Accession #: D196006998

Document #: SD-WM-ES-366

Title/Desc:
DETERMINE SEPARATIONS PROCESS STRATEGY DECISION

Pages: 89

JAN 16 1996 (21) Sta. 21

ENGINEERING DATA TRANSMITTAL

Page 1 of 1

1. EDT № 613844

2. To: (Receiving Organization)	3. From: (Originating Organization)	4. Related EDT No.:
Pretreatment Program, 73200	Process Design/73520	NA
5. Proj./Prog./Dept./Div.: TWRS	6. Cog. Engr.: E. J. Slaathaug, 376-5350 74A20/D5122	7. Purchase Order No.: NA
8. Originator Remarks:		9. Equip./Component No.: NA
		10. System/Bldg./Facility: NA
11. Receiver Remarks:		12. Major Assm. Dwg. No.: NA
		13. Permit/Permit Application No.: NA
		14. Required Response Date:

15. DATA TRANSMITTED					(F)	(G)	(H)	(I)
(A) Item No.	(B) Document/Drawing No.	(C) Sheet No.	(D) Rev. No.	(E) Title or Description of Data Transmitted	Approval Designator	Reason for Transmittal	Originator Disposition	Receiver Disposition
1	WHC-SD-WM-ES-366		0	Determine Separations Process Strategy Decision	NA KN	1	1	

16. KEY

Approval Designator (F)	Reason for Transmittal (G)		Disposition (H) & (I)	
E, S, Q, D or N/A (see WHC-CM-3-5, Sec.12.7)	1. Approval 2. Release 3. Information	4. Review 5. Post-Review 6. Dist. (Receipt Acknow. Required)	1. Approved 2. Approved w/comment 3. Disapproved w/comment	4. Reviewed no/comment 5. Reviewed w/comment 6. Receipt acknowledged

17. SIGNATURE/DISTRIBUTION (See Approval Designator for required signatures)

(G) Reason	(H) Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN	(J) Name	(K) Signature	(L) Date	(M) MSIN	(G) Reason	(H) Disp.
1	1	Cog.Eng. E. J. Slaathaug	[signature]	1-16-96	H5-49						
1	1	Cog. Mgr. J. S. Garfield	[signature]	1-16-96	H5-49						
		QA									
		Safety									
		Env.									

18.	19.	20.	21. DOE APPROVAL (if required)
EJ Slaathaug [signature] 1-16-96 Signature of EDT Originator / Date	KA Gasper [signature] 1/12/96 Authorized Representative for Receiving Organization / Date	JS Garfield [signature] 1/16/96 Cognizant Manager / Date	Ctrl. No. [ ] Approved [ ] Approved w/comments [ ] Disapproved w/comments

BD-7400-172-2 (04/94) GEF097

BD-7400-172-1

Determine Separations Process Strategy Decision

E. J. Slaathaug
Westinghouse Hanford Company, Richland, WA 99352
U.S. Department of Energy Contract DE-AC06-87RL10930

EDT/ECN: 613844 UC: 630
Org Code: 74A20 Charge Code: D5122
B&R Code: EW3130010 Total Pages: 101

Key Words: Strategy, Treatment, Separations

Abstract: This study provides a summary level comparative analysis of selected, top-level, waste treatment strategies. These strategies include No Separations, Separations (high-level/low-level separations), and Deferred Separations of the tank waste. These three strategies encompass the full range of viable processing alternatives based upon full retrieval of the tank wastes. The assumption of full retrieval of the tank wastes is a predecessor decision and will not be revisited in this study.

Printed in the United States of America. To obtain copies of this document, contact: WHC/BCS Document Control Services, P.O. Box 1970, Mailstop H6-08, Richland WA 99352, Phone (509) 372-2420; Fax (509) 376-4989.

Karen G. Noland 1/16/96
Release Approval Date

JAN 16 1996
DATE: HANFORD
STA: 21 RELEASE ID: 21
Release Stamp

Approved for Public Release

WHC-SD-WM-ES-366
Revision 0

DETERMINE SEPARATIONS PROCESS STRATEGY: DECISION 4.2.3

January 1996

E. J. Slaathaug

Prepared by
Westinghouse Hanford Company
Richland, Washington

This page intentionally left blank.

TABLE OF CONTENTS

APPENDIXES

LIST OF FIGURES

LIST OF TABLES

LIST OF TERMS

ALARA	As low as reasonably achievable
D&D	Decontamination and decommissioning
DOE	U.S. Department of Energy
EIS	Environmental Impact Statement
ESW	Enhanced sludge washing
HLW	High-level waste
LETF	Liquid Effluent Treatment Facility
LLW	Low-level waste
NRC	U.S. Nuclear Regulatory Commission
PA	Performance assessment
R&D	Research and development
TEC	Total Estimated Cost
TEDF	Treated Effluent Disposal Facility
TWRS	Tank Waste Remediation System
WHC	Westinghouse Hanford Company

DETERMINE SEPARATIONS PROCESS STRATEGY: DECISION 4.2.3

1.0 INTRODUCTION

This study addresses the Tank Waste Remediation System (TWRS) 4.2.3 architecture decision (Process Waste) as shown on Figure 1-1. Its main purpose is to provide the data necessary to determine if separating the waste into high-level waste (HLW) and low-level waste (LLW) fractions is warranted, but will not be used to determine how the waste is separated or to what degree. To accomplish this goal, this study provides a summary level comparative analysis of selected, top-level, waste treatment strategies. These strategies include No Separations, Separations (HLW/LLW separations), and Deferred Separations of the tank waste. These three strategies encompass the full range of viable processing alternatives based upon full retrieval of the tank wastes as determined in the *Draft Environmental Impact Statement for the Tank Waste Remediation System* (Ecology and DOE 1995). The assumption of full retrieval of the tank wastes is a predecessor decision and will not be revisited in this study (see Figure 1-1).

It is not the intent of this study to determine the exact processing scheme (i.e., extent of separations) that should be used, but instead to determine which processing strategies warrant further study. The definition of the processes within the selected processing scheme will be examined in future documents.

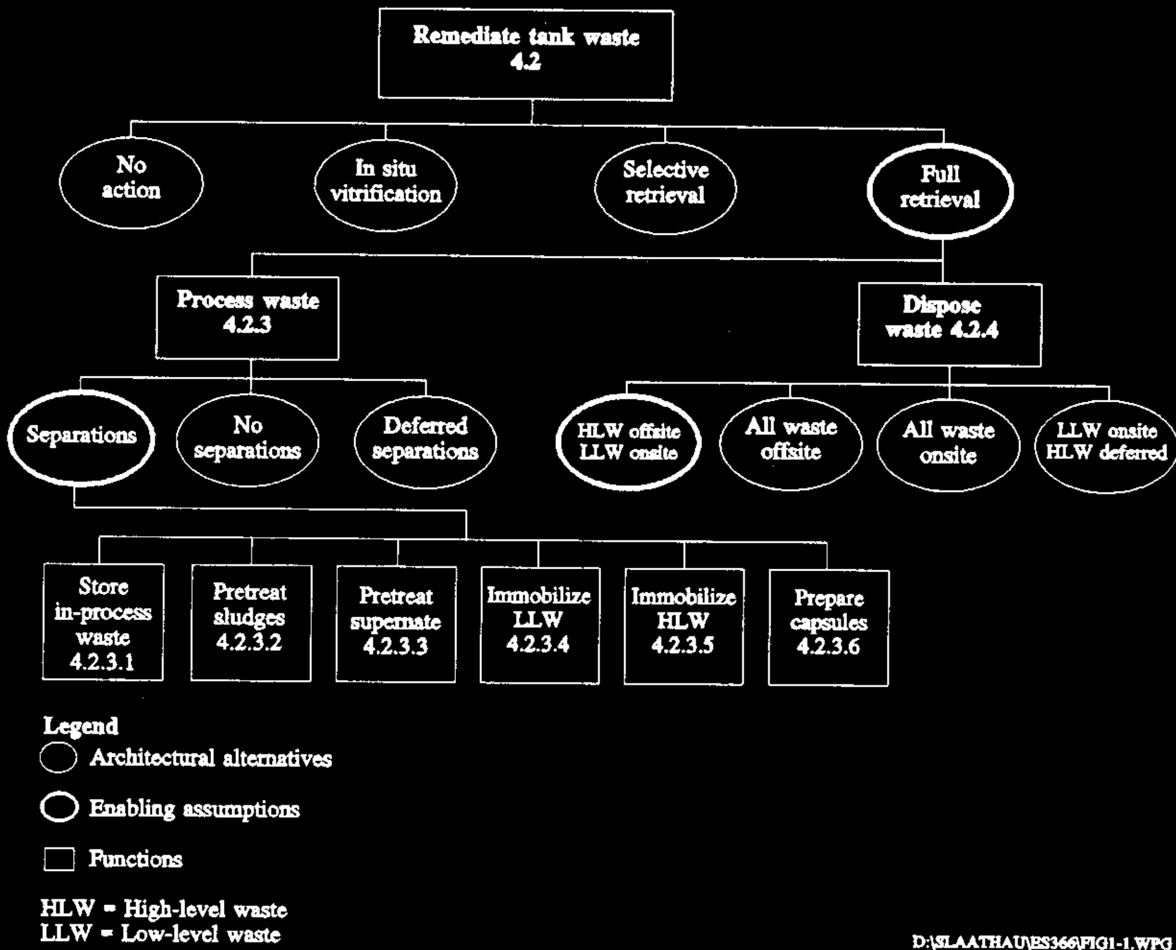
1.1 BACKGROUND

This section provides a discussion of background information necessary to understand the rationale for the current baseline treatment strategy. In addition, this section discusses the issues that drive the need for and scope of this study.

1.1.1 Current Treatment Strategy

The current baseline treatment strategy is outlined in several documents (Ecology et al. 1994, WHC 1994, and WHC 1995a) and consists of processes that separate the retrieved tank wastes into high and low level fractions. The baseline also calls for the separations processes to be coupled with immobilization processes to ultimately dispose of all retrieved tank wastes.

Figure 1-1. Tank Waste Remediation System Technical Scope Decision Logic.



Function	Key decision	Planning basis alternative	Selection basis	Validation by:
Remediate Tank Waste	Determine disposition of tank waste through NEPA	Retrieve all tank waste for treatment	DOE planning case as defined by Assistant Secretary for Environmental Protection and Waste Management (DOE 1993)	NEPA Process
Process Waste	Determine waste process strategy	Separate the waste into fractions	Tri-Party Agreement and DOE Planning Case (DOE 1993)	NEPA Process

DOE = U.S. Department of Energy
NEPA = *National Environmental Policy Act of 1969.*

1.1.2 Technical Basis For Current Separations Strategy

The technical basis for the current baseline treatment strategy was derived primarily from the *Tank Waste Technical Options Report* (TOR), WHC-EP-0616, Rev. 0 (Boomer et al. 1993). The TOR was a comprehensive engineering analysis of alternatives for the TWRS program mission. The TOR examined the range of treatment strategies via a suite of separations processes ranging from No Separations to Minimum Separations (sludge washing) to Extensive Separations (sludge washing, acid dissolution, caustic leaching, ion exchange, and solvent extraction processes).

1.1.3 Study Drivers

The following issues (all of which are interrelated) drive the need to perform this study:

1. Architecture engineering analysis 4.2.3, identified in the TWRS functions and requirements document (WHC 1995b), is to determine the waste processing strategy. Figure 1-1 shows the part of the decision logic tree that leads to the "Process Waste" decision. As shown in Figure 1-1, the decision is predicated on the retrieval of all tank waste for treatment. This study is intended to serve as the technical basis for the "Process Waste" architecture decision. The predecessor architecture decision (i.e., policy decisions inherent in Ecology et al. 1994) is assumed to be valid and is not revisited in this study.

2. The *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) (Ecology et al. 1994) adopts as its baseline method the separation of tank waste into HLW and LLW fractions. If it is shown that separating the waste is not the most cost effective manner to treat it, then the Tri-Party Agreement will need to be revised.

3. The TWRS tank waste disposal program strategy is continuing to evolve based on budget constraints and stakeholder input. This study attempts to support this evolution by validating the "constraints" imposed on the Tri-Party Agreement.

1.2 PURPOSE

The purpose of this study is to provide an analysis of strategies for treating the tank waste after retrieval. Separate decision analyses will be conducted to select recommended strategies for treating the retrieved tank wastes. The program baseline strategy may be modified based upon the results of these decision analyses.

1.3 DOCUMENT ORGANIZATION

A brief description of the organization for the remainder of this report is provided as follows:

- **Section 2.0, Summary of Findings**, provides the key findings of the study. A summary of policy constraints and uncertainties that influence the findings is also provided in this section.
- **Section 3.0, Description of Alternatives**, provides a summary level description of the alternatives.
- **Section 4.0, Methodology**, provides a discussion of the methodology used to compare alternatives including a discussion of the performance measures used.
- **Section 5.0, Evaluation of Alternatives**, provides a summary level evaluation of the alternatives described in Section 3.0 using the performance measures discussed in Section 4.0.
- **Section 6.0, References**, provides a list of the referenced documents.

2.0 SUMMARY

This study provides a summary level comparative analysis of selected waste separations alternatives proposed to represent the No Separations, Separations, and Deferred Separations strategies. These alternatives represent the full spectrum of possible strategies for processing retrieved tank wastes based upon full retrieval. Summary level definitions of the alternatives follow. More detailed alternative descriptions may be found in Section 3.0.

- **No Separations** vitrifies all of the tank waste for HLW disposal in an offsite geologic repository.
- **Separations** separates the tank waste into HLW and LLW fractions via physical and/or chemical means and vitrifies both fractions. The HLW fraction will be shipped to a geologic repository and the LLW fraction will be disposed of onsite.
- **Deferred Separations** treats the tank wastes to an intermediate form to await development of the final treatment options.

The treatment method (if any), the immobilization method, and the location for ultimate disposal of the HLW and LLW fractions will be addressed in future studies (see Figure 1-1, Architectures 4.2.3.2 and 4.2.3.3, 4.2.3.4, and 4.2.3.5, and 4.2.4 respectively).

To be consistent with the first two alternatives (ultimate disposal of all tank waste), two sub-alternatives will be included with the Deferred Separations alternative. Sub-alternative #1 will be the assumption that the intermediate material will meet HLW product specifications and can be shipped to the repository for final disposal. Sub-alternative #2 will assume that the intermediate material will be "retrieved" from the storage containers some time in the future, run through the baseline Separations process, and disposed of as HLW (geologic repository) and LLW (onsite).

2.1 SUMMARY FINDINGS FOR ALTERNATIVES

This section provides a discussion of the technical findings associated with the alternatives. Table 2-1 summarizes the performance of the alternatives with respect to eight identified performance measures (performance measures are defined in Section 4.0). More detailed evaluations of the alternatives are contained in Section 5.0 of this report.

The following technical findings are derived from the performance evaluation of the three separations alternatives. All dollar figures are in constant 1995 dollars:

Table 2-1. Performance Evaluation Summary.

Alternative	Cost	Schedule	Operability/ maintainability	Safety	Environmental	Technical maturity	Complexity of interfaces
No Separations	TEC[1] = 2.6 Life-Cycle = 20.0	Can meet all existing Tri-Party Agreement schedule objectives.	Determined to have the lowest level of complexity.	No unique issues identified.	HLW = 140,000 m^3 LLW = 0 m^3	Utilizes mature technologies. Is dependant on scale-up of vitrification operations.	Process consists of single, simple facility.
Separations	TEC[1] = 3.3 Life-Cycle = 12.1	Can meet all existing Tri-Party Agreement schedule objectives.	Determined to have higher complexity than No Separations, but lower complexity than Deferred Separations coupled with sub-alternative #2.	Increased handling of tank waste over No Separations leads to increased safety risks.	HLW = 8,600 m^3 LLW[2] = 220,000 m^3 LLW product will meet all near surface disposal requirements.	Utilizes mature technologies. Is dependant on scale-up of vitrification operations.	Multiple facilities and unit operations increases risk of interface problems and operations interruptions.
Deferred Separations Plus Sub-alternative #1	TEC[1] = 2.6 Life-Cycle = 19.4	Can meet all existing Tri-Party Agreement schedule objectives.	Direct comparison unable to be made due the dissimilarity between unit operations. Large number of calciners (60) will lead to problems.	Calciners will have lower operating temperatures. Final waste form will be dispersable and water soluble.	HLW = 120,000 m^3 LLW = 0 m^3	Dependent on development of calcination process.	Process consists of single, simple facility. Process is dependant on scale-up of calciner operations.
Deferred Separations Plus Sub-alternative #2	TEC[1] = 5.4 Life-Cycle = 22.2	Projected to miss existing milestones for final disposal of tank wastes.	Perceived to have the highest complexity due to reprocessing of the intermediate waste form.	Increased handling of tank waste leads to increased safety risks.	HLW = 8,600 m^3 LLW[2] = 220,000 m^3 LLW product will meet all near surface disposal requirements.	Dependent on development of calcination process.	Multiple facilities and unit operations increases risk of interface problems and operations interruptions.

HLW = High-level waste
LLW = Low-level waste
[1]TEC = Total Estimated Cost. Is equal to the sum of all direct construction costs (i.e., equipment, materials, and labor) plus program and construction management, engineering, and contingency.
[2]LLW form is glass in a polymer/sulfur matrix. Waste form has a volume percentage ration of 70/30 glass to polymer/sulfur.

- The Separations option results in a life-cycle (overall) cost savings of $7.9 billion over No Separations, $7.3 billion over Deferred Separations coupled with sub-alternative #1, and $10.1 billion over Deferred Separations coupled with sub-alternative #2.

  - The Separations option results in a total estimated cost (TEC) (see Table 2-1 for definition) increase of $0.7 billion over No Separations and Deferred Separations coupled with sub-alternative #1. A TEC savings of $2.1 billion is realized for Separations over Deferred Separations coupled with sub-alternative #2.

  - The Separations option results in an operating cost increase of $0.3 billion over No Separations. It also results in a operating cost savings of $3.3 billion over Deferred Separations coupled with sub-alternative #1 and $8.0 billion over Deferred Separations coupled with sub-alternative #2.

  - The Separations option results in a repository cost savings of $8.9 billion over No Separations and $4.7 billion over Deferred Separations coupled with sub-alternative #1. There is no assumed repository cost difference between Separations and Deferred Separations coupled with sub-alternative #2.

- The Separations, No Separations, and Deferred Separations with sub-alternative #1 options are capable of meeting all existing Tri-Party Agreement schedule objectives.

- The No Separations option has the least amount of technical uncertainty based on the performance measures evaluated.

This page intentionally left blank.

3.0 DESCRIPTION OF PROCESS STRATEGIES

The three alternatives addressed in this study are as follows:

1. **No Separations** is the treatment of all of the tank waste for HLW disposal. This option is consistent with the Tri-Party Agreement alternative for No Separations being considered in the *No Separations Data Package for the Tank Waste Remediation System Environmental Impact Statement* (TWRS EIS) (Colby 1995).

2. **Separations** is the separation of the tank waste via many different treatment options. However, to simplify the scope of this document, the only separations process evaluated will be the enhanced sludge wash separations process as outlined in the *Determine Waste Separations Process Trade Study* (Slaathaug 1995b). Although alternative LLW forms are acceptable, only glass will be considered as the final waste form for HLW and LLW to simplify the calculations.

3. **Deferred Separations** is the treatment of the tank wastes to an intermediate form to await development of the final treatment options. Only calcination will be included in this option. The reason for this is calcination is one of the treatment alternative investigated in the draft of the TWRS EIS and it meets the requirement of "treatment to an intermediate form." The calcine, unlike grout, ceramic, or glass, will be easily retrieved and will more readily allow for further separations if desired. Also, to simplify the calculations, the calcine option will treat all the tank waste. It will not allow for separation of the tank wastes, calcination of one of the fractions (HLW or LLW), and immobilization of the other (vitrification).

   The treatment process information will be consistent with the Calcine/Cask option outlined in the TOR (Boomer et al. 1993).

   To be consistent with alternatives 1 and 2 (ultimate disposal of all tank waste), two sub-alternatives will be included with this alternative. Sub-alternative #1 will be the assumption that the calcined material will meet the current HLW product specifications or that the current specifications will be altered so that the calcined material can be shipped to the repository for final disposal. Sub-alternative #2 will be that the calcined material will be "retrieved" from the storage containers some time in the future, processed through the Separations process (alternative #2 above), and disposed of as HLW and LLW.

This section provides a description of the three process strategies considered in this study. Also, included in this section are process specific uncertainties and constraints.

3.1 DESCRIPTION OF ALTERNATIVES

This section provides a summary of each of the processing strategies. The summary descriptions include the integration of LLW and HLW treatment processes for completeness where appropriate. The support systems such as offgas and condensate treatment processes will be nearly identical for all of the strategies and, therefore, are not considered a discriminating factor, and will not be included in the descriptions. However, the relative size of the streams requiring treatment will be included in the evaluation of the performance measures.

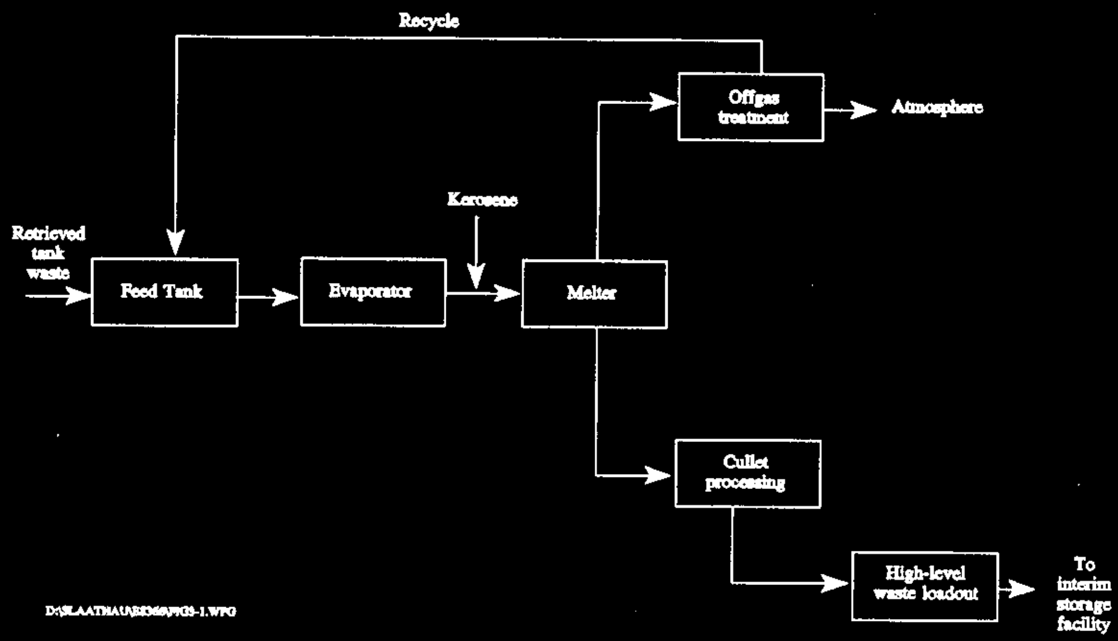
3.1.1 No Separations

The No Separations process discussed in this section is based upon the process employed by the No Separations alternative in the TWRS EIS data package (Colby 1995). A block flow diagram of this process is shown in Figure 3-1.

The No Separations alternative does not separate the tank waste into high and low level fractions. The retrieved waste enters the facility, combines with several recycle streams, and undergoes concentration in an evaporator. The concentrated waste solutions are mixed with the glass forming additives and fed simultaneously into a kerosene fired combustion melter(s) where they are vitrified. The glass product contains an average sodium oxide loading of 25 wt% with minor other components. Due to the relatively large volume of HLW per day estimated to be produced, a high production rate process (glass cullet) has been assumed. The glass is water quenched and crushed to form pea-sized cullet. The cullet is then placed into canisters, sealed, and sent to the cask storage pad(s) to await shipment to the HLW repository.

3.1.1.1 No Separations Facility Configuration Overview. The facility configuration used to represent the No Separations strategy consists of a single facility located in a central complex along with the necessary common support facilities (i.e., steam, water, compressed air, offices, shops, etc.). This is consistent with the configuration used in the No Separations TWRS EIS data package (Colby 1995).

Figure 3-1. No Separations Block Diagram.



3.1.2 Separations

There are many possible processing schemes for separating the waste into LLW and HLW fractions. These schemes range from just solid/liquid separations to solid/liquid separations coupled with ion exchange, organic destruction, caustic leaching, acid dissolution, solvent extraction, gel separations, and/or melter based separations. To add to this complexity, these operations can be accomplished in the facility or out of the facility and in different order. To simplify the task of this document the comparison will be based primarily on the current baseline separations process outlined in Ecology et al. 1994, WHC 1994, WHC 1995a, and Slaathaug 1995a and b. The baseline separations process will consist of the following elements:

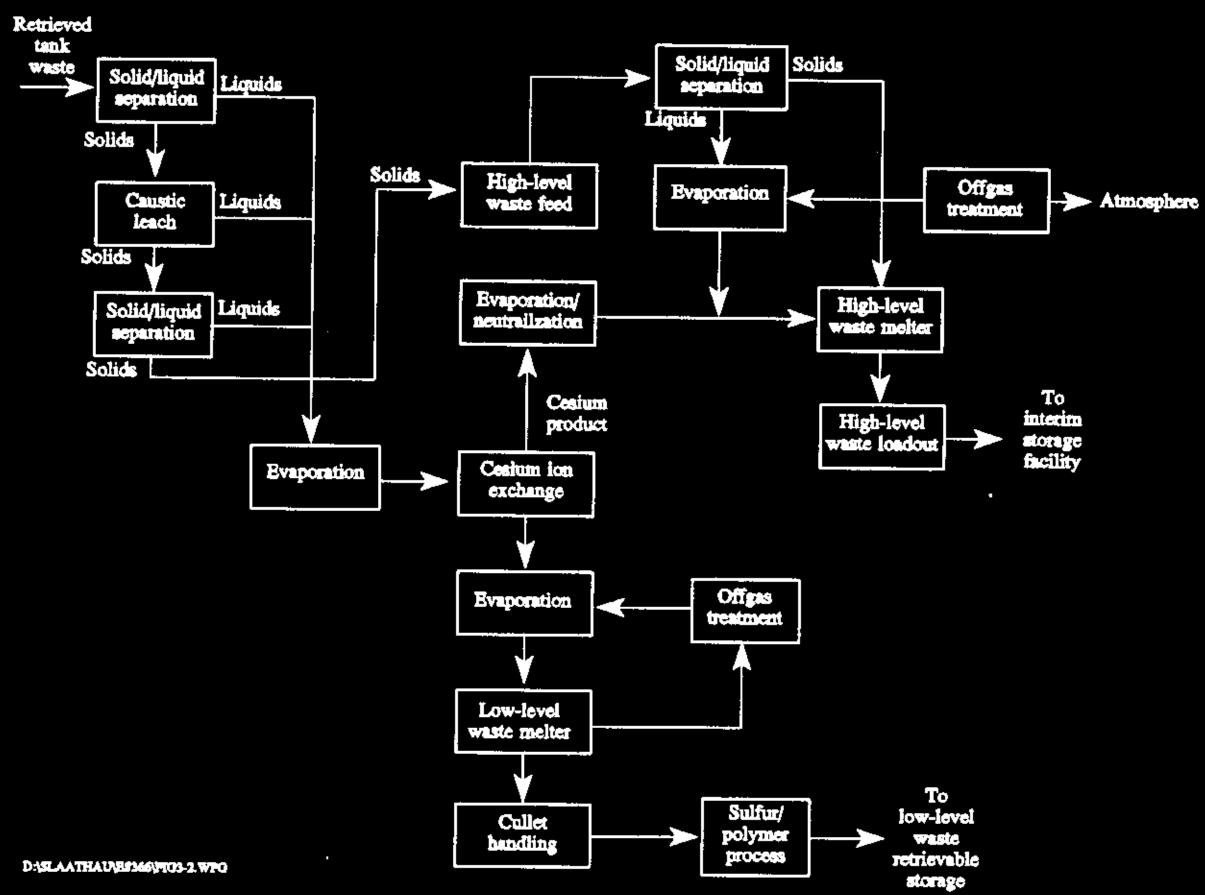
- Solid/Liquid Separations
- Blending of Tank Wastes
- Sludge Washing (i.e., water washing of solids/sludges)
- Caustic Leaching (i.e., enhanced sludge washing [ESW] of solids/sludges)
- Cesium Ion Exchange.

A block flow diagram of this process is shown in Figure 3-2. As can be seen from Figure 1-1, the comparison of this separations process to more advanced separations processes will be performed during the evaluation of sub-functions 4.2.3.2 and 4.2.3.3.

In the Separations process the tank waste undergoes an initial solid/liquid separations step before being leached with sodium hydroxide. Experiments with samples of Hanford Site tank wastes have shown that increased solubility of waste components such as aluminum, phosphate, and chromium may be achieved by leaching tank waste sludges with sodium hydroxide solutions (Colton 1994). The remaining solids are processed through a series of washing and solid/liquid separation steps before being routed to the HLW treatment section. The solubilized/leached waste components along with the supernatant are combined and concentrated before being routed to the ion exchange section where cesium is removed. The removed cesium stream is concentrated and neutralized before being routed to HLW treatment. The remaining waste stream is routed to the LLW treatment section.

In the LLW treatment section the waste stream combines with recycle streams and is concentrated. The concentrated LLW and glass formers feed into a melter where the streams combine to form glass. The glass exits the melter, passes through a water quench, a crushing stage, and enters into a cullet quench tank. The glass cools further in the quench tank water resulting in pea sized fractured glass or cullet. The cullet is screened to remove fines and transferred to a lag storage area. The glass cullet from lag storage is combined with a sulfur/polymer mixture before being packaged in 11-m^3 containers. The containers are then transferred to retrievable storage in 5,300-m^3 vaults.

Figure 3-2. Separations Block Diagram.



D:\SLAATHAU\ES#366\FIG3-2.WPG

The HLW feed slurry streams pass through waste staging and sampling tanks where sampling and final blending (if necessary) occurs. After sampling, the HLW slurry is transferred to the HLW feed preparation system where it is centrifuged. The resulting centrate and other aqueous recycle streams are then evaporated to dewater the HLW melter feed stream. The concentrated HLWs are recombined with the centrifuged solids and are also combined with the concentrated cesium product from cesium ion exchange. The resulting stream is transferred to the HLW melter feed system where it is mixed with glass formers before being fed to the melter.

The HLW glass stream continuously pours from separator sections downstream of the melter. Glass pours from the melter into canisters. The canisters are welded shut and decontaminated before being loaded in an interim storage cask. The casks are placed on a concrete pad for interim storage until shipment to the HLW repository.

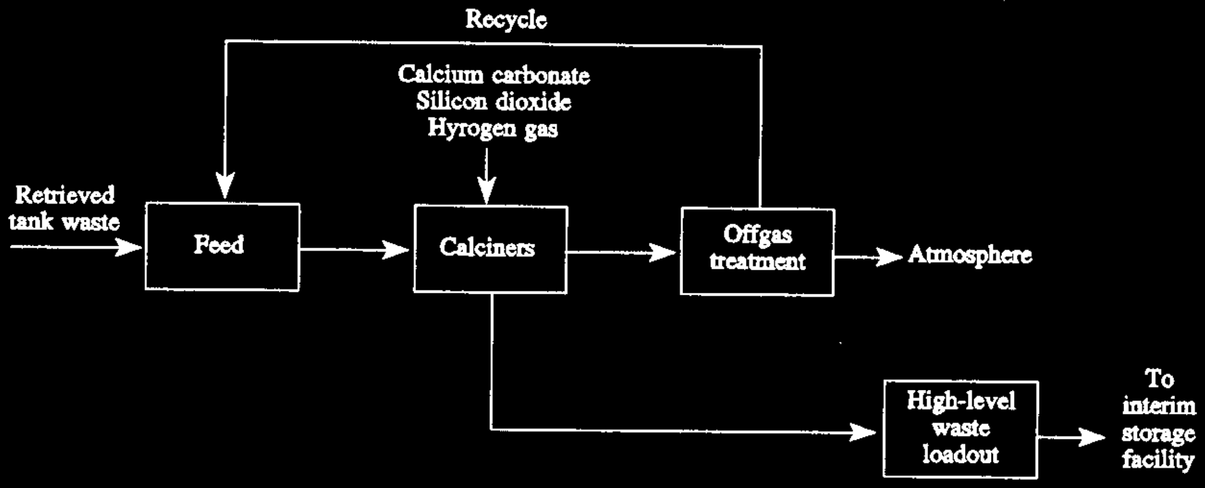
3.1.2.1 Separations Facility Configuration Overview. There are nearly as many facility configurations as processing schemes for separating the waste into LLW and HLW fractions. As stated previously, to simplify the task of this document the comparison will be based primarily on the baseline separations process outlined in the TWRS EIS data package (Slaathaug 1995a) and the updated information contained in the "Determine Waste Separations Process Trade Study" (Slaathaug 1995b).

The facility configuration used to represent Separations consists of three separate/detached facilities (i.e., separations facility, LLW vitrification facility, and HLW vitrification facility). The separations facility will house the solid/liquid separation, sludge washing, caustic leaching, and cesium ion exchange processes with the other two serving solely as vitrification facilities. The three facilities will be located in a central complex and will be served by common support facilities (i.e., steam, water, compressed air, offices, shops, etc.).

3.1.3 Deferred Separations

The thought process behind the Deferred Separations option is the tank waste would be retrieved and then processed to a stable intermediate form until the final treatment alternatives are developed to a sufficient level. In this way the tank wastes would be removed from the tanks and stabilized thereby reducing the impact on the environment from tank leakage and other related tank mishaps if development of the final treatment processes poses excessive delays in retrieval. A simplified block flow diagram of this process is shown in Figure 3-3.

Figure 3-3. Deferred Separations Block Diagram.



D:\SLAATHAU\ES366\FIG3-3.WPG

The Deferred Separations option employed in this report is based upon the Calcine/Cask option defined in the TOR (Boomer et al. 1993). In this option, the retrieved waste slurry is fed into a large bank (60) of hydrogen fueled, fluidized bed calciners. The fluidized bed is comprised of inert silica and solid calcium carbonate (the calcium carbonate is added to reduced the evolution of SO_2). The calcined product overflows the calciners (along with a fraction of the inert bed material) and is pneumatically transported to a collection bin before being loaded into storage casks (approximately 10,000 kg calcined material/cask). The storage casks are then routed by rail to the interim storage facility.

The Deferred Separations option will differ from the Calcine/Cask option in that the CO_2 recovery process (targeted at removing C^{14} from the offgas) will be eliminated. This is done because none of the other options contain a CO_2 recovery process and, therefore, to make a fair comparison, Deferred Separations should not employ one either.

Sub-alternative #1 defined in Section 3.0 will require no further treatment before disposal. For sub-alternative #2 it will be assumed that the final processing scenario will use the present baseline processing scheme as outlined in Section 3.1.2.

3.1.3.1 Deferred Separations Facility Configuration Overview. The facility configuration consists of a single facility served by common support facilities (i.e., steam, air, water, offices, etc.) as outlined in the TOR (Boomer et al. 1993). The facility layout is taken from the TOR and is included in Appendix B.

Sub-alternative #1 defined in Section 3.1 will require no further treatment before disposal and, therefore, will not impact the facility configuration. The final processing configuration for sub-alternative #2 will use the Separations process configuration as outlined in Section 3.1.2.1.

3.2 UNCERTAINTIES

This section provides a discussion of the key technical and policy uncertainties associated with the processing alternatives. Efforts to determine key decisions, risks, and uncertainties for the current TWRS waste disposal strategy in general, and separations alternatives in particular, are documented in a number of sources (Johnson 1994, Johnson 1995, Johnson et al. 1993, and WHC 1995c). The findings and results of this previous work are summarized and supplemented where appropriate in an attempt to provide decision makers with a tool to assess overall separations/pretreatment program risk.

It is not the intent of this study to provide closure on the uncertainties discussed herein since most are beyond the scope of this study, require DOE policy decisions, or require stakeholder involvement.

3.2.1 Policy Constraints and Uncertainties

Table 3-1 summarizes four policy constraints and uncertainties associated with the evaluation of the processing alternatives. Given along with the constraints/uncertainties are brief discussions of each topic plus possible implication of the constraint/uncertainty on the TWRS program. Also, listed in the table are the affected performance measures (see Section 4.2 for definition of measures) and the estimated program risk.

Table 3-1. Policy Constraints and Uncertainties.

Constraint	Affected performance measure	Estimated program risk	Uncertainty/discussion
All wastes contained in single-shell (SSTs) and double-shell tanks (DSTs) will be retrieved for disposal.	Cost Schedule Environmental	Low	The TWRS EIS may result in a record of decision that is different from the reference case.
Retrieved wastes will be separated into low-level and high-level fractions.	Cost Schedule Environmental	Low	If a repository is not available or economically viable, separations may not be warranted.
The HLW waste form will be glass.	Cost Environmental	Low	The making of HLW glass may not be warranted based upon disposal requirements. Based upon regulatory restrictions.
The reference disposal approach is to dispose LLW on site and HLW in a geologic repository	Cost Schedule Environmental	Low	If a repository is not available or funding or transportation issues preclude the use of the repository, the cost to perform separations may not be warranted. Regulatory rather than technical issues drive the need to perform separations.

The first policy constraint is a precursor decision made via the draft TWRS EIS (Ecology 1995) and *Justification of Mission Need* (DOE 1993) (see Figure 1-1). This constraint applies to all processing schemes investigated in this document. The second policy constraint is the one that is being investigated in this document. At this point it serves more as an uncertainty than a constraint. The third constraint applies to all the processing schemes investigated in this document except one, the disposal of the calcined material at the repository. The fourth constraint will be applied to all processes for comparison purposes, but it too serves more as an uncertainty than a constraint.

3.2.2 Technical Issues and Uncertainties

Table 3-2 summarizes the technical issues and uncertainties related to each of the alternatives. These issues/uncertainties have the potential to directly impact the outcome of this evaluation and, therefore, must be addressed before a decision is made.

Table 3-2. Technical Issues and Uncertainties. (2 sheets)

Technical issue	Affected performance measure	Estimated program risk	Uncertainty/discussion
Retrieval rate or sequence may not support the separations schedule.	Cost Schedule	Saltcake: Low Sludge: Medium	The retrieval rate may be lower than necessary to sustain feed to the separations process because the proposed retrieval methods have either not been practiced at the Hanford Site for many years (sluicing) or have not been demonstrated at all (mechanical arm based systems). In this case the disposal program schedule would be negatively impacted and costs would increase. A modeling effort is underway to evaluate retrieval scenarios.
U.S. Nuclear Regulatory Commission (NRC) determination of SST waste classification has not been performed. WHC interpretation of NRC "incidental waste" ruling for DST wastes must be confirmed.	Cost Schedule	Low	It has been assumed that a previous NRC ruling regarding DSTs will be applied to SSTs. If the NRC determination of SST waste classification is significantly different from the ruling on DSTs, additional separation requirements may be necessary. Also if the WHC interpretation of the previous NRC ruling regarding DSTs is not confirmed, higher separation efficiencies may be required. This impacts the Separations case as well as sub-alternative #2 to the Deferred Separations case.
Waste characterization data are needed to validate flowsheet assumptions and determine effectiveness of technologies	Schedule	Low	Flowsheet information and waste volume forecasts are currently based on historical information. Some characterization data are needed to confirm the accuracy of the historical data.
Effectiveness of waste separation technologies to reduce HLW volume must be confirmed	Cost Schedule Environmental	Low	The ability of the Separations processes to achieve forecasted reduction of volumes of HLW has not been confirmed.

Table 3-2. Technical Issues and Uncertainties. (2 sheets)

Technical issue	Affected performance measure	Estimated program risk	Uncertainty/discussion
Limits for the maximum allowable weight percentages of specific as well as total waste oxides in HLW glass must be confirmed.	Cost Environment	Low	This restriction has a direct impact on glass volumes. For example, if No Separations was limited to 12.5 wt% Na_2O (HLW limit for Separations case) instead of 25 wt% the mass (and therefore the volume) would double. However, it should also be noted that the Separations option would require a waste oxide limit of approximately 2.8% to produce as much glass as the No Separations option. The Deferred Separations case has no waste oxide restrictions on its calcine product.
Performance assessment of LLW has not been completed.	Cost Schedule Environmental	Low	The current working assumption is that no radionuclide removal (other than cesium) is required to meet performance assessment (PA) requirements based on preliminary PA information and current waste tank inventories. The current separations design provides capability to add additional radionuclide separations systems and engineered barriers as necessary to meet PA requirements. LLW matrix and barrier systems are being investigated in the event they are needed to achieve PA requirements.

DST = Double-shell tank
ESP = Extensive Separations Process
HLW = High-level waste
MSP = Minimum Separations Process
NRC = U.S. Nuclear Regulatory Commission
PA = Performance Assessment
SST = Single-shell tank.

This page intentionally left blank.

4.0 METHODOLOGY

The purpose of this study is to determine what is the best strategy for processing the wastes, not to define the exact process for accomplishing it. The processing alternatives used in this evaluation should be considered as examples of the treatment schemes, not as the defined process for the treatment schemes.

Alternatives to retrieving all tank wastes are not addressed in this study since this is considered an enabling assumption (i.e., as shown previously in Figure 1-1).

4.1 PERFORMANCE MEASURES

The three alternatives discussed in Section 3.0 will be compared based upon facility and process information developed by knowledgeable Architectural Engineering firms and WHC personnel. These alternatives will be evaluated both quantitatively and qualitatively according to the following performance measures:

- Cost
- Schedule
- Environmental
- Operability
- Maintainability
- Safety
- Technical Maturity
- Complexity of Interfaces.

4.2 DEFINITION OF PERFORMANCE MEASURES

This section provides a definition/description of each of the above performance measures that will be used to evaluate alternatives discussed in this study.

These performance measures have evolved from a previous TWRS Leadership Council (Boomer et al. 1993) and a TWRS Decision Board that was established in 1994 to recommend a TWRS facility configuration (WHC 1994). The performance measures were selected to envelop and consolidate the various stakeholder values (see Table 4-1).

Table 4-1. Stakeholder Values. (2 sheets)

Stakeholder value	Study performance measure
Protect the Columbia River	Indirectly assessed by water use and discharge (although discharges will meet environmental criteria, there may be an impact to migration of existing contamination plumes - this impact is estimated to be minimal)
Deal realistically and forcefully with groundwater contamination	Directly assessed by water discharge, indirectly by operability (i.e., systems that reduce potential for leaks, misroutings, etc.)
Do no harm during cleanup or with new development	Assessed by size and location of facilities.
Transport waste safely and be prepared	Indirectly assessed by quantities of HLW and LLW produced (i.e., less waste produced implies less chance of a handling, storage or transport problem)
Use the central plateau wisely for waste management	Assessed by land used by each alternative
Clean up areas of high future use value	Not assessed
Capture economic development opportunities locally	Not assessed
Involve the public in future decisions about the Hanford Site	This study will be available to the public
Protect the environment	Assessed in safety and environmental performance measures
Protect public/worker health and safety	Assessed in safety, operability, and maintainability performance measures. Also assessed in terms of quantities of hazardous materials handled (i.e., chemical usage).
Establish management practices that ensure accountability, efficiency and allocation of funds to high priority items	Not assessed
"Get on with the cleanup" to achieve substantive progress in a timely manner	Assessed in terms of capability of alternatives to meet Tri-Party Agreement schedule
Use a systems approach that keeps end points in mind as intermediate decisions are made	Systems engineering approach incorporated as part of study methodology
Protect Rights of Native American Indians	Not assessed
Cleanup to the level necessary to enable the future use option to occur	Not assessed
Ensure Compliance	Assessed in terms of Environmental Acceptability performance measure and permitting evaluation.
Do not rely on unproven technology (Enhance technology development)	Assessed indirectly by Technical Maturity Performance measure
Reduce Cost	Directly assessed by cost data for the alternatives
Improve waste management	Assessed by quantities of HLW and LLW produced for each alternative and by qualitative assessment of secondary wastes generated.

Table 4-1. Stakeholder Values. (2 sheets)

Stakeholder value	Study performance measure
Use Mature Technologies	Assessed qualitatively as Technical Maturity performance measure
Enhance public acceptance	Public input will be solicited for this decision
Use open and fair processes	Systems engineering methodology is used as basis for study and public input will be solicited.
Increase efficiency	Assessed by cost data for each alternative and by quantities of key consumables used (i.e., water, chemicals, etc.)

It is important to note that the performance measures represent a mixture of quantitative and qualitative factors. Some of the performance measures, such as cost, represent directly measurable variables that are influenced by qualitative factors because some assumptions are used to develop the costs. Other performance measures, such as operability, are much more dependent on the experience and values of evaluators. Although some decision makers tend to focus on tangible and immediately visible performance measures such as cost and schedule, it should be noted that some of the less tangible performance measures, such as operability and safety, can carry heavy hidden penalties.

For purposes of this report, the cost, schedule, and environmental performance measures are discussed in mostly quantitative terms and are considered the primary discriminating criteria for the alternatives evaluated. The other performance measures will be discussed in mostly qualitative terms and used as a means to understand the uncertainties associated with the alternatives.

4.2.1 Cost

To the extent practical/necessary the equipment, system, or component will be evaluated with respect to capital, operating, repository disposal fee, and life-cycle costs.

4.2.2 Schedule

Schedule impact/risk will be assessed relative to implementation of a given alternative. Schedules to be considered include startup, production, Tri-Party Agreement, and other internally (WHC) or externally (DOE, regulatory, stakeholder) driven schedules.

4.2.3 Operability

Operability of a system is a qualitative measure of the inherent complexity of a system that influences facility operating aspects such as the following:

- **Startup and shutdown of the system.** This is an important operability issue since most upset conditions occur during startup and shutdown when the system is in a state of flux and unsteady state conditions are prevalent. This is heavily influenced by the number of systems or unit operations involved and their operating relationship from a processing viewpoint.

- **Process Control.** Operability with regard to process control is influenced by the number and type of process control points (including process samples).

- **Troubleshooting and response to off-normal conditions.** This factor is influenced by the diversity of systems and equipment. Systems that use simple, mature technologies and equipment are favored over novel and unique technologies and equipment for which there is little operating experience.

- **Operator Interface.** This aspect of operability is influence by such factors as the level of training required to operate the system and the degree, type, and frequency of operator interaction with the system.

4.2.4 Maintainability

The maintainability of a system can be assessed by evaluating the complexity, reliability, and repairability of the associated equipment and components. Complexity is influenced by factors such as the level of training required to perform maintenance on the equipment, the need for special or unique tools or procedures, design qualities such as features that ease repair, standardized parts, and provisions for troubleshooting. Reliability can be directly measured by failure rates/mean time to failure data, but is also associated with frequency of test, calibration, and preventative maintenance procedures. Another key measure of reliability is the impact of failures on the process, including but not limited to recovery or downtime following a failure. Repairability is influenced by work space factors (interferences, confined work spaces, etc.), location of the equipment, means of repair or replacement (remote or contact maintenance), number and type of personnel required to support repairs, pre-maintenance preparation requirements, and post-maintenance impacts such as quantities and types of waste produced, and functional test requirements.

For purposes of this report (at the process level), the operability performance measure captures the maintainability issues for the alternatives considered. Therefore, the maintainability performance measure is not evaluated in detail.

4.2.5 Safety

To the extent practical and meaningful, alternatives should be compared on the bases of associated hazards and implications for onsite/offsite safety, worker safety, and mission and property protection. Topical areas for consideration include the following:

- Hazards
  - Introduction/Creation of Hazards
  - Ease of Hazard Prevention
  - Ease of Hazard Mitigation
- Offsite/Onsite Safety
  - Hazard Categorization
  - Safety Class
  - Performance Category, or Seismic/NPH Criteria
  - Radiological Risk Acceptance Criteria Compliance
  - Toxicological Risk Acceptance Criteria Compliance
- Process and Industrial Safety
  - Health Physics Requirements.
  - Compliance with 6430.1A and Related Industry Standards
- Mission and Property Protection
  - Potential for accident propagation and impacts to other facilities.
  - Potential impacts due to accidents initiated at other facilities.
  - Implications for recovery from accidents expected to occur during the lifetime of the mission.

4.2.6 Environmental

Environmental impacts will be divided into two sub-measures. One will deal with the environmental regulations that must be met and the second will deal with direct impacts on the immediate environment (i.e., volume of HLW and LLW, amount of restricted land usage, etc.).

The environmental (regulatory) impacts of a system can be assessed by evaluating the following factors:

- Liquid effluent generation
- Gaseous effluent generation
- Secondary dangerous waste generation
- Permitting requirements.

Liquid effluent generation is defined as the volume of liquid effluents discharged to the Liquid Effluent Treatment Facility (LETF) and/or the Treated Effluent Disposal Facility (TEDF). Ideally, the volume of liquid effluents should be minimized. The degree of treatment required before discharge to LETF/TEDF is also a factor that should be examined in comparing systems.

Gaseous effluent generation is defined as the rate of emission of regulated pollutants, both radioactive and nonradioactive. Ideally, emission rates should be kept as low as reasonable achievable (ALARA). The degree of treatment required to meet airborne effluent discharge limits is also a factor that should be examined in comparing systems.

Secondary dangerous waste generation is defined as the quantity of wastes (including mixed wastes) generated as a result of the primary processing operation. Secondary dangerous waste generation should be minimized as much as possible. The size and complexities of in-plant secondary waste treatment, dangerous waste packaging and storage, and accumulation areas are factors that should be considered when comparing systems based on secondary waste generation.

Permitting requirements should be evaluated based on the following factors:

- Number of permits required
- Complexity of required permitting documentation
- Potentially required permits or approvals that are unique to the system being examined (example: incinerator regulations potentially applicable to combustion melter)
- Regulatory obstacles (example: applying for an exemption, etc., or seeking a different ruling on a regulation)
- Impacts of permitting activities on the project schedule.

4.2.7 Technical Maturity

The technical maturity of a process, system or piece of equipment can be assessed in terms of the following maturity hierarchy (given in descending order of preference):

1. Technologies that are applied on a production scale in the nuclear industry.
2. Technologies that are applied on a production scale in a conventional commercial industry.
3. Technologies that have been demonstrated on a "hot" or nuclear pilot scale using actual feed materials.

4. Technologies that have been demonstrated on a "cold" or non-nuclear pilot scale using simulated feed materials.

5. Technologies that have been demonstrated on a "hot" or nuclear bench scale using actual feed materials.

6. Technologies that have been demonstrated on a "cold" or non-nuclear bench scale using simulated feed materials.

7. Technologies that are supported by studies that are backed by bench scale experiments.

8. Technologies that are supported by conceptual studies that are not backed by bench scale experiments.

In addition to the hierarchy given above, other factors that influence technical maturity or technology assurance include the following:

- Maximizing flexibility (adaptability for new technologies or mission change)
- Design flexibility or adaptability for incorporating improved technology
- Avoiding regulatory uncertainty.

4.2.8 Complexity of Interfaces

The complexity of facility and function interfaces is assessed by evaluating the following factors to the extent practical:

- **Flowsheet.** Compatibility with reference case and complexity introduced by needed changes.
- **Utilities.** Requirements for support functions and facilities.
- **Siting/Location.** Special requirements or restrictions imposed for siting within the 200 Area or for specific locations within a facility.
- **Constructability.** Special construction constraints or procedures imposed.

This page intentionally left blank.

5.0 EVALUATION OF ALTERNATIVES

This section provides an evaluation of the three treatment schemes with regard to the performance measures discussed in Section 4.2. Process facility configuration and upstream/downstream processes are evaluated only when considered to significantly influence a given performance measure.

The evaluation of the alternatives is mostly based on a summarization of data from previous work. It is not the intent of this document to reconcile differences in absolute values of the data from the reference documents, unless the data are in conflict for a given performance measure, since much of the data are subject to assumptions that still must be verified. This document is intended to be updated and the extent to which quantitative evaluation is meaningful will improve as the data evolve and mature. Therefore, the numbers reported should not be considered final. However, regardless of absolute values, the existing data represent trends that can be used to screen the process alternatives and help focus program resources and priorities.

5.1 COST

This section provides a summary of the costs associated with implementation of each of the separations process strategies and the downstream waste immobilization functions. The costs considered include capital, operating, and disposal costs as discussed in more detail in the following subsections. The Deferred Separations cost summary includes treatment of the waste to an intermediate form only. For it to be on a comparable basis to the other two options, it must be considered as a cost in addition to the cost of one of the sub-options. A summary comparison of these costs is given in Table 5-1.

Table 5-1. Life-Cycle Cost Summary.[1]

Option	Total estimated cost[2]	Operating costs[3]	Repository fee[4]	Total
No Separations	2.6	4.5	12.9	20.0
Separations	3.3	4.8	4.0	12.1
Deferred Separations	2.6	8.1	- -	10.7
Sub-Alternative #1	0	0	8.7	8.7
Sub-Alternative #2	2.8	4.7	4.0	11.5

[1]Excludes other TWRS program costs such as retrieval, tank upgrades, etc. All dollar figures are in billions of 1995 dollars.
[2]From Table 5-2.
[3]From Table 5-3.
[4]From Table 5-5.

5.1.1 Total Estimated Costs

Total Estimated Costs (TEC) are the sum of all direct construction costs (i.e., equipment, materials, and labor) plus any program and construction management, engineering, and contingency costs. The TECs for each of the treatment schemes are given in Table 5-2. The TECs include 40 percent contingency, which is consistent with preconceptual estimates for DOE remotely operated facilities.

Table 5-2. Total Estimated Costs (1995 Dollars).

Alternative	Total estimated cost (millions $)
No Separations	2,610[1]
Separations	3,340[2]
Deferred Separations	2,640[3]
Sub-Alternative #1	0
Sub-Alternative #2	2,820[4]

[1]Colby 1995.
[2]Slaathaug 1995b Table 5-2.
[3]Boomer et al 1993.
[4]Slaathaug 1995b Table 5-2. Excludes the cost for the support facilities that are assumed to already be built for the Deferred Separations facility.

5.1.2 Operating Costs

Table 5-3 shows the life-cycle operating costs for each of the treatment schemes. These costs consist of the following elements:

- Research and Development
- Startup
- Operating Staff
- Consumable Materials and Utilities
- Spares and Equipment
- HLW Storage and Containers
- LLW Containers and Vaults
- Decontamination and Decommissioning (D&D).

Table 5-3. Life-Cycle Operating Costs (millions of 1995 dollars).

Option	R&D	Startup	Staff[3]	Consumables	Spares and Equipment	HLW[4]	LLW[5]	D&D	Total
No Separations[1]	280	190	880	140	210	1,820	0	970	4,490
Separations[2]	630	230	1,450	370	320	240	300	1,230	4,770
Deferred Separations	280	690	3,430	320[6]	210	1,640[7]	0	1,480	8,050
Sub-Alternative #1	.0	0	0	0	0	0	0	0	0
Sub-Alternative #2[8]	630	230	1,450	370	320	120[9]	300	1,230	4,650

[1]Colby 1995.
[2]Slaathaug 1995b Table 5-3.
[3]Table 5-6.
[4]Costs for pads and containers.
[5]Costs for vaults and containers.
[6]Based on raw material costs from Boomer et al 1993 and new material balance (Appendix A).
[7]Table 5-7 for number of canisters.
[8]Slaathaug 1995b Table 5-5 for most information.
[9]Removes costs for pad ($13 million) and shipping casks (1700 @ $60k = $102 million).

A definition of each element and how the value for it was obtained are given below.

Research and Development (R&D). This is the cost for R&D for technology development and applied engineering associated with implementation of a process strategy (includes separations, LLW, and HLW immobilization). These costs are based on those developed for the TWRS EIS engineering data packages (Colby 1995 and Slaathaug 1995a). It is assumed that the R&D cost for the Deferred Separations option is equal to the amount needed for the No Separations option. The R&D cost for sub-alternative #2 will be set equal to the value calculated for Separations.

Startup. This represents the anticipated higher cost with startup of the facility and was estimated by assigning a cost equal to 3 years of peak operating staff cost (Boomer et al. 1994).

Operating Staff. Both direct and indirect staffing is accounted for as is ramp-up and ramp-down as operating modes change. The following labor rates are applied:

- Exempt (E) Staff: $130,000 per year
- Nonexempt (NE) Staff: $60,000 per year
- Bargaining Unit (BU) Staff: $90,000 per year.

The staff estimates for the No Separations process strategy were derived from the TWRS EIS engineering data package for the No Separations option (Colby 1995). The staff estimates are summarized in Table 5-4.

The staff estimates for the Separations process strategy were derived from the Tri-Party Agreement preferred alternative data package (Slaathaug 1995a). The values are given in Table 5-4.

The staff estimates for the Deferred Separations process strategy were taken from the TOR (Boomer et al. 1993) and are summarized in Table 5-4. These numbers may need to be reevaluated to be consistent with the other two alternatives. The staffing values for the sub-alternatives were set equal to the staffing requirements calculated in Slaathaug 1995b.

Consumable Materials and Utilities. This includes the costs for chemicals, steam, water, and electricity used to operate the facilities. These costs are based on those developed for the TWRS EIS engineering data packages (Colby 1995, Slaathaug 1995a) and the TOR (Boomer et al. 1993). The consumables for sub-alternative #2 will be set equal to the values calculated for Separations.

Table 5-4. Staffing Estimates (1995 Dollars)

Process operation	Duration (years)	Labor category				Total per year (millions $)	Total lifetime (millions $)
		Exempt	Nonexempt	Bargaining unit	Total per year		
No Separations[1]	14	227	53	338	618	63.1	883
Separations[2]	16	345	69	463	877	90.7	1,450
Deferred Separations[3]	15	733	428	1198	2359	228.8	3,430
Sub-Alternative #1							0
Sub-Alternative #2[4]							1,450

[1]Colby 1995.

[2]Slaathaug 1995b Table 5-4. The value was calculated by averaging the number of employees from the table for 16 years.

[3]Boomer et al. 1993.

[4]Slaathaug 1995b Table 5-3.

Spares and Equipment. This cost is associated with the periodic replacement of equipment from normal deterioration and failure. These costs are based on those developed for the TWRS EIS engineering data packages (Colby 1995, Slaathaug 1995a). This cost for Deferred Separations was set equal to the cost for the No Separations alternative due to the similarity between the two TECs. The spares and equipment cost for sub-alternative #2 will be set equal to the value calculated for Separations.

HLW Storage and Containers. This cost includes the cost associated with packaging and interim storage of the HLW glass and calciner product. It is assumed that:

- For the No Separations option, the HLW glass cullet will be packaged in an overpack container ($25,000 per container) for interim storage on a HLW storage pad ($13 million per pad [two required]). Each container is then placed in a shipping cask ($60,000 per cask) for transport to the HLW repository.

- For the Separations option, the HLW glass will be packaged in canisters ($10,000 per canister), four canisters will be packaged in an overpack container ($25,000 per container) for interim storage on a HLW storage pad ($13 million per pad [one required]). Each container is then placed in a shipping cask ($60,000 per cask) for transport to the HLW repository.

- For the Deferred Separations option, the calcine product will be packaged in an overpack container ($25,000 per container). Each container is then placed in a shielding cask ($60,000 per cask) before being railed to a interim storage pad ($13 million per pad [two required]).

For Deferred Separations sub-alternative #1 no additional containers will be necessary. For Deferred Separations sub-alternative #2, it will be assumed that the HLW glass will be packaged in canisters ($10,000 per canister) and four canisters will be packaged in an overpack container ($25,000 per container) for interim storage on the HLW storage pads provided for storage of the calcined wastes. Each container is then placed in a shipping cask (the shielding casks used for the calcined waste) for transport to the HLW repository. The overpack containers will need to be repurchased because it is assumed that during the calcine "retrieval" process the containers will be destroyed.

Costs for items were taken from EIS data packages (Colby 1995, Slaathaug 1995a) for the No Separations and the Separations options. For the Deferred Separations options, the canister/cask costs were assumed equal to the costs for the No Separations option as well as the cost and number of the storage pads.

ASPEN+™ flowsheet models were developed for all alternatives. The volume of the product streams for the No Separations option was taken from Colby 1995 and for the Separations options the volumes were taken from Slaathaug 1995b. For the Deferred Separations option the material balance was calculated using the same feed stream as the other two options. The material balance for the Deferred Separations alternative is contained in Appendix A. For sub-alternative #2 of Deferred Separations, the volumes of HLW and LLW will be set equal to the volumes given for the Separations alternative.

LLW Containers and Vaults. This cost includes construction and closure of the vaults and purchase of containers that will be used for retrievable storage of the LLW glass/sulfur cement matrix. A recent trade study (WHC 1995c) indicates that 42 vaults can be constructed and closed at a cost of $95 million. The cost of the 11-m^3 containers is about $10,000 per communication with Raytheon/BNFL staff. The use of 11-m^3 containers was recommended in WHC 1995c and is currently in the *TWRS Reference Flowsheet* (Orme 1995). It is assumed that 435, 11 m^3 containers can be placed in a vault (5,300 m^3/11 m^3 and 90 percent void for containers). See paragraph above for volumes used.

Decontamination and Decommissioning (D&D). This cost was determined by assuming that D&D costs could be approximated by assigning a cost equal to 30 percent of the total TEC (including contingency) plus 3 years of peak operating staff cost (Boomer et al. 1994).

5.1.3 High-Level Waste Repository Costs

The costs associated with disposal of the HLW for each of the treatment alternatives are given in Table 5-5. Most of these costs are based on recent communications with the Office of Civilian Waste Management as stated in the TWRS EIS data packages (Colby 1995, Slaathaug 1995a) and are consistent with the disposal costs reported in the aforementioned data packages. The cost for sub-alternative #1 is interpolated from the cost for the No Separations option and the Separations option.

ASPEN+ is a trademark of Aspen Technology, Inc.

Table 5-5. High-Level Waste Repository Costs (1995 dollars).

Separations option	High-level waste volume (m^3)	Net size of canister/cask	Number of canisters	Canisters per package	Number of packages	Cost (billions)
No Separations[1]	140,000	6.5 m^3	21,400	1	21,400	12.9
Separations[2]	8,600	1.26 m^3	6,800	4	1,700	4.0
Deferred Separations	--	--	--	--	--	--
Sub-Alternative #1[3]	120,000	10 m^3	12,000	1	12,000	8.7[5]
Sub-Alternative #2[4]	8,600	1.26 m^3	6,800	4	1,700	4.0

[1]Colby 1995.
[2]Slaathaug 1995b.
[3]Mass taken from material balance (Appendix A, stream 114) with an assumed specific gravity of 1.0.
[4]Slaathaug 1995b Table 5-5.
[5]Interpolated from No Separations and Separations cost.
= [(12.9B - 4.0B)/(21,400 - 1,700)] * (12,000 - 1,700) + 4.0
= 8.65 B => 8.7 B.

5.2 SCHEDULE

The technical strategy reflected in the Tri-Party Agreement (Ecology et al. 1994) has specific schedules that determine the length of the major TWRS functions. However, since this is a validation of a Level III decision, the milestones that were created under this decision should not be considered limiting. Therefore, the only milestones that are applicable are M-45-04-T01 (start of SST retrieval in 2003) and M-45-05 (completion of SST retrieval in 2018). It is assumed that these milestones will be met regardless of the scheme chosen and, therefore, schedule is determined to not be a discriminating factor. However, it is reasonable to assume that the No Separations and the Separations options will meet the existing milestones (Ecology et al. 1994) for treatment and disposal. Deferred Separations, if coupled with sub-alternative #1, should also meet all existing milestones (Ecology et al. 1994). If it is coupled with sub-alternative #2, however, the existing milestones for treatment and disposal will most likely not be met.

5.3 OPERABILITY

Operability is basically a function of the complexity of one system over another. Since it can be assumed that the Separations process would contain within its unit operations the No Separations unit processes, it will have more operability problems. However, comparing the operability of Deferred Separations to the other two alternatives depends on the sub-alternative chosen. A determination of the relative operability can not be made if Deferred Separations coupled with sub-alternative #1 is chosen (calcine material to HLW repository). This is because comparing processes that are not directly related (melters versus calciners) is dependant on the evaluators experience and point-of-view. Also since the exact process for Separations is not known, its operability can not be readily defined. If sub-alternative #2 is chosen, a comparison can be made since it entails processing the calcined waste to LLW and HLW glass (e.g., this sub-alternative contains the Separations alternative within it). Therefore it inherently has more operability problems than the other two alternatives. However, sub-alternative #2 does have the advantage of time. Since the Separations process is delayed, it has more time to mature and develop. How much of an effect this time will have is unknown.

5.4 MAINTAINABILITY

For purposes of this report, the complexity drivers that apply to operability also apply to maintainability.

5.5 SAFETY

Performance of various facility configurations and process alternatives have been evaluated previously (Boomer et al. 1993, Boomer et al. 1994, and Johnson et al. 1993) to determine the extent to which safety was a discriminator in selecting a preferred alternative. Safety was not found to be a discriminator in any of the work referenced above (i.e., all facilities can be designed to achieve an acceptable level of safety). However, the following observations and trends can be established based on the work to date:

- All facilities, regardless of facility configuration, are regarded as viable since all can be designed to provide adequate prevention and mitigation of radiological and nonradiological hazards. However, the impact of design or operating prevention and mitigation features could influence discrimination of alternatives based on cost. Sufficient design information and detailed analyses are not currently available to quantify this potential cost impact. It can be inferred that the potential cost impact may be greater for more complex processes with a more diverse inventory of hazardous materials than for less complex processes.

- Certain "risk factors" such as maximum potential dose commitment, occupational injuries, and potential exposure to nonradiological hazardous materials increase as a function of the number of workers involved increases. This observation is based on the assumption that all facilities adopt an equivalent maintenance and operating philosophy. The complexity of the facilities also influences the "risk factors" in that increased complexity may require increased worker interaction with the process. Therefore, a more complex process (such as Separations) would carry a higher inherent or statistical risk than smaller, less complex processes (No Separations). However, in all cases the risk can be managed to an acceptable level, although at different levels of engineering design, initial capital investment, operational controls, maintenance and surveillance, etc. In terms of "risk factors" alone, however, there may not be a significant difference in performance of one process over another.

5.6 ENVIRONMENTAL

It is anticipated that all process alternatives can be designed and operated within the bounds of regulatory acceptability. Therefore environmental regulations compliance (in terms of liquid/gaseous effluents and secondary wastes) is not considered a discriminating factor.

The ultimate disposal of the tank waste and the material resource requirements varies between alternatives. One of the alternatives and one of the sub-alternatives disposes part of the tank waste onsite (LLW). It is assumed that the LLW products will meet all regulatory requirements, but there will still be restricted land use near the disposal sites. It is not the intent of this comparison to state that the other alternatives will have zero restricted land use, but instead to state that the alternatives with LLW will have additional restricted areas.

Sub-alternative #2 of Deferred Separations assumes that the calcine material will be accepted by the high level waste repository. This will, in all probability, be an unfounded assumption. The calcine material will be a friable, easily dispersable, water soluble waste form. Upon contact with water it will form an extremely caustic solution (due to the solubilization of sodium dioxide to sodium hydroxide) and will corrode its container and adjacent containers. Since the waste is immobilized by its container (and not by its final form) the waste could be released to the environment.

The volume of the LLW and HLW products and the material usages are compared in Table 5-6.

5.7 TECHNICAL MATURITY

Technical maturity is deemed to not be a discriminating factor. This is because technical maturity relates to the maturity of the unit operations within a process. Since this study is not directed at that level of development, technical maturity will not be evaluated.

5.8 COMPLEXITY OF INTERFACES

Complexity of interface issues can be process or configuration driven or both. Since this document does not define the process nor sets the configurations, complexity of interfaces should not be used as a discriminating factor.

Table 5-6. Material Usage and Resource Requirements.

Alternative	No separations[1]	Separations[2]	Deferred separations		
			Calcine/cask	Sub-alternative #1[3]	Sub-alternative #2[4]
Product Volume (m^3)					
High-level waste	140,000	8,600	- -	120,000	8,600
Low-level waste	0	220,000	- -	0	220,000
Total	140,000	230,000	- -	120,000	230,000
Material Usage					
Water (m^3x1000)	7,300	12,000	7,300[5]	- -	12,000
Electricity (GWh)	4,700	9,000	6,600[6]	- -	9,000
Process Chemicals (MT)	450,000[7]	470,000	85,000[8]	- -	470,000

[1]Colby 1995.
[2]Slaathaug 1995 a and b
[3]Mass for product volume taken from material balance (Appendix A, stream 114) with an assumed specific gravity of 1.0.
[4]Slaathaug 1995b, Tables 5-8 and 5-9.
[5]Arbitrarily set to No Separations water usage. Value is underdeveloped.
[6]Boomer et al. 1993.
[7]Includes oxygen (185,000 MT).
[8]Raw material usage from material balance (Appendix A).

This page intentionally left blank.

6.0 REFERENCES

Boomer, K. D., S. K. Baker, A. L. Boldt, J. D. Galbraith, J. S. Garfield, C. E. Golberg, B. A. Higley, L. J. Johnson, M. J. Kupfer, R. M. Marusich, R. J. Parazin, A. N. Praga, G. W. Reddick, J. A. Reddick, E. J. Slaathaug, L. M. Swanson, T. L. Waldo, and C. E. Worcester, 1993, *Tank Waste Technical Options Report*, WHC-EP-0616, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Boomer, K. D., J. M. Colby, T. W. Crawford, J. S. Garfield, J. D. Galbraith, C. E. Golberg, C. E. Leach, D. E. Mitchell, F. D. Nankani, E. J. Slaathaug, L. M. Swanson, T. L. Waldo, C. M. Winkler, 1994, *Tank Waste Remediation System Facility Configuration Study*, WHC-SD-WM-ES-295, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Colby, S. A., 1995, *No Separations Data Package For The Tank Waste Remediation System Environmental Impact Statement*, WHC-SD-WM-EV-103, Westinghouse Hanford Company, Richland, Washington.

Colton, N. G., 1994, *Sludge Pretreatment Chemistry Evaluation and Enhanced Sludge Separation Factors*, TWRSPP-94-053, Pacific Northwest Laboratory, Richland, Washington.

DOE, 1993, US-DOE, *Justification of Mission Need*, Hanford Site Tank Waste Remediation System to the Energy System Acquisition Advisory Board, January, 1993.

Ecology, EPA, and DOE, 1994, *Hanford Federal Facility Agreement and Consent Order*, as amended, Washington State Department of Ecology, U.S. Environmental Protection Agency, and the U.S. Department of Energy, January, Olympia, Washington.

Ecology and DOE, 1995, *Draft Environmental Impact Statement for the Tank Waste Remediation System*, Draft, Revision A, November 1995, Washington State Department of Ecology and the U.S. Department of Energy, Richland, Washington.

Johnson, M. E., M. L. Grygiel, P. A. Baynes, S. P. Bekemeier, B. D. Zimmerman, and M. B. Triplett, 1993, *Tank Waste Decision Analysis Report*, WHC-EP-0617, Draft, Westinghouse Hanford Company, Richland, Washington.

Johnson, M. E., 1994, *Tank Waste Remediation System Decisions and Risk Assessment*, WHC-EP-0786, Westinghouse Hanford Company, Richland, Washington.

Johnson, L. J., and B. A. Higley, 1995, *Evaluation of Low Level Waste Forms For Immobilization of Hanford Site Tank Wastes*, WHC-SD-WM-ES-319 Draft, Westinghouse Hanford Company, Richland, Washington.

National Environmental Policy Act of 1969, 42 USC 4321 et seq.

Orme, R. M., 1995, *TWRS Reference Flowsheet*, WHC-SD-WM-TI-613, Rev 1, Westinghouse Hanford Company, Richland, Washington.

Slaathaug, E. J., 1995a, *Engineering Data Package for the Tri-Party Agreement Alternative*, WHC-SD-WM-EV-104, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Slaathaug, E. J., 1995b, *Determine Waste Separations Process Trade Study*, WHC-SD-WM-ES-356, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

WHC, 1994, Letter, W. T. Alumkal (WHC) to Distribution, *Tank Waste Remediation System Technical Strategy*, dated April 11, 1994, Westinghouse Hanford Company, Richland, Washington.

WHC, 1995a, *Tank Waste Remediation System Multi-Year Program Plan*, WHC-SP-1101, Rev. 1, September 1995, Westinghouse Hanford Company, Richland, Washington.

WHC, 1995b, *TWRS Functions and Requirements*, WHC-SD-WM-FRD-020, Draft Rev E, December 1995, Westinghouse Hanford Company, Richland, Washington.

WHC, 1995c, *Immobilized Low-Level Waste Disposal Options Configuration Study*, WHC-SD-WM-TI-686, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

APPENDIX A

CALCINE-CASK MATERIAL BALANCE

This page intentionally left blank.

APPENDIX A

CALCINE-CASK MATERIAL BALANCE

The process flow diagram (PFD) for the Calcine-Cask process is shown in Figure A-1. The PFD was taken from the *Tank Waste Technical Options Report* (Boomer et al. 1993). To be consistent with the other options, the material balance was recalculated using the same feed stream as was used with the other options. This material balance is given in Table A-1.

This page intentionally left blank.

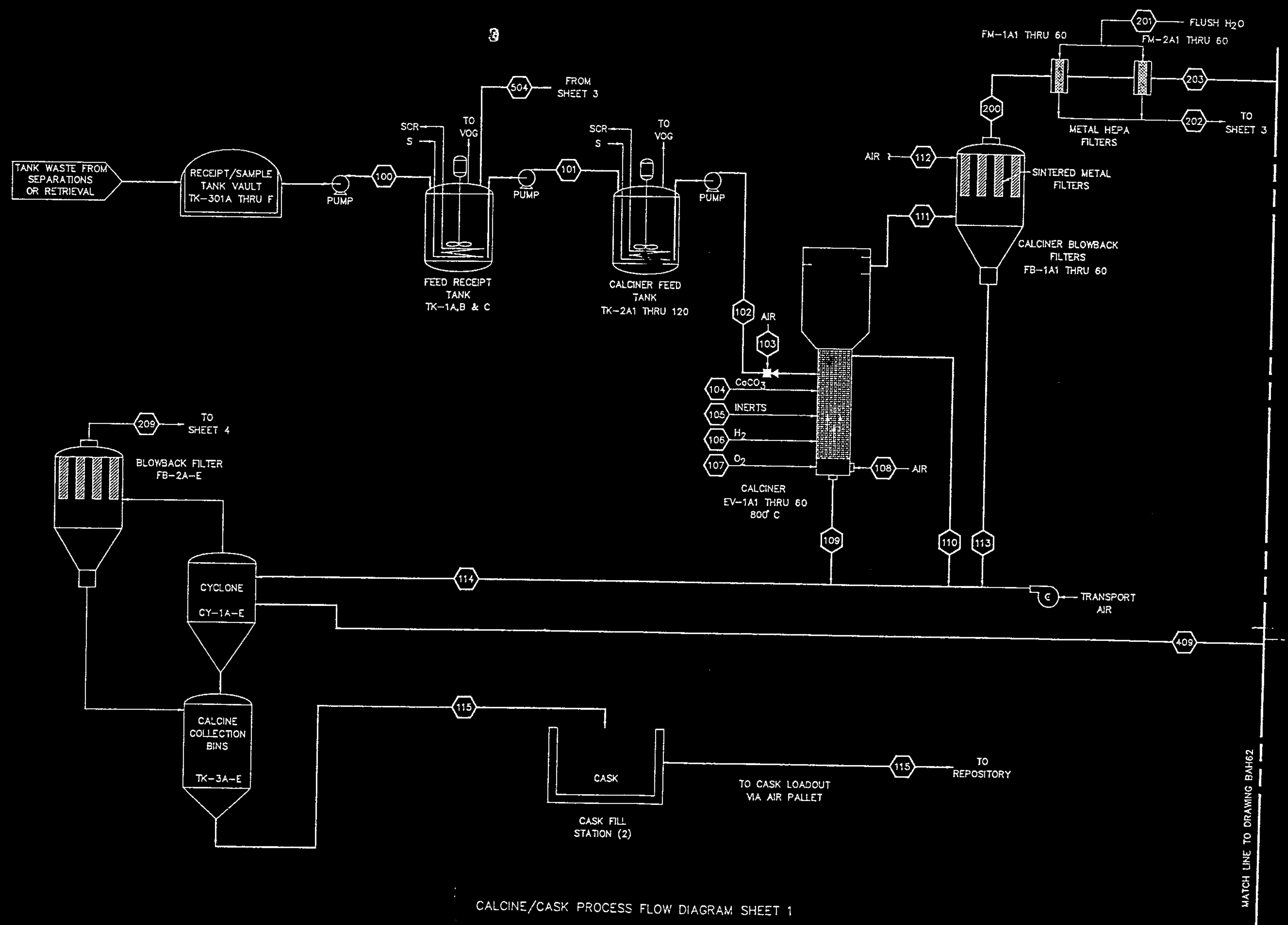


Figure A-1.
Calcine-Cask Process
Flow Diagram.
(Sheet 1 of 4)

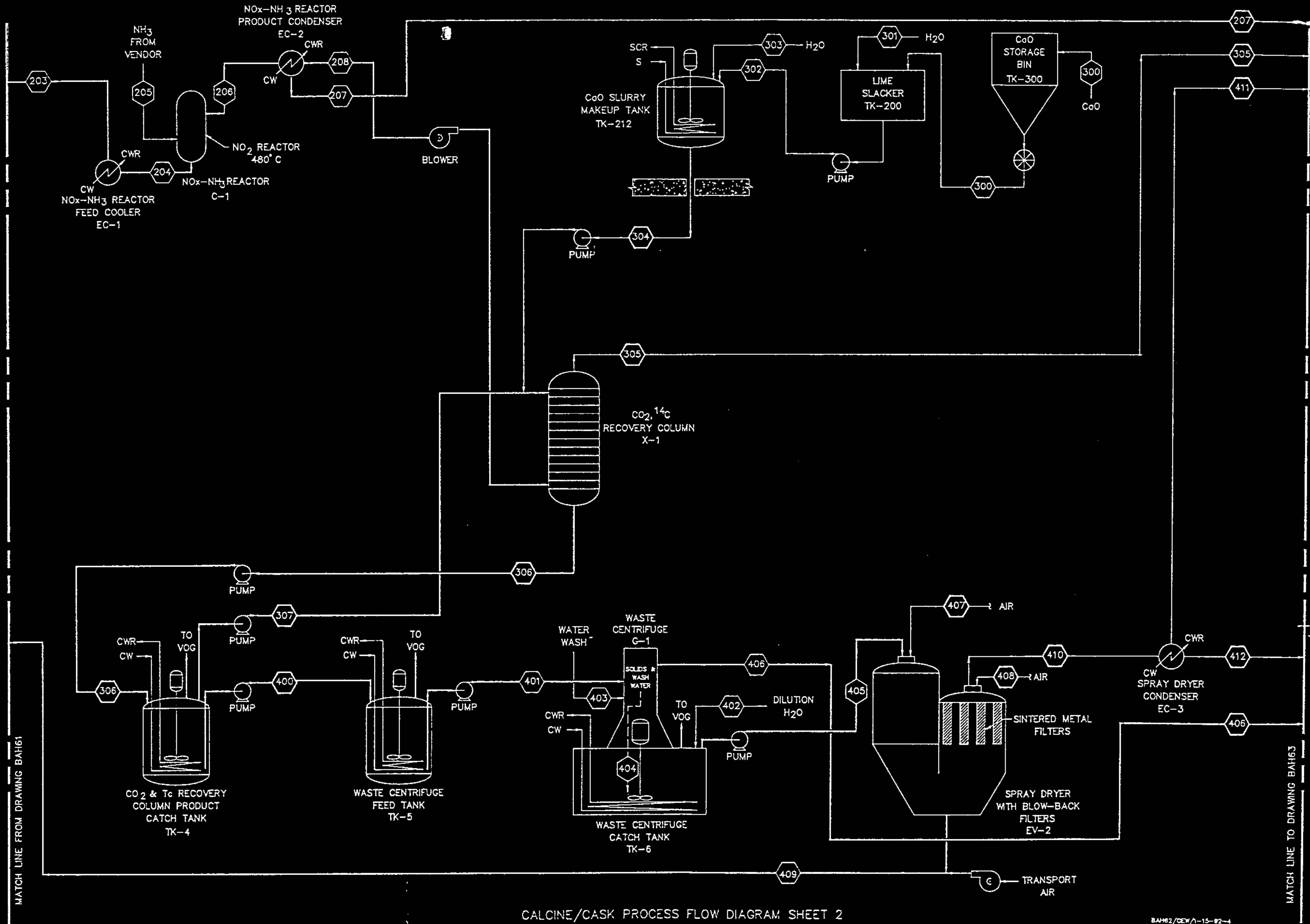


Figure A-1.
Calcine-Cask Process
Flow Diagram.
(Sheet 2 of 4)

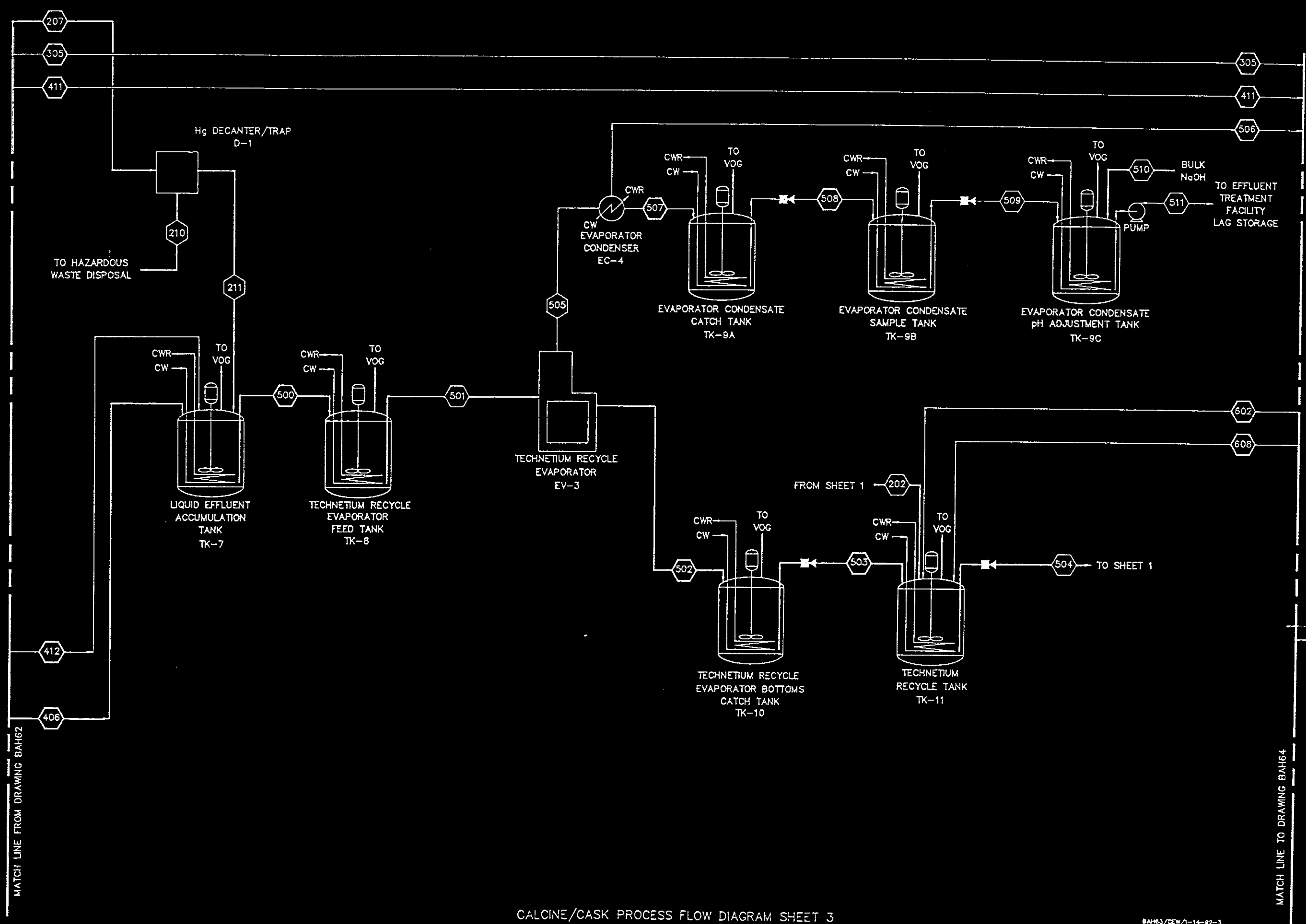


Figure A-1.
Calcine-Cask Process
Flow Diagram.
(Sheet 3 of 4)

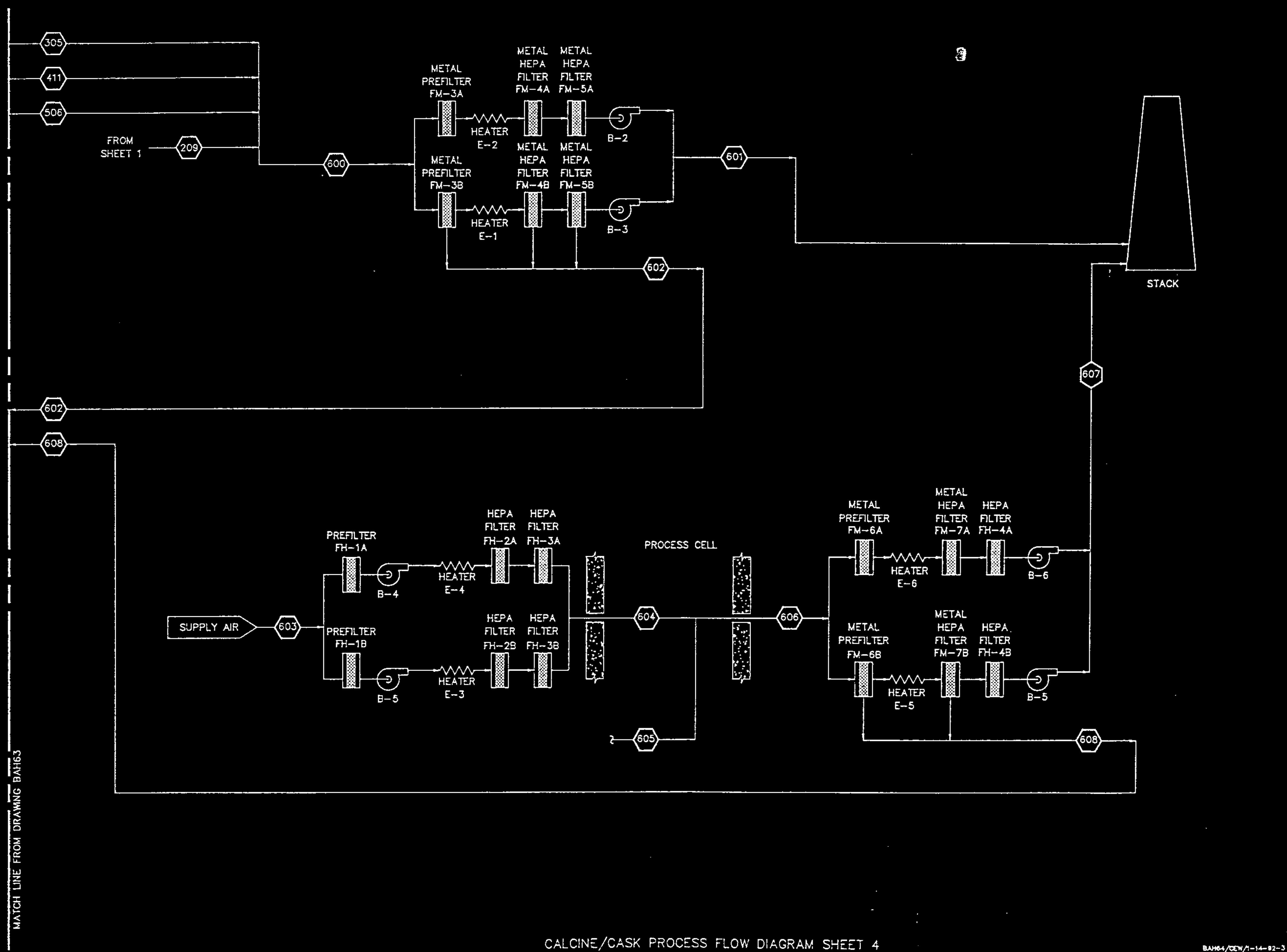


Figure A-1.
Calcine-Cask Process
Flow Diagram.
(Sheet 4 of 4)

Table A-1. Calcine-Cask Material Balance. (Sheet 1 of 14)

STREAM NAME	100	101	102	103	104	105	106	107	108	109
LIQUID COMPONENTS (MT)										
Total Mass Flow	4.27E+05	4.46E+05	4.46E+05	1.22E+05			8.62E+03	6.84E+04	2.19E+06	
AG+	3.28E-01	3.28E-01	3.28E-01							
AM+3	2.51E-03	2.51E-03	2.51E-03							
AS+5	7.70E-01	7.70E-01	7.70E-01							
B+3	5.19E-01	5.19E-01	5.19E-01							
BA+2	7.91E-01	7.91E-01	7.91E-01							
BE+2	8.19E-02	8.19E-02	8.19E-02							
BI+3	6.76E+01	6.76E+01	6.76E+01							
C14	7.43E-04	7.43E-04	7.43E-04							
CA+2	1.67E+01	1.67E+01	1.67E+01							
CD+2	2.09E+00	2.09E+00	2.09E+00							
CE+3	2.37E+00	2.37E+00	2.37E+00							
CL-	3.11E+02	3.11E+02	3.11E+02							
CL2										
CO2										
CO3-2	3.37E+03	3.37E+03	3.37E+03							
CS+	9.18E-02	9.18E-02	9.18E-02							
CU+2	1.77E-01	1.77E-01	1.77E-01							
F-	1.12E+03	1.12E+03	1.12E+03							
F2										
FE+3	1.44E+01	1.44E+01	1.44E+01							
H2										
H2O	2.29E+05	2.47E+05	2.47E+05				8.62E+03			
HG		1.06E+00	1.06E+00							
HG+2	9.49E-01	9.49E-01	9.49E-01							
I-	5.46E+02	5.46E+02	5.46E+02							
I2										
K+	2.19E-01	2.19E-01	2.19E-01							
LA+3	2.19E-01	2.19E-01	2.19E-01							
LI+	5.77E-03	5.77E-03	5.77E-03							
MG+2	9.65E-01	9.65E-01	9.65E-01							
MNO2	2.17E+01	2.17E+01	2.17E+01							
MO+6	4.87E+00	4.87E+00	4.87E+00							
N2				9.66E+04					1.73E+06	
NA+	6.51E+04	6.51E+04	6.51E+04							
NH3										
NI+3	4.07E+00	4.07E+00	4.07E+00							
NO										
NO2										
NO2-	9.54E+03	9.54E+03	9.54E+03							
NO3-	1.06E+05	1.06E+05	1.06E+05							
NP+4	1.46E-02	1.46E-02	1.46E-02							
O2				2.57E+04				6.84E+04	4.59E+05	
OH-	6.44E+03	6.44E+03	6.44E+03							
PB+4	1.96E+00	1.96E+00	1.96E+00							
PO4-3	2.58E+03	2.58E+03	2.58E+03							
PU+4	1.44E-05	1.44E-05	1.44E-05							
SI+4	5.65E+00	5.65E+00	5.65E+00							
SO2										
SO4-2	2.01E+03	2.01E+03	2.01E+03							
SR+2	3.51E-01	3.51E-01	3.51E-01							
TC2O7										
TCO4-	2.51E+00	5.58E+00	5.58E+00							
TOC	1.42E+03	1.42E+03	1.42E+03							
UO2+2	8.52E+01	8.52E+01	8.52E+01							
V+5	6.20E-02	6.20E-02	6.20E-02							
W+6	7.47E-01	7.47E-01	7.47E-01							
ZN+2	3.59E+00	3.59E+00	3.59E+00							
ZR+4	4.48E-01	3.34E+02	3.34E+02							
ZRO2:2H2O	2.15E+01	2.15E+01	2.15E+01							

Table A-1. Calcine-Cask Material Balance. (Sheet 2 of 14)

STREAM NAME	100	101	102	103	104	105	106	107	108	109
SOLID COMPONENTS (MT)										
Total Mass Flow	1.94E+04	2.43E+04	2.43E+04		4.12E+03	7.93E+03				
AG+	1.38E+00	1.38E+00	1.38E+00							
AG2O		1.53E-02	1.53E-02							
AL+3	2.37E+03	2.37E+03	2.37E+03							
AL2O3		3.73E+01	3.73E+01							
AM+3	2.77E-02	2.77E-02	2.77E-02							
AM2O3		2.77E-04	2.77E-04							
AS+5	4.98E-01	4.98E-01	4.98E-01							
AS2O5		1.62E-02	1.62E-02							
B+3	9.94E-01	9.94E-01	9.94E-01							
B2O3		4.06E-02	4.06E-02							
BA+2	3.09E+00	3.09E+00	3.09E+00							
BAO		3.61E-02	3.61E-02							
BE+2	7.61E-03	7.61E-03	7.61E-03							
BEO		2.07E-03	2.07E-03							
BI+3	1.96E+02	1.96E+02	1.96E+02							
BI2O3		2.45E+00	2.45E+00							
C14	4.53E-04	4.53E-04	4.53E-04							
CA+2	1.33E+02	1.33E+02	1.33E+02							
CACO3		1.09E+03	1.09E+03		4.12E+03					
CANCRINITE	2.70E+03	2.70E+03	2.70E+03							
CAO		2.83E+03	2.83E+03							
CASO4		2.36E+01	2.36E+01							
CD+2	7.93E+00	7.93E+00	7.93E+00							
CDO		9.54E-02	9.54E-02							
CE+3	2.35E+02	2.35E+02	2.35E+02							
CE2O3		2.32E+00	2.32E+00							
CL-	3.49E+00	3.49E+00	3.49E+00							
CO3-2	2.25E+02	2.25E+02	2.25E+02							
CR+3	1.32E+02	1.32E+02	1.32E+02							
CR2O3		1.61E+00	1.61E+00							
CS+	3.06E-02	3.06E-02	3.06E-02							
CS2O		1.08E-03	1.08E-03							
CU+2	7.46E-01	7.46E-01	7.46E-01							
CUO		9.64E-03	9.64E-03							
F-	5.97E+01	5.97E+01	5.97E+01							
FE+3	7.63E+02	7.63E+02	7.63E+02							
FE2O3		1.03E+01	1.03E+01							
HG+2	9.00E-03	9.00E-03	9.00E-03							
I-	2.02E+01	2.02E+01	2.02E+01							
K+	2.10E+01	2.10E+01	2.10E+01							
K2O		8.47E-02	8.47E-02							
LA+3	2.10E+01	2.10E+01	2.10E+01							
LA2O3		2.08E-01	2.08E-01							
LI+	2.46E-02	2.46E-02	2.46E-02							
LI2O		5.45E-04	5.45E-04							
MG+2	1.10E+01	1.10E+01	1.10E+01							
MGO		1.66E-01	1.66E-01							
MNO2	2.09E+02	2.11E+02	2.11E+02							
MO+6	8.01E-01	8.01E-01	8.01E-01							
MOO3		7.10E-02	7.10E-02							
NA+	7.77E+02	7.77E+02	7.77E+02							
NA2O		7.41E+02	7.41E+02							
NEPH		7.46E+00	7.46E+00							
NI+3	6.57E+00	6.57E+00	6.57E+00							
NI2FECN6	5.00E+02	5.00E+02	5.00E+02							
NI2O3		4.96E-02	4.96E-02							
NIO		1.89E+00	1.89E+00							
NO2-	7.38E+01	7.38E+01	7.38E+01							
NO3-	1.03E+03	1.03E+03	1.03E+03							
NP+4	1.32E-01	1.32E-01	1.32E-01							
NPO2		1.39E-03	1.39E-03							
OH-	5.00E+03	5.00E+03	5.00E+03							
P2O5		3.10E+01	3.10E+01							
P2O5:24WO2:44H2O	5.21E-01	5.21E-01	5.21E-01							
PB+4	3.28E+00	3.28E+00	3.28E+00							
PBO2		5.05E-02	5.05E-02							
PO4-3	2.39E+03	2.39E+03	2.39E+03							
PU+4	7.12E-04	7.12E-04	7.12E-04							
PUO2		6.87E-06	6.87E-06							
SI+4	7.90E+01	7.90E+01	7.90E+01							
SIO2		6.77E+01	6.77E+01			7.93E+03				
SO4-2	3.97E+01	3.97E+01	3.97E+01							
SR+2	3.47E+01	3.47E+01	3.47E+01							
SRO		3.46E-01	3.46E-01							
TC2O7										
TCO2		2.07E-02	2.07E-02							
TCO4-	5.65E-01	5.65E-01	5.65E-01							
THO2		2.63E-43	2.63E-43							
TOC	1.16E+02	1.16E+02	1.16E+02							
UO2+2	1.58E+03	1.58E+03	1.58E+03							
UO3		1.47E+01	1.47E+01							
V+5	1.88E-01	1.88E-01	1.88E-01							
V2O5		3.72E-03	3.72E-03							
WO2		3.68E-03	3.68E-03							
WO3		7.86E-03	7.86E-03							
ZN+2	9.45E-01	9.45E-01	9.45E-01							
ZNO		4.71E-02	4.71E-02							
ZR+4	2.77E+02	2.78E+02	2.78E+02							
ZRO2		2.78E+00	2.78E+00							
ZRO2:2H2O	4.08E+02	4.08E+02	4.08E+02							

Table A-1. Calcine-Cask Material Balance. (Sheet 3 of 14)

STREAM NAME	110	111	112	113	114	115	200	201	202	203
LIQUID COMPONENTS (MT)										
Total Mass Flow		2.75E+06	1.10E+04		3.48E+05		2.76E+06		3.42E+03	2.76E+06
AG+										
AM+3										
AS+5										
B+3										
BA+2										
BE+2										
BI+3										
C14										
CA+2										
CD+2										
CE+3										
CL-										
CL2		3.15E+02					3.15E+02			3.15E+02
CO2		8.89E+03					8.89E+03			8.89E+03
CO3-2										
CS+										
CU+2										
F-										
F2		1.18E+03					1.18E+03			1.18E+03
FE+3										
H2										
H2O		3.33E+05					3.33E+05		3.42E+03	3.29E+05
HG		2.02E+00					2.02E+00			2.02E+00
HG+2										
I-										
I2		5.66E+02					5.66E+02			5.66E+02
K+										
LA+3										
LI+										
MG+2										
MNO2										
MO+6										
N2		1.85E+06	8.66E+03		2.75E+05		1.86E+06			1.86E+06
NA+										
NH3										
NI+3										
NO		3.14E+02					3.14E+02			3.14E+02
NO2		1.34E+04					1.34E+04			1.34E+04
NO2-										
NO3-										
NP+4										
O2		5.41E+05	2.30E+03		7.31E+04		5.44E+05			5.44E+05
OH-										
PB+4										
PO4-3										
PU+4										
SI+4										
SO2		5.27E+02					5.27E+02			5.27E+02
SO4-2										
SR+2										
TC2O7		2.94E+00					2.94E+00			2.94E+00
TCO4-										
TOC										
UO2+2										
V+5										
W+6										
ZN+2										
ZR+4		3.34E+02					3.34E+02			3.34E+02
ZRO2:2H2O										

Table A-1. Calcine-Cask Material Balance. (Sheet 4 of 14)

STREAM NAME	110	111	112	113	114	115	200	201	202	203
SOLID COMPONENTS (MT)										
Total Mass Flow	7.93E+04	3.91E+04		3.87E+04	1.18E+05	1.84E+05	3.91E+02		3.80E+02	1.04E+01
AG+										
AG2O	1.24E+00	6.09E-01		6.03E-01	1.84E+00	1.83E+00	6.09E-03		6.06E-03	3.05E-05
AL+3										
AL2O3	3.02E+03	1.49E+03		1.47E+03	4.50E+03	4.47E+03	1.49E+01		1.48E+01	7.44E-02
AM+3										
AM2O3	2.25E-02	1.11E-02		1.10E-02	3.34E-02	3.32E-02	1.11E-04		1.10E-04	5.53E-07
AS+5										
AS2O5	1.31E+00	6.47E-01		6.41E-01	1.96E+00	1.95E+00	6.47E-03		6.44E-03	3.24E-05
B+3										
B2O3	3.29E+00	1.62E+00		1.61E+00	4.90E+00	4.87E+00	1.62E-02		1.61E-02	8.11E-05
BA+2										
BAO	2.93E+00	1.44E+00		1.43E+00	4.36E+00	4.33E+00	1.44E-02		1.44E-02	7.21E-05
BE+2										
BEO	1.68E-01	8.27E-02		8.18E-02	2.50E-01	2.48E-01	8.27E-04		8.23E-04	4.13E-06
BI+3										
BI2O3	1.99E+02	9.78E+01		9.68E+01	2.95E+02	2.94E+02	9.78E-01		9.73E-01	4.89E-03
C14										
CA+2										
CACO3						1.87E+04				
CANCRINITE										
CAO	2.04E+03	1.00E+03		9.94E+02	3.03E+03	5.07E+04	1.00E+01		9.99E+00	5.02E-02
CASO4	1.21E+03	5.95E+02		5.89E+02	1.80E+03	1.79E+03	5.95E+00		5.92E+00	2.97E-02
CD+2										
CDO	7.73E+00	3.81E+00		3.77E+00	1.15E+01	1.14E+01	3.81E-02		3.79E-02	1.90E-04
CE+3										
CE2O3	1.88E+02	9.26E+01		9.17E+01	2.80E+02	2.78E+02	9.26E-01		9.22E-01	4.63E-03
CL-										
CO3-2										
CR+3										
CR2O3	1.31E+02	6.43E+01		6.37E+01	1.94E+02	1.93E+02	6.43E-01		6.40E-01	3.22E-03
CS+										
CS2O	8.76E-02	4.32E-02		4.27E-02	1.30E-01	1.30E-01	4.32E-04		4.29E-04	2.16E-06
CU+2										
CUO	7.81E-01	3.85E-01		3.81E-01	1.16E+00	1.16E+00	3.85E-03		3.83E-03	1.92E-05
F-										
FE+3										
FE2O3	8.33E+02	4.10E+02		4.06E+02	1.24E+03	1.23E+03	4.10E+00		4.08E+00	2.05E-02
HG+2										
I-										
K+										
K2O	1.72E+01	8.47E+00		8.38E+00	2.56E+01	2.56E+01	8.47E-02			8.47E-02
LA+3										
LA2O3	1.68E+01	8.28E+00		8.20E+00	2.50E+01	2.49E+01	8.28E-02		8.24E-02	4.14E-04
LI+										
LI2O	4.41E-02	2.17E-02		2.15E-02	6.56E-02	6.53E-02	2.17E-04		2.16E-04	1.09E-06
MG+2										
MGO	1.34E+01	6.60E+00		6.54E+00	1.99E+01	1.98E+01	6.60E-02		6.57E-02	3.30E-04
MNO2	1.56E+02	7.68E+01		7.60E+01	2.32E+02	2.31E+02	7.68E-01		7.64E-01	3.84E-03
MO+6										
MOO3	5.75E+00	2.83E+00		2.80E+00	8.55E+00	8.51E+00	2.83E-02		2.82E-02	1.42E-04
NA+										
NA2O	6.00E+04	2.96E+04		2.93E+04	8.93E+04	8.89E+04	2.96E+02		2.94E+02	1.48E+00
NEPH	1.51E+03	7.46E+02		7.38E+02	2.25E+03	2.25E+03	7.46E+00			7.46E+00
NI+3										
NI2FECN6										
NI2O3	1.01E+01	4.96E+00		4.91E+00	1.50E+01	1.50E+01	4.96E-02			4.96E-02
NIO	1.53E+02	7.55E+01		7.47E+01	2.28E+02	2.27E+02	7.55E-01		7.51E-01	3.77E-03
NO2-										
NO3-										
NP+4										
NPO2	1.12E-01	5.53E-02		5.47E-02	1.67E-01	1.66E-01	5.53E-04		5.50E-04	2.76E-06
OH-										
P2O5	2.51E+03	1.24E+03		1.22E+03	3.73E+03	3.71E+03	1.24E+01		1.23E+01	6.18E-02
P2O5:24WO2:44H2O										
PB+4										
PBO2	4.09E+00	2.01E+00		1.99E+00	6.08E+00	6.05E+00	2.01E-02		2.00E-02	1.01E-04
PO4-3										
PU+4										
PUO2	5.57E-04	2.74E-04		2.71E-04	8.28E-04	8.24E-04	2:74E-06		2.73E-06	1.37E-08
SI+4										
SIO2	5.60E+03	2.76E+03		2.73E+03	8.32E+03	8.28E+03	2.76E+01		2.74E+01	1.38E-01
SO4-2										
SR+2										
SRO	2.80E+01	1.38E+01		1.37E+01	4.17E+01	4.15E+01	1.38E-01		1.37E-01	6.90E-04
TC2O7										
TCO2	1.68E+00	8.26E-01		8.18E-01	2.50E+00	2.48E+00	8.26E-03			8.26E-03
TCO4-										
THO2										
TOC										
UO2+2										
UO3	1.19E+03	5.86E+02		5.81E+02	1.77E+03	1.76E+03	5.86E+00		5.84E+00	2.93E-02
V+5										
V2O5	3.01E-01	1.48E-01		1.47E-01	4.48E-01	4.46E-01	1.48E-03		1.48E-03	7.42E-06
WO2	2.98E-01	1.47E-01		1.45E-01	4.44E-01	4.41E-01	1.47E-03		1.46E-03	7.34E-06
WO3	6.37E-01	3.14E-01		3.10E-01	9.47E-01	9.42E-01	3.14E-03		3.12E-03	1.57E-05
ZN+2										
ZNO	3.81E+00	1.88E+00		1.86E+00	5.67E+00	5.64E+00	1.88E-02		1.87E-02	9.39E-05
ZR+4	1.86E+02	9.17E+01		9.07E+01	2.77E+02	2.77E+02	9.17E-01			9.17E-01
ZRO2	2.25E+02	1.11E+02		1.10E+02	3.34E+02	3.33E+02	1.11E+00		1.10E+00	5.54E-03
ZRO2:2H2O										

Table A-1. Calcine-Cask Material Balance. (Sheet 5 of 14)

STREAM NAME	204	205	206	207	208	209	210	211	300	301
LIQUID COMPONENTS (MT)										
Total Mass Flow	2.76E+06	6.85E+03	2.76E+06	3.24E+05	2.44E+06	3.52E+05	9.58E-01	3.24E+05		1.70E+05
AG+										
AM+3										
AS+5										
B+3										
BA+2										
BE+2										
BI+3										
C14										
CA+2										
CD+2										
CE+3										
CL-										
CL2	3.15E+02		3.15E+02		3.15E+02					
CO2	8.89E+03		8.89E+03		8.89E+03					
CO3-2										
CS+										
CU+2										
F-										
F2	1.18E+03		1.18E+03		1.18E+03					
FE+3										
H2										
H2O	3.29E+05		3.40E+05	3.23E+05	1.70E+04			3.23E+05		1.70E+05
HG	2.02E+00		2.02E+00	1.92E+00	1.01E-01		9.58E-01	9.58E-01		
HG+2										
I-										
I2	5.66E+02		5.66E+02		5.66E+02					
K+										
LA+3										
LI+										
MG+2										
MNO2										
MO+6										
N2	1.86E+06		1.87E+06		1.87E+06	2.78E+05				
NA+										
NH3		6.85E+03	6.87E+01	6.19E+01	6.87E+00			6.19E+01		
NI+3										
NO	3.14E+02		3.14E-01		3.14E-01					
NO2	1.34E+04		1.39E+02		1.39E+02					
NO2-										
NO3-										
NP+4										
O2	5.44E+05		5.43E+05		5.43E+05	7.40E+04				
OH-										
PB+4										
PO4-3										
PU+4										
SI+4										
SO2	5.27E+02		5.27E+02		5.27E+02					
SO4-2										
SR+2										
TC2O7	2.94E+00		2.94E+00		2.94E-02					
TCO4-				3.04E+00				3.04E+00		
TOC										
UO2+2										
V+5										
W+6										
ZN+2										
ZR+4	3.34E+02		3.34E+02	3.34E+02				3.34E+02		
ZRO2:2H2O										

Table A-1. Calcine-Cask Material Balance. (Sheet 6 of 14)

STREAM NAME	204	205	206	207	208	209	210	211	300	301
SOLID COMPONENTS (MT)										
Total Mass Flow	1.04E+01		1.04E+01	9.34E+00	1.09E+00	9.10E+02		9.34E+00	5.66E+04	
AG+										
AG2O	3.05E-05		3.05E-05	1.31E-05	1.74E-05	9.20E-03		1.31E-05		
AL+3										
AL2O3	7.44E-02		7.44E-02	3.20E-02	4.24E-02	2.25E+01		3.20E-02		
AM+3										
AM2O3	5.53E-07		5.53E-07	2.38E-07	3.15E-07	1.67E-04		2.38E-07		
AS+5										
AS2O5	3.24E-05		3.24E-05	1.39E-05	1.84E-05	9.77E-03		1.39E-05		
B+3										
B2O3	8.11E-05		8.11E-05	3.49E-05	4.62E-05	2.45E-02		3.49E-05		
BA+2										
BAO	7.21E-05		7.21E-05	3.10E-05	4.11E-05	2.18E-02		3.10E-05		
BE+2										
BEO	4.13E-06		4.13E-06	1.78E-06	2.36E-06	1.25E-03		1.78E-06		
BI+3										
BI2O3	4.89E-03		4.89E-03	2.10E-03	2.79E-03	1.48E+00		2.10E-03		
C14										
CA+2										
CACO3						9.38E+01				
CANCRINITE										
CAO	5.02E-02		5.02E-02	2.16E-02	2.86E-02	2.55E+02		2.16E-02	5.66E+04	
CASO4	2.97E-02		2.97E-02	1.28E-02	1.69E-02	8.98E+00		1.28E-02		
CD+2										
CDO	1.90E-04		1.90E-04	8.19E-05	1.09E-04	5.75E-02		8.19E-05		
CE+3										
CE2O3	4.63E-03		4.63E-03	1.99E-03	2.64E-03	1.40E+00		1.99E-03		
CL-										
CO3-2										
CR+3										
CR2O3	3.22E-03		3.22E-03	1.38E-03	1.83E-03	9.71E-01		1.38E-03		
CS+										
CS2O	2.16E-06		2.16E-06	1.94E-06	2.16E-07	6.52E-04		1.94E-06		
CU+2										
CUO	1.92E-05		1.92E-05	8.27E-06	1.10E-05	5.81E-03		8.27E-06		
F-										
FE+3										
FE2O3	2.05E-02		2.05E-02	8.82E-03	1.17E-02	6.19E+00		8.82E-03		
HG+2										
I-										
K+										
K2O	8.47E-02		8.47E-02	8.47E-02				8.47E-02		
LA+3										
LA2O3	4.14E-04		4.14E-04	1.78E-04	2.36E-04	1.25E-01		1.78E-04		
LI+										
LI2O	1.09E-06		1.09E-06	4.67E-07	6.19E-07	3.28E-04		4.67E-07		
MG+2										
MGO	3.30E-04		3.30E-04	1.42E-04	1.88E-04	9.97E-02		1.42E-04		
MNO2	3.84E-03		3.84E-03	1.65E-03	2.19E-03	1.16E+00		1.65E-03		
MO+6										
MOO3	1.42E-04		1.42E-04	6.09E-05	8.07E-05	4.28E-02		6.09E-05		
NA+										
NA2O	1.48E+00		1.48E+00	6.36E-01	8.43E-01	4.47E+02		6.36E-01		
NEPH	7.46E+00		7.46E+00	7.46E+00				7.46E+00		
NI+3										
NI2FECN6										
NI2O3	4.96E-02		4.96E-02	4.96E-02				4.96E-02		
NIO	3.77E-03		3.77E-03	1.62E-03	2.15E-03	1.14E+00		1.62E-03		
NO2-										
NO3-										
NP+4										
NPO2	2.76E-06		2.76E-06	1.19E-06	1.58E-06	8.35E-04		1.19E-06		
OH-										
P2O5	6.18E-02		6.18E-02	2.66E-02	3.52E-02	1.87E+01		2.66E-02		
P2O5:24WO2:44H2O										
PB+4										
PBO2	1.01E-04		1.01E-04	4.33E-05	5.74E-05	3.04E-02		4.33E-05		
PO4-3										
PU+4										
PUO2	1.37E-08					4.14E-06				
SI+4										
SIO2	1.38E-01		1.38E-01	5.93E-02	7.85E-02	4.16E+01		5.93E-02		
SO4-2										
SR+2										
SRO	6.90E-04		6.90E-04	2.97E-04	3.93E-04	2.08E-01		2.97E-04		
TC2O7										
TCO2	8.26E-03		8.26E-03	8.26E-03		1.25E-02		8.26E-03		
TCO4-										
THO2										
TOC										
UO2+2										
UO3	2.93E-02		2.93E-02	1.26E-02	1.67E-02	8.86E+00		1.26E-02		
V+5										
V2O5	7.42E-06		7.42E-06	3.19E-06	4.23E-06	2.24E-03		3.19E-06		
WO2	7.34E-06		7.34E-06	3.16E-06	4.19E-06	2.22E-03		3.16E-06		
WO3	1.57E-05		1.57E-05	6.74E-06	8.94E-06	4.74E-03		6.74E-06		
ZN+2										
ZNO	9.39E-05		9.39E-05	4.04E-05	5.35E-05	2.84E-02		4.04E-05		
ZR+4	9.17E-01		9.17E-01	9.17E-01				9.17E-01		
ZRO2	5.54E-03		5.54E-03	2.38E-03	3.16E-03	1.67E+00		2.38E-03		
ZRO2:2H2O										

Table A-1. Calcine-Cask Material Balance. (Sheet 7 of 14)

STREAM NAME	302	303	304	305	306	307	400	401	402	403
LIQUID COMPONENTS (MT)										
Total Mass Flow	1.70E+05		1.70E+05	2.41E+06	1.00E+06	8.16E+05	2.00E+05	2.00E+05	1.85E+05	2.10E+05
AG+										
AM+3										
AS+5										
B+3										
BA+2										
BE+2										
BI+3										
C14										
CA+2										
CD+2										
CE+3										
CL-										
CL2				3.15E+02						
CO2				8.89E+02						
CO3-2										
CS+										
CU+2										
F-										
F2				1.18E+03						
FE+3										
H2										
H2O	1.70E+05		1.70E+05	1.00E+03	1.00E+06	8.16E+05	2.00E+05	2.00E+05	1.85E+05	2.10E+05
HG					5.04E-01	4.04E-01	1.01E-01	1.01E-01		
HG+2										
I-										
I2				5.66E+02						
K+										
LA+3										
LI+										
MG+2										
MNO2										
MO+6										
N2				1.87E+06						
NA+										
NH3				1.43E+00	2.72E+01	2.18E+01	5.44E+00	5.44E+00		
NI+3										
NO				3.14E-01						
NO2				1.39E+02						
NO2-										
NO3-										
NP+4										
O2				5.43E+05						
OH-										
PB+4										
PO4-3										
PU+4										
SI+4										
SO2				5.27E+02						
SO4-2										
SR+2										
TC2O7				2.94E-04						
TCO4-					1.52E-01	1.22E-01	3.04E-02	3.04E-02		
TCC										
UO2+2										
V+5										
W+6										
ZN+2										
ZR+4										
ZRO2:2H2O										

Table A-1. Calcine-Cask Material Balance. (Sheet 8 of 14)

STREAM NAME	302	303	304	305	306	307	400	401	402	403
SOLID COMPONENTS (MT)										
Total Mass Flow	5.66E+04		5.66E+04		3.51E+05	2.86E+05	7.01E+04	7.01E+04		
AG+										
AG2O					8.68E-05	6.94E-05	1.74E-05	1.74E-05		
AL+3										
AL2O3					2.12E-01	1.70E-01	4.24E-02	4.24E-02		
AM+3										
AM2O3					1.58E-06	1.26E-06	3.15E-07	3.15E-07		
AS+5										
AS2O5					9.22E-05	7.38E-05	1.84E-05	1.84E-05		
B+3										
B2O3					2.31E-04	1.85E-04	4.62E-05	4.62E-05		
BA+2										
BAO					2.06E-04	1.64E-04	4.11E-05	4.11E-05		
BE+2										
BEO					1.18E-05	9.42E-06	2.36E-06	2.36E-06		
BI+3										
BI2O3					1.39E-02	1.11E-02	2.79E-03	2.79E-03		
C14										
CA+2										
CACO3					9.87E+04	8.05E+04	1.97E+04	1.97E+04		
CANCRINITE										
CAO	5.66E+04		5.66E+04		2.52E+05	2.06E+05	5.04E+04	5.04E+04		
CASO4					1.07E-01	8.98E-02	2.14E-02	2.14E-02		
CD+2										
CDO					5.43E-04	4.34E-04	1.09E-04	1.09E-04		
CE+3										
CE2O3					1.32E-02	1.06E-02	2.64E-03	2.64E-03		
CL-										
CO3-2										
CR+3										
CR2O3					9.16E-03	7.33E-03	1.83E-03	1.83E-03		
CS+										
CS2O					1.08E-06	8.63E-07	2.16E-07	2.16E-07		
CU+2										
CUO					5.48E-05	4.38E-05	1.10E-05	1.10E-05		
F-										
FE+3										
FE2O3					5.84E-02	4.68E-02	1.17E-02	1.17E-02		
HG+2										
I-										
K+										
K2O										
LA+3										
LA2O3					1.18E-03	9.44E-04	2.36E-04	2.36E-04		
LI+										
LI2O					3.10E-06	2.48E-06	6.19E-07	6.19E-07		
MG+2										
MGO					9.41E-04	7.53E-04	1.88E-04	1.88E-04		
MNO2					1.09E-02	8.75E-03	2.19E-03	2.19E-03		
MO+6										
MOO3					4.03E-04	3.23E-04	8.07E-05	8.07E-05		
NA+										
NA2O					4.21E+00	3.37E+00	8.43E-01	8.43E-01		
NEPH										
NI+3										
NI2FECN6										
NI2O3										
NIO					1.08E-02	8.60E-03	2.15E-03	2.15E-03		
NO2-										
NO3-										
NP+4										
NPO2					7.87E-06	6.30E-06	1.58E-06	1.58E-06		
OH-										
P2O5					1.76E-01	1.41E-01	3.52E-02	3.52E-02		
P2O5:24WO3:44H2O										
PB+4										
PBO2					2.87E-04	2.30E-04	5.74E-05	5.74E-05		
PO4-3										
PU+4										
PUO2						4.30E-40				
SI+4										
SIO2					3.89E-01	3.11E-01	7.78E-02	7.78E-02		
SO4-2										
SR+2										
SRO					1.97E-03	1.57E-03	3.93E-04	3.93E-04		
TC2O7						8.92E-42				
TCO2										
TCO4-										
THO2										
TOC										
UO2+2										
UO3					8.36E-02	6.69E-02	1.67E-02	1.67E-02		
V+5										
V2O5					2.12E-05	1.69E-05	4.23E-06	4.23E-06		
WO2					2.09E-05	1.67E-05	4.19E-06	4.19E-06		
WO3					4.47E-05	3.57E-05	8.94E-06	8.94E-06		
ZN+2										
ZNO					2.68E-04	2.14E-04	5.35E-05	5.35E-05		
ZR+4										
ZRO2					1.58E-02	1.26E-02	3.16E-03	3.16E-03		
ZRO2:2H2O										

Table A-1. Calcine-Cask Material Balance. (Sheet 9 of 14)

STREAM NAME	404	405	406	407	408	409	410	411	412	500
LIQUID COMPONENTS (MT)										
Total Mass Flow	1.69E+04	2.02E+05	3.94E+05	5.46E+04	1.10E+04	4.38E+03	2.68E+05	7.56E+04	1.92E+05	9.09E+05
AG+										
AM+3										
AS+5										
B+3										
BA+2										
BE+2										
BI+3										
C14										
CA+2										
CD+2										
CE+3										
CL-										
CL2										
CO2										
CO3-2										
CS+										
CU+2										
F-										
F2										
FE+3										
H2										
H2O	1.69E+04	2.02E+05	3.94E+05				2.02E+05	1.01E+04	1.92E+05	9.09E+05
HG	4.15E-03	4.15E-03	9.67E-02				4.15E-03	2.07E-04	3.94E-03	1.06E+00
HG+2										
I-										
I2										
K+										
LA+3										
LI+										
MG+2										
MNO2										
MO+6										
N2				4.31E+04	8.66E+03	3.46E+03	5.18E+04	5.18E+04		
NA+										
NH3	2.24E-01	2.24E-01	5.22E+00				2.24E-01	2.24E-01		6.71E+01
NI+3										
NO										
NO2										
NO2-										
NO3-										
NP+4										
O2				1.15E+04	2.30E+03	9.21E+02	1.38E+04	1.38E+04		
OH-										
PB+4										
PO4-3										
PU+4										
SI+4										
SO2										
SO4-2										
SR+2										
TC2O7										
TCO4-	1.25E-03	1.25E-03	2.92E-02				1.25E-03		1.25E-03	3.07E+00
TOC										
UO2+2										
V+5										
W+6										
ZN+2										
ZR+4										3.34E+02
ZRO2:2H2O										

Table A-1. Calcine-Cask Material Balance. (Sheet 10 of 14)

STREAM NAME	404	405	406	407	408	409	410	411	412	500
SOLID COMPONENTS (MT)										
Total Mass Flow	6.73E+04	6.73E+04	2.81E+03			6.67E+04	6.73E+02	3.84E+02	2.90E+02	3.10E+03
AG+										
AG2O	1.67E-05	1.67E-05	6.94E-07			1.65E-05	1.67E-07	9.50E-08	7.17E-08	1.39E-05
AL+3										
AL2O3	4.07E-02	4.07E-02	1.70E-03			4.03E-02	4.07E-04	2.32E-04	1.75E-04	3.39E-02
AM+3										
AM2O3	3.03E-07	3.03E-07	1.26E-08			3.00E-07	3.03E-09			2.50E-07
AS+5										
AS2O5	1.77E-05	1.77E-05	7.38E-07			1.75E-05	1.77E-07	1.01E-07	7.61E-08	1.47E-05
B+3										
B2O3	4.44E-05	4.44E-05	1.85E-06			4.39E-05	4.44E-07	2.53E-07	1.91E-07	3.69E-05
BA+2										
BAO	3.95E-05	3.95E-05	1.64E-06			3.91E-05	3.95E-07	2.25E-07	1.70E-07	3.28E-05
BE+2										
BEO	2.26E-06	2.26E-06	9.42E-08			2.24E-06	2.26E-08	1.29E-08	9.73E-09	1.88E-06
BI+3										
BI2O3	2.68E-03	2.68E-03	1.11E-04			2.65E-03	2.68E-05	1.53E-05	1.15E-05	2.23E-03
C14										
CA+2										
CACO3	1.90E+04	1.90E+04	7.90E+02			1.88E+04	1.90E+02	1.08E+02	8.15E+01	8.71E+02
CANCRINITE										
CAO	4.84E+04	4.84E+04	2.02E+03			4.79E+04	4.84E+02	2.76E+02	2.08E+02	2.22E+03
CASO4	2.05E-02	2.05E-02	8.54E-04			2.03E-02	2.05E-04	1.17E-04	8.81E-05	1.37E-02
CD+2										
CDO	1.04E-04	1.04E-04	4.34E-06			1.03E-04	1.04E-06	5.94E-07	4.48E-07	8.67E-05
CE+3										
CE2O3	2.53E-03	2.53E-03	1.06E-04			2.51E-03	2.53E-05	1.44E-05	1.09E-05	2.11E-03
CL-										
CO3-2										
CR+3										
CR2O3	1.76E-03	1.76E-03	7.33E-05			1.74E-03	1.76E-05	1.00E-05	7.56E-06	1.46E-03
CS+										
CS2O	2.07E-07	2.07E-07	8.63E-09			2.05E-07	2.07E-09			1.95E-06
CU+2										
CUO	1.05E-05	1.05E-05	4.38E-07			1.04E-05	1.05E-07	6.00E-08	4.52E-08	8.75E-06
F-										
FE+3										
FE2O3	1.12E-02	1.12E-02	4.68E-04			1.11E-02	1.12E-04	6.40E-05	4.82E-05	9.33E-03
HG+2										
I-										
K+										
K2O										8.47E-02
LA+3										
LA2O3	2.27E-04	2.27E-04	9.44E-06			2.24E-04	2.27E-06	1.29E-06	9.74E-07	1.88E-04
LI+										
LI2O	5.95E-07	5.95E-07	2.48E-08			5.89E-07	5.95E-09	3.39E-09	2.56E-09	4.95E-07
MG+2										
MGO	1.81E-04	1.81E-04	7.53E-06			1.79E-04	1.81E-06	1.03E-06	7.77E-07	1.50E-04
MNO2	2.10E-03	2.10E-03	8.75E-05			2.08E-03	2.10E-05	1.20E-05	9.03E-06	1.75E-03
MO+6										
MOO3	7.75E-05	7.75E-05	3.23E-06			7.67E-05	7.75E-07	4.42E-07	3.33E-07	6.44E-05
NA+										
NA2O	8.09E-01	8.09E-01	3.37E-02			8.01E-01	8.09E-03	4.61E-03	3.48E-03	6.73E-01
NEPH										7.46E+00
NI+3										
NI2FECN6										
NI2O3										4.96E-02
NIO	2.06E-03	2.06E-03	8.60E-05			2.04E-03	2.06E-05	1.18E-05	8.88E-06	1.72E-03
NO2-										
NO3-										
NP+4										
NPO2	1.51E-06	1.51E-06	6.30E-08			1.50E-06	1.51E-08			1.25E-06
OH-										
P2O5	3.38E-02	3.38E-02	1.41E-03			3.35E-02	3.38E-04	1.93E-04	1.45E-04	2.81E-02
P2O5:24WO2:44H2O										
PB+4										
PBO2	5.51E-05	5.51E-05	2.30E-06			5.45E-05	5.51E-07	3.14E-07	2.37E-07	4.58E-05
PO4-3										
PU+4										
PUO2										
SI+4										
SIO2	7.47E-02	7.47E-02	3.11E-03			7.40E-02	7.47E-04	4.26E-04	3.21E-04	6.27E-02
SO4-2										
SR+2										
SRO	3.78E-04	3.78E-04	1.57E-05			3.74E-04	3.78E-06	2.15E-06	1.62E-06	3.14E-04
TC2O7										
TCO2										8.26E-03
TCO4-										
THO2										
TOC										
UO2+2										
UO3	1.60E-02	1.60E-02	6.69E-04			1.59E-02	1.60E-04	9.15E-05	6.90E-05	1.34E-02
V+5										
V2O5	4.06E-06	4.06E-06	1.69E-07			4.02E-06	4.06E-08	2.31E-08	1.75E-08	3.38E-06
WO2	4.02E-06	4.02E-06	1.67E-07			3.98E-06	4.02E-08			3.32E-06
WO3	8.58E-06	8.58E-06	3.57E-07			8.49E-06	8.58E-08	4.89E-08	3.69E-08	7.14E-06
ZN+2										
ZNO	5.14E-05	5.14E-05	2.14E-06			5.09E-05	5.14E-07	2.93E-07	2.21E-07	4.27E-05
ZR+4										9.17E-01
ZRO2	3.03E-03	3.03E-03	1.26E-04			3.00E-03	3.03E-05	1.73E-05	1.30E-05	2.52E-03
ZRO2:2H2O										

Table A-1. Calcine-Cask Material Balance. (Sheet 11 of 14)

STREAM NAME	501	502	503	504	505	506	507	508	509	510
LIQUID COMPONENTS (MT)										
Total Mass Flow	9.09E+05	9.35E+03	9.63E+03	1.89E+04	9.00E+05	9.01E+04	8.10E+05	8.34E+05	8.59E+05	6.88E+02
AG+										
AM+3										
AS+5										
B+3										
BA+2										
BE+2										
BI+3										
C14										
CA+2										
CD+2										
CE+3										
CL-										
CL2										
CO2										
CO3-2										
CS+										
CU+2										
F-										
F2										
FE+3										
H2										
H2O	9.09E+05	9.01E+03	9.29E+03	1.86E+04	9.00E+05	9.00E+04	8.10E+05	8.34E+05	8.59E+05	3.44E+02
HG	1.06E+00	1.06E+00	1.06E+00	1.06E+00						
HG+2										
I-										
I2										
K+										
LA+3										
LI+										
MG+2										
MNO2										
MO+6										
N2										
NA+										1.98E+02
NH3	6.71E+01				6.71E+01	6.71E+01				
NI+3										
NO										
NO2										
NO2-										
NO3-										
NP+4										
O2										
OH-										1.46E+02
PB+4										
PO4-3										
PU+4										
SI+4										
SO2										
SO4-2										
SR+2										
TC2O7										
TCO4-	3.07E+00	3.07E+00	3.07E+00	3.07E+00						
TOC										
UO2+2										
V+5										
W+6										
ZN+2										
ZR+4	3.34E+02	3.34E+02	3.34E+02	3.34E+02						
ZRO2:2H2O										

Table A-1. Calcine-Cask Material Balance. (Sheet 12 of 14)

STREAM NAME	501	502	503	504	505	506	507	508	509	510
SOLID COMPONENTS (MT)										
Total Mass Flow	3.10E+03	3.10E+03	3.10E+03	4.87E+03						
AG+										
AG2O	1.39E-05	1.39E-05	1.39E-05	1.53E-02						
AL+3										
AL2O3	3.39E-02	3.39E-02	3.39E-02	3.73E+01						
AM+3										
AM2O3	2.50E-07	2.50E-07	2.50E-07	2.77E-04						
AS+5										
AS2O5	1.47E-05	1.47E-05	1.47E-05	1.62E-02						
B+3										
B2O3	3.69E-05	3.69E-05	3.69E-05	4.06E-02						
BA+2										
BAO	3.28E-05	3.28E-05	3.28E-05	3.61E-02						
BE+2										
BEO	1.88E-06	1.88E-06	1.88E-06	2.07E-03						
BI+3										
BI2O3	2.23E-03	2.23E-03	2.23E-03	2.45E+00						
C14										
CA+2										
CACO3	8.71E+02	8.71E+02	8.71E+02	1.09E+03						
CANCRINITE										
CAO	2.22E+03	2.22E+03	2.22E+03	2.83E+03						
CASO4	1.37E-02	1.37E-02	1.37E-02	2.36E+01						
CD+2										
CDO	8.67E-05	8.67E-05	8.67E-05	9.54E-02						
CE+3										
CE2O3	2.11E-03	2.11E-03	2.11E-03	2.32E+00						
CL-										
CO3-2										
CR+3										
CR2O3	1.46E-03	1.46E-03	1.46E-03	1.61E+00						
CS+										
CS2O	1.95E-06	1.95E-06	1.95E-06	1.08E-03						
CU+2										
CUO	8.75E-06	8.75E-06	8.75E-06	9.64E-03						
F-										
FE+3										
FE2O3	9.33E-03	9.33E-03	9.33E-03	1.03E+01						
HG+2										
I-										
K+										
K2O	8.47E-02	8.47E-02	8.47E-02	8.47E-02						
LA+3										
LA2O3	1.88E-04	1.88E-04	1.88E-04	2.08E-01						
LI+										
LI2O	4.95E-07	4.95E-07	4.95E-07	5.45E-04						
MG+2										
MGO	1.50E-04	1.50E-04	1.50E-04	1.66E-01						
MNO2	1.75E-03	1.75E-03	1.75E-03	1.92E+00						
MO+6										
MOO3	6.44E-05	6.44E-05	6.44E-05	7.10E-02						
NA+										
NA2O	6.73E-01	6.73E-01	6.73E-01	7.41E+02						
NEPH	7.46E+00	7.46E+00	7.46E+00	7.46E+00						
NI+3										
NI2FECN6										
NI2O3	4.96E-02	4.96E-02	4.96E-02	4.96E-02						
NIO	1.72E-03	1.72E-03	1.72E-03	1.89E+00						
NO2-										
NO3-										
NP+4										
NPO2	1.25E-06	1.25E-06	1.25E-06	1.39E-03						
OH-										
P2O5	2.81E-02	2.81E-02	2.81E-02	3.10E+01						
P2O5:24WO2:44H2O										
PB+4										
PBO2	4.58E-05	4.58E-05	4.58E-05	5.05E-02						
PO4-3										
PU+4										
PUO2				6.87E-06						
SI+4										
SIO2	6.27E-02	6.27E-02	6.27E-02	6.77E+01						
SO4-2										
SR+2										
SRO	3.14E-04	3.14E-04	3.14E-04	3.46E-01						
TC2O7										
TCO2	8.26E-03	8.26E-03	8.26E-03	2.07E-02						
TCO4-										
THO2				2.63E-43						
TOC										
UO2+2										
UO3	1.34E-02	1.34E-02	1.34E-02	1.47E+01						
V+5										
V2O5	3.38E-06	3.38E-06	3.38E-06	3.72E-03						
WO2	3.32E-06	3.32E-06	3.32E-06	3.68E-03						
WO3	7.14E-06	7.14E-06	7.14E-06	7.86E-03						
ZN+2										
ZNO	4.27E-05	4.27E-05	4.27E-05	4.71E-02						
ZR+4	9.17E-01	9.17E-01	9.17E-01	9.17E-01						
ZRO2	2.52E-03	2.52E-03	2.52E-03	2.78E+00						
ZRO2:2H2O										

Table A-1. Calcine-Cask Material Balance. (Sheet 13 of 14)

STREAM NAME	511	600	601	602	603	604	605	606	607	608
LIQUID COMPONENTS (MT)										
Total Mass Flow	8.60E+05	2.93E+06	2.93E+06	5.06E+03	2.19E+04	2.19E+04	4.38E+04	6.58E+04	6.58E+04	
AG+										
AM+3										
AS+5										
B+3										
BA+2										
BE+2										
BI+3										
C14										
CA+2										
CD+2										
CE+3										
CL-										
CL2		3.15E+02	3.15E+02							
CO2		8.89E+02	8.89E+02							
CO3-2										
CS+										
CU+2										
F-										
F2		1.18E+03	1.18E+03							
FE+3										
H2										
H2O	8.60E+05	1.01E+05	9.60E+04	5.06E+03						
HG		2.07E-04		2.07E-04						
HG+2										
I-										
I2		5.66E+02	5.66E+02							
K+										
LA+3										
LI+										
MG+2										
MNO2										
MO+6										
N2		2.20E+06	2.20E+06		1.73E+04	1.73E+04	3.46E+04	5.20E+04	5.20E+04	
NA+	1.98E+02									
NH3		6.87E+01	6.87E+01							
NI+3										
NO		3.14E-01	3.14E-01							
NO2		1.39E+02	1.39E+02							
NO2-										
NO3-										
NP+4										
O2		6.31E+05	6.31E+05		4.60E+03	4.60E+03	9.21E+03	1.38E+04	1.38E+04	
OH-	1.46E+02									
PB+4										
PO4-3										
PU+4										
SI+4										
SO2		5.27E+02	5.27E+02							
SO4-2										
SR+2										
TC2O7		2.94E-04	2.94E-04							
TCO4-										
TOC										
UO2+2										
V+5										
W+6										
ZN+2										
ZR+4										
ZRO2:2H2O										

Table A-1. Calcine-Cask Material Balance. (Sheet 14 of 14)

STREAM NAME	511	600	601	602	603	604	605	606	607	608
SOLID COMPONENTS (MT)										
Total Mass Flow		1.29E+03	6.47E-01	1.29E+03						
AG+										
AG2O		9.20E-03	4.60E-06	9.20E-03						
AL+3										
AL2O3		2.25E+01	1.12E-02	2.25E+01						
AM+3										
AM2O3		1.67E-04	8.35E-08	1.67E-04						
AS+5										
AS2O5		9.77E-03	4.89E-06	9.77E-03						
B+3										
B2O3		2.45E-02	1.22E-05	2.45E-02						
BA+2										
BAO		2.18E-02	1.09E-05	2.18E-02						
BE+2										
BEO		1.25E-03	6.24E-07	1.25E-03						
BI+3										
BI2O3		1.48E+00	7.38E-04	1.48E+00						
C14										
CA+2										
CACO3		2.02E+02	1.01E-01	2.02E+02						
CANCRINITE										
CAO		5.30E+02	2.65E-01	5.30E+02						
CASO4		8.98E+00	4.49E-03	8.97E+00						
CD+2										
CDO		5.75E-02	2.88E-05	5.75E-02						
CE+3										
CE2O3		1.40E+00	6.99E-04	1.40E+00						
CL-										
CO3-2										
CR+3										
CR2O3		9.71E-01	4.86E-04	9.70E-01						
CS+										
CS2O		6.52E-04	3.26E-07	6.51E-04						
CU+2										
CUO		5.81E-03	2.90E-06	5.80E-03						
F-										
FE+3										
FE2O3		6.19E+00	3.10E-03	6.19E+00						
HG+2										
I-										
K+										
K2O										
LA+3										
LA2O3		1.25E-01	6.25E-05	1.25E-01						
LI+										
LI2O		3.28E-04	1.64E-07	3.28E-04						
MG+2										
MGO		9.97E-02	4.99E-05	9.97E-02						
MNO2		1.16E+00	5.80E-04	1.16E+00						
MO+6										
MOO3		4.28E-02	2.14E-05	4.27E-02						
NA+										
NA2O		4.47E+02	2.23E-01	4.46E+02						
NEPH										
NI+3										
NI2FECN6										
NI2O3										
NIO		1.14E+00	5.70E-04	1.14E+00						
NO2-										
NO3-										
NP+4										
NPO2		8.35E-04	4.17E-07	8.34E-04						
OH-										
P2O5		1.87E+01	9.33E-03	1.87E+01						
P2O5:24WO2:44H2O										
PB+4										
PBO2		3.04E-02	1.52E-05	3.04E-02						
PO4-3										
PU+4										
PUO2		4.14E-06	2.07E-09	4.14E-06						
SI+4										
SIO2		4.16E+01	2.08E-02	4.16E+01						
SO4-2										
SR+2										
SRO		2.08E-01	1.04E-04	2.08E-01						
TC2O7										
TCO2		1.25E-02	6.24E-06	1.25E-02						
TCO4-										
THO2										
TOC										
UO2+2										
UO3		8.86E+00	4.43E-03	8.85E+00						
V+5										
V2O5		2.24E-03	1.12E-06	2.24E-03						
WO2		2.22E-03	1.11E-06	2.22E-03						
WO3		4.74E-03	2.37E-06	4.73E-03						
ZN+2										
ZNO		2.84E-02	1.42E-05	2.84E-02						
ZR+4										
ZRO2		1.67E+00	8.36E-04	1.67E+00						
ZRO2:2H2O										

APPENDIX B

CALCINE-CASK FACILITY LAYOUTS

This page intentionally left blank.

APPENDIX B

CALCINE-CASK FACILITY LAYOUTS

The facility layouts (11 sheets total) for the Calcine-Cask facility were taken directly from *The Tank Waste Technical Options Report* (Boomer et al. 1993) without modification.

This page intentionally left blank.

PROJECT TITLE:

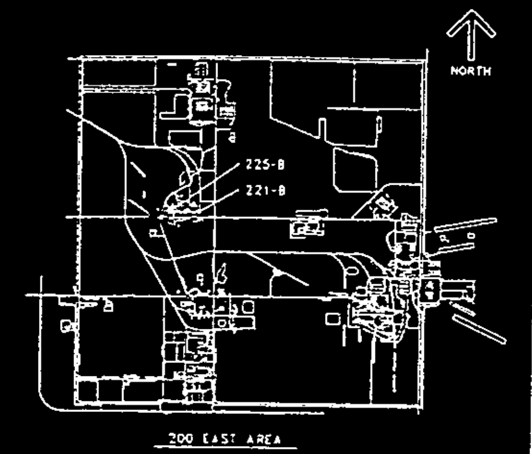
CALCINE CASK FACILITY

FOR:

WESTINGHOUSE HANFORD COMPANY

BY:

KAISER ENGINEERS HANFORD



DRAWING LIST

DRAWING LIST

DRAWING NO.	INDEX NO.	TITLE
ES-S70-M00	0000	DRAWING LIST

PIPING & VESSELS

DRAWING NO.	INDEX NO.	TITLE
ES-S70-M01	2500	CALCINE CASK FACILITY SITE PLAN
ES-S70-M02	2500	CALCINE CASK FACILITY PLAN @ 42'-0"
ES-S70-M03	2500	CALCINE CASK FACILITY PLAN @ 21'-0"
ES-S70-M04	2500	CALCINE CASK FACILITY PLAN @ 0'-0"
ES-S70-M05	2500	CALCINE CASK FACILITY PLAN @ (-) 21'-0"
ES-S70-M06	2500	CALCINE CASK FACILITY PLAN @ (-) 42'-0"
ES-S70-M07	2500	CALCINE CASK FACILITY SECTION A-A
ES-S70-M08	2500	CALCINE CASK FACILITY SECTIONS B-B, C-C
ES-S70-M09	2500	CALCINE CASK STORAGE SITE PLAN
ES-S70-M10	2500	CALCINE CASK STORAGE DETAILS

Figure B-1. Calcine-Cask Facility Layout.
(Sheet 1 of 11)

PRELIMINARY
NOT APPROVED FOR CONSTRUCTION

U.S. DEPARTMENT OF ENERGY
RICHLAND OPERATIONS OFFICE
KAISER ENGINEERS HANFORD COMPANY

DRAWING LIST

ES-S70-M00 0

Figure B-1. Calcine-Cask Facility Layout.
(Sheet 2 of 11)

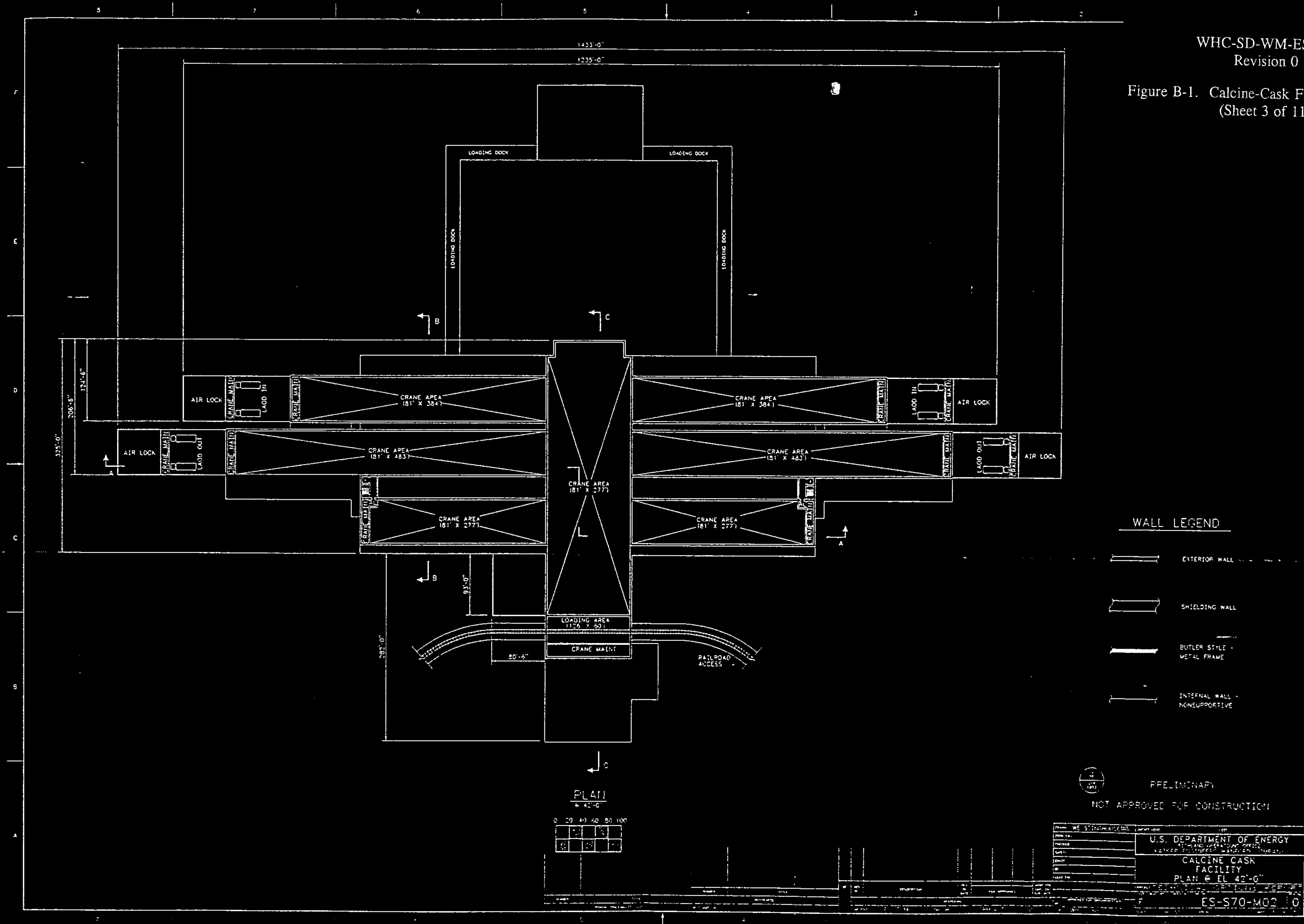
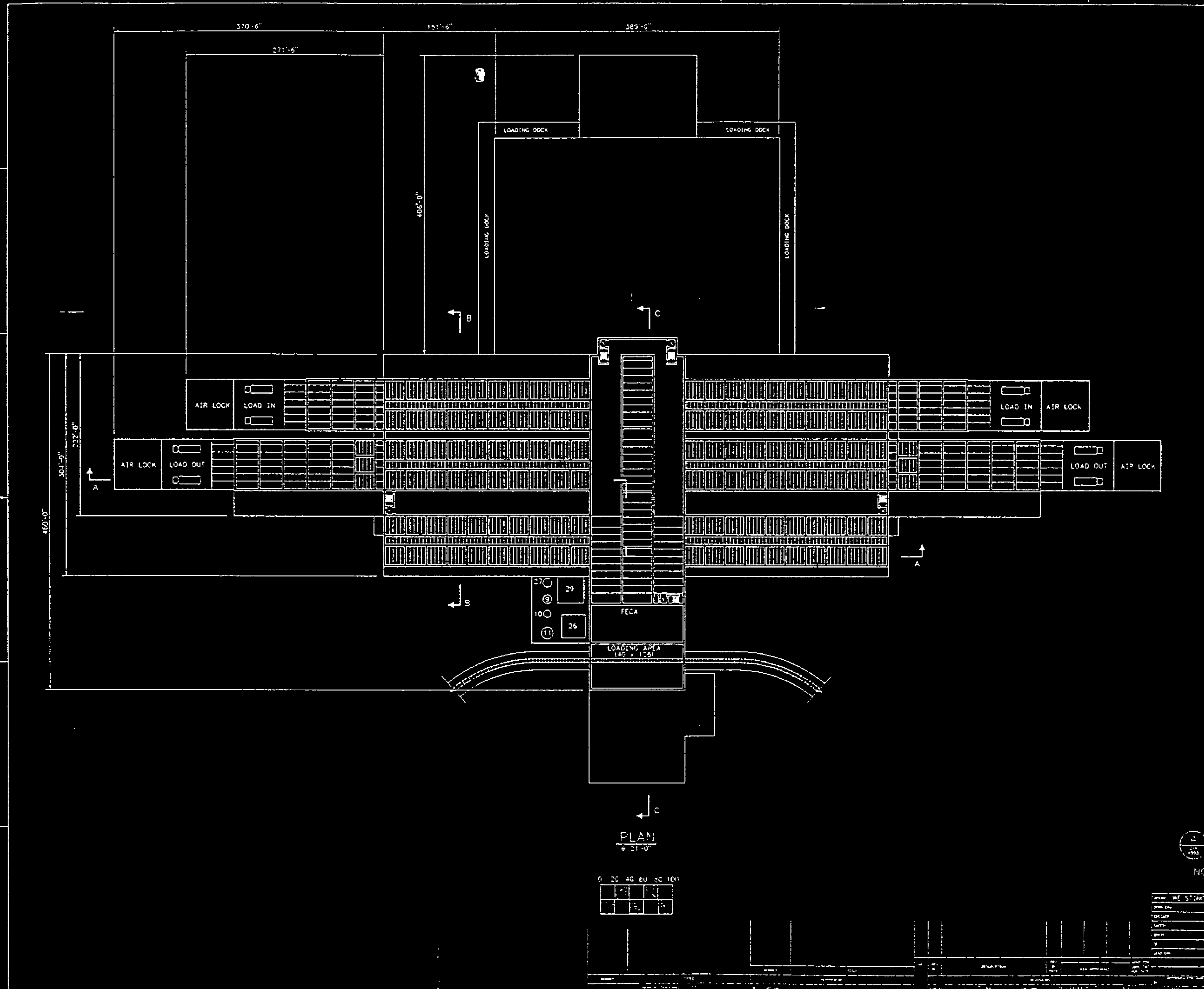
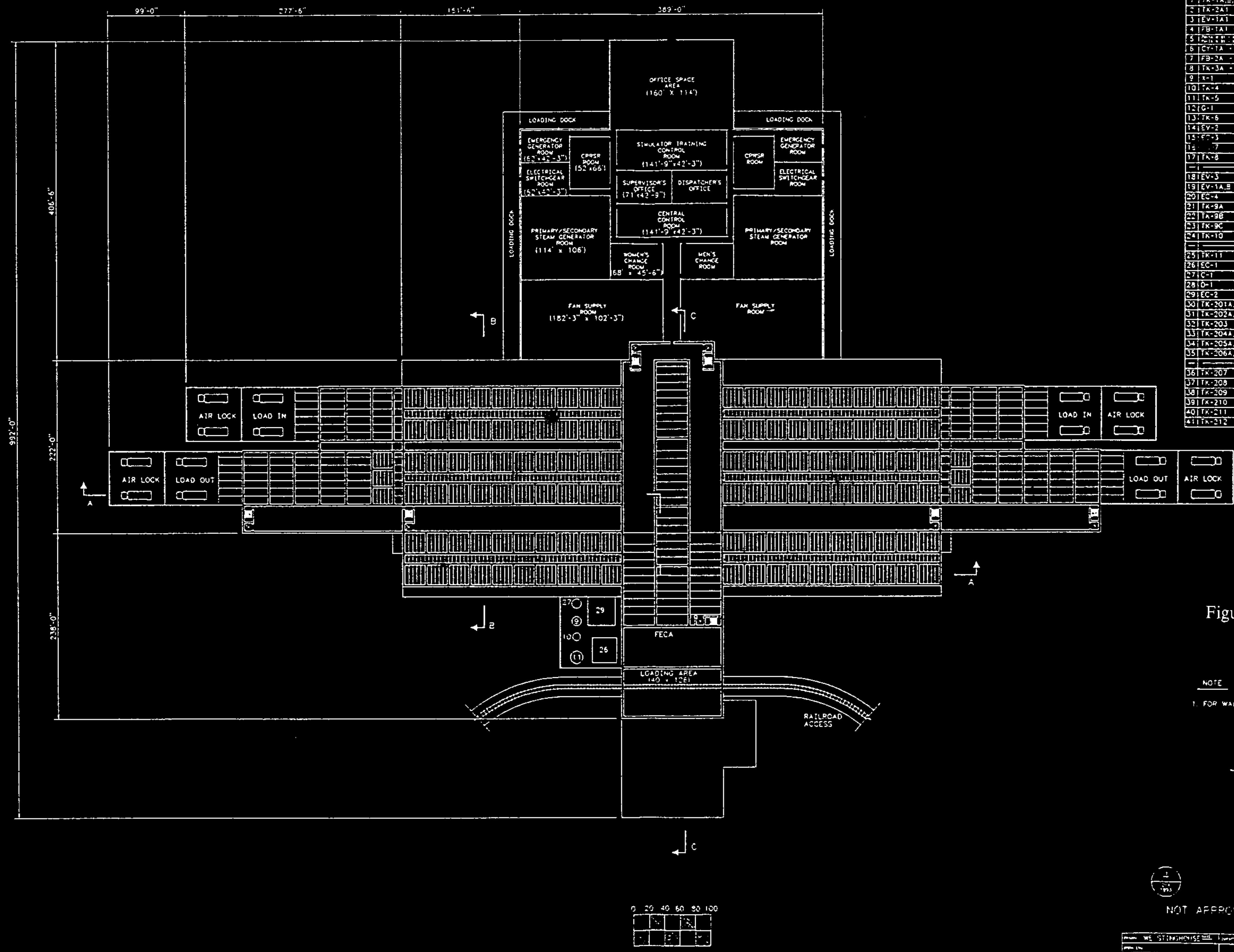


Figure B-1. Calcine-Cask Facility Layout.
(Sheet 3 of 11)



PN	EQPT ID	AMU EQUIPMENT DESCRIPTION
1	TK-1A,B,C	FEED RECEIPT TANK
2	TK-2A1 - A120	CALCINER FEED TANK
3	EV-1A1 - A60	CALCINER
4	FB-1A1 - A60	CALCINER BLOWBACK FILTER
5	[illegible]	METAL HEPA FILTERS
6	CY-1A - 1F	CYCLONE
7	FB-2A - 2F	BLOWBACK FILTERS
8	TK-3A - 3F	CAL[illegible]NE COLLECTION BIN
9	X-1	CO[illegible]C RECOVERY COLUMN
10	TK-4	RE[illegible]Y PRODUCT CATCH TANK
11	TK-5	CEN[illegible]FUGE FEED TANK
12	G-1	WASTE CENTRIFUGE
13	TK-6	CENTRIFUGE CATCH TANK
14	EV-2	SPRAY DRYER W/BLOWBACK FILTERS
15	EC-3	SPRAY DRYER CONDENSER
16	TK-7	LIQUID EFFLUENT ACCUMULATION TK
17	TK-8	TECHNETIUM RECYCLE EVAPORATOR
—	———	FEED TANK
18	EV-3	TECHNETIUM RECYCLE EVAPORATOR
19	EV-1A,B	REBOILER
20	EC-4	EVAPORATOR CONDENSER
21	TK-9A	EVAPORATOR COND CATCH TANK
22	TK-9B	EVAPORATOR COND SAMPLE TANK
23	TK-9C	EVAPORATOR COND pH ADJUST TANK
24	TK-10	TECHNETIUM RECYCLE EVAPORATOR
—	———	BOTTOMS CATCH TANK
25	TK-11	TECHNETIUM RECYCLE TANK
26	EC-1	GAS COOLER
27	C-1	NOx REACTOR
28	D-1	DECANTER/TRAP
29	EC-2	CONDENSER (NOx REACTOR)
30	TK-201A,B	12.2M NITRIC ACID TANK
31	TK-202A,B	1M NITRIC ACID TANK
32	TK-203	50wt% SODIUM HYDROXIDE
33	TK-204A,B	1M SODIUM HYDROXIDE TANK
34	TK-205A,B	RECYCLE pH ADJUST METER TK
35	TK-206A,B	EVAPORATOR COND pH ADJUST
—	———	METER TANK
36	TK-207	CASK DECON TANK
37	TK-208	CRANE DECON TANK
38	TK-209	FAILED EQPT DECON SOLUTION 1
39	TK-210	FAILED EQPT DECON SOLUTION 2
40	TK-211	DEMINERALIZED WATER TANK
41	TK-212	CaO SLURRY MAKEUP TANK

Figure B-1. Calcine-Cask Facility Layout.
(Sheet 4 of 11)



PM	EQPT ID	AMU EQUIPMENT DESCRIPTION
1	TK-1A,B,C	FEED RECEIPT TANK
2	TK-2A1 - A120	CALCINER FEED TANK
3	EV-1A1 - A60	CALCINER
4	FB-1A1 - A60	CALCINER BLOWBACK FILTER
5	[illegible]	METAL HEPA FILTERS
6	CY-1A - 1F	CYCLONE
7	FB-2A - 2F	BLOWBACK FILTERS
8	TK-3A - 3F	CALCINE COLLECTION BIN
9	X-1	CO_2 & ^{14}C RECOVERY COLUMN
10	TK-4	RECOVERY PRODUCT CATCH TANK
11	TK-5	CENTRIFUGE FEED TANK
12	C-1	WASTE CENTRIFUGE
13	TK-6	CENTRIFUGE CATCH TANK
14	EV-2	SPRAY DRYER W/BLOWBACK FILTERS
15	[illegible]-3	SPRAY DRYER CONDENSER
16	[illegible]-7	LIQUID EFFLUENT ACCUMULATION TK
17	TK-8	TECHNETIUM RECYCLE EVAPORATOR
—	—	FEED TANK
18	EV-3	TECHNETIUM RECYCLE EVAPORATOR
19	EV-1A,B	REBOILER
20	EC-4	EVAPORATOR CONDENSER
21	TK-9A	EVAPORATOR COND CATCH TANK
22	TK-9B	EVAPORATOR COND SAMPLE TANK
23	TK-9C	EVAPORATOR COND pH ADJUST TANK
24	TK-10	TECHNETIUM RECYCLE EVAPORATOR
—	—	BOTTOMS CATCH TANK
25	TK-11	TECHNETIUM RECYCLE TANK
26	EC-1	GAS COOLER
27	C-1	NO_x REACTOR
28	D-1	DECANTER/TRAP
29	EC-2	CONDENSER (NO_x REACTOR)
30	TK-201A,B	12.2M NITRIC ACID TANK
31	TK-202A,B	1M NITRIC ACID TANK
32	TK-203	50wt% SODIUM HYDROXIDE
33	TK-204A,B	1M SODIUM HYDROXIDE TANK
34	TK-205A,B	RECYCLE pH ADJUST METER TK
35	TK-206A,B	EVAPORATOR COND pH [illegible]DJUST
—	—	METER TANK
36	TK-207	CASK DECON TANK
37	TK-208	CRANE DECON TANK
38	TK-209	FAILED EQPT DECON SOLUTION 1
39	TK-210	FAILED EQPT DECON SOLUTION 2
40	TK-211	DEMINERALIZED WATER TANK
41	TK-212	CaO SLURRY MAKEUP TANK

Figure B-1. Calcine-Cask Facility Layout.
(Sheet 5 of 11)

NOTE

1. FOR WALL LEGEND, SEE ES-S70-M02.

PRELIMINARY

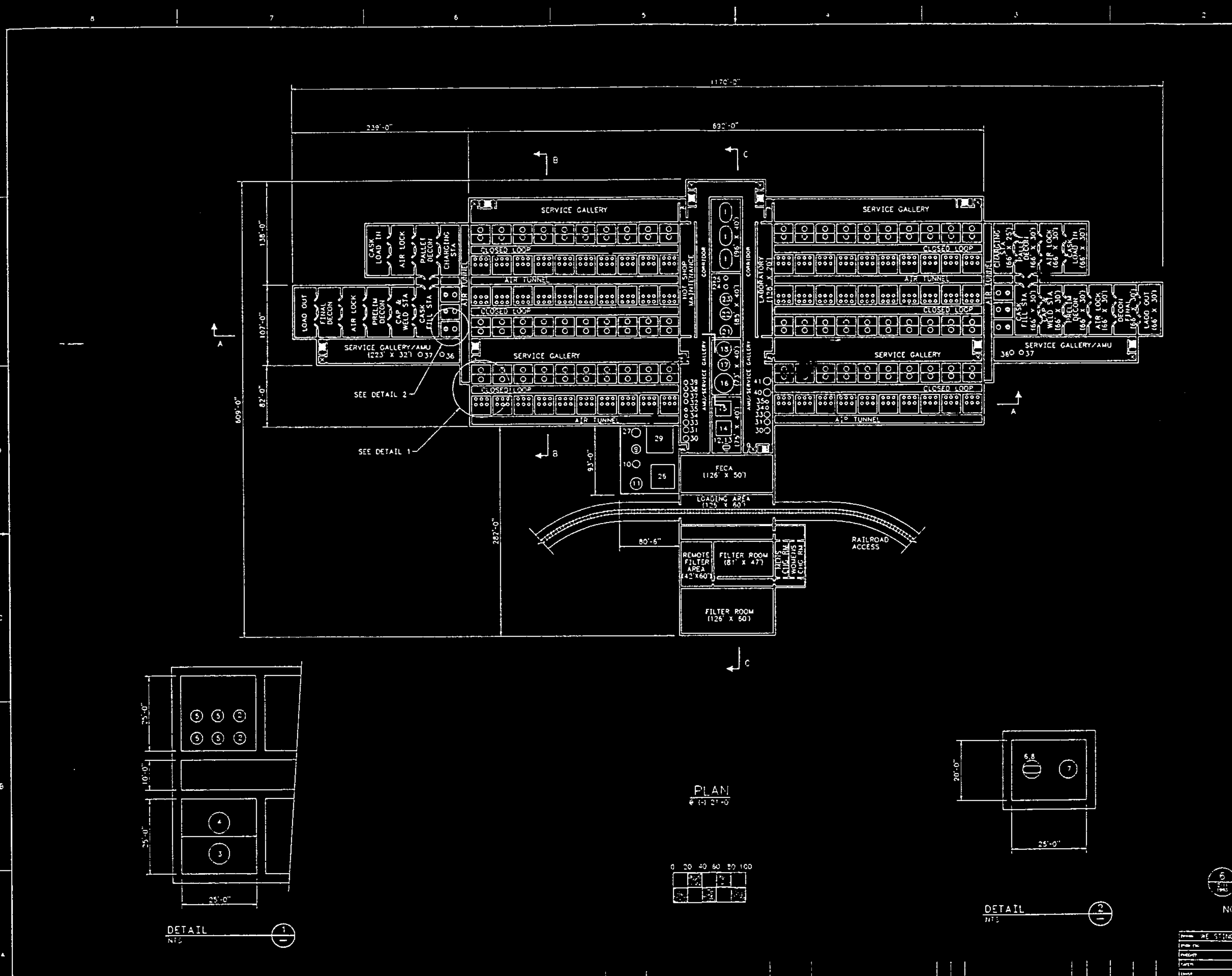
NOT APPROVED FOR CONSTRUCTION

U.S. DEPARTMENT OF ENERGY

CALCINE CASK FACILITY PLAN @ EL 0'-0"

ES-S70-M04 0

PM	EQPT ID	AMU EQUIPMENT DESCRIPTION
1	TK-1A,B,C	FEED RECEIPT TANK
2	TK-2A1 - A120	CALCINER FEED TANK
3	EV-1A1 - A60	CALCINER
4	FB-1A1 - 460	CALCINER BLOWBACK FILTER
5	[illegible]	METAL HEPA FILTERS
6	CY-1A - 1F	CYCLONE
7	FB-2A - 2F	BLOWBACK FILTERS
8	TK-3A - 3F	CALCINE COLLECTION BIN
9	X-1	CO_2 & ^{14}C RECOVERY COLUMN
10	TK-4	RECOVERY PRODUCT CATCH TANK
11	TK-5	CENTRIFUGE FEED TANK
12	G-1	WASTE CENTRIFUGE
13	TK-6	CENTRIFUGE CATCH TANK
14	EV-2	SPRAY DRYER W/BLOWBACK FILTERS
15	EC-3	SPRAY DRYER CONDENSER
16	TK-7	LIQUID EFFLUENT ACCUMULATION TK
17	TK-8	TECHNETIUM RECYCLE EVAPORATOR
—	—	FEED TANK
18	EV-3	TECHNETIUM RECYCLE EVAPORATOR
19	EV-1A,B	REBOILER
20	EC-4	EVAPORATOR CONDENSER
21	TK-9A	EVAPORATOR COND CATCH TANK
22	TK-9B	EVAPORATOR COND SAMPLE TANK
23	TK-9C	EVAPORATOR COND pH ADJUST TANK
24	TK-10	TECHNETIUM RECYCLE EVAPORATOR
—	—	BOTTOMS CATCH TANK
25	TK-11	TECHNETIUM RECYCLE TANK
26	EC-1	GAS COOLER
27	C-1	NO_x REACTOR
28	D-1	DECANTER/TRAP
29	EC-2	CONDENSER (NO_x REACTOR)
30	TK-201A,B	12.2M NITRIC ACID TANK
31	TK-202A,B	1M NITRIC ACID TANK
32	TK-203	50wt% SODIUM HYDROXIDE
33	TK-204A,B	1M SODIUM HYDROXIDE TANK
34	TK-205A,B	RECYCLE pH ADJUST METER TK
35	TK-206A,B	EVAPORATOR COND pH ADJUST
—	—	METER TANK
36	TK-207	CASK DECON TANK
37	TK-208	CRANE DECON TANK
38	TK-209	FAILED EQPT DECON SOLUTION 1
39	TK-210	FAILED EQPT DECON SOLUTION 2
40	TK-211	DEMINERALIZED WATER TANK
41	TK-212	CaO SLURRY MAKEUP TANK



NOTE:
1. FOR WALL LEGEND, SEE ES-S70-M02.

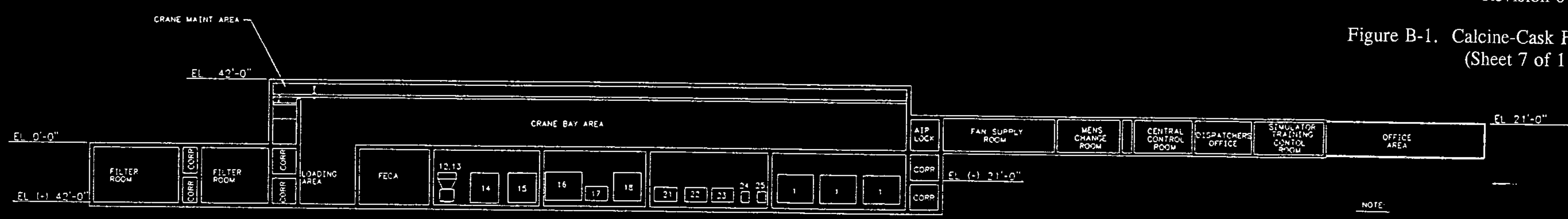
PRELIMINARY
NOT APPROVED FOR CONSTRUCTION

U.S. DEPARTMENT OF ENERGY
RICHLAND OPERATIONS OFFICE
WESTINGHOUSE HANFORD COMPANY
CALCINE CASK FACILITY
PLAN @ EL (-) 21'-0"
ES-S70-M05 0

Figure B-1. Calcine-Cask Facility Layout.
(Sheet 6 of 11)

PN	EQPT ID	AMU EQUIPMENT DESCRIPTION
1	TK-1A,B,C	FEED RECEIPT TANK
2	TK-2A1 - A120	CALCINER FEED TANK
3	EV-1A1 - A60	CALCINER
4	FB-1A1 - A60	CALCINER BLOWBACK FILTER
5	[illegible]	METAL HEPA FILTERS
6	CY-1A - 1F	CYCLONE
7	FB-2A - 2F	BLOWBACK F[illegible]ERS
8	TK-3A - 3F	CALCINE COLLECTION BIN
9	X-1	CO₂ & ¹⁴C RECOVERY COLUMN
10	TK-4	RECOVERY PRODUCT CATCH TANK
11	TK-5	CENTRIFUGE FEED TANK
12	G-1	WASTE CENTRIFUGE
13	TK-6	CENTRIFUGE CATCH TANK
14	EV-2	SPRAY DRYER W/BLOWBACK FILTERS
15	EC-3	SPRAY DRYER CONDENSER
16	TK-7	LIQUID EFFLUENT ACCUMULATION TK
17	TK-8	TECHNETIUM RECYCLE EVAPORATOR
—	———	FEED TANK
18	EV-3	TECHNETIUM RECYCLE EVAPORATOR
19	EV-1A,B	REBOILER
20	EC-4	EVAPORATOR CONDENSER
21	TK-9A	EVAPORATOR COND CATCH TANK
22	TK-9B	EVAPORATOR COND SAMPLE TANK
23	TK-9C	EVAPORATOR COND pH ADJUST TANK
24	TK-10	TECHNETIUM RECYCLE EVAPORATOR
—	———	BOTTOMS CATCH TANK
25	TK-11	TECHNETIUM RECYCLE TANK
26	EC-1	GAS COOLER
27	C-1	NO₂ REACTOR
28	D-1	DECANTER TRAP
29	EC-2	CONDENSER (NO₂ REACTOR)
30	TK-201A,B	12.2M [illegible]TRIC ACID TANK
31	TK-202A,B	1M NITRIC ACID TANK
32	TK-203	50wt% SODIUM HYDROXIDE
33	TK-204A,B	1M SODIUM HYDROXIDE TANK
34	TK-205A,B	RECYCLE pH ADJUST METER TK
35	TK-206A,B	EVAPORATOR COND pH ADJUST
—	———	METER TANK
36	TK-207	CASK DECON TANK
37	TK-208	CRANE DECON TANK
38	TK-209	FAILED EQPT DECON SOLUTION 1
39	TK-210	FAILED EQPT DECON SOLUTION 2
40	TK-211	DEMINERALIZED WATER TANK
41	TK-212	CaO SLURRY MAKEUP TANK

SECTION B-B
SCALE: NTS



SECTION C-C
SCALE: NTS

NOTE:
1. FOR WALL LEGEND, SEE ES-S70-M02

PRELIMINARY
NOT APPROVED FOR CONSTRUCTION

U.S. DEPARTMENT OF ENERGY
CALCINE CASK FACILITY SECTIONS
ES-S70-M08 0

Figure B-1. Calcine-Cask Facility Layout. (Sheet 7 of 11)

PM	EQPT ID	AMU EQUIPMENT DESCRIPTION
1	TK-1A,B,C	FEED RECEIPT TANK
2	TK-2A1 - A120	CALCINER FEED TANK
3	EV-1A1 - A60	CALCINER
4	FB-1A1 - A60	CALCINER BLOWBACK FILTER
5	[illegible]	METAL HEPA FILTERS
6	CY-1A - 1F	CYCLONE
7	FB-2A - 2F	BLOWBACK FILTERS
8	TK-3A - 3F	CALCINE COLLECTION BIN
9	X-1	CO₂ & ¹⁴C RECOVERY COLUMN
10	TK-4	RECOVERY PRODUCT CATCH TANK
11	TK-5	CENTRIFUGE FEED TANK
12	G-1	WASTE CENTRIFUGE
13	TK-6	CENTRIFUGE CATCH TANK
14	EV-2	SPRAY DRYER W/BLOWBACK FILTERS
15	EC-3	SPRAY DRYER CONDENSER
16	TK-7	LIQUID EFFLUENT ACCUMULATION TK
17	TK-8	TECHNETIUM RECYCLE EVAPORATOR
—	—	FEED TANK
18	EV-3	TECHNETIUM RECYCLE EVAPORATOR
19	EV-1A,B	REBOILER
20	EC-4	EVAPORATOR CONDENSER
21	TK-9A	EVAPORATOR COND CATCH TANK
22	TK-9B	EVAPORATOR COND SAMPLE TANK
23	TK-9C	EVAPORATOR COND pH ADJUST TANK
24	TK-10	TECHNETIUM RECYCLE EVAPORATOR
—	—	BOTTOMS CATCH TANK
25	TK-11	TECHNETIUM RECYCLE TANK
26	EC-1	GAS COOLER
27	C-1	NOₓ REACTOR
28	D-1	DECANTER/TRAP
29	EC-2	CONDENSER (NOₓ REACTOR)
30	TK-201A,B	12.2M NITRIC ACID TANK
31	TK-202A,B	1M NITRIC ACID TANK
32	TK-203	50wt% SODIUM HYDROXIDE
33	TK-204A,B	1M SODIUM HYDROXIDE TANK
34	TK-205A,B	RECYCLE pH ADJUST METER TK
35	TK-206A,B	EVAPORATOR COND pH ADJUST
—	—	METER TANK
36	TK-207	CASK DECON TANK
37	TK-208	CRANE DECON TANK
38	TK-209	FAILED EQPT DECON SOLUTION 1
39	TK-210	FAILED EQPT DECON SOLUTION 2
40	TK-211	DEMINERALIZED WATER TANK
41	TK-212	CaO SLURRY MAKEUP TANK

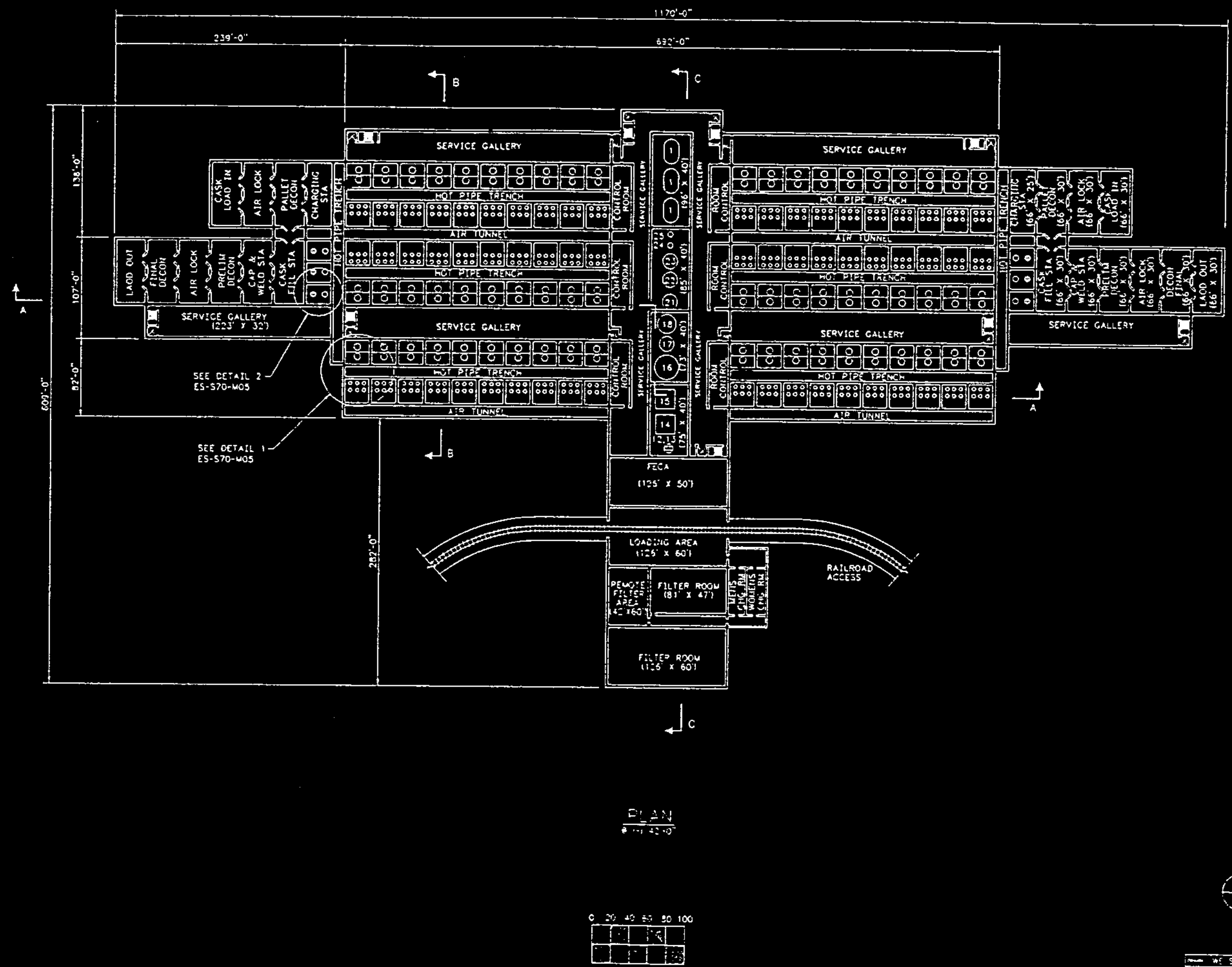


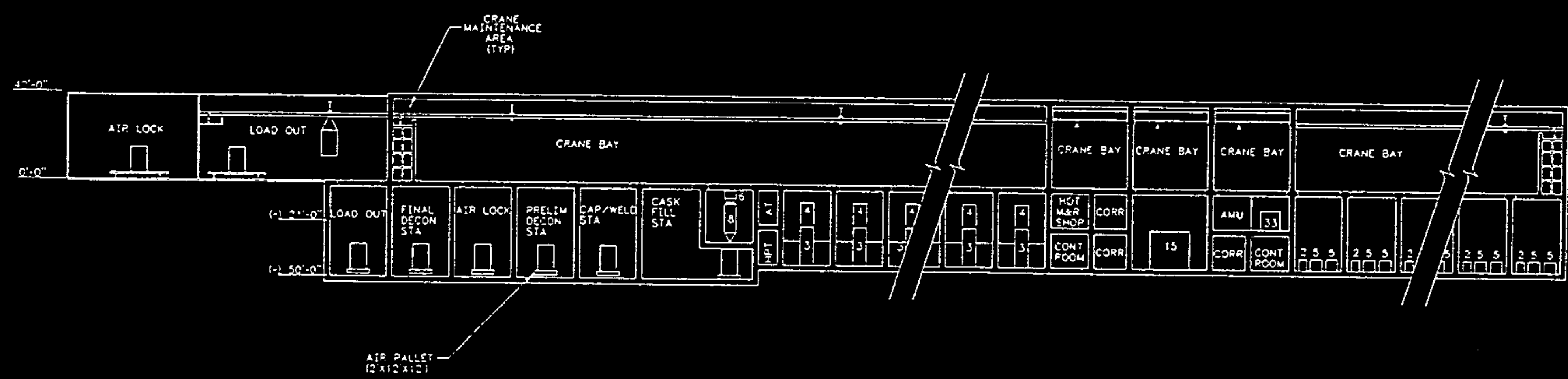
Figure B-1. Calcine-Cask Facility Layout.
(Sheet 8 of 11)

NOTE:
1. FOR WALL LEGEND, SEE ES-S70-M02.

PRELIMINARY
NOT APPROVED FOR CONSTRUCTION

U.S. DEPARTMENT OF ENERGY
RICHLAND OPERATIONS OFFICE
KAISER ENGINEERS HANFORD COMPANY
CALCINE CASK FACILITY
PLAN @ EL (-) 42'-0"
ES-S70-M06 0

PN#	EQPT ID	AMU EQUIPMENT DESCRIPTION
1	TK-1A,B,C	FEED RECEIPT TANK
2	TK-2A1 - A120	CALCINER FEED TANK
3	EV-1A1 - A60	CALCINER
4	FB-1A1 - A60	CALCINER BLOWBACK FILTER
5	[illegible]	METAL HEPA FILTERS
6	CY-1A - 1F	CYCLONE
7	FB-2A - 2F	BLOWBACK FILTERS
8	TK-3A - 3F	CALCINE COLLECTION BIN
9	X-1	CO_2 & ^{14}C RECO[illegible]Y COLUMN
10	TK-4	RECOVERY PRODU[illegible] CATCH TANK
11	TK-5	CENTRIFUGE FEED TANK
12	G-1	WASTE CENTRIFUGE
13	TK-6	CENTRIFUGE CATCH TANK
14	EV-2	SPRAY DRYER W/BLOWBACK FILTERS
15	EC-3	SPRAY DRYER CONDENSER
16	TK-7	LIQUID EFFLUENT ACCUMULATION TK
17	TK-8	TECHNETIUM RECYCLE EVAPORATOR
—	—	FEED TANK
18	EV-3	TECHNETIUM RECYCLE EVAPORATOR
19	EV-1A,B	REBOILER
20	EC-4	EVAPORATOR CONDENSER
21	TK-9A	EVAPORATOR COND CATCH TANK
22	TK-9B	EVAPORATOR COND SAMPLE TANK
23	TK-9C	EVAPORATOR COND pH ADJUST TANK
24	TK-10	TECHNETIUM RECYCLE EVAPORATOR
—	—	BOTTOMS CATCH TANK
25	TK-11	TECHNETIUM RECYCLE TANK
26	EC-1	GAS COOLER
27	C-1	NO_x REACTOR
28	D-1	DECANTER/TRAP
29	EC-2	CONDENSER (NO_x REACTOR)
30	TK-201A,B	12.2M NITRIC ACID TANK
31	TK-202A,B	1M NITRIC ACID TANK
32	TK-203	50wt% SODIUM HYDROXIDE
33	TK-204A,B	1M SODIUM HYDROXIDE TANK
34	TK-205A,B	RECYCLE pH ADJUST METER TK
35	TK-206A,B	EVAPORATOR COND pH ADJUST
—	—	METER TANK
36	TK-207	CASK DECON TANK
37	TK-208	CRANE DECON TANK
38	TK-209	FAILED EQPT DECON SOLUTION 1
39	TK-210	FAILED EQPT DECON SOLUTION 2
40	TK-211	DEMINERALIZED WATER TANK
41	TK-212	CaO SLURRY MAKEUP TANK



SECTION A-A
SCALE: 1"=30'-0"

0 20 40 60 80 100

WHC-SD-WM-ES-366
Revision 0

Figure B-1. Calcine-Cask Facility Layout.
(Sheet 9 of 11)

NOTE:
1. FOR WALL LEGEND, SEE ES-S70-M02.

PRELIMINARY
NOT APPROVED FOR CONSTRUCTION

U.S. DEPARTMENT OF ENERGY
CALCINE CASK
FACILITY
SECTIONS
ES-S70-M07 0

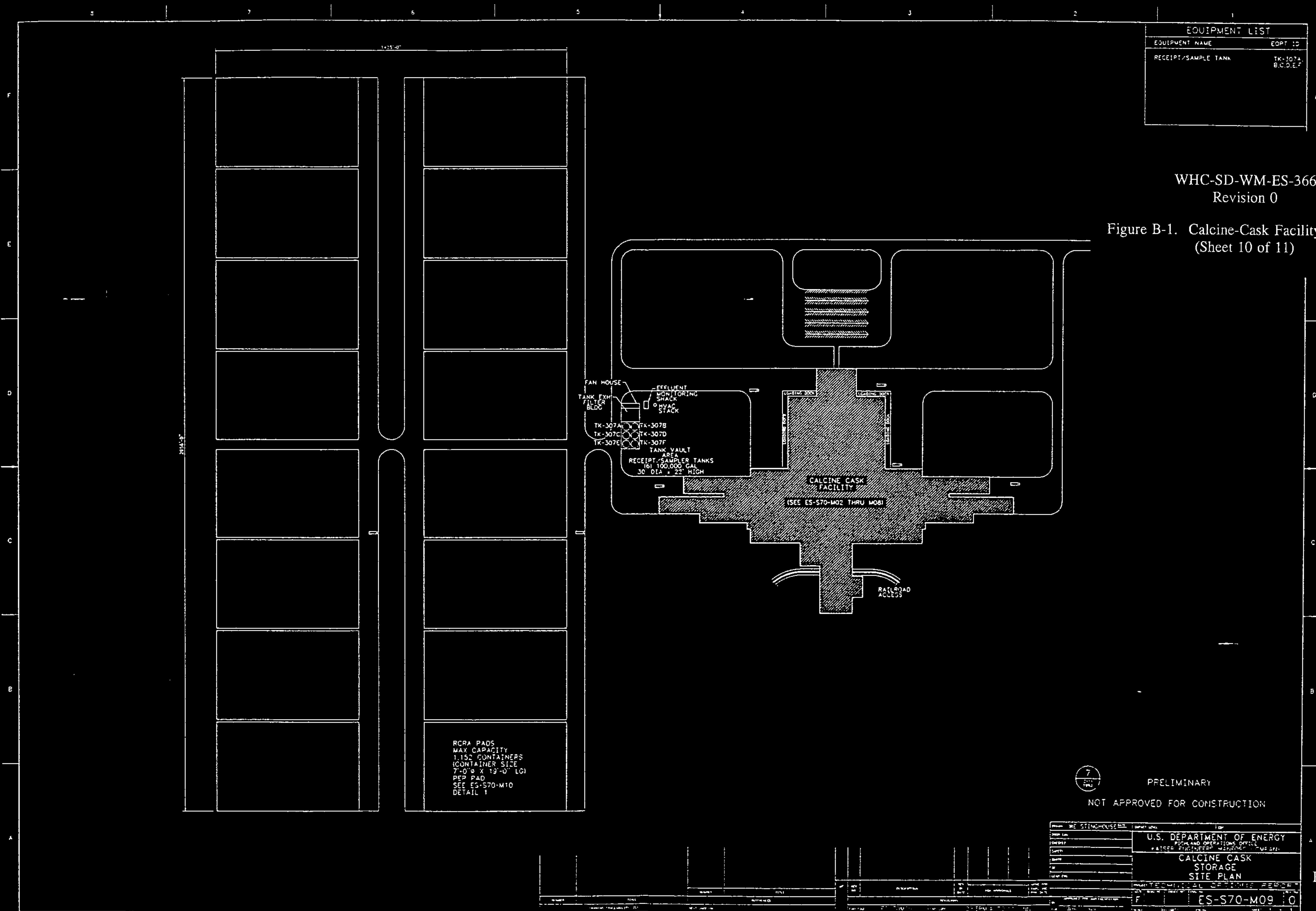


Figure B-1. Calcine-Cask Facility Layout.
(Sheet 10 of 11)

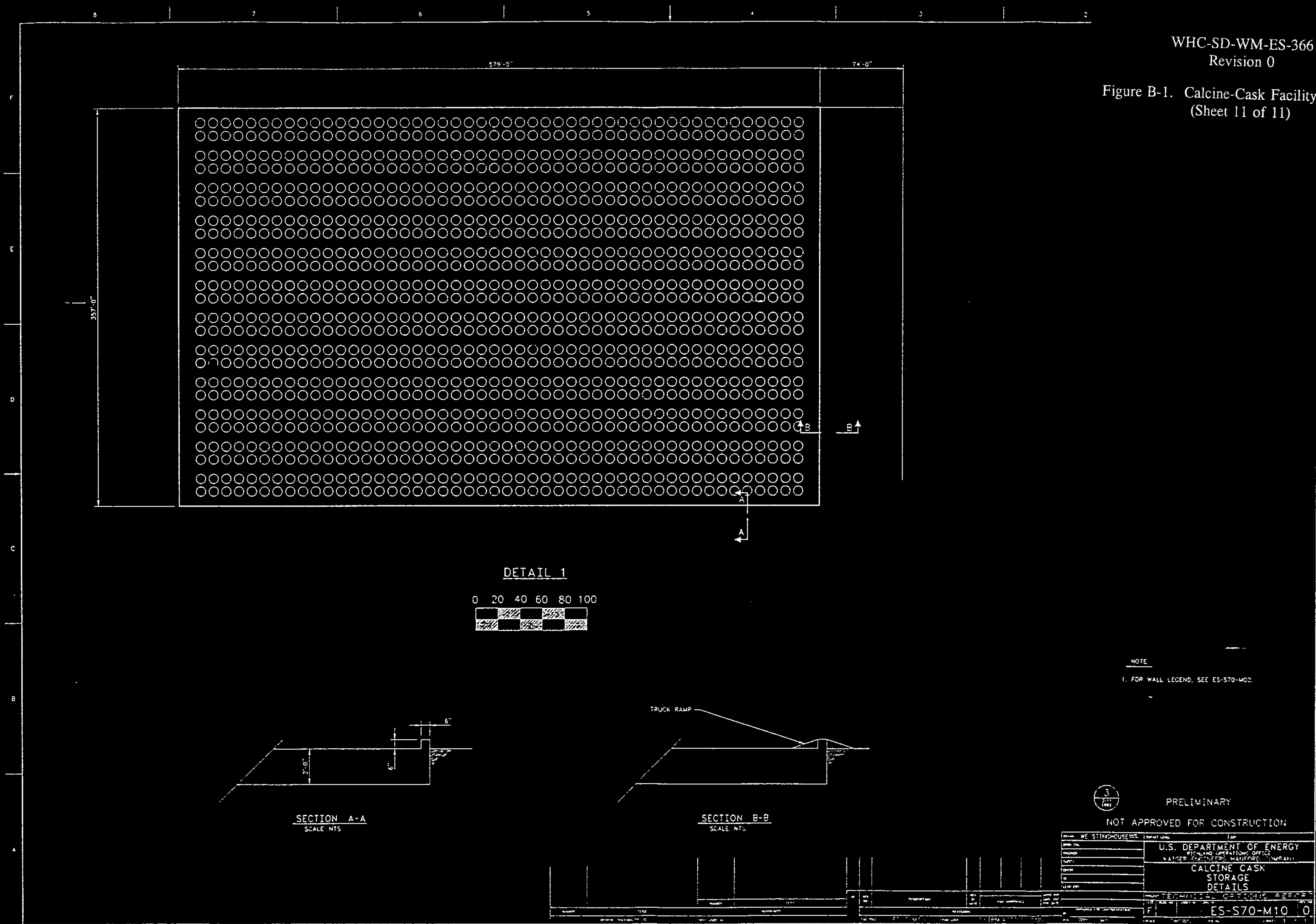


Figure B-1. Calcine-Cask Facility Layout.
(Sheet 11 of 11)

DISTRIBUTION SHEET

To	From	Page 1 of 1
Distribution	J. S. Garfield	Date 1/8/96
Project Title/Work Order		EDT No. 613844
Determine Separations Process Strategy Decision, WHC-SD-WM-ES-366, Rev. 0		ECN No.

Name	MSIN	Text With All Attach.	Text Only	Attach./ Appendix Only	EDT/ECN Only
Central Files (2)	A3-88	X			
Public Reading Room	A1-64	X			
S. K. Baker	H5-57	X			
A. L. Boldt	H5-49	X			
K. D. Boomer	H5-49	X			
D. K. Carter	G3-21	X			
R. D. Claghorn	H5-49	X			
J. S. Garfield	H5-49	X			
K. A. Gasper	G3-21	X			
J. O. Honeyman	S7-81	X			
M. E. Johnson	H5-27	X			
R. A. Kirkbride	H5-27	X			
R. W. Powell	G3-21	X			
I. E. Reep	G3-21	X			
D. A. Seaver	K8-07	X			
E. J. Slaathaug	H5-49	X			
D. J. Washenfelder	L4-75	X			