Treatment Facility

Mass Flow Values

Mass flows for modules 3 through 13 were obtained from a WHC ASPEN run dated January 21, 1994 (Combined Separations, Parallel HLW & LLW Vitrification, 50-20% Solids, 45% HLW WO Loading).

Fugitive Emissions

The processes and facilities are designed to run at a slightly negative pressure (Gail Allen, WHC), and there are extensive vapor recovery systems designed for the processes. It has therefore been assumed that there will be no fugitive emissions from the processes or the facilities.

Decontamination and Decommissioning (D&D) Waste

It has been assumed that the average size of a piece of equipment within any process is 1,000 gallons and that 0.1% of the inventory within each piece of equipment will be leaked during D&D (BEJ). The estimated mass of D&D waste has been calculated as 0.1% of the mass of each stream multiplied by the number of pieces of equipment within the module and the assumed 1,000 gallon volume of each piece of equipment, and multiplying the total by the density of the stream.

Radiation Level

Streams have been designated as high activity, low activity, or non-radioactive, based on the radionuclide concentration. Streams with 0.13 Ci/kg or greater have been designated as high activity waste and streams with less than 0.13 Ci/kg have been designated as low activity waste. Chemical additions to the process are designated as non-radioactive.

Stream 4.1:

This low activity stream flows from the Cesium Ion Exchange Supernatant Evaporation System into the Liquid Effluent Treatment Facility Process Condensate Recycle System. Since this stream contains only trace amounts of radionuclides, all radionuclide values are assumed to be zero.

Stream 5.1:

This low activity stream flows from the LLW Glass in Sulfur Evaporator System into the Liquid Effluent Treatment Facility Process Condensate Recycle System. Since this stream contains only trace amounts of radionuclides, all radionuclide values are assumed to be zero.

Stream 5.4:

This low activity stream flows from the LLW Glass in Sulfur Cullet Drying System into the Liquid Effluent Treatment Facility Process Condensate Recycle System. Since this stream contains only trace amounts of

Treatment Facility Process Condensate Recycle System. Since this stream contains only trace amounts of radionuclides, all radionuclide values are assumed to be zero.

Stream 8.3:

This low activity stream flows from the HLW Glass Cullet Evaporator System into the Liquid Effluent Treatment Facility Process Condensate Recycle System. Since this stream contains only trace amounts of radionuclides, all radionuclide values are assumed to be zero.

Stream 8.5:

This low activity stream flows from the HLW Glass Cullet Drying System into the Liquid Effluent Treatment Facility Process Condensate Recycle System. Since this stream contains only trace amounts of radionuclides, all radionuclide values are assumed to be zero.

Stream 11.1:

This low activity stream flows from the Liquid Effluent Treatment Facility Process Condensate Recycle System into the Cesium Ion Exchange Feed. Since this stream contains only trace amounts of radionuclides, all radionuclide values are assumed to be zero.

Stream 11.2:

This stream flows from the Liquid Effluent Treatment Facility pH Adjustment Tank into the tank farms. The ASPEN run used as the basis for this model showed this stream as zero. However, due to the presence of trace amounts of radionuclides, it is designated as low activity.

Stream 11.3:

This low activity stream flows from the Liquid Effluent Treatment Facility Retention Basin into the DST Sludge Wash Settle Tanks. Since this stream contains only trace amounts of radionuclides, all radionuclide values are assumed to be zero.

Stream 11.4:

This low activity stream flows from the Liquid Effluent Treatment Facility Retention Basin into the DST Sludge Wash. Since this stream contains only trace amounts of radionuclides, all radionuclide values are assumed to be zero.

Stream 11.5:

This low activity stream flows from the Liquid Effluent Treatment Facility Retention Basin to the LEPARD (Liquid effluent Processing for Recycle or Discharge). Since this stream contains only trace amounts of radionuclides, all radionuclide values are assumed to be zero.

Stream 11.6:

This stream represents fugitive emissions from the Liquid Effluent Treatment Facility. It is assumed to be zero. However, due to the presence of trace amounts of radionuclides, it is designated as low activity.

Stream 11.7:

This low activity stream represents D&D waste from the Liquid Effluent Treatment Facility. The Liquid Effluent Treatment Facility contains 10 pieces of equipment. Since this stream contains only trace amounts of radionuclides, all radionuclide values are assumed to be zero.

Stream 12.14:

This non-radioactive stream flows from the Chemical Make-up Unit Bulk Liquid Storage into the Liquid Effluent Treatment Facility pH Adjustment Tank.

Assumptions for Module 12, Chemical Makeup Unit

Mass Flow Values

Mass flows for modules 3 through 13 were obtained from a WHC ASPEN run dated January 21, 1994 (Combined Separations, Parallel HLW & LLW Vitrification, 50-20% Solids, 45% HLW WO Loading).

Fugitive Emissions

The processes and facilities are designed to run at a slightly negative pressure (Gail Allen, WHC), and there are extensive vapor recovery systems designed for the processes. It has therefore been assumed that there will be no fugitive emissions from the processes or the facilities.

Decontamination and Decommissioning (D&D) Waste

It has been assumed that the average size of a piece of equipment within any process is 1,000 gallons and that 0.1% of the inventory within each piece of equipment will be leaked during D&D (BEJ). The estimated mass of D&D waste has been calculated as 0.1% of the mass of each stream multiplied by the number of pieces of equipment within the module and the assumed 1,000 gallon volume of each piece of equipment, and multiplying the total by the density of the stream.

Radiation Level

Streams have been designated as high activity, low activity, or non-radioactive,based on the radionuclide concentration. Streams with 0.13 Ci/kg or greater have been designated as high activity waste and streams with less than 0.13 Ci/kg have been designated as low activity waste. Chemical additions to the process are designated as non-radioactive.

Stream 12.1:

This non-radioactive stream represents purchased chemicals into the Chemical Make-up Unit Dry Storage.

Stream 12.2:

This non-radioactive stream represents purchased chemicals into the Chemical Make-up Unit Bulk Liquid Storage.

Stream 12.3:

This non-radioactive stream represents purchased chemicals into the Chemical Make-up Unit Bulk H2O Storage.

Stream 12.4:

This non-radioactive stream represents purchased chemicals into the Chemical Make-up Unit Bulk

This non-radioactive stream represents purchased chemicals into the Chemical Make-up Unit Bulk Combustible Liquid Storage.

Stream 12.5:
This non-radioactive stream represents purchased chemicals into the Chemical Make-up Unit Glass Melter Batch Mixers.

Stream 12.6:
This non-radioactive stream flows from the Chemical Make-up Unit Dry Storage into the DST Sludge Wash Feed.

Stream 12.7:
This non-radioactive stream flows from the Chemical Make-up Unit Dry Storage into the Cesium Ion Exchange Supernatant Evaporation System.

Stream 12.8:
This non-radioactive stream flows from the Chemical Make-up Unit Dry Storage into the Cesium Ion Exchange Feed.

Stream 12.9:
This non-radioactive stream flows from the Chemical Make-up Unit Bulk Liquid Storage into the DST Sludge Wash Feed.

Stream 12.10:
This non-radioactive stream flows from the Chemical Make-up Unit Bulk Liquid Storage into the Cesium Ion Exchange Supernatant Evaporation System.

Stream 12.11:
This non-radioactive stream flows from the Chemical Make-up Unit Bulk Liquid Storage into the Cesium Ion Exchange Feed.

Stream 12.12:
This non-radioactive stream flows from the Chemical Make-up Unit Bulk Liquid Storage into the Cesium Ion Exchange Eluent/Regeneration System.

Stream 12.13:
This non-radioactive stream flows from the Chemical Make-up Unit Bulk Liquid Storage into the LLW Glass in Sulfur Vault Sulfur Cement Mixing.

Stream 12.14:
This stream flows from the Chemical Make-up Unit Bulk Liquid Storage into the Liquid Effluent Treatment Facility pH Adjustment Tank. The ASPEN run used as the basis for this model showed this stream as zero.

Stream 12.15:
This non-radioactive stream flows from the Chemical Make-up Unit Bulk Liquid Storage into the Cullet Rework and Melter Off-gas Processing NOx/SO2 Separator System.

Stream 12.16:
This stream flows from the Chemical Make-up Unit Bulk Liquid Storage into the Cullet Rework and Melter Off-gas Processing HLW Separator System. The ASPEN run used as the basis for this model showed this stream as zero.

Stream 12.17:
This non-radioactive stream flows from the Chemical Make-up Unit Bulk H2O Storage into the DST Sludge Wash Feed.

Stream 12.18:
This non-radioactive stream flows from the Chemical Make-up Unit Bulk H2O Storage into the Cesium Ion Exchange Supernatant Evaporation System.

Stream 12.19:
This non-radioactive stream flows from the Chemical Make-up Unit Bulk H2O Storage into the Cesium Ion Exchange Eluent/Regeneration System.

Stream 12.20:
This non-radioactive stream flows from the Chemical Make-up Unit Bulk H2O Storage into the LLW Glass in Sulfur Quenching System.

Stream 12.21:
This non-radioactive stream flows from the Chemical Make-up Unit Bulk H2O Storage into the LLW Glass in Sulfur Cyclone System.

Stream 12.22:
This non-radioactive stream flows from the Chemical Make-up Unit Bulk H2O Storage into the Cullet Rework and Melter Off-gas Processing Cyclone System.

Stream 12.23:

This non-radioactive stream flows from the Chemical Make-up Unit Bulk H2O Storage into the Cullet Rework and Melter Off-gas Processing HLW Separator System.

Stream 12.24:

This non-radioactive stream flows from the Chemical Make-up Unit Bulk H2O Storage into the Cullet Rework and Melter Off-gas Processing LLW Separator System.

Stream 12.25:

This non-radioactive stream flows from the Chemical Make-up Unit Bulk H2O Storage into the Air/Vapor Filtration CVOG/VOG System.

Stream 12.26:

This non-radioactive stream flows from the Chemical Make-up Unit Bulk H2O Storage into the Air/Vapor Filtration Process Stack Filter System.

Stream 12.27:

This non-radioactive stream flows from the Chemical Make-up Unit Bulk H2O Storage into the Air/Vapor Filtration Storage Stack Filter System.

Stream 12.28:

This non-radioactive stream flows from the Chemical Make-up Unit Bulk Combustible Liquid Storage into the LLW Glass in Sulfur Melter System.

Stream 12.29:

This non-radioactive stream flows from the Chemical Make-up Unit Bulk Combustible Liquid Storage into the HLW Glass Cullet Melter System.

Stream 12.30:

This stream flows from the Chemical Make-up Unit Bulk Combustible Liquid Storage into the Cullet Rework and Melter Off-gas Processing Claus Reactor System. The ASPEN run used as the basis for this model showed this stream as zero.

Stream 12.31:

This stream flows from the Chemical Make-up Unit Bulk Combustible Liquid Storage into the Air/Vapor Filtration Oxygen Supply System. The ASPEN run used as the basis for this model showed this stream as zero.

Stream 12.32:

This non-radioactive stream flows from the Chemical Make-up Unit Glass Melter Batch Mixers into the LLW Glass in Sulfur Melter System.

Stream 12.33:

This non-radioactive stream flows from the Chemical Make-up Unit Glass Melter Batch Mixers into the HLW Glass Cullet Melter System.

Stream 12.34:

This non-radioactive stream flows from the Chemical Make-up Unit Bulk H2O Storage into the HLW Glass Cullet Cyclone System.

Stream 12.35:

This stream represents fugitive emissions from the Chemical Make-up System. It is assumed to be zero.

Stream 12.36:

This non-radioactive stream represents D&D waste from the Chemical Make-up System. The Chemical Make-up System contains 28 pieces of equipment.

Assumptions for Module 13, Air / Vapor Filtration System

Mass Flow Values

Mass flows for modules 3 through 13 were obtained from a WHC ASPEN run dated January 21, 1994 (Combined Separations, Parallel HLW & LLW Vitrification, 50-20% Solids, 45% HLW WO Loading)

Fugitive Emissions

The processes and facilities are designed to run at a slightly negative pressure (Gail Allen, WHC), and there are extensive vapor recovery systems designed for the processes. It has therefore been assumed that there will be no fugitive emissions from the processes or the facilities.

Decontamination and Decommissioning (D&D) Waste

It has been assumed that the average size of a piece of equipment within any process is 1,000 gallons and that 0.1% of the inventory within each piece of equipment will be leaked during D&D (BEJ). The estimated mass of D&D waste has been calculated as 0.1% of the mass of each stream multiplied by the number of pieces of equipment within the module and the assumed 1,000 gallon volume of each piece of equipment, and multiplying the total by the density of the stream.

Radiation Level

Streams have been designated as high activity, low activity, or non-radioactive, based on the radionuclide concentration. Streams with 0.13 Ci/kg or greater have been designated as high activity waste and streams with less than 0.13 Ci/kg have been designated as low activity waste. Chemical additions to the process are designated as non-radioactive.

Stream 4.2:

This low activity stream flows from the Cesium Ion Exchange Supernatant Evaporation System into the Air/Vapor Filtration CVOG/VOG System. Since this stream only contains trace amounts of radionuclides, radionuclide values are assumed to be zero.

Stream 4.6:

This low activity stream flows from the Cesium Ion Exchange Concentrator System into the Air/Vapor Filtration CVOG/VOG System. Since this stream only contains trace amounts of radionuclides, radionuclide values are assumed to be zero.

Stream 5.2:

This low activity stream flows from the LLW Glass in Sulfur Evaporator System into the Air/Vapor Filtration CVOG/VOG System. Since this stream only contains trace amounts of radionuclides, radionuclide values are assumed to be zero.

radionuclide values are assumed to be zero.

Stream 5.6:
This low activity stream flows from the LLW Glass in Sulfur Cullet Drying System into the Air/Vapor Filtration BVOG System.

Stream 5.8:
This low activity stream flows from the LLW Glass in Sulfur Cyclone System into the Air/Vapor Filtration Process Stack Filter System.

Stream 8.4:
This low activity stream flows from the HLW Glass Cullet Evaporator System into the Air/Vapor Filtration CVOG/VOG System. Since this stream only contains trace amounts of radionuclides, radionuclide values are assumed to be zero.

Stream 8.7:
This high activity stream flows from the HLW Glass Cullet Drying System into the Air/Vapor Filtration BVOG System.

Stream 8.9:
This high activity stream flows from the HLW Glass Cullet Cyclone System into the Air/Vapor Filtration Process Stack Filter System.

Stream 10.3:
This low activity stream flows from the Cullet Rework and Melter Off-gas Processing Cyclone System into the Air/Vapor Filtration Process Stack Filter System.

Stream 10.8:
This low activity stream flows from the Cullet Rework and Melter Off-gas Processing NOx/SO2 Separator System into the Air/Vapor Filtration Process Stack Filter System.

Stream 12.25:
This non-radioactive stream flows from the Chemical Make-up Unit Bulk H2O Storage into the Air/Vapor Filtration CVOG/VOG System.

Stream 12.26:
This non-radioactive stream flows from the Chemical Make-up Unit Bulk H2O Storage into the Air/Vapor Filtration Process Stack Filter System.

Stream 12.27:

This non-radioactive stream flows from the Chemical Make-up Unit Bulk H2O Storage into the Air/Vapor Filtration Storage Stack Filter System.

Stream 12.31:

This stream flows from the Chemical Make-up Unit Bulk Combustible Liquid Storage into the Air/Vapor Filtration
Oxygen Supply System. The ASPEN run used as the basis for this model showed this stream as zero.

Stream 13.1:

This stream represents air flowing into the Air/Vapor Filtration CVOG/VOG/PVOG Air Supply System. The ASPEN run used as the basis for this model showed this stream as zero.

Stream 13.2:

This stream represents air flowing into the Air/Vapor Filtration BVOG Air Supply System. The ASPEN run used as
the basis for this model showed this stream as zero.

Stream 13.3:

This stream represents air flowing into the Air/Vapor Filtration Oxygen Supply System.

Stream 13.4:

This stream flows from the Air/Vapor Filtration CVOG/VOG System into the LLW Glass in Sulfur Evaporator System. The ASPEN run used as the basis for this model showed this stream as zero. However, due to the presence of trace amounts of radionuclides, it is designated as low activity.

Stream 13.5:

This low activity stream flows from the Air/Vapor Filtration Process Stack Filter System into the LLW Glass in Sulfur Evaporator System.

Stream 13.6:

This low activity stream flows from the Air/Vapor Filtration Process Stack Filter System and is discharged into the
atmosphere.

Stream 13.7:

This low activity stream flows from the Air/Vapor Filtration Storage Stack Filter System into the LLW Glass in Sulfur Evaporator System.

Glass in Sulfur Evaporator System.

Stream 13.8:
This low activity stream flows from the Air/Vapor Filtration Storage Stack Filter System and is discharged into the
atmosphere.

Stream 13.9:
This non-radioactive stream flows from the Air/Vapor Filtration Oxygen Supply System into the Cullet Rework and
Melter Off-gas Processing NOx/SO2 Separator System.

Stream 13.10:
This non-radioactive stream flows from the Air/Vapor Filtration Oxygen Supply System into the LLW Glass in Sulfur Melter System.

Stream 13.11:
This non-radioactive stream flows from the Air/Vapor Filtration Oxygen Supply System into the HLW Glass Cullet
Melter System.

Stream 13.12 :
This non-radioactive stream represents a nitrogen Cover-gas flowing from the Air/Vapor Filtration Oxygen Supply System. The ASPEN run that was the basis for this model did not utilize this stream elsewhere in the system model (Gail Allen, WHC).

Stream 13.13:
This stream represents fugitive emissions from the Air/Vapor Filtration Oxygen Supply System. It is assumed to be zero. However, due to the presence of trace amounts of radionuclides, it is designated as low activity.

Stream 13.14:
This low activity stream represents D&D waste from the Air/Vapor Filtration Oxygen Supply System. The Air/Vapor Filtration Oxygen Supply System contains 51 pieces of equipment.

Stream 13.15:
This stream represents flow from the vessel vent system to the Air/Vapor Filtration CVOG/VOG System. The ASPEN run used as the basis for this model showed this stream as zero.

Stream 13.16:

This stream represents fugitive leaks to the Air/Vapor Filtration Storage Stack Filter System. The ASPEN run used
as the basis for this model showed this stream as zero.

Costs

The cost sheets are found in Appendix M.

Routine Worker Risk Parameters

The routine worker risk parameter sheet are found in Appendix J.

Nonroutine Risk Parameters

The nonroutine risk parameter sheets are found in Appendix L.

Frequency/Weighting Scale

DEVELOPMENT OF FREQUENCY VALUES FOR FAILURE EVENTS

Parameter / Rank	VERY LOW	LOW	MEDIUM	HIGH
Probability - Frequency of happening	Highly unlikely to occur	Possible to occur within facility lifetime	Likely to occur within facility lifetime	Anticipated to occur within 2 years
Frequency Values:	0.0001	0.01	0.1	1
		GENERAL INDICATORS		
Accident Failures:	-Nonflammable materials -Low energetic reaction potential -nonreactive materials -stable materials -compatible materials -Low pressure and temperature process	-Small quantities of flammable materials -Low energetic reaction potential -small quan. reactive materials -small quan. slightly unstable materials -small quan incompatible materials -High pressure and temperature process	-Large quantities of flammable materials -Moderate energetic reaction potential -Mod. quan. reactive materials -Mod. quan. slightly unstable materials -Mod. quan incompatible materials -High pressure and temperature process	-Same characteristics as Moderate Category -Complex process, difficult to control -multiple individual operations -high process flow rates
Nonroutine Maintenance Failures:	-No mechanical equipment -Minimal control requirements -Low suspended solids -Neutral pH/ corrosivity	-Moderate quantity of mechanical equipment of routine complexity -Moderate control requirements and instrumentation -Up to 10 percent suspended solids -Low pH/ moderate corrosivity	-Moderate quantity of mechanical equipment of routine complexity -Moderate control requirements and instrumentation -Up to 10 percent suspended solids -Low pH/ moderate corrosivity	-Extensive mechanical equipment, unique without operating history, highly complex -Extensive control requirements and instrumentation -Greater than 20 percent suspended solids -Low pH/ high corrosivity

Consequence Weighting Scale

DEVELOPMENT OF CONSEQUENCE VALUES FOR FAILURE EVENTS							
Rank	**8**	**7**	**5\6**	**4**	**3**	**2**	**1**
Attribute							
Public Safety:	No impact on Public health and safety	Public Inconvenience	Low-level radiation or chemical exposure	Exposures near Limits Moderate injuries	Multiple exposures >100 rem or >>IDLH		Single loss of life
Worker Safety:	No impact on Worker health and safety	Minor injuries requiring first aid Exposure below limits Removable skin contamination	Exposure >DOE limit Injury with 7 to 70 days lost time	Exposures of 100 rem or >>IDLH Injury with > 70 days lost time		Single loss of life (1500) Permanent disability and degraded lifestyle	
Environmental:	No releases affecting environment	Reportable releases to environment with no impact	Environmental damage that exceeds regulatory limits Cleanup costs approx $250K	Cleanup costs >$1M	Environmental cleanup >$100M onsite Cleanup >$25M offsite	Offsite cleanup >$100M, long recovery time	
Cost:	Equip/facility damage <<$1M Incr. operating cost <<$200K		Equip/facility damage $1M to $25M Incr. operating cost $200K to $5M/yr	Equip/facility damage >$25M (40) Incr. operating cost >$5M/yr (40)			
Relative Consequence							
Values	1	5	25	100	300	1000	3000

Attribute / Rank	8	7	5\6	4	3	2	1
Waste Inventory							
- Type	LLW or Low Tox Waste	LLW or High Tox Waste	LLW, HLW, or High Tox Wastes	LLW, HLW, or High Tox Wastes	HLW or Extremely Tox Wastes	HLW or Extremely Tox Wastes	HLW or Extremely Tox Wastes
- Quantity	Small quantity	Small quantity	Moderate quantity	Large quantity	Large quantity		
- Physical form	Liquid or non-dispersable solid* * e.g. monolithic solid	Liquid or non-dispersible solid	Any form** LLW or Tox, liquid or ** except monolithic solid	Any form LLW, HLW or Tox	Any form HLW or Tox	Any form HLW or Tox	Any form HLW or Tox
Containment Characteristics							
- Container	High integrity container	Moderate integrity container	Moderate integrity container	Low integrity container	Low integrity container	No container	No container
- Primary containment	High integrity primary containment area	Moderate integrity primary containment area	Low integrity primary containment area	No primary containment area	No primary containment area	No primary containment area	No primary containment area
- Facility containment	High integrity structure	High integrity structure	Moderate integrity structure	Moderate integrity structure	Moderate integrity structure	Low integrity structure	no structure
Energetic Release Potential							
- Temperature	Ambient	Ambient	T up to 100 C	T up to 100 C	T > 100 C	T > 100 C	T > 100 C
- Pressure	Ambient	Ambient	P up to 100 psi	P up to 100 psi	P > 100 psi	P > 100 psi	P > 100 psi
- Reactive/ unstable	Nonreactive & stable	Low reactivity & stable	Low reactivity & instability	Moderately reactive	Moderately reactive	Highly reactive	Highly reactive
- Flammable	Nonflammable	Nonflammable	Flammable	Flammable	Flammable	Highly flammable	Highly flammable

Rank / Attribute	8	7	5\6	4	3	2	1
Public Safety:	No impact on Public health and safety	Public Inconvenience	Low-level radiation or chemical exposure	Exposures near Limits Moderate injuries	Multiple exposures >100 rem or >>IDLH		Single loss of life
Worker Safety:	No impact on Worker health and safety	Minor injuries requiring first aid Exposure below limits Removable skin contamination	Exposure >DOE limit Injury with 7 to 70 days lost time	Exposures of 100 rem or >>IDLH Injury with > 70 days lost time		Single loss of life (1500) Permanent disability and degraded lifestyle	
Environmental:	No releases affecting environment	Reportable releases to environment with no impact	Environmental damage that exceeds regulatory limits Cleanup costs approx $250K	Cleanup costs >$1M	Environmental cleanup >$100M onsite Cleanup >$25M offsite	Offsite cleanup >$100M, long recovery time	
Cost:	Equip/facility damage <<$1M Incr. operating cost <<$200K		Equip/facility damage $1M to $25M Incr. operating cost $200K to $5M/yr	Equip/facility damage >$25M (40) Incr. operating cost >$5M/yr (40)			
Relative Consequence Values	1	5	25	100	300	1000	3000

Cost/Risk Summary

Base Case: Risk and Cost Analysis

	System Indices	System Indices		M.1, SST Waste Retrieval		M.2, DST Waste Retrieval	
		Operational Phase	Disposal Phase	Operational Phase	Disposal Phase	Operational Phase	Disposal Phase
Public							
Cancer Risk	2.51E-05	3.63E-15	2.51E-05	0.00E+00	1.98E-05	0.00E+00	5.36E-06
Toxicant HI	4.75E-01	7.10E-05	4.75E-01	0.00E+00	4.33E-01	0.00E+00	4.26E-02
Worker							
Collective Radiation Dose (man-rem)	16,991	16,991	NA	3,018	NA	696	NA
Failure Events Qualitative Risk							
Accidents	2.50	2.50	NA	2.50	NA	0.25	NA
Nonroutine Maintenance	58.92	58.92	NA	2.15	NA	2.05	NA
Costs	$13,431,080,000	$13,431,080,000		$1,451,620,000		$503,770,000	

Base Case: Risk and Cost Analysis

	M.3, DST Sludge Wash		M.4, Cesium Ion Exchange		M.5, LLW Glass in Sulfur		M.6, LLW Glass in Sulfur Vaults	
	Operational Phase	Disposal Phase	Operational Phase	Disposal Phase	Operational Phase	Disposal Phase	Operational Phase	Disposal Phase
Public								
Cancer Risk	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Toxicant HI	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Worker								
Collective Radiation Dose (man-rem)	1,467	NA	1,742	NA	1,449	NA	1,260	NA
Failure Events Qualitative Risk								
Accidents	0.05	NA	0.25	NA	2.50	NA	0.05	NA
Nonroutine Maintenance	0.53	NA	0.83	NA	16.55	NA	5.41	NA
Costs	$352,940,000		$605,240,000		$1,627,590,000		$537,930,000	

Base Case: Risk and Cost Analysis

	M.7, HLW Glass Cullet Feed Lag Storage		M.8, HLW Glass Cullet		M.9, HLW Glass Cullet Cask Storage Pad		M.10, Cullet Rework and Melter Off-Gas Processing	
	Operational Phase	Disposal Phase	Operational Phase	Disposal Phase	Operational Phase	Disposal Phase	Operational Phase	Disposal Phase
Public								
Cancer Risk	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Toxicant HI	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Worker								
Collective Radiation Dose (man-rem)	1,031	NA	1,932	NA	1,716	NA	1,055	NA
Failure Events Qualitative Risk								
Accidents	0.25	NA	2.50	NA	0.05	NA	0.05	NA
Nonroutine Maintenance	1.20	NA	22.06	NA	0.30	NA	5.97	NA
Costs	$119,280,000		$3,733,780,000		$3,315,820,000		$710,690,000	

Base Case: Risk and Cost Analysis

	M.11, Liquid Effluent Treatment Facility		M.12, Chemical Make-up Unit		M.13, Air/Vapor Filtration System	
	Operational Phase	Disposal Phase	Operational Phase	Disposal Phase	Operational Phase	Disposal Phase
Public						
Cancer Risk	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.63E-15	0.00E+00
Toxicant HI	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.10E-05	0.00E+00
Worker						
Collective Radiation Dose (man-rem)	1,092	NA	0	NA	534	NA
Failure Events Qualitative Risk						
Accidents	0.05	NA	0.10	NA	0.01	NA
Nonroutine Maintenance	0.12	NA	1.16	NA	0.57	NA
Costs	$107,070,000		$94,350,000		$271,000,000	

Test Case 1: Risk and Cost Analysis

	System Indices	System Indices		M.1, SST Waste Retrieval		M.2, DST Waste Retrieval	
		Operational Phase	Disposal Phase	Operational Phase	Disposal Phase	Operational Phase	Disposal Phase
Public							
Cancer Risk	1.49E-05	3.63E-15	1.49E-05	0.00E+00	9.55E-06	0.00E+00	5.36E-06
Toxicant HI	2.52E-01	7.10E-05	2.52E-01	0.00E+00	2.09E-01	0.00E+00	4.26E-02
Worker							
Collective Radiation Dose (man-rem)	17,300	17,300	NA	3,327	NA	696	NA
Failure Events Qualitative Risk							
Accidents	2.50	2.50	NA	2.50	NA	0.25	NA
Nonroutine Maintenance	59.03	59.03	NA	2.26	NA	2.05	NA
Costs	$16,692,950,000	$16,692,950,000		$4,713,490,000		$503,770,000	

Test Case 1: Risk and Cost Analysis

	M.3, DST Sludge Wash		M.4, Cesium Ion Exchange		M.5, LLW Glass in Sulfur		M.6, LLW Glass in Sulfur Vaults	
	Operational Phase	Disposal Phase	Operational Phase	Disposal Phase	Operational Phase	Disposal Phase	Operational Phase	Disposal Phase
Public								
Cancer Risk	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Toxicant HI	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Worker								
Collective Radiation Dose (man-rem)	1,467	NA	1,742	NA	1,449	NA	1,260	NA
Failure Events Qualitative Risk								
Accidents	0.05	NA	0.25	NA	2.50	NA	0.05	NA
Nonroutine Maintenance	0.53	NA	0.83	NA	16.55	NA	5.41	NA
Costs	$352,940,000		$605,240,000		$1,627,590,000		$537,930,000	

Test Case 1: Risk and Cost Analysis

	M.7, HLW Glass Cullet Feed Lag Storage		M.8, HLW Glass Cullet		M.9, HLW Glass Cullet Cask Storage Pad		M.10, Cullet Rework and Melter Off-Gas Processing	
	Operational Phase	Disposal Phase	Operational Phase	Disposal Phase	Operational Phase	Disposal Phase	Operational Phase	Disposal Phase
Public								
Cancer Risk	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Toxicant HI	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Worker								
Collective Radiation Dose (man-rem)	1,031	NA	1,932	NA	1,716	NA	1,055	NA
Failure Events Qualitative Risk								
Accidents	0.25	NA	2.50	NA	0.05	NA	0.05	NA
Nonroutine Maintenance	1.20	NA	22.06	NA	0.30	NA	5.97	NA
Costs	$119,280,000		$3,733,780,000		$3,315,820,000		$710,690,000	

Test Case 1: Risk and Cost Analysis

	M.11, Liquid Effluent Treatment Facility		M.12, Chemical Make-up Unit		M.13, Air/Vapor Filtration System	
	Operational Phase	Disposal Phase	Operational Phase	Disposal Phase	Operational Phase	Disposal Phase
Public						
Cancer Risk	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.63E-15	0.00E+00
Toxicant HI	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.10E-05	0.00E+00
Worker						
Collective Radiation Dose (man-rem)	1,092	NA	0	NA	534	NA
Failure Events Qualitative Risk						
Accidents	0.05	NA	0.10	NA	0.01	NA
Nonroutine Maintenance	0.12	NA	1.16	NA	0.57	NA
Costs	$107,070,000		$94,350,000		$271,000,000	

Test Case 2: Risk and Cost Analysis

	System Indices	System Indices		M.1, SST Waste Retrieval		M.2, DST Waste Retrieval	
		Operational Phase	Disposal Phase	Operational Phase	Disposal Phase	Operational Phase	Disposal Phase
Public							
Cancer Risk	1.20E-05	3.63E-15	1.20E-05	0.00E+00	6.62E-06	0.00E+00	5.36E-06
Toxicant HI	1.87E-01	7.10E-05	1.87E-01	0.00E+00	1.45E-01	0.00E+00	4.26E-02
Worker							
Collective Radiation Dose (man-rem)	21,530	21,530	NA	7,558	NA	696	NA
Failure Events Qualitative Risk							
Accidents	2.50	2.50	NA	2.50	NA	0.25	NA
Nonroutine Maintenance	60.27	60.27	NA	3.50	NA	2.05	NA
Costs	$15,937,950,000	$15,937,950,000		$3,958,490,000		$503,770,000	

Test Case 2: Risk and Cost Analysis

	M.3, DST Sludge Wash		M.4, Cesium Ion Exchange		M.5, LLW Glass in Sulfur		M.6, LLW Glass in Sulfur Vaults	
	Operational Phase	Disposal Phase	Operational Phase	Disposal Phase	Operational Phase	Disposal Phase	Operational Phase	Disposal Phase
Public								
Cancer Risk	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Toxicant HI	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Worker								
Collective Radiation Dose (man-rem)	1,467	NA	1,742	NA	1,449	NA	1,260	NA
Failure Events Qualitative Risk								
Accidents	0.05	NA	0.25	NA	2.50	NA	0.05	NA
Nonroutine Maintenance	0.53	NA	0.83	NA	16.55	NA	5.41	NA
Costs	$352,940,000		$605,240,000		$1,627,590,000		$537,930,000	

Test Case 2: Risk and Cost Analysis

	M.7, HLW Glass Cullet Feed Lag Storage		M.8, HLW Glass Cullet		M.9, HLW Glass Cullet Cask Storage Pad		M.10, Cullet Rework and Melter Off-Gas Processing	
	Operational Phase	Disposal Phase	Operational Phase	Disposal Phase	Operational Phase	Disposal Phase	Operational Phase	Disposal Phase
Public								
Cancer Risk	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Toxicant HI	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Worker								
Collective Radiation Dose (man-rem)	1,031	NA	1,932	NA	1,716	NA	1,055	NA
Failure Events Qualitative Risk								
Accidents	0.25	NA	2.50	NA	0.05	NA	0.05	NA
Nonroutine Maintenance	1.20	NA	22.06	NA	0.30	NA	5.97	NA
Costs	$119,280,000		$3,733,780,000		$3,315,820,000		$710,690,000	

Test Case 2: Risk and Cost Analysis

	M.11, Liquid Effluent Treatment Facility		M.12, Chemical Make-up Unit		M.13, Air/Vapor Filtration System	
	Operational Phase	**Disposal Phase**	**Operational Phase**	**Disposal Phase**	**Operational Phase**	**Disposal Phase**
Public						
Cancer Risk	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.63E-15	0.00E+00
Toxicant HI	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.10E-05	0.00E+00
Worker						
Collective Radiation Dose (man-rem)	1,092	NA	0	NA	534	NA
Failure Events Qualitative Risk						
Accidents	0.05	NA	0.10	NA	0.01	NA
Nonroutine Maintenance	0.12	NA	1.16	NA	0.57	NA
Costs	$107,070,000		$94,350,000		$271,000,000	

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APPENDIX O

MODEL SOFTWARE

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DISCLAIMER

The System Risk Analysis Model is supplied as is. This software is an application which runs under and requires the use of Microsoft Excel version 4.0 which is a trademark of Microsoft Corporation, Redmond, Washington. Excel is not supplied with the enclosed software.

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This program was produced by Enserch Environmental Corporation for Westinghouse Hanford Company under Order No. MGK-SVV-186918. Questions regarding installation and operation of the software should be directed to

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20	Pacific Northwest Laboratory	
	W. F. Bonner	P7-41
	P. M. Daling	K8-07
	K. M. Fowler (2)	K8-19
	B. M. Johnson	K1-78
	G. H. McCabe	HARC
	P. A. O'Mara	K8-24
	R. K. Quinn	K1-73
	D. A. Seaver	K8-27
	S. C. Slate (4)	K1-19
	T. G. Stewart	K1-73
	W. G. Stillwell	K1-30
	D. L. Strenge	K3-54
	M. J. Quadrel (3)	K1-73
	Hanford Technical Files*	P8-55
21	Westinghouse Hanford Company	
	J. N. Appel	G3-21
	W. B. Barton	L4-75
	J. D. Bazinet	S4-53
	K. D. Boomer	H5-49
	J. M. Cruse	L5-63
	R. C. Eschenbaum	N1-21
	K. A. Gasper	R2-08
	R. L. Gilchrist	L5-63
	J. M. Henderson	S6-12
	W. C. Miller	B1-58
	R. J. Murkowski	R4-01
	R. C. Roal	H5-27
	D. G. Sutherland	L4-72
	D. J. Washenfelder	L4-75
	G. F. Williamson	R4-01
	D. D. Wodrich	B1-59
	Central Files	L8-04
	Environmental Data Management	H4-22
	File/LB*	L5-63
	Information Release Administration (2)	A3-36

*Software not included.