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DECONTAMINATION AND DECOMMISSIONING PLAN FOR PROCESSING CONTAMINATED NaK AT THE INEL

D. M. LaRue
M. R. Dolenc

EG&G Idaho

Work performed under DOE Contract No. DE-AC07-76ID01570

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DECONTAMINATION AND DECOMMISSIONING PLAN FOR PROCESSING OF CONTAMINATED NaK AT THE IDAHO NATIONAL ENGINEERING LABORATORY

WASTE MANAGEMENT PROGRAMS

D. M. LaRue
M. R. Dolenc

September 1986

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Idaho Falls, Idaho 83415

Prepared for the
U.S. Department of Energy
Idaho Operations Office
Under DOE Contract No. DE-AC07-76ID01570

SUMMARY

This decontamination and decommissioning (D&D) plan describes the work elements and project management plan for processing four containers of contaminated sodium/potassium (NaK) and returning the Army Reentry Vehicle Facility Site (ARVFS) to a reusable condition. The document reflects the management plan for this project before finalizing the conceptual design and preliminary prototype tests of the reaction kinetics. As a result, the safety, environmental, and accident analyses are addressed as preliminary assessments before completion at a later date.

ARVFS contains an earth-covered bunker, a cylindrical test pit and metal shed, and a cable trench connecting the two items. The bunker currently stores the four containers of NaK from the meltdown of the EBR-1 Mark II core.

The D&D project addressed in this plan involves processing the contaminated NaK and returning the ARVFS to potential reuse after cleanup. The estimated cost is $1,703,000. The projected waste volume is 378 ft^3.

ACRONYMS

ACWP	Actual cost of work performed
ALARA	As low as reasonably achievable
ARVFS	Army Reentry Vehicle Facility Site
BCWP	Budgeted cost of work performed
BCWS	Budget and cost of work scheduled
CAM	Constant air monitor
CAPS	Cost and Planning System
CC	Component checkout
CFA	Central Facilities Area
CPP	Chemical Processing Plant
CSSF	Calcined Solids Storage Facility
D&D	Decontamination and Decommissioning
DOE/ID	U.S. Department of Energy, Idaho Operations Office
EBR-I	Experimental Breeder Reactor - I
GFE	Government-furnished equipment
ICPP	Idaho Chemical Processing Plant
HP	Health physics
INEL	Idaho National Engineering Laboratory
IWMIS	Industrial Waste Management Information System
MSA	Mine Safety Appliance
NaK	Sodium/potassium eutectic metal solution
PBF	Power Burst Facility
PREPP	Process Experimental Pilot Plant
PSAR	Preliminary safety analysis report
QPP	Quality program plan

RWMC	Radioactive Waste Management Complex
RWMIS	Radiological Waste Management Information System
SO	System operations
SP	Standard procedure
SWP	Safe work permit
SWR	Site work release
t	time
TAN	Test Area North
TRA	Test Reactor Area
UBC	Uniform Building Code
TRU	Transuranic
WAC	Waste acceptance criteria
WBS	Work breakdown schedule
WCB	Willow Creek Building
WERF	Waste Experimental Reduction Facility
WMPD	Waste Management Programs Department
WR	Work release

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DECONTAMINATION AND DECOMMISSIONING PLAN FOR PROCESSING OF CONTAMINATED NaK AT THE IDAHO NATIONAL ENGINEERING LABORATORY

1. INTRODUCTION

The U.S. Department of Energy, Idaho Operations Office (DOE/ID), assigned EG&G Idaho, Inc. the responsibility for implementing the decontamination and decommissioning (D&D) program at the Idaho National Engineering Laboratory (INEL).

Approximately 180 gal of sodium/potassium (NaK) eutectic liquid metal were severely contaminated during a meltdown of the Mark-II core of the Experimental Breeder Reactor - I (EBR-I) in November 1955. This contaminated NaK is contained in four vessels and is currently stored in an underground bunker located at the Army Reentry Vehicle Facility Site (ARVFS), approximately at the center of the INEL (Figure 1). Figure 2 is a photograph of the ARVFS bunker and site.

The 180 gal of NaK are contained in two 55-gal drums and two vessels fabricated from pipe sections. Figure 3 is a photograph of these containers. Originally, after cleanup of the EBR-I Mark-II core, the NaK was stored in a pit at the EBR-I site until 1974. During D&D operations for EBR-I in 1974, this contaminated NaK was removed from the EBR-I pit, placed into a dumpster (Figure 4), and then moved into storage at the ARVFS bunker. An inspection of the ARVFS bunker and the NaK containers was performed in 1979. Since that time, the NaK containers have not been further disturbed.

At the time of the Mark-II core meltdown, uranium (238) was being transmuted to plutonium (239). It is believed that the radioactive contamination was from the core meltdown and not from the surrounding blanket being transmuted. In addition, a 10.5-g sample of plutonium, contained in a foil inside the reactor, was not recovered during cleanup,

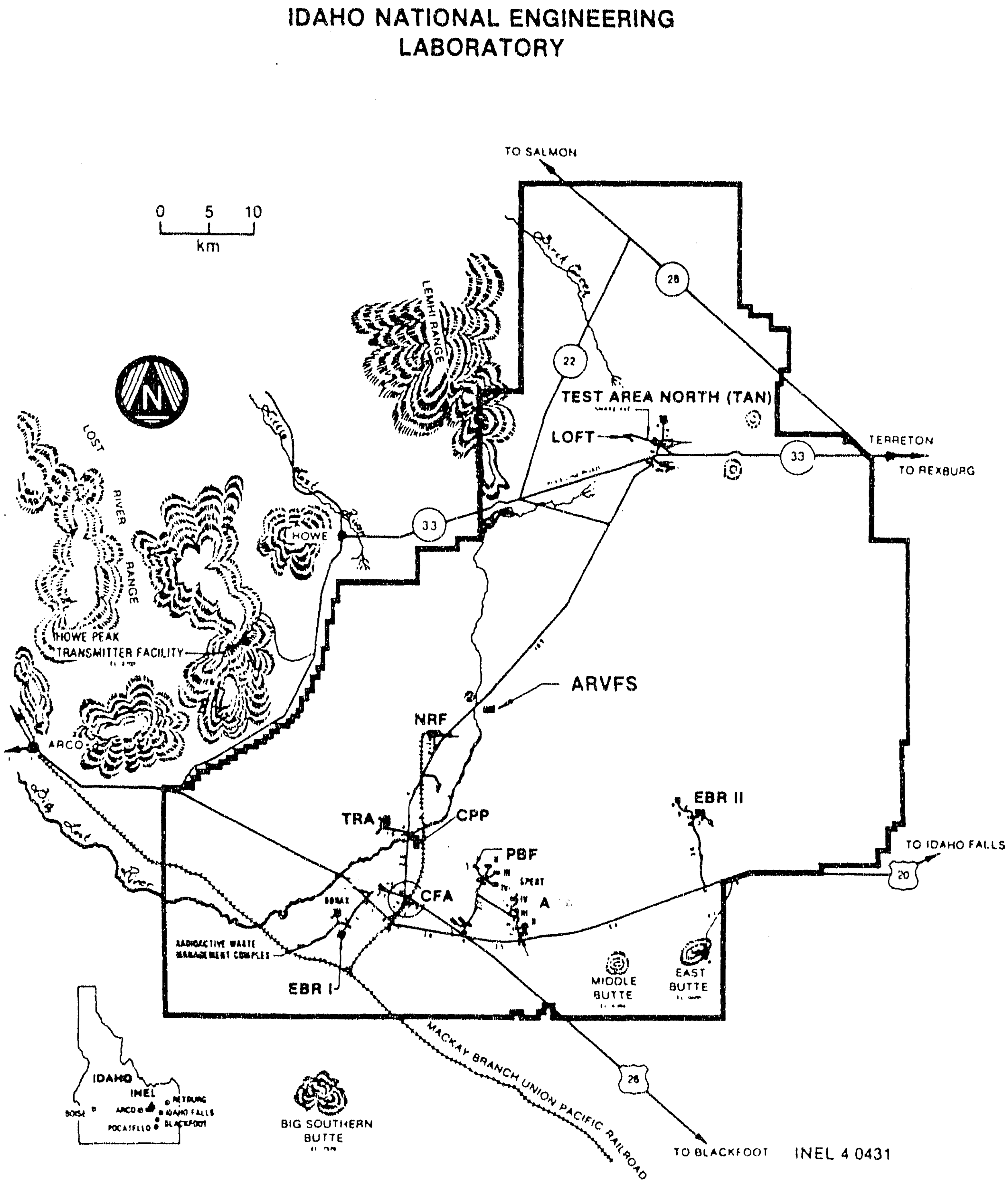

Figure 1. Map of INEL showing the location of ARVFS.

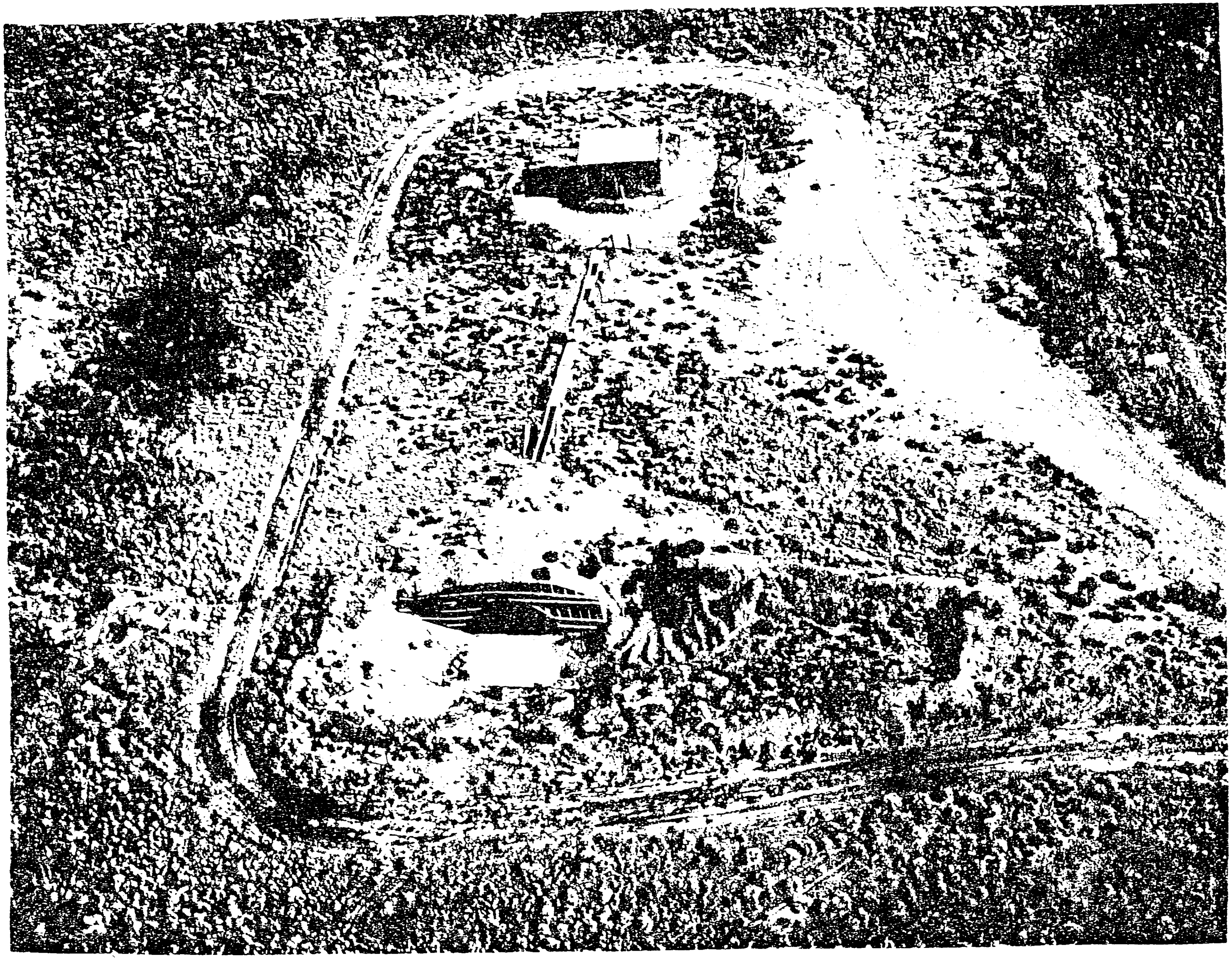

Figure 2. Aerial view of ARVFS loking to the east.

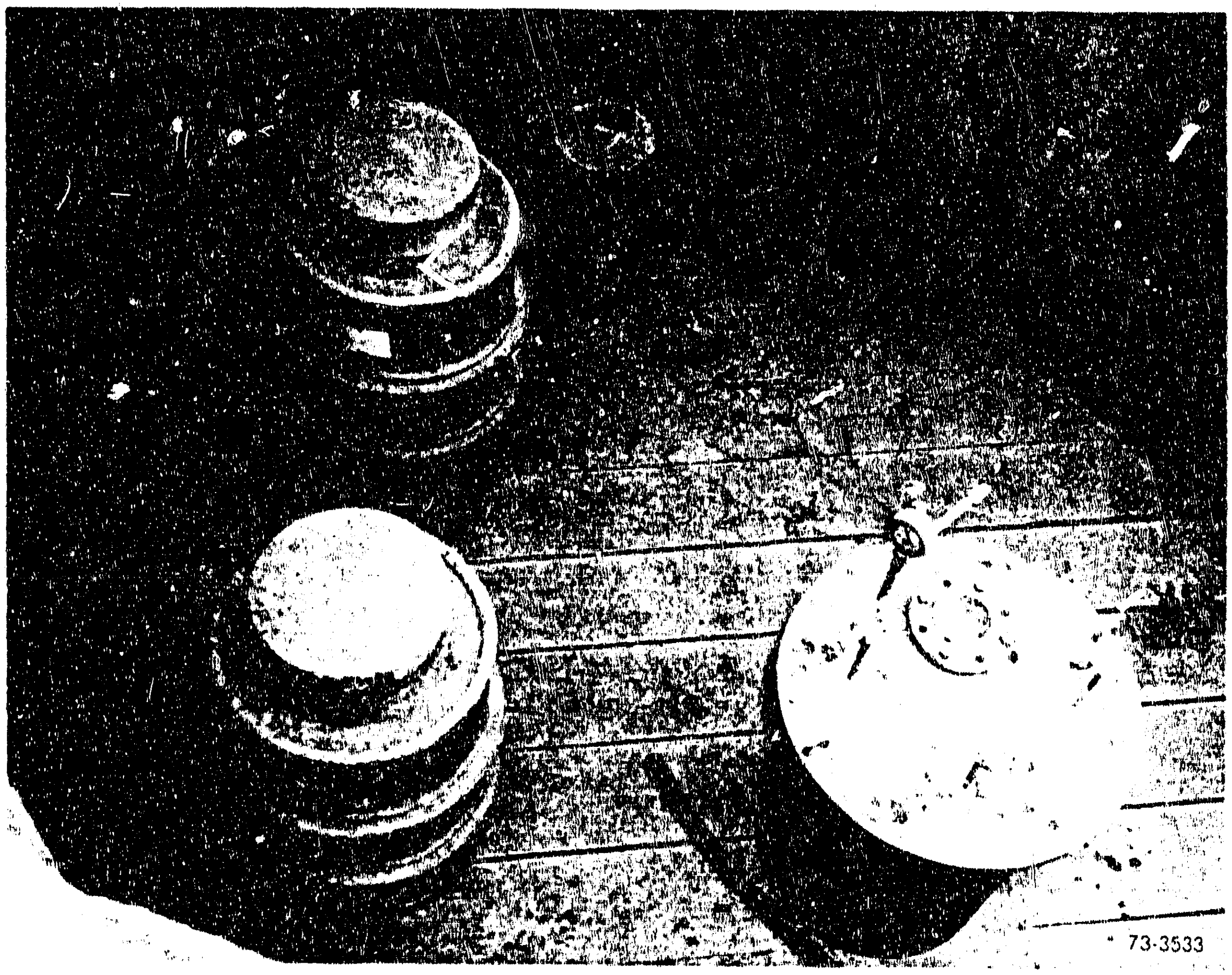

Figure 3. Four containers of contaminated NaK placed in storage pit at the INEL EBR-I site from 1955 to 1974

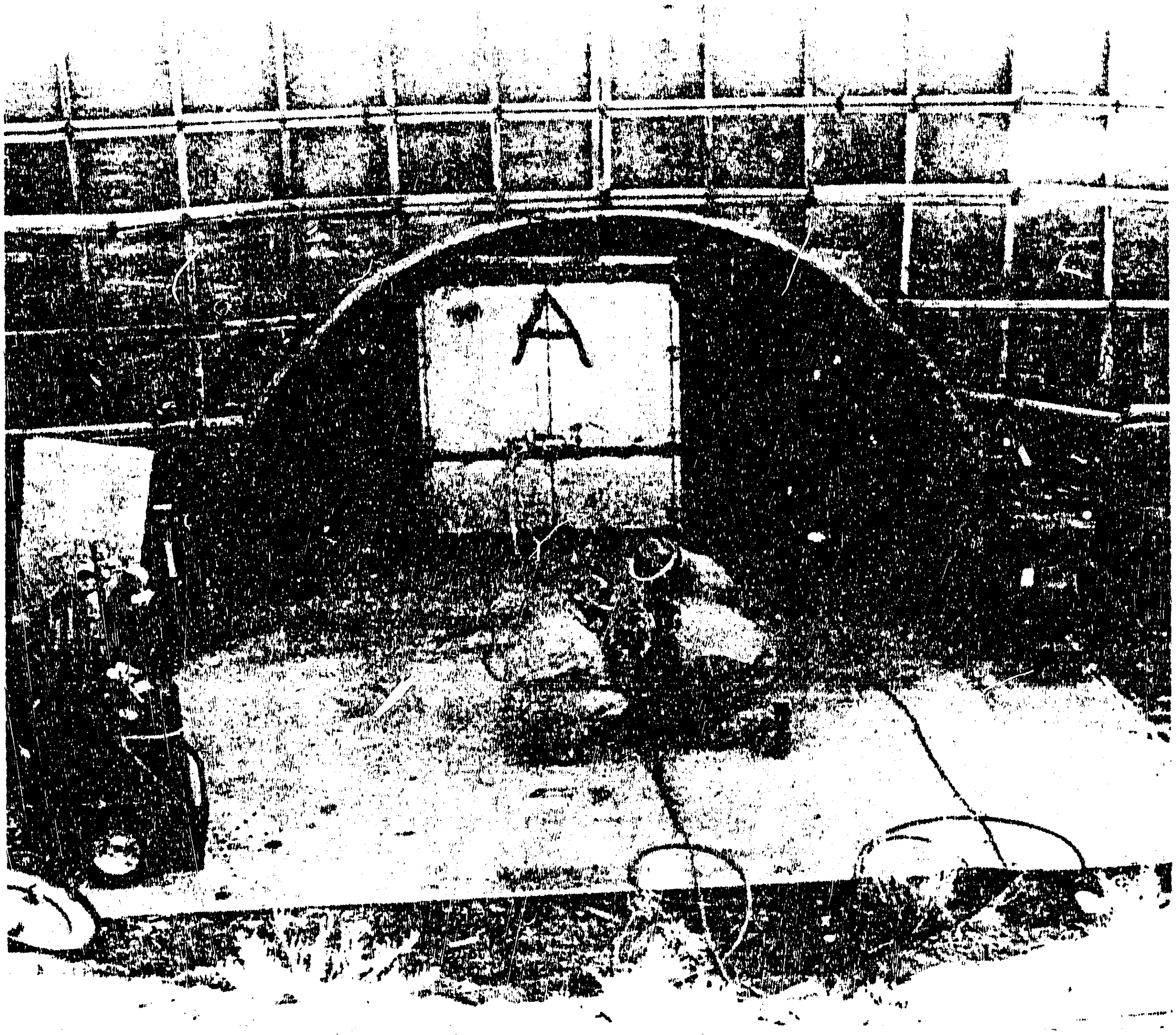

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Figure 4. Dumpster containing NaK drums and containers in ARVFS bunker.

and is likely present in the NaK. The present estimated level (Appendix A) of contaminated NaK is less than 30 g of radioactive material; NaK may also contain some nonradioactive core debris.

This document presents the D&D Management Plan for decontamination and decommissioning of the contaminated NaK and the four containers, and return of the ARVFS to a reusable condition.

2. PROJECT OBJECTIVES

The objectives of this project are as follows:

1. Chemically deactivate and stabilize the NaK (see Appendix D)

2. Dispose of the contaminated product at a designated burial site

3. Chemically deactivate and stabilize any residual NaK in the containers, and dispose of the containers at a designated burial site

4. D&D any contaminated process equipment used in these operations

5. D&D the ARVFS bunker site.

Safe conduct of the above technical objectives will allow for the effective disposition of the NaK and for the decontamination and return of the ARVFS bunker and immediate area to a reusable condition. Upon completion, the EBR-I NaK, which is now considered a significant potential hazard, will be removed from the Surplus Facilities Management Program priority listing of projects.

3. FACILITY DESCRIPTION

3.1 Physical

The physical description of the NaK containers and of the ARVFS have been presented in detail in several reports (References 1-5). The description provided in this section summarizes the information contained in those reports.

NaK has been stored in two stainless steel 55-gal Mine Safety Appliance (MSA) drums and in two carbon steel containers fabricated from pipe sections. During an inspection in 1979 (Reference 5), the smaller of these fabricated vessels indicated some minimal external corrosion. The internal condition of the NaK containers is unknown. Several attempts over the years since the 1955 incident have been unsuccessful in locating engineering drawings for the two fabricated NaK containers. The four containers were originally blanketed with argon during their filling in 1955. These four containers have since been placed inside a sheet metal dumpster, and covered with vermiculite to a depth of approximately 12 in. above the NaK containers. The dumpster and contents have been stored inside an underground bunker at the ARVFS since 1974.

ARVFS is located approximately 1 mile east of Lincoln Blvd., about 2-1/2 miles northeast of the Naval Reactor Facility (Figure 1). This remote location does not have electrical or water service. However, a 230-Kva line runs past the site, 1/4 mile to the east; and 1/2 mile to the west is a water well, USGS 17. The Big Lost River is about 1 mile to the west.

ARVFS consists of an earth-covered bunker (Figure 2), a cylindrical test pit, and a metal shed covering the test pit (Figure 5). A cable trench (Figure 6) runs from the test pit to the bunker.

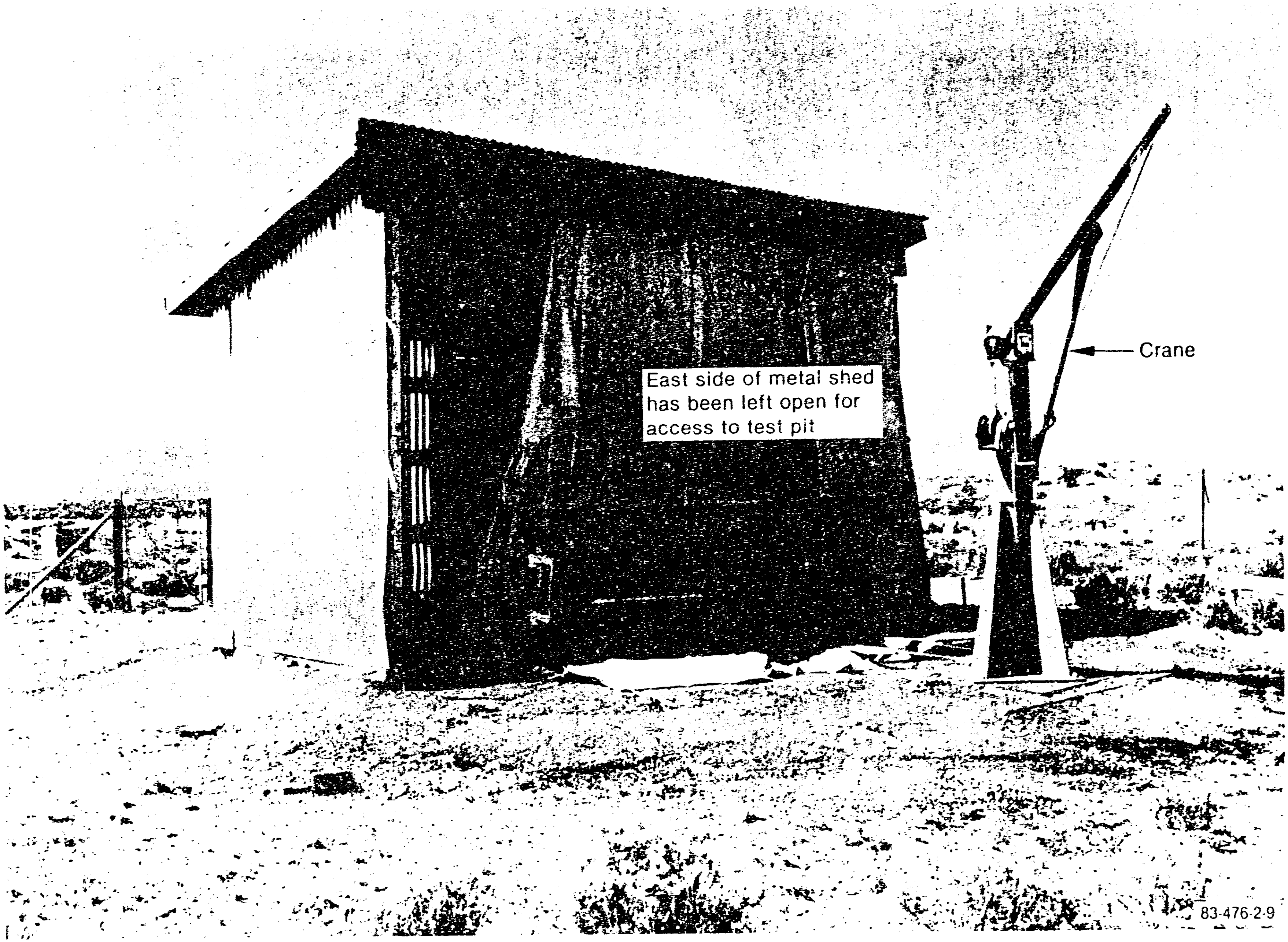

Figure 5. Metal shed covering test pit.

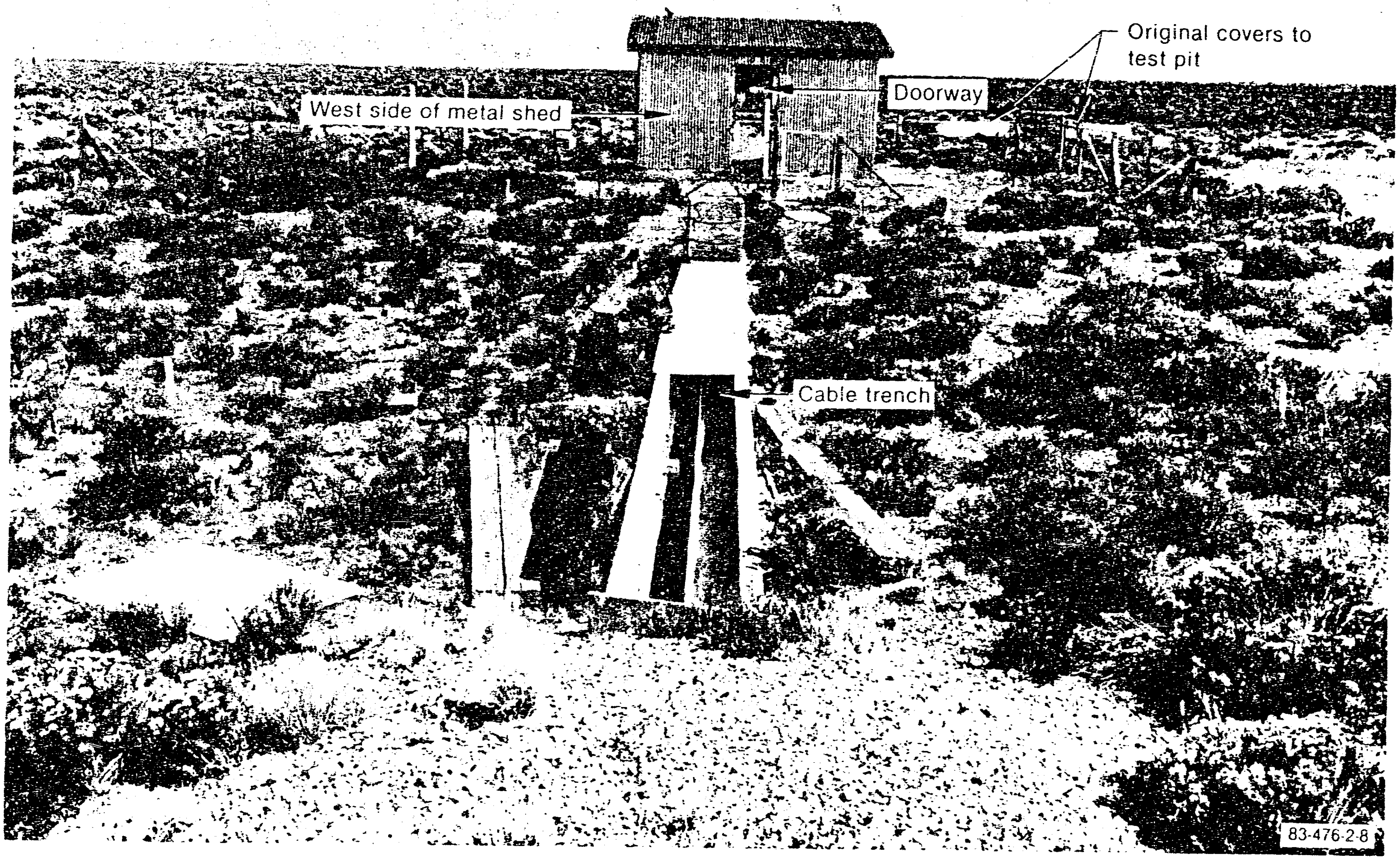

Figure 3. Metal shed and cable trench at ARVFS looking east.

The bunker is an ARMCO multiplate arch building 9 ft, 3 in. high at the center, 16 ft wide and 18 ft long. It has a concrete floor about 9 ft below grade. Soil is mounded over the top of the building about 3 ft higher than the surrounding terrain.

The cylindrical test pit is an open-top vessel made of 1/4 in. A-36 structural steel. It has an inside diameter of 12 ft and is 16 ft deep.

The metal shed covering the test pit is a wood frame structure with corrugated sheet metal nailed to three sides and to the floor (Figure 5). The hand-operated crane, located in front of the shed, has since been removed and excessed. The metal shed is 9 x 17 ft and about 8 ft high. The open side has been covered with a wood frame and plastic cover.

The cable trench, approximately 100 ft long, runs from the west side of the test pit to the bunker (Figure 6). The trench is 1.5 ft deep and 1 ft wide, and is made of concrete.

3.2 Chemical Hazards

The chemical hazards associated with NaK have been described in detail in an Engineering Design File (EDF) document, Appendix B. This EDF addresses toxicity, fire, and explosion hazards. It also addresses potential contaminants in the NaK, which may not actually be present, but have a probability of existing in the NaK, particularly potassium superoxide (KO_2).

Probably the most significant chemical hazard is the explosive capability of NaK if exposed to air and allowed to form KO_2. The superoxide is extremely oxidizing and can cause thermal explosions, deflagrations, or detonations, depending upon reactant materials.

NaK is a toxic substance and, as explained in Appendix B, will readily attack living tissue because of its moisture and oxidizing potential.

There is a strong possibility that air has leaked into one or more of the containers since their original containment. If air has entered the containers, oxygen will react with the potassium present to form potassium superoxide, potassium peroxide, and potassium oxide. The sodium will react to form sodium oxide. The sodium and potassium oxides, which are essentially inert, can bridge within the containers and isolate the potassium superoxide and peroxide from the NaK. This bridge could be broken with movement or vibration of the containers. If the contaminants are present, they could react as described above if brought into sudden and immediate contact.

3.3 Radiological Hazards

The radiological hazards associated with the NaK have been addressed in detail in an EDF (Appendix A). This EDF utilizes the available radiological information from earlier surveys to assess the hazards that will likely be encountered at the time of processing. The EDF on radiological hazards is further supported by an EDF on exposure estimates (Appendix C). A summary of the findings of these two EDFs is provided in the following discussion.

The radiological hazards EDF reevaluated the 1966 EBR-I meltdown and concluded that the dominant radiological hazard associated with the NaK processing was fission product contamination. Based upon core operating history and makeup, a calculated (maximum credible value) fission product inventory for the NaK was developed. The inventory is presented in Appendix A. The total fission mass inventory is approximately 23.3 g, and the total fission product activity is about 133 Ci.

The radiation exposure EDF uses the fission product inventory and data gathered from radiation exposure estimates made in 1974 and 1979 to project exposure estimates. These exposure rates are presented in Appendix C, which also estimates thicknesses of lead and soil required to establish times that workers could spend in the high gamma field while remaining in compliance with EG&G Idaho Administrative Dose Guidelines.

4. MANAGEMENT APPROACH

4.1 Project Management Organization and Interfaces

The NaK D&D organization and key interfaces are shown in Figure 7, and key responsibilities are described below.

4.1.1 D&D Program Manager

The D&D program manager provides the interface between EG&G Idaho and DOE-ID. All official correspondence between EG&G Idaho and DOE-ID relative to this project will be between the EG&G Idaho Waste Management Programs Department (WMPD) Manager and the DOE-ID Reactor Research and Waste Technology Division Manager.

4.1.2 NaK Project Manager

The project manager is responsible for management and control of all D&D work to ensure completion of the project within budget and schedule. Project responsibilities include preparing the D&D Plan, reviewing and approving integrated planning sheets, preparing detailed operating procedures, preparing and updating detailed schedules, developing a work breakdown structure (WBS), interfacing with support organizations to help ensure safe completion of the project, monitoring progress of the project, reporting progress and status to the D&D program manager, and preparing all reports for the project.

4.1.3 NaK Processing Lead Engineer

The NaK processing lead engineer is responsible for coordinating all engineering and development activities associated with this project. Included in this task are preparation of conceptual design and Title I and Title II design packages. The lead engineer will prepare the engineering and development work packages for the project manager's approval. Upon approval of the work packages, the lead engineer will issue work releases

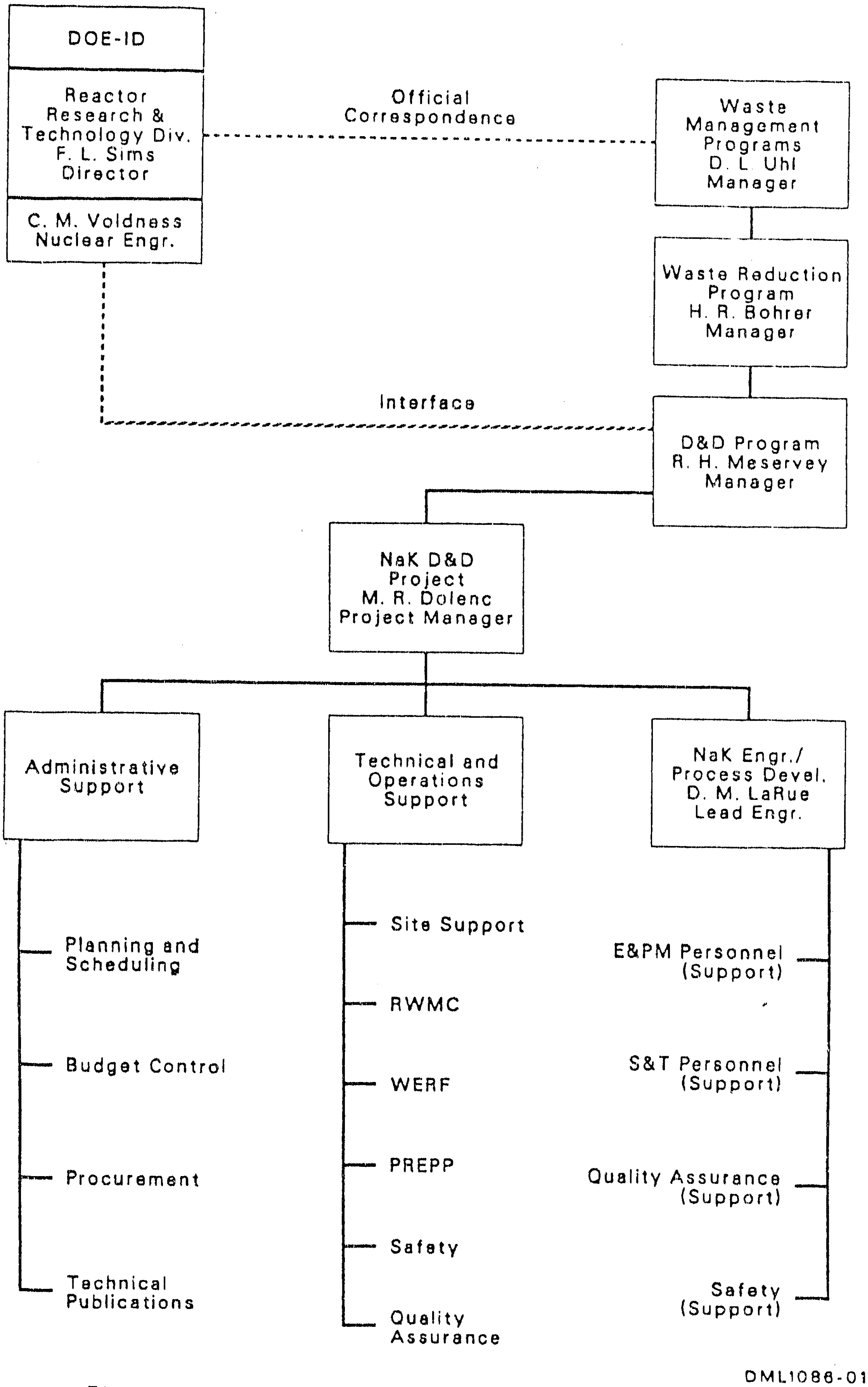

Figure 7. NaK Project Organization and Interfaces.

to the supporting organizations performing tasks identified in engineering and development work packages.

4.1.4 D&D Operations

D&D operations include supervision and performance of all jobs related to NaK D&D, including boxing of the waste and waste shipment to the Radioactive Waste Management Complex (RWMC), Waste Experimental Reduction Facility (WERF), Process Experimental Pilot Plant (PREPP), or sanitary landfill. Personnel will be assigned from EG&G Idaho Plant Services to accomplish the D&D operations. These personnel include required crafts and foremen.

4.1.5 Planning and Scheduling

Planning consists of preparing work packages, including integrated planning sheets that incorporate as low as reasonably achievable (ALARA) principles. Scheduling will utilize available resources to ensure that the D&D project is completed on schedule. Planning and scheduling for field work will be performed by Central Facilities Area (CFA) Planning and Scheduling.

4.1.6 Health Physicist (HP) Support

The HP tehnician covering this project will be assigned from the South INEL Safety Unit.

4.1.7 Budget Control

WMPD maintains a budget control staff. This staff provides actual spending information through the CAPS system comparison with budgeted costs. To maintain budget control, this information is made available weekly to the project manager.

4.1.8 Quality Assurance

Quality engineering review and work inspection services will be provided by EG&G Idaho Quality Assurance South. The review services include support for both design and work package activities to ensure compliance with the EG&G Idaho Quality Manual and the Quality Program Plan--Waste Management Programs Department, QPP-053.

4.1.9 Safety and Environmental Programs

An independent safety review will be provided by EG&G Idaho Safety and Environmental Programs. Included in the review activities is this D&D Plan, with special emphasis on the preliminary safety evaluation presented in Section 10. The independent review is to ensure that all project activities comply with the EG&G Idaho Safety Manual.

4.2 Administrative Controls

Appropriate project administrative controls, as described below, have been implemented for budget and schedule control, work control, reporting requirements, and the physical and documentation configuration control process for beginning the decommissioning operations.

4.2.1 Budget and Schedule Control

A budget for the NaK D&D project has been established and is maintained by the Cost and Planning System (CAPS) used at EG&G Idaho. A cost review is implemented on a monthly basis at the end of each accounting period. In addition to the cost review, the schedule presented in Section 6 is reviewed for progress and impact on the budget/schedule relationship, and will be used to provide the necessary elements for management budget control.

A work release (WR) will be issued for each subtask on the WBS discussed in Subsection 5.3. This document is a written agreement between the lead engineer and the performing organization identifying funds, materials, task description, and schedule of performance. The WR will define the work to be accomplished, the deliverables from that work, the required man-hours to complete, and the allocated costs. No work beyond that described by the WR will be authorized without modification to the WR. The WR is identified by a nine-digit number. The project work is divided into major categories, and subtasks are identified by the last three digits of the WR number.

4.2.2 Work Control

The control of work is performed in accordance with WMPD standard practices (SPs) and the applicable INEL and EG&G Idaho standard practices. The SPs include definition of work requiring procedural coverage, procedure development, approval and change control, and safe work permit requirements.

At periodic planning meetings (e.g., monthly) conducted by the project manager, the project progress, and current work plans and costs will be checked against scheduled progress and budget. These meetings will include the lead engineer, a representative of the D&D Group, members of the project team, engineering support, and others as appropriate. These periodic reviews will provide the necessary perspective of work progress and schedule data, and permit management and funding decisions required for successful accomplishment of project activities. Supplemental meetings will be held, as necessary, to ensure the proper craft work coordination/ interfaces are understood, are being implemented, and will support the overall project schedule.

4.2.3 Reporting Requirements

4.2.3.1 Periodic Status Reports. The project manager will prepare a monthly project progress report to be submitted for inclusion in the WMPD Programs Status Report transmittal to DOE-ID.

Informal reports describing progress will be made to the WMPD management as requested.

4.2.3.2 Waste Release Reports

4.2.3.2.1 Radiological--In accordance with the EG&G Idaho Safety Manual, Section 15, "Waste Management," and the EG&G Idaho Radiological Controls Manual, Chapter 8, "Radioactive Waste Management," radiological atmospheric emissions and waste disposal data are reported to the INEL Radiological Waste Management Information System (RWMIS). The RWMIS began using a remote data entry system on August 15, 1986. This system is the principal means for reporting airborne, liquid, and solid wastes generated by this project. Only one written form, DOE-ID-F-5820.2A (Certified Waste Data Base), will be required. This form will be completed for each radioactive solid waste load being transferred to the RWMC, WERF, or PREPP, and submitted in accordance with INEL Low-Level Radioactive Waste Acceptance Criteria, DOE/ID-10112, and INEL Transuranic (TRU) Waste Acceptance Criteria, IDO-100074.

4.2.3.2.2 Industrial Waste--In accordance with EG&G Idaho Section 15, "Waste Management," nonradioactive, nonhazardous, airborne, liquid, or solid waste information is reported monthly on the INEL Industrial Waste Management Information System (IWMIS) on Form ID-F-136, "Industrial Waste Form." The form will be submitted to the CFA industrial waste coordinator by the end of each month following the reporting period. The form will be completed for each nonradioactive, nonhazardous solid waste load being transferred to the sanitary landfill and will be submitted to the facility supervision.

4.2.4 Configuration Control Process

The project configuration control consists of (a) engineering drawings and documents, and (b) project documents.

4.2.4.1 Engineering Drawings and Documents. The preparation and processing of all engineering drawings will be in accordance with the EG&G Idaho Drawing Requirements Manual. All project engineering drawings and documents will be assigned the same project number established at the request of the lead engineer.

4.2.4.2 Project Documentation. Project control of documentation consists of establishing and maintaining project files. Project files will be maintained by the D&D Program office, presently at PBF-632.

An engineering design file (EDF) system will be included as part of the project documentation file and will use Form EG&G-2631. The purpose of the EDF system is to provide simple storage/retrieval for project information (e.g., studies, analyses, procedures, data) not covered by formal reports or memoranda. Numerical sequence of EDFs will be maintained in a log along with the author's name, subject, and date. The EDF file and log will be maintained in the lead engineer's office, Willow Creek Building, and will be incorporated in the project files at project completion.

4.3 Performance and Completion Measurement Criteria

The "Earned Value" concept will be used to measure and report project performance by tracking cost and schedule and reporting variances.

For this project, cost and schedule variances are defined as follows:

Cost Variance = ACWP - BCWP

Schedule Variance = $t_{BCWP} - t_{BCWS}$

where

ACWP = actual cost of work performed

BCWP = budgeted cost of work performed

BCWS = budgeted cost of work scheduled

t = time.

5. TECHNICAL PLAN

This section establishes the plan for implementing the D&D Project delineated in Section 2 in regard to total work scope (5.1), applicable design criteria (5.2), work breakdown structure (5.3), and waste management (5.4).

5.1 Total Work Scope

The scope of the EBR-1 (Mark-II core) NaK D&D Project is to chemically deactivate the radioactively contaminated NaK, to dispose of the resulting radioactive waste, to D&D the original NaK containers, to D&D contaminated processing equipment, to D&D the ARVFS bunker where the NaK has been stored, and to D&D the ARVFS Bunker site. Also included in this scope are the necessary project management, design, development, procurement, construction, testing, and operational elements, as illustrated in Figure 8.

5.2 Design Criteria

The design criteria for equipment to be used in this project are defined in the INEL Architectural Engineering Standards and ID 12049, Operational Safety Design Criteria Manual.

Rigging and lifting equipment employed in this project will be in accordance with guidelines and requirements as defined in the DOE Hoisting and Rigging Manual and the EG&G Idaho Safety Manual.

Special containers that may be required for packaging waste for receipt at the RWMC will be designed and fabricated in compliance with the criteria as defined in INEL Low-Level Radioactive Waste Acceptance Criteria, DOE/ID-10112, current revision, Reference 6; and INEL Transuranic (TRU) Waste Acceptance Criteria, IDO-10074, current revision, Reference 7.

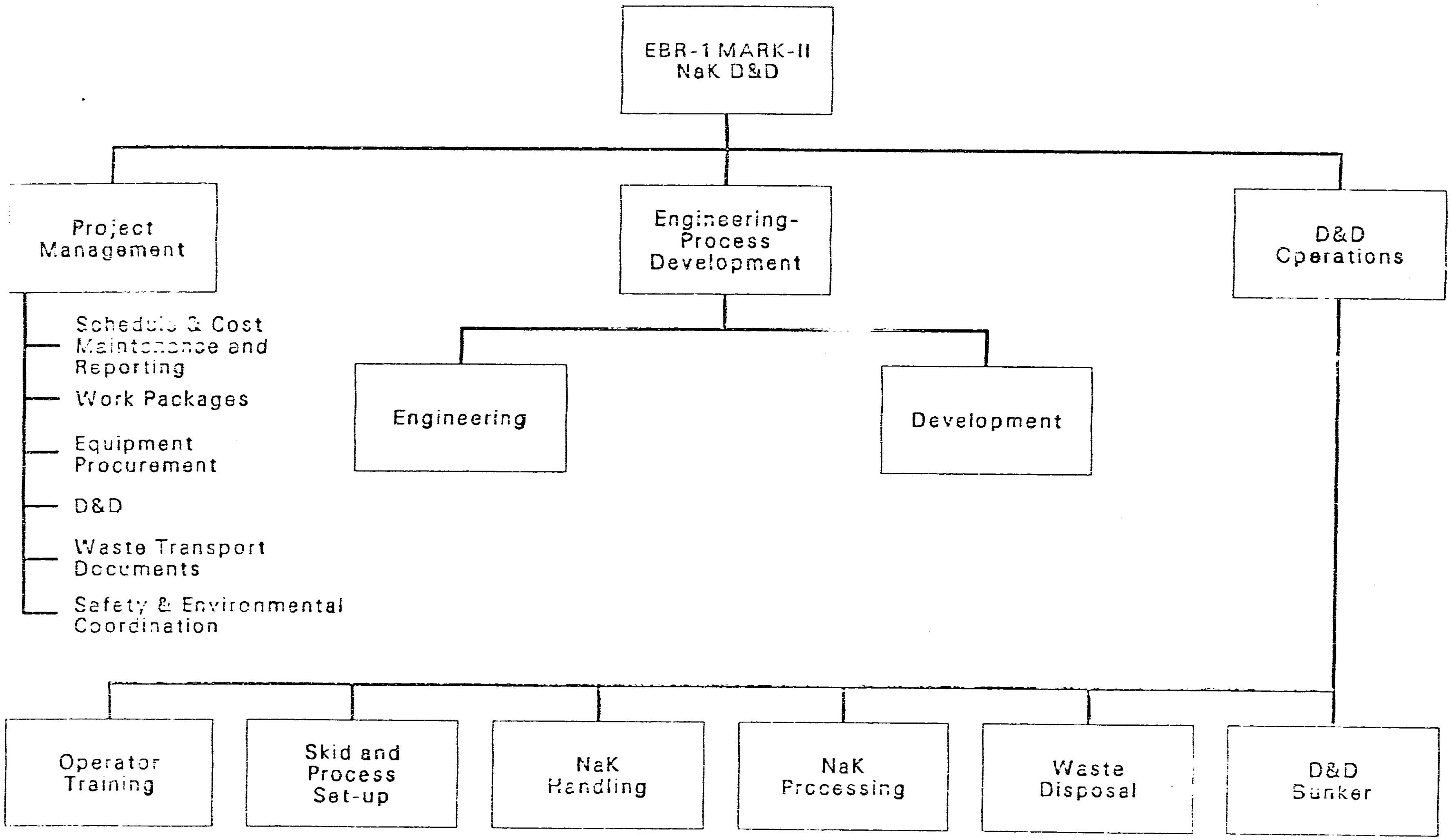

Figure 8. Generalized Work Breakdown Structure for the NaK D&D project.

5.3 Work Breakdown Structure

Figures 8 through 10 illustrate the work breakdown structure for this project. Specific tasks defined under the major elements within this work breakdown structure are discussed below.

The following general work control guidelines will be adhered to throughout the D&D activities and are given here to prevent undue repetition. In performing all of the D&D operations in radioactive areas and with contaminated components, it is mandatory that personnel exposure to radiation or hazardous chemicals be maintained as low as reasonably achievable (ALARA). Anti-contamination clothing, NaK protection equipment (i.e., fire extinguishers), respirators, and other personnel protective equipment are, without exception, to be worn or used when necessary by all personnel in accordance with requirements of the EG&G Idaho Safety and Radiological Controls Manuals. No less than two persons, with a Health Physicist to monitor radiation levels, will perform D&D operations. All D&D operations will be accomplished in accordance with approved site work releases, safe work permits or special site work permits, and approved detailed operating procedures. Constant air monitors (CAMs) with alarms to indicate airborne release and radiation area monitors (RAMs) to indicate high radiation fields will be in operation at the processing site. Chlorine monitoring with an alarm to indicate airborne release will be kept in operation at the processing site.

Thermal monitoring of containers will be employed during retrieval, movement, and penetration of the NaK containers to alert operators to possible thermal breaching of the containers from superoxide NaK reaction. The secondary NaK containment will be blanketed with argon gas to prevent formation of superoxide during container penetration and processing operations.

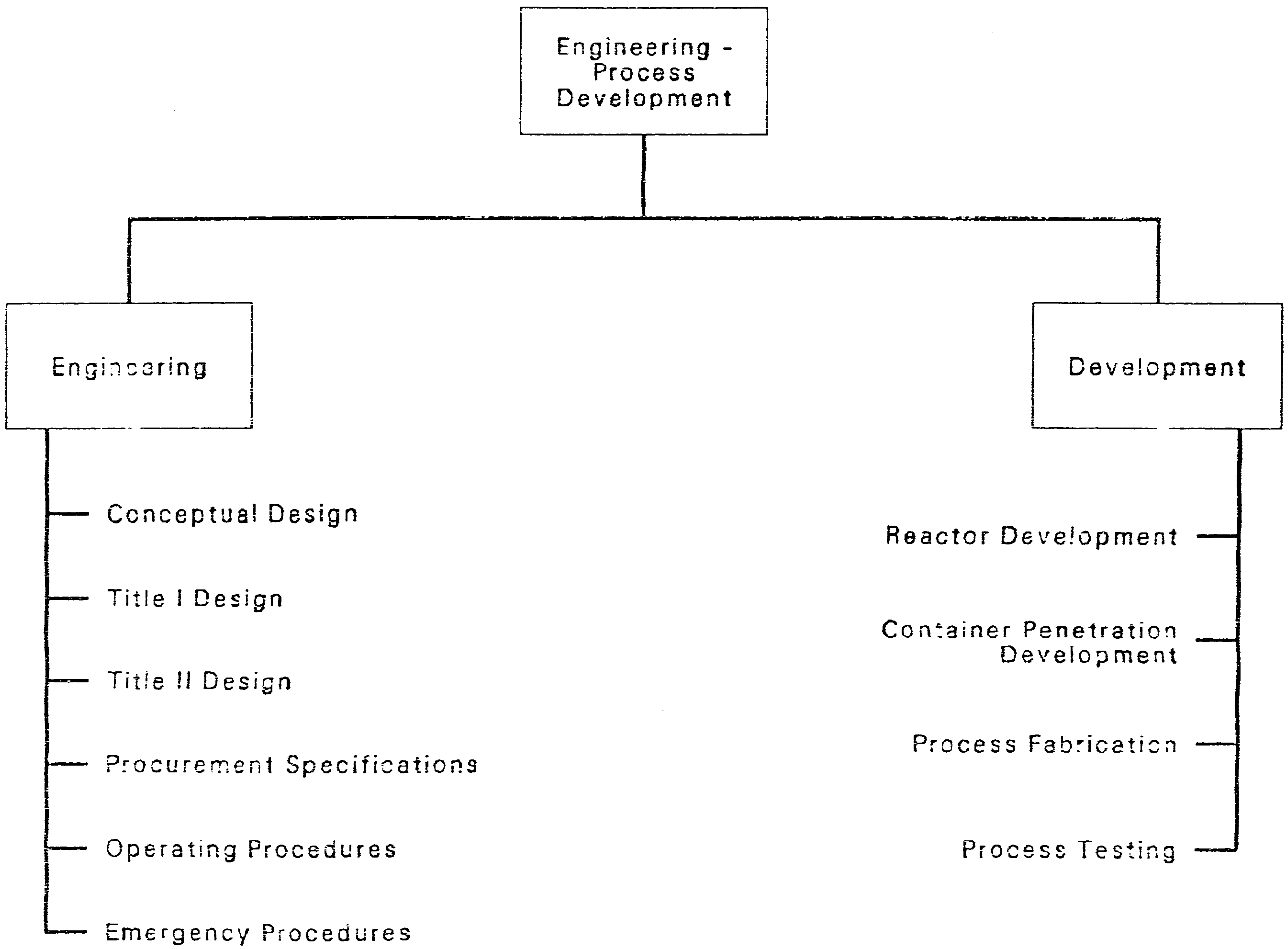

Figure 9. Work Breakdown Structure for the NaK Engineering and Process Development.

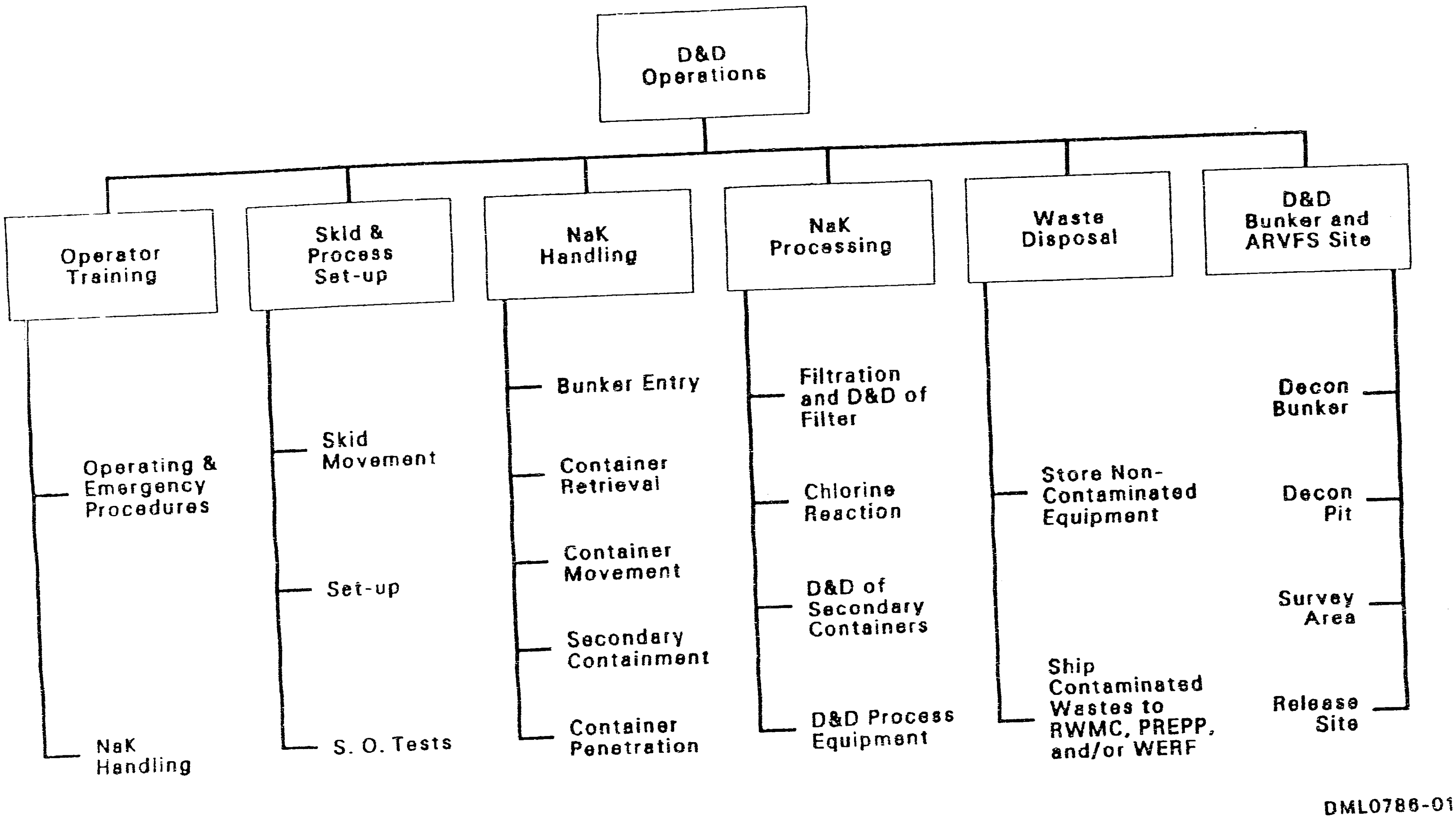

Figure 10. Work Breakdown Structure for D&D operations.

All process equipment will be monitored and controlled to permit safe, reliable processing of the NaK. Radiation meters will be incorporated into the processing system to provide accurate inventory of radioactive materials.

Contaminated piping and equipment will be decontaminated to the extent practicable as the work progresses to facilitate acceptance at WERF, PREPP, or the RWMC and to minimize D&D costs.

Contaminated piping and equipment will be packaged as prescribed in Reference 6, or in specifically designed and fabricated containers (e.g., the reaction vessel) for special shielding or unusual configurations, as appropriate for transport and receipt at a designated disposal location. For each shipment to RWMC, WERF, or PREPP, the type and nature of the shipment, type of container, and level of radiation will be indicated for review and approval. Any deviation from packaging practices will be approved prior to implementation.

5.3.1 Project Management

The project management element covers the overall performance and coordination of this project. Specific responsibilities and authorities are discussed below.

5.3.1.1 D&D Plan Preparation. This plan is generated to establish policy; assign responsibility and authority; and define the scope, schedule, and budget for the project. Guidelines for this plan are contained in the EG&G Idaho Project Directive WT-D&D-1.1.6, 6/3/85.

5.3.1.2 Work Package Preparation. Work packages will be generated and approved by the project manager and the performer before performance of the tasks, as outlined in the work breakdown structure. Work releases and site work releases, integrated planning sheets, and detailed operating procedures will be used to formalize work instructions that accompany the work packages (as appropriate) to related hazards and the complexity of the task.

5.3.1.3 Equipment Procurement. This work element is responsible for procurement (in some cases coordinating the borrowing of equipment) for the project. Specifications for equipment will be generated in the engineering work package.

5.3.1.4 Schedule and Cost Maintenance and Reporting. This work element is responsible for the generation of schedules and cost estimates for the project. Subsequent monitoring and maintenance of the schedule and costs will be performed. Reporting on cost, schedule, and technical status to EG&G Idaho management and DOE (as appropriate) is the responsibility of this work element. Preparation and finalization of the project's final report will be the responsibility of this work package.

5.3.1.5 Waste Transport Documents. This work element encompasses the preparation and approval of necessary waste transport documents for the resulting contaminated materials from the project. The documents generated will also include the necessary documents for acceptance of materials for PREPP, WERF, or RWMC, depending on waste type.

5.3.1.6 Safety and Environmental Coordination. This project element coordinates the passage of information and reviews documents, procedures, and plans to the safety and environmental functions at the INEL.

5.3.2 Project Concept/Engineering/Process Development

The Engineering/Process Development element is responsible for the development of the methodology to accomplish the D&D project. Because of the nature of the problem, some developmental work is requisite to increase the probability of a successful project and to perform the project in a safe and cost-effective manner. Two major areas for development are container penetration and reactor vessel design and operation.

The NaK will be processed by chemically reacting it with chlorine gas. This method was chosen over other processing methods upon consideration of waste form, safety, and cost (see Appendix D).

Engineering design work is in progress using this concept for processing. Laboratory tests are planned to verify that this chlorine reaction technique can be safely controlled. Development work is also in progress on a drum penetration method, containment, system, and reaction vessel. Work planned for FY-1987 will support these work elements.

5.3.2.1 Engineering. This work package is responsible for the performance of all engineering and design activities associated with the project. Information gathered in the development work package will be utilized in accomplishing the design effort.

5.3.2.1.1 Conceptual Design--This sub-work package is responsible for conceptualizing the NaK handling and processing scheme. A conceptual design report, which will be utilized in subsequent engineering, will be the deliverable of this sub-work package.

5.3.2.1.2 Title I Design--This sub-work package is responsible for preparing the preliminary design (Title I). This will include sizing major components, specifying reactant flow rates, heat rates, instrumentation and control loops, control and shutdown schedules, power requirements, and preliminary normal and emergency operating procedures.

Because of the small size and simplicity of the process, a formal Title I design package will not be generated, although a formal Title I design review meeting will be held with review from Quality, Safety (DOE and EG&G Idaho), Engineering, and Programs (DOE and EG&G Idaho) personnel. Equipment specifications for required long-lead government-furnished equipment (GFE) will also be delivered under this work package.

5.3.2.1.3 Title II Design--This sub-work package is responsible for preparing and finalizing the design (Title II) to the point of construction readiness. The design package will be sufficient for construction by EG&G Idaho maintenance and crafts personnel, but not presented in the format typical of that utilized for outside subcontracting. Because of the nature of the project, i.e., small-scale processing, this project does not fall under Davis-Bacon requirements.

The design package will finalize design on mechanical, electrical, civil/structural, and instrumentation and control.

5.3.2.1.4 Procurement Specifications--Coincident with the Title II design, this sub-work package will deliver procurement specifications for non-long-lead GFE components and parts for the project.

5.3.2.1.5 Operating Procedures--This sub-work package will prepare the operating procedures, including the operator training manuals, for the project. This activity will include researching equipment design and procedural requirements, writing procedures, identifying and listing required materials and equipment, effecting text processing, implementing preparation of appropriate illustrations, issuing procedural drafts for review, evaluating and resolving comments from the review process, and obtaining consensus and approval of the final procedure documents.

5.3.2.1.6 Emergency Procedures--This sub-work package will be responsible for generating emergency procedures, including input for the operator training manuals. This effort will be coordinated with the process and instrumentation and control Title II design efforts wherein fault-tree analysis will be used to identify possible emergency scenarios. This activity will include researching equipment design and procedural requirements, writing procedures, identifying and listing required emergency interfaces, specifying communication requirements for emergency operations and emergency equipment requirements, effecting text processing, implementing preparation of appropriate illustrations, issuing emergency procedures drafts for review, evaluating and resolving review comments, and obtaining consensus and approval of the final procedures document.

5.3.2.2 Development. This work package is responsible for the performance of experimentation and development of the process for penetrating the NaK containers and the chemical deactivation of the NaK. It will be responsible for the nonradioactive fabrication and testing (cold) of the system before moving the system to the ARVFS bunker area for the actual processing of the contaminated NaK.

5.3.2.2.1 Reactor Development--This sub-work package is responsible for designing, building, testing, collecting, and reducing data of a prototype reaction vessel. These data will be used in the design of the reaction vessel for the project. The information gathered under this exercise will be utilized in the Title I and Title II design efforts.

This sub-work package is also responsible for generating procedures and safety documentation required before testing in the laboratory.

5.3.2.2.2 Container Penetration Development--This sub-work package is responsible for designing, building, testing, collecting, and reducing data from a prototype secondary containment system capable of penetrating the NaK containers after they are placed within the secondary containers. The information gathered under this effort will be utilized in the Title I and Title II design efforts.

This sub-work package is also responsible for generating procedures and safety documentation required before testing in the laboratory.

5.3.2.2.3 Fabrication--This sub-work package is responsible for overseeing the fabrication of the processing system and skid mounting of the system. Upon completion of fabrication, component checkout (CC) tests, and system operations (SO) tests will be performed. The preparation of all procedures and safety documentation for this effort is also the responsibility of this sub-work package.

5.3.2.2.4 Process Testing--Upon completion of SO testing for the system, this sub-work package is responsible for cold-testing (nonradioactively contaminated NaK) the system. All test plans, operating procedures, and safety documentation for the tests will be the responsibility of this sub-work package.

5.3.3 D&D Operations

This work element is responsible for the actual performance of the D&D activities associated with this project. The work packages assigned to this element are discussed below.

5.3.3.1 Operator Training. This work package is responsible for the Alkali Metals Training Class (NaK handling, operating procedures, and emergency procedures) of the operators who will perform the D&D operations. This class involves classroom, field demonstrations, and field training.

Efforts will be coordinated between this work package and the sub-work package (5.3.2.1.5), the element responsible for producing the training manuals.

Operators will be present during the Process Testing operations (5.3.2.2.4) to facilitate their comprehension of the process system.

Necessary NaK handling training and emergency procedures training will be coordinated with EG&G Idaho Safety and Environmental Programs.

5.3.3.2 Skid and Process Setup. Upon completion of the testing (5.3.2.2.4) of the process, this work package will be responsible for moving, setting up the process at the ARFVS bunker, and performing required SO tests after the setup of the unit.

Any required grubbing and grading at the ARVFS bunker, preceding the setup, will be the responsibility of this work package.

5.3.3.3 NaK Handling. This work package is responsible for entry into the ARVFS bunker, movement of the dumpster containing the NaK containers, movement of the containers into their secondary containments, and penetration of the NaK containers. The necessary procedural and safety documentation for this effort is the responsibility of this work package.

This work package will precede the initiation of the NaK processing to decrease personnel exposure hazards. These operations will be performed by rigging and crane personnel under the direction of the project manager and cognizant safety personnel. All processing material will be designed for remote operation and will be totally shielded. Personnel not required to be present during this operation will not be allowed into the area to reduce the potential of personnel exposure.

5.3.3.4 NaK Processing. This work package is responsible for the processing of the contaminated NaK. All operating procedures and emergency procedures will have been formalized external to this work package. Personnel who have not been through the operator and emergency procedures training will not be allowed into the processing area. Once processing begins, the goal will be to conduct operations around the clock until all the NaK has been processed. After NaK processing is completed, residual material present in the secondary containers and the process piping and equipment will be chemically deactivated.

5.3.3.5 Waste Disposal. This work package is responsible for the disposition of all contaminated waste, including secondary containers, process piping, and the reaction vessel. Noncontaminated equipment will become surplus. Process piping and equipment will be broken down and packaged in proper containers (depending on disposition) before movement from the site.

5.3.3.6 D&D Bunker and ARVFS Site. Upon completion of removal of contaminated and noncontaminated materials from the bunker area, the bunker will be available for storage if required at a later time. The test pit will be decontaminated, and the entire ARVFS will be released for potential reuse.

5.4 Waste Management

This project will generate only solid waste that will be transferred to INEL disposal and treatment sites. This section identifies the candidate processing, storage, and disposal sites; summarizes the applicable acceptance criteria (e.g., radioactivity limits); provides waste volume estimates; lists special packaging requirements for the different processing/storage/disposal sites; discusses modes of transportation; and shows the planned schedule of waste disposal/treatment.

5.4.1 Waste Processing, Short-Term Storage, and Disposal Sites

The candidate site for processing the NaK is adjacent to the ARVFS bunker. This site was chosen based on considerations for safety, environmental impact, availability, and access (Appendix E). Current estimates of operational requirements indicate minimal water requirements (to cool the reaction vessel) and electrical requirements that could be supplied with a portable generator. Selection of this location minimizes handling and transport, thereby providing a significant degree of safety should superoxides be present.

Upon completion of deactivating the NaK, the following sites are candidates for processing, short-term storage, and/or disposal of the solid wastes:

- Radioactive Waste Management Complex

- Waste Experimental Reduction Facility

- o Process Experimental Pilot Plant

- o INEL sanitary landfill.

The RWMC is the DOE-ID designated INEL site for disposal of low-level solid waste and interim storage of transuranic radioactively contaminated materials. WERF is a low-level beta/gamma volume-reduction waste processing facility. PREPP is a transuranic processing facility scheduled to be operable during 1988.

5.4.2 Acceptance Criteria

5.4.2.1 RWMC. The radioactive classes for generated solid waste are described in Section 2 of Reference 6. Additional criteria showing restrictions on hazardous materials and conditions are presented in Section 3 of Reference 6. Any wastes determined to be transuranic (TRU) waste will be handled in accordance with requirements for such waste, as outlined in Reference 7.

5.4.2.2 WERF. The radioactive class for solid waste material that can be processed at WERF is shown as Class 4 in Section 2 of Reference 6.

5.4.2.3 PREPP. The radioactive class for solid waste material that can be processed at PREPP is defined as TRU waste in Section 2 of Reference 7.

5.4.2.4 Sanitary Landfill. Solid waste disposed of in the sanitary landfill is to be nonradioactive and nonhazardous, as defined in Section 15, Waste Management, of the EG&G Idaho Safety Manual.

5.4.3 Contaminated Piping and Equipment

This waste is divided into two categories. One category consists of stainless steel piping, valves, and pumps. Estimated volume is presented in Section 8 of this plan. The metal will be either processed at WERF or at PREPP, depending upon the level and type of contamination.

The second type of waste will be the reaction vessel and the secondary containment vessels, which will be shipped to RWMC for interim storage. It is anticipated that these wastes may qualify as TRU waste.

5.4.4 Packaging Criteria

The packaging criteria pertain to the requirements for acceptance at the RWMC, WERF, and PREPP.

5.4.4.1 RWMC. General criteria are provided in Section 3 of Reference 6. Specific criteria for waste disposal Classes 1 and 2 at the RWMC are provided in Table 1; and for Class 3, in Table 2 of Reference 6. Documentation requirements are provided in Section 5 of Reference 6. Requirements to obtain special authorization for new and nonstandard shipments, such as the Class 5 items, are provided in Section 6 of Reference 6. Comparable criteria and documentation requirements for TRU waste are found in Sections 3 and 6, respectively, of Reference 7. Nonstandard TRU shipments are addressed in Section 8 of Reference 7.

5.4.4.2 PREPP. Specific criteria for TRU waste to PREPP are provided in Table 8 of Reference 8.

5.4.4.3 WERF. Specific criteria for Class 4 waste to WERF are provided in Table 3 of Reference 6.

5.4.4.4 Offsite Hazardous Materials Disposal. No known nonradioactive hazardous waste should be generated as a result of this project.

5.4.5 Transportation

Generated solid waste will require transportation to the disposal sites. Waste transportation is onsite, and waste will be conveyed by trucks operating from the CFA transportation pool. There are no further special road restrictions, except as may be specified in any required transport plans or noted on shipping papers.

6. COST AND SCHEDULE

The total estimated cost for D&D of the NaK and decommissioning of the ARVFS area is $1,703,000. This estimated cost is in FY-86 dollars and does not contain any contingency.

The project was initiated in the first quarter of FY-86 and will be completed in FY-89. Figure 11 presents the overall schedule for the project for fiscal years FY-86 through FY-89. Figure 12 presents the detailed schedule for FY-86.

The estimated cost of the project will be spread as indicated in Table 1. The FY-86 budget will concentrate on establishment of design requirements, preparation of the D&D plan, and site selection. During FY-87, necessary laboratory work, system design, and procurement of long-lead GFE will occur. Construction, system testing, and processing of the NaK are planned for FY-88; final cleanup of the ARVFS area and issuance of the final report are scheduled for FY-89.

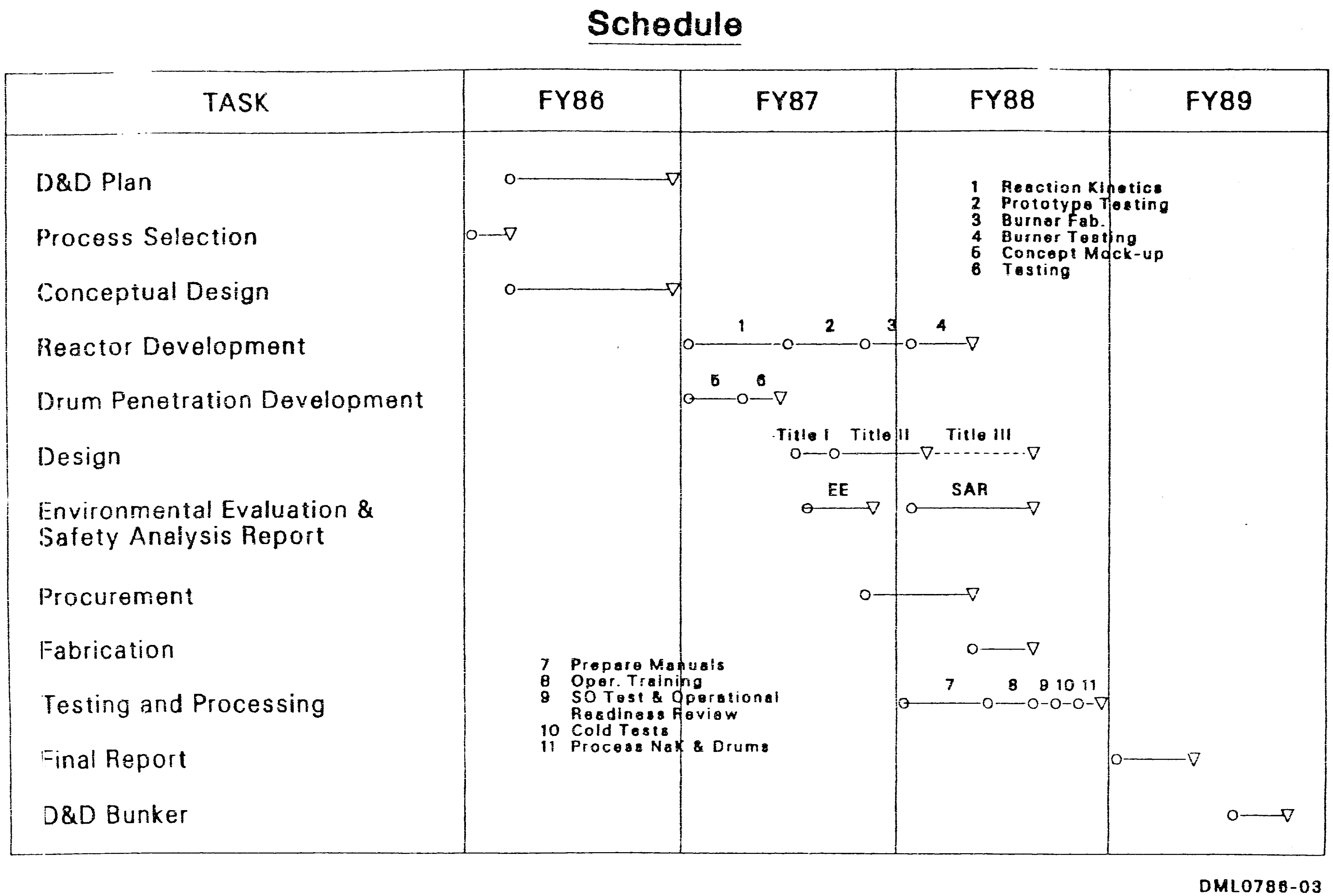

Figure 11. NaK D&D schedule FY-86 through FY-89.

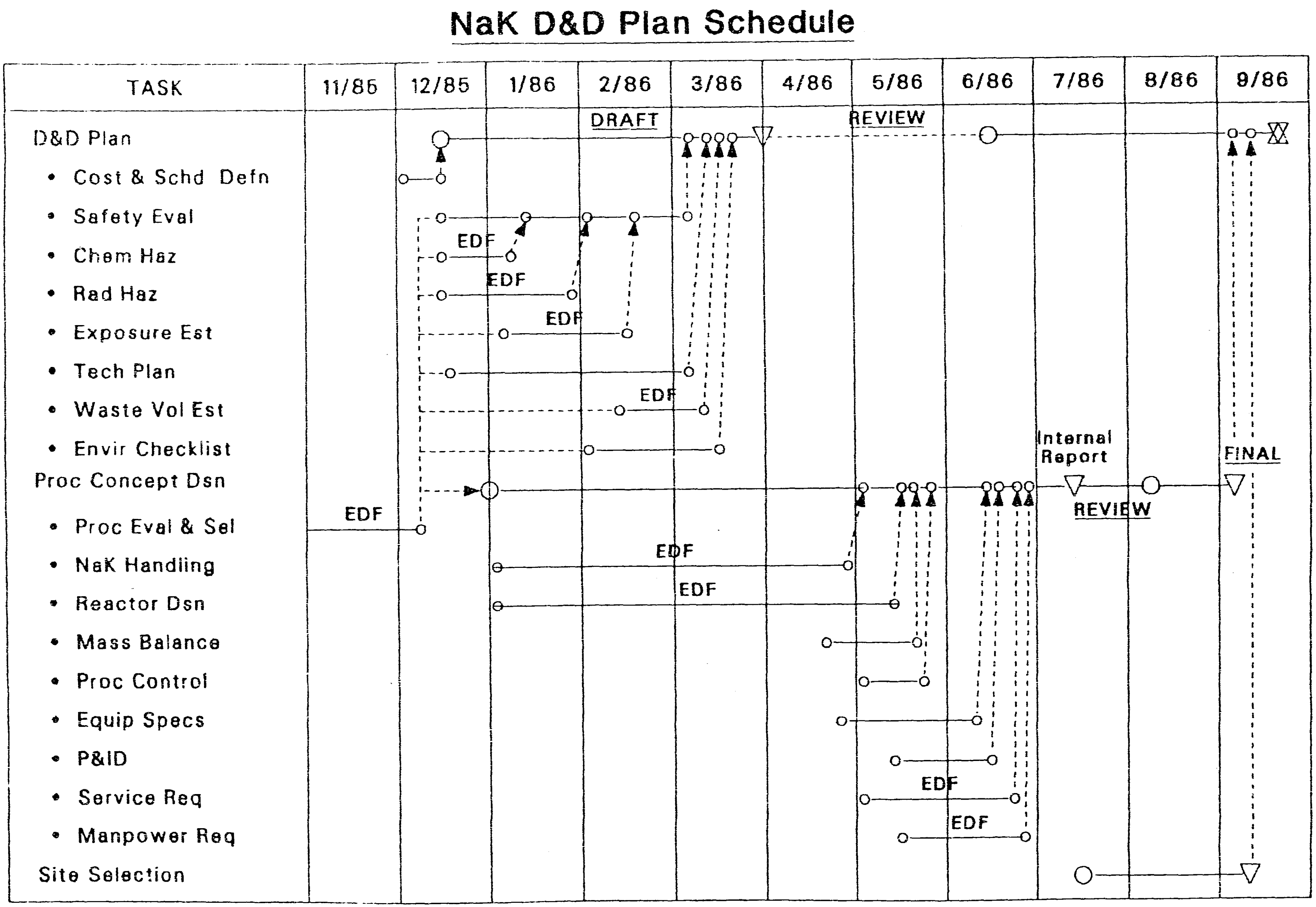

Figure 12. Detailed FY-86 schedule of NaK work.

Budget Estimate (Baseline)

TASKS	FY86	FY87	FY88	FY89
D&D Plan & Project Management	$172K	$80K	$85K	$15K
Process Selection & Conceptual Design	$101K			
Reactor Development		$196K	$63K	
Drum Penetration Development		$65K		
Design		$166K	$48K	
Procurement		$118K	$136K	
Fabrication			$132K	
Testing & Processing			$236K	
Final Report				$40K
D&D Bunker				$50K
Totals :	$273K	$625K	$700K	$105K
Cumulative Totals :	$273K	$898K	$1598K	$1703K

TABLE 1. ESTIMATED COST OF NaK D&D PROJECT

Thermal and Process Analysis Br. Date : ____________

No	Name	UserID	BinNo	TelNo	
24	Townsend, W. C. (Jerry)	WCT		0426	
25	VanHaaften, Dave H.	DVH		0256	
26	Watkins, John C.	JCW		0567	
27	Watson, O. Kay	OKW		9116	
28					
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7. OCCUPATIONAL EXPOSURE ESTIMATES

Predictions of personnel exposure to radiation are made to estimate the number of workers required to complete the D&D project, and, more importantly, to identify the need for shielding barriers during certain phases of the operation when workers may be exposed to higher-than-desirable levels of radiation. During the project, individual exposure must be kept as low as reasonably achievable (ALARA), and, in any event, never exceed the maximum allowable radiation exposures as specified in the EG&G Idaho Rad Con Manual, Table 3-1. A worker whose exposure approaches the maximum limits must be replaced with a worker with a lower exposure history. The predicted radiation exposure to personnel will help to determine the number of personnel required to be trained and utilized for the project. It is emphasized, however, that the actual number of personnel utilized will be based on measured exposures during project performance.

Some simplifying assumptions made in predicting personnel exposure to radiation are as follows:

1. The primary exposure will occur when the NaK containers are removed from the bunker and placed into their individual secondary containments.

2. During processing of NaK, exposure to radiation will be minimized because of the remotely operated and controlled nature of the operations.

3. A secondary period of exposure will occur when the system is broken down and components are prepared for final disposition.

In reviewing the present exposure estimates, it should be kept in mind that the numbers presented in Table 2 are preconceptual estimates only.

As the project nears completion of Title II design and when the operational procedures are defined, a much more accurate estimate will be generated to be used in defining manpower requirements.

8. WASTE VOLUME PROJECTIONS

At this early phase of the project, it is not possible to generate an accurate projection of anticipated waste volumes for the NaK processing. The estimate presented below should be considered as an order of magnitude estimate only. As the project and design mature, updated estimates of waste volumes will be projected.

8.1 Radioactive Waste

1. Reaction vessel:

   4 ft diameter x 8 ft high

   100 ft^3

2. Secondary NaK containment vessels:

   2 @ 3 ft diameter x 5 ft high

   70.7 ft^3

   1 @ 5 ft diameter x 5 ft high

   98 ft^3

   1 @ 2 ft diameter x 3 ft high

   9.4 ft^3

   Subtotal 178.1 ft^3

3. Process piping, pump, and filter; boxed and shielded:

   100 ft^3

4. Waste volume from decontamination of ARVFS test pit (Reference 2):

   100 ft^3

Total radioactive waste 478 ft^3

8.2 Nonradioactive Waste

Approximately 200 gal of Dowtherm/water comes from the reactor coolant system. Dowtherm is a commercial polyglycol heat transfer/antifreeze fluid.

9. QUALITY ASSURANCE PROGRAM

A quality assurance program for this project is the responsibility of the project manager. Details of the quality assurance (QA) program for D&D activities are documented in the Quality Program Plan - Waste Management Programs Department, Decontamination and Decommissioning Number 053 (QPP-053). Waste Technology Programs Project Directive WT-D&D-1.1.10 ("D&D Program Quality Assurance" dated October 1984) will be utilized to implement the quality assurance program. In addition, the EG&G Idaho Quality Manual will have precedence over engineering, procurement, and construction activities.

Applicable procedures for inspection, audit, and documentation of project activities will be identified as part of the project QA documentation. The records/documents required to support project closeout and to verify performance of planned project activities will also be identified.

10. PRELIMINARY SAFETY EVALUATION

This preliminary safety evaluation identifies and summarizes the hazards and risks associated with this project at this early stage of the conceptual design. Each hazard is described, and the appropriate safety measure to minimize the hazard is developed. Recovery measures to be used, should an unpredicted incident occur, are also described. The administrative controls developed to ensure safe working conditions and practices are discussed.

A safety analysis report (SAR) will be prepared as Title I design nears completion. The SAR will benefit not only from design work, but also from laboratory and development work planned for early FY-1987. The SAR will describe the hazards (including thermal explosions, NaK leaks and spills, fires, and admixture reactions), the probability and consequences of such events, and the barriers and controls to reduce the risk to such hazards.

10.1 Industrial Health and Safety

All work will be conducted in accordance with established regulations in effect at the INEL, including, but not necessarily limited to, ID Appendix 0550, IDO-12044, DOE Order 5480.1A, EG&G Idaho Safety Manual, DOE Hoisting and Rigging Manual, and the Occupational Safety and Health Act of 1970. Area health and safety personnel will be assigned to the project to evaluate the safety and health aspects of the operations for protection of property and personnel involved in the operations.

Cranes and hoisting operations will meet the DOE Hoisting and Rigging Manual requirements.

Any hazardous material will be transported according to the EG&G Idaho Safety Manual, Section 19, and in compliance with DOE regulations. Radioactive material will be transported according to the EG&G Idaho Safety Manual, Section 13.

10.2 Hazards Associated with NaK Processing

The hazards of processing NaK have been addressed in EDFs and are available as appendices to this plan. Work will be performed under the review and guidance of the Safety and Environmental Programs, and appropriate safety measures will be developed and implemented as they are identified.

All operators and supervisory personnel will be required to be qualified to work on the NaK before processing is performed by attending NaK training sessions conducted by Safety and Environmental Programs. Only those personnel so trained will be allowed access to the area during on-going operations.

10.2.1 Electrical

Electrical power for the operations will be provided from portable generators. Backup systems will be immediately ready, should a problem arise with the primary power generator. To prevent system shutdown should a temporary power failure occur, critical process instrumentation and the process control system will have emergency battery backup.

10.2.2 Hoisting

The hoisting hazards associated with equipment failure, incorrect rigging procedures, and inadequate operating procedures may be encountered. Measures will be implemented to minimize risks from hoisting hazards. Lifting instructions and/or detailed procedures with rigging sketches will be included in engineering work packages that involve lifting large equipment or hazardous items. The job foreman for hoisting operations will be a rigging specialist who will ensure compliance with the DOE Hoisting and Rigging Manual.

10.2.2.1 Equipment Adequacy. To ensure equipment adequacy, the crane, hooks, cables, and other lifting apparatus used will have current certification of load testing and periodic inspections per the DOE Hoisting and Rigging Manual, Section VII. The person in charge of the lift will verify this certification before use of crane and associated lifting apparatus. The project foreman will ensure that the slings are sized adequately for the load.

10.2.2.2 Procedures. The DOE Hoisting and Rigging Manual will be adhered to strictly in the procedures to be followed during hoisting and rigging operations. All equipment operators and riggers will be fully qualified for the particular equipment and load being rigged for hoisting.

10.2.3 Radiation Exposure

To prevent undue worker exposure, all D&D site operations personnel will be trained radiation workers and respirator-trained. This ensures familiarity with radiation hazards and procedures for work performance in radiation fields.

All D&D work performed will be under HP technician and Safety Engineering surveillance. Constant air monitors (CAMs) will be operating continuously, sampling air near the work location and downwind from the area in which work is being performed. Personnel working in the contamination area will wear anticontamination clothing, protective respiratory equipment, and appropriate radiation dosimetry. Components producing significant radiation fields in an area will be removed or shielded as soon as possible to reduce the working field during removal of remaining components.

Should any D&D operation expose NaK outside the reactor vessel or other containments, the operation will be stopped, until the source of the leak can be identified and corrected. Any leak will be surveyed for radiation hazards, and removed before continuing operations. If periodic smearing reveals the presence of contamination levels that present a hazard, D&D work will stop, and the contamination will be cleaned up before work progresses.

All tasks in this project will be covered by approved engineering work packages. Every practical provision will be included in work instructions and procedures to incorporate the ALARA philosophy of personnel radiation exposure. Guidance on maintaining exposures to ALARA levels is given in the EG&G Idaho Rad Con Manual, Chapter 3. Provisions will be included in the instructions and packages to ensure that the maximum allowable personnel radiation dose is not exceeded. If a CAM indicates the presence of airborne activity that exceeds allowable limits, the work area will be evacuated until the activity abates or workers equipped with appropriate respiratory protection can remove the source of air activity.

As a minimum, workers will survey themselves for contamination before the lunch break, before leaving the work area, and again at the end of their shift.

10.3 Hazards Associated with Natural Phenomena

10.3.1 Earthquake

Earthquake hazards are extremely remote. If an earthquake should occur during D&D operations, the work will stop and the hazardous work area will be evacuated immediately after safe shutdown. Work will be resumed later after assessment of the working conditions. The probability of an earthquake occurring during the D&D operations is extremely low, but it exists. Some of the probable consequences of an earthquake occurring are discussed here to identify the associated risks. The major risk is a hoisting incident. If an earthquake should occur during a hoisting operation, the load could possibly sway enough to lose its rigging and drop. Because of the swaying of the load, the falling material could possibly hit someone. Damage and/or shock to the container could also result in extreme conditions such as an explosion or fire. Probability of coincidence of timing of container movement and an earthquake is extremely small.

The INEL is located between the Intermountain Seismic Belt to the south and east and the Central Idaho Seismic Belt to the north. There is evidence of seismic activity near the INEL within recent geological times. The most recent activity of large seismic-induced displacements near the INEL has been placed at 4,000 to 30,000 years ago (Reference 8). This conclusion was based on geological studies of the Arco and Howe scarps. In a review of these data during 1972, the largest earthquake that may be expected to occur near the ARVFS was determined not to exceed magnitude 7 (Richter scale). This was based on the nearest active fault, the Arco scarp, with an epicenter assumed to be approximately 16 miles from the ARVFS.

During the seismic analysis period of the 1970s, the INEL was within a Uniform Building Code (UBC) Seismic Probability Zone 3. The seismic zone is now 2. The change from a Seismic Zone 3 to 2 was approved at the International Conference of Building Officials meeting of October 8, 1981 (Reference 8).

In a previous safety analysis of an operating Test Reactor Area (TRA) facility (the Sodium Loop Safety Facility Hazards Assessment), a major earthquake that would normally incur some structural damage was postulated to have an unlikely probability of occurrence. Experience observed during the 1983 Mackay earthquake showed only minor structural effects on INEL facilities.

10.3.2 Flood

10.3.2.1 Excessive Runoff. Runoff from snowmelt in the Lost River and Lemhi Ranges drains onto the INEL via three drainages: the Big Lost River, the Little Lost River, and Birch Creek. The Big Lost River channel runs between TRA and the Idaho Chemical Processing Plant (ICPP) to the north towards Test Area North (TAN); the closest approach to ARVFS is 1 mile away. Often this channel is dry. Birch Creek feeds towards TAN and the large depression in the northern part of the INEL. Thus, flooding from this drainage is not a problem to this project because ARVFS is on much higher ground. The Little Lost River drains east to an area northeast of ARVFS.

The primary concern is the possibility of flooding from the Big Lost River. ARVFS is located about 1 mile from the Big Lost River. Two dams are located on the river upstream of ARVFS: the Mackay Reservoir, about 50 miles upstream from the ARVFS; and the INEL flood diversion dam, about 10 miles upstream from the ARVFS. Several factors can influence and amplify the conditions for flooding: remaining reservoir capacity, snowpack, climatic change, and ground conditions affecting seepage. The river channel could overflow if there is a full reservoir, a very large snowpack, and a rapid warming trend and the ground is still frozen (eliminating seepage losses). The INEL flood diversion facilities, consisting of the dam, dikes, and spreading areas to the south, have been designed to divert a Big Lost River flood away from the INEL facilities under normal flood conditions. Weather conditions will be of primary concern in scheduling the actual processing operations. Since NaK will react violently with water, it is imperative that the processing takes place during dry weather, should a leak in the system occur.

In the Preliminary Safety Analysis Report (PSAR) for the Sixth ICPP Calcined Solids Storage Facility (CSSF), the worst-evaluated flooding conditions at the ICPP were shown as a probable maximum precipitation storm occurring between the diversion dam facilities and the ICPP (Reference 8). This would be in the form of a large thunderstorm developing into 2 to 3 in. of rainfall in about 1-h duration, which could lead to a flash flood in the Big Lost River channel. Maximum crest of the flooded river was shown to be at about 2 h at approximately 35,000-cfs flow rate. The flooded water elevation was found to just reach the building complex of CPP-601/602, which has an elevation of 4915.7 ft above sea level. Since nominal elevation at ARVFS is approximately 4830 ft above sea level, it is likely that the probable maximum precipitation storm could cause flooding at ARVFS, since no major topographic highs exist in the immediate area to the south of ARVFS. Although an ~1-ft earth berm exists near the bunker, the maximum precipitation storm would inundate the bunker area if additional berms were not put in place. This again makes it imperative that the processing be scheduled during dry warm weather. July through October are the driest months of the year and the likely time for processing to take place.

10.3.2.2 Dam Failure. Failure of the INEL diversion dam facilities and the Mackay Reservoir dam is considered. The diversion dam facilities include the dam, four floodwater impounding areas (A, B, C, and D), and connecting channels. Impounding areas A and B both require dikes to retain water. According to the Sixth CSSF PSAR (Reference 8), failure of dike 2 at impounding area B is more critical than dike 1 at impounding area A. Further, the resulting riverflow flooding condition was found to be essentially the same as the postulated probable maximum precipitation flood; hence, this failure event could also cause floodwaters at ARVFS.

Failure of the Mackay Dam has been studied by the U.S. Geological Survey (Reference 8). The Mackay Dam is an earthen dam, about 80 ft high and approximately 1968 ft long at dam crest on the Big Lost River, 4.5 miles northwest of Mackay, Idaho. The reservoir behind the dam contains 1.93 million cubic feet of water at spillway crest. The dam was built in 1905. Results of the study are considered valid downstream only to above the diversion dam because of inadequate knowledge of the flood plain geometry below the diversion dam. At 2.6 miles above the diversion dam, the peak discharge for a full breach was calculated to be about 54,000 cfs (Reference 8). In the ICPP PSAR for the Sixth CSSF (Reference 8), it was shown that a flood of about 81,000 cfs would be necessary to flood CPP 601/602. Such an event of probable flooding at ARVFS would be of concern.

10.3.3 Lightning

As previously noted, scheduling of activities will take into account applicable weather forecasts. The potential for accidents from a lightning strike is minimal. However, an anomalous thunderstorm could occur that may create a concern. Rigging and hoisting will not be initiated when a potential lightning hazard exits. If lightning should strike any part of the operation, an evaluation of the damage will be made before resumption of work.

10.3.4 Tornado and/or High Winds

Work will be terminated on the project any time tornado or high wind warnings are in effect at the INEL. Evaluation of any damage will be made before resumption of work. Hopefully, by scheduling the processing of NaK only during favorable weather conditions, the likelihood of such events will be minimized.

10.4 Administrative Controls

10.4.1 Training

Personnel working on the D&D project will receive standard EG&G Idaho safety training applicable to the tasks involved. This training includes:

1. Radiation worker training

2. Respirator training

3. Initial safety meeting to acquaint workers with hazards of work

4. Work instructions and/or procedures reviewed and discussed with involved personnel before performance

5. Daily meetings to identify job progress, future tasks, and potential hazards of upcoming work

6. In addition to the standard safety training, all personnel will be required to be certified in NaK safety training. This course will be taught in advance of other operational training.

10.4.2 Site Work Release

All work performed by EG&G Idaho crafts will be covered by a site work release (SWR). An SWR contains the written description of the work to be performed along with drawings, instructions, procedures, and other support material to allow a qualified craftsman to complete the job within normal supervision standards.

10.4.3 Safe Work Permits

An SWP will be required for all jobs involving radiation safety. The criteria for use of a SWP are specified in the EG&G Idaho Rad Con Manual, Chapter 7. A required SWP will be processed at the beginning of each phase of the operations, where appropriate.

11. ENVIRONMENTAL DOCUMENTATION

Processing NaK and returning the ARVFS bunker to a reusable condition will remove a significant radiological hazard from the INEL, and convert this hazard into a safe, disposable form. This activity, however, will not be performed without some environmental concerns. At this time, because of the preconceptual state of the project, these concerns cannot be addressed in detail. Recognizing these current deficiencies, the environmental checklist (Figure 13) is enclosed as a reflection of environmental documentation required at this time. Upon completion of the conceptual design and site selection, all other necessary documentation will be completed and subsequently incorporated into the final D&D plan.

In terms of summarizing potential environmental concerns at this time, it is recognized that the NaK processing will result in the transformation of TRU waste, mixed with NaK, to a stable salt form sufficient for disposal. Solid filterable materials present in the NaK will be treated at another INEL waste management facility (i.e., PREPP or WERF).

This project may require minor short-term adjustments to the environment (e.g., modifications to an existing berm at ARVFS). Any short-term alterations to the site will be returned to their "near-natural" state upon completion of the processing and the decommissioning of the ARVFS.

This project is not anticipated to result in any change in noise levels, air emissions, liquid effluents, or hazardous or mixed wastes.

Suggested alternatives that might be addressed in the environmental documentation are as follows:

1. Process the NaK as proposed

2. Process the NaK by some other technique (addressed in Reference 1)

EG&G Idaho, Inc
FORM EG&G 992
(Rev. 03/85)

Environmental Checklist

Date: March 31, 1986

Activity/Project Name: Processing of NaK and Decommissioning of ARVFS

Line Manager or Requestor: Max R. Dolenc

A. Project/Activity Description: (Include justification, location with figures and maps if appropriate, schedule, cost, etc.)

(see attached draft D&D Plan)

B. Environmental Concerns	Yes	No
1. Is the project or activity new,	X	
a modification,		
or a direct replacement.		
(General note: New or modified activities will generally have more impact than a direct replacement.)		
2. Will the project or activity result in, or have the potential to result in, long-term changes to the environment (e.g. constructing a building, erecting above-ground power lines, development of new waste ponds or landfills)?	X	
3. Will the project or activity result in changes and/or disturbances of the following existing factors:		
• Noise levels		X
• Air emissions		X
• Liquid effluents		X
• Solid waste		X
• Radioactive waste (including contaminated soil) -(TRU)	X	
• Hazardous waste		
• Mixed waste (radioactive and hazardous)		
• Chemical or petroleum product storage		X
• Water use (Withdrawal of groundwater or diversion or withdrawal of surface water) (minimal)		X
• Drinking water system		X
• Sewage disposal system		X
• Soil movement outside facility fences		X
• Site clearing, excavation, or other alterations	X	

Copy 1—Safety Division
Copy 2—Originator retain

Figure 13. Environmental checklist.

3. Transfer the NaK into new storage containers (addressed in Reference 1)

4. Do nothing (addressed in Reference 1).

These alternatives have received a thorough analysis and option 1 above is the only reasonable course to follow.

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APPENDIX A

EDF RADIOLOGICAL HAZARDS

EG&G Idaho, Inc.

FORM EG&G-2631 (Rev. 4-78)

ENGINEERING DESIGN FILE

PROJECT FILE NO. 015094

EDF SERIAL NO. NAK003

FUNCTIONAL FILE NO. 3KNOPNAKE

DATE March 25, 1986

PROJECT/TASK NaK Disposal/EBR-I

SUBTASK Engineering

EDF PAGE NO 1 OF 9

SUBJECT FISSION PRODUCT INVENTORY ESTIMATES

ABSTRACT

Fission product inventory and activity estimates are developed for contaminated NaK from the 1955 EBR-I meltdown. Maximum credible values are calculated using conservative models for the core irradiation history and fission product release to the NaK.

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M. R. Dolenc, R. H. Meservey, S. R. Adams, D. L. Crandall, D. M. La Rue, B. G. Schnitzler

DISTRIBUTION (COVER SHEET ONLY): PROJECT EDF FILE LOG, EDF SERIAL NO. LOG

J. A. Lake

AUTHOR	DEPT.	REVIEWED	DATE	APPROVED	DATE
B. G. Schnitzler (signed)		J. A. Lake (signed)	3/25/86	(signed)	3/25/86

Summary

Fission product inventory estimates are required to support planned disposal of contaminated NaK from the 1955 EBR-I meltdown. Maximum credible fission product inventory and activity estimates are developed using conservative models for the core irradiation history and fission product release to the NaK.

Background

The EBR-I Mark II core had been fabricated using a uranium - 2 wt% zirconium alloy for both fuel and blanket regions. The fuel region (93.2 wt% ^{235}U) contained approximately 52 kilograms ^{235}U. The second core was installed in the early part of 1954 and operated intermittently until late 1955. A partial meltdown occurred on November 29, 1955, and involved 40 - 50% of the fueled (core) region.[1] There was no significant involvement of the axial blanket regions in the meltdown. Plutonium samples totaling 10.5 grams were not recovered from the core and assumed dispersed to the molten fuel alloy.[1]

The damaged core was removed early in 1956. The NaK coolant was transferred to containers and stored at the EBR-I site until 1974 when it was moved to a bunker at the Army Reentry Vehicle Facility Site (ARVFS).[2] Past radiological hazard characterization work includes radiation surveys of the NaK containers prior to the 1974 relocation[2] and during a bunker inspection[3] conducted in August, 1979. Radiological consequences of fires involving the NaK were addressed in References 4 and 5.

Fission product contamination provides the dominant radiological hazard associated with the NaK processing. The NaK drum contents are not yet well characterized but could potentially include solid fuel particle debris, remains of the plutonium samples, structural material activation products, and potassium-40.

Activated structural material and ^{40}K activity levels should be very low compared with the fission product activity levels. Some accident scenarios (e.g., NaK fire and atmospheric dispersal) may require consideration of ^{40}K and the plutonium samples; these contaminants will not impact shielding requirements. Materials of radiological significance in the fuel debris would be limited to uranium and the retained fission products. Negligible quantities of ^{239}Pu would have been produced in the high enrichment core region involved in the meltdown. No criticality hazard exists as long as the ^{235}U inventory is less than about 760 grams.[6] Estimates of TRU content may be required prior to final disposal.

Calculational Model

The core fission product inventory available for release to the NaK coolant is a function of the core operating history. Operating history data is difficult (perhaps impossible) to recover after more than 30 years. The only definitive items identified to date are measured radial and axial fission rate distributions[7] for the earlier (Mark I) core loading and a reported maximum core burnup of approximately 0.1 atom percent[8] at the time of the meltdown.

Fission product inventories have been calculated using the isotopic generation and depletion code ORIGEN2[9] and a modified cross section library. The ^{235}U radiative capture cross section was adjusted to reflect measured[10] capture-to-fission ratios reported for the EBR-I Mark I core loading. The measured ratios varied from about 0.11 at the core center to about 0.17 at the core periphery. The ^{235}U radiative capture cross section was adjusted based on the lowest reported value (0.11 $\pm$ 0.01). This procedure is conservative since it will result in the highest calculated fission product inventory for a specified atom percent burnup.

The burnup for the entire fuel region was conservatively assumed to be the 0.1 atom percent reported as the core maximum. The entire exposure was assumed to be accumulated at constant power during the 45 days of operation immediately preceding the meltdown. The resulting burnup is about 45 MWd compared to the more conservative assumption of 75 MWd utilized in the analyses reported in References 4 and 5.

The calculated inventory was decayed to August, 1988. The entire fission product inventory from 50% of the core region was assumed to be released to the NaK. All the released fission products, including noble gases and other volatiles, were assumed to remain in the NaK.

The isotopic inventory associated with the unrecovered plutonium samples was approximated using ORIGEN2 and assuming simple decay of the initial 10.5 gram sample inventory to August, 1988. This conservative treatment yields the maximum heavy metal inventory; the fission product inventory resulting from fission events in the plutonium sample is negligible compared to that from the fueled core.

Results

Calculated fission product inventories are shown in Table 1. All fission products with an activity of greater than one microcurie are listed. The corresponding mass for each isotope is included. The calculated fission product elemental composition is listed in Table 2. All fission product elements with mass inventories of greater than one milligram are shown. The total activity for all isotopes of that element is also tabulated.

The total fission product mass inventory is approximately 23.3 grams and the total fission product activity is about 133 curies. The calculated fission product decay heat is only 380 milliwatts.

The initial and August, 1988, plutonium sample inventories are listed in Table 3. Table 4 documents the ORIGEN2 input model employed for the fission product inventory calculations.

Conclusions

The calculated fission product inventories hinge on two critical assumptions made for this analysis. The entire exposure history has been constructed around a single reported burnup value. Although there is no reason to suspect the reported burnup, it is disconcerting to not have some confirmation of so important a parameter.

The assumption of total fission product release to the NaK is also important. This assumption is clearly conservative for the primary application of estimating maximum fission product contamination levels in the NaK. Actual release fractions could be expected to vary from almost complete for many volatiles (e.g., halogens) to very small for many isotopes preferentially retained in the fuel (e.g., ^{144}Ce). All reported values should be viewed as the maximum credible fission product inventories in the NaK.

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TABLE 1. CALCULATED ISOTOPIC INVENTORY FOR EBR-I NaK (ALL FISSION PRODUCTS FROM 50% OF CORE, DECAYED TO AUGUST 1988).

Isotope	Inventory (Grams)	Activity (Curies)
^{3}H	5.24×10^{-6}	5.05×10^{-2}
^{79}Se	4.17×10^{-3}	2.91×10^{-4}
^{85}Kr	2.76×10^{-3}	1.08×10^{0}
^{90}Sr	2.36×10^{-1}	3.22×10^{1}
^{90}Y	5.91×10^{-5}	3.22×10^{1}
^{93}Zr	5.99×10^{-1}	1.51×10^{-3}
^{93m}Nb	4.11×10^{-6}	1.16×10^{-3}
^{99}Tc	6.09×10^{-1}	1.03×10^{-2}
^{107}Pd	2.06×10^{-2}	1.06×10^{-5}
^{113m}Cd	8.64×10^{-6}	1.87×10^{-3}
^{121m}Sn	6.72×10^{-7}	3.98×10^{-5}
^{125}Sb	1.38×10^{-6}	1.42×10^{-3}
^{125m}Te	1.92×10^{-8}	3.47×10^{-4}
^{126}Sn	9.07×10^{-3}	2.58×10^{-4}
^{126}Sb	4.31×10^{-10}	3.60×10^{-5}
^{126m}Sb	3.28×10^{-12}	2.58×10^{-4}
^{129}I	9.20×10^{-2}	1.62×10^{-5}
^{134}Cs	1.25×10^{-9}	1.62×10^{-6}
^{135}Cs	8.34×10^{-1}	9.61×10^{-4}
^{137}Cs	3.92×10^{-1}	3.41×10^{1}
^{137m}Ba	6.00×10^{-8}	3.23×10^{1}
^{147}Pm	5.93×10^{-5}	5.50×10^{-2}
^{151}Sm	4.90×10^{-2}	1.29×10^{0}
^{152}Eu	3.43×10^{-8}	5.94×10^{-6}
^{154}Eu	1.14×10^{-6}	3.07×10^{-4}
^{155}Eu	5.74×10^{-5}	2.67×10^{-2}

TABLE 2. CALCULATED ELEMENT INVENTORY FOR EBR-I NaK (ALL FISSION PRODUCTS FROM 50% OF CORE, DECAYED TO AUGUST 1988).

Element	Inventory (Grams)	Activity (Curies)
Se	4.38×10^{-2}	2.91×10^{-4}
Br	1.72×10^{-2}	0.0
Kr	3.06×10^{-1}	1.08×10^{0}
Rb	3.29×10^{-1}	1.96×10^{-8}
Sr	5.57×10^{-1}	3.22×10^{1}
Y	4.25×10^{-1}	3.22×10^{1}
Zr	3.15×10^{0}	1.51×10^{-3}
Mo	2.38×10^{0}	0.0
Tc	6.09×10^{-1}	1.03×10^{-2}
Ru	1.14×10^{0}	2.48×10^{-8}
Rh	3.24×10^{-1}	2.48×10^{-8}
Pd	1.88×10^{-1}	1.06×10^{-5}
Ag	4.84×10^{-3}	$<10^{-9}$
Cd	1.11×10^{-2}	1.87×10^{-3}
In	1.85 x 10-3	$<10^{-9}$
Sn	2.35×10^{-2}	2.97×10^{-4}
Sb	5.14×10^{-3}	1.71×10^{-3}
Te	2.51×10^{-1}	3.47×10^{-4}
I	1.13×10^{-1}	1.62×10^{-5}
Xe	2.89×10^{0}	0.0
Cs	2.12×10^{0}	3.41×10^{1}
Ba	1.38×10^{0}	3.23×10^{1}
La	8.94×10^{-1}	$<10^{-9}$
Ce	1.67×10^{0}	2.05×10^{-8}
Pr	8.29×10^{-1}	$<10^{-9}$
Nd	2.96×10^{0}	$<10^{-9}$
Sm	5.98×10^{-1}	1.29×10^{0}
Eu	3.95×10^{-2}	2.70×10^{-2}
Gd	9.83×10^{-3}	$<10^{-9}$

TABLE 3. EBR-I PLUTONIUM SAMPLE PROPERTIES.

Isotope	November 1955 Inventory (Grams)	November 1955 Activity (Curies)	August 1988 Inventory (Grams)	August 1988 Activity (Curies)
^{235}U	---	---	9.22×10^{-3}	1.99×10^{-8}
^{236}U	---	---	1.69×10^{-3}	1.09×10^{-7}
^{239}Pu	9.97×10^{0}	6.20×10^{-1}	9.96×10^{0}	6.20×10^{-1}
^{240}Pu	4.97×10^{-1}	1.13×10^{-1}	4.95×10^{-1}	1.13×10^{-1}
^{241}PU	3.15×10^{-2}	3.25×10^{0}	6.54×10^{-3}	6.74×10^{-1}
^{242}Pu	1.26×10^{-3}	4.81×10^{-6}	1.26×10^{-3}	4.81×10^{-6}
^{241}Am	---	---	2.42×10^{-2}	8.30×10^{-2}
TOTAL	10.500	3.983	10.498	1.490

TABLE 4. ORIGEN2 INPUT MODEL.

```
    205   922350   5.138   0.0   0.0  46.71   0.0   0.0   -1
    205   922380   2.929   0.0   0.0   0.0    0.0   0.0   -1
*EOR
    -1
    -1
    -1
    BAS    EBR-I MARK II FUEL (52 KG U-235)
    TIT    CONSTANT FLUX IRRADIATION TO 0.1 ATOM PERCENT BURNUP
    CUT    3 1.0E-25   5 1.0E-12   7 1.0E-24   27 0.1   28 1.0E-75   -1
    LIP    0 0 0
    LPU    922350   922380   -1
    LIB    0  0  2  3  0  -205  206  9  3  0  4  0
    PHO    0  102  103  10
    OPTL   8 8 8 8 8   8 8 8 8 8   8 8 8 8 8   8 8 8 8 8   8 8 8 8
    OPTA   8 8 7 8 7   8 7 8 6 8   8 8 6 8 6   8 6 8 5 5   5 5 8 8
    OPTF   8 8 7 8 7   8 7 8 6 8   8 8 6 8 6   8 6 8 8 8   8 8 8 8
    INP    1   2   -1   -1   1   1
    IRF     5.0   4.96E+12    1    2    4    2
    IRF    10.0   4.96E+12    2    3    4    0
    IRF    15.0   4.96E+12    3    4    4    0
    IRF    20.0   4.96E+12    4    5    4    0
    IRF    25.0   4.96E+12    5    6    4    0
    IRF    30.0   4.96E+12    6    7    4    0
    IRF    35.0   4.96E+12    7    8    4    0
    IRF    40.0   4.96E+12    8    9    4    0
    IRF    45.0   4.96E+12    9   10    4    0
    OUT    10   0   0   0
    DEC        32.67        10    1    5    0
    MOV    1    2    0    0.5
    HED    1  * AUG 1988
    HED    2  *HALF CORE
    OUT     2   0   0   0
    STP    4
    2        922350   221.2766       923800    15.9412       0    0.0
    0
```

APPENDIX B

EDF CHEMICAL HAZARDS

EG&G Idaho, Inc.

FORM EG&G-2631 (Rev 4-78)

ENGINEERING DESIGN FILE

PROJECT FILE NO. 3KNOPNAKO

EDF SERIAL NO. NAK002

FUNCTIONAL FILE NO. 3KNOPNAKE

DATE 1/21/86

PROJECT/TASK NaK Disposal - EBR-II

SUBTASK Engineering

EDF PAGE NO ___ OF ___

SUBJECT

Chemical Hazards Analysis

ABSTRACT

This EDF addresses the chemical hazards associated with the EBR-I Mark-II NaK. It addresses the toxicity, fire, and explosion hazards associated with the NaK, NaK contaminants, and processing scheme. This EDF does not discuss the safety methodology to be employed in handling of these materials.

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M. Dolenc, R. Meservey, R. Green, D. Crandall

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D. M. LaRue	E&PM	[signature]	23 Jan 85	[signature]	1-23-85

Introduction

This EDF addresses the chemical hazards associated with the decommissioning of the EBR-I Mark-II NaK stored at the ARVFS Bunker. The radiological concerns associated with this material will be discussed in a subsequent EDF. The purpose of this EDF is to specify the hazards, not to formally address the methodology of how these materials will be safely handled. That discussion will take place in subsequent EDF's, design package documents, and safety documents. Due to the uncertainties associated with the contaminants of this material, this EDF will also address the chemical hazards associated with contaminants which may not actually be present, but which have some probability of existing in the NaK. In addition, the chemical hazards associated with the planned chemical deactivation of the NaK will also be addressed. The chemical hazards of the materials will be discussed under the following classifications (where data is available):

1) Toxicological Characteristics

2) Fire Hazards

3) Explosion Hazards

1. NaK Eutectic Metal

1.1 Physical Properties

Sodium-potassium alloy is generally referred to as NaK. Eutectic NaK is an alloy containing approximately 78% potassium (K) and 22% sodium (Na). The melting point is -12.6 C (9.3 F). Liquid NaK is similar to mercury in appearance. The density and viscosity of eutectic NaK at 20 C (68 F) are 0.87 g/cc and 0.9 centipoise, respectively, compared to 1.0 g/cc and 1.0 centipoise, respectively, for water at 20 C. The boiling point of eutectic NaK is 785 C (1445 F). The surface tension, at room temperature, is approximately 105 dynes/cm, compared to water which has a surface tension of 72.8 dynes/cm at room temperature.

1.2 Toxicological Characteristics

NaK in elemental form is highly reactive, particularly with moisture, with which it reacts violently, and therefore, attacks living tissue. NaK reacts exothermally with the moisture of body or tissue surfaces, causing thermal and chemical burns due to the reaction with NaK and the hydroxides formed. NaK is not a systemic poison.

If exposed to air, the NaK will burn to produce oxides; these oxides will react with moisture to form their respective hydroxides which are extremely corrosive and irritating to skin, eyes, and mucous membrane. Ingestion may cause violent pain in throat and epigastrium, hematemesis, and collapse. Inhalation of the dust can cause damage to the upper respiratory tract and lung tissue, depending upon the severity of the exposure. Thus, affects of inhalation may vary from mild irritation of the mucous membrane to a severe pneumonitis. It can cause an irritation to the skin.

1.3 Fire Hazard

Sodium-potassium alloy reacts violently with moisture to form hydroxides and hydrogen. The reaction evolves much heat, causing the metal to splatter. It also ignites the hydrogen, which burns, or, if there are sufficient concentrations, the hydrogen can explode. Burning NaK is a Class D fire and requires and requires a Class D extinguishing agent; dry powdered soda ash or NaCl are recommended.

1.4 Explosion Hazard

NaK reacts violently with the following materials under required conditions of temperature, state of division, and reactant concentrations: acetylene, air, chlorocuprate, water, $AlBr_3$, metal halides, ammonium chlorocuprate, ammonium bromide, ammonium iodide, ammonium sulfates and nitrates, antimony and arsenic halides, bismuth oxide, boric acid, carbon, carbon dioxide, carbon disulfide, carbon tetrachloride, charcoal, chlorinated hydrocarbons, and a number of other compounds. When reacting with water, sufficient concentrations of hydrogen can be generated to explode if oxygen is present. Potassium metal, if exposed to the air, will form the peroxide (K_2O_2), potassium oxide (K_2O), and the superoxide (KO_2). The the peroxide and the superoxide are strong oxidizing compounds, and if sufficient oxidizable material is present, can cause thermal explosions, deflagarations, or detonations depending upon the reactant.

2. Potassium Chloride (KCl)

2.1 Physical Properties

Colorless or white crystals or powder. KCl is soluble in water. Specific gravity is 1.987. Melting point is 773 C (1500 F) and it sublimes at 1500 C (2880 F).

2.2 Toxicological Characterstics

KCl is a nutrient and/or dietary supplement food additive. Large oral doses cause gastric irritations, purging, weakness, and circulatory problems.

2.3 Fire Hazard

None.

2.4 Explosion Hazard

None.

3. Sodium Chloride (NaCl)

3.1 Physical Properties

Colorless, transparent crystals or white crystalline powder. NaCl is soluble in water. Specific gravity is 2.165. Melting point is 801 C (1554 F), and NaCl boils at 1413 C (2717 F).

3.2 Toxicological Characteristics

NaCl is common table salt. A skin or eye irritant. Ingestion of large quantities can cause irritation of the stomach.

3.3 Fire Hazard

None.

3.4 Explosion Hazard

None.

4. Chlorine (Cl_2)

4.1 Physical Properties

Greenish-yellowish gas, liquid, or rhombic crystal. Specific gravity of vapor is 2.49 (heavier than air). Melting point is -101 C (-160 F). Boiling point is -34.5 C (-30 F). Vapor pressure at 20 C (68 F) is 4800 mm (92.8 psi).

4.2 Toxicological Characteristics

Chlorine is extremely irritating to the mucous membrane of the eyes at 3 ppm and the respiratory tract. It combines with moisture to form hydrochloric acid and liberate nascent oxygen. Both these substances, if present in quantity, cause inflammation of the tissue with which they come in contact. If the lung tissues are attacked, pulmonary edema may result. A concentration of 3.5 ppm produces a detectable odor; 15 ppm causes immediate irritation of the throat. Concentrations of 50 ppm are dangerous for even short exposures, 1000 ppm may be fatal, even when the exposure is brief. Because of its intensely irritating properties, severe industrial exposure seldom occurs, as the workman is forced to leave the exposure area before he can be seriously affected. In cases where this is impossible, the initial irritation of the eyes and mucous membrane of the nose and throat is followed by a cough, a feeling of suffocation, and later, pain and a feeling of constriction of the chest. If the exposure has been severe, pulmonary edema may follow, with rales being heard over the chest. It is a common air contaminant. It is used in the chlorination of swimming pools and water supplies.

4.3 Fire Hazard

Since chlorine is a strong oxidizer, stronger than oxygen, it can react to cause fires upon contact with many substances which are combustible in air if the proper concentrations of reactants are present.

4.4 Explosion Hazard

There is a potential of explosion with many organic and metal materials if sufficient concentrations, division of reactants, and confinement are present. The danger of explosion is greatly reduced if the reactants are not confined.

5. Potassium Superoxide (KO_2 or K_2O_4) [1]

5.1 Physical Properties

Potassium superoxide is yellowish in color, resembling flowers of sulfur. KO_2 has a specific gravity of 2.14. It melts at 380 C (716 F) and disassociates at 600 C (1112 F).

5.2 Toxicological Characteristics

Potassium superoxide, although not a systemic poison, is a very strong oxidizer. It will attack living tissue in the same manner as potassium hydroxide, since it reacts with the moisture in the skin to form the hydroxide, see section 1.2.

1 There is a strong possibility that air has leaked into one or more of the NaK containers since there original containment. If air has gotten into the containers, oxygen will react with the potassium present to form potassium superoxide, potassium peroxide, and potassium oxide. The potassium oxide, which is essentially inert, can bridge within the containers and isolate the potassium super and peroxides from the NaK. This bridge could be broken with movement or vibration of the containers.

5.3 Fire Hazard

Since potassium superoxide is such a strong oxidizing material, it can initiate fires with many materials which will combust in air. It will not itself burn in air.

5.4 Explosion Hazard

KO_2 is such a strong oxidizer, there is considerable concern about explosions. If the superoxide comes in contact with organic materials, it can detonate. It can also react so exothermally with other materials, that there is the potential of a thermal explosion under certain conditions of confinement and sufficient reactants. Of particular concern, is the thermal reaction between NaK and KO_2.

6. Potassium Peroxide (K_2O_2) [1]

Although not as strong an oxidizer as KO_2, it still presents the same toxicological, fire, and explosion hazards as the superoxide.

7. Potassium Peroxyferrate (K_2FeO_5) [2]

Can self explode or react violently with non-metals.

8. Potassium Chromates [2]

Potassium Bichromate ($K_2Cr_2O_7$) or Potassium Chromate (K_2CrO_4), these compounds are potentially carcinogenic.

9. Uranium (U238) [3]

9.1 Physical Properties

A heavy, silvery-white, malleable, ductile, softer-than-steel metal. Specific gravity is 18.95; it melts at 1132 C (2183 F); and boils at 3818 C (7286 F). Uranium (238) is non-radioactive.

[2] If the superoxide has formed inside the containers, this is a potential corrosion product between the superoxide and the stainless steel containers.

[3] The Mark II fuel elements which contaminated this NaK were U(238) being transmuted to Pu(239). It is highly probable that the NaK contains some U(238).

9.2 Toxicological Characteristics

Uranium is a highly toxic element on an acute basis. The permissible levels for soluble compounds are based on chemical toxicity. The high chemical toxicity of U and its salts is largely shown in kidney damage, and acute necrotic arterial lesions. The rapid passage of soluble uranium compounds through the body tends to allow relatively large amounts to be taken in.

9.3 Fire Hazard

Uranium is pyrophoric.

9.4 Explosion Hazard

Can react violently with certain oxidizers, including air.

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APPENDIX C
EDF EXPOSURE ESTIMATES

EG&G Idaho, Inc.

FORM EG&G-2531 (Rev. 4-78)

ENGINEERING DESIGN FILE

PROJECT FILE NO 015094

EDF SERIAL NO NAK004

FUNCTIONAL FILE NO SRA-10-86

PROJECT/TASK EBR-I Mark II NaK Disposal

DATE March 31, 1986

SUBTASK Radiological Engineering

EDF PAGE NO 1 OF

SUBJECT Radiation Exposure Rates in the Vicinity of the Containers of EBR-I Mark II NaK

ABSTRACT

Radiation exposure rates were calculated at several points around the four EBR-I Mark II core NaK containers. The calculations were designed to produce bounding values for the potential exposure rates that could be encountered during disposal of the EBR-I Mark II core NaK. The data included in this report is conservative and can be used for calculating shielding requirements or in planning radiation safety procedures. The highest radiation exposure rate calculated was 35.7 R/h at the side of the MSA container. Approximately 98% of all exposure rates calculated were due to Cs-137. Radiation rates as a function of shield thickness for lead and soil shielding were also calculated.

Introduction

In November 1955 the Mark II core of the EBR-I partially melted during the last of a series of experiments designed to study its behavior when put on positive periods with reduced or zero coolant flow. A certain fixed amount of reactivity was put into the reactor with the control rods, and the reactor was started up on a short enough period so that temperature differentials would be established in the fuel slugs. A prompt positive temperature coefficient appeared, and, as the power increased, the reactivity increased, thus further shortening the period. When the period reached one second, the operator mistakenly activated the slow-acting motor-driven control rods instead of the faster acting scram rods. By the time the scram was initiated the period had reached 0.3 seconds. The uranium became heated above 720°C and the uranium-iron eutectic formed. Melting occurred in 40-50% of the EBR-I core. The core assembly was removed from the reactor by use of a temporary hot cell and shipped to ANL-W for examination and disassembly (Reference 1).

The NaK coolant from the EBR-I Mark II core was contaminated with fission products, fuel, and plutonium samples totaling 10.5 grams. The NaK coolant is stored in four containers at the Army Reentry Vehicle Facility Site (ARVFS). Post radiological hazard characterization work was performed in 1974 and 1979 (Reference 2). The previous radiation exposure measurements were performed under conditions of poor geometry and with uncalibrated instruments; therefore, the radiation

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S. R. Adams	S&E Programs	[signature]	4/1/86	[signature] for M. R. Dolenc	4/1/86

fields reported are only considered rough estimates (Reference 2). This EDF presents the maximum credible radiation exposure rates using conservative models for the core irradiation history and fission product release to the NaK. Discussions of the effects of shielding on radiation exposure fields and man-rem dose estimates are also included.

Analysis

The fission product inventory assumed was that of Reference (3). As stated in the reference, "Operating history data is difficult (perhaps impossible) to recover after more than 30 years. The only definitive items identified to date are measured radial and axial fission rate distributions for the earlier (Mark I) core loading and a reported maximum core burnup of approximately 0.1 atom present at the time of the meltdown."

Table 1 lists the fission product radionuclides used in this analysis. The inventory of activation products was assumed to be negligible because of the short operating time of the Mark II core and the total lack of activation product signal in the gamma spectrum taken of the NaK containers (Reference 2, Figure 7).

The ISOSHLD II code was used to model the four NaK containers. The code input is included as an addendum to the EDF (Reference 4). The following assumptions were made in the code calculations:

- o The fission product inventory is uniformly distributed throughout the NaK. The density of the NaK is 0.75 g/cm^3 (Reference 5).

- o The MSA containers were modeled as a right circular cylinder with a radius of 30.16 cm, a height of 91.12 cm, and a steel wall thickness of 0.3175 cm (Reference 2, Figure 9).

- o The fabricated container #2 was modeled as a right circular cylinder with a radius of 29.2 cm, a height of 91.12 cm, a steel wall thickness of 0.3175 cm, and a steel cap 3.175 cm thick (Reference 2, Figure 10).

- o The fabricated container #1 was modeled as a right circular cylinder with a radius of 13.0 cm, a height of 66.0 cm and a wall thickness of 0.3175 cm (Reference 2, Figure 11).

The results of the calculations are shown in Table 2. The calculated radiation exposure rates at the surface of the containers varied from 20-36 R/h. The highest values were calculated at the side of MSA containers, about 36 R/h. These values were calculated conservatively and should bound the actual radiation exposure rates encountered in the vicinity of the NaK containers.

These calculated values would preclude any extended stay times in the vicinity of the NaK containers. The EG&G Administrative Dose Guides for the whole body and hands are 0.05 and 0.4 rem/day respectively. Without additional shielding, and assuming the worker is one foot away from the container while their hands were in contact, would limit stay times to about 18 seconds. For this reason a series of calculations were made to determine the radiation exposure rate as a function of shielding thickness. The MSA container was used for these calculations since it presents the highest radiation exposure rate. The results are shown in Figure 1. This data can then be used to plan the amount of shielding required to perform the necessary hands-on operations during the NaK container D&D project. For example, assume that workers will be required to remain in close proximity to each container for approximately 15 minutes. That would result in a total stay time of one hour. Therefore, the radiation exposure to the whole body should not exceed 0.05 R/h. Figure 1 shows that this would require about 4.3 cm of lead shielding around the containers.

Per the verbal request of M. R. Dolenc of Waste Programs, the radiation field as a function of shielding thickness using soil was estimated. Examination of the ISOSHLD II output shows that about 98% of the exposure is due to the 0.66 MeV photons of the Cs-137/Ba-137m. The attenuation coefficient for Pb at this energy is approximately 1.28 cm^{-1}. For soil the attenuation coefficient was calculated assuming an atomic elemental distribution of: Oxygen - 0.452, Hydrogen - 0.156, Flurine - 0.189, Silicon - 0.136. Aluminum - 0.044, and Fe - 0.012; and a density of 1.5 g/cm^3 (Reference 6). The attenuation coefficient is then 0.115.

As a first approximation, the ratio of soil/lead to obtain equivalent radiation exposure rate attentuation is 1.28/0.115 or 11.2 (see Figure 2). Because of the wide variability in soil composition, water content, and density a more rigorous calculation was not made. Figure 2 gives the approximate radiation field as a function of soil shield thickness for the MSA NaK containers.

Conclusions

A series of calculations have been made to bound the potential radiation exposure rates around the four EBR-I Mark II NaK containers. These calculated values are conservative, the actual values should be less. More precise values could be obtained if the radiological source terms could be defined exactly. As the radiological terms will most likely remain speculative, the values calculated in this EDF are still useful for planning purposes. The following points should be considered when applying the calculated values:

- The radiation exposure rates were for single containers. Grouping the containers together will modify the expected results due to a combination of photon field additive interactions, self-shielding, and sky-shine.

- The radiation fields at the top of the MSA and fabricated container #2 could be considerably less than the values in Table 1 due to the shielding in their lids. Figure 9 of Reference 2 shows an 8 inch, 16 inch O.D. lid of unstated material on the MSA container. Figure 10 shows 1.25 inch, 30 inch O.D. flange on the fabricated container #2, though the text describes it as a 0.5 inch plate.

The data below should assist in the planning of the EBR-I Mark NaK container disposal. This data is very preliminary, more exact calculations can be made as the project tasks are defined.

Time spent in the vicinity of each NaK Container (minutes)	Shielding thickness required to remain in compliance with the EG&G Administrative Dose Guides Lead (cm)	Soil (cm)
5.0	3.4	38
10.0	4.0	45
20.0	4.6	51
60.0	5.4	61

References

1. S. R. Adams, Theory Design and Operation of Liquid Metal Fast Breeder Reactors, Including Operational Health Physics, NUREG/CR-4375, October 1985.

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4. G. L. Simmons, et al., ISOSHLD-II: A Computer Code for General Purpose Isotope Shielding Analysis, BNWL-236 and Supplements, March 1967.

5. A. J. Friedland, Coolant Properties, Heat Transfer, and Fluid Flow of Liquid Metals, in Fast Reactor Technology Plant Design, J. G. Yevick, (Ed) MIT Press, Cambridge, Mass., 1966.

6. R. G. Jeager, (Ed) Engineering Compendium on Radiation Shielding, v II, p 31, Springer-Verlag, New York, 1975.

TABLE 1. CALCULATED ISOTOPIC INVENTORY FOR EBR-I NaK (ALL FISSION PRODUCTS FROM 50% OF CORE, DECAYED TO AUGUST 1988). (Reference 2)

Isotope	Inventory (Grams)	Activity (Curies)
^{3}H	5.24×10^{-6}	5.05×10^{-2}
^{79}Se	4.17×10^{-3}	2.91×10^{-4}
^{85}Kr	2.76×10^{-3}	1.08×10^{0}
^{90}Sr	2.36×10^{-1}	3.22×10^{1}
^{90}Y	5.91×10^{-5}	3.22×10^{1}
^{93}Zr	5.99×10^{-1}	1.51×10^{-3}
^{93m}Nb	4.11×10^{-6}	1.16×10^{-3}
^{99}Tc	6.09×10^{-1}	1.03×10^{-2}
^{107}Pd	2.06×10^{-2}	1.06×10^{-5}
^{113m}Cd	8.64×10^{-6}	1.87×10^{-3}
^{121m}Sn	6.72×10^{-7}	3.98×10^{-5}
^{125}Sb	1.38×10^{-6}	1.42×10^{-3}
^{125m}Te	1.92×10^{-8}	3.47×10^{-4}
^{126}Sn	9.07×10^{-3}	2.58×10^{-4}
^{126}Sb	4.31×10^{-10}	3.60×10^{-5}
^{126m}Sb	3.28×10^{-12}	2.58×10^{-4}
^{129}I	9.20×10^{-2}	1.62×10^{-5}
^{134}Cs	1.25×10^{-9}	1.62×10^{-6}
^{135}Cs	8.34×10^{-1}	9.61×10^{-4}
^{137}Cs	3.92×10^{-1}	3.41×10^{1}
^{137m}Ba	6.00×10^{-8}	3.23×10^{1}
^{147}Pm	5.93×10^{-5}	5.50×10^{-2}
^{151}Sm	4.90×10^{-2}	1.29×10^{0}
^{152}Eu	3.43×10^{-8}	5.94×10^{-6}
^{154}Eu	1.14×10^{-6}	3.07×10^{-4}
^{155}Eu	5.74×10^{-5}	2.67×10^{-2}

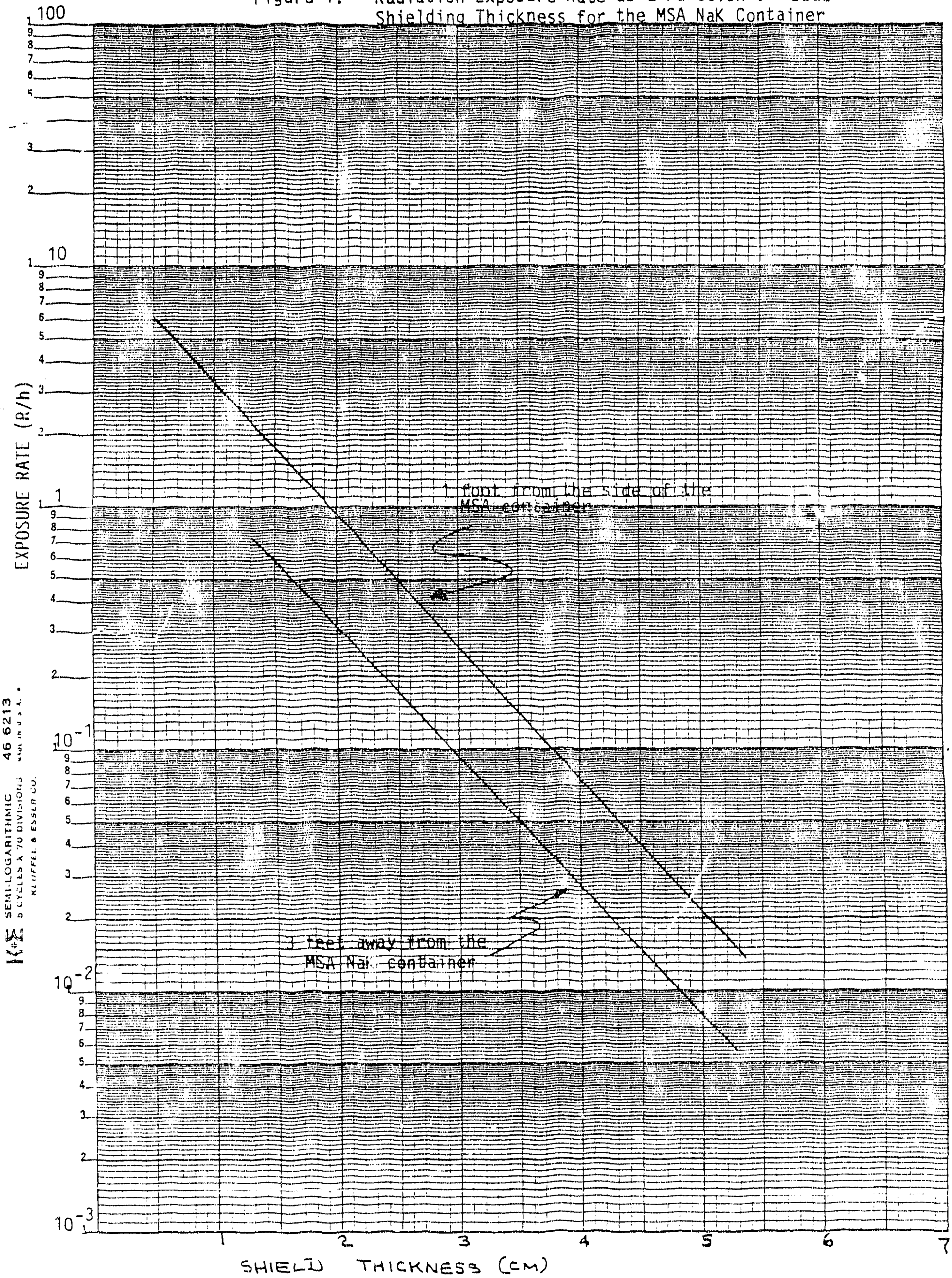
Table 2. Radiation Exposure Rates in the Vicinity of the NaK Containers (R/hour)

Container Type	Geometry	Exposure At The Surface	Exposure At 1 Ft.	Exposure At 3 Ft.
Fabricated #1	Side	23.1	3.38	0.66
	Top	20.3	1.95	0.71
Fabricated #2	Side	34.5	9.61	2.51
	Bottom[a]	33.9	7.78	1.72
MSA	Side	35.7	10.0	2.64
	Bottom[b]	30.2	7.12	1.57

a. The bottom of the container was calculated to have greater radiation fields. Exposure rate at the top, due to 0.25 inches of steel were approximately 17 R/h at the surface and 6 R/h at a foot.

b. Figure 9 in Reference 7 shows an 8 inch thick, 16 inch O.D. "Lid" on the MSA container. No information could be obtained on what material(s) this "Lid" was constructed. This thickness of steel, for instance, would reduce the exposure rate to about 10 mR/h at the surface.

Figure 1. Radiation Exposure Rate as a Function of Lead Shielding Thickness for the MSA NaK Container



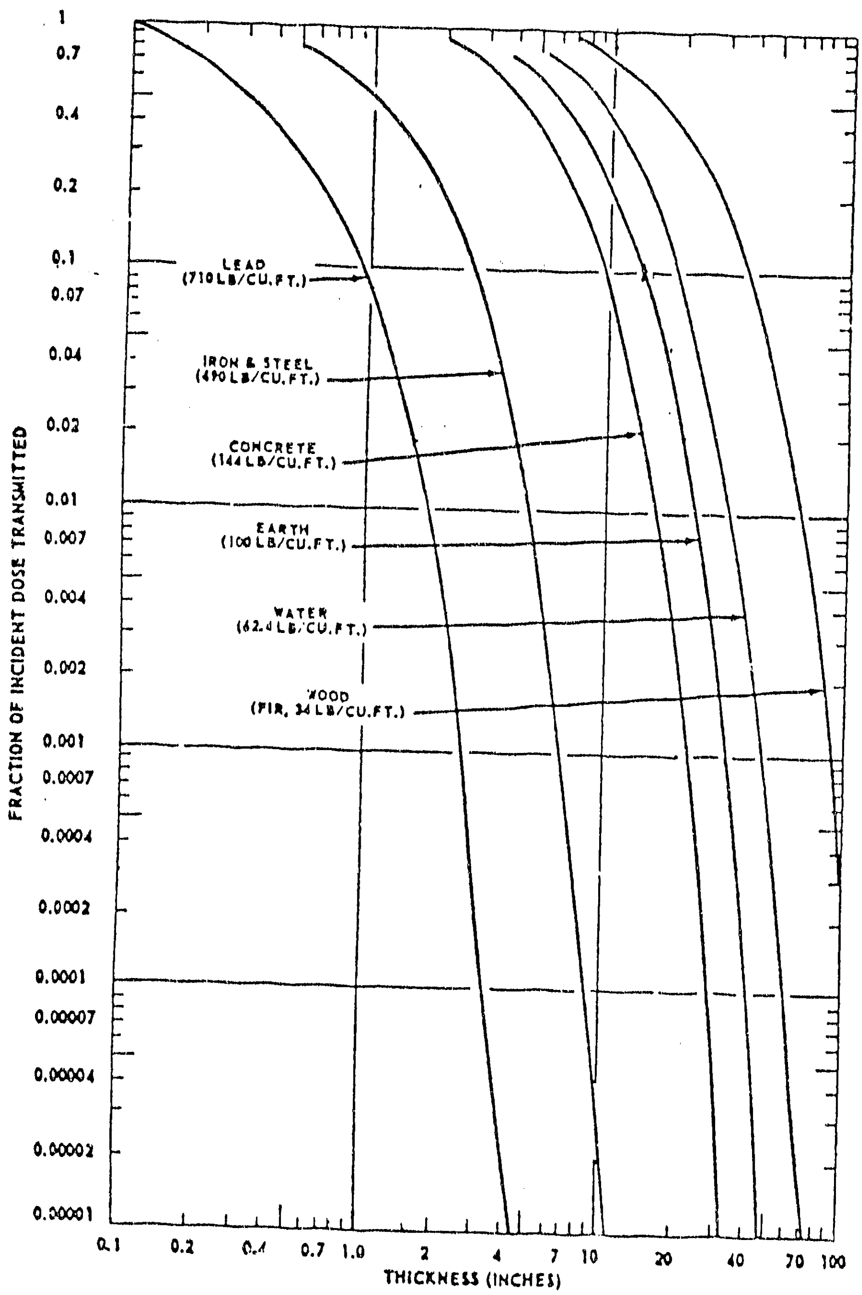
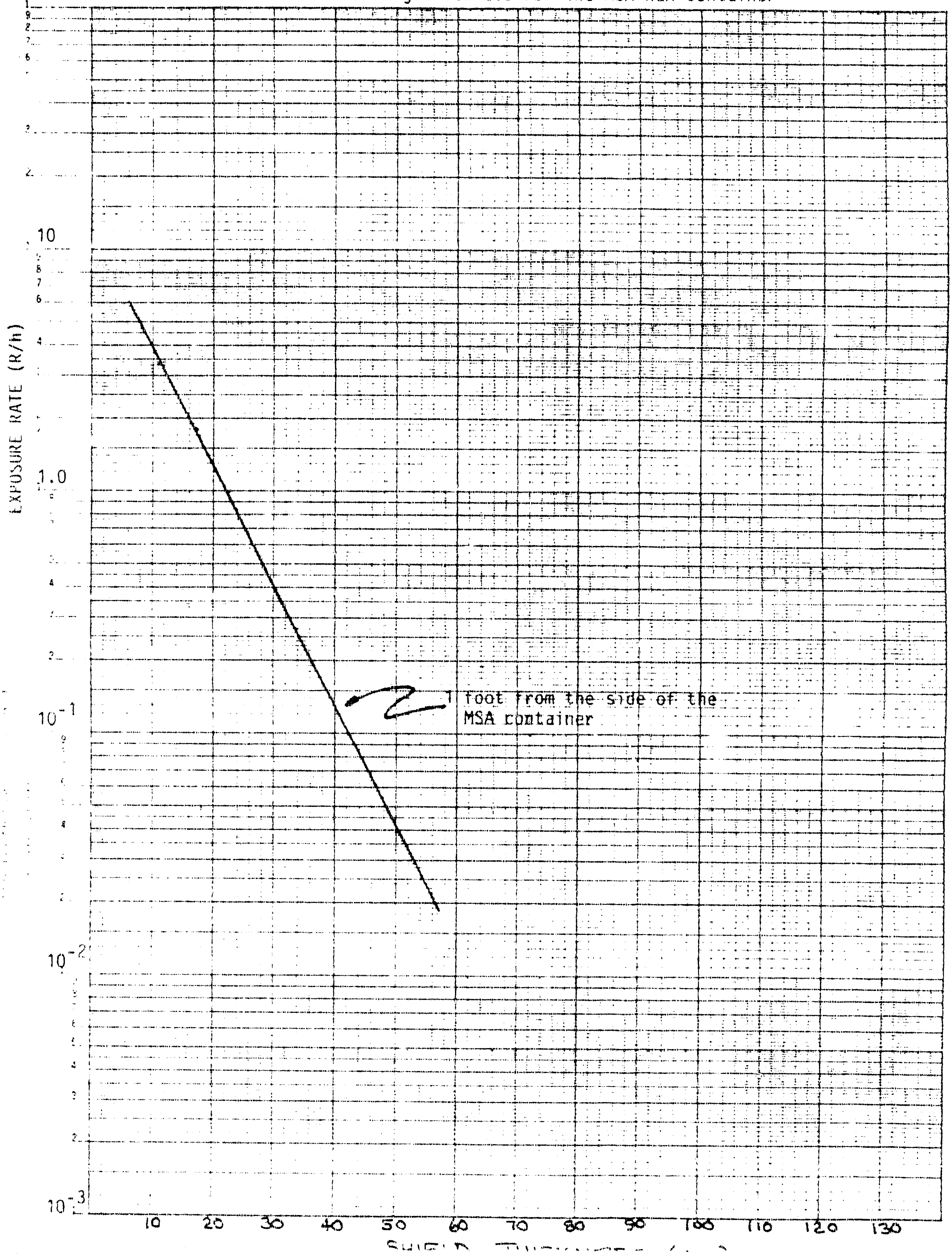


FIGURE 2

Transmission of fission product gamma radiation in several shield materials (From Brodsky, A., & G.V. Beard, Ed. A Compendium of Information for Use in TID-8206, Controlling Radiation Emergencies, 1960)

Figure 3. Radiation Exposure Rates as a Function of Soil Shielding Thickness for the MSA NaK Container



```
           2
R/H FROM THE  CONTAMINATED WAK IN FAD CONTAINE   2, TOP OF THE CONTAINER
 $INPUT NEXT=1,
 IGEOM=9,NSHLD=2,JBUF=1,
 WEIGHT(055)=.4822,
 WEIGHT(082)=14.38,
 WEIGHT(084)=14.38,
 WEIGHT(141)=4.6E-3,
 WEIGHT(206)=8.35E-4,
 WEIGHT(269)=5.34E-4,
 WEIGHT(335)=15.22,
 WEIGHT(380)=.02456,
 WEIGHT(403)=.576,
 WEIGHT(418)=1.16E-4,
 SLTH=29.2,
 T(1)=91.12,
 T(2)=.3175,
  NTHETA=19,
 DELR=1.,
 Y=91.44,
 SSV1=0.0,
 ISPEC=3,
 $END
         7          .75
         9                  7.3                                  1
R/H AT 1 FT FROM THE TOP OF THE CONTAINER
  $INPUT NEXT=4,X=121.9,$END
R/H AT 3 FT FROM THE TOP OF THE CONTAINER
  $INPUT NEXT=4,X=182.9,$END
```

```
         2
R/H FROM CONTAMINATED NA[illegible] IN [illegible] CONTAINER #1, SIDE OF CONTAINER
 $INPUT NEXT=1,WEIGHT(055)=.0725,WEIGHT(082)=2.163,WEIGHT(084)=[illegible],
 WEIGHT(141)=6.92E-4,WEIGHT(206)=1.[illegible]E-4,WEIGHT(269)=9.54E-5,
 WEIGHT(335)=2.29,WEIGHT([illegible])=3.69E-3,WEIGHT(403)=.087,
 WEIGHT(419)=1.79E-3,
 IGEOM=7,NSHLD=2,JFUF=1,
 T(1)=13.,
 T(2)=.3125,
 SLTH=66.,
 X=13.4,
 Y=33.,
 NTHETA=29,
 NPSI=29,
 DELR=1.0,
 ISPEC=3,
 $END
         7          .75
         9                 7.3                                          1
R/H AT 1 FT FROM THE SIDE OF THE CONTAINER
 $INPUT NEXT=4,X=43.88,$END
R/H AT 3 FT FROM THE SIDE OF THE CONTAINER
 $INPUT NEXT=4,X=104.3,$END
```

```
          2
R/H FROM CONTAMINATED NAK IN FAR CONTAINER #2, SIDE OF CONTAINER
 $INPUT NEXT=1, IGEOM=7,NSHLD=2,JCUF=1,
 WEIGHT(055)=.4823,
 WEIGHT(082)=14.38,
 WEIGHT(084)=14.38,
 WEIGHT(141)=4.6E-3,
 WEIGHT(206)=8.35E-4,
 WEIGHT(269)=6.34E-4,
 WEIGHT(335)=15.23,
 WEIGHT(380)=.02456,
 WEIGHT(403)=.576,
 WEIGHT(418)=1.16E-4,
 T(1)=29.2,
 T(2)=.3175,
 SLTH=91.44,
 X=29.6,
 Y=45.72,
 NTHETA=29,
 NPSI=29,
 DELR=1.0,
 ISPEC=3,
  $END
        7          .75
        9                   7.3                              1
R/H AT 1 FT FROM THE SIDE OF THE CONTAINER
 $INPUT NEXT=4,Y=60.,$END
R/H AT 3 FT FROM THE SIDE OF THE CONTAINER
 $INPUT NEXT=4,X=121.,$END
```

```
                  2
R/H AT THE TOP SURFACE OF THE FAB 1 CONTAINER
 $INPUT NEXT=1,
 WEIGHT(055)=.072E,WEIGHT(082)=2.163,WEIGHT(084)=2.163,
 WEIGHT(141)=6.92E-4,WEIGHT(206)=1.26E-4,WEIGHT(269)=9.54E-5,
 WEIGHT(335)=2.29,WEIGHT(386)=3.69E-3,WEIGHT(403)=.087,
 WEIGHT(418)=1.79E-2,
 IGEOM=9,
 NSHLD=2,JRUF=1,
 SLTH=13.4,
 T(1)=66.,
 T(2)=.3175,
 X=66.4,
 SSV1=0.0,
 NTHETA=29,
 NPSI=29,
 DELR=.1,
 ISPEC=3,
 $END
        7        .75
        9                7.3                                    1
R/H AT 1 FT FROM THE TOP OF FAB 1
 $INPUT NEXT=4,X=96.88,$END
R/H AT 3 FT FROM THE TOP OF FAB 1
 $INPUT NEXT=4,X=127.4,$END
```

```
                  2
R/H FROM THE CONTAMINATED NAK I* NSA CONTAINER, TOP
 $INPUT NEXT=1,
 ISEOM=9,NSHLD=2,JBUF=2.
 WEIGHT(055)=.525,
 WEIGHT(082)=15.7,
 WEIGHT(084)=15.7,
 WEIGHT(141)=.005,
 WEIGHT(206)=.0009,
 WEIGHT(269)=.0007,
 WEIGHT(335)=16.6,
 WEIGHT(380)=.027,
 WEIGHT(403)=.63,
 WEIGHT(418)=.013,
 SLTH=30.16,
 T(1)=91.2,
 T(2)=.3175,
 NTHETA=19,
 DELR=1.,
 X=91.44,
 SSV1=0.0,
  ISPEC=3,
 $END
            7          .75
            9                7.3                                  1
R/H AT 1 FT FROM THE TOP OF THE CONTAINER
 $INPUT NEXT=4,X=121.9,$END
R/H AT 3 FT FROM THE TOP OF THE CONTAINER
 $INPUT NEXT=4,X=182.9,$END
```

```
R/H FROM CONTAMINATED NAK IN NS[illegible] CONTAINER, SIDE OF CONTAINER
 $INPUT NEXT=1,
 IGEOM=7,NSHLD=2,JSLF=1,
 WEIGHT(055)=.525,
 WEIGHT(082)=15.7,
 WEIGHT(084)=15.7,
 WEIGHT(141)=.005,
 WEIGHT(206)=.0009,
 WEIGHT(269)=.0007,
 WEIGHT(335)=16.6,
 WEIGHT(380)=.027,
 WEIGHT(403)=.63,
 WEIGHT(418)=.013,
 T(1)=30.16,
 T(2)=.3175,
 X=30.5,
 SLTH=91.44,
 Y=45.72,
 NTHETA=19,
 NPSI=19,
 DELR=1.,
 ISPEC=3,
 $END
```

7 .75

9 7.3 1

```
R/H AT 1 FT FROM THE SIDE OF THE CONTAINER
 $INPUT NEXT=4,X=61.,$END
R/H AT 3 FT FROM THE SIDE OF THE CONTAINER
 $INPUT NEXT=4,X=122.,$END
```

```
          2
R/H FROM CONTANINATED NAK IN MSA CONTAINER, SIDE OF CONTAINER
  $INPUT NEXT=1,
  WEIGHT(055)=.525,
  WEIGHT(082)=15.7,
  WEIGHT(084)=15.7,
  WEIGHT(141)=.005,
  WEIGHT(206)=.0009,
  WEIGHT(269)=.0007,
  WEIGHT(335)=16.6,
  WEIGHT(380)=.027,
  WEIGHT(403)=.63,
  WEIGHT(418)=.013,
  IGEOM=7,NSHLD=3,JBUF=1,
  T(1)=30.16,
  T(2)=.3175,
  T(3)=0.5,
  X=31.,
  SLTH=91.44,
  Y=45.72,
  NTHETA=19,
  NPSI=19,
  DELR=1.,
  ISPEC=3,
  $END
          7        .75
          9                  7.3
          14                           11.3                          1
  R/H AT 1 FT, 5 CM PB
  $INPUT NEXT=4,T(3)=5.,X=66.,$END
R/H AT 1 FT, 10 CM PB
  $INPUT NEXT=4,T(3)=10.,X=71.,$END
R/H AT 3 FT, 10 CM PB
  $INPUT NEXT=4,T(3)=10.,X=132.,$END
R/H AT 3 FT, 5 CM PB
  $INPUT NEXT=4,T(3)=5.,X=127.,$END
R/H AT 3 FT 2.5 CM PB
  $INPUT NEXT=4,T(3)=2.5,X=124.5,$END
R/H AT 3 FT, 2 CM PB
  $INPUT NEXT=4,T(3)=2.,X=124.,$END
R/H AT 3 FT, 1.5 CM PB
  $INPUT NEXT=4,T(3)=1.5,X=123.5,$END
R/H AT 3 FT, 1 CM PB
  $INPUT NEXT=4,T(3)=1.,X=123.,$END
```

```
        2
R/H FROM CONTAMINATED NAK IN MSA CONTAINER, SIDE OF CONTAINER
 $INPUT NEXT=1,
 WEIGHT(055)=.525,
 WEIGHT(082)=15.7,
 WEIGHT(084)=15.7,
 WEIGHT(141)=.005,
 WEIGHT(206)=.0009,
 WEIGHT(269)=.0007,
 WEIGHT(335)=16.6,
 WEIGHT(380)=.027,
 WEIGHT(403)=.63,
 WEIGHT(418)=.013,
 IGEOM=7,NSHLD=3,JBUF=1,
 T(1)=30.16,
 T(2)=.3175,
 T(3)=0.5,
 X=31.,
 SLTH=91.44,
 Y=45.72,
 NTHETA=19,
 NPSI=19,
 DELR=1.,
 ISPEC=3,
 $END
          7          .75
          9                    7.3
         14                          11.3                          1
R/H AT 1 FT FROM THE SIDE OF THE CONTAINER,0.5 CM PB SHIELD
 $INPUT NEXT=4,X=61.5,$END
R/H AT 1 FT,  1 CM PB SHIELD
 $INPUT NEXT=4,T(3)=1.,X=62.,$END
R/H AT 1 FT 1.5 CM OF PB
 $INPUT NEXT=4,T(3)=1.5,X=62.5,$END
R/H AT 1 FT FROM THE SIDE OF THE CONTAINER, 2 CM OF PB
 $INPUT NEXT=4,T(3)=2.,X=63.,$END
R/H WITH 2.5 CM OF PB
 $INPUT NEXT=4,T(3)=2.5,X=63.5,$END
```

APPENDIX D

EDF PROCESS SELECTION

EG&G Idaho, Inc.

FORM EG&G-2631 (Rev 4-78)

ENGINEERING DESIGN FILE

PROJECT FILE NO. 3KNOPNAKO

EDF SERIAL NO. NAK001

FUNCTIONAL FILE NO. 3KNOPNAKE

DATE 1/3/86

PROJECT/TASK Nak Disposal - EBR I

SUBTASK Engineering

EDF PAGE NO ___ OF ___

SUBJECT

PROCESS SELECTION

ABSTRACT

This EDF addresses the selection of a process to chemically deactivate the EBR-I Mark-II radioactively contaminated Nak stored at ARVFS Bunker.

The conclusion reached by this EDF is that the processing of the Nak with chlorine is the best process option. The major concerns in performing this selection were:

1. Safety
2. Environmental impact
3. Final waste form stability
4. Final waste form volume
5. Cost

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AUTHOR	DEPT	REVIEWED	DATE	APPROVED	DATE
D. La Rue	E & PM	[signature]	6 Jan 85	Mark R. Dolenc	1-6-86

1. INTRODUCTION

Four containers of contaminated Sodium/Potassium (NaK) are stored in an underground bunker at the ARMY Reentry Vehicle Site (ARVFS). The NaK was originally used as primary reactor coolant in the EBR-I. During November 1955 this NaK was radioactively contaminated during the testing of the EBR-I Mark II fuel. During this testing, Uranium (238) was being transmuted to Plutonium (239) when the core overheated. It is unknown as to how much of the Uranium had been transmuted and how much of this material was released into the NaK during the core failure. In addition, a 10.5 gram foil sample of Plutonium was being tested inside the reactor; this sample was lost and believed to be contained in the NaK. Estimates have been made that the NaK contains about 16 grams of radioactive material. No documentation for this estimate has been found. The NaK also probably contains some non-radioactive fuel rod debris.

This NaK coolant, estimated volume is 200 gal (maximum), was removed from the reactor and placed into two 55 gal Mine Safety Appliance Research (MSAR) drums and two containers fabricated from pipe. Each container was pressurized with an argon blanket gas. These containers were then placed in a storage pit at the EBR-I site until 1974. During 1974, these drums were removed from this storage pit, and then placed into a steel dumpster. The dumpster was filled with sand and the package transferred to the ARVFS bunker.

A bunker inspection was performed in August 1979 to characterize the external condition of the NaK containers. Most of the sand was removed from around the containers and radiation and physical measurements were taken. No contamination external to the containers or in the removed sand was found. The containers/drums were not moved or lifted during this inspection activity; therefore, no information exists on the condition of the bottoms of these containers. Vermiculite was added to the dumpster to a depth of approximately 12 in. above the drums. The sheet metal dumpster lid was replaced and the package located inside the bunker for continued storage.

Inspection of the NaK storage containers in 1979 verified that the integrity of the containers had not been breached. However, the smaller of the fabricated containers did have some rust on its lower outer surface. Based on these inspection results, it can be assumed that no significant external deterioration of the containers has occurred during their storage. Although the external condition of the containers has been verified, uncertainties exist regarding the overall integrity of the containers since corrosion could be occurring inside the containers. In particular, the fabricated containers are of concern since design and construction information on these two containers cannot be located.

There is also some concern that the NaK may contain Potassium Superoxide, KO_2, which if present, could present significant problems during the handling of these containers.

Radiation data for the NaK containers and dumpster taken in August of 1979 are summarized in Table 1. The isotopic curie quantities that were calculated (during 1979) to be present in the EBR-I NaK are presented in Table 2. Figure 1 presents the radiation levels measured for these drums prior to their relocation to the bunker in 1974. Comparison of the 1974 measurements with the 1979 measurements shows a significant discrepancy. Further complicating this issue was the known miscalibration of the radiation meter used during the 1979 inspection. Due to the significance of the radiation hazard associated with these drums, and the inability to reinspect the drums prior to their processing in 1988, the 1979 readings will be used for engineering. This should be sufficiently conservative for personnel safety. (See references 1 & 2)

2. Process Evaluation Considerations

In selecting a proposed process for the chemical deactivation and stabilization of the radioactively contaminated NaK eutectic solution from EBR-I, the following process scheme characteristics were of prime importance:

1) Safety (both chemically and radiologically)
2) Potential of adverse environmental impact during processing
3) Final Waste Form Stability
4) Final Waste Form Volumes
5) Cost (operational and equipment)

Also of concern, although to a lesser degree than the characteristics listed above were the following considerations:

1) Service Requirements (water, power, etc.) at processing site
2) Could the NaK be processed at or near its present location.
3) Rate of Processing
4) Simplicity of Process Scheme

In performing the evaluation, consideration was given to methods which have been employed in the past. In addition, other potential chemical methods were also investigated.

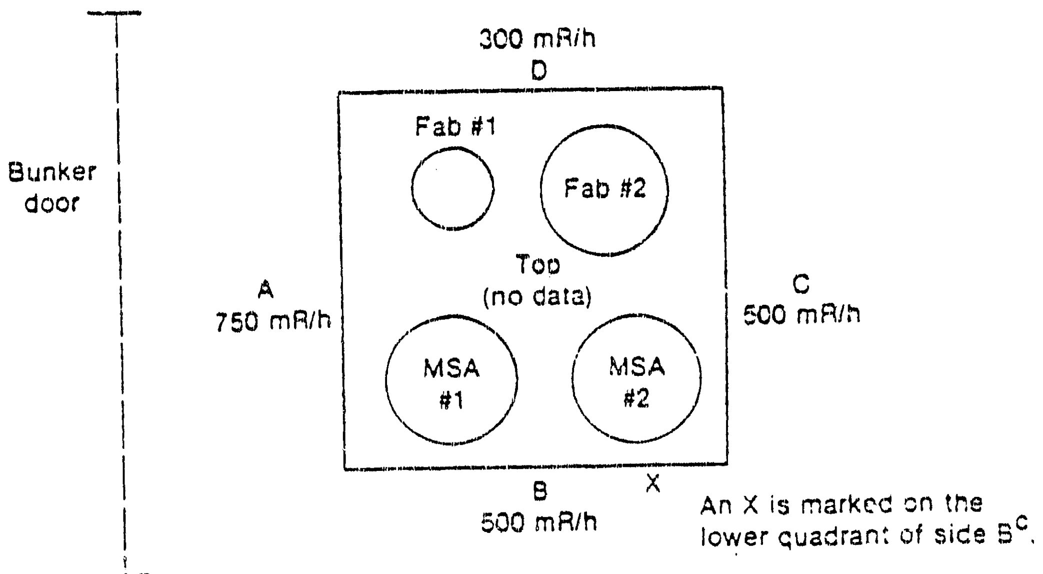
TABLE 1. RADIATION DATA FOR NaK STORAGE CONTAINERS AND DUMPSTER
1979

CONTAINERS

	Top of Container @ Contact (R/hr)	Container Height (ft)	Elevation[a] (ft)	Maximum Radiation Reading
MSA #1	1.6	3	1.5	40.0 R/h
MSA #2	2.0	3	1.0	23.3 R/h
Fab #1	0.2	2.2	1.0	16.7 R/h
Fab #2	0.5	3	0.5	16.7 R/h

a. Elevation where the maximum radiation reading was taken, measured downward from container top flange.

DUMPSTER[b]



b. Maximum readings at contact with sides A, B, C, D.

c. Hot spot marked X reading 1.5 R/h.

INEL 4 0453

TABLE 2. ISOTOPIC CURIE QUANTITIES CALCULATED TO BE PRESENT IN THE EBR-I NaK IN SEPTEMBER 1979

Isotope	Curie Value
Sr-90	7.12 +1[a]
Y-90	7.12 +1
Zr-93	4.21 -3
Tc-99	1.74 -2
Ru-106	1.59 -5
Rh-106	1.59 -5
Sn-121m	6.79 -3
Sb-125	1.27 -2
Te-125	2.95 -4
Cs-135	1.92 -3
Cs-137	7.20 +1
Ba-137m	6.63 -1
Pm-147	6.84 +0
Sm-151	2.79 +0
Pu-239	5.16 -1
Pu-240	1.13 -1
Pu-241	1.174 +0

a. $7.12 +1 = 7.12 \times 10^{1}$

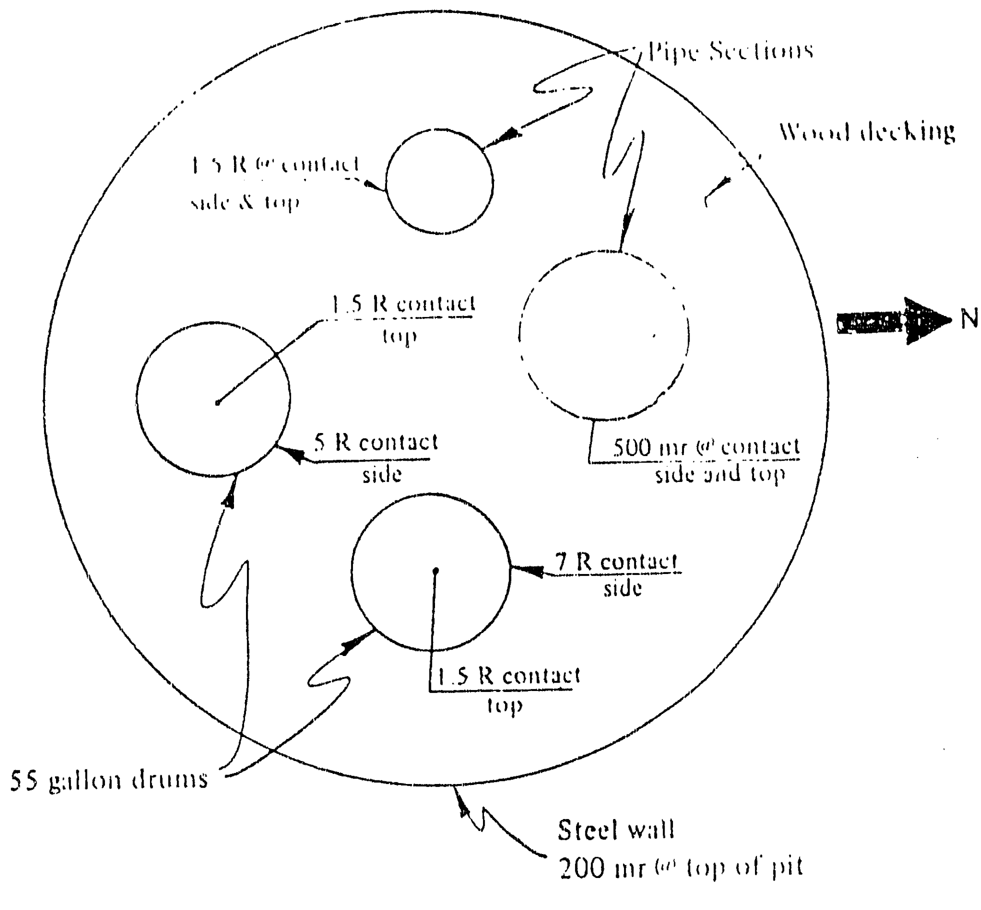


Fig. 1. NaK Storage Pit Radiation Survey.

3. PROCESSES INVESTIGATED

In the discussion below, brief descriptions of the various processing scenarios investigated are presented. This list does not include all the process schemes conceived during this exercise; it contains only those schemes not rejected off-hand because of safety, complexity, or cost.

3.1 Steam/Nitrogen Reaction

This process has been used successfully to chemically deactivate liquid sodium and NaK, in some cases where the NaK was radioactively contaminated. (See Reference 3 and 4). The process uses the fact that Na and K will react with water to form hydroxides

$$2\ NaK_2 + 6\ H_2O \longrightarrow 2\ NaOH + 4\ KOH + 3\ H_2 \uparrow$$

along with hydrogen gas. The water (water vapor), in significant dilution with nitrogen, is passed over the metal to be reacted. The nitrogen serves two functions: (1)the NaK-water reaction is exothermic and the nitrogen conducts a portion of the heat of reaction away from the reactants to maintain reasonable working temperatures; and (2) the hydrogen generated can present a significant explosion hazard with air, therefore the nitrogen serves as a diluent to maintain the hydrogen concentration below explosion limits when it is vented from the system.

The hydroxides generated by this process are neutralized with mineral acids (e.g., sulfuric acid) prior to disposal. The off-gas is vented through a filter (HEPA) to prevent the introduction of radioactive material into the atmosphere. Figure 2 illustrates this process in schematic form.

3.2 Oxygen Reaction

This process has also been successfully employed to chemically deactivate Sodium. (See Reference 5). In this process, warm air, with a small amount of moisture to catalyze the reaction, is slowly passed over the sodium to oxidixe it. A small amount of hydrogen is produced in this reaction, but this is maintained below the combustion limits by maintaining a low partial pressure of water in the reactant gas stream. The Sodium Oxide can be stored in its solid form or it can be further stabilized by reacting with water to form sodium hydroxide. This can then be reacted with mineral acids to form salt solutions. The advantage of this system is that smaller quantities of hydrogen are formed during the reaction.

$$4\ Na + O_2 \rightarrow Na_2O$$
$$K + O_2 \rightarrow KO_2$$

This process is illustrated in Figure 3.

This process is not as attractive when processing Potassium containing liquid metal solutions. The Potassium preferentially reacts with the Oxygen to form Potassium Superoxide. (See Reference 6). This superoxide can then spontaneously react with sodium to form sodium and potassium oxides. The rate and exotherm of this reaction is similar to thermite reactions, and although not explosive in the normal sense, can produce sufficient thermal energy to penetrate the vessel containing the reactants, or release sufficient energy to produce a thermal explosion. (See Reference 7).

3.3 Reaction with Alcohols

Alcohols are mildly acidic and will react with alkali metals to form alkoxides. The relative acidity of the alcohols is tertiary < secondary < primary < methanol. The reaction rate between the alkali metal and the alcohol is enhanced with the presence of a small amount of water due to the formation of hydronium ions in the solution. The reactions with alcohols produce Hydrogen:

$$2\ ROH + 2Na \rightarrow 2\ RONa + H_2\uparrow$$
R is a paraffin chain

A flow scheme for this reaction is schematically illustrated in Figure 4. (See Reference 8). A safety concern would be the presence of KO_2 which could react violently with the organic chain of the alcohol.

3.4 Reaction with Sulfur

The alkali metals react with Sulfur to form ionic molecules. i.e., soluble in water.

$$2Na + S \rightarrow Na_2S$$
$$4Na + 2S \rightarrow Na_4S_2$$
$$6Na + 3S \rightarrow Na_6S_3$$

$$2K + S \rightarrow K_2S$$
$$4K + 2S \rightarrow K_4S_2$$

In this reaction screme, the Sulfur would be in the molten state (slightly greater than 120 C) within the reactor vessel. The NaK would be slowly introduced into the vessel to react with the Sulfur. Due to density considerations ($NaK < Na_2S < S$) the reactor would have to be agitated. Upon completion of the processing of the NaK, the vessel would be allowed to cool, solidifying the Sulfur and Sulfide mixture, and then disposed. This process is illustrated in Figure 5.

3.5 Reaction with Acids

The alkali metals react vigorously with all acids. The acids which were considered in this investigation were:

- Sulfuric
- Hydrochloric
- Nitric
- Hydrogen Sulfide
- Ammonia

In all of these systems, Hydrogen is produced. Due to the concerns associated with the handling of these fluids, there is no advantage of these reaction schemes over the reaction with water vapor, also acidic to alkali metals.

3.6 Reaction with Halogens

The halogens (Fluorine, Chlorine, Bromine, and Iodine) are very reactive with the alkali metals and react to form ionic salts, e.g., NaCl.

Fluorine and Chlorine are gasses at standard conditions, Bromine is a liquid, and Iodine is a solid. Due to the significant exotherm for these reactions, the halogens should be diluted in an inert gas. This condition therefore restricts Bromine and Iodine from being strongly considered.

In this reaction scheme, the NaK would be slowly sprayed into a dilute atmosphere of Fluorine or Chlorine.

$$2\ Na + Cl_2 \rightarrow 2\ NaCl$$
$$2\ K + Cl_2 \rightarrow 2\ KCl$$

The diluting gas should be Helium or Argon, other gasses, e.g., nitrogen, would react in this system to form compounds not as stable as the desired final products.

Fluorine or Chlorine would be slowly injected into the reaction vessel to maintain the desired partial pressure. At the completion of the processing of the NaK, the small amount of residual halogen gas would be vented through an absorbant, e.g., water: the vessel purged with Helium, and then the entire system could be disposed.

Depending upon the process flow rates, it may be necessary to provide some form of cooling for the reaction vessel.

Figure 6 illustrates this process.

4. CHARACTERIZATION OF PROCESSES

The discussion below briefly describes the characteristics of the investigated processes. This discussion is primarily aimed at addressing the process considerations outlined in Section II of this EDF.

4.1 Steam/Nitrogen Reaction

This process is illustrated in Figure 2.

4.1.1 Safety

This process has been successfully used to process NaK with radioactive contamination present. The safety concerns, i.e., Hydrogen, caustic handling, and heat of reaction, have been safely monitored and controlled. The control system required for the safe operation of this process does present a substantial cost penalty, but not an unaffordable one. Real time and chromatographic (GC) analytical equipment is required to monitor the radiation and explosion hazards. The system for handling the NaK requires no additional equipment when compared to the other processing options.

The process safety considerations must also address the handling of caustic and acids if the product is to be neutralized prior to storage.

4.1.2 Cost (Operational and Equipment)

The system represents a moderately high total equipment cost; the major cost items are:

Nitrogen Heater
Steam Generator
Gas Moving Equipment
HEPA Filter
Gas Sampling and Analytical Equipment

Operational costs should be slightly higher due to the energy requirements for steam generation, gas heating, and gas moving equipment. Sufficient water would be required for the processing and neutralization steps. Manpower costs would probably be comparable to the other proposed systems.

4.2.3 Final Waste Form Stability

The hydroxides generated under this process are corrosive and, due to the long half-lives of the radionuclide contamination, the product should be neutralized with acid prior to long term storage.

4.2.4 Final Waste Form Volumes

The volume of radioactive wastes generated by this process are fairly high. The S1G Sodium deactivation produced approximately 2000 gal of liquid waste in the processing of about 80 gal of sodium. (See Reference 3). This suggests that the final amount of liquid waste from processing the EBR-I NaK would be approximately 3000-5000 gal.

During the processing, the following components would become contaminated and would have to be either decontaminated or wasted:

Nitrogen Heater, Gas Compressor, NaK Pump, NaK Storage Tank, Demister, and HEPA Filter.

4.1.5 Potential of Environmental Impact

The potential for environmental impact during the processing is considered to be of moderate concern. The possible sources of contamination are gas circulation line leaks, compressor or pump leaks, and possible HEPA filter failure.

4.1.6 Other Considerations

Due to the amount of power and water required for the process, it may not be practical to process the NaK at its present location. The rate of the processing should be about average when compared to the other processing options.

This process scheme is fairly complicated when compared to some of the other process options.

4.2 Oxygen Reaction

This process is illustrated in Figure 3.

4.2.1 Safety

The only major safety concern for this system when compared to the other process options is the high probability of formation of potassium superoxide. This superoxide would remain in the system, unless it reacted (potentially violently). For this reason, although this is a viable process for sodium, it does not appear to be viable for the processing of NaK.

Further discussion of this process is unnecessary.

4.3 Alcohol Process

This process is illustrated in Figure 4.

4.3.1 Safety

A similar process is routinely used to clean Sodium containers in industry. The process should work safely for cleaning NaK components and containers with the careful selection of the alcohol to be used. Since the off-gas produced will be rich in Hydrogen, the same safety considerations and safety equipment costs would be required as in the Steam/Nitrogen process option.

The process does present a significant safety concern if applied to the processing of the EBR-I NaK. There is considerable concern, although no positive evidence, that the EBR-I NaK contains Potassium Superoxide. If present, this compound can be anticipated to attack the C-C and C-H bonds of the alcohol, and if significant quantities of the superoxide are present, an explosive mixture could be generated within the reactor. Prior to using this process, determination must be made as whether or not superoxide is present.

There would be a significant cost and schedule penalty associated with the sampling of the NaK containers to determine the presence of superoxide, and since this process option appears to offer no unique advantages over the other processing options, continued investigation of the alcohol process is unwarranted.

4.4 Reaction with Sulfur

This process is illustrated in Figure 5.

4.4.1 Safety

There is no evidence that this reaction scheme has been used in the past to process sodium or sodium-potassium mixtures. The reaction is known to proceed at a reasonable rate in the presence of a catalyst, e.g., iron.

A significant safety advantage of this concept over some of the other process options is that no gaseous reaction product is formed. There are only two significant safety concerns associated with this concept (in addition to the NaK handling concerns). These are:

1) the need for 150 lb steam and the potential of sulfur leakage and subsequent fires. Molten sulfur is routinely handled in the chemical and petroleum industries on a very safe basis, and it is therefore felt that these safety concerns are not prohibiti e. It is suggested that if this process is the one chosen, that an outside A/E, e.g., Matthew Hall Engineering, Inc, Houston, Texas, with experience in sulfur systems be used. Sulfur piping and valving systems are very difficult to design due to freezing and plugging problems.

2) The potential of uncontrollable reactions between KO_2 and Sulfur if appreciable quantities of KO_2 were to enter the reactor.

4.4.2 Cost (Operational and Equipment)

This system represents a moderately high total equipment cost; the major cost items for thisprocess are:

Reactor Vessel (150 lb jacketed and agitated)
Sulfur Storage and Piping System
150 lb Steam Boiler

Operational costs will be higher than other options due to the fuel costs for the steam generator. Manpower costs would probably be comparable to the other proposed systems.

4.4.3 Final Waste Form Stability

The solid material generated, K_2S and Na_2S and S, are all stable chemicals and should not present a significant hazard in long term storage.

4.4.4 Final Waste Form Volumes

The final waste volume should be no greater than two to three times the initial NaK volume. This volume increase is primarily due to the need to process the NaK in excess sulfur.

The equipment to be D & D'd or wasted after the processing would be the NaK storage tank and the NaK pump and piping.

4.4.5 Potential of Environmental Impact

The potential for environmental impact during the processing is considered to be of low-moderate concern. The potential sources for radioactive material entering the environment are from leaks in the NaK storage, pump, and transfer lines. The chance of Sulfur leaking is low and would not be of consequence unless a catastrophic leak occurred.

4.4.6 Other Considerations

This process could be operated at the NaK's present site, but it would require the use of a packaged 150 lb steam boiler. This

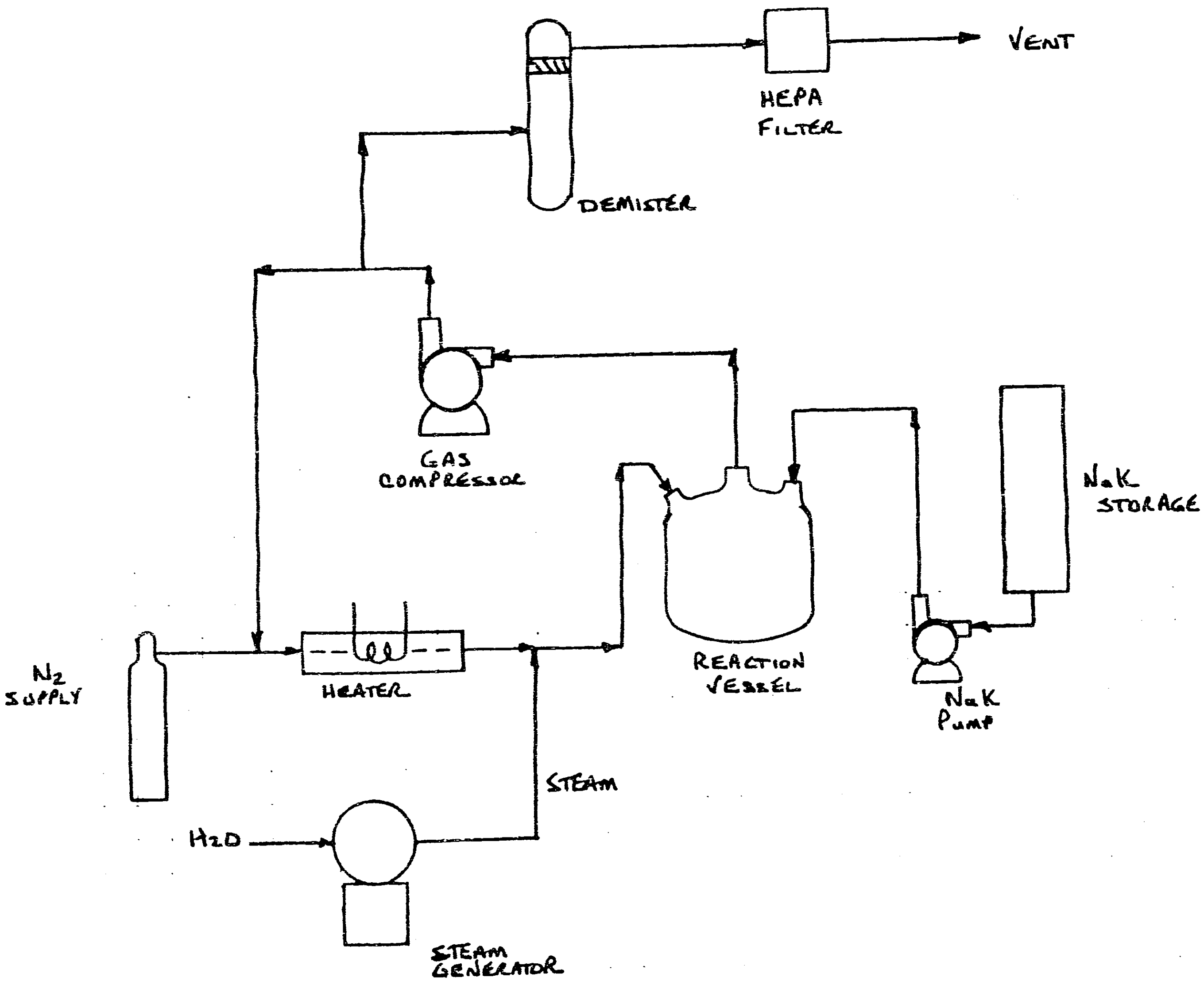


FIGURE 2 STEAM/NITROGEN PROCESS

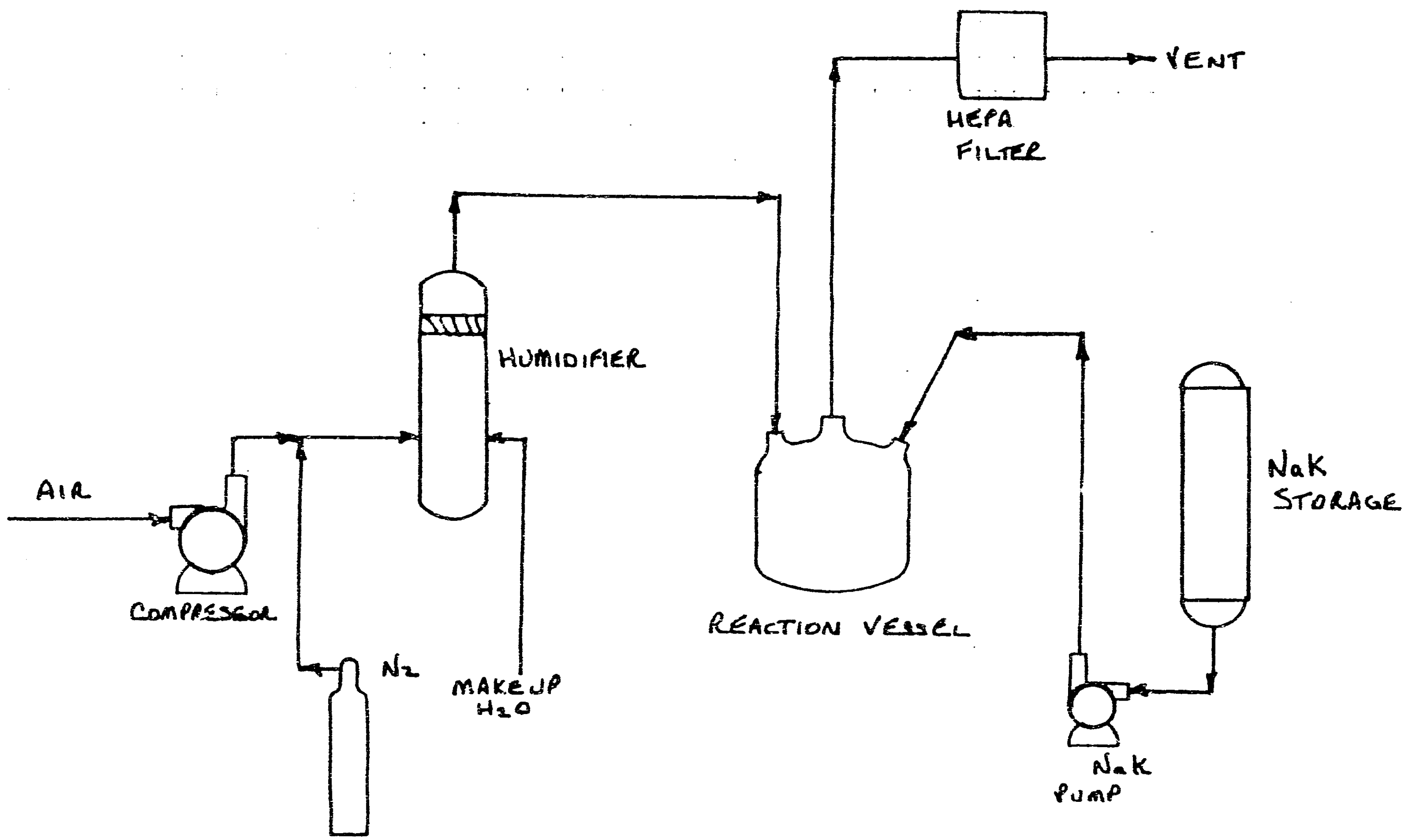


FIGURE 3 OXYGEN PROCESS

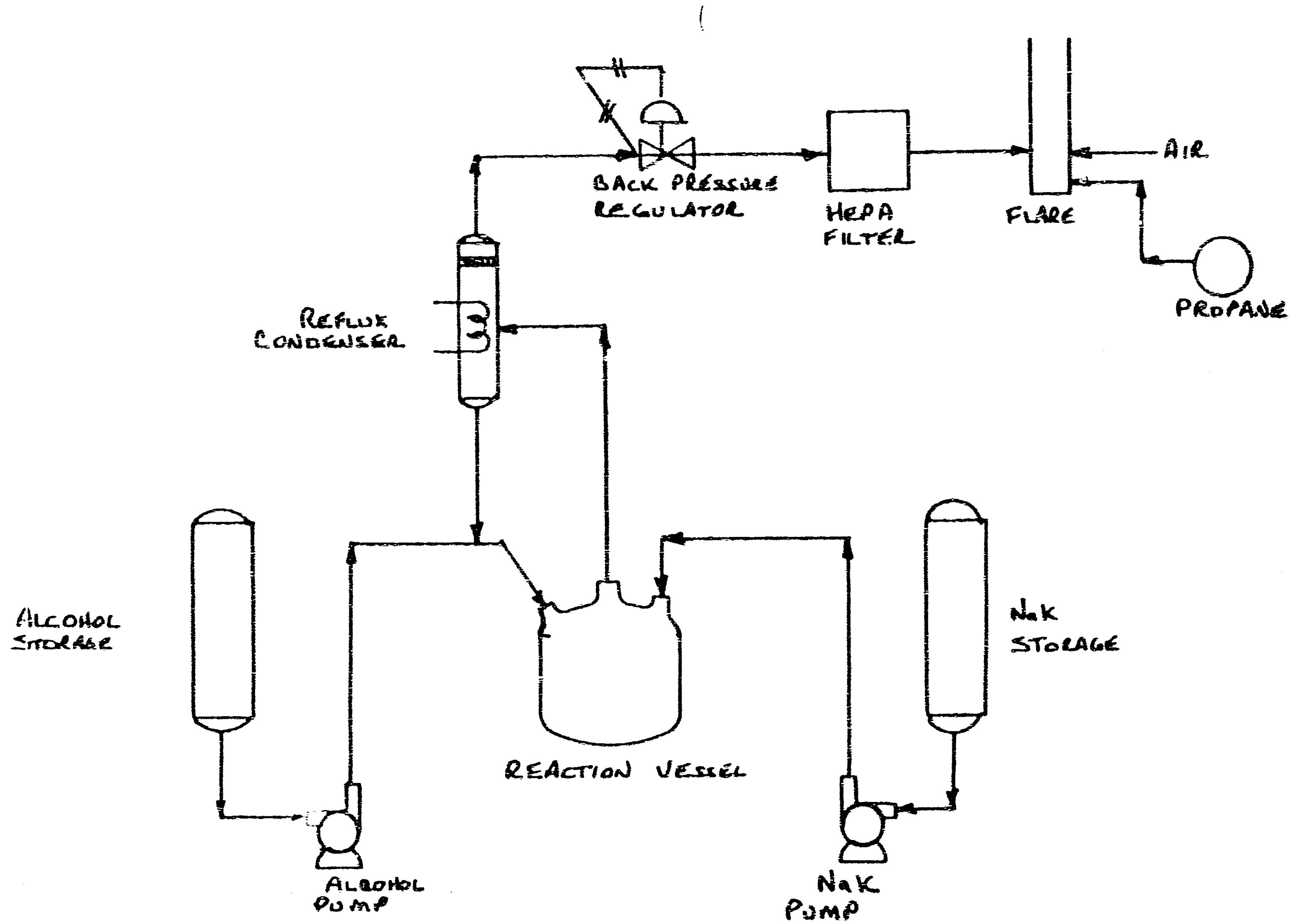


FIGURE 4 ALCOHOL PROCESS

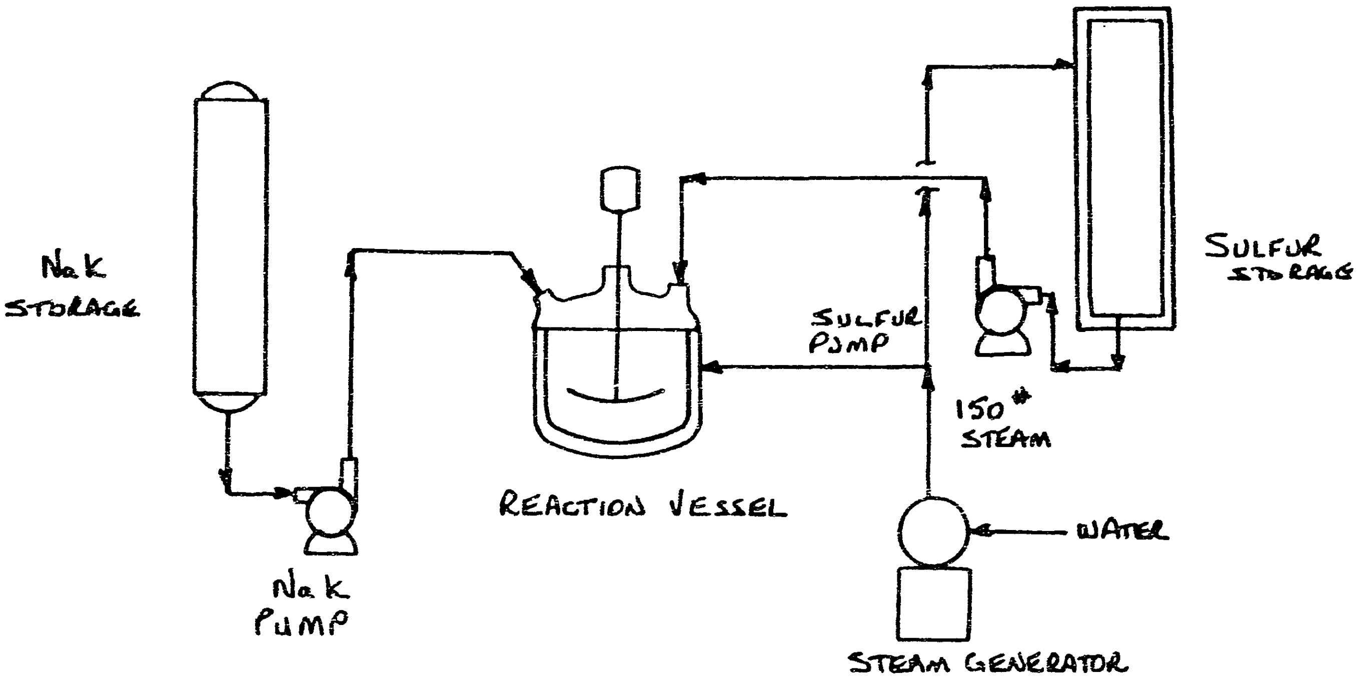


FIGURE 5 SULFUR PROCESS

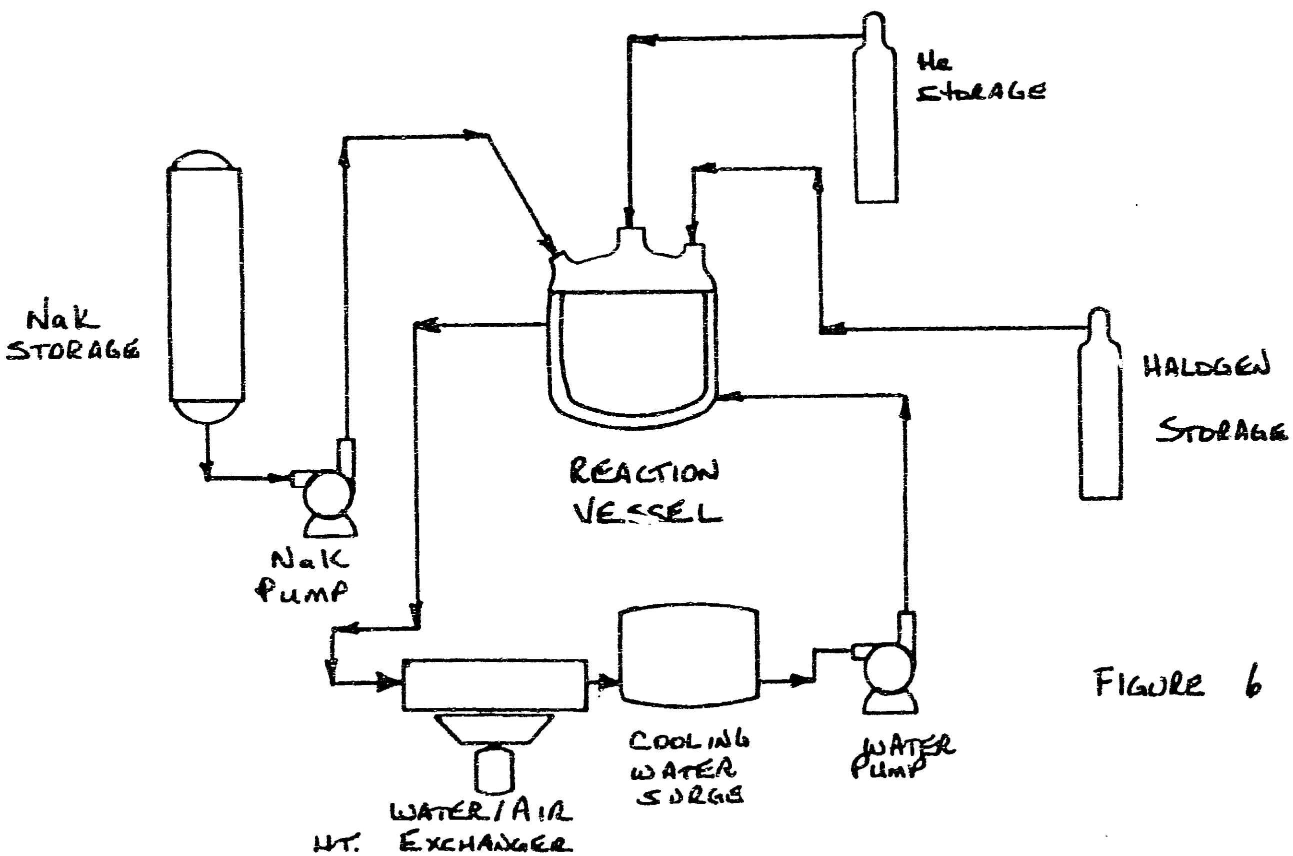


FIGURE 6 HALOGEN PROCESS

processing scheme is less complex than some systems considered, but the piping and Sulfur storage systems would require that these systems be wasted to prevent a substantial waste volume from being generated if they were to be cleaned.

4.5 Reaction with Acids

Since there is no distinct advantage of operating with acid over the Steam/Nitrogen process, and since the equipment costs for acid handling would require higher overall costs, this process will not be considered to be a viable option.

4.6 Reaction with Halogens

This process is illustrated in Figure 6.

There are distinct advantages of using Chlorine over the case where Fluorine is the considered reactant. These advantages are:

- Materials of construction costs
- The lower chemical reactivity of Chlorine compared to Fluorine
- Package chlorinators are available at a reasonable cost which would mean a lower design and construction cost.

For these reasons, Chlorine will be considered a better option than Fluorine, and will be compared to the other process options in the following discussion.

4.6.1 Safety

Although chlorine is a very reactive and a strong pulmonary irritant, it is used routinely and safely due to its industrial and public health importance.

Chlorine is extremely irratating to the mucous membrane of the eyes at 3ppm and the respiratory tract. It combines with moisture to liberate nascent oxygen and form hydrochloric acid. Both these substances, if present in quantity, cause inflammation of the tissues with which they come in contact. If the lung tissues are attacked, pulmonary edema may result. A concentration of 3.5 ppm produces a detectable odor; 15 ppm causes immediate irratation of the throat.

Concentrations of 50 ppm are dangerous for even short exposures. 1000 ppm may be fatal. even when the exposure is brief. Because of its intensely irritating properties. severe industrial exposure seldom occurs. as the workman is forced to leave exposure area before he can be seriously affected. In cases where this is impossible, the initial irritation of the eyes and mucous membrane of the nose and throat is followed by cough, a feeling of suffocation, and later, pain and a feeling of constriction in the chest. If exposure has been severe, pulmonary edema may follow, with rales being heard over the chest. It is a common air contaminant. (See Reference 9)

Fire hazard: Chlorine can react to cause fires or explosions upon contact with many substances which are combustible with air if the proper concentrations of reactants are present.

The reaction between NaK and chlorine gas has a similar exotherm and free energy of formation as the reaction between NaK and oxygen. The mechanisms for the reaction of oxygen and the reaction of chlorine with NaK are undoubtably different, but it is still highly probable that a controlled reaction scheme can be demonstrated. and therefore this reaction should offer no greater safety hazard then the combusting of NaK or reacting NaK with steam. Indeed, since no Hydrogen is released in this reaction scheme. the overall explosion hazard of this process should be less than the Steam/Nitrogen process.

4.6.2 Cost (Operational and Equipment)

The equipment costs for this system should be lower than the other viable process options. Since there is no off-gas, there is no need for gas heating, gas moving, or gas filtration equipment.

The major capital equipment items will be the NaK storage and metering system, the reactor/final containment, and the Chlorine gas metering equipment. Chlorine storage can be provided from rental bottles.

The operational costs should be as low as or lower than the other options since no process heating is required. Manpower costs would probably be comparable to the other options.

4.6.3 Final Waste Form Stability

The salts generated by this process, NaCl and KCl, are very stable and common compounds; and, in a dry environment, of no significant corrosion problem.

4.6.4 Final Waste Form Volume

The process will generate the smallest quantity of waste of the considered process options. The salt generated will be approximately 70 % of the original NaK volume. The reactor vessel will serve as the final containment for the waste. The only equipment to be disposed of, other than the reactor, is the NaK storage, pump, feed system, and the present NaK containers.

4.6.5 Potential of Environmental Impact

There is no significant probability of environmental impact with any of the processes considered if proper control and monitoring systems are employed. Since no gaseous products are released from this reaction scheme, the probability of adverse environmental impact with this process can be assumed lower than those processes which produce a gaseous byproduct.

4.6.6 Other Considerations

Since this process has not been used in this manner before, there is a slightly greater risk in the successful operation than that compared with the steam/nitrogen process. To overcome this risk differential, some laboratory work will be required to bring the reactor design confidence level to that of the other process options. The cost of this laboratory work, over and above the laboratory work associated with the other processes, should be less than $ 200 K. This expense would be more than offset in equipment cost savings alone.

5. Evaluation of Processes and Selection

In the evaluation of the processes, certain project objectives were considered of prime importance. These objectives, in their decreasing importance are:

1) The ability to safely process the NaK with a minimal chance of exposure of manpower to chemical or radioactive hazard

2) Potential of adversely impacting the environment during the processing

3) Confidence in the process's ability to react with all the NaK to remove all chemical hazard, i.e., to prevent the inclusion of unreacted NaK in the solid and liquid products formed

4) Final waste form stability

5) Final waste form volume

6) Overall cost of system and processing

Although this ranking is somewhat subjective, sensitivity analysis of the results indicates that reordering of the above objectives does not significantly impact the process selected.

In addition to these prime objectives, other process characteristics were rated to select the process. These characteristics, in the decreasing order of their importance, are:

1) The ability to field operate the system

2) The overall process simplicity

3) The service requirements (water, power, etc.)

4) Rate of processing the NaK

Finally, the potential downside characteristics of the processes were rated. These characteristics, in the decreasing order of their potential adverse impacts on meeting the project objectives, are:

1) Impact if there were a catastrophic equipment failure

2) Ability to further treat the process products if this were to be required at a future date due to changes in disposal requirements

3) Uncertainties in construction and operation

4) Uncertainties in design

5.1 Results of Evaluation

The results of the individual process evaluations are presented in Tables 3-1 through 3-6.

5.2 Process Ranking and Selection

Table 4 presents the summary from the individual evaluations. From this table, it can be seen that the processing of the NaK with Chlorine has significant advantages over the other processes investigated.

The major competitors with this process are the Sulfur process and the Steam/Nitrogen process.

In making this assessment, since the Chlorine system is untried, the scoring was performed with some concern about the Chlorine systems performance. It is this reviewer's belief, that these concerns can be dissipated with proper laboratory testing, and if the evaluation was again performed after this laboratory work, the Chlorine process would be ranked substantially higher than the other process options.

6. Conclusions

The processing of the NaK with Chlorine clearly offers substantial advantages over the other processing options investigated. Among these advantages are: cost; safety; simplicity; and final waste form volume.

Due to the untried nature of this process, some laboratory testing is requisite. This testing will not adversely impact schedule or cost of the project. The final cost of completing the project, including the indicated laboratory work, should still be lower than the other processing options investigated.

The laboratory effort will be primarily aimed at quantifying the following engineering data needs:

1) Reaction rates as a function of concentrations to define safe reaction parameters

2) Required NaK droplet size to prevent inclusion of unreacted NaK in the salts formed

3) Overall reaction heat-transfer rates to allow for reactor design.

PROCESS STEAM/NITROGEN — PROCESS SCORING SHEET — TABLE 3-1

CHARACTERISTIC	WT.	SCORE	TOTAL VALUE	COMMENTS
SAFETY	9	6	54	There has been one major incidence of explosion. Requires more handling
COST	4	3	12	Higher Costs for equipment and Instrumentation
FINAL WASTE FORM STABILITY	6	8	48	STABLE AFTER Neutralization
FINAL WASTE FORM VOLUME	5	2	10	Produces largest quantity of WASTES
ENVIRONMENTAL CONCERNS (PROBABILITY of NON-IMPACT)	8	9	72	
Confidence in Successfully Processing NaK	7	10	70	Has been operated successfully at INEL and Elsewhere
SERVICE REQUIREMENTS	1.0	7	7	
FIELD OPERATION	2.0	5	1	
RATE OF PROCESSING	0.5	8	4	
SIMPLICITY	1.5	4	6	MOST Complex of process options
Uncertainties in DESIGN	-0.5	2	-1	
IMPACT if CATASTROPHIC EQUIP. FAILURE	-2.0	8	-16	Potential of explosion
Ability to Further Treat WASTE Form if Necess.	-1.5	4	-6	WAste form would contain a lot of water
Uncertainties in CONSTRUCTION & OPERATION	-1.0	1	-1	

TOTAL SCORE 260

PROCESS Oxygen

PROCESS SCORING SHEET

TABLE 3-2

CHARACTERISTIC	WT.	SCORE	TOTAL VALUE	COMMENTS
SAFETY	9	0	0	Produces KO_2 - Potential for uncontrolled Reaction
COST	4	5	20	
FINAL WASTE FORM STABILITY	6	0	0	KO_2 would be unacceptable in Waste
FINAL WASTE FORM VOLUME	5	5	25	
ENVIRONMENTAL CONCERNS (PROBABILITY of NON-IMPACT)	8	7	56	
Confidence in Successfully Processing NaK	7	2	14	
SERVICE REQUIREMENTS	1.0	8	8	
FIELD OPERATION	2.0	8	16	
RATE OF PROCESSING	0.5	8	4	
SIMPLICITY	1.5	7	10.5	
Uncertainties in DESIGN	-0.5	3	-1.5	
IMPACT if CATASTROPHIC EQUIP. FAILURE	-2.0	2	-4	
Ability to Further Treat WASTE Form if NECESS.	-1.5	8	-12	
Uncertainties in CONSTRUCTION & OPERATION	-1.0	2	-2	

TOTAL SCORE 134

PROC. is Alcohol

PROCESS SCORING SHEET

TABLE 3-3

CHARACTERISTIC	WT.	SCORE	TOTAL VALUE	COMMENTS
SAFETY	9	2	18	May cause reaction with KO_2 and Alcohol
COST	4	5	20	
FINAL WASTE FORM STABILITY	6	6	36	
FINAL WASTE FORM VOLUME	5	3	15	
ENVIRONMENTAL CONCERNS (PROBABILITY of NON-IMPACT)	8	6	48	Some potential for explosion
Confidence in Successfully Processing NaK	7	3	21	
Service Requirements	1.0	7	7	
FIELD OPERATION	2.0	8	16	
RATE OF Processing	0.5	8	4	
SIMPLICITY	1.5	7	10.5	
Uncertainties in Design	-0.5	1	-0.5	
IMPACT if CATASTROPHIC EQUIP. FAILURE	-2.0	10	-20	High Fire danger
Ability to Further Treat Waste Form if Necess.	-1.5	2	-3	
Uncertainties in Construction & Operation	-1.0	8	-8	

TOTAL SCORE 164

PROCESS SULFUR

PROCESS SCORING SHEET

TABLE 3-4

CHARACTERISTIC	WT.	SCORE	TOTAL VALUE	COMMENTS
SAFETY	9	7	63	Some concern over Sulfur handling
COST	4	6	24	
FINAL WASTE FORM STABILITY	6	8	48	
FINAL WASTE FORM VOLUME	5	8	40	
ENVIRONMENTAL CONCERNS (PROBABILITY of NON-IMPACT)	8	7	56	
Confidence in Successfully Processing NaK	7	8	56	
SERVICE REQUIREMENTS	1.0	4	4	
FIELD OPERATION	2.0	6	12	
RATE OF PROCESSING	0.5	8	4	
SIMPLICITY	1.5	6	9	
Uncertainties in DESIGN	-0.5	8	-4	
IMPACT if CATASTROPHIC EQUIP. FAILURE	-2.0	7	-14	
Ability to Further Treat WASTE Form if Necess.	-1.5	8	-12	SULFUR WOULD BE PRESENT IN SOLID FORM
Uncertainties in CONSTRUCTION & OPERATION	-1.0	7	-7	

TOTAL SCORE 279

PRO[illegible]SS Acids

PROCESS SCORING SHEET

TABLE 3-5

CHARACTERISTIC	WT.	SCORE	TOTAL VALUE	COMMENTS
SAFETY	9	4	36	Concentration of hydrogen would be high.
COST	4	3	12	
FINAL WASTE FORM STABILITY	6	8	48	
FINAL WASTE FORM VOLUME	5	4	20	
ENVIRONMENTAL CONCERNS (PROBABILITY of NON-IMPACT)	8	6	48	
Confidence in SUCCESSFULLY PROCESSING NaK	7	9	63	
SERVICE REQUIREMENTS	1.0	8	8	
FIELD OPERATION	2.0	8	16	
RATE OF PROCESSING	0.5	8	4	
SIMPLICITY	1.5	8	12	
Uncertainties in DESIGN	-0.5	6	-3	Materials
IMPACT if CATASTROPHIC EQUIP. FAILURE	-2.0	6	-12	
Ability to Further Treat WASTE Form if NECES.	-1.5	8	-12	
Uncertainties in CONSTRUCTION & OPERATION	-1.0	5	-5	

TOTAL SCORE 235

PROCESS CHLORINE   PROCESS SCORING SHEET   TABLE 3-6

CHARACTERISTIC	WT.	SCORE	TOTAL VALUE	COMMENTS
SAFETY	9	8	72	
COST	4	9	36	Should be least costly of systems
FINAL WASTE FORM STABILITY	6	8	48	
FINAL WASTE FORM VOLUME	5	9	45	LEAST WASTE of All options
ENVIRONMENTAL CONCERNS (PROBABILITY of NON-IMPACT)	8	9	72	
Confidence in Successfully Processing NaK	7	7	49	WILL REQUIRE LAB WORK to INCREASE confidence level
SERVICE REQUIREMENTS	1.0	9	9	
FIELD OPERATION	2.0	8	16	
RATE OF PROCESSING	0.5	8	4	
SIMPLICITY	1.5	8	12	
UNCERTAINTIES IN DESIGN	-.5	8	-4	WILL REQUIRE MORE LAB TIME to remove uncertainties
IMPACT if CATASTROPHIC EQUIP. FAILURE	-2.0	7	-14	Some potential for fire
Ability to Further Treat Waste Form if Necess.	-1.5	2	-3	
UNCERTAINTIES IN CONSTRUCTION & OPERATION	-1.0	8	-8	New process concept

TOTAL SCORE 334

TABLE 4 PROCESS SCORING SUMMARY

	STEAM/ N_2	OXYGEN	Alcohol	SULFUR	ACIDS	CHLORINE
SAFETY	54	0	18	63	36	72
COST	12	20	20	24	12	36
FINAL WASTE FORM STABILITY	48	0	36	48	48	48
FINAL WASTE FORM VOLUME	10	25	15	40	20	45
ENVIRONMENTAL CONCERNS (PROBABILITY OF NON-IMPACT)	72	56	48	56	48	72
CONFIDENCE IN SUCCESSFULLY PROCESSING NaK	70	14	21	56	63	49*
SERVICE REQUIREMENTS	7	8	7	4	8	9
FIELD OPERATION	1	16	16	12	16	16
RATE OF PROCESSING	4	4	4	4	4	4
SIMPLICITY	6	10.5	10.5	9	12	12
UNCERTAINTIES IN DESIGN	-1	-1.5	-0.5	-4	-3	-4
IMPACT IF CATASTROPHIC EQUIP. FAILURE	-16	-4	-20	-14	-12	-14
ABILITY TO FURTHER TREAT WASTE FORM, IF NEC.	-6	-12	-3	-12	-12	-3
UNCERTAINTIES IN CONSTRUCTION & OPERATION	-1	-2	-8	-7	-5	-8
TOTAL	260	134	164	279	235	334
RANKING	3	6	5	2	4	1

* SEE SECTION 4.6.6 (Ranking will be considerably higher after laboratory work)

REFERENCES:

1) EDF 2701 (3KKBJ00E1) EBR-I Mark-II NaK/Bunker Inspection R.D. Turner, 9-11-79.

2) Planning Document for Removal of NaK Drums from EBR-I Storage Pit to ARVFS Bunker (Actual title unknown, document was photocopied without copying title page).

3) Decontamination and Decommissioning of the EBR-I Complex Final Report, July 1975, ANCR-1242, UC-70.

4) S1G Reactor Vessel Decommissioning Project-Final Report. EG&G Internal Technical Report, PG-WM-83-031, Sept. 1983.

5) Disposal of Radioactive Sodium Waste, McPheeters, C.C., Wolson, R.D., (Argonne National Lab, IL) Sept. 1978, ANL-78-87.

6) Telecon with Jack Bicehouse, Mine Safety Appliances, Advanced Systems Division, Evans City, PA, Dec. 19,1985.

7) An Explosion Hazards Analysis and Evaluation of the Eutectic Soultion of Sodium and Potassium (NaK) and Potassium Superoxide (KO_2) - WIS-6-74, Cook Associates, Inc., Feb 1974, Subcontract to Aerojet Nuclear Company, S-1306.

8) Sodium-NaK Engineering Handbook, Volume 1, Sodium Chemistry and Physical Properties. O. J. Foust, editor. Gordon and Breech Science Publishers, Inc., NY, NY, 1972,

9) Dangerous Properties of Industrial Materials, Sixth Edition N. Irving Sax, Van Nostrand Reinhold Company, NY, NY, 1984.

APPENDIX E
NaK PROCESSING SITE K-T ANALYSIS

EG&G Idaho, Inc.

FORM EG&G-2631 (Rev. 4-78)

ENGINEERING DESIGN FILE

PROJECT FILE NO. 15094

EDF SERIAL NO. NaK-008

FUNCTIONAL FILE NO.

PROJECT/TASK NaK PROCESSING SITE K-T ANALYSIS

DATE 9·10·86

SUBTASK

EDF PAGE NO A OF 15

SUBJECT

NaK PROCESSING SITE K-T ANALYSIS

ABSTRACT

NINE POTENTIAL PROCESSING SITES FOR THE EBR I MARK II NaK ARE EVALUATED USING K-T ANALYSIS TECHNIQUES. THE ARVFS SITE HAS THE HIGHEST SCORE BY APPROXIMATELY 15%.

CONTENTS:

DISTRIBUTION (COMPLETE PACKAGE): D.L. CRANDALL, M.R. DOLENC, D.M. LARUE, R.H. MESERVEY, R.C. GREEN, R.J. Beers

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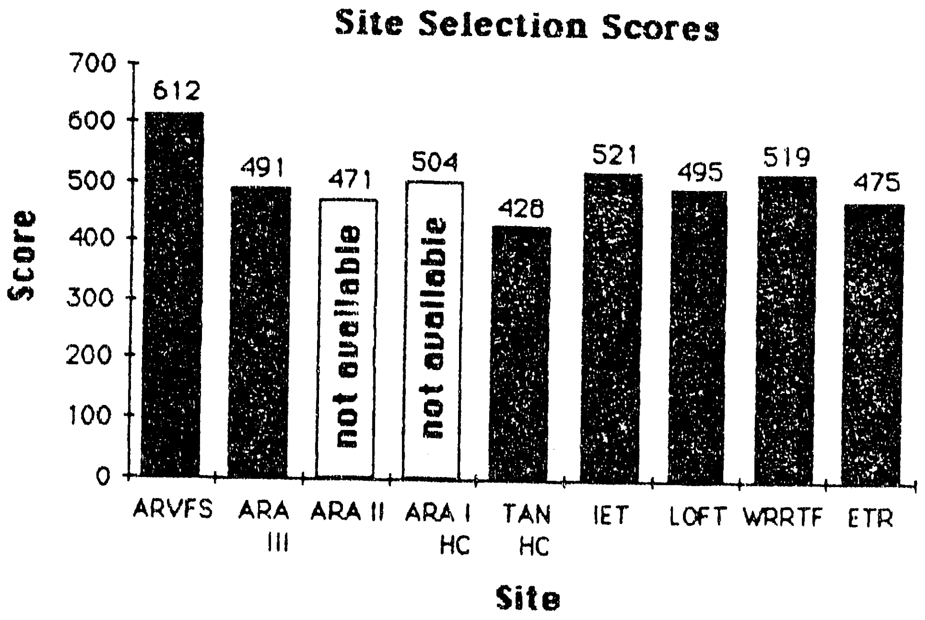
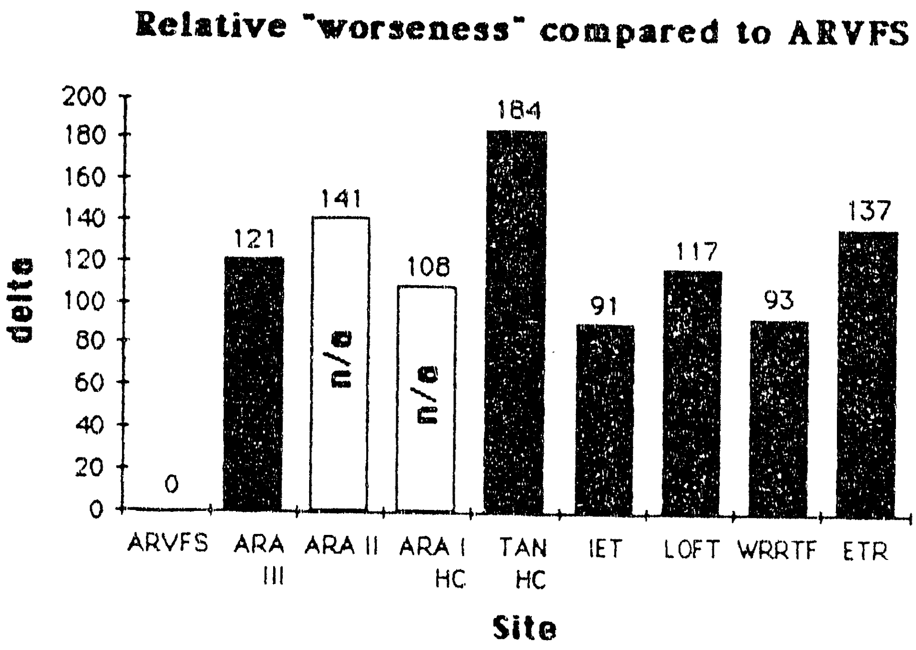
ZABRISKIE	E320	David L Crandall	9-11-86	Max R. Dolenc	9-11-86



The graph above shows the scores each potential NaK processing site received. The ARVFS site shows a clear lead of approximately 15% over the next best site, the IET.

The graph below shows the point spread each potential site has with ARVFS. In this case, the lower the score, the better.



EDF NaK-008

SITE AND SELECTION CRITERIA FOR EBR I MARK II NaK PROCESSING

SELECTION CRITERIA	SITE weight	ARVFS		ARA III		ARA II		ARA I HC		TAN HC		IET		LOFT		WRRTF		ETR	
Currently available ?	must	yes	OK	yes	OK	no contaminated	OUT	no early	OUT 1/87	no thru	OUT 8/87	yes	OK	yes OK by	OK 10/86	yes	OK	yes	OK
Non-op personnel safety @ site	10	10	100	6	60	8	80	6	60	3	30	10	100	6	60	10	100	4	40
Personnel safety @ other sites	10	9	90	6	60	5	50	5	50	8	80	8	80	8	80	7	70	5	50
General public safety	10	9	90	6	60	5	50	4	40	6	60	5	50	7	70	4	40	8	80
Environmental impact (accident)	9	2	18	7	63	5	45	8	72	8	72	5	45	7	63	6	54	7	63
Accident impact to current site ops.	7	10	70	4	28	10	70	8	56	2	14	10	70	9	63	10	70	6	42
Transport impact from ARVFS to site	7	10	70	4	28	4	28	4	28	1	7	1	7	1	7	1	7	5	35
Site mods to handle processing	6	2	12	8	48	2	12	8	48	8	48	3	18	7	42	6	36	6	36
Ease of accident cleanup	6	9	54	8	48	5	30	10	60	10	60	8	48	8	48	8	48	8	48
Impact to proposed future operations	4	10	40	5	20	8	32	5	20	2	8	7	28	4	16	6	24	5	20
Site procedural compliance	3	10	40	9	36	9	36	8	32	3	12	10	40	2	8	8	32	4	16
Unauthorized access security	3	6	18	8	24	8	24	8	24	7	21	7	21	8	24	8	24	9	27
Machinery, personnel and equip access	2	5	10	8	16	7	14	7	14	8	16	7	14	7	14	7	14	9	18
	TOTAL SCORE		612		491		471		504		428		521		495		519		475

Discussion

Forward:

The following sections contain explanations of the selection criteria used in table of the EBR I Mark II NaK processing site selection analysis. The purpose is to discuss what was considered an important factor and how the relative risk value was to be assessed when evaluating the potential sites. Each selection criteria was assigned a weight from 1 - 10 to indicate its relative importance. Relative risks at each of the sites under consideration were also assigned a value of 1 - 10, 1 being a very high risk and 10 being a very low risk.

Selection Criteria

Currently available ? - This means that if the go ahead is given tomorrow, could people and equipment start moving in and setting up? This is considered a "must" requirement. If the candidate site is not available it is eliminated from contention.

Non-operations personnel safety - This category addresses the potential risk to other personnel at the site that are not involved with the NaK processing operation. These would be people working on another project, program or experiment. Considered here is the proximity to the processing area, personnel protection available, prevailing winds and ease of evacuation. Since safety aspects are considered the highest priority, their relative importance dictates a weight of 10. [Note that operation personnel safety is ignored for this evaluation, since it would more appropriately be a design consideration for the actual NaK processing system.]

Personnel safety at other sites - This criteria is concerned with the potential risk to other personnel at other locations around the INEL. Also considered here is the proximity to the processing site, personnel protection available, prevailing winds and ease of evacuability. Its safety aspects also give it a relative weight of 10.

General public safety - The potential hazard to the public is addressed here. Proximity to unrestricted highways, traffic density, distance to population centers and prevailing winds are considered. Again, since safety is involved, the relative weight factor is 10.

Discussion

Environmental impact (accident) - If there were some sort of accident, how would it affect the environment at and around the processing site. Impacts common to all the proposed sites would be factored out of consideration. However, potential releases to the air, soil, flora and fawna are considered. Environmental considerations rate very highly and are given a relative weight of 9.

Accident impact to current site operations - What risk is faced by existing operations at the candidate site that would be impacted by some sort of accident at the NaK processing area. The relative risk to, potential disruption of and possible termination of such operations are the factors considered for evaluation. This has a relative importance less than that of safety or environmental aspects and is given a relative weight of 7.

Transportation impact from ARVFS to site - Addressed here are the concerns of a potential problems with the super oxide - NaK reaction while on the highway, the quality of the road surface, whether or not the highway is open to the public, and the extent of the transportation plan. This is considered to be quite an important consideration and is also given a relative weight of 7.

Site modifications required to handle processing - All the modifications to the proposed site to take it from its current status to being able to connect to the NaK processing system are considered. Of course, some sites will have more existing support services and facilities. These would then need less auxiliary equipment brought in. Support services considered are main and backup electrical power, service and potable water supplies, chemical handling / waste disposal facilities, and operations support space - control rooms, office space, lunchroom, and restrooms. This is fairly important and is assigned a relative weight of 6.

Ease of accident cleanup - Although related to the environmental considerations, the ease of candidate site cleanup after potential accidents (a chlorine gas release, potassium superoxide explosion or NaK fire) is considered separately. Since the environmental aspects have already been considered, its relative importance is much less yielding a rating factor of 6.

Discussion

Impact to proposed future operations - Included aspects for consideration are future operations at the candidate site running concurrently with the NaK processing, future operations subsequent to the end of NaK processing, and potential impact to future operations as a result of an accident. The relative importance is much less than other considerations, giving it a weight of 4.

Site procedural compliance - What is meant here, is the cost of reworking the NaK processing documentation to reflect compliance with the procedures and standard practices in effect that control operations at the candidate site. This does not have a very severe impact on the site selection process, other than the cost of implementation. Its relative weight then, is a 3.

Unauthorized access security - How secure is this proposed site? Are security personnel already on site? Is access to the site controlled to an extent that minimizes the chance of unauthorized personnel gaining entry? Although an important consideration, security is considered a relatively minor aspect relating to site selection. The weight of 3 reflects the low risk factor and small resource drain required to achieve "adequate security."

Machinery, personnel and equipment access - This area is concerned with how easy it is to get resources into and on the candidate sites. Transportation links, proximity to equipment pools and road quality aspects are factored into the evaluation. A weight of 2 has been assigned in accordance with its relatively minor importance.

Candidate Site Evaluation:

ARVFS - score: 612

Currently available? (yes) - The waste is stored here and nothing else is going on.

Non-op personnel safety @ site (10 pts) - ARVFS scores really well in this area since no one else other than operations personnel and a security guard or two would be at the site.

Discussion

Personnel safety @ other sites (9 pts) - Since ARVFS is near the center if the INEL, it offers the greatest distance from all the other locations at the INEL. Although the ARVFS site is the remotest, the prevailing winds could carry particulates from a release to sites at TAN. Due to the distance, any release would be greatly diluted.

General public safety (9 pts) - Since the ARVFS site is so remote (near the center of the INEL) and not near population centers or public highways, it scores very well. The potential risk of a release making it to the Mud Lake / Terreton area is very small, even with the prevailing winds generally toward that direction.

Environmental impact (accident) (2 pts) - If there were some sort of accident, the impact would be moderately severe due to the open exposure at the ARVFS. The lack of a containment building would aid in dispersion of release products.

Accident impact to current site ops. (10 pts) - The full score here is due to not having anything else going on here at this site.

Transport impact from ARVFS to site (10 pts) - There is absolutely no impact at all.

Site mods to handle processing (2 pts) - ARVFS scores the worst here since this site has no facilities at all. From personnel trailers to electrical power, everything must be brought in. This is deemed to have the greatest impact. However, soil berming to aid in exposure and dispersion control would be very easy to implement.

Ease of accident cleanup (9 pts) - The very high score is due to being able to cleanup any post accident effects with a earthmover. There are no facilities or buildings to D & D.

Impact to proposed future operations (10 pts) - No future operations for this site have been proposed.

Site procedural compliance (10 pts) - There are no procedures in effect at the ARVFS site, therefore none of the operations documents would have to be rewritten.

Discussion

Unauthorized access security (6 pts) - Credit is taken for relative remoteness and distance from a public highway. The lack of a security fence and need for security personnel to control access at the road is a debit.

Machinery, personnel and equip access (5 pts) - The distance from craft and equipment pools counts against the ARVFS site. This is offset however, by the equidistant location between CFA and TAN. The unpaved road leading to the site is a debit also.

ARA III - score: 491

Currently available? (yes) - There is space available for the processing system.

Non-op personnel safety @ site (6 pts) - ARA III does not score quite as well due to the presence of other personnel running experiments.

Personnel safety @ other sites (6 pts) - Although the prevailing winds would not carry particulates to other sites, ARA III is relatively close to PBF and the other ARA sites, I & II.

General public safety (6 pts) - The potential risk of a release making it to the Mud Lake / Terreton area is fairly good, since the prevailing winds are directly toward that area. However, any release would be relatively diluted due to the distance. The risk to the public is moderately high along Route 20, a relatively popular route across the desert.

Environmental impact (accident) (7 pts) - If there were some sort of accident, the impact would not be too severe due to having a containment building. This would tend to control dispersion of release products.

Accident impact to current site ops. (4 pts) - Since there is other ongoing work at ARA III, this would be impacted by an accident. It would most probably not be a severe impact due to the "cell-like" separations of the other experiments.

Transport impact from ARVFS to site (4 pts) - There is a moderately severe impact due to the distance traveled and the present poor quality of the road increasing the probability of the super oxide problem.

Discussion

Site mods to handle processing (8 pts) - ARA III scores well here due to good facilities needing minimum modifications to handle processing. The chem lab has been stripped however, and would need refurbishment. They do not normally handle radioactive waste.

Ease of accident cleanup (8 pts) - The fairly high score is due to the relative ease of cleaning the proposed area (built to reactor specs) and the confined aspect of an accident in that area.

Impact to proposed future operations (5 pts) - Some future operations for this site have been proposed. However, none of them are large or critical programs.

Site procedural compliance (9 pts) - There are only a few procedures in effect at ARA III. These are SP's and would not impact operational procedures much.

Unauthorized access security (8 pts) - ARA III is quite secure, having a locked (only at night) perimeter fence and being somewhat remote from general access. There is no guard, however.

Machinery, personnel and equip access (8 pts) - ARA III is relatively close to CFA and the roads are paved.

ARA II - score: 471

Currently available? (no) - The site is contaminated and would need to be cleaned up prior to use.

Non-op personnel safety @ site (10 pts) - ARA II is presently empty.

Personnel safety @ other sites (5 pts) - ARA II is closely situated between ARA I & III. The prevailing winds would carry release products to ARA III.

General public safety (5 pts) - The potential risk of a release making it to the Mud Lake / Terreton area is fairly good, since the prevailing winds are directly toward that area. However, any release would be relatively diluted due to the distance. The risk to the public is proportionately higher (than ARA III) along Route 20 due to the closer proximity of the site to the highway.

Discussion

Environmental impact (accident) (5 pts) - If there were some sort of accident, the impact would be moderate due to having a some containment area. This would tend to control dispersion of release products.

Accident impact to current site ops. (10 pts) - Since nothing is going on at present, there would be no impact.

Transport impact from ARVFS to site (4 pts) - There is a moderately severe impact due to the distance traveled and the present poor quality of the road increasing the probability of the super oxide problem.

Site mods to handle processing (2 pts) - ARA II needs to have a major amount of work done to refurbish some of the facilities and services required for processing.

Ease of accident cleanup (5 pts) - The moderate score is due to the somewhat difficult nature of cleaning the proposed area, since prior work after the SL-1 accident placed an earth cover over contaminated soils.

Impact to proposed future operations (8 pts) - Not many future operations for this site have been proposed.

Site procedural compliance (9 pts) - There are only a few procedures in effect at ARA II. These are SP's and would not impact operational procedures much.

Unauthorized access security (8 pts) - ARA II is quite secure, having a locked perimeter fence and being somewhat remote from general access. There is no guard, however.

Machinery, personnel and equip access (7 pts) - ARA II is relatively close to CFA and the roads are paved. It is a bit further down the road than ARA III.

Discussion

ARA I Hot Cell - score: 504

Currently available? (no) - The hot cell is booked thru January of 1987.

Non-op personnel safety @ site (6 pts) - The ARA I hot cell does not score well due to the other operations and experiments going on there, particularly th low level lab.

Personnel safety @ other sites (5 pts) - Although the prevailing winds would not carry particulates to other sites, ARA I is relatively close to PBF and the other ARA sites, II & III. The prevailing winds would carry airborne matter to the other ARA sites.

General public safety (4 pts) - The potential risk of a release making it to the Mud Lake / Terreton area is fairly good, since the prevailing winds are directly toward that area. However, any release would be relatively diluted due to the distance. The risk to the public is very high along Route 20, since ARA I is visible from the highway.

Environmental impact (accident) (8 pts) - If there were some sort of accident, the impact would not be severe due to the radioactive containment nature of the hot cell confine.

Accident impact to current site ops. (8 pts) - Although there is other ongoing work at ARA I, the nature of the hot cell containment would limit accident effects on other operations.

Transport impact from ARVFS to site (4 pts) - There is a moderately severe impact due to the distance traveled and the present poor quality of the road increasing the probability of the super oxide problem.

Site mods to handle processing (8 pts) - ARA I scores well here due to good facilities needing minimum modifications to handle processing. They have limited water usage requirements for decontamination work.

Ease of accident cleanup (10 pts) - The hot cell area is relatively easy to decon and clean up.

Impact to proposed future operations (5 pts) - Future operations at this site are planned. Most are definite.

Discussion

Site procedural compliance (9 pts) - There are no limiting SP's at ARA I, however there are some for actual hot cell work that may need to be incorporated.

Unauthorized access security (8 pts) - ARA I is quite secure, having a locked perimeter fence and being somewhat remote from general access. There is no guard, however.

Machinery, personnel and equip access (7 pts) - ARA I is relatively close to CFA (but the farthest ARA site) and the roads are paved.

TAN Hot Cell - score: 428

Currently available? (no) - The facility is currently booked through August of 1987.

Non-op personnel safety @ site (3 pts) - The TAN hot cell scores relatively poorly due to the number of other operations going on at TAN.

Personnel safety @ other sites (8 pts) - Both LOFT and the WRRTF are fairly close to the TAN hot cell. The prevailing winds do not blow toward those sites. However the winds are in a direct line with the IET, although no personnel are currently working at that location.

General public safety (6 pts) - The potential risk to the public is fairly high due to the close proximity of State Highway 33. The prevailing winds blow away from the highway.

Environmental impact (accident) (8 pts) - If there were some sort of accident, the impact would be somewhat limited due to the nature of the hot cell confines.

Accident impact to current site ops. (2 pts) - Although contained in a hot cell environment, an accident might impact critical ongoing TMI work in other areas contiguous to the hot cell.

Transport impact from ARVFS to site (1 pt) - There is a severe impact due to the distance traveled along a public highway and the potential super oxide problem necessitating a full-blown transportation plan.

Discussion

Site mods to handle processing (8 pts) - The TAN hot cell would need minimum modifications to handle processing.

Ease of accident cleanup (10 pts) - The high score is due to the ease of cleaning the hot cell.

Impact to proposed future operations (2 pts) - Definite plans for future use of the TAN hot cell would be impacted by this project and any accident during its lifetime.

Site procedural compliance (3 pts) - There are many procedures in effect at the TAN hot cell. These would definitely need to be incorporated into the operations documents.

Unauthorized access security (7 pts) - Although the TAN area is perimeter fenced and has a manned guard station, access to the hot cell area is not restricted.

Machinery, personnel and equip access (8 pts) - The roads at TAN are paved and TAN has a craft and equipment pool.

IET - score: 521

Currently available? (yes) - The IET has been freshly D & D'ed.

Non-op personnel safety @ site (10 pts) - The IET gets full points since no one other operations are going on at the site.

Personnel safety @ other sites (8 pts) - Although the prevailing winds would not carry particulates to other sites, the IET is located somewhat close to TAN and the WRRTF.

General public safety (5 pts) - The IET is fairly close to State Highway 33, although the prevailing winds blow from the road toward the IET.

Environmental impact (accident) (5 pts) - If there were some sort of accident, the impact would be somewhat severe. However, the existing structure would tend to limit dispersion of release products.

Accident impact to current site ops. (10 pts) - No other operations are at the IET.

Discussion

Transport impact from ARVFS to site (1 pt) - The severe impact is due to the distance traveled along a public highway and the potential super oxide problem necessitating a full-blown transportation plan.

Site mods to handle processing (3 pts) - The IET hasn't got much in the way of facilities and services. Fairly extensive modifications are required to handle processing.

Ease of accident cleanup (8 pts) - The fairly high score is due to the relative ease of cleaning the proposed area and the fact that it has been freshly D & D'ed.

Impact to proposed future operations (7 pts) - A few future operations for this site have been proposed. However, nothing is definite yet.

Site procedural compliance (10 pts) - No procedures are in effect at the IET.

Unauthorized access security (7 pts) - The IET is moderately secure. Although not inside the TAN security area, it does have its own perimeter fence.

Machinery, personnel and equip access (7 pts) - The IET is fairly close to TAN.

LOFT - score: 495

Currently available? (yes) - The LOFT facility will be ready for another project by the first of October,1986.

Non-op personnel safety @ site (6 pts) - LOFT has some other D & D work ongoing as part of the post-test cleanup that will be finished in FY-86.

Personnel safety @ other sites (8 pts) - Although the prevailing winds would not carry particulates to other sites, LOFT is located fairly close to TAN.

General public safety (7 pts) - The LOFT facility is somewhat removed from State Highway 33.

Discussion

Environmental impact (accident) (7 pts) - If there were some sort of accident, the impact would not be severe due to the containment building.

Accident impact to current site ops. (9 pts) - Other than minor cleanup work, no other operations at LOFT would be impacted.

Transport impact from ARVFS to site (1 pt) - The severe impact is due to the distance traveled along a public highway and the potential super oxide problem necessitating a full-blown transportation plan.

Site mods to handle processing (7 pts) - LOFT has good facilities and services and would not need too much modification to handle processing.

Ease of accident cleanup (8 pts) - The fairly high score is due to the relative ease of cleaning the LOFT containment and the fact that it has been freshly D & D'ed.

Impact to proposed future operations (4 pts) - LOFT has been proposed as the site for several future operations, some of them quite major and having a high probability of realization.

Site procedural compliance (2 pts) - LOFT has an extensive set of procedures that would be necessary to incorporate into the operational documents.

Unauthorized access security (8 pts) - LOFT is inside the TAN security area.

Machinery, personnel and equip access (7 pts) - LOFT is fairly close to TAN and has a paved connecting road.

WRRTF - score: 519

Currently available? (yes) - Nothing is going on at the WRRTF; it is in stand-by mode.

Non-op personnel safety @ site (10 pts) - The WRRTF gets full points since no other operations are going on at the site.

Discussion

Personnel safety @ other sites (7 pts) - The WRRTF is located moderately close to TAN and with a small wind shift (a few degrees from prevailing), release products would be carried to TAN and the IET.

General public safety (4 pts) - The WRRTF is fairly close to state highway 33, and the prevailing winds blow toward the road.

Environmental impact (accident) (6 pts) - If there were some sort of accident, the impact would be somewhat severe. However, the existing structures would tend to limit dispersion of release products.

Accident impact to current site ops. (10 pts) - No other operations are at the WRRTF.

Transport impact from ARVFS to site (1 pt) - The severe impact is due to the distance traveled along a public highway and the potential super oxide problem necessitating a full-blown transportation plan.

Site mods to handle processing (6 pts) - The WRRTF has fairly good facilities and services. However, some modifications would be required to handle processing.

Ease of accident cleanup (8 pts) - The fairly high score is due to the relative ease of cleaning the proposed area.

Impact to proposed future operations (6 pts) - A few future operations for this site have been proposed. The potential impact would be on the extent of the modifications changing the suitability of the WRRTF for these proposed operations.

Site procedural compliance (8 pts) - Some procedures are in effect at the WRRTF, but these are SP's and not too difficult to incorporate.

Unauthorized access security (8 pts) - The WRRTF is quite secure. Although not inside the TAN security area, it does have its own perimeter fence with remote door/gate operation.

Machinery, personnel and equip access (7 pts) - The WRRTF is close to TAN and is connected by a paved road.

Discussion

ETR - score: 475

Currently available? (yes) - ETR has been shut down and is in an idle mode.

Non-op personnel safety @ site (4 pts) - The number of concurrent operations at TRA impact the safety of non-operations personnel near ETR.

Personnel safety @ other sites (5 pts) - TRA is somewhat removed from CPP, however the prevailing winds would carry any release to NRF.

General public safety (8 pts) - ETR is not close to any public highways,but the prevailing winds would carry any release toward State Highway 33, between TAN and Howe.

Environmental impact (accident) (7 pts) - If there were some sort of accident, the impact would not be severe due to the containment aspects of the reactor building.

Accident impact to current site ops. (6 pts) - Due to the number of operations underway at TRA an accident at ETR would possibly have a moderate impact.

Transport impact from ARVFS to site (5 pt) - The moderate impact is due to the distance traveled and the potential super oxide problem.

Site mods to handle processing (6 pts) - ETR has fairly complete facilities and services. Moderate modifications are required to handle processing due to the shut down nature of the area.

Ease of accident cleanup (8 pts) - The fairly high score is due to the relative ease of cleaning the proposed area and the fact that it has already been inactivated.

Impact to proposed future operations (5 pts) - Several future operations for this site have been proposed. It seems to be popular for reactor and rocket testing proposals.

Site procedural compliance (4 pts) - There are a few procedures in effect at TRA that would cover ETR and would require incorporation.

Discussion

Unauthorized access security (9 pts) - Since ETR is inside the TRA complex, it is quite secure. However, it does not have quite the extent of security that ATR has.

Machinery, personnel and equip access (9 pts) - ETR has excellent access to machinery, personnel and equipment due to its location within the TRA complex.

Conclusion:

As can be seen from the summary table and graphs of the results, the ARVFS site is approximately 15% better than the next best contenders (the IET and the WRRTF) in this K-T analysis. Therefore, the analysis leads to the conclusion (based on the previously discussed assumptions and considerations) that the ARVFS site is the best one at the INEL for processing the EBR I Mark II NaK.

END

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