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**DECONTAMINATION AND DECOMMISSIONING
OF THE EBR-1 COMPLEX
FINAL REPORT**

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MASTER

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**AEROJET NUCLEAR COMPANY
IDAHO FALLS, IDAHO**

Date Published - July 1975

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ABSTRACT

This final report covers the Decontamination and Decommissioning (D&D) of the Experimental Breeder Reactor No. 1 (EBR-I) Complex funded under Contract No. AT(10-1)-1375. The major effort consisted of removal and processing of 5500 gallons of sodium/potassium (NaK) coolant from the EBR-I reactor system. Tests were performed to assess the explosive hazards of NaK and KO_2 in various environments and in contact with various contaminants likely to be encountered in the removal and processing operations. A NaK process plant was designed and constructed and the operation was successfully completed. Lesser effort was required for D&D of the Zero Power Reactor (ZPR-III) Facility, the Argonne Fast Source Reactor (AFSR) Shielding, and removal of contaminated NaK from the storage pit. The D&D effort was completed by 13 June 1975, ahead of schedule.

SUMMARY

In 1966, the late President Johnson designated the Experimental Breeder Reactor No. 1 (EBR-I) a Registered National Historic Monument, and it was planned to transfer custody of the facility to the National Park Service (NPS). The purpose of the EBR-I Complex Decontamination and Decommissioning (D&D) Program was to make the EBR-I Complex safe for the public use and enjoyment as a National Historic Monument prior to the transfer. The EBR-I Complex located in the southwestern portion of the Idaho National Engineering Laboratory (INEL) consists of the Experimental Breeder Reactor Building (EBR-601), the Zero Power Reactor Building (RTP-601), the Argonne Fast Source Reactor (AFSR) Shielding, and the contaminated NaK (eutectic solution of sodium and potassium) Storage Pit.

The D&D Program scope of work included: extraction of 5500 gallons of NaK coolant contained in the EBR-I reactor primary and secondary coolant loops; conversion of the NaK to a solid caustic for drummed waste disposal in the INEL Radioactive Waste Management Complex (RWMC); decontamination of all NaK and/or radioactive contaminated portions of the complex; demolition and removal of portions which could not be decontaminated to safe levels; isolation of areas which could not be removed or decontaminated to safe levels; decontamination and removal of the ZPR-III reactor; demolition of the AFSR shielding; and removal of contaminated NaK in the NaK storage pit.

While much of the EBR-I Complex presented only minor D&D problems, those associated with the EBR-I facility were far from minor. The primary coolant system, approximately 4400 gallons of the total NaK inventory, was contaminated by residues from the 1955 EBR-I Mark II Core meltdown. Both primary and secondary coolant systems were assumed to contain alkali metal oxides due to the ingress of oxygen via molecular diffusion, oxygen contamination in the argon cover gas and air entering the reactor tank during fuel handling. Potassium superoxide and NaK were suspected of being capable of producing violent explosions under certain conditions. Additionally, the EBR-I facility contained many items which were radioactive from induced radiation or contaminated by fission product absorption which were extremely difficult to remove or decontaminate.

The EBR-I Complex D&D Program Plan was prepared in September 1973. The plan identified four subplans: EBR-I; ZPR-III; AFSR; and the contaminated NaK storage pit. Each subplan contained seven major areas of activity: Program Management; Technical Research and Development; Engineering; Safety Review; Energy Research and Development Administration (ERDA) Approvals; D&D Operations; and Transfer Operations. The program was initiated in October 1973 and all D&D effort was satisfactorily completed by 13 June 1975.

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I. INTRODUCTION

On 26 August 1966, the late President Lyndon B. Johnson participated, together with AEC Chairman Glenn T. Seaborg and other officials from government and industry, in ceremonies at the INEL to officially designate EBR-I as a Registered National Historic Monument (Figure 1).

EBR-I took into retirement a record of these notable firsts:

- Production of the first usable electricity from nuclear heat (in 1951).
- Demonstration of the feasibility of breeding (in 1953).
- Production, in July 1963, of usable electricity with plutonium as the major component in the fuel.
- Demonstration of the feasibility of using liquid metal (sodium-potassium) at high temperatures as a reactor coolant.

Plans were made to make the building, EBR-601, a part of the National Park System (NPS). Accordingly, the Decontamination and Decommissioning (D&D) Program was undertaken to make the EBR-I Complex safe for public use and enjoyment as a National Historic Monument prior to transfer of the building and grounds to the National Park Service.^[a] To accomplish this objective, it was necessary not only to convert the facility to a safe condition, but to maintain its physical appearance as an operational facility.

The program plan for accomplishing the D&D program dated September 1973 was prepared and is attached as Appendix A. All D&D work was completed satisfactorily, ahead of schedule, on 13 June 1975.

[a] In a subsequent agreement between ERDA and the NPS, it was decided that ERDA would continue to maintain and control the EBR-I facility as U. S. Government property and that the NPS would supervise the public use of the facility during the period from mid-June to mid-September on an eight hours per day, seven days per week basis.

the world's first electricity from nuclear energy," President Johnson told more than 15,000 persons who travelled 50 miles and farther to greet him at the NRTS. Later, he and AEC Chairman Seaborg attached the brass plaque which honors EBR-I for its technical feats.

Fig. 1 President Johnson Dedicating EBR-I.

II. DISCUSSION

The program scope consisted of decontamination and decommissioning of the EBR-I Complex (Figure 2), which includes the Experimental Breeder Reactor I Building EBR-601, the Zero Power Reactor III Building RTF-601, the Argonne Fast Source Reactor AFSR Shielding Structure and NaK storage pits, drums and miscellaneous equipment. The major effort consisted of extraction of approximately 5500 gallons of the 22% sodium-78% potassium eutectic alloy (NaK) coolant contained in the EBR-I reactor loops, conversion of the NaK to a solid caustic for drum disposal in the Idaho National Engineering Laboratory (INEL) Radioactive Waste Management Complex (RWMC), decontamination of all NaK and/or radioactive contaminated portions of the complex, and demolition and removal of certain parts of the complex that could not be decontaminated to acceptably safe levels. Secondary effort consisted of permanent isolation of portions of the complex that were radioactive or could not be decontaminated to acceptably safe levels, restoration of the EBR-I physical appearance, demolition of the AFSR shielding, removal of all nonradioactive debris to the INEL Central Facility Area (CFA) Sanitary Landfill, and performance of final surveillance and safety inspection to assure the safe condition of the entire EBR-I complex. In addition, modifications were made to reactivate support services necessary for the National Park Service, such as the water system, fire protection system, sanitary system, and heating and ventilation system.

The facilities and equipment that comprise the EBR-I complex are described in Section II-1 and the D&D plan and operation are described in Section II-2.

The D&D work was initiated in October 1973, the EBR-I building was certified as meeting the ERDA decontamination criteria, and the U.S. National Park Service was given beneficial occupancy of the building on 27 May 1975. All D&D work was completed by 13 June 1975, ahead of the original schedule. The final radiation survey report, after completion of D&D, is included as Appendix B.

1. DESCRIPTION OF FACILITIES AND EQUIPMENT

The EBR-I Complex is located in the southwest part of the Idaho National Engineering Laboratory, as shown in Figure 3. The complex, consisting primarily of the Experimental Breeder Reactor Building (EBR-601), the Zero Power Reactor Building (RTF-601), the Argonne Fast Source Reactor Shielding (EBR-605), and the NaK storage pit, are shown in Figure 4. Building RTF-601 will be converted into an office building to be retained by INEL. The ZPR-III reactor was decontaminated and moved into Building EBR-601 for display. The Control House (EBR-602) will be retained as a guard office for Building RTF-601. Buildings EBR-603 and -604 had been removed from the complex prior to initiation of the D&D effort.

Fig. 2 Photo of EBR-I Complex.

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Fig. 3 Idaho National Engineering Laboratory.

Fig. 4 EBR-I Complex Plan View

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1.1 Experimental Breeder Reactor I Building EBR-601

The EBR-I reactor sustained initial criticality in 1951 and was retired early in 1964 for lack of further assignments. It had demonstrated that a nuclear reactor, designed to operate in the high-energy neutron range, is capable of breeding (creating more fuel than its operation consumes) and also of achieving competitive nuclear power. The reactor was unmoderated and used sodium-potassium alloy (NaK) as coolant and enriched uranium (^{235}U) as fuel. A blanket of natural uranium (^{238}U) around the core provided the “fertile” material in which breeding took place. The liquid metal coolant is low in neutron capture or moderation, permitting the neutron energies to be kept high to promote the breeding of fissionable material. In addition, the coolant enabled high-temperature and low-pressure operation, both conducive to efficient power production.

EBR-I was brought to full power with the Mark I core on 21 December 1951, with an operational loading of 52 kilograms of ^{235}U , and subsequently operated with three different core loadings. Experiments performed with the Mark I and II cores achieved a breeding ratio of at least one; that is, as much fissionable material was produced as was consumed. Projections indicated the possibility of 1.2 and 1.5 breeding ratios for uranium and plutonium-fueled power plants, respectively.

The Mark III core was installed late in 1957 with a more rigid configuration to rule out mechanical movement as a source of feedback. Extensive operation under varying conditions of flow and power demonstrated that careful design had eliminated instabilities which had caused a partial meltdown of the previous Mark II core in November 1955. Plutonium fuel elements were fabricated for the Mark IV core and the reactor was loaded with 28.7 kg of plutonium in November 1962. The technology and feasibility of plutonium as a reactor fuel was advanced greatly by the successful operation of this core from first criticality on 27 November 1962, until the EBR-I was retired in April 1964.

The Experimental Breeder Reactor is housed in Building EBR-601. The main building is a multi-level structure, 122 feet long by 77 feet wide. The height of the building above ground is approximately 50 feet and underground levels extend 30 feet below the surface. The basic floor plans for the basement, the ground floor and the mezzanine are shown in Figures 5, 6 and 7. The reactor utilized a two-stage NaK coolant system that then transferred the heat to a steam generator and this, in turn, powered a turbine-generator. In addition to housing the reactor, its associated controls, cooling and power generation systems, office, heating, utility and maintenance provisions, the building housed facilities and equipment for handling, storage and wash-down of nuclear fuel elements. Consequently, even though all nuclear elements had been removed from this facility many years ago, some areas of the building retained radioactivity. These activated and/or contaminated areas included the reactor core area, the fuel rod farm, fuel handling, storage and wash-down areas and the conveyer area below the reactor. In addition, the primary coolant system, containing 4400 gallons of NaK, had been radioactively contaminated by the core meltdown

Fig. 5 EBR-I Main Floor Plan.

Fig. 6 EBR-I Basement Plan.

Fig. 7 EBR-I Mezzanine Plan.

that took place in 1955. At the time that the facility was deactivated, both the primary and secondary NaK systems had been drained into their respective drain tanks; 4400 gallons of radioactively contaminated NaK in the primary drain tank and 1100 gallons of uncontaminated NaK in the secondary drain tank. Observations at the reactor tank showed evidence of oxide scum over the NaK. Even though the NaK systems had been pressurized with argon gas, it was deduced that some leakage of air and moisture into the systems probably occurred by means of molecular diffusion and permeability of system materials. It was considered very likely, therefore, that portions of the coolant systems contained residues of NaK and its oxides. Analysis showed a total cesium (^{137}Cs) contamination of 16.2 curies. However, due to surface affinity, relative concentrations were expected to be higher in the oxide scum. Therefore, before initiation of effort to remove the NaK, it was necessary not only to take precautionary measures to limit the exposure of radioactivity to the workmen, but to determine the fire and explosive hazards associated with exposure of NaK and their oxides to moisture and various hydrocarbon fluids. This information was derived (see Reference 2 and Appendix G) and then used in the design of suitable processing equipment and establishment of procedures for the safe removal, handling and processing of the NaK.

1.2 Zero Power Reactor III Building RTF-601

The zero power reactor designated ZPR-III, consists of a split-table machine in which criticality was achieved by bringing two halves of a fuel configuration together. ZPR-III was used for determining the accuracy of predicted critical mass geometries and to determine critical measurements in connection with various loadings for makeup of fast reactor core designs. Trays with fissionable material and other metals were used to simulate cores of various reactor types and configurations. The cores of EBR-II, Fermi, Rapsodie, and SEFOR reactors were originally mocked-up in this facility. Theoretical predictions of the performance of such systems took into account neutron reactions of importance to the neutron chain occurring over a wide range of energies, from 50 kilovolts to several million volts. Core designs for plutonium-fueled fast power reactors also were improved by ZPR-III. Experimental critical assembly results in this field were almost completely lacking before advent of the ZPR-III facility in October 1955. This facility was placed in standby status in November 1970.

ZPR-III was contained in Building RTF-601 which is situated approximately 74 ft east of EBR-I and is within the same fenced area. The basic building floor plan is shown in Figure 8. The building has a 48 ft by 66 ft by 31 ft high bay reactor/assembly area which housed the ZPR-III reactor and a 102 ft by 66 ft by 13 ft low bay area which contained office space, restrooms and service areas. The high bay section is constructed of massive structural concrete walls, some of which are five feet thick. The high bay area had some alpha contamination in the Assembly Room around the reactor location. The low bay area is constructed of concrete block and was essentially radiation-free.

Fig. 8 ZPR-III (Bldg. RTF-601) Floor Plan.

1.3 Argonne Fast Source Reactor (AFSR) Shielding

The AFSR was developed as a tool to study the physics of fast breeder reactors. It was placed in operation in October 1959, with a design power of one kilowatt. The AFSR (EBR-603) was located south and slightly east of the ZPR-III building. The original AFSR building (Figure 9) had been dismantled and the reactor, control instrumentation and electrical gear had all been removed to EBR-II prior to initiation of the EBR-I D&D program. Remaining were the below-grade basement, source storage vault and withdrawal hardware; and the above-grade steel-lined concrete shielding structure with view ports and access ports to the centrally located reactor cell shown in Figure 10. External radiation levels were too low to register, and internal radiation levels were also low based on the Argonne National Laboratory (ANL) close-out survey.

1.4 NaK Storage Pit, Drums and Miscellaneous Equipment

The EBR-I Complex also contained a number of items, not physically connected to major structures, that needed to be processed in order to complete the EBR-I Complex D&D. These items are described as follows:

NaK Storage Pit. This pit was located approximately 100 feet west of Building EBR-601. It was approximately 8 feet deep by 10 feet in diameter with ¼-inch thick carbon steel wall. The pit contained four waste packages, as shown in Figure 11, including two 55-gallon drums and two specially fabricated containers which were filled with the NaK present in the reactor core at the time of the core meltdown in November of 1955. The NaK was highly radioactive and probably contained uranium, plutonium, and potassium superoxide (KO₂). The pit was covered by a heavy metal lid. The radiation level at six inches above the lid was approximately 200 mR.

Drums. There were thirty-seven 55-gallon drums stockpiled along the west fence line. These drums contained residual amounts of NaK and were left in a sealed state with an argon gas cover. There was no radiation level associated with the drums or their contents. It was suspected that NaK oxides including the superoxide may have formed on the surfaces of NaK residuals remaining in the drums.

Miscellaneous Equipment. There were 36 large concrete shielding blocks approximately 1.3 feet by 2 feet by 5 feet in dimension. One or two of these blocks appeared to be contaminated to a spot contact level of 200 mR; however, the remainder did not appear to be contaminated. There were several sections of steel buildings which had been partially demolished and left on the site. These steel sections were not contaminated. Finally, there were two concrete slabs from which the buildings had been removed. The slabs were not contaminated.

2. DECONTAMINATION AND DECOMMISSIONING PLAN AND OPERATIONS

The major decontamination effort consisted of the extraction and disposal of 5500 gallons of NaK from the EBR-I coolant drain tanks. A lesser effort was required for clean-up of other contaminated areas of the complex and demolition and removal of certain parts of

Fig. 9 Original AFSR Facility.

Fig. 10 AFSR Shielding.

Fig. 11 EBR-I NaK Storage Pit.

the complex and equipment that had become activated or could not be decontaminated to safe levels. The decontamination criteria established for the EBR-I Complex were based upon radiological condition survey and the intended use involving unrestricted access to the complex by the general public. Accordingly, areas that meet the following criteria do not require radiation warning markers. However, locations where authorized access can be obtained which exceed the radiation or contamination criteria shall be identified with appropriate warning signs.

- (1) External surfaces of materials and equipment and all surfaces of buildings shall not exceed contamination levels listed in Table I following, and should be decontaminated to the lowest levels that are technically and economically feasible.
- (2) Radiation levels at locations accessible to people without restrictions should not exceed 0.1 mR/hr of X, gamma, or beta radiation at 1 cm. The beta radiation must be measured with an instrument sufficient to pass 95% of all beta particles having an energy greater than 0.1 MeV (7 mg/cm² window).
- (3) Areas inaccessible to man without authorization shall be decontaminated to the lowest levels that are technically and economically feasible.
- (4) Soil contamination within the EBR-I complex shall not exceed 10⁻⁵ μ Ci/g for beta-gamma decay modes above background. Tritium contamination levels in soil shall not exceed 10⁻³ μ Ci/g of soil moisture. External beta-gamma radiation levels of soils shall not exceed an overall average of 0.05 mR/hr at 3 feet from the surface, as measured with instrumentation having an absorber window of 7 mg/cm² or less. Maximum levels shall not exceed 0.2 mR/hr at 3 feet above the surface. These levels are exclusive of natural background.

2.1 Experimental Breeder Reactor I Building EBR-601

A generalized decontamination plan was prepared and is attached as Appendix C. The program plan for D&D of Building EBR-601 was established and is described in Appendix A. The program plan, summarized in Figure 12, identified seven major areas of activity. These activities are discussed below:

(1) Project Management was delegated the responsibility for planning and directing the total effort including assembly of the Task Force, providing personnel training, preparation of the D&D procedures (Appendices D and E), and preparation of the Safety Analysis Report (SAR), Reference 1. All operating personnel were trained in the procedures for handling sodium, NaK and caustic, for fighting liquid metal fires and in the use of respirators and Scott air packs. Each person working in the vicinity of the processing plant wore a Nomex suit, chemical splash goggles, a fiberglass hard hat with a face shield, neoprene or chrome leather gloves, chrome leather spats and leather shoes. Metal X powder, shovels, Scott air packs, and full-face respirators were available to personnel. A safety shower and eye wash system was installed close to the working area in case of an accident. A Health Physicist was on duty with each shift to monitor radiation fields and to assure safety of personnel working conditions.

TABLE I
SURFACE CONTAMINATION LEVELS

Nuclide	Removable	Total
Natural uranium, ^{235}U , Natural thorium, ^{232}Th , and all associated decay products	1,000 dpm/100 cm ²	10,000 dpm/100 cm ²
All other nuclides which decay by alpha emissions or by spontaneous fission	100 dpm/100 cm ²	1,000 dpm/100 cm ²
Beta-gamma emitting nuclides	1,000 dpm/100 cm ²	---

NOTES

1. Where surface contamination occurs, both by alpha and beta-gamma-emitting nuclides, the contamination limits listed above shall be applied independently.
2. Standard health physics monitoring techniques shall be used in applying the above criteria.
3. Instrumentation used shall not exceed 7 mg/cm² for absorbing window.
4. Beta radiation levels shall be determined using instruments with sufficient sensitivity to pass 95% of all beta particles having energies greater than 0.1 MeV.

Fig. 12 EBR-I D&D Program Plan.

(2) Technical Research and Development effort was supported by Allied Chemical Corporation (ACC), Argonne National Laboratories (ANL) and others. The EBR-I Plant Assessment was conducted, consisting of a detailed radiation level survey of the facility (reported in Appendix F), physical assessment of the support systems, an inventory of all nonfacility materials and equipment, review of the EBR-I operating procedures related to the primary and secondary NaK coolant loops, and a listing of components suspected of containing undrainable pockets or deposits of NaK and/or their oxides.

Hazards evaluation was undertaken, consisting of a radiation hazard evaluation, alkali liquid metal safety evaluation (Appendix G) and a chemical (fire and explosive) hazards evaluation associated with NaK/KO₂. The latter work, reported in Reference 2, included performance and evaluation of field tests to determine the fire and explosive hazards associated with combining of the sodium-potassium eutectic alloy with the superoxide of potassium (KO₂) under various conditions of state, contamination and detonation initiation. Testing was performed by Cook Associates, Inc. at IRECO Chemicals' Pelican Point R&D Facility in Utah.

The NaK removal and processing criteria (Appendix H) were developed following the hazards analyses and included the conceptual approach, design limits, safety standards, system operating limits, system requirements, and sequence of removal operations. Since the NaK treatment equipment was expendable, emphasis was placed on the use of surplus equipment wherever possible. The design criteria for the NaK disposal facility was prepared as Reference 3.

Decontamination criteria were prepared to include conceptual design, system requirements, operating limits, design limits and safety standards. The system level of contamination and degree of danger involved in the decontamination effort was considered at this point and, where possible, decisions were made as to whether specific items were to be decontaminated in place, cut out and removed, or permanently isolated in place.

Demolition and isolation criteria were prepared to define the areas where demolition or isolation was required. Demolition was required in order to provide access to isolated equipment and to permit extraction of hazardous components from the system prior to decontamination. Isolation was considered when radiation levels were above allowable limits and could not be reduced economically or when an existing hazardous condition could not be rectified.

The support services reactivation criteria (Appendix I) were prepared to cover review of the support systems including water, power, lighting, heating and ventilation, plant air, materials handling and involvement of reactivation requirements.

(3) Engineering Functions consisted of design and drafting services required to convert design criteria to complete work packages. The major items of work were as follows:

Support services reactivation design included preparation of work packages for reactivation of services required to support the D&D program and to provide these services for future use by the Park Service. These services consisted of the plant water system, the

fire protection system, portions of the electrical light and power system, and the heating and ventilation system.

NaK removal system design included preparation of work packages to support the bulk NaK removal from the coolant systems. The design approach consisted of using a nitrogen gas system to pressurize the respective NaK drain tanks and cause the NaK to flow in the reverse direction to the normal fill sequence. This required the design of a transfer pipeline extension from the fill line valves on the main floor to the NaK treatment equipment, design of a dip leg into the reactor vessel where approximately 30 gallons of residual NaK was trapped, and design of the connecting piping between the dip leg and the transfer pipeline. In addition, supplementary heating provisions for the drain tanks and piping were designed.

NaK process equipment design included preparation of work packages required for fabrication of the conversion equipment. The treatment approach taken was to convert the NaK to concentrated caustic solution which will solidify in drums upon cooling from the reaction temperature. The NaK process equipment concept shown in Figure 8 required design of a NaK feed tank, a reaction vessel, demister, HEPA filter installation, flare stack, control and process electrical system, instrumentation system and a drum filling, weighing and valving system. The NaK processing equipment was located on an existing concrete pad southwest of Building EBR-601. Upon completion of the D&D operation, all of the processing equipment was removed from the pad and transported to the RWMC for disposal.

Decontamination system design included preparation of work packages required for fabrication and installation of the decontamination system equipment. The decontamination system concept was based on the use of moist nitrogen gas (GN_2) to react with the NaK and oxide residues to form hydroxides with the evolution of hydrogen gas (GH_2), followed by a water rinse. The system required a rental liquid-to-gas vaporizer capable of supplying approximately 200,000 cubic feet of GN_2 per week; a means of introducing controlled amounts of moisture; process piping from the GN_2 system to the EBR-I primary and secondary coolant piping systems; off-gas scrubber, filters and flare stack capable of flaring GH_2 ; containers for collecting nuclide-contaminated caustic; and a water flush system.

Demolition and isolation design included preparation of work packages required to identify the demolition work. For minor activities, field sketches and handwritten instructions were prepared by the engineer at the site. For designs involving instructions for removal of potentially hazardous items, however, the instructions required prior safety evaluation and Program Management approval. Items in this category included components containing significant residues of NaK and/or its oxides such as the primary gas system strainer; the NaK primary system cold trap; the NaK bubbler (argon gas purifier); and the NaK primary system expansion tank. Wherever areas could not be decontaminated to safe levels, isolation barriers were designed to prevent personnel entry. These areas included the wash room, the convection room, the elevator and the reactor cell.

Design follow-up and inspection included checkout of fabricated items and installed systems used in the D&D effort and inspection of reactivated support services. Any field changes resulting from this activity were subject to a formal review system.

(4) Safety. ANC's Safety Division provided the Health-Physics surveillance, safety reviews and audits required to ensure that all D&D work was accomplished in a safe manner and that the resulting EBR-I facility was safe for public enjoyment as a National Historic Monument.

Health-Physics surveillance was carried out at all times that Building EBR-601 was occupied. The ANL close-out survey was used as a basis for comparison against radiation levels recorded just prior to decontamination activities, for estimation of induced radiation decay rates, and for planning of decontamination activities.

Safety reviews were performed on all NaK removal and decontamination systems and procedures. In addition, Safety performed all normal audit functions associated with work in a hazardous area.

(5) ERDA Approval of the Program Plan, the NaK Removal and Processing Systems and Procedures, the D&D Criteria and the SAR was required through ERDA-Idaho Operations.

(6) D&D Operations were physically carried out by ANC's Site Services Division under the supervision of ANC's Waste Management Program Division. These operations consisted of support services reactivation, fabrication of the NaK removal system, NaK treatment equipment and the decontamination system, performing the NaK removal and treatment operation, disposal of the solidified caustic waste, performing decontamination, demolition and isolation operations and restoration of the EBR-I physical appearance.

(7) Transfer Operations concerned the turning over of the EBR-I facility to the National Park Service. Final inspection assured that the facility was safe and that restoration activities had, to the greatest practical extent, restored the physical appearance of the facility. These operations were accomplished by ANC's Waste Management Program Division in conjunction with the Safety Division and ERDA-ID representatives. The EBR-I building was certified as meeting the ERDA decontamination criteria by ANC's Safety Division and the U. S. National Park Service was given beneficial occupancy of the building on 27 May 1975. The facility will not be transferred to the National Park Service, however, since in a draft agreement between ERDA and the NPS, ERDA agreed to continue as the Government entity responsible for control and maintenance of the facility as Government property. The NPS agreed to supervise the public use of the EBR-I facility during the period mid-June to mid-September, on an eight hours per day and seven days per week basis.

2.1.1 Removal and Processing of NaK from EBR-I Coolant Systems. The EBR-I primary and secondary NaK coolant systems are shown pictorially in Figure 13 and in diagram form in Figure 14. Both coolant systems had been drained into their respective drain tanks (T-3 and T-6) about twelve years ago. T-3 contained approximately 4400 gallons of NaK which was contaminated by induced activity, absorbed fission products and residues from the 1955 EBR-I Mark II core meltdown; and T-6 contained approximately 1100 gallons of uncontaminated NaK. Both systems had been provided with an argon gas cover; however, they contained a small amount of alkali oxides due to the ingress of oxygen via molecular diffusion, the 20 ppm allowable contamination in the argon cover gas, and

Fig. 13 Simplified Pictorial of EBR-I Coolant Flow.

Fig 14 EBR-I NaK System Diagram

leakages to the system that probably occurred during reactor fueling operations. NaK samples were taken from the primary system drain tank on 23 February 1970 which, upon analysis, indicated a total cesium (^{137}Cs) contamination of 16.2 curies and 2.1 mCi of strontium (^{90}Sr). No other radioactive nuclides were detected. The primary system filters and cold trap were expected to contain a like amount of ^{90}Sr which is nonsoluble in NaK and would be expected to be found as a particulate in the filter and cold trap elements. There was no evidence of alkali oxides in the samples taken. However, just prior to the plant shutdown, there was visual evidence of an oxide film on the NaK surface within the reactor vessel.

The 5500 gallons of NaK were disposed of by reacting it with water in a strongly basic solution, solidifying the solution by evaporation and cooling and disposal of the solid waste at the INEL RWMC. Processing of the NaK is described in Reference 4 and summarized hereunder.

2.1.1.1 Process Description and Development. The NaK process plant flow diagram, equipment arrangement and electrical diagram are shown in Figures 15, 16 and 17, and photographs of the plant are shown in Figures 18 and 19. In the disposal process, the NaK was reacted with water in the caustic in the VFE-1 vessel to produce additional caustic. Water was injected into the vessel to make up for the water consumed by the NaK and for vaporization of water in the vessel. Water flow was controlled by a control valve to maintain the caustic/water mixture at 200°C . Water from recycle of the scrubber vessel solution, knockout vessel contents and the stack condensate was also added to VFE-1 from a spray nozzle at the top of the vessel.

The off-gas from the vessel was passed through a demister, a scrubber vessel, and a knockout vessel. (The scrubber and knockout vessels were used only with the processing of primary system NaK.) The off-gas then passed through one of two filter units, each of which contained a glass wool or a steel wool prefilter and a high efficiency particulate (HEPA) filter. The off-gas was sampled and then passed through a flare stack containing a flame arrester. Condensate formed in the off-gas line was continuously drained and periodically recycled to the VFE-1 vessel. Product from the VFE-1 vessel was drained into 55-gallon drums which, after solidification, were shipped to the INEL RWMC.

To clear up the final traces of NaK, moist GN_2 was passed through the NaK feed tanks and lines followed by a water rinse. Finally the residual liquid was evaporated until a 25 M concentration was attained for solidification and disposal.

The flowsheet for the NaK conversion process is shown in Table II. The conversion apparatus was designed to react 125 g/hr of NaK with the caustic solution to form the mixed NaOH-KOH solution. Water was to be consumed, by reaction with NaK and by vaporization, at a rate of 252 g/hr . Caustic product at 25 M was to be removed periodically at an average rate of 128 g/hr . The off-gas was to be filtered, released to the atmosphere via a flare stack and burned.

Fig 16 NaK Process Plant Equipment Arrangement 27

SKETCH EBR 1 NaK D & D PROCESS PLANT
 ELECTRICAL DIAGRAM

DRAWN: JAY PEASE 8 29 74
 DESIGN: S L FRIEDMAN 8 29 74
 REQUESTER: J. W. Hall 8 29 74

Fig 17 NaK Process Plant Electrical Diagram 28

Fig. 18 EBR-I NaK Process Plant - View I.

Fig. 19 EBR-I NaK Process Plant - View II.

TABLE II
FLOWSHEET FOR NaK REACTION

	NaK Feed	Water Addition	Caustic Produced	Off-Gas
Flowrate	125 ℓ/hr	255 ℓ/hr	128 ℓ/hr	172 scfm
NaK, <u>M</u>	25.6	---	25	---
H ₂ Vol. %	---	---	---	12%
H ₂ O (vapor) Vol. %	---	---	---	83%
GN ₂ Vol. %	---	---	---	5%

Laboratory tests of the 67.6% mole KOH and 37.4% mole NaOH caustic product exhibited the following characteristics:

Concentration	25 <u>M</u>
Boiling Point	200°C (@ 640 mm Hg)
Freezing Point	101°C
Density	1.798-0.0007645 t g/cc (for t = 101°C to 200°C)

For studying some of the design variables for the NaK alloy disposal process, a pilot plant test was performed on 16 May 1974. Its objectives were to: (1) examine the relative merits of two nozzles for NaK injection, (2) examine the problems of injection of water into the high-temperature reaction medium, (3) evaluate the use of the electromagnetic flowmeter (EMFM), (4) measure the strains and pressures generated on the walls of the vessel caused by the reaction of the NaK with the caustic, and (5) evaluate and demonstrate startup, operation and shutdown techniques. The safety analysis of the pilot test NaK processing equipment is attached as Appendix J.

In the pilot plant test, 126 ℓ or 109 kg of NaK was successfully converted to caustic by reaction with water in a caustic solution. During this reaction, an air atomizing nozzle was identified as the best nozzle for NaK injection into caustic for the disposal process. The nozzle gave a smooth reaction of NaK with caustic and could be turned off and restarted as long as a gas purge through the nozzle was maintained. Pressure pulses and strains in the reaction vessel during the NaK injection were adequately low. Purging the lines with a dry inert gas was found to be an adequate pretreatment for drying the steel surfaces before NaK service. The EMFM worked satisfactorily during the test. The NaK volume calculated from the estimated average flow rate and time of injection agreed with the volume of NaK disposed of during the test. The cleaning procedures to remove traces of NaK using water-saturated inert gas followed by a water rinse worked well. The water in the saturated inert gas apparently had reacted with nearly all the liquid metal residues in the vessel lines before the subsequent water rinses. Due to loss of caustic by splashing from the top of the open reaction barrel, water had to be added before the caustic reached 200°C. Consequently, the caustic temperature reached a maximum of 125°C during

the test so that the injection of water at the expected steady-state operating conditions of VFE-1 was not possible. Nevertheless, at the 125°C temperature, no difficulties were encountered with water injection.

2.1.1.2 Process Operation and Performance. The entire system was dried by passing dry GN_2 through the lines, tanks, valves, and nozzles for several days prior to service with the NaK. The moisture content of the GN_2 flowing through the feed system was determined with a moisture monitor Type 26-301 from Consolidated Electrodynamics Corporation and was required to be approximately 2 ppm prior to introduction of NaK into the system. Processing of uncontaminated NaK from drain tank T-6 was undertaken first. To start the operation of the system, the EBR-I drain tank T-6 was pressurized to 15 psig and the air operated bellows valves V-104 and V-30 (shown in Figure 15) were opened to permit filling of the No. 2 NaK feed tank. Valve V-104 was closed briefly to permit the area of pipe near the EMFM to be heated with a propane torch in order to insure that the inner surface of the pipe would be wet with NaK. This was required only once during the process operation. Valve V-104 was then reopened until the high level alarm on the No. 2 NaK feed tank sounded. Valves V-104 and V-30 were then closed and Valves V-102 and V-29 were opened for filling of the No. 1 feed tank. After filling, both tanks were pressurized with GN_2 to 40 to 55 psig. During the subsequent operation, the two feed tanks were filled alternately, so that while one tank was being filled, the other tank was feeding NaK to the VFE-1 vessel.

The NaK flowing from the feed tanks to the VFE-1 vessel passed through an EMFM, one of two parallel filter systems and one of two atomizing spray nozzles. NaK flow was controlled by valve V-157 or V-158, depending upon which of the two parallel lines was in use. The output of the EMFM was recorded on a Honeywell Electronic 194 recorder. The valves, level detection system on the feed tanks, filters and the EMFM all functioned well during the entire processing operation. The spray nozzles, however, did not function properly during much of the operation, although they functioned sufficiently well to permit completion of the operation. The major problem with the spray nozzles was that the atomizing side of the nozzles tended to become partially clogged during operation and particularly after a shutdown. In order to operate at the desired flow rate, it was necessary to flow through both nozzles simultaneously during much of the operation. In addition, the gasket of one of the NaK nozzles developed a crack after approximately one day of operation, resulting in the appearance of a very slow NaK leak. However, the leakage stopped by itself, apparently by the formation of an oxide layer when the NaK was exposed to the atmosphere. No further leakage occurred throughout the remainder of the operation.

During processing of secondary system NaK, the system was field-modified to improve performance and to correct design errors; therefore, continuous operation of the system was not possible. The system was operated intermittently for several days during this checkout period. From the product collected and EMFM output, it was estimated that 1100 gallons of secondary system NaK was processed.

The average flow rate of NaK during disposal of the primary system NaK as determined by the EMFM was 91.5% of the design flow rate. From the quantity of caustic product collected, the average NaK flow was 95.8% of design flow rate. The average flow as estimated from the amount of product collected is probably the more accurate. The amount of NaK processed from the primary system was estimated on this basis to be 4400 gallons.

The control valve which controlled the temperature by water addition to VFE-1 gave very good control of the temperature in VFE-1 with the temperature of the caustic varying by no more than 5°C from the 200°C set-point. Dilute caustic solution from the scrubber and knockout vessels, and condensate collection from the off-gas stack drain were periodically pumped into VFE-1 to prevent excessive buildup of contaminated liquids. During the latter stages of the processing of primary system NaK, a failure of a bushing on TE-11 resulted in the loss of approximately 25 gallons of 25 M caustic product to the catch pan. By lowering the caustic level in VFE-1, it was possible to complete the processing of the primary system NaK without further loss of caustic.

The product collection system consisted of a flexline, a remote-operated valve, hand-operated gate valve, a clamp to seal the transfer line to the barrel, a neoprene rubber seal, a drum and off-gas filter on the drum. The caustic was drained into the barrels sitting on a scale during the loading operation. The scale was set to trip and actuate an alarm when the barrel contained approximately 50 gallons of caustic. In addition, a heat-sensitive coating was used to indicate caustic level in the barrels during filling.

Except for the carbon steel flexline, the product collection system worked very well. Due to air exposure to caustic coated surfaces of the flex hose, severe corrosion of the flex hose occurred, resulting in several hose failures which also caused the heat tapes around the flex hose to fail. To improve this condition during processing of the primary system NaK, the flex hose was rearranged so that the caustic would drain from the carbon steel flex hose. This resulted in a much longer service life. One failure did occur during latter stages of processing of primary system NaK and the flex hose was replaced with a ½-inch black iron pipe. The barrels were, in this case, raised into place with a forklift truck.

The off-gas system originally consisted of a demister, two filter units each with a prefilter and a 6-inch thick HEPA filter, an off-gas line with a manually-valved drain, and a stack for venting of the gas. During processing of the EBR-I secondary coolant NaK system, some problems occurred that necessitated two shutdowns of operations and implementation of changes to the system. The first shutdown resulted from overheating of the filter box area that melted the silver solder that secured the Calrod heating elements and caused heat distortion of the filter frame to pop the restraining rivets, which in turn resulted in collapse of the filter. One of the reasons for the overheating was that the Calrod heaters had been installed only around the filter compartment, while the thermocouple sensors were installed in the approach section to the filter compartment. As a result, there was a considerable difference between the temperature indicated by the thermocouple and the actual temperature in the filter compartment. This condition was corrected by placing additional Calrod heating elements in the approach section. It had also been noticed that

condensed moisture tended to collect in the elbow between the filter and the vent stack, to the extent that a buildup of back pressure frequently occurred before the line was drained manually. This condition was corrected by replacing the valved drain line with an open drain line having a U-tube trap to drain the condensate and prevent air intake. During the shutdown, the N₂ check valves, V-66 and V-67, that had 1/10 psi breakaway pressure, were changed to check valves with 2 psi breakaway pressure. In addition, a pressure regulator was added to isolate the purges, giving them their own supply through the flow meters. These changes improved the system operation but did not solve all of the problems, in that the filters continued to fail at frequent intervals due to caustic carry-over plating out on the filter element and causing the filter (paper) to collapse. Typical filter failures are shown in Figures 20 and 21. As a result, analysis of gas samples during processing of the secondary system NaK indicated that at least 1.5% of the caustic produced in the NaK processing passed the demister. This caustic loading on the filters was much greater than expected and was responsible for the failures. It is likely that the droplet size being carried over was very small, since the demister should have had >99.9% efficiency for removal of droplets >10 μ diameter. As a result, operations were shut down a second time to permit addition of a scrubber and a knockout tank upstream of the filter, and 1½-inch thick filters were installed to replace the 6-inch thick filters used previously. The installation diagram for the scrubber and the knockout tanks is shown in Figure 22. This installation included a pump to take out condensate from both tanks and pump it back to the VFE-1 processing tank. During this shutdown, some additional changes were made, including the addition of a fourth thermocouple to the VFE-1 tank, and inverted U-tubes were added to the lines leading to the two pressure differential cells on the VFE-1 tank to prevent retention of fluids that would solidify and block off the lines upon cooling.

The scrubber vessel removed approximately 83% of the caustic carried past the demister, or about 1.3% of the NaK injected into VFE-1. The knockout vessel removed an additional 10% of the caustic carried past the demister, or approximately 0.15% of the NaK injected into the VFE-1 vessel. Thus, the amount of caustic carried to the filters was reduced from 1.5% to approximately 0.10%. As a result, the filters lasted for the entire period of time in which the primary system NaK was processed. Post-processing inspection showed little, if any, damage to the filter elements. Di-octyl Phthalate (DOP) tests of the filters confirmed that the filters had not failed during use; however, the off-gas samples and samples of the stack off-gas indicated some bypassing of the filters. This bypassing of the filters may have been due to thermal buckling of the heated filter housings.

The off-gas sampling system worked well during most of the time. The oxygen analyzer gave O₂ contents of less than 0.1% before startup of the NaK caustic reaction. Occasional pressure surges in the off-gas line during operation caused carryover of condensate to the oxygen analyzer and flowmeter. The constant air monitor indicated that essentially all of the ¹³⁷Cs was removed by the condenser of the sampling system. The pH meter gave an average pH of 11.5 and indicated a decontamination factor (DF) for caustic at the point of sampling of 5300. An additional DF of 3.3 in the off-gas line gave an overall DF to the stack of 17,000 and indicated a release of 0.9 mCi of ¹³⁷Cs. The analysis of three off-gas samples from the stack gave DF of >40,000, 10,000 and >3000. Due to problems with the first and third sample bombs, only the second analysis, giving a DF of 10,000, is considered valid. This DF is in fairly good agreement with the DF obtained from the pH

Fig. 20 HEPA Filter Failure.

Fig. 21 HEPA Filter Failure.

Fig 22 Piping Diagram - Scrubber and Knockout Tank Addition

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meter results. The release of ^{137}Cs was calculated from the sample bomb results and gave 1.6 mCi. The 0.9 mCi released is believed to be the more accurate determination since it is a time-averaged release.

The flame arrestor worked well during the entire NaK disposal run, although at times it was difficult to burn the GH_2 released from the stack due to wind conditions and low flammability of the GN_2 , GH_2 and steam mixture.

After removal of bulk quantities of NaK from the EBR-I primary and secondary coolant systems, it was necessary to remove residual heels, films of NaK and oxides to complete the decontamination. The decontamination system consisted of portions of the NaK processing system and included the Linde GN_2 supply; a moisturizer; piping to the two drain tanks; and a vent system similar to that used for the NaK processing. Moist GN_2 (4% water) was piped to the low points of the primary and secondary systems and cover gas systems. The gas was supplied at high velocity in order to promote turbulent flow and maximum contact between the moist gas and the residual heels and films, converting these to a caustic with the emission of GH_2 . The GN_2 velocities and moisture content were maintained at levels which kept the GH_2 generation and concentration below the explosive limits. The existing drain tanks were filled with water after all NaK had been converted to caustic, and water was circulated through the systems via pressure transfer. The water flush continued until all of the caustic had been collected at the drain tanks. The caustic was then transferred to the NaK processing system and evaporated until a 25 molar solution was achieved. This solution was drummed and disposed of at the INEL RWMC, as was the processed NaK. During this operation, an incident occurred that resulted in minor injury to a workman and also slight contamination spread about the process plant pad area. The HEPA filter, downstream of vessel VFE-1, had been damaged by the action of the caustic solution. A piece of unidentified material, possibly from the filter, floated downstream and clogged the condensate line, which caused contaminated caustic to overflow the vent line into the surrounding area. In an attempt to clear the line, a workman unplugged the line and contaminated caustic liquid was ejected into the immediate area. The workman received minor burns from the 1.4 molar caustic. (He was given first aid and sent to the dispensary for further treatment.) A survey of the area with an RM-14 showed contamination to 50,000 c/m in the immediate area of the NaK pad, 30,000 c/m twenty feet north and west of the pad, 1000 c/m fifty feet north and west of the pad, and 100 c/m at seventy-five feet north and west of the pad. While changing the HEPA filter on the NaK pad on 5 May 1975, an estimated 10 gallons of contaminated caustic spilled out, further contaminating the area to the north and west. It also contaminated an area to the south of the NaK pad. This area is about 20 feet by 100 feet and was contaminated to a level of 4000 c/m. Air samples were taken and showed no evidence of air activity. Frequent surveys were made to ensure that the contamination had spread no further. The contaminated dirt was subsequently collected and transported to the INEL RWMC for disposal.

2.1.2 Removal of Highly Contaminated Items. The EBR-I Complex contained a number of items which, by reason of activation during reactor operation, or fission product absorption, were impractical to decontaminate to safe levels. One of these items was the cup base located in Repair Room No. 1. The cup base, a stainless steel ring 3 feet in diameter by 3 inches thick and weighing approximately 650 pounds, exhibited radioactivity of 10 R/hr on contact. Due to this degree of activation and contamination, it was considered hazardous for workmen to attempt to decontaminate this item or to decontaminate the Repair Room while it was located there. A decision was made therefore to remove the cup base, package it and transport it to the INEL RWMC for disposal. The procedure for accomplishing this was prepared and is attached as Appendix K. The removal operation was carried out successfully without mishap.

Other items that were radioactively contaminated included the fuel element washing fluid containers and trolley assembly in the wash room, the elevator mechanism in the conveyer room and several fuel handling casks. Since the wash room and the conveyer rooms were to be permanently sealed as noted in the following section, the items contained in these rooms were permitted to remain in these sealed rooms. The fuel handling casks, radioactively contaminated internally but uncontaminated on the outside, were left in place for display purposes. These casks were marked with appropriate caution signs indicating internal radiation hazard. It is to be noted that access to the inside of the casks requires special handling equipment, including a heavy load capacity hoist. Consequently, accidental access to the cask interior is not possible.

2.1.3 Isolation of Uncleanable Areas. It was not possible nor practical to decontaminate some areas in Building EBR-601 to safe levels. These areas included the fuel rod farm, the fuel wash room, the conveyer room containing the elevator, the reactor cell, and the primary NaK drain tank. Since these areas could not be satisfactorily decontaminated, isolation walls or barriers were constructed to prevent personnel entry into these areas. In addition, some areas such as the fuel cave, although satisfactorily decontaminated, were sealed to prevent personnel entry so as not to damage the fuel handling equipment. These sealed areas, as well as closed-off areas, are indicated in Figures 5, 6 and 7.

After NaK removal and flushing out of the EBR-I NaK systems was completed, there remained approximately 80 gallons of contaminated caustic sludge at the bottom of the T-3 primary drain tank. This residual sludge was not readily removable through the normal system fill or drain lines. A preliminary study showed that removal of the residual sludge could be accomplished by cutting the 4-inch gravity tank drain line located at the top of the T-3 tank, and pumping out the sludge with a sump-type pump having a flexible suction line inserted through the opening. The sludge could be pumped into receiving barrels located in a prepared area in the filter access alley floor adjacent to the tank compartment hatch. The barrels could then be sealed, hoisted out through the NaK area escape hatch with a mobile crane, and disposed of. However, this operation not only would involve considerable cost, but more importantly, would present safety hazards to operating personnel and offer the possibility of spreading contamination should an accidental spill occur. As a consequence, it was decided not to attempt to remove the sludge, but to solidify the residue in place in the T-3 tank, seal up the tank and isolate the T-3 tank area to prevent personnel entry. Accordingly, four 90-pound bags of cement and

sixteen 50-pound bags of moisture absorbing compound were poured into the tank through the 4-inch opening to completely solidify the fluid. The opening was then welded shut, the T-3 tank area entry hatch shield blocks were replaced and the steel frame was welded closed.

2.2 Zero Power Reactor III Building RTF-601

Inasmuch as Building RTF-601 was only slightly contaminated with alpha contamination and this was limited to the ZPR-III reactor, Figure 23, and the reactor/assembly area located in the high bay section, the following four alternative approaches were considered for the building:

- (1) Construct an isolation barrier fence between EBR-I and RTF-601 and maintain RTF-601 in a locked condition.
- (2) Reactivate RTF-601 low bay area only for use and permanently isolate ZPR-III in the high bay assembly area by filling in all openings with reinforced concrete block walls.
- (3) Remove all contaminated material, including the ZPR-III reactor, from the high bay area and reactivate the entire building, both high and low bay, for future use.
- (4) Remove contaminated material, including ZPR-III, from RTF-601, dispose of radioactive contaminated waste at the INEL RWMC, demolish the building, dispose of uncontaminated solid waste at the CFA Sanitary Landfill, and return the site to its original condition.

Alternative (3) above was selected and formed the basis for the Building RTF-601 D&D program plan. It was felt that the first two approaches did not meet the intent of the D&D directive and the fourth approach would result in the unnecessary demolition of a usable building at considerable expense to the Government.

Except for contamination of the ZPR-III reactor and the small amount of alpha contamination in the reactor/assembly room, the remainder of the building was uncontaminated. Consequently, hazards involved in the D&D effort were minimal. The program plan is described in Appendix A and summarized in Figure 24. Similar to the program plan for D&D of Building EBR-601, this plan includes the seven areas of activity; namely, Project Management, Technical Evaluation, Engineering, Safety, ERDA Approval, D&D Operations and Transfer Operations. No separate SAR was prepared for this activity, since the basic SAR, Reference 1, included this operation. The D&D operations were relatively simple and straightforward. After the area and equipment were surveyed for contamination, the ZPR-III reactor was partially disassembled and wiped clean using commercial cleaning solutions. The original plan to ultrasonically clean the parts, particularly the reactor core matrix boxes, was discarded due to the high cost. The reactor core matrix boxes were disposed of at the INEL RWMC. The decontaminated reactor was transported to Building EBR-601 and reassembled with dummy core matrix boxes for display. The high bay area of the building was cleaned using "Pullman" vacuum cleaners

Fig. 23 ZPR-III

ZPR-III PROGRAM PLAN

[Activity Bar] indicates activity period

Fig. 24 ZPR-III D&D Program Plan.

backed up with HEPA filters and then wet mopped. Residue from the cleaning operations, including the filters, was collected and disposed of at the INEL RWMC. The balance of the building, i.e., the low bay area, was cleaned in substantially the same manner except that no contaminated waste was involved. The uncontaminated waste was disposed of at the INEL Sanitary Landfill. Building ZPR-III RTF-601 was certified as meeting the ERDA decontamination criteria by ANC's Safety Division on November 1974. A copy of the final radiation survey of the ZPR-III facility is attached as Appendix L.

2.3 Argonne Fast Source Reactor (AFSR) Shielding

At inception of the EBR-I D&D program, all that remained of the AFSR were the below-grade basement containing the source storage vault and withdrawal hardware, and the above-ground steel-lined concrete shielding structure shown in Figure 10. The ANL close-out survey had indicated that the external radiation levels were less than 0.1 mR/hr and the internal radiation levels varied from 0.1 to 2 mR/hr. Three alternate approaches were considered for D&D of the AFSR shielding, as follows:

- (1) Construct an isolation barrier around the AFSR and seal all openings in the remaining concrete structure.
- (2) Demolish the above-grade portion of the structure to the level of the concrete slab, fill all open spaces in the basement with earth, pour concrete plugs in openings in the slab, and create a terrain feature by covering the concrete slab with five feet of native soil and rocks.
- (3) Demolish the total structure, remove all materials to the INEL RWMC or the Sanitary Landfill as appropriate, and fill the remaining void with native soil and rocks.

Alternate (2) was selected because the first alternate did not meet the intent of the D&D directive, while the third alternate involved the unnecessary expense of demolition and removal of the below-grade concrete. The AFSR D&D program plan is described in Appendix A and summarized in Figure 25.

A demolition plan was prepared and is included as Appendix M. In the actual demolition operation, the initial blast fractured the reinforced concrete structure, but did not totally separate the above-ground structure from the below-ground structure. Structural steel ties between the two portions of the structure remained intact. As a consequence, it was necessary to arc gouge the steel ties. A second blast using smaller charges was then set off, which satisfactorily demolished the structure. Figures 26 and 27 show the containment structure after explosive demolition and after completion of the D&D operation. The above-grade portion of the AFSR shielding structure was demolished to the level of the concrete slab. The total structure materials above-grade were transferred to the INEL RWMC for disposal. The remaining void below-grade and the concrete slab were surveyed for radioactivity, were found to be within the established allowable limits and were filled and covered with approximately five feet of native soil and rock. The AFSR shielding D&D was completed on schedule and certified to be contamination-free by ANC's Safety Division on 10 January 1975.

AFSR PROGRAM PLAN

■ indicates activity period

Fig. 25 AFSR D&D Program Plan.

Fig 26 AFSR Shielding After Demolition Blast

Fig 27 AFSR Shielding After D&D

2.4 NaK Storage Pits, Drums and Miscellaneous Equipment

The NaK Storage Pit, the drums of residual NaK stockpiled along the west fence line and miscellaneous equipment of no further use, had to be disposed of. The program plan for this operation is described in Appendix A and summarized in Figure 28. The four packages of contaminated NaK were located in the NaK storage pit, approximately 100 feet west of EBR-601. They include two 55-gallon drums and two specially fabricated containers which were partially filled with the NaK present in the reactor core at the time of the partial core meltdown in November of 1955. Radionuclide analysis showed that the NaK was highly radioactive and contained uranium, plutonium and potassium superoxide.^[a] The containers and contents were removed from the NaK storage pit and transported to the Army Re-Entry Vehicle Facility Site (ARVFS) bunker for temporary storage as described in Reference 5. Procedure for removal of NaK from the EBR-I storage pit is attached as Appendix N. The pit was found to be uncontaminated, after removal of the drums and containers. Therefore, after removal of the packages, the pit walls and concrete pad were demolished and backfilled into the pit. Further backfill to grade level was completed with native soil.

A small portion of the uncontaminated NaK in the thirty-seven 55-gallon drums was used in development of the EBR-I NaK processing equipment. The remainder of the barrels was processed by filling the barrels with steam and water in accordance with the procedures spelled out in Appendix E. Upon completion of processing, the water-filled barrels were transported to the east acid pit. Liquid from the barrels was drained into the acid pit and the empty barrels were then removed to the INEL Salvage Yard.

Disposal of the miscellaneous equipment was considered to be nonhazardous. The large concrete blocks were used for explosive shielding until the NaK disposal program was completed. They were then moved to the CFA INEL Sanitary Landfill, as were the several portions of metal building which littered the site. The uncontaminated concrete pads were allowed to remain in place.

3. RELEASE OF RADIONUCLIDES TO THE ENVIRONMENT AND HEALTH RISK

3.1 Release of Radionuclides to the Environment

From analyses of primary system NaK and the caustic product, the primary system NaK process was found to contain 16.2 Ci of ^{137}Cs and 2.1 μCi of ^{90}Sr . There were no other radioactive nuclides found. The estimated release of ^{137}Cs to the atmosphere was 0.9 mCi. The estimated release of ^{90}Sr was approximately 0.1 μCi . The average concentrations of ^{137}Cs and ^{90}Sr in the off-gas from the stack are respectively $1.3 \times 10^{-8} \mu\text{Ci/ml}$ and $1.4 \times 10^{-11} \mu\text{Ci/ml}$. Peak concentrations were no higher than twice these values. Diffusion and dispersal from the vent stack would further reduce the ground level concentrations and assure that the concentrations of nuclides were below maximum permissible concentrations.

[a] Radionuclide Analysis by ANC Safety Division

NaK STORAGE PIT, DRUMS AND MISC. EQUIPMENT PROGRAM PLAN

████████ indicates activity period

Fig. 28 NaK Storage Pit, Drums, and Miscellaneous Equipment D&D Program Plan.

The spill of approximately 25 gallons of caustic to the drain pan (explained in Section 2.1.1.2) did not result in release of a significant amount of contamination to the environment. The caustic spill was contained by the drain pan, cleaned up, solidified in barrels and disposed of at the INEL RWMC. Similarly, the 93 full or partially-full drums filled during disposal of the EBR-I primary system NaK were shipped to the INEL RWMC after solidification of the caustic. The top heads of all the drums contaminated during the filling operation were covered with polyethylene and drums with external contamination were completely wrapped in polyethylene to prevent release of contamination during shipment and disposal operations.

During the last stages of processing of EBR-I, the contents of the scrubber and knockout vessels were pumped into the VFE-I vessel. Two partially-full 55-gallon drums containing condensate from the stack were shipped to ICPP for disposal as a liquid waste.

After all NaK processing was completed and the rinse solution had been evaporated and solidified in the VFE-I vessel, the entire processing equipment was dismantled and removed to the INEL RWMC for disposal. Quantities of dirt around the concrete pad that had exhibited slight contamination were scooped up, packaged in polyethylene bags in a Demster Dumpster and disposed of at the INEL RWMC. Finally, the concrete pad upon which the NaK process plant was located was broken up, packaged and disposed of at the INEL RWMC.

3.2 Health Risk

The health risk during decontamination of the EBR-I Complex was controlled by standard methods. Air monitoring was used where applicable, as were personnel dosimetry methods. Health risk after decontamination concerns two groups of people: National Park Service employees who will spend considerable time in the facility; and visitors who will individually be present for short, seldom-repeated periods. The risk analysis below concerns primarily workers involved with the D&D effort and National Park Service employees.

3.2.1 Health Risk to D&D Workers:

EBR-I. NaK contaminated with ^{137}Cs and ^{90}Sr that existed in the primary coolant system was removed and processed by aqueous oxidation. The oxidation process was developed and applied successfully to barrel volume quantities of uncontaminated NaK. Oxidation of contaminated NaK was done to contain the ^{137}Cs and ^{90}Sr . Primary protection was provided by a system appended to the proven oxidation process to demist and filter the gaseous discharge and flare the generated hydrogen. During the oxidation process, all nearby personnel were required to wear full alkali metal protective gear and have, on standby, Scott Air Pak respiratory protection. The risk to workers due to ^{137}Cs and ^{90}Sr in the NaK was minimized by (1) the low concentrations in air that might be generated by an unconfined oxidation, (2) cleansing of the discharges from the oxidation, (3) low probability of a process failure, (4) use of respiratory protection and (5) relative low concentrations when vectored through air.

The primary coolant system and related items were decontaminated after the Cs-bearing NaK had been drained to the process equipment for processing. Residues of NaK were reacted with moisture carried by GN_2 . The decontamination involved flushing operations using demineralized water which formed a mild caustic. Neither the reaction nor the flushing provided a mechanism for releasing significant contamination into the air. The collecting and handling of caustic cleaning solutions are routine operations and the solutions involved were of low risk in any case. The cesium and strontium contained in the flushing solutions were confined by collecting the solutions in the NaK system drain tanks. The solutions were transferred to the VFE-1 tank, evaporated to a 25M concentration, solidified and the tank and its content were disposed of at the INEL RWMC. Health risk during cleanup of external contaminations by vacuuming, wet scrubbing, and sandblasting, was minimized by the use of face masks and protective clothing. Because contamination levels were low, health risk was small.

Some induced radioactivity remained in structural components at EBR-I which could not be removed without compromising the integrity of the National Monument. Placement of shield blocks around these areas and installation of barriers to prevent subsequent entry involved some radiation risk to workers. This risk was mitigated, however, by the use of temporary shielding and radiation exposure control methods that are used routinely elsewhere within INEL operations. Dangerous levels of radiation did not exist; the highest field discovered was 2.0 R/hr. Items with induced radioactivity which could be removed, were disposed of at the INEL RWMC.

ZPR-III. Prior to the D&D effort, radiation and contamination levels of the ZPR-III building were already near or within safe levels except for the front part of the ZPR-III reactor assembly. The equipment that caused the higher radiation was removed, packaged and disposed of at the INEL RWMC. Packaging, transport and disposal of this type of equipment was essentially a routine operation. Health risk from this operation was controlled by standard methods for exposure monitoring to verify that doses received by workers are within acceptably safe values. Health risk to personnel during decontamination (scrubbing) operations was negligible because of the low levels of the radiation present and the standard precautionary methods employed.

AFSR Shielding. Similar to ZPR-III and as indicated in Section 2.2, the ANL close-out survey had indicated that the external radiation levels were less than 0.1 mR/hr and the internal radiation levels varied from 0.1 to 2 mR/hr. The exercise of standard safety measures and standard exposure monitoring methods ensured that no health risk resulted from this operation.

NaK Storage Pit. Four containers of contaminated NaK were removed from the pit using remote handling equipment, placed in sand shielding inside of a metal box, and transported to an engineered storage facility for interim storage. These safety precautions enabled relocation of the NaK containers without incident. The pit was found to be noncontaminated, hence without future radiation risk. Direct radiation received by workers from the drums was negligible. No smearable or airborne contamination was associated with these drums.

Outdoor Contamination. The soil adjacent to the buildings was sampled and radioactive contamination was found to be low. Where radiation contamination existed above the established limits, the soil was removed, packaged, and taken to the INEL RWMC for disposal. The resulting measured contamination levels are within the established safe limits. All operations were performed in accordance with standard safety procedures and monitored with standard exposure monitoring methods. Consequently, the D&D operation did not present any significant health risk to the workers.

3.2.2 Health Risk to National Monument Employees and Visitors. D&D of the EBR-I building and grounds has been accomplished to the extent that radioactivity in all areas accessible to NPS employees and visitors are within the acceptable safe standards. Some areas where minor radioactive or other hazards exist have been placarded with caution signs and closed off to prevent unauthorized personnel entry.

Finally, some areas where significant contamination remains, such as the fuel washroom, reactor cell and the primary NaK drain tank, have been permanently sealed off. Consequently, hazardous radiation exposure to National Park Service employees and visitors is considered to be nonexistent.

III. CONCLUSIONS AND RECOMMENDATIONS

The foregoing program demonstrated that the D&D of a major radioactively contaminated complex could be accomplished satisfactorily, on schedule, within budgeted funding and without significant safety hazard to the personnel involved in the operation. From the experience, certain conclusions may be drawn and some recommendations given for consideration in the event similar D&D operations are entertained in the future.

On the basis of the D&D work performed and the results of the final radiation and contamination survey, the following conclusions may be drawn:

- (1) The EBR-I complex has been rendered safe for visitors and NPS personnel.
- (2) Areas not meeting the ERDA radiation and/or contamination criteria have been effectively isolated from the public and NPS personnel.
- (3) The physical appearance of the EBR-I as an operational reactor has been preserved.
- (4) The procedures established for facility and equipment decontamination, and for handling, transport and disposal of contaminated and/or radioactive materials were proven to be satisfactory and safe.
- (5) The isolation concept (as applied to certain areas of the facility where decontamination efforts were proven to be extremely costly or impossible to achieve short of demolition and removal) is considered valid where physical appearance must be preserved.
- (6) The safe removal, processing and disposal of bulk quantities of alkali metal (NaK) has been demonstrated.

Experience gained in the EBR-I D&D operation, particularly as related to NaK removal, processing and disposal, suggest the following recommendations for consideration should similar D&D operations be entertained in the future:

- (1) Use nickel or high-nickel alloy steel for vessels, pipe lines and components which will be in long-term contact with caustic liquids.
- (2) Avoid use of thin wall carbon steel or stainless steel flex lines for any liquid caustic service – intermittent or long term.
- (3) Injection of NaK and GN_2 through an atomizing nozzle, as herein described, should be accomplished with higher injection pressure to reduce the problem of nozzle plugging.
- (4) When using an atomizing nozzle, as herein described, provide for introduction of wet GN_2 or steam to the atomizing side of the nozzle to help clear a plugged nozzle.

- (5) The demister, in the system herein described, did not provide acceptable caustic removal from the process vessel VFE-1 off gas. Back-up removal systems such as a condensor or a scrubber and knockout drum should be provided to achieve the required level of caustic removal. This requirement is particularly necessary for longterm operation of a plant to avoid filter problems.
- (6) Use of heat tape for preheating of thin walled components such as filter assemblies should be done with caution to avoid problems due to thermal stresses.
- (7) An integrator should be used in conjunction with the EMFM in order to keep a running total of the amount of NaK processed.
- (8) The vent stack drain should be supplied with a pump and return line to recycle condensate to the process vessel, VFE-1.
- (9) Redundant pumps should be supplied in critical service such as the demineralized water system and the scrub water recycle system in order to provide capability for continuous operation during periods of pump outage for service.

IV. REFERENCES

- (1) Safety Analysis Report for D&D of the EBR-I Complex (SAR 74-3).
- (2) An Explosive Hazards Analysis of the Eutectic Solution NaK and KO_2 (ANCR-1217).
- (3) Design Criteria for the EBR-I NaK Disposal Facility (ACI-154).
- (4) Waste Treatment Process for the Liquid Metal Coolant From the EBR-I Reactor (ICP-1076—to be published).
- (5) D&D of the EBR-I Complex, Topical Report No. 1—Removal of NaK from the EBR-I Storage Pit (ANCR-1166).

APPENDICES

- A. Program Plan for Decontamination and Decommissioning of the EBR-I Complex
- B. EBR-I Post-D&D Radiation Survey
- C. Plan for EBR-I Decontamination
- D. Operating Procedure EBR-I Pilot Plant
- E. Procedure for (NaOH) (KOH) Barrel Loading and Preparation for Disposal at the INEL RWMC
- F. EBR-I Pre-D&D Radiation Survey
- G. Alkali Metals Safety for the Decontamination and Decommissioning of EBR-I
- H. Design Criteria for the Removal of NaK at EBR-I
- I. EBR-I Support Services Reactivation Criteria
- J. Safety Analysis of the Pilot Test NaK Processing Equipment
- K. Procedure for Loading and Transfer of the EBR-I Cup Base From EBR-I to INEL RWMC
- L. Final Radiation Survey ZPR-III Facility
- M. Demolition Plan for the Argonne Fast Source Reactor Shielding
- N. Procedure for Removal of NaK From EBR-I Storage Pit

APPENDIX A

PROGRAM PLAN

FOR

DECONTAMINATION AND DECOMMISSIONING OF THE EBR-1 COMPLEX

Aerojet Nuclear Company

National Reactor Testing Station

September 1973

Prepared for the U. S. Atomic Energy Commission

Idaho Operations Office

Under Contract No. AT(10-1)-1375

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Program Plan
for
Decontamination and Decommissioning of the EBR-I Complex

I. Scope:

The object of this program is to make the EBR-I Complex, shown in Figure A-1, safe for the public use and enjoyment as a National Monument. The program scope includes Decontamination and Decommissioning (D&D) of: The Experimental Breeder Reactor (EBR-I-601); the Zero Power Reactor (RTF-601 ZPR-III); Argonne Fast Source Reactor (AFSR), and NaK Storage Pits, Drums and Miscellaneous Equipment. The decontamination effort includes: extraction of approximately 5000 gallons of sodium-potassium eutectic alloy (NaK) coolant contained in the EBR-I reactor loops; conversion of the NaK to a solid caustic for drum disposal in the NRTS burial ground; decontamination of all NaK and/or radioactive contaminated portions of the complex; and demolition or removal of parts of the complex which cannot be decontaminated to safe levels. The decommissioning effort includes: permanent isolation of portions of the complex which cannot be decontaminated to safe levels; restoration of the EBR-I physical appearance; restoration of EBR-I and ZPR-III support utilities; demolition of the AFSR containment; removal of all radioactive contaminated debris to the NRTS Burial Ground and all noncontaminated debris to the CFA Sanitary Landfill; and final surveillance and safety inspection to assure the safe condition of the EBR-I Complex.

II. Technical Plan

A Program Task Force was assembled August 15, 1973 under the direction of Project Manager J. C. Commander. The Task Force has participated in the development of the technical plan which is presented in four sections as follows: EBR-I Program Plan; ZPR-III Program Plan; AFSR Program Plan; and Miscellaneous Pits, Drums and Equipment Program Plan. Each section includes ANC's recommended course of action and alternative courses considered. The key personnel and organizations who have and will continue to participate are shown in Section IV, Task Force and Assignments.

A. EBR-I Program Plan. EBR-I has been designated a Registered National Historic Monument, and it is planned to make the building EBR-I-601, a part of the National Park System. Prior to transfer of this building to the National Park Service, it must be made safe for the general public. This portion of the Program Plan outlines the recommended course of action for converting the building to a safe condition while maintaining its physical appearance as an operational facility. The major problem involves the 5,000 gallons of bulk NaK stored in two drain tanks, and films and residues of NaK or its oxides distributed in the remainder of the piping and appurtenances. Figure A-2 shows the approximate configuration of the EBR-I NaK Systems. The Primary and Secondary NaK systems were drained into their respective drain tanks (T-3 and T-6) about ten years ago. At that time observations at an observable location, such as at the reactor tank, showed evidence of oxide

A-2

Figure A-1 EBR-I Area

scum. Since that time the NaK systems have been pressurized with argon gas, however, it is probable that some limited leakage into the system of oxygen and water vapor could have occurred via molecular diffusion and permeability of system materials. It is considered very likely, therefore, that portions of the NaK systems will contain residues of NaK and its various oxides. In addition, the primary system, which contains 4000 gallons of NaK, was contaminated by the 1955 core meltdown. Analysis indicates a total cesium contamination of 18 curies; however, due to surface affinity relative concentrations could be higher in the oxide scum. In view of the potential hazards associated with the NaK extraction from these systems, a comprehensive program plan, Figure A-3, has been prepared and is recommended for AEC approval. The plan is arranged to identify seven major areas of activity, each of which is further subdivided into the specific scheduled activities which must be done to complete the EBR-I D&D.

1. Project Management. The Project Manager is responsible for the planning and direction of the project and has assembled the Task Force which will accomplish the work. The key people and their task assignments are shown in Section IV of the Program Plan. Additionally, the Project Manager will address the tasks of personnel training, preparation of D&D Procedures, and preparation of the SAR.

2. Technical Research and Development. The R&D effort will be supported by Allied Chemical Corporation (ACC) and Argonne National Laboratories (ANL). The extent of involvement and the interface between these organizations and ANC is defined in Section III of the Program Plan.

The EBR-I Plant Assessment is in process and consists of: a detailed radiation level facility survey; physical assessment of the support systems; an inventory of all non-facility materials and equipment; review of the EBR-I operating procedures related to the Primary and Secondary NaK coolant loops; and a listing of components suspected of containing undrainable pockets or deposits of NaK and/or oxides.

The Hazards Evaluation has not yet been initiated, and will consist of: a radiation hazard evaluation; and a chemical (NaK/KO₂) hazards evaluation. Specific questions to be investigated in the latter are: propagation rate of the NaK/KO₂ reaction including the effects of shock, vibration, sound, temperature and contamination; maximum credible contamination of the NaK loops by various contaminants such as O₂, H₂O, N₂ organics, etc.; expected locations of contaminate concentrations; worse case hypothetical overpressure to the system due to reaction of calculated concentrations of contaminants; and steps to be taken to prevent overpressurizing the NaK systems. A consultant, Dr. Jack Riley of ANSUL Chemical Corporation, will be retained to support the NaK/KO₂ hazards analysis. The reaction rate studies will consist of approximately 30 experiments which will be conducted under laboratory conditions in one of the TRF Hot Cells, where remote handling equipment can be utilized to minimize danger to personnel.

The NaK Removal Criteria will be developed following hazards analysis and will include: conceptual approach, design limits, safety standards, system operation limits, system requirements, and sequence of removal operations.

indicates activity period

Figure A-3 EBR-I Program Plan

The NaK Processing Criteria can proceed independent of the NaK/KO₂ studies and will include: conceptual design; system requirements; process flow sheet; operating limits; design limits; and safety standards. Since the NaK treatment equipment will be expendable, use of surplus vessels and equipment will be investigated at this stage.

The Decontamination Criteria will parallel the NaK removal criteria and will include: conceptual design; system requirements; operating limits; design limits; and safety standards. The system level of contamination and degree of danger involved in the decontamination effort will be considered at this point, and decision will be made as to whether a specific item should be decontaminated in place, cut-out and removed, or permanently isolated in place.

The Demolition and Isolation Criteria will parallel and be similar to the Decontamination Criteria. All areas where demolition or isolation is required will be defined. Demolition will be required in order to gain access to isolated equipment and to extract hazardous components from the system prior to decontamination. Isolation will be considered when radiation levels are above allowable limits and cannot be economically reduced, or when a hazardous condition exists and can't be rectified.

The Support Services Reactivation Criteria can be initiated immediately. This will involve review of the support systems including water, power, lighting, heating and ventilation, plant air, materials handling, etc., and involvement of reactivation requirements.

3. Engineering. ANC's Engineering Division will provide the design and drafting services required to convert design criteria to complete work packages.

Support Services Reactivation Design will include preparation of work packages for reactivation of services required to support the D&D program and to provide for public safety. Specific areas of concern include the plant water system which has been partially deactivated, the boiler plant which may not be economical to reactivate, the fire protection system, portions of the electrical light and power system, and the heating and ventilating system.

NaK Removal System Design will include preparation of work packages to support the bulk NaK removal from the system. Involved is 4000 gallons of slightly contaminated NaK in the primary loop and 1000 gallons of contaminated NaK in the secondary loop. The tentative design approach will be to use the present argon cover gas system to pressurize the respective NaK drain tanks causing the NaK to flow in reverse of the fill sequence. This would require design of a transfer pipe line extension from the fill line valves on the main floor to the NaK treatment equipment, design of a dip leg into the reactor vessel where approximately 50 gallons of residual NaK is trapped, and connection piping between the dip leg and the transfer pipe line. Supplementary heating or cooling systems may be required pending the results of the NaK/KO₂ reaction studies.

NaK Process Equipment Design will include preparation of work packages required to allow fabrication of the conversion equipment. The conceptual treatment approach is to convert the NaK to concentrated caustic solution which will solidify in drums upon cooling from the reaction temperature. The concept shown by Figure A-4 requires design of a NaK

Figure A-4 NaK Processing Equipment Concept

feed tank, a reaction vessel, demister, HEPA filter, flare stack, control and process electrical, feed instrumentation, safety instrumentation, and a drum filling, weighing and valving system. It is tentatively planned to locate the treatment equipment on an existing concrete pad located southwest of Building EBR-601. The treatment equipment is considered expendable, therefore maximum use will be made of excessed government equipment. In line with this, a hold has been placed on several EOCR excessed vessels (VFE-1,2,3, and 4) pending development of firm design criteria and evaluation of their potential value as NaK feed and reaction vessels.

Decontamination System Design will include preparation of work package required for the fabrication and installation of the decontamination system equipment. The conceptual decontamination approach is based upon use of moist nitrogen gas (GN_2) to react the NaK and oxide residues to hydroxides with the evolution of hydrogen gas (GH_2), to be followed by a water rinse. The system will require a rental liquid to gas vaporizer capable of supplying approximately 200,000 CF of GN_2 per week; a means of introducing controlled amounts of moisture; process piping from the GN_2 system to the EBR-I primary and secondary piping systems and components; off-gas scrubber, filter and flare stack capable of flaring GH_2 ; containers for collecting nuclide-contaminated caustic; and a water flush system.

Demolition and Isolation Design will include preparation of work packages required to identify the demolition work. For minor activities the design may consist of field sketches and hand written instructions prepared at the work site by the engineer. If the design involves preparation of instructions for removal of potentially hazardous items, however, it will require prior safety evaluation and Program Management approval. Items in this category may include any component suspected of containing significant residues of NaK and/or oxides such as the primary gas system strainer; the NaK primary system cold trap, the NaK bubbler (argon gas purifier) and the primary system expansion tank. In the event components and/or areas cannot be decontaminated to safe levels, it may be necessary to design permanent isolation walls to prevent public entrance. Areas in this category may include the cave, the washer rack, the elevator shaft, and the reactor cell.

Design Follow up and Inspection will include checkout of fabricated items and installed systems which will be used in the D&D work; and inspection of reactivated support services. Field changes shall be subject to a formal design review system.

4. Safety. ANC's Safety Division will provide the Health-Physics Surveillance, Safety Reviews and Audits required to insure that the work of EBR-I D&D is proceeding in a safe manner.

Health-Physics Surveillance will be required at all times the EBR-I Building 601 is occupied. The ANL close-out survey will provide a basis for comparison against current radiation levels, for estimation of induced radiation decay rates, and for planning decontamination activities.

Safety Reviews will be required of the NaK removal system and procedures; the NaK processing system and procedures, and the decontamination system and procedures. In addition, Safety will perform the normal audit associated with work in a hazardous area.

5. AEC Approval. AEC-ID will be expected to provide all necessary AEC reviews and obtain approval of the Program Plan, the NaK Removal System; the NaK Treatment System, the D&D Criteria and the SAR. Approvals will be required in accordance with the program plan schedule.

6. D&D Operations. ANC's Construction and Site Services Division will provide the supervision and labor to perform the D&D Operations, assuming that the work is found to be non-covered by the ANC and AEC Davis-Bacon Committees. The work will include:

- . Support Services Reactivation
- . Fabricate NaK Removal System (Temporary Installation)
- . Fabricate NaK Treatment Equipment (Expendable Equipment)
- . Fabricate Decontamination System (Temporary Installation)
- . NaK Removal Operations
- . NaK Treatment Operations (By ACC)
- . Solidified Caustic Disposal Operations (Approximately one hundred 55-gallon drums)
- . Demolition and Isolation
- . Restoration of Physical Appearance.

7. Transfer Operations. ANC's Technical Services Division in conjunction with the Safety Division and AEC participants will make the final inspection of the EBR-I to assure that the facility is safe for transfer to the National Park Service, and that restoration activities have, to the greatest extent possible, restored the physical appearance of the facility. Transfer operations will include preparation of an EBR-I D&D report and the necessary transfer documents. Transfer of EBR-I to the National Park Service will take place prior to July 1, 1975.

B. ZPR-III Program Plan. ZPR-III is contained in Building RTF-601 which is situated approximately 74 ft east of EBR-I and is within the same fenced area, as can be seen in Figure 1. The building has a 48' x 66' x 31' high bay reactor assembly area which houses the ZPR-III reactor and a 102' x 66' x 13' low bay area which contains office space, restrooms and service areas, etc. The high bay section is constructed of massive structural concrete walls, some of which are 5 - 0 thick. The high bay area is suspected of having some alpha contamination in and around ZPR-III. The low bay area is constructed of concrete block and is essentially radiation free. Based on the foregoing, alternative approaches considered for ZPR-III D&D were as follows:

Construct an isolation barrier fence between EBR-I and RTF-601 and maintain RTF-601 in a locked condition.

Reactivate RTF-601 low bay support services for public use and permanently isolate ZPR-III in the high bay assembly area by filling in all openings with reinforced concrete block walls.

Reactivate RTF-601 high and low bay support services for public use; remove all contaminated material including the ZPR-III reactor from the high bay area; and dispose of radioactive contaminated waste in the Burial Ground.

Remove contaminated material including ZPR-III from RTF-601, dispose of radioactive contaminated waste at the Burial Ground, demolish the building, dispose of uncontaminated solid waste at the CFA Sanitary Landfill, return site to original condition.

The approach which is recommended and forms the basis for the ZPR-III Program Plan is to reactivate RTF-601 high and low bay for public use; to remove all contaminated material including the ZPR-III reactor from the high bay area; and to dispose of the radioactive waste in the Burial Ground. It is felt that the first two alternatives do not meet the intent of the D&D directive and that the last alternative would require the unnecessary demolition of a usable building at considerable expense to the government. Except for the suspected alpha contamination, hazards involved in the proposed D&D work are minimal, therefore, the Program Plan is comparatively simple. The plan, Figure A-5, identifies seven areas of activity, each of which is subdivided into specific scheduled activities which must be done to complete the ZPR-III D&D.

1. Project Managment. The Task Force which will accomplish the ZPR-III D&D has not yet been assembled; however, it is expected that many of the key people assigned to the EBR-I D&D will also receive assignments to the ZPR-III D&D Task Force.

2. Technical Evaluation. The ZPR-III Plant Assessment and Hazards Evaluation will be accomplished by ANC's Technical Services Division and the Safety Division. The close-out survey for ZPR-III has been received from ANL and will form a base for evaluation of the direct radiation and alpha contamination levels and preparation of a hazards evaluation and decontamination criteria. The feasibility of decontamination of the ZPR-III reactor parts to levels below 10 nanocuries of Pu per gram will be investigated. Parts so decontaminated could be stored at Pad A at the NRTS Burial Ground. Parts which cannot be cleaned sufficiently will require packaging for transportation and disposal on the ITSA Pad.

3. Engineering. ANC's Engineering Division will design the work packages required to provide for reactivation of support services, to direct the demolition of the ZPR-III reactor into parts which can be decontaminated; and to provide for fabrication of packaging for alpha contaminated waste.

4. Safety. ANC'S Safety Division will provide similar services to those defined in the EBR-I Program Plan. Health-Physics surveillance will be required during the ZPR-III demolition and decontamination activities.

■ indicates activity period

Figure A-5 ZPR-III Program Plan

5. AEC Approval. AEC-ID will be expected to obtain approval of the ZPR-III Program Plan and the contamination cleanup criteria.

6. D&D Operations. ANC's Construction and Site Services Division will provide the supervision and labor to perform the support services reactivation, the ZPR-III reactor demolition and the decontamination effort. ANL recommends the use of "Filter Queen" vacuum cleaner for cleaning up residual dust. Ultrasonic cleaners will be used to clean the contaminated reactor parts. Residues from the cleaning operations will be collected, solidified and packaged for disposal at the Burial Ground

7. Transfer Operations. Transfer operations will be similar to those described in the EBR-I Program Plan.

C. AFSR Program Plan. The AFSR building and the AFS reactor have been removed as has all the control instrumentation and electrical gear. Remaining are the below-grade basement, source storage vault and withdrawal hardware; and the above-grade steel-lined concrete shielding structure with view ports and access ports to the centrally located reactor cell. External radiation levels are too low to register, and internal radiation levels are expected to be low judging from the ANL close-out survey. Based on the foregoing information, alternative approaches considered for the AFSR D&D were as follows:

Construct an isolation barrier around the AFSR and seal all openings in the remaining concrete structure.

Demolish the above-grade portion of the structure level to the concrete slab; fill all open spaces in the basement with sand; pour concrete plugs in openings in the slab; and create a terrain feature by covering the slab with five feet of native soil and rock.

Demolish the total structure; remove all materials to the Burial Ground or the Sanitary Landfill; and fill the remaining void with native soil and rock.

The second approach is recommended and forms the basis for the AFSR Program Plan. The first alternative doesn't meet the intent of the D&D directive, and the third alternative involves the unnecessary expense of demolition and removal of below-grade inert concrete. The Program Plan, Figure A-6, identifies the scheduled activities required to complete the AFSR D&D. Supplemental narrative to explain the plan is not felt to be necessary.

D. NaK Storage Pit, Drums and Miscellaneous Equipment Program Plan. The EBR-I Complex contains a number of items not physically connected to major structures which must be processed in order to complete the EBR-I Complex D&D. These items are described as follows:

NaK Storage Pit. This pit is located approximately 100 ft west of EBR-601. It is approximately 8 ft deep by 10 ft in diameter with 1/4 in. thick carbon steel wall. The pit contains four waste packages including two 55-gallon drums and two specially fabricated containers which were filled with the NaK present in the reactor core at the time of the core

Figure A-6 AFSR Program Plan.

meltdown in November of 1955. The NaK is highly radioactive and may contain uranium, plutonium, and potassium super oxide. The pit is covered by a heavy metal lid. The radiation level at 6 in. above the lid is approximately 200 mR.

Drums. There are thirty-seven 55-gallon drums stock-piled along the west fence line. These drums have residual amounts of NaK remaining and were left in a sealed state with an argon gas cover. There is no radiation level associated with the drums or their contents. It is suspected that NaK oxides including the superoxide (KO_2) may have formed on the surfaces of NaK residuals remaining in the drums.

Miscellaneous Equipment. There are 36 large concrete shielding blocks approximately 1' - 4" x 2' - 0" x 5' - 0" in dimension. One or two of these blocks appear to be contaminated to a spot contact level of 200mr; however, the remainder do not appear to be contaminated. There are several sections of steel buildings which have been partially demolished and left on the site. The section's do not appear to be contaminated. There are two concrete slabs from which the buildings have been removed. The slabs are not contaminated.

Based on the foregoing information, alternative approaches considered for the NaK Storage Pit and its contents were as follows:

Leave contaminated packages in place in the NaK Storage Pit; cast packages in concrete to a level two feet below grade; remove upper two feet of pit well; and fill and grade with native soil.

Freeze the contents of packages using LN_2 or Solid CO_2 ; remove the contaminated packages and transport to temporary engineered storage area; seal packages in place for future recovery and processing; demolish top two feet of pit; and fill pit to the surface with native soil.

Freeze the contents of packages using LN_2 or Solid CO_2 ; move packages to hot cell; cut packages open; extract controlled amounts of frozen contaminated NaK; allow controlled portions to react slowly with hot moist GN_2 ; vent gases through HEPA filter; collect caustic reaction product for disposal at Burial Ground.

The second approach is recommended and forms the basis for the D&D of the NaK Storage Pit. The first approach has the disadvantage of leaving radioactive contaminated material unattended at a National Monument. This is not felt to be acceptable regardless of the isolation technique utilized to protect the public. The third approach may form the basis for a future decontamination program; however, it is felt that more research and development effort than is presently contemplated would be required to prove the feasibility of the controlled freeze-thaw decontamination technique.

Alternative approaches considered for the disposal of residuals in the 37 NaK Drums were as follows:

Move NaK drums individually to the NaK Disposal Pad; erect concrete shield blocks around the drum; using remote torch to cut cover from drum; react contents with remote directed water spray.

Freeze contents of NaK Drums using LN_2 or Solid CO_2 ; move drums individually to the NaK Disposal Pad; attach GN_2 Line to NaK discharge nozzle; attach vent line to vent stack; react NaK with moist GN_2 ; collect caustic product of reaction.

Same as second alternative except use caustic solution to react the NaK.

Since the NaK in these drums is non-contaminated, use them for experimental purposes, i.e., use all three methods on individual drums; document results; establish best treatment method; apply benefits of experience and learning curve to the problem of the bulk quantities of NaK in EBR-I.

The last approach is recommended and forms the basis for the D&D of the residual NaK in the thirty-seven 55-gallon drums.

Disposal of the Miscellaneous Equipment is considered to be non-hazardous. The large concrete blocks will be used for explosive shielding until the NaK disposal program is completed. They will then be moved to the CFA Sanitary Landfill, as will the several portions of metal building which litter the site. The uncontaminated concrete pads will be allowed to remain in place. The Program Plan Figure A-7, identifies the scheduled activities required to complete the NaK Storage Pit, Drums and Miscellaneous Equipment D&D. Supplemental narrative to explain the Program Plan in greater detail is not felt to be necessary.

NaK STORAGE PIT, DRUMS AND MISC. EQUIPMENT PROGRAM PLAN

indicates activity period

Figure A-7 NaK Storage Pit, Drums, and Miscellaneous Equipment Program Plan

III. ANC/ACC/ANL Interface and Involvement.

As lead organization responsible for carrying out the Commission's decontamination and decommissioning program for ID facilities at the NRTS, ANC has already established contact with key personnel in ACC and ANL to support the D&D of the EBR-I Complex. Supporting personnel from ACC and ANL will interface directly with the ANC Project Manager, Mr. J. C. Commander. ACC has assigned Dr. L. C. Lewis of the Process & Technical Support Branch as their interface with the project. ANL has participated in our early assessment of the project by designating Messrs. C. C. Miles and C. B. Doe as key personnel who are knowledgeable of EBR-I facilities and the potential problems associated with the D&D of the EBR-I Complex. ANL-West Manager, Mr. R. G. Staker, has been very cooperative in allowing ANL personnel to assist ANC in the information gathering cycle; however, he has to this date received no direction from the ANL home office to provide continued technical support to ANC.

A. ANL Consultant Service. Very few personnel who were members of the EBR-I staff when it was an operational facility are still employed by ANL-West. Among them is Mr. C. C. Miles, a chemical engineer, who was the ANL designated project manager for proposed study and decontamination operations at EBR-I. In that capacity, he obtained experience and information which should be made available to ANC. It is recommended that the AEC attempt to obtain Mr. Miles services on a part time basis as a technical consultant during the R&D effort associated with the hazards evaluation of NaK/KO₂. Additionally, Mr. C. B. Doe, a technician, is the only person available who has operational experience at EBR-I. He was also responsible for the plant shutdown and his experience would be of great value during the D&D operations. It is therefore recommended that the AEC attempt to obtain Mr. Doe's services on a part-time basis as an operations consultant during the D&D operations.

B. ACC-EBR-I NaK Disposal. ACC will support the effort associated with the hazards evaluation of NaK/KO₂ and the preparation of the SAR. They will prepare the design criteria for NaK aqueous processing equipment and operating procedures for its use. They will provide technical and operations direction of the NaK processing operations and the operating personnel required to operate the equipment including the drumming operations associated with the solid caustic waste generated. Dr. L. C. Lewis has been assigned by ACC as the key man associated with this effort.

IV. Task Force and Assignments.

The EBR-I Complex D&D program task force was assembled August 15, 1973 in anticipation of ANC receiving responsibility for the Commissions D&D program of inactive ID Facilities at the NRTS. The Task Force members shown in Figure A-8 were given an indoctrination tour of the EBR-I facility and provided with preliminary program plans. The plan now presented includes the constructive efforts of the task force members to present a realistic and comprehensive plan.

V. Cost Estimate.

The cost estimate by fiscal year for D&D of the EBR-I Complex has been prepared based on the four program plans described in Section II. The ANC labor and material costs for FY 74 and 75 associated with the EBR-I Program Plan are shown in Table A-1. ACC labor for the same program is shown in Table A-2. ANC labor and material costs for FY 74 and 75 associated with the ZPR-III, the AFSR and the NaK Storage Pit, Drums and Miscellaneous Equipment Program Plans are shown in Tables A-3, A-4, and A-5 respectively. A summary cost schedule is shown in Table A-6. The total program plan is based on an expenditure of \$325,000 in FY 74 and \$415,000 in FY 75.

VI. Environmental Assessment.

A. Title: Decontamination and Decommissioning of the EBR-I Complex,

B. Proposed Action: This program will provide for the final decommissioning of the first Experimental Breeder Reactor (EBR-I), the Zero Power Reactor (ZPR-III), the Argon Fast Source Reactor (AFSR) shielding, and NaK storage pits, drums and miscellaneous equipment. It involves the removal and processing of the liquid metal coolant (the eutectic alloy of sodium and potassium) NaK; The decontamination of all radioactive contaminated portions of the complex; the demolition and removal of portions of the complex which cannot be made safe and/or detract from the area appearance; and rendering of EBR-I-60I and RTF-60I-APR-III and EBR-I safe for the public use and enjoyment as a National Historic Landmark. The program is described in detail in Section II of the EBR-I complex D&D program plan.

C. Potential Environmental Impact: This program is to remove physical, chemical and radiation hazards associated with the EBR-I complex. Since the EBR-I will be maintained as a National Historic Landmark with free access by the public, no physical appearance changes will be permitted to violate the historic appearance of the facility. Accordingly, no permanent facilities will be constructed, and equipment used for processing the NaK and decontaminating the facilities will be dismantled and removed from the complex. As a result, environmental impact from construction activities will be minimal. Materials potentially hazardous to the environment are presently being stored at the EBR-I complex. These materials will be removed and processed to produce a more stable product which can

Assignment	Name	Organization
Project Manager	J. C. Commander	ANC, Tech. Services
Technical, R&D	L. C. Lewis	ACC, Process & Support Tech.
Technical, Consultant	C. C. Miles ⁽¹⁾	ANL, Chemist
Technical, Consultant	Dr. J. Riley ⁽²⁾	ANSUL Chem. Corp.
Technical, Explos. Tests	R. C. Green	ANC, Safety
Engineering	R. S. McPherson	ANC, Engineering
Safety Review & Audit	T. H. Stickley	ANC, Safety
Safety Health Physics	R. C. Green	ANC, Safety
D&D Oper. Consultant	C. B. Doe ⁽¹⁾	ANL, Technician
D&D Oper. Superintendent	C. F. Peeper	ANC, Maintenance
D&D Oper. Process.	Dr. L. C. Lewis	ACC, Proc. & Support Tech.
D&D Oper. Transportation	C. E. Denning	ANC, Transportation
Transfer Operation	W. Koutnik	ANC, C&SS

(1) Subject to AEC/ANL Negotiations

(2) Subject to ANC/ANSUL Consulting Agreement

Figure A-8 EBR-I Complex D&D Program Task Force and Assignments

TABLE A-1

EBR-I D&D COST ESTIMATE - ANC LABOR & MATERIALS

Activity	FY-74				FY-75			
	1stQ	2ndQ	3rdQ	4thQ	1stQ	2ndQ	3rdQ	4thQ
Project Management	2	5	5	5	5	5	5	5
Technical Research & Dev.	6	19						
EBR-I Plant Assessment	2	3						
Hazards Evaluation	2	10						
Support Services React. Criteria	2	2						
NaK Removal Criteria		2						
Decontamination Criteria		1						
Demolition & Isolation Criteria		1						
Engineering	5	27	14	12	8			
Support Services React. Design	5							
NaK Removal System Design		5	4					
NaK Processing Equip. Design		20	7					
Decontamination System Design				4	4			
Demolition & Isolation Design				5	4			
Design Followup & Inspection			2	3	3			
Safety	1	2	5	8	5	2	3	
Health Physics Surveillance		2	2	2	2	2		
Safety Review & Audit			3	3	3		3	
D&D Operations	3	10	14	26	20	28	9	
Support Services Reactivation	3	10			2			
Fab. NaK Removal System			2	6				
Fab. NaK Processing Equip.			12	12				
Fab. Decontamination Equip.				4	2			
Perform NaK Removal				2	4			
Perform NaK Processing				2	6			
Perform Caustic Disposal					3	1		
Perform Decontamination					3	12	1	
Perform Demolition & Isolation						9	6	
Restoration of Physical Appear.						6	2	
Materials	2	10	13	52	11	2	2	
Expendable Equipment	2	5	8	40	9			
Supplies	2	5	5	12	2	2		
Transfer Operations						2	6	9
Safety Inspection							3	
Final Report						2	6	4
Facility Transfer								2
Summary Cost/Quarter	11	44	60	93	59	39	44	23

Total ANC Labor & Mat. FY-74 \$208^k
 75 \$165^k
 Σ \$373^k

Note: Numbers represent units of \$1,000 and are additive to the solid lines above the dashed lines.

TABLE A-2

EBR-I D&D COST ESTIMATE - ACC LABOR

Activity	FY-74				FY-75			
	1stQ	2ndQ	3rdQ	4thQ	1stQ	2ndQ	3rdQ	4thQ
Technical Research & Dev.	5	15						
EBR-I Plant Assessment	2	1						
Hazards Evaluation	3	1						
NaK Removal Criteria			3					
NaK Processing Equip. Criteria		10						
Safety - SAR Support		5						
D&D Operations - NaK Process			15	15	30	30		
Process Support & Tech.			15	15	15	15		
Operations					10	15		
Operations & Env. Safety					5			
D&D Operations - Caustic Disposal					1	7	2	
Process Support & Tech.					1	2		
Operations						5	2	
D&D Operations Decontamination						5	10	
Process Support & Tech.						5		
Operations							10	
Summary Costs/Quarter	5	20	15	15	31	42	12	

Total ACC Labor FY-74 = \$ 55^k

$$\begin{array}{r} 75 = \$ 85^k \\ \hline \Sigma \quad \$140^k \end{array}$$

Note: Numbers represent units of \$1,000 and are additive to the solid lines above the dashed lines.

TABLE A-3

ZPR-III COST ESTIMATE - ANC LABOR & MATERIAL

Activity	FY-74				FY-75			
	1stQ	2ndQ	3rdQ	4thQ	1stQ	2ndQ	3rdQ	4thQ
Project Management	1 ←	2 →			2 ←	2 →	2 →	1 →
Technical Evaluation	1 ←	6 →						
ZPR-III Plant Assessment	1 ←	2 →						
Hazards Evaluation		2 →						
Decontamination Criteria		2 →						
Engineering		4 →						
Support Services Reactivation Des.		2 →						
Demolition Design		2 →						
Alpha Contamination Waste Pack Des.		2 →						
Safety					2 ←	4 →	1 →	1 →
Health Physics Surveillance					2 ←	1 →	1 →	1 →
Safety Review						3 →		
D&D Operations					8 ←	12 →	18 →	10 →
Support Services Reactivation					4 ←			
Decontamination					4 ←	6 →		
Demolition ZPR-III						6 →	18 →	
Package Alpha Contamination Part								6 →
Removal Parts to BG								4 →
Materials					3 ←	9 →	9 →	6 →
Equipment					2 ←	6 →	6 →	6 →
Supplies					1 ←	3 →	3 →	
Transfer Operations							3 →	3 →
Safety Inspection								1 →
Final Report							3 →	1 →
Facility Transfer								1 →
Summary Cost/Quarter	2	12			15	33	39	21

Total ANC Labor & Mat'l FY-74 \$ 14^k
 75 \$108^k
 Σ \$122^k

NOTE: Numbers represent units of \$1,000 and are additive to the solid lines above the dashed lines.

TABLE A-4

AFSR Cost Estimate ANC Labor & Materials

Activity	FY-74				FY-75			
	1stQ	2ndQ	3rdQ	4thQ	1stQ	2ndQ	3rdQ	4thQ
Project Management		1			2	1		
Technical Evaluation		2						
AFSR Assessment		1						
Hazards Evaluation		1						
Engineering		2						
Demolition Design		2						
Safety Review					2	2		
D&D Operations					9	10		
Demolition AFSR								
Removal Waste Material								
Fill and Cover								
Material					8	7		
Equipment								
Supplies								
Facility D&D Certification						1		
Summary Cost/Quarter		5			21	21		
Total ANC Labor & Mat. FY-74	\$ 5k							
	75 42k							
	Σ \$47k							

Note: Numbers represent units of \$1,000 and are additive to the solid lines above the dashed lines.

TABLE A-5

NaK STORAGE PIT, DRUMS AND MISC. EQUIPMENT COST EXT. ANC L&M

Activity	FY-74				FY-75			
	1stQ	2ndQ	3rdQ	4thQ	1stQ	2ndQ	3rdQ	4thQ
Project Management	1	2	2	1				
Technical Evaluation	2	6						
Assessment of Items	1	1						
Hazards Evaluation	1	4						
D&D Criteria			1					
Engineering		2	4					
NaK Storage Pit D&D Proc.			2					
NaK Drum Decon. & Removal Proc.	2							
NaK Disposal Pad - Support Design			1					
Misc. Equip. Disposal Proc.				1				
Safety	2		2	1				
Health Physics Surveillance	1		1	1				
Safety Review		1		1				
D&D Operations	6		4	2	5			
NaK Storage Pit				3				
NaK Drum Decon. & Removal		4						
Fab. NaK Disp. Pad Equip.	2							
Remove Contam. Residue to BG			1					
Remove Noncontam. Residue S.L.F.				2				
Materials	4		2		10			
Equipment		2	2					
Supplies	2							
Summary Cost/Quarter	3	22	14	4	15			

Total ANC Labor & Mat. FY-74 \$43k
 75 15k
 Σ \$58k

Note: Numbers represent units of \$1,000 and are additive to the solid lines above the dashed lines.

TABLE A-6

EBR-I Complex D&D Cost Summary

Program	FY-74	FY-75
EBR-I		
Labor ANC	131	150
Labor ACC	58	85
Materials	77	15
ZPR-III		
Labor ANC	14	81
Materials		27
AFSR		
Labor ANC	5	27
Materials		15
NaK Storage P.T. Drum & Misc. Equip.		
Labor ANC	37	5
Material	6	10
Total Labor & Materials	325	415

Note: Numbers represent units
of \$1,000.

be stored at the NRTS Burial Ground. Approximately 4000 gallons of NaK slightly contaminated with fission products (18 Ci of Cs¹³⁷) and 1000 gallons of uncontaminated NaK will be reacted with a low molar caustic solution to produce a highly concentrated 25 molar caustic product which will be drummed and allowed to solidify upon cooling. The reaction of the NaK with caustic solution will produce a water vapor - hydrogen off-gas, concentrated caustic, and heat. The off-gas will be scrubbed, filtered, and then flared at the point of release, which results in an acceptable release of water vapor. The caustic will be produced at a concentration which will allow solidification upon cooling. Cooling waters used during the reaction will be monitored for any sign of contamination, and, if uncontaminated, released to the environment with the only environmental effect being a slight increase in temperature of the water. The radioactively contaminated caustic waste must be isolated from the environment for long time periods, necessitating some minimal level of surveillance until it can be sent to permanent storage in a federal repository. Loss of integrity of a caustic storage drum would result in a maximum potential release per drum of 180 millicuries of Cs¹³⁷. The uncontaminated solid caustic will be delivered to the Idaho Chemical Processing Plant (ICPP) for use in plant operations, or disposed of at the NRTS acid disposal pit.

The NaK Storage Pit at EBR-I contains 4 waste packages including two 55-gallon drums and two specially fabricated containers which are filled with highly contaminated NaK and are also suspected of containing potentially explosive potassium superoxide. These containers will be cooled using LN₂ or solid CO₂ until the contents are frozen to minimize handling hazards. The packages will then be removed from the NaK Storage Pit and placed in acceptable interim storage at NRTS until such time as a facility is available to safely open and treat the contents of the containers.

There are thirty-seven 55-gallon drums which contain residual amounts of non-radioactive contaminated NaK. These containers will be transferred individually to the NaK Disposal Pad, and used to experimentally evaluate alternative methods for disposal of NaK. The caustic solution resulting from the reaction will be stored for use in the NaK Processing Equipment which will process the bulk quantities of NaK. After the NaK has been removed from the primary and secondary systems, it will be necessary to decontaminate the systems in order to remove films and pockets of NaK and its oxides. A moist GN₂ purge will be used to react the residual NaK and oxides, followed by a water flush and a hot GN₂ drying. Off-gases from the decontamination cycle will be scrubbed, filtered, and flared to produce an acceptable water vapor and GN₂ off-gas. The contaminated caustic solutions resulting from the decontamination flush activities will be delivered to the ICPP for processing. The uncontaminated dilute caustic solutions will be disposed of at the NRTS Acid Disposal Pit.

The only conceivable detrimental environmental impact which could be associated with this program would result from an unplanned accident such as possible explosions during the NaK removal operations. There is some justifiable concern regarding the potential for an explosion due to the interaction between NaK and potassium superoxide (KO₂). In light of this concern, a technical research and development effort will precede any NaK removal operations. The effort will include: a hazards evaluation; NaK/KO₂ explosives potential laboratory experiment and a Safety Analysis Report (SAR). The research and development effort will provide the information to develop a NaK removal criteria and

procedures which will minimize the chances of an unexpected violent reaction. The uncontaminated NaK will be removed and processed first in order that the experience gained can be utilized to provide the maximum level of confidence in the NaK removal techniques prior to their use to remove the contaminated NaK.

D. Alternatives: Since EBR-I is to be made accessible to the public, non-action as an alternative cannot be considered due to the radiation and chemical hazards associated with the NaK coolant in the facility. Alternatives to the program recommended, with discussion and evaluation, are as follows:

1. Leave primary and secondary drain tanks "as is", - isolate them from public access; and decontaminate the remainder of the NaK systems. This approach would eliminate the need to remove contaminated NaK systems. This approach would eliminate the need to remove contaminated NaK and to process the bulk quantities of NaK contained in the system drain tanks. The disadvantage of this approach is that once the facility is transferred to the National Park Service, the inert cover gas cannot be guaranteed. Eventually caustic attack could cause leaks in the drain vessels with metal fires and contamination resulting.

2. Remove Bulk Quantities of NaK and Oxide Residuals. This alternative requires removal and treatment of the bulk NaK. However, it doesn't provide for decontamination of the system. If the metal were solid at room temperature and if no radioactivity existed, the approach would be adequate. The major disadvantage is that it would be impossible to determine that all residuals of NaK had oxidized. If unreacted pockets of NaK remained, corrosion could eventually release the liquid metal or vibrations could cause a NaK/KO₂ reaction with a potential release of radioisotopes.

3. Remove Bulk NaK Quantities and React Residuals with Organics. In this scheme, an organic is used to react the NaK residuals. The organic could be pumped through the system as a liquid or a hot vapor. Since the reaction products are usually insoluble in the hydrocarbon, a final water wash will be necessary. The disadvantages of this system are: contacting possible films of KO₂ with organics is not recommended; and use of large quantities of flammable liquids in EBR-I with the resultant concentrations of explosive vapors is questionable.

4. Remove Bulk NaK Quantities and Dissolve Residuals with Liquid Ammonia. In this approach, the residual NaK would be dissolved in liquid ammonia and drained from the system. The metal oxides will not dissolve in the ammonia and would require reaction and flushing with water. The advantage of this approach is that there is little heat or hydrogen evolution associated with the process. The disadvantages of this system are: Liquid ammonia at 80° SF forms explosive mixtures in air in the concentration range of 15-28%; to successfully use the method, about 5000 gallons of liquid ammonia would be necessary; ammonia is a poisonous and highly detectable gas and an accidental release would be very hazardous; and the disposal of 5000 gallons of contaminated liquid ammonia adds unnecessarily to the waste disposal problem.

5. Demolish and Remove System Components. In this approach, all piping, pumps, valves and tanks having NaK residuals or films would be removed from the EBR-I building and the residual NaK reacted on the outdoor NaK disposal Pad. The advantage is that the NaK reaction could be done external to the building minimizing damage to the building in the event of a NaK/KO₂ explosive reaction. Disadvantages are that the operation could be hazardous to the cleanup crew; the removed component would require reinstallation after cleaning in order to restore the physical appearance of the facility; and in some cases such as removal of the drain tanks, the tasks would involve massive demolition work and be extremely expensive.

6. Removal of Bulk NaK to Storage and Decontaminate Systems per Program Plan. The advantage of this approach is that the NaK would not require processing. The disadvantages include: Need to procure approximately 100 NaK storage drums; and identification of a suitable storage location for both the uncontaminated and the contaminated NaK. Storage of NaK at the NRTS Burial Ground would not be acceptable because of its liquid state and potential explosive and fire hazard.

Removal of Bulk NaK for Processing at ICPP and Decontamination of Systems per Program Plan. The disadvantages of this approach is: It would require collection of the NaK in small storage tanks; hauling the contaminated NaK across public highways; and preparation of a suitable isolated area for conducting the processing operations.

Alternative methods for Decommissioning and Decontamination of other features of the EBR-I Complex are described and evaluated in Section II of this Program Plan.

E. Cumulative and Long Term Environmental Effects: This project will remove any potential fire or explosion hazards associated with the NaK at EBR-I. It will enable public access to the EBR-I site for its historical value. Surveillance of the abandoned facility must continue in any event. Accordingly, use of the facility by the public is desirable. Because of the historical significance of the EBR-I facility the cumulative effects of this project on the environment must be minimal. The small packages of contaminated NaK will be placed in a retrievable storage area for future processing in a facility capable of handling the material. The uncontaminated caustic will be used in routine operations at the Idaho Chemical Processing Plant in place of caustic procured from commercial suppliers. Because the quality of this chloride-free caustic is so much higher than that provided by commercial suppliers, corrosion problems caused by impurities will be lessened.

F. Irreversible and Irretrievable Commitments: Disposal of approximately 100 drums of caustic product and the conversion equipment in a contaminated storage area will necessitate a small amount of land and surveillance until the only detectable isotope, ¹³⁷CS (30 year half life), has decayed to background. The highly contaminated NaK will be placed in retrievable storage for processing according to future guidelines on disposal of highly contaminated alkali metal wastes.

G. Conflicts with State, Regional, or Local Programs: There are no known conflicts with any state, regional, or local plans as a result of implementation of this proposal. In fact the State of Idaho Governor requested the D&D of EBR-I to be completed by July 1, 1975 for the Bicentennial Celebration.

H. Cost Benefit Analysis: Disposal of contaminated solid caustic is immeasurably safer than the storage of contaminated liquid metal because of the fire and explosion hazards that are associated with the metal and not with the caustic.

In terms of public relations, the ability for the public to have access to a facility that has contributed so much to the energy needs of the United States has a significant favorable information value for the atomic industry. It would represent a facility constructed during a period of environmental "non-awareness" and that had suffered a significant malfunction, operated subsequent to that malfunction, and yet had been successfully decommissioned without significant problems.

A limited amount of surveillance, much of it routinely provided during routine operation of the NRTS Burial Ground, would be required to guarantee that no release of activity could occur inadvertently from the stored caustic and the contaminated equipment. A small amount of space in the burial ground will be committed to the disposal of contaminated equipment and the 100 drums of contaminated caustic.

I. Recommendation Concerning Environmental Statement: Since the EBR-I Complex is an existing facility requiring only the decommissioning and decontamination services to allow its transfer to the Department of Interior, it is felt that the preparation of an Environmental Statement is unnecessary. The Environmental Assessment adequately portrays the desirability of proceeding with the program, and the improved position of the clean EBR-I Complex with regard to potential environmental impact.

J. Summary. It is in the public interest to allow public access to the EBR-I Complex which has been declared a National Historic Landmark. Before public access can be freely allowed, the physical, chemical and radioactive hazards must be removed. This program provides for the safe removal of hazards, for the conversion of contaminated NaK to a more readily stored solid caustic; for the removal of all conversion equipment, caustic product and contaminated effluent from the Complex. A small space at the NRTS Burial Ground will be utilized for storage of the radioactive contaminated solids. Nonexplosive radioactive liquids will be sent to the ICPP for processing. Hazards (potentially explosive) contaminated NaK will be stored at an interim storage facility awaiting future processing. Alpha contaminated portions of the ZPR-III Facility will also be decontaminated, and equipment which defies decontamination will be disassembled, packaged and stored at the NRTS Burial Ground. It is felt that the benefits of proceeding with this course of action far outweigh those of continued inaction regarding D&D of the Complex.

APPENDIX B

EBR-I FINAL RADIATION SURVEY POST D&D OPERATION

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Prepared For:
U.S. ENERGY RESEARCH & DEVELOPMENT ADMINISTRATION
IDAHO OPERATIONS OFFICE
UNDER CONTACT NO. AT(10-1)-1375

ABSTRACT

EBR-I FINAL RADIATION SURVEY POST D&D OPERATION

The EBR-I Final Radiation Survey consists of a summary, table of contents, the final radiation survey reports for each area listed in the table of contents and a table which shows radiation survey comparisons, pre vs post D&D operations. The radiation survey report includes: the location; name of HP surveyor; instruments used in the survey; results of the survey; and area plot plans showing the smear sample locations. Those areas where direct radiation could not be reduced to 0.1 mR/hr; or where smear samples registered higher than 1000 d/m/100² cm βγ; or registered higher than 20 d/m/100² cm α were isolated in an approved manner so that the radiation level at the isolation barrier would not exceed 0.1 mR/hr. Those areas which were isolated from the public are in the EBR-I Radiation Survey Summary. Details of the survey may be obtained by turning to the survey report for the area of interest.

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EBR-I RADIATION SURVEY SUMMARY

All areas of the EBR-I Complex either meet the exposure limits set forth in the EBR-I Decontamination and Decommissioning Criteria, or are isolated. Areas isolated are as follows:

1. The gallery has 0.5 mR/hr to 1.5 mR/hr direct radiation sources. These sources have been isolated with a concrete slab and read 0.1 mR/hr at contact with the slab.
2. The left corner of the cold gas pump room (on the Mezzanine Floor) has fixed contamination on both the wall and floor. The levels of this contamination are 0.5 to 1.8 mR/hr. Concrete slabs reduce these levels to 0.1 mR/hr at contact.
3. The convection loop room has 45 mR/hr at contact with piping and 5 mR/hr general field in the rear. The entrance has been sealed off with plexiglass and reads 0.1 mR/hr at the entrance.
4. The rod farm is isolated with plexiglass sheeting covering 0.5 mR/hr to 3 mR/hr direct radiation. The reading at the surface of the plexiglass is 0.1 mR/hr.
5. There are three casks placed in the reactor area that have fixed contamination levels of from 0.3 to 60 mR/hr at contact with the bottoms. While left in upright position, with the bottom of the cask on the floor, the contact reading with the cask is 0.1 mR/hr.
6. The washroom cell is isolated with a lead shielding door bolted to the floor. The cell has a contact reading of 15 mR/hr with a general field of 1 mR/hr. The radiation level at the sealed door is 0.05 mR/hr.
7. The elevator cell is also isolated with a lead shielding door bolted to the floor. The cell radiation levels are: 25 R/hr contact with cylinder, 5 R/hr general field on platform and 250 mR/hr general field at ground level. The radiation level at the sealed door is 0.1 mR/hr.
8. The T-2 NaK tank room has radiation levels of 3 mR/hr at contact with pipes and a general field of 0.1 mR/hr. This area is isolated with plexiglass at the entrance and reads 0.1 mR/hr at the doorway.

9. The NaK-to-NaK heat exchange room has radiation levels of 30 mR/hr at contact with a general field of 0.5 mR/hr. This area is isolated with plexiglass at the entrance. The radiation level at the entrance is 0.1 mR/hr.

10. The primary NaK dump tank room radiation levels are 50 mR/hr at contact with tank and 5 mR/hr general field. This area is isolated with concrete blocks and reads 0.1 mR/hr at entrance.

RADIATION SURVEY REPORT

LOCATION: Gallery

DATE: 5/21/75

SURVEYOR: S. J. Keating

TIME: 1000

RESULTS: $< 1,000 \text{ d/m/100}^2 \text{ cm}^2$ and $< 20 \text{ d/m/100}^2 \text{ cm}^2$ removable contamination with 0.1 mr/hr direct radiation.

The isolated area is a concrete slab placed on a 0.5 to 1.5 mr/hr fixed contamination source. The contact reading on the slab is 0.1 mr/hr.

<p>INSTRUMENTS USED:</p> <p>☐ PIC 6</p> <p>☒ GM</p> <p>☒ RM-14</p> <p>☐ Other</p>	<p>AIR SAMPLE TAKEN: ☐ Yes ☒ No</p> <p>RESULTS:</p> <p>Was Respiratory Equipment Used? ☐ Yes ☒ No</p> <p>Type:</p>
---	--

Gallery

Room <i>Galley</i>		Smear Media <i>Whitman 50's</i>		Remarks: <i>90 μ/100μ - B8 4 μ/100μ - L 0.1 m/hr direct radiation</i>		
Date <i>5/21/75</i>	Time <i>1000</i>	Sampled & Counted by: <i>L.J.K.</i>				
Unit Area Smear <i>100μ Cu</i>		Count time <i>1 min</i>				

Location Smear	Counts/minute gross	Background counts/minute	Counts/minute net	Counter yield	Disintegrations per minute/unit area	Initials
1	0 / 15	.72 / 16.85	0 / 0	33% / 100%	0 / 0	LJK
2	0 / 21		0 / 5		0 / 50	
3	0 / 18		0 / 2		0 / 20	
4	1 / 16		.3 / 0		.9 / 0	
5	1 / 25		.3 / 9		.9 / 90	
6	0 / 20		0 / 4		0 / 40	
7	0 / 17		0 / 1		0 / 10	
8	0 / 13		0 / 0		0 / 0	
9	0 / 22		0 / 6		0 / 60	
10	0 / 18		0 / 2		0 / 20	
11	1 / 17		.3 / 3		.9 / 30	
12	0 / 22		0 / 6		0 / 60	
13	1 / 23		.3 / 7		.9 / 70	
14	0 / 22		0 / 6		0 / 60	
15	2 / 17		.3 / 1		.9 / 10	
16	0 / 24		0 / 8		0 / 80	
17	0 / 19		0 / 3		0 / 30	
18	1 / 16		.3 / 0		.9 / 0	
19	0 / 25		0 / 9		0 / 90	
20	0 / 15		0 / 0		0 / 0	
21	1 / 26		.3 / 4		.9 / 40	

RADIATION SURVEY REPORT

LOCATION: Mezzanine Floor

DATE: 3/6/75

SURVEYOR: S. J. Keating

TIME: 1300

RESULTS: ≤ 1000 d/m/100² cm $\beta\gamma$ and ≤ 20 d/m/100² cm α removable contamination with .1 mr/hr direct radiation.

The left corner of the cold gas pump room is isolated with a 6" concrete slab on the wall. This is covering a 0.5 mr/hr to 1.8 mr/hr fixed contamination source. There is also a 4" concrete slab on the floor covering a 0.5 to 1 mr/hr fixed contamination source.

INSTRUMENTS USED:

- ☐ PIC 6
- ☒ GM
- ☒ RM-14
- ☐ Other

AIR SAMPLE TAKEN:

☐ Yes ☒ No

RESULTS:

Was Respiratory Equipment Used?

☐ Yes ☒ No

Type:

B

Room		Smear Media		Remarks:		
Megjansu floor		Whalman 50's		180 d/m/100cm ² B8		
Date	Time	Sampled & Counted by:		3.6 d/m/100cm ² α		
2/6/75	1300	S.J.K		0.1 mR/hr direct radiation		
Unit Area Smeared		Count time				
100cm ²		1 min				
Location Smeared	Counts/minute gross	Background counts/minute	Counts/minute net	Counter yield	Disintegrations per minute/unit area	Initials
1	1 17	.8 α 11 B8	.2 6	33% 10%	.6 60	S.J.K
2	0 21		0 10		0 100	
3	0 21		0 10		0 100	
4	0 9		0 0		0 0	
5	1 15		.2 4		.6 40	
6	0 12		0 1		0 10	
7	0 14		0 3		0 30	
8	2 23		1.2 12		3.6 120	
9	0 16		0 5		0 50	
10	0 5		0 0		0 0	
11	0 11		0 0		0 0	
12	0 13		0 2		0 20	
13	0 18		0 7		0 40	
14	1 12		.2 1		.6 10	
15	1 25		.2 14		.6 140	
16	1 29		.2 18		.6 180	
17	0 7		.2 0		.6 0	
18	0 11		0 0		0 0	
19	1 13		.2 2		.6 20	
20	0 10		0 0		0 0	
21	1 7	✓	.2 0	✓	.6 0	✓

B-12

B

Location Smeared	Counts/minute gross	Background counts/minute	Counts/minute Net	Counter Yield	Disintegrations per minute per unit area	Initials
22	2 / 11	.82 / 11.82	1.2 / 0	33% / 10%	3.6 / 0	S.J.K.
23	1 / 19		.2 / 8		.6 / 80	
24	1 / 17		.2 / 6		.6 / 60	
25	0 / 20		0 / 9		0 / 90	
26	0 / 22		0 / 11		0 / 11	
27	0 / 15		0 / 4		0 / 40	
28	0 / 21		0 / 10		0 / 100	
29	0 / 20		0 / 9		0 / 90	
30	0 / 28		0 / 17		0 / 170	
31	1 / 23	↓	.2 / 12	↓	.6 / 120	↓

RADIATION SURVEY REPORT

LOCATION: Top Floor Office Area

DATE: 5/22/75

SURVEYOR: S. J. Keating

TIME: 0900

RESULTS: $< 1000 \text{ d/m/100}^2 \text{ cm}^2$ and $< 20 \text{ d/m/100}^2 \text{ cm}^2$
removable contamination with 0.1 mr/hr direct radiation.

INSTRUMENTS USED:	AIR SAMPLE TAKEN:	☐	☒
		Yes	No
☐ PIC 6	RESULTS:		
☐ GM			
☒ RM-14	Was Respiratory Equipment Used?	☐	☒
☐ Other	Type:	Yes	No

Top Floor Office Area

Room		Smear Media		Remarks:		
Top floor office area		Whatman 50's		140 d/m/100 ² cm B8		
Date	Time	Sampled & Counted by:		3.3 d/m/100 ² cm 2		
5/22/75	0900	S.J.K.		0.1 mR/hr direct radiation		
Unit Area Smeared		Count time				
100 ² cm		1 min				
Location Smeared	Counts/minute gross	Background counts/minute	Counts/minute net	Counter yield	Disintegrations per minute/unit area	Initials
1	0 22	.9 180	0 24	33% 100	0 40	S.J.K.
2	1 17		.1 0		.3 0	
3	1 16		.1 0		.3 0	
4	0 19		0 1		0 10	
5	1 25		.1 7		.3 7	
6	1 32		.1 14		.3 140	
7	1 18		.1 0		.3 0	
8	1 17		.1 0		.3 0	
9	0 21		0 3		0 30	
10	0 27		0 9		0 90	
11	1 23		.1 5		.3 50	
12	1 20		.1 2		.3 20	
13	2 28		1.1 10		3.3 100	
14	2 22		1.1 4		3.3 40	
15	0 21		0 3		0 30	
16	1 25		.1 7		.3 70	
17	0 18		0 0		0 0	
18	1 15		.1 0		.3 0	
19	0 17		0 0		0 0	
20	0 21		0 3		0 30	
21	0 29	✓	0 11	✓	0 110	✓

Location Smear	Counts/minute gross	Background counts/minute	Counts/minute Net	Counter yield	Disintegrations per minute per unit area	Initials
22	280 28	.92	0 10	33%	0 100	JyK
23	0 23	1808	0 5	10%	0 50	
24	2 26		1.1 8		3.3 80	
25	1 19		.1 1		.3 10	
26	2 18		1.1 0		3.3 0	
27	1 20		.1 2		.3 20	
28	1 26		.1 8		.3 80	
29	1 20		.1 2		.3 20	
30	1 23		.1 5		.3 50	
31	1 29		.1 11		.3 110	
32	0 22		0 4		0 40	
33	0 25		0 7		0 70	
34	1 18		.1 0		.3 0	
35	1 19		.1 1		.3 10	
36	1 19		.1 1		.3 10	
37	0 26		0 8		0 80	
38	0 20		0 2		0 20	
39	0 24		0 6		0 60	
40	0 29		0 11		0 110	
41	0 25		0 7		0 70	
42	1 22		.1 4		.3 4	
43	0 16		0 0		0 0	
44	1 17		.1 0		.3 0	
45	1 23		.1 5		.3 5	
46	0 25	✓	0 7	✓	0 70	✓

RADIATION SURVEY REPORT

LOCATION: Machinist Area

DATE: 6/5/75

SURVEYOR: S. J. Keating

TIME: 1400

RESULTS: $<1000 \text{ d/m/100}^2 \text{ cm } \beta\gamma$ and $<20 \text{ d/m/100}^2 \text{ cm } \alpha$
removable contamination with 0.1 mr/hr direct radiation.

INSTRUMENTS USED:

- ☐ PIC 6
- ☒ GM
- ☒ RM-14
- ☐ Other

AIR SAMPLE TAKEN:

☐ Yes ☒ No

RESULTS:

Was Respiratory Equipment Used?

☐ Yes ☒ No

Type:

B-20

D

Room <i>Machinest Area</i>		Smear Media <i>Whatman 50's</i>		Remarks: <i>140 d/m/100² cm B8</i> <i>5.4 d/m/100² cm α</i> <i>.1 mR/hr direct radiation</i>		
Date <i>6/5/75</i>	Time <i>1400</i>	Sampled & Counted by: <i>S.J.K.</i>				
Unit Area Smeared <i>100² cm</i>		Count time <i>1 min</i>				
Location Smeared	Counts/minute gross	Background counts/minute	Counts/minute net	Counter yield	Disintegrations per minute/unit area	Initials
1	1 10	.2 α	.8	33% 10%	2.4 20	<i>S.J.K.</i>
2	0 15		0 7		0 70	
3	0 6		0 0		0 0	
4	0 12		0 4		0 40	
5	0 19		0 11		0 110	
6	0 17		0 9		0 9	
7	0 25		0 17		0 170	
8	0 16		0 8		0 80	
9	0 12		0 4		0 40	
10	1 5		.8 0		2.4 0	
11	1 10		.8 2		2.4 20	
12	0 9		0 1		0 10	
13	0 10		0 2		0 20	
14	0 13		0 5		0 50	
15	1 11		.8 3		2.4 30	
16	0 16		0 8		0 80	
17	0 12		0 4		0 40	
18	0 7		0 0		0 0	
19	1 8		.8 0		2.4 0	
20	1 12		.8 4		2.4 40	
21	1 14	✓	.8 6	✓	2.4 60	

Location Smeared	Counts/minute gross	Background counts/minute	Counts/minute Net	Counter yield	Disintegrations per minute per unit area	Initials
22	0 / 17	22 / 8.8	0 / 9	33% / 102%	0 / 90	J/K
23	0 / 21		0 / 13		0 / 130	
24	0 / 20		0 / 12		0 / 120	
25	2 / 11		1.8 / 3		5.4 / 30	
26	1 / 15		.8 / 7		2.4 / 70	
27	0 / 8		0 / 0		0 / 0	
28	0 / 5		0 / 0		0 / 0	
29	0 / 14		0 / 6		0 / 60	
30	0 / 10		0 / 2		0 / 20	
31	1 / 17		.8 / 9		2.4 / 90	
32	0 / 11		0 / 3		0 / 30	
33	0 / 12		0 / 4		0 / 40	
34	1 / 15		.8 / 7		2.4 / 70	
35	0 / 18		0 / 10		0 / 100	
36	1 / 22	✓	.8 / 14	✓	2.4 / 140	✓

RADIATION SURVEY REPORT

LOCATION: Boiler Room

DATE: 6/5/75

SURVEYOR: S. J. Keating

TIME: 1430

RESULTS: <1000 d/m/100² cm $\beta\beta$ and <20 d/m/100² cm α removable contamination with 0.1 mr/hr direct radiation.

INSTRUMENTS USED:

- ☐ PIC 6
- ☐ GM
- ☒ RM-14
- ☐ Other

AIR SAMPLE TAKEN:

☐

Yes

☒

No

RESULTS:

Was Respiratory Equipment Used?

☐

Yes

☒

No

Type:

BOILER ROOM

E

Room <i>Boiler room</i>		Smear Media <i>Whatman 50's</i>		Remarks: <i>170 d/m/100² cm B8</i> <i>2.4 d/m/100² cm α</i> <i>.05 mR/hr direct radiation</i>		
Date <i>6/5/75</i>	Time <i>1430</i>	Sampled & Counted by: <i>S.J.K.</i>				
Unit Area Smear <i>100² cm</i>		Count time <i>1 min</i>				

Location Smear	Counts/minute gross	Background counts/minute	Counts/minute net	Counter yield	Disintegrations per minute/unit area	Initials
1	1 / 10	.22 / 8 B8	.8 / 2	33% / 100%	2.4 / 20	SJK
2	0 / 8		0 / 0		0 / 0	
3	0 / 7		0 / 0		0 / 0	
4	0 / 12		0 / 4		0 / 40	
5	0 / 15		0 / 7		0 / 90	
6	1 / 25		.8 / 17		2.4 / 170	
7	1 / 18		.8 / 10		2.4 / 100	
8	0 / 10		0 / 2		0 / 20	
9	1 / 8		.8 / 0		2.4 / 0	
10	0 / 11		0 / 3		0 / 30	
11	0 / 13		0 / 5		0 / 50	
12	1 / 15		.8 / 7		2.4 / 70	
13	0 / 14		0 / 6		0 / 60	
14	0 / 9		0 / 1		0 / 10	
15	0 / 6		0 / 0		0 / 0	
16	0 / 19		0 / 11		0 / 110	
17	0 / 15	✓	0 / 7	✓	0 / 70	

RADIATION SURVEY REPORT

LOCATION: Convection Loop Room

DATE: 4/23/75

SURVEYOR: S. J. Keating

TIME: 1130

RESULTS: $< 1000 \text{ d/m}/100^2 \text{ cm}$ $\beta\gamma$ and $< 20 \text{ d/m}/100^2 \text{ cm}$ α removable contamination with 45 mr/hr at contact with piping and 5 mr/hr general field at the rear.

This area is isolated with a plexiglass barrier at the entrance. The direct radiation field at the entrance is 0.1 mr/hr.

INSTRUMENTS USED:

- ☐ PIC 6
- ☒ GM
- ☒ RM-14
- ☐ Other

AIR SAMPLE TAKEN:

☐

Yes

☒

No

RESULTS:

Was Respiratory Equipment Used?

☐

Yes

☒

No

Type:

Convection Loop Room

Room <i>Construction Shop room</i>		Smear Media <i>Whitman 50's</i>		Remarks: <i>180 d/m/100² cm 38</i> <i>7.8 d/m/100² cm 2</i>			
Date <i>4/23/75</i>	Time <i>1130</i>	Sampled & Counted by: <i>SJK</i>					
Unit Area Smeared <i>100² cm</i>		Count time <i>1 min.</i>					
Location Smeared	Counts/minute gross	Background counts/minute	Counts/minute net	Counter yield	Disintegrations per minute/unit area	Initials	
1	1 / 18	.42 / 11.58	.6 / 7	33% / 107%	1.8 / 70	SJK	
2	2 / 10		1.6 / 0		4.8 / 0		
3	0 / 14		0 / 3		0 / 30		
4	0 / 15		0 / 4		0 / 40		
5	0 / 17		0 / 6		0 / 60		
6	1 / 11		1.6 / 0		1.8 / 0		
7	0 / 15		0 / 4		0 / 40		
8	1 / 21		.6 / 10		1.8 / 100		
9	3 / 12		2.6 / 1		7.8 / 10		
10	0 / 19		0 / 8		0 / 80		
11	0 / 27		0 / 16		0 / 160		
12	0 / 29		0 / 18		0 / 180		
13	2 / 24	✓	1.6 / 13	✓	4.8 / 130		✓

RADIATION SURVEY REPORT

LOCATION: Crane Bay Area

DATE: 6/5/75

SURVEYOR: S. J. Keating

TIME: 1500

RESULTS: $< 1000 \text{ d/m/100}^2 \text{ cm } \beta\gamma$ and $< 20 \text{ d/m/100}^2 \text{ cm } \alpha$ removable contamination with 0.1 mr/hr direct radiation.

<p>INSTRUMENTS USED:</p> <p>☐ PIC 6</p> <p>☐ GM</p> <p>☒ RM-14</p> <p>☐ Other</p>	<p>AIR SAMPLE TAKEN: ☐ Yes ☒ No</p> <p>RESULTS:</p> <p>Was Respiratory Equipment Used? ☐ Yes ☒ No</p> <p>Type:</p>
--	--

Room		Smear Media		Remarks:		
Date	Time	Sampled & Counted by:				
Unit Area Smear	Count time					
Cromley Ave		Whalman 50's		330 d/m/100 ² cm B8 5.4 d/m/100 ² cm d .1 m ² /hr direct radiation		
6/5/75 1500		S.J.K.				
100 ² cm		1/min.				
Location Smear	Counts/minute gross	Background counts/minute	Counts/minute net	Counter yield	Disintegrations per minute/unit area	Initials
1	1 / 20	.2 / 8.50	.8 / 12	33% / 10%	2.4 / 120	S.J.K.
2	1 / 15		.8 / 8		2.4 / 90	
3	0 / 12		0 / 4		0 / 40	
4	0 / 17		0 / 9		0 / 90	
5	1 / 19		.8 / 11		2.4 / 110	
6	0 / 13		0 / 5		0 / 50	
7	0 / 14		0 / 6		0 / 60	
8	1 / 21		.8 / 13		2.4 / 130	
9	1 / 25		.8 / 17		2.4 / 170	
10	2 / 17		1.8 / 9		5.4 / 90	
11	0 / 32		0 / 24		0 / 240	
12	0 / 19		0 / 11		0 / 110	
13	1 / 10		.8 / 2		2.4 / 20	
14	0 / 9		0 / 1		0 / 10	
15	1 / 36		.8 / 28		2.4 / 280	
16	1 / 28		.8 / 20		2.4 / 20	
17	1 / 16		.8 / 8		2.4 / 80	
18	1 / 41		.8 / 33		2.4 / 330	
19	0 / 27		.8 / 19		0 / 190	
20	0 / 18		0 / 10		0 / 100	
21	0 / 10	↓	0 / 12	↓	0 / 20	

RADIATION SURVEY REPORT

LOCATION: Reactor Area

DATE: 6/5/75

SURVEYOR: S. J. Keating

TIME: 1500

RESULTS: $< 1000 \text{ d/m/100}^2 \text{ cm}^2$ and $< 20 \text{ d/m/100}^2 \text{ cm}^2$ removable contamination with 0.1 mr/hr direct radiation.

The rod farm is isolated with plexiglass sheeting covering 0.5 mr/hr to 3 mr/hr. The reading at the surface of the plexiglass is 0.1 mr/hr.

Three casks were placed in the reactor area with fixed direct radiation readings of .3 to 15 mr/hr on the bottom of each cask. There is a 60 mr/hr radiation source on the bottom of the cask on the reactor step. These contaminated areas are isolated as long as they are not moved. In a fixed position these casks read 0.1 mr/hr.

INSTRUMENTS USED:

- ☐ PIC 6
- ☒ GM
- ☒ RM-14
- ☐ Other

AIR SAMPLE TAKEN:

☐

Yes

☒

No

RESULTS:

Was Respiratory Equipment Used?

☐

Yes

☒

No

Type:

H

Room <i>Reactor area</i>		Smear Media <i>Whitman 50's</i>		Remarks: <i>430 d/m/100²cm (38)</i> <i>5.4 d/m/100²cm α</i> <i>0.1 mR/m direct radiation</i>		
Date <i>6/5/75</i>	Time <i>1500</i>	Sampled & Counted by: <i>S.J.K.</i>				
Unit Area Smeared <i>100² cm</i>		Count time <i>1 min</i>				
Location Smeared	Counts/minute gross	Background counts/minute	Counts/minute net	Counter yield	Disintegrations per minute/unit area	Initials
1	0 / 10	0.2	0 / 2	33%	0 / 20	<i>S.J.K.</i>
2	1 / 15		0.8 / 7	10%	2.4 / 70	
3	0 / 19		0 / 11		0 / 110	
4	0 / 21		0 / 13		0 / 130	
5	0 / 17		0 / 9		0 / 90	
6	0 / 14		0 / 6		0 / 60	
7	0 / 18		0 / 10		0 / 100	
8	0 / 20		0 / 12		0 / 120	
9	1 / 19		0.8 / 11		2.4 / 110	
10	0 / 29		0 / 21		0 / 210	
11	0 / 18		0 / 10		0 / 100	
12	0 / 15		0 / 7		0 / 70	
13	0 / 23		0 / 15		0 / 150	
14	0 / 17		0 / 9		0 / 90	
15	0 / 10		0 / 2		0 / 20	
16	0 / 8		0 / 0		0 / 0	
17	0 / 10		0 / 2		0 / 20	
18	1 / 15		0.8 / 7		2.4 / 70	
19	1 / 16		0.8 / 8		2.4 / 80	
20	1 / 32		0.8 / 24		2.4 / 240	
21	0 / 32		0 / 24		0 / 240	

Location Smeared	Counts/minute gross	Background counts/minute	Counts/minute Net	Counter yield	Disintegrations per minute per unit area	Initials
22	1 / 45	.2 / 8	.8 / 37	33%	2.4 / 370	SJK
23	2 / 38		1.8 / 30	10%	5.4 / 300	
24	0 / 42		0 / 34		0 / 340	
25	0 / 48		0 / 40		0 / 40	
26	1 / 25		.8 / 7		2.4 / 70	
27	1 / 30		.8 / 22		2.4 / 220	
28	2 / 49		1.8 / 41		5.4 / 410	
29	1 / 26		.8 / 18		2.4 / 180	
30	0 / 41		0 / 33		0 / 330	
31	1 / 51		.8 / 43		2.4 / 430	
32	0 / 21		0 / 13		0 / 130	
33	0 / 29		0 / 21		0 / 210	
34	0 / 16		0 / 8		0 / 80	
35	0 / 22		0 / 14		0 / 140	
36	1 / 21		.8 / 13		2.4 / 130	
37	1 / 26		.8 / 18		2.4 / 180	
38	1 / 14		.8 / 6		2.4 / 60	
39	0 / 23		0 / 15		0 / 150	
40	0 / 23		0 / 15		0 / 150	
41	0 / 10		0 / 2		0 / 20	
42	0 / 21		0 / 13		0 / 130	
43	2 / 49		1.8 / 41		5.4 / 410	
44	1 / 30		.8 / 22		2.4 / 220	
45	0 / 47		0 / 39		0 / 390	
46	0 / 25		0 / 17		0 / 170	
47	0 / 23	✓	0 / 15	✓	0 / 150	✓

Location Smeared	Counts/minute gross	Background counts/minute	Counts/minute Net	Counter yield	Disintegrations per minute per unit area	Initials
48	0 / 20	.2 / 8	0 / 12	33% / 10%	0 / 120	JLK
49-70 taken in and around Cave						
49	0 / 20		0 / 12		0 / 120	
50	1 / 25		.8 / 17		2.4 / 170	
51	0 / 28		0 / 20		0 / 200	
52	1 / 26		.8 / 18		2.4 / 180	
53	1 / 40		.8 / 32		2.4 / 320	
54	1 / 42		.8 / 34		2.4 / 340	
55	0 / 40		0 / 32		0 / 320	
56	0 / 45		0 / 37		0 / 370	
57	0 / 49		0 / 41		0 / 410	
58	0 / 41		0 / 33		0 / 330	
59	0 / 51		0 / 43		0 / 430	
60	0 / 29		0 / 21		0 / 210	
61	0 / 38		0 / 30		0 / 300	
62	1 / 33		.8 / 25		2.4 / 250	
63	0 / 47		0 / 39		0 / 390	
64	0 / 29		0 / 21		0 / 210	
65	0 / 19		0 / 11		0 / 110	
66	1 / 31		.8 / 23		2.4 / 230	
67	0 / 23		0 / 15		0 / 150	
68	0 / 33		0 / 25		0 / 250	
69	1 / 40		.8 / 32		2.4 / 320	
70	2 / 21	✓	1.8 / 13	✓	5.4 / 130	✓

RADIATION SURVEY REPORT

LOCATION: Annex Office Area

DATE: 5/5/75

SURVEYOR: S. J. Keating

TIME: 1030

RESULTS: ≤ 1000 d/m/100² cm $\beta\gamma$ and ≤ 20 d/m/100² cm α removable contamination with 0.05 mr/hr direct radiation.

INSTRUMENTS USED:

- ☐ PIC 6
- ☐ GM
- ☒ RM-14
- ☐ Other

AIR SAMPLE TAKEN:

☐

Yes

☒

No

RESULTS:

Was Respiratory Equipment Used?

☐

Yes

☒

No

Type:

Room		Smear Media		Remarks:		
Date	Time	Sampled & Counted by:				
Unit Area Smear	Count time					
Annex		Whitman 150's		340 d/m/100 ² cm Bx 6.9 d/m/100 ² cm d 105 m ² /hr direct radiation		
5/5/75	1030	SJT				
100 ² cm	1 min					
Location Smear	Counts/minute gross	Background counts/minute	Counts/minute net	Counter yield	Disintegrations per minute/unit area	Initials
1	12	.5	.5	33%	1.6	SJT
2	19		0	10%	0	
3	23		0		0	
4	17		0		0	
5	20		0		0	
6	21		.5		1.6	
7	32		.5		1.6	
8	18		1.5		47	
9	21		.5		1.6	
10	38		.5		1.6	
11	17		2.5		6.9	
12	15		0		0	
13	9		.5		1.6	
14	13		0		0	
15	19		0		0	
16	28		.5		1.6	
17	27		.5		1.6	
18	15		.5		1.6	
19	16		0		0	
20	38		0		0	
21	29	✓	0	✓	0	

Location Smeared	Counts/minute gross	Background counts/minute	Counts/minute Net	Counter yield	Disintegrations per minute per unit area	Initials
22	1 / 25	5 / 15	10	33% / 10%	1.6 / 100	J.K.
23	0 / 32		17		0 / 170	
24	0 / 17		2		0 / 20	
25	1 / 21		6		1.6 / 60	
26	1 / 19		4		1.6 / 40	
27	1 / 43		28		1.6 / 280	
28	1 / 37		22		1.6 / 220	
29	0 / 30		15		0 / 150	
30	0 / 37		22		0 / 220	
31	0 / 35		20		0 / 200	
32	0 / 22		7		0 / 70	
33	0 / 18		3		0 / 30	
34	0 / 32		17		0 / 170	
35	0 / 20		5		0 / 50	
36	0 / 31		16		0 / 160	
37	0 / 26		11		0 / 110	
38	1 / 27		12		1.6 / 112	
39	1 / 10		0		1.6 / 0	
40	2 / 14		0		4.7 / 0	
41	1 / 23		8		1.6 / 80	
42	0 / 19		4		0 / 40	
43	0 / 15		0		0 / 0	
44	10 / 32		22		0 / 220	
45	2 / 40		25		4.7 / 250	
46	1 / 49		34		1.6 / 340	
47	10 / 25	✓	10	✓	0 / 100	✓

I

Location Smeared	Counts/minute gross	Background counts/minute	Counts/minute Net	Counter yield	Disintegrations per minute per unit area	Initials
48	1 23	.5 15	8	35% 107%	1.6 80	S.K.
49	1 40		25		1.6 250	
50	0 32		17		0 170	
51	0 20		5		0 50	
52	0 37	↓	32	↓	0 220	↓

RADIATION SURVEY REPORT

LOCATION: Basement

DATE: 5/29/75

SURVEYOR: S. J. Keating

TIME: 1500

RESULTS: $< 1000 \text{ d/m}/100^2 \text{ cm } \beta\gamma$ and $< 20 \text{ d/m}/100^2 \text{ cm } \alpha$ removable contamination, with the exception of certain isolated areas, 0.1 mr/hr direct radiation

The washroom cell is isolated with a lead shielding door bolted to the floor. It has a contact reading of 15 mr/hr with a general field of 1 mr/hr. The radiation level at the entrance, through the shielding, is 0.05 mr/hr.

The elevator cell is also isolated with a lead shielding door bolted to the floor. It has a contact reading with the cylinder of 25 r/hr and 5 r/hr general field on the platform. There is a 250 mr/hr general field at ground level. See attachments on pages 4/ and 2 for the readings pertaining to the sodium vapor lights.

INSTRUMENTS USED:

- ☒ PIC 6
- ☒ GM
- ☒ RM-14
- ☐ Other

AIR SAMPLE TAKEN:

☐ Yes ☒ No

RESULTS:

Was Respiratory Equipment Used?

☐ Yes ☒ No

Type:

Room <i>Basement</i>		Smear Media <i>Whatman 50's</i>		Remarks: <i>320 d/m/100²cm P8</i> <i>2.1 d/m/100²cm d</i> <i>All areas not isolated</i> <i>are .1 m²/hr or less</i>		
Date <i>5/29/75</i>	Time <i>1500</i>	Sampled & Counted by: <i>SJK</i>				
Unit Area Smear <i>100²cm</i>		Count time <i>1 min</i>				

Location Smear	Counts/minute gross	Background counts/minute	Counts/minute net	Counter yield	Disintegrations per minute/unit area	Initials
1.	1 23	.3 10	.7 13	35% 10%	2.1 130	<i>SJK</i>
2	0 15		0 5		0 50	
3	0 17		0 7		0 70	
4	0 21		0 11		0 110	
5	0 19		0 9		0 90	
6	0 25		0 15		0 150	
7	0 16		0 6		0 60	
8	1 10		.7 0		2.1 0	
9	0 18		0 8		0 80	
10	0 5		0 0		0 0	
11	0 26		0 16		0 160	
12	0 14		0 4		0 40	
13	1 12		.7 2		2.1 20	
14	1 11		.7 1		2.1 10	
15	0 29		0 19		0 190	
16	0 17		0 7		0 70	
17	0 20		0 10		0 100	
18	0 23		0 13		0 130	
19	1 13		.7 3		2.1 30	
20	1 18		.7 8		2.1 80	
21	31	✓	0 21	✓	0 210	✓

Location Smeared	Counts/minute gross	Background counts/minute	Counts/minute Net	Counter yield	Disintegrations per minute per unit area	Initials
22	0 / 19	.3 / 10	0 / 9	35% / 10%	0 / 90	J/K
23	0 / 25		0 / 15		0 / 150	
24	0 / 27		0 / 17		0 / 170	
25	0 / 16		0 / 6		0 / 60	
26	0 / 32		0 / 12		0 / 120	
27	0 / 19		0 / 9		0 / 90	
28	0 / 10		0 / 0		0 / 0	
29	0 / 17		0 / 7		0 / 70	
30	0 / 9		0 / 0		0 / 0	
31	0 / 26		0 / 16		0 / 160	
32	0 / 19		0 / 9		0 / 90	
33	0 / 19		0 / 9		0 / 90	
34	0 / 17		0 / 7		0 / 70	
35	1 / 27		.7 / 17		2.1 / 170	
36	1 / 35		.7 / 25		2.1 / 250	
37	1 / 10		.7 / 0		2.1 / 0	
38	0 / 28		0 / 18		0 / 180	
39	0 / 20		0 / 10		0 / 100	
40	0 / 26		0 / 16		0 / 160	
41	0 / 26		0 / 16		0 / 160	
42	0 / 21		0 / 11		0 / 110	
43	0 / 17		0 / 7		0 / 70	
44	1 / 39		0 / 29		0 / 290	
45	1 / 42		.7 / 32		2.1 / 320	
46	1 / 26		0 / 16		0 / 160	
	1 / 19	✓	.7 / 9	✓	2.1 / 90	✓

sodium Vapor Lamps. elevation - south wall
elevator Room

RADIATION SURVEY REPORT

LOCATION: Subpile Room

DATE: 5/21/75

SURVEYOR: S. J. Keating

TIME: 1400

RESULTS: <1000 d/m/100² cm $\beta\gamma$ and <20 d/m/100² cm α removable contamination with 0.5 mr/hr that has been isolated. The rest of the room is 0.1 mr/hr direct radiation.

INSTRUMENTS USED:

- ☐ PIC 6
- ☒ GM
- ☒ RM-14
- ☐ Other

AIR SAMPLE TAKEN:

☐

Yes

☒

No

RESULTS:

Was Respiratory Equipment Used?

☐

Yes

☒

No

Type:

SUB PILE ROOM

K

Room <i>Silpik room</i>		Smear Media <i>Whalman 50's</i>		Remarks: <i>170 d/p/100² cm 58</i> <i>2.1 d/p/100² cm 2</i> <i>.1 m/p/m at sealed entrance</i>		
Date <i>5/21/75</i>	Time <i>1400</i>	Sampled & Counted by: <i>S.J.K.</i>				
Unit Area Smeared <i>100² cm</i>		Count time <i>1 min</i>				
Location Smeared	Counts/minute gross	Background counts/minute	Counts/minute net	Counter yield	Disintegrations per minute/unit area	Initials
1	1 / 17	32 / 10.8	.7 / 7	33% / 10%	2.1 / 70	<i>S.J.K.</i>
2	0 / 21		0 / 11		0 / 110	
3	0 / 16		0 / 6		0 / 60	
4	0 / 12		0 / 2		0 / 20	
5	0 / 17		0 / 7		0 / 90	
6	1 / 23		.7 / 13		2.1 / 130	
7	0 / 14		0 / 4		0 / 40	
8	0 / 12		0 / 2		0 / 20	
9	0 / 15		0 / 5		0 / 50	
10	0 / 18		0 / 8		0 / 80	
11	0 / 20		0 / 10		0 / 100	
12	1 / 27		.7 / 17		2.1 / 170	
13	0 / 22		0 / 12		0 / 120	
14	1 / 24	↓	.7 / 14	↓	2.1 / 140	

RADIATION SURVEY REPORT

LOCATION: T2 NaK Tank

DATE: 5/21/75

SURVEYOR: S. J. Keating

TIME: 1430

RESULTS: $<1000 \text{ d/m/100}^2 \text{ cm}^2$ and $<20 \text{ d/m/100}^2$ removable contamination.

This area is isolated with plexiglass at the entrance. It has pipes that 3 mr/hr at contact with a general field of 0.15 mr/hr. The radiation readings at the doorway is 0.1 mr/hr.

<p>INSTRUMENTS USED:</p> <p>☐ PIC 6</p> <p>☒ GM</p> <p>☒ RM-14</p> <p>☐ OTHER</p>	<p>AIR SAMPLE TAKEN ☐ Yes ☒ No</p> <p>RESULTS:</p> <p>Was Respiratory Equipment used? ☐ Yes ☒ No</p> <p>Type:</p>
---	---

Primary NaK
Transfer Corridor

Room		Smear Media		Remarks:		
Date		Sampled & Counted by:				
Unit Area Smeared		Count time				
T2 tank room		Whelton 50's		120 d/m/100 ² cm P8		
5/21/75		S.J.K.		2.1 d/m/100 ² cm 2		
1430		1 min				
100 ² cm						
Location Smeared	Counts/minute gross	Background counts/minute	Counts/minute net	Counter yield	Disintegrations per minute/unit area	Initials
1	20	.32	.02	10%	100	SJK
2	16		6		60	
3	13		3		30	
4	11		1		10	2.1
5	13		3		30	2.1
6	17		7		70	
7	19		9		90	
8	22		12		120	
9	20		10		10	
10	10		0		0	
11	21		11		110	

RADIATION SURVEY REPORT

LOCATION: NaK to NaK Heat Exchange

DATE: 5/21/75

SURVEYOR: S. J. Keating

TIME: 1330

RESULTS: $< 1000 \text{ d/m/100}^2\text{cm}$ $\beta\gamma$ and $< 20 \text{ d/m/100}^2\text{cm}$ α removable contamination.

The Heat Exchange area is isolated with plexiglass at the entrance. It has a contact radiation reading of 30 mr/hr and a general field reading of 0.5 mr/hr. It is 0.1 mr/hr at the entrance..

INSTRUMENTS USED:

☐ PIC 6

☒ GM

☒ RM-14

☐ OTHER

AIR SAMPLE TAKEN

☐ Yes ☒ No

RESULTS:

Was Respiratory Equipment used?

☐ Yes ☒ No

Type:

Room		Smear Media		Remarks:		
Date		Time		Sampled & Counted by:		
Unit Area Smeared		Count time				
NaK to NaK heat exchanger		Whalman 50's		330 d/n/100 ² cm Bx		
5/21/75		1330		S.J.K.		
100 ² cm		1 min		5.1 d/n/100 ² cm		
Location Smeared	Counts/minute gross	Background counts/minute	Counts/minute net	Counter yield	Disintegrations per minute/unit area	Initials
1	0 / 24	.30x / 10.5x	0 / 14	33% / 102	0 / 140	SJK.
2	0 / 31		0 / 21		0 / 210	
3	0 / 18		0 / 8		0 / 80	
4	0 / 17		0 / 7		0 / 70	
5	0 / 29		0 / 19		0 / 190	
6	0 / 23		0 / 13		0 / 130	
7	1 / 34		.9 / 24		2.1 / 240	
8	0 / 38		0 / 28		0 / 280	
9	0 / 41		0 / 31		0 / 310	
10	0 / 26		0 / 16		0 / 160	
11	2 / 23		1.7 / 13		5.1 / 130	
12	0 / 42		0 / 32		0 / 320	
13	0 / 43		0 / 33		0 / 330	
14	1 / 40		.7 / 30		2.1 / 200	
15	1 / 37	✓	.7 / 27	✓	2.1 / 270	✓

RADIATION SURVEY REPORT

LOCATION: Secondary NaK Pump & Dump Room

DATE: 5/21/75

SURVEYOR: S. J. Keating

TIME: 1500

RESULTS: $< 1000 \text{ d/m/100}^2\text{cm}$ $\beta\gamma$ and $< 20 \text{ d/m/100}^2\text{cm}$ α removable contamination.

This area is isolated with plexiglass at the entrance. The radiation levels are: 3 mr/hr at contact with pipes, the general field is 0.15 mr/hr. and the level at the doorway is 0.1 mr/hr.

INSTRUMENTS USED:

- ☐ PIC 6
- ☒ GM
- ☒ RM-14
- ☐ Other

AIR SAMPLE TAKEN:

☐

Yes

☒

No

RESULTS:

Was Respiratory Equipment Used?

☐

Yes

☒

No

Type:

N

N

Room <i>Secondary Rock pump & dump</i>		Smear Media <i>Whalmaria 50's</i>		Remarks: <i>190 d/m/100² m 38</i> <i>2.1 d/m/100² m 2</i> <i>.1 m/dm direct rad check</i>	
Date <i>5/31/75</i>	Time <i>1500</i>	Sampled & Counted by: <i>SJK</i>			
Unit Area Smeared <i>100² m</i>		Count time <i>1 min</i>			

Location Smeared	Counts/minute gross	Background counts/minute	Counts/minute net	Counter yield	Disintegrations per minute/unit area	Initials
1	15	3	.7	33%	2.1	SJK
2	25		0	10%	50	
3	10		0		150	
4	17		.7		10	
5	21		0		170	
6	16		.7		210	
7	14		0		2.1	
8	9		0		160	
9	28		0		0	
10	8		.7		40	
11	14		0		8	
12	17		.7		180	
13	29		.7		2.1	
14	14		0		0	
15	17	↓	0	↓	40	
					70	↓

RADIATION SURVEY REPORT

LOCATION: Primary NaK Dump Tank Room

DATE: 5/21/75

SURVEYOR: S. J. Keating

TIME: 1130

RESULTS: ≤ 1000 d/m/100²cm $\beta\gamma$ and ≤ 20 d/m/100²cm α removable contamination.

The NaK Tank has a contact reading with the tank of 50 mr/hr and a general field of 5 mr/hr. This area is isolated with concrete blocks and is reading 0.1 mr/hr. at contact with the entrance.

INSTRUMENTS USED:

- ☐ PIC 6
- ☒ GM
- ☒ RM-14
- ☐ Other

AIR SAMPLE TAKEN:

☐

Yes

☒

No

RESULTS:

Was Respiratory Equipment Used?

☐

Yes

☒

No

Type:

0

Room <i>Pumery</i> <i>Nah Dunge tank</i>		Smear Media <i>Whitman 50's</i>		Remarks: <i>360 d/m/100² in P8</i> <i>5.1 d/m/100² in d</i>	
Date <i>5/21/75</i>	Time <i>1130</i>	Sampled & Counted by: <i>SJK</i>			
Unit Area Smear <i>100² cm</i>		Count time <i>1 min</i>			

Location Smear	Counts/minute gross	Background counts/minute	Counts/minute net	Counter yield	Disintegrations per minute/unit area	Initials
1	1 / 25	.32 / 10 P8	.7 / 15	33% / 10%	2.1 / 150	SJK.
2	0 / 31		0 / 21		0 / 210	
3	0 / 37		0 / 27		0 / 270	
4	2 / 41		1.7 / 31		5.1 / 310	
5	1 / 46		.7 / 36		2.1 / 360	
6	1 / 29		.7 / 19		2.1 / 190	
7	1 / 27		.7 / 17		2.1 / 170	
8	0 / 14		0 / 4		0 / 40	
9	0 / 30		0 / 20		0 / 200	
10	0 / 32		0 / 22		0 / 220	
11	0 / 31		0 / 26		0 / 260	
12	1 / 12		.7 / 2		2.1 / 20	
13	0 / 19		0 / 9		0 / 90	
14	1 / 43		.7 / 33		2.1 / 330	
15	1 / 26		.7 / 16		2.1 / 160	
16	0 / 29		0 / 19		0 / 190	
17	1 / 38	↓	.7 / 28	↓	2.1 / 280	↓

RADIATION SURVEY REPORT

Location: External Grounds at EBR-I Date: 6/13/75
Requestor: J. C. Commander Time: 0930-1630
Surveyor: S. Keating
Request: Contamination and direct radiation survey of the external grounds at EBR-I
Results: Soils under the NaK processing pad (contaminated with ^{137}Cs when EBR-I was operational) and surface soils local to the NaK processing pad (which were contaminated to levels as high as 30,000 c/m during NaK processing) were removed, packaged and disposed of at the INEL RWMC. Soil was removed until a contamination reduction to 1000 c/m was achieved as a maximum. Every effort was made to achieve an even lower level of 500 c/m, which was possible in 90% of the contaminated areas. At this point, the average external beta-gamma radiation levels of the soil did not exceed 0.1 mR/hr at 125 cm (2000 c/m using an RM-14 with an HP 210 probe) and external beta-gamma radiation levels of soils were less than the specified 0.05 mR/hr at 3 feet from the surface. Residual low level contamination in the soil was then covered with approximately 3 inches of clean soil after which the area so treated was surveyed and found to be free from detectable radioactive contamination.

TABLE I RADIATION SURVEY COMPARISON - PRE VS POST D&D OPERATIONS

Area	Predecontamination		Post Decontamination		Remarks
	General Field mR/hr	Contact mR/hr	General Field mR/hr	Contact mR/hr	
Filter tank room	3	20	-	-	Piping and tank
Gravity tank room	3	12	0.5	4	Tank (isolated)
Convection loop room	50	190	5	45	Piping (isolated)
Cave rails	-	80	-	-	Spot reading
Cave	-	.7	-	-	Manipulators
Rod farm	-	-	-	-	-
Rod holes	-	-	-	3	(isolated)
West cell	-	-	-	-	-
Middle cell	2 R/hr	10 R/hr	-	-	At contact with ^{238}U Cup(removed)
Elevator cell	* 90	**1.5 R/hr	* 250	** 25 R/hr	Cylinder (isolated)
" "	* 60	-	* 200	-	At door
Decon cell	10	3	1	1	At door
" "	-	100	-	-	Wash tubes (removed)
Ventilator room	-	-	-	-	Middle ventilator
Sub pile room	-	-	-	0.5	At rear
T ₂ NaK receiving tank room	5	40	.15	3	At tank
" " " "	0.5	-	-	-	At door
NaK-to-NaK heat exchanger room	15	100	0.5	30	Heat exchanger
" " " " "	1	-	-	-	At door
Secondary NaK pump/pump room	3	-	-	-	Entrance to corridor leading to primary pump room
" " " "	-	5-45	-	-	Pipes near ceiling
" " " "	-	80	-	-	Primary pump
Primary NaK dump tank	200	250	5	50	Tank (isolated)

* The general field readings in the cell and at the door were taken from ground level. However, the post D & D readings were taken with the instrument pointed toward the 25 R/hr source.

** The contact radiation level of 1.5 R/hr was taken from floor level, whereas the 25 R/hr was taken from the platform.

APPENDIX C

PLAN FOR EBR-I DECONTAMINATION

J. C. Commander

Aerojet Nuclear Company
National Reactor Testing Station
Idaho Falls, Idaho 83401

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U. S. Atomic Energy Commission
Idaho Operations Office
Under Contract No. AT(10-1)-1375

PLAN FOR EBR-I DECONTAMINATION

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PLAN FOR EBR-I DECONTAMINATION

I. Introduction

The purpose of this document is to present the generalized plan for decontamination of the EBR-I facility (Building EBR-I-601 and its contained equipment). Detailed decontamination procedures will be developed following approval of the general plan for decontamination.

II. General

The EBR-I sustained initial criticality in 1951 with an operational loading of 52 kilograms of ^{235}U , and subsequently operated as planned between 1951 and 1954 with occasional operations to the maximum authorized power level of 1150 kw. Early in 1954, core II was loaded. Operations continued as planned until November, 1955, when an experiment was devised to operate at higher than normal fuel temperatures. At the time of the experiment, a slight operator error resulted in a 40 to 50% core melt down. Since the NaK coolant system was shut down during the experiment, the core contents had not migrated to a great extent beyond the core volume. After the core II removal, the contaminated NaK in the core vessel was removed in four sealed, argon blanketed containers to a NaK storage pit. Subsequent to the melt down of core II, an improved core III was installed in 1957. The final core loading, core IV containing 28.7 kg of plutonium, was installed in November, 1962, and operated until the EBR-I was decommissioned in April, 1964.

On August 26, 1966, President Lyndon B. Johnson, AEC Chairman Glen T. Seaborg and other officials from government and industry, participated in ceremonies at NRTS officially designating EBR-I as a registered National historic landmark. Since that time, the facility has remained in shut down condition, however, the radioactively contaminated primary coolant system, NaK, was left in the primary system drain tank, and the primary system lines and components were left containing contaminated

NaK residuals and film. Additionally, certain areas had been isolated due to high radiation levels, and other areas were semi-isolated by heavy concrete shielding blocks. The radiological condition of the facility coupled with the potentially unresolved alkali metals hazards, left the landmark unavailable to the public.

III. Radiation Contamination

1. NaK Storage Pit

The residue from the core II melt down, which is contained in four steel fabricated containers and stored in the NaK Storage Pit, will be removed from the EBR-I complex to an interim storage at the Army Reentry Vehicle Facility Site (ARVFS) Bunker^(a). This highly contaminated NaK will be processed in the future using a permanent shielding alkali metal processing plant facility. With the removal of the contaminated NaK from the NaK Storage Pit, there are no known areas of radioactive contamination external to the EBR-I and ZPR-III buildings within the EBR-I complex.

2. EBR-I

The radioactive contamination and radiation levels found to exist at the EBR-I facility are detailed in the EBR-I Radiation Survey. Radiation levels surveyed are due to a combination of: fission product contamination external to systems; fission product contamination within the primary coolant system and the NaK-to-NaK heat exchanger; activation products; and induced radiation within structural materials such as concrete and steel.

3. ZPR-III

The ZPR-III radiation survey indicates the radiation levels are due to low level ²³⁵U contamination. All background readings are 0.1 mR/hr or less except for the front part of the ZPR-III

(a) The removal and restorage of the four NaK containers were accomplished successfully April 4, 1974, and a topical report of the activity (ANCR-1166) was prepared. The NaK Storage Pit was surveyed, found uncontaminated, and filled to grade with native soil.

assembly which reads 35 mR/hr with shielding blocks removed. Smears taken indicate contamination levels on the ZPR-III assembly up to 200 d/m/100 cm² βγ and 100 d/m/100 cm² α, and up to 100 d/m/100 cm² βγ and 25 d/m/100 cm² α in the Mezzanine Filter Room. All of the contamination appears to be removable fissile material.

IV. Decontamination Plans

1. EBR-I

The EBR-I Radiation Survey indicates there are approximately 17 areas where direct radiation exceeds 0.5 mR/hr and/or where smear samples registered higher than 250 d/m/100 cm² βγ or higher than 10 d/m/100 cm² α. (a) The general plan of decontamination action and expected results will be described for those areas.

1.1 Fission Product Contamination Within Systems

The NaK primary coolant system and interfacing systems such as the NaK-to-NaK heat exchanger are radioactively contaminated from within by films and residues of contaminated NaK primary coolant. The NaK contains in solution approximately 18 Ci of ¹³⁷Cs, and approximately the same amount of ⁹⁰Sr is expected to be found in the sludges and oxide residues in filters and system cold traps. These systems have little if any external contamination and no induced radiation except for the primary system piping within the EBR-I reactor cavity shielding. Areas where the above pertains includes the filter tank room, the gravity tank room, the convection loop room, the T-2 NaK receiving tank room, the NaK-to-NaK heat exchanger room, the secondary NaK pump/dump room, and the primary NaK dump tank room.

(a) Arbitrary cut-off point for discussion of radiation decontamination plans.

The decontamination plan for internally contaminated systems includes the following phases:

- (1) Removal of the bulk NaK from the NaK dump tanks and processing of the NaK to form a solid 25 molar caustic as outlined in the EBR-I program plan.
- (2) Back purge of the primary coolant system with moisturized gaseous nitrogen (2 to 4% moisture entrainment). Continue purge until all NaK residues and film have been reacted to caustic. Vent purge gas and evolved hydrogen gas through the NaK processing system exhaust gas cleanup flare system. Caustic product of the moisturized purge will flow by gravity to the NaK dump tank.
- (3) After all NaK has been reacted, fill the NaK dump tank with water and circulate water throughout the entire system. Transfer flush water to the NaK process tank for volume reduction by evaporation.
- (4) Repeat flushing operation with low concentration acid solution rinse. Transfer acid solution to the NaK process equipment evaporator tank for volume reduction by evaporation.
- (5) Repeat flushing operation with demineralized water and sample flushings for radioactive contamination.
- (6) When system is clear, dry by purging with dry, heated GN_2 .
- (7) Resurvey all of the NaK primary system to verify acceptable decontamination level.

1.2 Fission Product Contamination External to Systems

Certain areas are contaminated externally with fission products primarily $\beta\gamma$ and small amounts of ^{235}U α . These areas include the cave rails, cave, rod farm, rod holes, west cell, middle cell, elevator cell, decontamination cell, ventilator room and sub pile room.

The decontamination plan for externally contaminated areas include the following phases:

- (1) Thorough vacuum cleaning of contaminated area using a HEPA filter attachment to the vacuum.
- (2) Scrub contaminated area with Chlorox and wipe dry with disposable wipes.
- (3) If decontamination not acceptable, use wire brush with Chlorox and again wipe dry with disposable wipes.
- (4) If contamination is being reduced, continue for three cycles of scrubbing and drying.
- (5) If contamination is not reduced to acceptable level, use sand blasting equipment fitted with HEPA filter.
- (6) After sandblasting, fix contamination with neat cement finish (for concrete surfaces) or paint for metallic surfaces.
- (7) Areas which are still not decontaminated to acceptable levels shall be isolated from the public using existing shielding blocks or engineered isolation systems.

1.3 Induced Radiation Within Structural Materials

Certain areas are contaminated by induced radiation. These areas included: the elevator cell, reactor cavity, and biological shielding. Irradiated items in these areas which can be readily removed will be removed, however, we do not expect to reach acceptable radiation levels in these areas. Therefore, these areas shall be isolated from the public using the existing shielding blocks. Radiation levels external to these areas with the shielding blocks in place will be less than 0.1 mR/hr.

2. ZPR-III

The close out radiation survey for ZPR-III indicates all contamination should be removable. The decontamination effort will consist of two phases.

2.1 Stripout Operation

Contaminated items such as the fuel bird cages, loading room hoods and the ZPR-III reactor will be disassembled, wrapped and sent to the NRTS Burial Ground.

2.2 Decontamination Operations

The decontamination of floors and walls will be accomplished in the following manner:

- (1) Thorough vacuum cleaning of the contaminated area using a HEPA filter attachment to the vacuum.
- (2) Scrub contaminated area with Chlorox and wipe dry with disposable wipes.
- (3) If decontamination not acceptable, use wire brush with Chlorox and again wipe dry with disposable wipes.
- (4) If contamination is being reduced, continue for three cycles of scrubbing and drying.
- (5) If contamination is not reduced to an acceptable level use sand blasting equipment fitted with a HEPA filter.
- (6) After sand blasting, fix contamination with neat cement (for concrete surfaces) or paint (for metallic surfaces).
- (7) Resurvey to assure radiation has been reduced to an acceptable level.

V. CONCLUSIONS AND RECOMMENDATIONS

1. Conclusions

Based upon the radiation survey of EBR-I, the close out radiation survey of ZPR-III and experience gained to date in attempting spot decontamination of specific areas, the following conclusions are offered:

- (1) It will be possible to decontaminate the fission product contamination within systems to an acceptable level with the proposed system.
- (2) It will be possible to decontaminate most of EBR-I external fission product contamination to an acceptable level.
- (3) It will not be possible to decontaminate the induced radiation to acceptable levels, short of demolition and replacement of the materials involved.
- (4) Decontamination to a criteria one order of magnitude lower in allowable surface contamination than the AEC Guidelines^(a)

^(a) Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use of Termination of Licenses for By-Product, Source, or Special Nuclear Material. USAEC Division of Materials Licensing, April 22, 1970.

will cost on the order of \$100,000 additional in decontamination labor and materials.

- (5) The decontamination program outlined can be accomplished without subjecting personnel to radiation exposure above AEC and NRTS site radiation protection standards.

2. Recommendations

Preparation of the Program Plan for Decontamination and Decommissioning of the EBR-I complex was based upon the acceptance of the AEC of Guidelines for Decontamination of Facilities and Equipment, and of the principal of isolation where applied to non-decontaminatable facility. The D&D funding currently requested for EBR-I does not provide for major demolition and reconstruction of areas such as the reactor cavity, biological shielding, elevator cell, and elevator. It is therefore recommended that:

- (1) The decontamination criteria for EBR-I be established based upon the AEC Guidelines.
- (2) The isolation principal be approved for areas which are not cleanable to the criteria.
- (3) The areas so designated will be isolated from the public by the installation of barriers designed to prevent entry of the public or other non-authorized personnel.
- (4) The radiation levels outside of the barriers will meet the criteria.

APPENDIX D

OPERATING PROCEDURE

EBR I PILOT PLANT

Date 5/2/74

J. C. Commander
Program Approved

D. P. Halls / TNS
Safety Division

EBR I NaK D&D

PILOT PLANT OPERATING PROCEDURE

INTRODUCTION

The purpose of this test is to:

- (1) demonstrate startup, shutdown and restart sequence;
- (2) demonstrate that the NaK lines can be kept dry prior to operation;
- (3) investigate the injection of NaK through various nozzles;
- (4) investigate injection of water into 200°C caustic and observe subsequent reaction;
- (5) obtain pressure readings due to reactions and observe the NaK caustic environment;
- (6) demonstrate cleanup procedures for NaK contaminated system.

General: The single inlet pneumatic atomizing nozzle should be installed in the drum for the initial run. The pilot plant test will be conducted in accordance with the safety practices as outlined in the report "Alkali Liquid Metals Safety for the Decontamination and Decommissioning of EBR I".

PROCEDURE

1. Trace out tubing runs to verify that equipment and lines have been installed in accordance with drawings 405194 and 405195.
2. Check to see that all valves and regulators are closed.
3. Open valves V19, V28, V9, V10, V11 and V20 to leak test connections around the NaK feed tank.
4. Open V3, V36 and adjust PR3 to 30 psig.
5. Close V36. After 10 minutes observe pressure reading on PG-4. If reading indicates leakage, locate leak by soap test, reduce pressure and repair leak. Repeat tests as necessary to provide a leak-tight system. Bleed off pressure through V18.
6. Leak test NaK supply drum pressurization line by opening V2, V35 and V33 and adjusting PR2 to 8 psig. Check for leaks and then close V35 and vent through V27. Then close V27.

7. Verify that nozzle in feed line to mixing drum is clear by opening V1 and adjusting PR1 for 10 psi downstream pressure. Then open V4 and verify flow through the nozzle in the mixing drum.
8. Shut off V4.
9. Turn on the NaK feed tank and feed line heat tapes. Adjust for 250 F temperature control.
10. Adjust propane regulator PR4, open V14 and ignite propane flare.
11. After a few minutes of trial burning of the flare, close V14.
12. When tape temperatures reach 250 F begin dryout flow of the NaK feed tank and NaK feed line by opening V16, V10, V11, V19, V36, and adjusting PR3 for 5 psi. Purge tank and line until N₂ bottle pressure has dropped 600 psi. Make mirror check for water content in purge stream at the outlet of the NaK feed line at the mixing drum. If moisture is still present, continue purge until subsequent tests indicate no moisture.
13. Close V36
V19
V10
V11
V16
14. Install single NaK flow straight jet nozzle assembly into mixing drum and connect to NaK feed line.
15. Transfer the contents of the NaK supply drum (approximately 40 gallons) to the NaK feed tank as follows:

Open V18
Open V12
Open V13
Open V20
Open V33
16. Open V35.
17. Adjust PR-2 to 8 psig control pressure.
18. Transfer NaK from the supply drum until there is an indication of rapid gas flow from V18. Then close V35 and allow NaK feed tank pressure to decrease to ambient and NaK in feed line to drain back to NaK feed drum.
19. Then close V12
V13
V18
V20
V33.

20. Open V36 and V37. Adjust PR3 to 10 psig. Then close V37.
21. Establish a purge through the NaK feed line by adjusting PR-1 to 40 psig and throttling V4 to give a flow of 1 SCFM as read on AFM3.
22. Fill the NaK mixing drum to the 35-gal mark with raw water.
23. Slowly add 50 lbs of NaOH to the mixing drum.
24. Open V19 and pressurize feed tank to 10 psig. Stabilize tank pressure.
25. Verify that all instruments are turned on and functioning properly. CPP will monitor the mixing drum to assure that essentially all the NaOH has been dissolved.
26. Set flow rate of argon purge to water line at 0.3 SCFM as read on AFM1 by adjusting V6.
27. Establish flow from propane tank by opening PR-4 and V14.
28. Ignite torch.

Note: Steps 29-33 should be done as rapidly as possible.
29. Open V16.
30. Throttle V4 until AF M3 reads zero flow.
31. Increase argon pressure on NaK feed tank to 20 psig by adjusting PR-3. Allow pressure to stabilize in tank as read on P4.
32. Increase argon pressure on NaK feed tank to 30 psig by adjusting PR-3. Allow pressure to stabilize in tank.
33. Open V16 until flow has been increased to 2 ℓ /min as indicated on EMFM. It may also be necessary to increase the pressure above 30 psig to obtain 2 ℓ /min flow. Note: Relief valve setting is 44 psig.
34. Continue at the flow rate until caustic solution reaches 200°C.
35. After NaK OH solution reaches 200°C start water feed by opening V7. Establish a feed rate of 1 gpm. At this point, CPP personnel will make observations and determine length of run.
36. Then reestablish an argon purge through AF M3 by adjusting V4 to give a purge of .1 SCFM.
37. Shut off NaK feed by closing V16.

38. Reestablish NaK feed by opening V16 and stabilizing at a flow of 2 l/min while at the same time slowly reducing the flow of argon to zero through AF M3 by closing V4.
39. When temperature reaches 200°C, turn off water by closing V7.
40. Reestablish argon purge of 1 SCFM through AF M3 by adjusting V4. Then shut off NaK feed by closing V16.
41. Turn on the water flow to 1 gpm by opening V7.
42. Observe the reaction in the mixing drum using the mirror. Record observations. CPP personnel will determine duration and type of observations.
43. Turn off water by closing V7.
44. Reduce the argon purge to the mixing drum to 0.5 SCFM through AF M3 by adjusting V4.
45. Shut off propane torch by closing V14.

CAUTION: Caustic spills are very slippery. Lay plank or plywood for access to mixing drum.

46. Close V36 and bleed off pressure to ambient by opening V18. Then close V18.
47. Shut off argon purge through AF M3 by closing V4.
48. Disconnect the single NaK flow straight jet nozzle assembly on the NaK feed line above the mixing drum and remove assembly from drum. Make provision to catch drippings.
49. Check caustic level. Drain mixing drum to a level 12" below top of drum. Drain into a catch drum.
50. Connect atomizing line from AFM2 to the dual inlet pneumatic atomizing nozzle. Note: This is done with unit outside the drum.
51. Check all bottle pressures to assure that pressures are above 500 psi. Replace with full bottles as necessary.
52. Establish a purge of 4 SCFM through AF M2 and the assembly by opening V5.
53. Insert dual inlet pneumatic atomizing nozzle into mixing drum and connect NaK feed line to union.
54. Establish a purge of 0.5 SCFM through AF M3 by opening V4.

55. Reduce purge through AF M2 to 1 SCFM by closing V5.
56. Position assembly in mixing drum positioning blocks and clamp to side of drum.
57. Reignite propane torch. Increase the argon flow through AF M2 to 4 SCFM by opening V5.
58. Slowly increase pressure on NaK feed tank to 30 psi by opening V36.
59. Open V16, then close V4 and increase pressure on NaK feed tank until flow has been increased to 2 l/min as indicated on EMFM. Note: Relief valve setting in feed tank is 44 psig.
60. Continue at this flow rate until caustic solution reaches 200°C.
61. After NaK OH solution reaches 200°C, start water feed by opening V7. Establish a water feed rate of 4 l/min. At this point, CPP personnel will make observations and determine length of run.
62. Then shut off NaK feed by closing V16. Reestablish argon purge of 1 SCFM through AFM3 by adjusting V4.
63. Slowly reduce the flow of argon to zero through AF M3 by closing V4.
64. Reestablish NaK feed by opening V16 and stabilizing flow at 2 l/min.
65. Then shut off NaK feed by closing V16. Reestablish argon purge of 1 SCFM through AF M3 by adjusting V4.
66. Slowly reduce the flow of argon to zero through AF M3 by closing V4.
67. Reestablish NaK feed by opening V16 and stabilizing flow at 2 l/min.
68. Continue feed until all NaK has been reacted as indicated on EMFM.
69. Close V36, V16, and open V18 to bleed off feed tank gas pressure.
70. Reduce flow through AF M2 to 1 SCFM by throttling V5.
71. Shut off propane torch by closing V14.
72. Continue water flow to mixing drum until the liquid level is within 3-4 inches from top and overspill is not occurring.
73. Drain mixing drum to catch drum.

Note: Caustic may weigh as much as 13 lbs/gal and may present a moving problem when draining to the catch drum if filled too full.

74. Verify that V12, V13, V20, V21, V22, V23, V16, V33 are closed.
75. Close V10, V11, V18, V5.
76. Locate the saturator tank and water dropout tank outside the drip pan.
77. Connect the water supply to the saturator tank. Fill the tank to the top of the gage glass.
78. Install connecting piping between tanks.
79. Connect the dropout gas outlet line to V22. Connect the saturator gas inlet line to V23.

Purge feed tanks and lines

80. Adjust PR-2 to control downstream pressure of 7 psig.
81. Verify V15 to be closed.
82. Open V35, V23, V15, V10, V11 and V16 to purge dry argon through NaK feed tank and force NaK from low spot in feed line. Then open V22 while simultaneously closing V15.
83. Continue saturated argon purge until PR2 bottle pressure has dropped 600 psi.

Original cylinder press _____
Final cylinder press _____

Then close V10 and V11.

Purge NaK Supply Drum

84. Break the tubing connection on the outer side of V12.
85. Open V20, V13 and V12.
86. Establish argon purge through NaK supply drum until there has been a 400 lb pressure drop on argon cylinder.

Original cylinder, press _____
Final cylinder, press _____

87. Close V23, V22, V20, V13, V12.
88. Connect the steam generator feed line to the upstream side of V22.

89. Disconnect the NaK feed line union above the mixing drum and the argon plastic line to the nozzle assembly. Withdraw dual inlet pneumatic atomizing nozzle assembly from the mixing drum. Make provision to catch dripping.
90. Start up steam generator and allow to operate until a steady stream is produced.
91. Open V22, V20, V12 and V13.
92. Close steam generator bypass valve.
93. Continue steam purge for 15 minutes.
94. Open V10 and V11 and then close V20.
95. Continue steam flow for 1 hour.
96. Shut off steam generator and open generator bypass valve.
97. Close V22.
98. Disconnect generator steam line at V22.
99. Disconnect water line to water nozzle in mixing drum above union.
100. Connect water line to V22. Close V10 and open V18.
101. Open V7 and note flow rate.
102. Continue flow rate until 45 gal have entered the NaK feed tank, then shut off V7 and V22.
103. Install temporary drain from NaK feed line to catch drum.
104. Close V18 and open V10.
104. Place catch drum under NaK feed line.
105. Pressurize NaK feed tank by opening V36 and V19.
106. Flush water from NaK feed tank.
107. Close V36 and V19 and open V18.
108. Open V7 and V22 and fill NaK feed tank a second time with 45 gal of water.
109. Close V7 and V22.
110. Pressurize NaK feed tank by opening V36 and V19.

111. Extend a temporary drain line from NaK feed line union to drainage off the pad. CPP will catch sample of first drainings and determine caustic content. If concentration is too high, it may be necessary to catch drainings. Otherwise, drain to off-pad area.
112. Close V36 and V19, V1, V2, and V3.
113. Disconnect and remove instrumentation from mixing drum.
114. Remove propane flare line back to propane regulator. Save flare tip.
115. Remove heat tapes.
116. Disconnect tubing runs.
117. Save all valves, regulators, purge meters, EMFM and filter.
118. Remove instrumentation from bottom of drum.
119. Remove NaK drum, mixing drum, and blocks from pad. Save blocks; dispose of drums to cold waste.
120. Other instructions will be issued to maintenance for cleanup of the drip pan.

NOTES: 1 FIELD SUPPORT ALL TUBING & COMPONENTS AS REQUIRED WITH UNISTRUT SUPPORTS & HANGERS
2 PROVIDE 1/2 DRUM CATCH TANK
3 ITEMS NOTED, PLUS ANY OTHERS IN P/L MAY BE SUPPLIED BY PROJECT, OR FROM SURPLUS
4 LOCATE VENT LINE APPROX 2 INCHES ABOVE DRIP PAN SURFACE.
5 LIQUID PENETRANT INSPECT WELDS IN INDICATED AREA
6 SIZE & LENGTH OF REACH ROD TO BE DETERMINED AT ASSY 2 PLACES
7 AREA SHOWN TO HAVE FITTING'S BACK WELDED & INSPECTED PER NOTE 5
8 TACK WELD PADS OF ITEM 1 (WC 103) TO DRIP PAN

1	BUSHING 1/2 X 1/2 SCD	STL	43
AR 600 1-4	MALE CONNECTOR	SWAGelok CRAWFORD FITTING CO. SOLON OHIO	42
1 B 601 A-6	MALE ADAPTER	SWAGelok CRAWFORD FITTING CO. SOLON OHIO	41
1	COUPLING 1/2 SCH 40, SCD	STL	40
1	BUSHING 1/2 X 1/2 SCD	STL	39
AR ET-2A	HEAT CABLE 168 W 120 V	EASY HEAT	38
AR	CONCRETE BLOCKS 16" X 16" X 8"		37
1	BOTTLE RACK		36
1	DRIP PAN 12x24		35

AR	REACH ROD		34
1 B-1023	PILOT TIP 3/4" OD	MANCHESTER	33
AR	TUBING 3/8 X 0.035 WALL		32
AR	TUBING 1/4 X 0.035 WALL		31
AR	REDUCING UNION 3/8" X 1/4"	SWAGelok CRAWFORD FITTING CO. SOLON OHIO	30
AR	TEE 3/8 TUBE UNION		29
AR	TEE 1/4 TUBE UNION		28
2 SS 600-6	UNION 3/8 TUBE	SWAGelok CRAWFORD FITTING CO. SOLON OHIO	27
1	TEE 3/4 SCH 40 B.W.		26
1	ADAPTER 3/8 TUBE TO 3/4 PIPE	CAJON CO CLEVELAND OHIO	25
1	REDUCER 1/4 X 1/2 SCH 40		24
1	FLANGE 3/4" 150# WELD NECK		23
3	PURGE METER		22

1	ROTOMETER		21
2	PRESSURE GAGE 0-60 PSI		20
1	SODIUM FILTER 1/2" 50 MESH	BRASS	19
1	ELECTROMAGNETIC FLOWMETER		18
3 VTS-400-0	ARGON GAS REGULATOR	VICTOR	17
1 B10L	CD GAS REGULATOR	FISHER PORTER	16
1 2701	VALVE 3/4" RELIEF 150# FLANGED	TELEWIDE FABRICS	15
1 0609K11	VALVE 3/4" RELIEF	BRONZE MC MASTER CARR LOS ANGELES CA	14
1 B-6T	SWAGelok ENDS	NUPRO CLEVELAND OHIO	13
2	VALVE 3/8" SWAGelok ENDS	NUPRO CLEVELAND OHIO	12
3	VALVE 3/8" SWAGelok ENDS	SST HOKING CRESSKILL N.J.	11
16	VALVE 3/8" SWAGelok ENDS	BRASS HOKING CRESSKILL N.J.	10
1	MIRROR 18x20"		9
1 005195-1	MIXING DRUM ASSY		8
3	ARGON BOTTLES		7
1	PROPANE TANK		6
1 B-500996	NAK SHIPPING BARREL	MSA RESEARCH CORP CALLERY PA	5
1 405292-1	NAK FEED TANK		4

UNLESS OTHERWISE SPECIFIED
DIMENSIONS AND SYMBOLS ARE AMERICAN NATIONAL STANDARD
DIMENSIONS AND TOLERANCES ARE IN INCHES
TOLERANCES
DECIMALS X = 2 1
XX = 2 00
FRACTIONS 1/16 = 2 1/16
ANGULAR 2 1/2"
DO NOT SCALE DRAWING

DATE 3/7/79
DRAWN BY J. J. J. J.
CHECKED BY J. J. J. J.
APPROVED BY J. J. J. J.
TITLE NAK PILOT PLANT PROCESSING SYSTEM
DRAWING NUMBER 405194
SHEET 1 OF 1

APPENDIX E

PROCEDURE FOR (NaOH)(KOH) BARREL LOADING
AND
PREPARATION FOR DISPOSAL AT THE INEL BURIAL GROUND

REVISED - November 7, 1974 *ML*

[Signature]
Program Approved

[Signature] 3/5/77
Safety Approved

PROCEDURE FOR (NaOH)(KOH) BARREL LOADING
AND
PREPARATION FOR DISPOSAL AT THE NRTS BURIAL GROUND

The following steps will be performed prior to transporting approximately 120 barrels to the Burial Ground.

NOTE: NaK protective clothing will be worn at all times while performing these steps! Reference: Alkali Metals Safety for D&D of EBR-I, Section 6.0. Radiation monitoring shall be adhered to during the entire D&D of EBR-I.

1. Place pallet on the Fairbanks-Morse scales to allow removal by use of a forklift truck.
2. Place a pre-dried barrel on the pallet, oriented to ease the product line connection between the barrel and the process tank. Fasten barrel to pallet with barrel tie-down chains.
3. Remove both threaded barrel plugs from the barrel and store for future use in plugging the filled barrel.
4. Connect the product line securely to the large barrel plug opening using the fill connection to barrel adaptor.
5. Connect the absolute vent filter securely to the small barrel plug opening using the vent to barrel adaptor.
6. Set the scales to read approximately 680 pounds over the tare of pallet, barrel, product line and absolute vent filter.
7. With reach rod connected to the product line manual shut-off valve, slowly open the valve to fill the barrel.

NOTE: Monitor the scales visually to detect the moment that the counter-weight balance starts to move.

8. When the counter-weight balance begins to move, use the reach rod to fully close the product line manual valve.
9. Allow product to drain from the fill line and then carefully remove it from the large barrel plug opening and store on process tank hook. This must be done cautiously since the barrel and line will be a temperature of approximately 200°C.
10. Install the large threaded barrel plug using long handled plug wrench and verify at least three threads have been engaged. Remove any spilled caustic from the barrel using a wet mop.

NOTE: Barrel and contents will still be hot (about 200°C), therefore, caution during handling must be maintained.

11. Remove the barrel and pallet from the scales with a forklift truck and place on south side of EBR-I roadway to cool. Calculated cooling period will be approximately 28 hours to ambient temperature. Area shall be posted to caution personnel of "hot caustic".
12. Remove any spilled caustic from the drip pan after it has solidified prior to installation of the next barrel. Place solid caustic drippings into a covered metal can for future disposal.
13. Repeat steps 1 through 12 for filling barrels with the caustic product.
14. Remove the absolute vent filter from the small barrel plug using long handled plug wrench approximately 30 minutes after removal from the scales and install a molecular seive-type filter in its place.
15. When the barrel has cooled to 80°F as determined by a contact thermometer, remove the molecular seive-type filter.
16. Install the small threaded barrel plug securely using long handled plug wrench and verify the large threaded barrel plug is securely installed.
17. Repeat steps 13 through 15 for all barrels filled with the caustic product.
18. When all the barrels have been cooled and the barrel plugs have been securely installed, they shall be transferred to the Burial Ground disposal.
19. Transfer operations, including barrel handling, transport to the Burial Ground, off-loading and burial will be identical to those used in transfer of Rocky Flats barrels except that these barrels will be disposed of inside the Burial Ground.
20. A shallow pit over near-surface rock shall be dug and then a sand or gravel bed will be placed in the bottom of the pit. The barrels shall be stacked in a vertical or horizontal position.
21. The barrels shall be covered with plywood and poly-vinyl sheeting.
22. The barrels shall be covered with three feet thickness of soil cover, sloped (1"/ft) to drain precipitation away from the burial.
23. Forms ID-109B and ID-135 shall be generated for each shipment to the Burial Ground.

APPENDIX F
EBR-I PRE-D&D RADIATION SURVEY

S. Keating
R. C. Green
J. C. Commander

Aerojet Nuclear Company
Idaho National Engineering Laboratory
Idaho Falls, Idaho 83401

Date Published, June 1974

Prepared for:
U.S. Energy Research & Development
Idaho Operations Office
Under Contract No. AT (10-1)-1375

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SUMMARY OF EBR-I PRE-D&D RADIATION SURVEY

The EBR-I Pre-D&D Radiation Survey consists of a summary, table of contents, and the radiation survey reports for each area listed in the table of contents. The radiation survey reports include: The location; name of Health Physics Technician surveyor; instruments used in the survey; results of the survey; and a plot plan of the area showing smear sample locations. Areas where direct radiation exceeded 0.5 mR/hr, or where smear samples registered higher than 250 d/m /100 cm² $\beta\gamma$ or higher than 10 d/m /100 cm² α are summarized in Table I, Radiation Survey EBR-I. Details of the survey may be obtained by turning to the survey report for the area of interest.

TABLE I. RADIATION SURVEY EBR-I

Area	General Field mR/hr	Contact mR/hr	Smear d/m /100 cm^2		Remarks
			By	α	
Filter tank room	3	20	-	-	pipng and tank
Gravity tank room	3	12	100	25	tank
Convection loop room	50	190	210	<20	-
Cave rails	-	80	4,890	<10	spot reading
Cave	-	.7	6,700	4.5	Manipulators
Rod farm	-	-	<250	<10	-
Rod holes	-	-	11,380	4.5	-
West cell	-	-	640	<20	-
Middle cell	2 R/hr	10 R/hr	1,970	169	at contact with ^{238}U Cup.
Elevator cell	90	1.5 R/hr	-	-	9' high in the center
" "	60	-	-	-	at the door
Decon cell	10	3	11,400	30	at the door
" "	-	100	-	-	wash tubes
Ventilator room	-	-	840	240	middle ventilator
Sub pile room	-	-	700	<20	-
T ₂ NaK receiving tank room	5	40	-	-	at the tank
" " " "	0.5	-	-	-	at the door
NaK to NaK heat exchanger room	15	100	-	-	heat exchanger
" " " " "	1	-	-	-	at the door
Secondary NaK pump/ dump room	3	-	-	-	entrance to corridor leading to primary dump room
" " " " "	-	5-45	-	-	pipes near ceiling
" " " " "	-	80	-	-	primary pump
Primary NaK dump tank	200	250	-	-	tank

LOG NO.

RADIATION SURVEY REPORT

LOCATION: *Mezzanine & Filter Tank Rm* DATE: *5-21-74*
REQUESTOR: *JC Cammerster* TIME: *0930*
SURVEYOR: *S Keating*
REQUEST: *Contamination and direct radiation survey of TRZ*

RESULTS: *<100 μ R/100 cm^2 P8 and <10 μ R/100 cm^2
The filter tank room has piping and tanks reading up to 200 mR/hr.
with a general field in the room of 3 mR/hr. The rest of the
mezzanine floor has a general field of <.05 mR/hr.*

INSTRUMENTS USED:	AIR SAMPLE TAKEN:	☐	☒
☐ JGM	RESULTS:	YES	NO
☐ GM			
☒ GPCR	HAS ADEQUATE EQUIPMENT USED?	☐	☒
<i>5-14</i>		YES	NO
<i>PIC</i>			

TPG-FD-10
(C-61)

SMEAR SAMPLE DATA

DATE <i>E-21-74</i>	TIME <i>1245</i>	UNIT AREA SMEARED <i>100²cm</i>	REMARKS: <i>≤ 70%/100²cm BS and ≤ 4.8 d/100²cm d</i>
	ROOM <i>Mezzanine</i>	SMEAR MEDIA <i>Whetstone</i>	
SAMPLED BY: <i>SE</i>		☐ wet ☒ dry	
COUNTED BY: <i>SE</i>		NOTES:	

Location Smeared	Date and Time Counted	Total Count	Count Time in Minutes	Counts per Minute Gross	Background Counts per Minute	Counts per Minute Net	Counter Yield	Disintegrations per Minute per Unit area	Unit Area	Type of Activity Counted	Initials
# 1	<i>5-21-74 1245</i>		<i>1</i>	<i>16 2</i>	<i>16 2</i>	<i>3 .7</i>	<i>35%</i>	<i>30 2</i>	<i>100²cm</i>	<i>BS</i>	<i>SE</i>
2	<i>1247</i>			<i>15 0</i>		<i>2 0</i>		<i>20 0</i>			
3	<i>1249</i>			<i>18 1</i>		<i>5 0</i>		<i>50 0</i>			
4	<i>1251</i>			<i>16 1</i>		<i>3 0</i>		<i>30 0</i>			
5	<i>1253</i>			<i>14 1</i>		<i>1 0</i>		<i>10 0</i>			
6	<i>1255</i>			<i>13 3</i>		<i>0 1.7</i>		<i>0 4.8</i>			
7	<i>1257</i>			<i>20 3</i>		<i>7 1.7</i>		<i>70 4.8</i>			
8	<i>1300</i>			<i>15 0</i>		<i>2 0</i>		<i>20 0</i>			
9	<i>1301</i>			<i>15 2</i>		<i>2 .7</i>		<i>20 2</i>			
10	<i>1303</i>			<i>12 1</i>		<i>0 0</i>		<i>0 0</i>			
11	<i>1305</i>	<i>✓</i>		<i>10 2</i>	<i>✓</i>	<i>5 .7</i>	<i>✓</i>	<i>50 2</i>	<i>✓</i>	<i>✓</i>	<i>✓</i>

B
LOG NO.

RADIATION SURVEY REPORT

LOCATION: *Top Floor & gravity tank room* DATE: *5-21-74*
 REQUESTOR: *J.C. Commander* TIME: *1000*
 SURVEYOR: *S. Keating*
 REQUEST: *Contamination and direct radiation survey of ERK*

RESULTS: $< 100 \mu\text{Ci}/\text{sq ft}$ and $< 10 \mu\text{Ci}/100 \text{ cm}^2$
*The gravity tank room has a general field of 3 mR/hr with a contact reading with the tank of 10 mR/hr. with 100% $\mu\text{Ci}/\text{sq ft}$, 25% $\mu\text{Ci}/100 \text{ cm}^2$.
 The rest of the floor has a general field of .05 mR/hr.*

INSTRUMENTS USED: ☐ JUNK ☒ GM ☒ OTHER <i>GM-14</i> <i>Be-L</i>	AIR SAMPLE TAKEN: <div style="display: flex; justify-content: space-between;"> ☐ YES ☒ NO </div> RESULTS: WAS RESPIRATORY EQUIPMENT USED? <div style="display: flex; justify-content: space-between;"> ☐ YES ☒ NO </div> TYPE:
---	--

SHEET

BLDG. E.B.

DATE:

SMOKE SAMPLE DATA

DATE	TIME	UNIT AREA SWEARED	REMARKS
	ROOM	SMEAR MEDIA	
SAMPLED BY:		☐ wet ☒ dry	
COUNTED BY:		NOTES:	

Location Smear	Date and Time Counted	Total Count	Count Time in Minutes	Gross Counts per Minute	Background Counts per Minute	Counts per Minute Net	Counter Yield	Distributions per Minute per Unit area	Unit Area	Type of Activity Counted	Initials
1	5-22-74		1	17	13	4	35%	40	100 sq. ft.	β	JA
2	1109			10	0	0	10%	0			
3	1113			19	1	6	0	60			
4	1115			15	3	2	17	20			
5	1120			13	1	0	0	0			
6	1122			11	0	0	0	0			
7	1123			13	1	0	0	0			
8	1124			15	2	2	7	20			
9	1125			18	0	5	0	50			
10	1126			19	3	6	17	60			
11	1128			11	2	6	4	10

LOG NO. 12

RADIATION SURVEY REPORT

LOCATION: *Machinists Area (main floor)*DATE: *5-21-74*REQUESTOR: *JC Commander*TIME: *1045*SURVEYOR: *S. K. King*REQUEST: *Continuous and direct radiation survey of EBNL*

RESULTS: *< 100%/100cm² (SD), < 10%/100cm² with a general field of .05 mR/hr*

INSTRUMENTS USED:

- ☐ JUMO
☒ GM
☒ OTHER
LIT-N

AIR SAMPLE TAKEN:

YES

NO

RESULTS:

WAS RESPIRATORY EQUIPMENT USED?

YES

NO

TYPE:

TJS-1D-10
(3-57)

SEEA SAMPLE DATA

DATE	TIME	UNIT AREA SAMPLED	REMARKS
	ROOM	SWEEP MEDIA	
SAMPLED BY.		☐ 100 ☒ 1000	
COUNTED BY		NOTES	

Lot no. entered	Date and Time Counted	Total Count	Count Time in Minutes	Counts per Minute Gross	Background Counts per Minute	Net Counts per Minute	Counter Yield	Disintegrations per Minute per Unit area	Unit Area	Type of Activity Counted	Initials
1	0630	17	2	16	4	1.6	35%	4.6	100 sq ft	β	JA
2	0631	18	1	1	2	.6	10%	1.7			
3	0632	16	1	1	0	.6		0			
4	0633	21	0	0	5	0		0			
5	0635	21	0	0	5	0		0			
6	0636	16	0	0	0	0		0			
7	0637	16	0	0	0	0		0			
8	0637	17	3	3	1	2.6		7.4			
9	0640	20	0	0	4	0		0			
10	0641	20	0	0	4	0		0			
11		18	0	0	2	0		0			

Location Smeared	Date and Time Counted	Total Count	Count Time in Minutes	Counts per Minute Gross	Background Count per Minute	Counts per Minute Net	Counter Yield	Disturbances per Unit area	Unit Area	Type of Activity Counted	Initial
12	0843		1	20	16	4	35%	40	100 sq m	β	β
13	0845			16		0	10%	0			
14	0846			15		0		0			
15	0847			26		10		100			
16	0849			16		0		0			
17	0851			20		4		40			
18	0852			17		1		10			
19	0854			17		1		10			
20	0855			12		0		0			
21	0856			16		0		0			
22	0858			17		1		10			
23	0900			13		0		0			
24	0901			13		0		0			
25	0903			16		0		0			
26	0904			15		0		0			
27	0905			16		0		0			
28	0907			14		0		0			
29	0909			23		6		60			
30	0910			15		0		0

LOG NUMB

RADIATION SURVEY REPORT

LOCATION: *Generator and boiler area*DATE: *5-30-74*REQUESTOR: *J.C. Commander*TIME: *1300*SURVEYOR: *S. Keating*REQUEST: *Contamination and direct radiation survey of EBRT*

RESULTS: *2150 $\mu\text{R}/100^2\text{cm}$ PT, 210 $\mu\text{R}/100^2\text{cm}$ d with
a direct radiation field of .05 mR/hr*

INSTRUMENTS USED:

☐ JUNK☒ GM☒ OTHER*Em 14*

AIR SAMPLE TAKEN:

YES

NO

RESULTS:

WAS RESPIRATORY EQUIPMENT USED?

YES

NO

TYPE:

SMEA SAMPLE DATA

DATE	TIME	UNIT AREA SMEARED	REMARKS:
	ROOM	SMEAR MEDIA	
SAMPLED BY:		☐ wet ☐ dry	
COUNTED BY:		NOTES:	

Location Smear	Date and Time Counted	m	Count Time In Minutes	Counts per Minute Gross	Background Counts per Minute	Counts per Minute Net	Counter C.P.M.	Disintegrations per Minute per Unit area	Unit Area	Type of Activity Counted	Initials
1	1345		1	35 0	20 13	0 0	35%	0 0	100%	0 0	SL
2	1349			27 3		7 1.7		70 4.8			
3	1349			18 3		0 1.7		0 4.8			
4	1352			31 0		11 0		110 0			
5	1354			14 0		0 0		0 0			
6	1356			16 0		0 0		0 0			
7	1400			24 1		4 0		40 0			
8	1401			13 1		0 0		0 0			
9	1403			19 1		0 0		0 0			
10	1404			23 1		3 0		30 0			
11	1405		✓	17 3	✓	0 1.7	✓	0 4.8	✓	✓	✓

LOG NAME

RADIATION SURVEY REPORT

LOCATION: *Convection loop room*DATE: *5-22-74*REQUESTOR: *J.C. Commander*TIME: *1100*SURVEYOR: *S. Reating*REQUEST: *Confirmation and direct radiation survey of ERDF*

RESULTS: *210 μ /100 2 cm BX, 420 μ /100 2 cm L with a general field of 50 μ /hr. There is a 190 μ /hr max. towards the back and .5 μ /hr at the door.*

INSTRUMENTS USED:

☐ JUNG☒ GM☒ OTHER*Smith
Pico*

AIR SAMPLE TAKEN:

☐

YES

☒

NO

RESULTS:

WAS RESPIRATORY EQUIPMENT USED?

☐

YES

☒

NO

TYPE:

IHS-ID-10
(8-57)

Convection Loop Room

190 mR/HR max.

50 mR/HR
general
Field

210 μ R/100²cm BX
420 μ R/100²cm α

.5 mR/HR

LOG NUMBER

RADIATION SURVEY REPORT

LOCATION: *Welding supply and adjoining area* DATE: *5-21-74*
REQUESTOR: *J.C. Combs* TIME: *1245*
SURVEYOR: *S. Kenting*
REQUEST: *Contamination and direct radiation survey of E8LF*

RESULTS: *250 μ R/100 cm β , 210 μ R/100 cm α with a direct radiation field of .05 mR/hr*

INSTRUMENTS USED:

☐ JUNG
☒ GM
☒ OTHER
BM-1

AIR SAMPLE TAKEN:

☐

YES

☒

NO

RESULTS:

HAD RESPIRATORY EQUIPMENT USED?

☐

YES

☒

NO

TYPE:

INS-ID-2G
(8-67)

SURVEY SHEET

BLDG. - EBR

DATE:

CRANE BAY

WELDING SUPPLY
AREA

PERISCOPE HOLE

PERISCOPE HOLE

.05 me/hr
general
field

SMEAR SAMPLE DATA

DATE	TIME	UNIT AREA SMEARED	REMARKS
	ROOM	SMEAR MEDIA	
SAMPLED BY		☐ wet ☒ dry	
COUNTED BY		NOTES.	

Location Specimen	Date and Time Counted	Total Count	Count Time In Minutes	Counts per Minute Gross	Background Counts per Minute	Counts per Minute Net	Counter Yield	Disintegrations per Minute per Unit area	Unit Area	Type of Activity Counted	Initials
#1	5-21-71 1045		1	23 0	16 4	7 0	35 10	70 0	100 cm ²	2	SL
2	1046			21 3		5 2.6		50 2.4			
3	1048			21 0		5 0		50 0			
4	1049			18 0		2 0		20 0			
5	1050			18 0		2 0		20 0			
6	1051			16 0		0 0		0 0			
7	1052			20 0		4 0		40 0			
8	1054			15 1		0 0.6		0 1.7			
9	1056			19 0		3 0		30 0			
10	1057			15 0		0 0		0 0			
"	1058		✓	16 0	✓	0 0	✓	0 0		✓	✓

LOG NUMBER

RADIATION SURVEY REPORT

LOCATION: *Reactor area (main floor)*DATE: *5-21-74*REQUESTOR: *J.C. Commander*TIME: *1330*SURVEYOR: *S. Keating*REQUEST: *Contamination and direct radiation survey of E&R I*

RESULTS: *<100 $\mu\text{Ci}/100\text{cm}^2$ Pb, <10 $\mu\text{Ci}/\text{m}^2$ with the exception of the rails and the Rod farm and Cave. (This area will be covered in more detail in section H). This area has a general field of .05 mCi/m^2 with a maximum of .1 mCi/m^2 in the vault and on the reactor top.*

INSTRUMENTS USED:

☐ JUMO
☒ GM
☒ OTHER
GM 14

AIR SAMPLE TAKEN:

☐ YES
☒ NO

RESULTS:

WAS RESPIRATORY EQUIPMENT USED?

☐ YES
☒ NO

TYPE:

IHS-ID-10
(8-51)

SMEAR SAMPLE DATA

DATE	TIME	UNIT AREA SMEARED	REMARKS
	ROOM	SMEAR MEDIA	
SAMPLED BY		☐ wet ☒ dry	
COUNTED BY		NOTES	

Location	Date and Time Counted	Test Count	Count Time in Minutes	Counts per Minute Gross	Background Counts per Minute	Counts per Minute Net	Counter Yield	Disintegrations per Minute per Unit area	Unit Area	Type of Activity Counted	Initials
1	5-21-74 1115		1	26 0	16 4	10 0	107.5%	100 0	100 ² cm	00 d	LL
2	1117			19 1		3 .6		30 1.9			
3	1118			21 0		4 0		40 0			
4	1119			74 1		58 .6		580 1.7			
5	1120			24 1		8 .6		20 1.7			
6	1121			29 0		13 0		130 0			
7	1122			25 3		8 2.6		80 7.4			
8	1124			20 1		4 .6		40 1.7			
9	1125			25 0		9 0		90 0			
10	1127			30 2		14 1.6		140 4.6			
			✓	19 2	✓	3 1.6		30 4.6			

Location Searched	Date and Time Counted	Exp 1 Count	Count Time in Minutes	Counts per Minute Gross	Background Counts per Minute	Counts per Minute Net	Counter Yield	Disintegrations per Minute per Unit area	Unit Area	Type of Activity Counted	1 mil
12	1130		1	19	16	3	35%	30	100 cm ²	AB	✓
13	1131			19		3	107%	30			
14	1132			20		4		40			
15	1134			16	2	0		47			
16	1136			15	0	0		0			
17	1138			15	3	0		74			
18	1139			15	0	0		0			
19	1140		✓	11	0	0	✓	0		✓	
20	1141			18	1	2	✓	20	1.7	✓	
21	1142			18	0	2		20	0		
22	1143			20	1	4		40	1.7		
23	1145			20	0	4		40	0		
24	1146			15	0	0		0	0		
25	1150			17	0	0		10	0		
26	1151			16	0	0		0	0		
27	1152			20	0	4		40	0		
28	1153			16	2	0		0	47		
29	1155			16	0	0		0	0		
30	1156		✓	20	2	4	✓	20	47	✓

LOG NUMBER

RADIATION SURVEY REPORT

LOCATION: *Rails, Rod Farm & Cave*

DATE: *5-28-74*

REQUESTOR: *J. C. Commander*

TIME: *0930*

SURVEYOR: *S. Keating*

REQUEST: *Contamination and direct radiation survey
of EBR-I*

RESULTS: *The rails were contaminated to 4890 d/m/100²cm
(β & and ≤ 10 d/m/100²cm), with a direct radiation level of 80 mR/hr max.*

*The cave was contaminated to ≤ 6700 d/m/100²cm (β &
and 4.5 d/m/100²cm), with a direct radiation field of 0.7 mR/hr.*

*The rod farm was contaminated to ≤ 250 d/m/100²cm (β &
and ≤ 10 d/m/100²cm). (Rod holes were contaminated to 11,380 d/m/100²cm (β &
and 4.5 d/m/100²cm), and direct radiation field of 0.5 mR/hr.)*

INSTRUMENTS USED:

- ☐ JUNO
☒ GM
☒ OTHER

AIR SAMPLE TAKEN:

☐ YES ☒ NO

RESULTS:

WAS RESPIRATORY EQUIP. USED? ☐ YES ☒ NO

TYPE:

IHS-ID-10
(8-67)

SMEAR SAMPLE DATA

DATE	TIME	UNIT AREA SMEARED	REMARKS:
	ROOM	SMEAR MEDIA	
SAMPLED BY:		☐ wet ☒ dry	
COUNTED BY:		NOTES:	

Location Smear	Date and Time Counted	Count Time In Minutes	Counts per Minute Gross	Background Counts per Minute	Counts per Minute Net	Counter CPM	Disintegrations per Minute per Unit area	Unit Area	Type of Activity Counted	Initials
#1	5-30-70 1515	1	29 / 1	13	4 / 0	35% 10%	40 / 0	100%	2	SL
2	1516		21 / 0		1 / 0		10 / 0			
3	1517		25 / 0		5 / 0		50 / 0			
4	1519		29 / 1		9 / 0		90 / 0			
5	1520		36 / 1		16 / 0		160 / 0			
6	1521		44 / 2		24 / .7		290 / 0			
7	1523		25 / 1		5 / 0		50 / 0			
8	1525		22 / 2		2 / .7		20 / 2			
9	1526		24 / 0		4 / 0		40 / 0			
10	1529		31 / 1		11 / 0		110 / 0			
11	1529	✓	30 / 0	✓	10 / 0	✓	100 / 0	✓	✓	✓

LOG NUMBER

RADIATION SURVEY REPORT

LOCATION: *Office Area (main floor)*DATE: *5-21-74*REQUESTOR: *J.C. Commander*TIME: *1416*SURVEYOR: *S. Keating*REQUEST: *Contamination and direct radiation survey of FBI*

RESULTS: *< 100 $\mu\text{Ci}/100^2\text{cm}$ PB, < 10 $\mu\text{Ci}/100^2\text{cm}^2$ with
direct radiation field of .05 mR/hr*

INSTRUMENTS USED:

- ☐ JUMO
☒ GM
☒ OTHER

Rm 14

AIR SAMPLE TAKEN:

☐

YES

☒

NO

RESULTS:

WAS RESPIRATORY EQUIPMENT USED?

☐

YES

☒

NO

TYPE:

IHS-ID-20
(3-67)

17-1-19

SMEAR SAMPLE DATA

DATE	TIME	UNIT AREA SMEARED	REMARKS
	ROOM	SMEAR MEDIA	
SAMPLED BY:		☐ Wet ☒ Dry	
COUNTED BY:		NOTES:	

Location Smear	Date and Time Counted	Total Count	Count Time in Minutes	Gross Counts per Minute	Background Counts per Minute	Counts per Minute Net	Counter Yield	Disintegrations per Minute per Unit area	Unit Area	Type of Activity Counted	Initials
1	5-24-74 1245		1	15	4	0	35%	0	100 cm ²	B	ll
2	1246			14	0	0	10%	0			
3	1248			15	0	0		0			
4	1249			18	0	2		20			
5	1250			19	0	3		30			
6	1252			19	1	3		30			
7	1253			19	0	3		30			
8	1254			17	1	1		10			
9	1256			17	0	1		10			
10	1258			18	2	2		20			
11	1250			18	0	2		20			

Location Smeared	Date and Time Counted	Test Count	Count Time in Minutes	Counts per Minute Gross	Background Counts per Minute	Counts per Minute Net	Counter Yield	Distintegrations per Minute per Unit area	Unit Area	Type of Activity Counted	Unit
12	1301		1	17	16	1	35%	10	100 cm ²	α	1 ft
13	1302			18	1	2		20	1.7		
14	1304			17	1	1		10	1.7		
15	1305			16	0	0		0	0		
16	1306			17	1	1		10	1.7		
17	1307			17	0	1		10	0		
18	1309			16	0	0		0	0		
19	1301			16	0	0		0	0		
20	1313			15	0	0		0	0		
21	1314			22	0	6		60	0		
22	1315			22	0	6		60	0		
23	1316			21	1	5		50	1.7		
24	1317			20	0	4		40	0		
25	1319			19	0	3		30	0		
26	1320			15	0	0		0	0		
27	1322			16	1	0		0	1.7		
28	1324			19	0	3		30	0		
29	1325			14	0	0		0	0		
30	1325			11	0	0		0	0		

RADIATION SURVEY REPORT

J.

LOCATION: *Basement.*

DATE: *3 22 74*

LOG NO. *627*

REQUESTOR: *JC Cummings*

TIME: *1230*

SURVEYOR: *S Keating*

REQUEST: *Confirmation and direct radiation survey of TBR L*

RESULTS With the exception of the cells, T_2 , and the Nak-to-Nak heat exchanger, the contamination levels are $<100 \mu\text{Ci}/\text{m}^2$ BS, $<10 \mu\text{Ci}/\text{m}^2$ d. The west cell has $640 \mu\text{Ci}/\text{m}^2$ BS and $<20 \mu\text{Ci}/\text{m}^2$ d with direct radiation at $.1 \text{ mR/hr}$.

The middle cell has $1.97 \times 10^3 \mu\text{Ci}/\text{m}^2$ BS and $169 \mu\text{Ci}/\text{m}^2$ d with a general field of 10 mR/hr and 200 mR/hr at the door.

The elevator cell has $100 \mu\text{Ci}/\text{m}^2$ BS and $100 \mu\text{Ci}/\text{m}^2$ d with a general field of 90 mR/hr and a maximum of 1.5 mR/hr at 9' in the center. There is 60 mR/hr at the door.

The Decon cell has $1.14 \times 10^4 \mu\text{Ci}/\text{m}^2$ BS and $30 \mu\text{Ci}/\text{m}^2$ d with a general field of 10 mR/hr , 100 mR/hr contact with wastube, and 3 mR/hr at the door.

T_2 and Nak-to-Nak heat exchanger are located in detail in section K and L respectively.

INSTRUMENTS USED:

☒ SMEAR ☐ JUNG
☐ α METER ☒ GM
☐ OTHER ☐ SCINTILLATOR

PROTECTIVE CLOTHING WORN:

☒ FULL ANTI-C
☐ GLOVES ☐ LAB COAT
☒ SHOE COVERS ☐ EYE SHIELD
115-10-10
10-69 ☐ OTHER _____

AIR SAMPLE TAKEN:

☐ YES ☒ NO

RESULTS:

WAS RESPIRATORY EQUIPMENT USED? ☒ YES ☐ NO

TYPE: MASK ☐ CANISTER
ACME ☐ 502 R
SCOTT ☐ ALL PURPOSE
CONFO ☒

SMEAR - SAMPLE DATA

DATE	TIME	UNIT AREA SMEARED	REMARKS
	ROOM	SMEAR MEDIA	
SAMPLED BY.		☐ 100% ☒ 10%	
COUNTED BY		NOTES	

Location Smeared	Date and Time Counted	Count Time in Minutes	Gross Counts per Minute	Background Counts per Minute	Counts per Minute Net	Counter Yield	Disintegration* per Minute per Unit area	Unit Area	Type of Activity Counted	Initials
1	5-24-78 1430	1	20	16	4	35% 10%	0	100 cm ²	8B	JA
2	1431	21	0	5	0	50	0			
3	1432	17	1	1	.6	10	1.7			
4	1434	16	3	0	26	0	7.9			
5	1435	18	0	2	0	20	0			
6	1437	19	0	3	0	30	0			
7	1438	23	2	7	16	70	4.6			
8	1440	21	1	5	.6	50	1.7			
9	1441	14	0	0	0	0	0			
10	1442	14	1	0	.6	0	1.7			
11	1443	18	2	2	1.6	20	4.6			

Location Sampled	Date and Time Counted	IC at Count	Count Time in Minutes	Counts per Minute Gross	Background Counts per Minute	Counts per Minute Net	Counter Yield	Distrations per Unit area	Unit Area	Type of Activity Counted	Initial
12	1445		1	17	16	1	35%	10	100 sq ft	PA	ll
13	1446			16	0	0		0			
14	1448			11	0	0		0			
15	1449			21	0	5		50			
16	1450			19	0	3		30			
17	1452			18	0	2		20			
18	1454			15	0	0		0			
19	1455			21	1	5		50			
20	1457			20	2	4		40			
21	1458			20	0	4		40			
22	1459			15	1	0		0			
23	1501			17	3	1		10			
24	1503			19	1	3		30			
25	1504			23	2	7		70			
26	1506			16	1	0		0			
27	1509			17	1	1		10			
28	1510			15	0	0		0			
29	1512			16	1	0		0

LOG TIME

RADIATION SURVEY REPORT

LOCATION: *Subpile Room*

DATE: *5-23-54*

REQUESTOR: *J.C. Commander*

TIME: *1930*

SURVEYOR: *S. Yee / wj*

REQUEST: *Contamination and direct radiation survey of 15R1*

RESULTS: *700 μ /m/100 μ in BB and 420 μ /m/100 μ in α With
1 m μ /hr general field, a maximum of .5 m μ /hr and .05 m μ /hr at the
entrance.*

INSTRUMENTS USED:

☐ JUNG

☒ GM

☐ OTHER

Line

Sub

AIR SAMPLE TAKEN:

YES

NO

RESULTS:

HAD RESPIRATORY EQUIPMENT USED?

YES

NO

TIME:

INS-ID-20
(8-57)

Sub Pile Room

.1 $\frac{m}{m^2}$ general field

700 $\frac{d}{m}/100^2m$ B8

L 20 $\frac{d}{m}/100^2m$ α

Max - .5 $\frac{m}{m^2}$

.05 $\frac{m}{m^2}$

LOG FUMDE

RADIATION SURVEY REPORT

LOCATION: To Nak Tank RoomDATE: 5-23-74REQUESTOR: J.C. CommanderTIME: 1030SURVEYOR: S. KeatingREQUEST: Contamination and direct radiation survey of EBRI

RESULTS: 80 μ m/100²cm BG and 10 μ m/100²cm α with 5 mR/hr general field, 40 mR/hr contact with tank and .5 mR/hr at the door.

INSTRUMENTS USED:

☐ JUMO☒ GM☒ OTHER2-11-7411:50

AIR SAMPLE TAKEN:

☐

YES

☒

NO

RESULTS:

WAS RESPIRATORY EQUIPMENT USED?

☐

YES

☒

NO

TYPE:

IHS-ID-10
(8-57)

LOG NUMBER:

RADIATION SURVEY REPORT

LOCATION: *NaK-to-NaK Heat Exchanger*

DATE: *5-23-74*

REQUESTOR: *J. C. Crossen*

TIME: *11:00*

SURVEYOR: *S. Keating*

REQUEST: *Contamination and direct radiation survey of EBR-I*

RESULTS: *200 μ m/100cm PB, 10 μ m/100cm α with
15 mR/hr general field, 100 mR/hr contact, and 1 mR/hr
at door.*

INSTRUMENTS USED:

☐ JUMO

☒ GM

☒ OTHER

*Frank
Pick*

AIR SAMPLE TAKEN:

YES

NO

RESULTS:

HAD RESPIRATORY EQUIPMENT USED?

YES

NO

TYPE:

LOG NAME

RADIATION SURVEY REPORT

LOCATION: Secondary Nuk Pump & Pump Room DATE: 5-24-74
REQUESTOR: J.C. Commander TIME: 0950
SURVEYOR: S. Keating
REQUEST: Contamination and direct radiation survey of EBRF

RESULTS: <100 μ R/100 μ rem B8 and <10 μ R/100 μ rem with a
3 μ R at entrance to second corridor and 5-45 μ R on pipes near
ceiling, also 80 μ R on pump at contact.

INSTRUMENTS USED:

☐ JUNG
☒ GM
☒ OTHER

AIR SAMPLE TAKEN:

YES

NO

RESULTS:

EAD RESPIRATORY EQUIPMENT USED:

YES

NO

TYPE:

DATE	TIME	UNIT AREA SHEARED	REMARKS:
	ROOM	SMEAR MEDIA	
SAMPLED BY:		☐ wet ☒ dry	
COUNTED BY:		NOTES:	

Location Smear	Date and Time Counted	Count Time in Minutes	Gross Counts per Minute	Background Counts per Minute	Net Counts per Minute	Counter ϵ %	Disintegrations per Minute per Unit Area	Unit Area	Type of Activity Counted	Initials
1	5-30-54	17	0	13	0	35%	0	100 cm ²	2	RL
2	15-46	18	1	0	0	10%	0			
3	15-31	28	0	8	0		80			
4	15-49	18	3	0	1.7		0 4.8			
5	15-50	21	1	1	0		10			
6	15-52	29	1	3	0		30			
7	15-55	18	2	0	0		0 2			
8	15-56	26	1	6	0		60			
9	15-57	25	1	5	0		50			
10	15-58	22	0	2	0		20			
11	16-00	25	1	5	0		50			✓

0

LOG (U)

RADIATION SURVEY REPORT

LOCATION: *Primary Nuk Drain Tank Room*

DATE: *5-25*

REQUESTOR: *J.C. Commanded*

TIME: *1230*

SURVEYOR: *S. Kauting*

REQUEST: *Contamination and direct radiation survey of EBR-2*

RESULTS: *80 μ R/hr on PG and 10 μ R/hr on d with a 200 mR/hr general field and 250 mR/hr contact with tank.*

INSTRUMENTS USED:

- ☐ JUNK
- ☒ GM
- ☒ OTHER

14

AIR SAMPLE TAKEN:

☐ YES ☒ NO

RESULTS:

HAD RESPIRATORY EQUIPMENT USED?

☐ YES ☒ NO

TYPE:

APPENDIX G

ALKALI METALS SAFETY FOR THE DECONTAMINATION
AND DECOMMISSIONING OF EBR-I

Program Approved

NOS Approved

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ALKALI METALS SAFETY FOR THE DECONTAMINATION
AND DECOMMISSIONING OF EBR-I

1.0 PURPOSE

This document outlines the Alkali Metals Safety Policies that will be in effect during the decontamination and decommissioning of EBR-I.

2.0 REFERENCES

412 Alkali and Liquid Metals Safety Committee Guide, August 13, 1951
Knolls Atomic Power - Alkali Metals
Aerojet General Corporation AGC-STD-1240A
Phillips Petroleum Alkali Metals Handbook
AEC-ID Fire Department Alkali Metals Lesson Plan
Phillips Petroleum Company First Aid for NaK Burns
Sodium Technology - Atomics International
MSA Research Corporation Cleaning Procedures for Potassiums
Chemistry and Industry, April 24, 1965 "Explosions Due to Potassium
Superoxide"
Health and Safety Information Issue No. 251, "Explosions Involving
Metallic Potassiums or NaK"
EBR-II Systems Training Program
AEC Emergency and Followup Treatment of Sodium Burns
GAF Projects Mount Catalogue No. 253-201 Protective Measures with Sodium
Summary of Information on the Superoxides of Sodium Potassium Liquid
Metals Information Center October 16, 1969
Liquid Metals Handbook - Sodium and NaK Supplement

3.0 RESPONSIBILITIES

NRTS Manager of Decontamination and Decommissioning shall:

- (1) Insure that the necessary safety equipment as stated in this Alkali Metals Handbook is available for use at EBR-I
- (2) Insure that the task force personnel are adequately trained in the proper use of this safety equipment and applicable procedures.

EBR-I Project Engineer shall:

- (1) Insure that all the task force personnel involved in the alkali metal operation are properly using the safety equipment and safety procedures as outlined in this handbook.

EBR-I Task Force Personnel shall:

- (1) Follow prescribed safety procedures.

AEC-ID Fire Department shall:

- (1) Provide an officer to supervise the disposal of spilled alkali metal and/or residues.

Visitors to sites involved in alkali metals operations shall:

- (1) Be escorted by a person trained in Alkali Metals Safety
- (2) Remain clear of alkali metal operations unless properly dressed in alkali metal protective clothing.

4.0 GENERAL DESCRIPTION

4.1 Alkali Metals and Potassium Superoxide Characteristics

Elements that make up matter may be loosely divided into two groups; the metals and the nonmetals. Most of the metals are solids at or near room temperature. Five liquid or low melting point metals have similar chemical properties and are known as alkali metals. These are the mono-valent elements of the first group of the periodic system: lithium (Li) sodium (Na), potassium (K), rubidium (Rb) and cesium (Cs). All are strongly electro-positive, have a low specific gravity, a low melting point, are silver-white and ductile; and react vigorously with water, liberating hydrogen and forming hydroxides.

The alkali metals require special safety and fire protection consideration because of their high degree of reactivity with many common materials. The general properties of these five alkali metals are shown in Table I. The remainder of this handbook will be concerned primarily with sodium, potassium, their eutectic alloy (NaK), and oxides of these metals.

TABLE I

PROPERTIES OF ALKALI METALS

-
1. Silver color (unoxidized), except for Cesium which is gold color
 2. Good conductors of electricity and heat
 3. Low specific gravity for metals
 4. Low melting and high boiling points
 5. Soft in their solid states

<u>Metal</u>	<u>Cesium</u>	<u>Rubidium</u>	<u>Potassium</u>	<u>Sodium</u>	<u>Lithium</u>
M. P. °F	83	102	146	308	354
B. P. °F	1260	1270	1400	1618	2440
Liq. Range °F	1177	1168	1254	1410	2086
Sp. Gr.	1.873	1.532	0.859	0.972	0.534

4.1.1 Sodium

- (1) Element. The symbol for sodium is Na; its atomic number is 11, its atomic weight is 23. The specific gravity of sodium is 0.971 at 20°C. It has a melting point of 97°C and a boiling point of 880°C. Upon heating in air, sodium burns, yielding the Na-monoxide and dioxide. It dissolves in liquid ammonia to give a blue solution.
- (2) Compounds. Metallic or pure sodium is usually insoluble. However, its salts are generally soluble in water. Sodium hydride, NaH, is a crystalline substance obtained by combining hydrogen and sodium at about 360°C. Na oxidizes in dry air and ignites in moist air. It reacts with water to yield caustic soda and hydrogen gas. Dry carbon dioxide is decomposed by sodium to produce free carbon. When sodium is heated in an excess of oxygen or air to 300°C, the peroxide, Na_2O_2 , is formed. This compound has a yellowish tinge which whitens upon exposure to air. When Na_2O_2 is dissolved in water, NaOH and H_2O_2 are obtained. Sodium peroxide is a powerful oxidizer and will ignite organic matter or alcohol.

4.1.2 Potassium

- (1) Element. The symbol for potassium is K (from kalium). Its atomic number is 19, the atomic weight is 39.105. It is a silvery white metal tinged with blue, with a specific gravity of 0.859. Potassium fuses at 62.5°C and boils at 760°C, emitting an intensely green vapor. At temperatures below 0°C, potassium is hard and brittle; at ordinary temperatures it is so soft that it can be cut with a blunt knife. Except for lithium, potassium is the lightest metal known.
- (2) Compounds. Upon exposure to air, a film of oxide is formed on the metal. Upon prolonged exposure to air, it deliquesces into a solution of hydrate and carbonate. When heated in air, potassium burns readily. It reacts with water with explosive violence according to the reaction $2\text{K} + 2\text{H}_2\text{O} = 2\text{KOH} + \Delta^\circ + \text{H}_2$. Potassium reacts

with alcohol to form potassium ethoxide and hydrogen,
which passes off in the gaseous state.

4.1.3 Sodium-Potassium (NaK) Properties

Sodium-potassium alloys are currently prepared commercially by the distillation of Na counter current to molten KCl. The term NaK (pronounced "Nack") has come to be rather widely used to designate these alloys. The percentage composition of NaK is normally given in terms of potassium, the more expensive metal. NaK 77.2 is a mixture of 77.2% potassium and 22.8% sodium by weight. This is the eutectic mixture which has a melting point of 9.95°F. The heat-transfer properties improve as the percent of sodium increases, but the melting temperature is also raised. Fluidity at ambient temperature is the main reason for using NaK rather than sodium as a heat-transfer agent. NaK has a shiny silvery appearance similar to mercury. Its physical properties are shown in Table II.

TABLE II
PHYSICAL PROPERTIES OF NaK

Property	Unit	NaK
		<u>78 ± 1% K; 22 ± 1% Na</u>
Atomic Weight	AMU	33.7 - 34.1
Melting Point	°F	10
Boiling Point @ 14.7 psia	°F	1443
Density @ 75°F	lb/gal	7.20
Density @ 75°F	lb/ft ³	54.0
Absolute Thermal Expansion Coefficient	ft ³ /lb°F	3.65 x 10 ⁻⁶
Relative Thermal Expansion Coefficient		2.0 x 10 ⁻⁴
Pressure-Head Equivalent @ 75°F	inches/psi	31.8
Color		Silver

NaK reacts similarly to sodium with the exception that, in general, it is more reactive. Since potassium is the more reactive component, its chemistry should be emphasized. When exposed to the action of oxygen, potassium oxidizes finally to the superoxide (KO_2), which is a stable oxide of potassium at ambient temperature and pressure.

In general, alloys of sodium containing the more reactive potassium should be handled under conditions similar to those described for potassium. Added precautions are required to prevent formation of oxides of potassium with oxygen which react explosively with organic material. Also, since most NaK alloys are liquid at room temperature, care must be taken to prevent liquid metal spills.

Oxides of potassium will form locally in apparatus if oxygen is allowed to enter and accumulations of superoxide may react violently when subsequently brought in contact with potassium or NaK. Therefore, oxygen should be excluded from the alloy at all times. It is good practice to maintain an inert atmosphere in the apparatus during filling, operating, and after emptying the apparatus.

4.1.4 Potassium Superoxide

Potassium metal and (NaK) will oxidize at surfaces exposed to ambient air, ultimately to form material containing potassium superoxide (KO_2). Potassium superoxide is yellow in color, resembling flowers of sulphur and is a strong oxidizer. The primary hazard appears to be due to the combination of unreacted potassium metal or NaK and/or organics with potassium superoxide, producing an explosive hazard.

Sodium superoxide does not form at room or elevated temperature except under special conditions (high pressure and temperature). There appears to be no explosive hazard with sodium superoxide although there is a higher percentage of oxygen in sodium superoxide.

Potassium superoxide has a melting point of 380°C , a disassociation temperature (at 1 atmosphere) of 600°C , and a density of 2.14 gm per cc. An important use of KO_2 is in chemox cannister breathing apparatus.

4.2 Hazards of Alkali Metals

The hazards associated with the use of sodium potassium and NaK are due primarily to their high chemical reactivity with many common materials or substances including moist human tissue. The reaction

products themselves pose a problem as irritants (sodium and potassium oxide), they may be highly corrosive (sodium and potassium hydroxides), and may lead to fires and explosions unless properly controlled. Sodium, potassium, and NaK which have been exposed in a reactor core to neutron flux pose an additional hazard due to the induced radioactivity in the constituent isotopes.

The principal hazards involved in using sodium, potassium and NaK are:

- (1) Explosions and fires resulting from contact of the alkali metal with water.
- (2) Fire resulting from exposure of the alkali metal to the air.
- (3) Injury to personnel from contact of alkali metal with the skin; chemical burns.
- (4) Exposure of oxide fumes to the respiratory tract and subsequent caustic burns to mucous tissues of mouth, throat, and lungs.
- (5) Explosions resulting from contamination of the alkali metal with organic material and KO_2 .

Every effort must be made to prevent any contact of water including perspiration with alkali metals. The reaction of alkali metals with water produces free hydrogen and enough heat to ignite the hydrogen and eventually the metal. Minor explosions are produced by the sudden generation of hydrogen gas and steam, and more serious explosions can result from ignition of the hydrogen in the presence of air. Alkali metal scattered by such an explosion spreads fire and is a hazard to personnel. The cardinal rule of alkali metal safety is: Keep Water Away From Alkali Metals!

In order to prevent NaK-water contact, the following rules are to be followed:

- (1) NaK is to be used and stored only in specially designated areas of EBR-I.
- (2) NaK is to be kept and transported only in closed metal containers.
- (3) All NaK containers should be labeled "NaK, Keep Water Away."
- (4) Water should Never be used on a NaK fire.

Oxides and hydroxides of sodium and potassium, all being alkaline materials, have a corrosive action on body tissues, more so than do most acids. Internally (mouth, throat and lungs) particles of sodium, sodium oxide, sodium hydroxide and potassium hydroxide will destroy tissue upon contact but are not known to be a systemic poison. The Threshold Limit Value (TLV), for sodium hydroxide and potassium hydroxide is 2 mg/m^3 .

The following is a list of common alkali metal reactions with associated hazards.

- (1) Alkali Metal - Air reactions. The most common reaction encountered in using alkali metals is their interaction with air. Liquid sodium and NaK may ignite spontaneously in air and combustion will be sustained if certain conditions of temperature, heat and moisture exist.
In the case of NaK or potassium, superoxide (KO_2) may form very rapidly, in the presence of oxygen. KO_2 is an explosive hazard when contaminated with H_2O or hydrocarbons.
- (2) Alkali Metal-Water Reactions.
 1. Alkali metals react violently with water usually with an accompanying explosion caused by the secondary reaction of hydrogen with the oxygen of the air in the presence of heat from the reaction.
 2. When handling, keep alkali metals completely isolated from water.
- (3) Alkali Metal-Steam Reactions.
 1. Does not necessarily react the same as water.
 - a. Hydrogen resulting from the reaction is often diluted so that the danger of an explosion is greatly reduced.
 2. Dry steam (steam free of condensed water) or moist gaseous nitrogen (GN_2) is used to clean piping and apparatus.
 - a. Steam or moist GN_2 dilutes hydrogen
 - b. Excludes oxygen
 - c. Dissipates heat of the reaction
- (4) Alkali Metal-Carbon Dioxide.
 1. Produces caustic oxide
 2. Produces carbon monoxide
 3. Do not use as an extinguishment

(5) Alkali Metal-Carbon Tetrachloride - Trichloroethylene.

1. Reacts with explosive violence
2. Phosgene gas is formed
3. Do not use as cleaner or solvent

(6) Alkali Metal-Alcohols.

1. Same reaction as water, but less violent
2. A large volume of alcohol with a small amount of NaK produces a slower reaction.
 - a. Hydrogen is released
 - b. Alcohol is flammable
 - c. Butyl alcohol is the most desirable of the alcohols to use.

4.3 General Safety Precautions

- (1) Personnel must receive adequate training to qualify for work with alkali metals. This training includes, but is not limited to, instruction in general alkali metal characteristics and procedures, personnel protection and safety, and emergency situations and procedures.
- (2) Approved written procedures and/or safe work permits are required for all alkali metal operations.
- (3) Adequate protective equipment will be required for everyone working with alkali metals in accordance with Section 6.2.
- (4) Where alkali metals are being handled, at least two persons will be present and a backup person and equipment must be standing by.
- (5) No smoking or open flames shall be permitted in alkali metal areas.
- (6) The AEC Fire Department shall be advised prior to beginning operations involving open disposal of alkali metal.
- (7) An adequate supply of extinguishing material must be on hand to control spillage or extinguish fires.
- (8) Metal drip pans shall be used for catching alkali metal spills.
- (9) An inert cover gas, sodium carbonate (Na_2CO_3) or metal cover shall be used when transferring alkali metals.
- (10) Alkali metals or containers of alkali metals suspected of containing superoxides shall be handled with care.

4.4 Handling and Storage of Alkali Metals

Handling and Storage of alkali metals shall be governed by the following instructions:

- (1) Workmen handling alkali metals shall wear liquid metal protective clothing and equipment prescribed for the job areas being occupied or traversed.
- (2) Alkali metals shall be stored in a segregated area in an unsprinklered, fire resistant building, except when the metal is contained in stainless steel drums under inert gas cover, in which case storage in the open is acceptable. An inert gas (GN_2 or Argon) shall be used to blanket alkali metal storage systems whether in the open or indoors. Storage systems shall be designed to eliminate any possibility of water or moisture coming into contact with the alkali metal.
- (3) Alkali metal containers shall be kept closed except when filling or emptying operations are in progress.
- (4) When opening an alkali metal container which is not under inert gas cover, loosen the cover and listen for a hissing sound which could indicate the presence of hydrogen gas. If hissing occurs, allow the hydrogen to escape prior to completion of cover removal.
- (5) "No Smoking" signs shall be posted in the alkali metal work area and the no smoking restriction shall extend a minimum of 20 ft from any open alkali metal container or system.
- (6) If the possibility exists that hydrogen gas can be generated and trapped within a facility, the electrical equipment in the facility shall be provided and installed in accordance with the National Electric Code (NFPA #70). Equipment shall be Class I, Division I, Group B.
- (7) Water must never be used on burning metal or equipment in which the metals are stored or used. Only approved fire extinguishing agents shall be used on metal fires. (See Table VIII). Chemical solution type, vaporizing liquid type, or carbon-dioxide extinguishers are not effective and their use will add to rather than reduce the hazard. The chemical solution type of extinguisher (soda acid) contains water,

while the vaporizing liquid type (carbon-tetrachloride) and carbon-dioxide both react violently with alkali metals.

- (8) Prior to removal of alkali metal from its shipping or storage container, the receiving equipment should be thoroughly dried and kept dry while the metal is added. Equipment to be used in the transfer operation should also be clean, dry, and at a suitable temperature. Every precaution should be taken to prevent moisture, even perspiration, from dropping onto the metals. A suitable inert gas should be used as an atmosphere for blanketing the metals wherever possible during handling. Nitrogen argon or helium is suitable for blanketing sodium potassium and NaK, however only helium or argon can be used to blanket lithium.
- (9) The residue from an alkali metal fire must be handled with as great a care as is used with original metal.
- (10) Personnel who may be exposed to toxic fumes shall wear approved Scott Air Pack respiratory protection equipment and protective clothing.
- (11) If personnel are exposed to alkali metal, they should examine their bodies including hair for metal residues and brush their clothes thoroughly. When brushing is not done thoroughly, severe burns or damage to clothing may result, or fires may start in lockers after the clothing has been stored. Skin areas affected by caustic should be washed with dilute (2% Normal) acetic acid and water. All caustic or liquid metal residues on tools and clothing must be removed by copious flushing with water.
- (12) Alkali metals should be transferred at the lowest possible temperature to minimize handling hazards. Molten metals should not be exposed to the atmosphere during transfer.
- (13) Appropriate signs shall be posted at areas where alkali metals are stored or used, to warn of the hazards to be encountered, materials to keep from contact with the metal, and to advise which fire extinguishing agents can be used.
- (14) Alkali metal contaminated materials, metal residues, and metals which are no longer suitable for use must be placed in the special containers provided.

- a. Waste alkali metals and metal residues will be placed under UL (Underwriters Laboratory) approved sodium carbonate (NAX), Met-L-X powder or under inert gas atmosphere in labeled, metal cans with gasketed lids. The can labels shall identify the contents and designate incompatible materials.
 - b. Waste materials contaminated with small quantities of alkali metal, such as spent insulation, and spent fire extinguishing agents will be placed in sheet metal cans appropriately labeled and with tight fitting lids. If the waste material contains definitely separated masses of metal which the operator feels would constitute an explosion or fire hazard, it should be placed under sodium carbonate or Met-L-X powder.
 - c. Cans should be of such size that when filled two men can safely carry them by hand.
- (15) All organic and hydrocarbon materials shall be kept out of the alkali metal storage or working areas. Alkali metal received packed under kerosene should be stored separately from that received under inert gas.
 - (16) Prolonged storage of NaK residues in contact with air leads to the formation of potassium superoxide, therefore NaK residues which have been exposed to the air should be disposed of immediately.
 - (17) Area in which alkali metals are stored should be used for this purpose only.
 - (18) The alkali metal storage area will be clearly marked and approved Class "D" type fire extinguishing equipment and protective clothing will be stationed nearby.
 - (19) Inspection of the storage area will be done monthly and will be documented in a manner suitable for audit.
 - (20) NaK containers suspected of containing potassium superoxide shall be handled remotely with Safety Division approval required.
 - (21) NaK containers suspected of containing potassium superoxide should be stored a minimum of 20 ft apart from other alkali metal storage containers.

- (22) An inert cover gas or approved fire extinguishment powder shall be maintained at all times over unsealed alkali metal containers.
- (23) If there is any possibility that air has entered a container of NaK or potassium, as through a loss of cover gas pressure, it must be assumed that potassium superoxide has formed on the containment walls or the metal surface.
- (24) If potassium or NaK has been received packaged under kerosene and the kerosene has been depleted to the extent that a yellow color has appeared on the metal, extreme care must be exercised. The reaction of potassium superoxide with hydrocarbons and organics is explosively violent.
- (25) Keep organics and hydrocarbons away from potassium superoxide!

4.5 NaK Containment and Material Compatibility

NaK containment and material compatibility is shown in Table III.

TABLE III

NAK CONTAINMENT AND MATERIAL COMPATIBILITY

<u>Material</u>	<u>NaK Compatibility</u>
Stainless steel, 300-series	Very good
Copper	Poor
Steel	Fair
Brass	Poor
Aluminum	Poor
Polyethylene	Good
Teflon	Poor
Glass	Good
Pyrex	Good
Earthenware	Fair
Neoprene	Good
Tygon	Good
Viton A	Good

4.6 Compatibility of Common Liquids with NaK

Most liquids are incompatible with NaK, and as a general rule, the only materials that should come in contact with NaK are the materials used for its containment and the inert cover gas. The compatibility of common liquids with NaK is shown in Table IV. (See page 16.)

4.7 Alkali Metal Facilities, NaK Area Definition and Access

The areas in which alkali metals are stored, transferred, disposed of, or used are to be designated as alkali metal areas, and will be posted with signs. In the case of EBR-I the signs shall read, "NaK AREA Use NO WATER". A barrier ribbon or rope with an explanatory tag referencing access regulations will be placed across access entry. Access to the alkali metal areas are limited to working personnel and authorized observers all of whom must wear proper equipment and comply with current safety regulations. A minimum of two persons shall be present to gain access to a alkali metal area; and any handling of alkali metals shall be accomplished by a minimum of two persons and one backup man adjacent to the working area.

TABLE IV
COMPATIBILITY OF COMMON LIQUIDS WITH NaK

<u>Material</u>	<u>NaK Compatibility</u>	<u>Remarks</u>
Mercury	Very Poor	Can result in large temperature excursion
NaK		
Mix-4P3E	No Reaction to Poor	Some experimental data indicate no reaction until elevated temperature is achieved and then very little reaction
Ammonia (NH ₃)	Good	NH ₃ is a true solvent for NaK
HNO ₃	Very Poor	HNO ₃ reacts violently with NaK
Water	Very Poor	Water reacts violent with NaK and generates hydrogen gas
Alcohol	Poor	Alcohol reacts with NaK to form alcoholates and hydrogen gas
Mineral Oil	No Reaction	Mineral oil does not react with NaK unless potassium superoxide is also present in which case the reaction can be explosive
Chlorinated & fluorinated hydrocarbon liquids	Very Poor	These liquids can react violently with NaK
Fluorinated oils	Very Poor	These oils can react violently with NaK
Silicone oils	Very Poor	After an incubation period, silicone oil will react vigorously with NaK
Caustic (KOH/NaOH)	Vigorous	Caustic solutions react with NaK to form hydrogen gas, however the reaction is less violent than the water/NaK reaction.

5.0 FUNDAMENTAL PROCEDURES

5.1 Alkali Metal System Entry and Service

- (1) The opening, repairing, welding or otherwise servicing of tanks, lines or valves containing alkali metal, shall be done only under Standard Operating Procedure and/or Safe Work Permit. Safety Division approval will be required.
- (2) Approved personnel safety equipment as listed in Section 6.2 will be worn when performing any of the above operations. If a metal fire results, safety clothing and Scott Air Packs must be worn by personnel taking counter measures.
- (3) Alkali metal shall be removed from the equipment prior to its being serviced.
- (4) Opening NaK Contaminated systems. The most dangerous aspect of opening a NaK system is the unknown presence of pressure in the system. Probably more fires and accidents have occurred because of this than from any other single cause. Occasionally lines leading to pressure gages and/or transducers will plug with oxides which results in the gage giving an erroneous reading. Therefore, whenever a NaK system is opened it should always be assumed that it is under pressure and the opening of the system should be handled accordingly. When it becomes necessary to open a NaK system, it must be drained completely, or freeze blocks can be used to isolate the affected area. A tried and proven procedure for cutting into a NaK system for removal of a section with a minimum of air contamination to the system is as follows:
 - a. Drain the system of NaK or apply refrigerant locally to form freeze blocks, and reduce the cover gas pressure in the system to less than 1 psig.
 - b. Assemble all necessary equipment.
 - Dry ice or LN_2
 - Roll of 2-4 inch tuck tape
 - Ansul fire extinguisher w/Ansul UL Approved Sodium carbonate and extra barrels of agent.
 - Proper safety clothing
 - pipe clamps

Metal drip pan

Rubber expandable bladder of correct size for pipe

- c. Pack dry ice on both sides of each cut to be made or spray with LN_2 to freeze any residual NaK which may be in the pipe. Cut approximately 3/4 through the pipe with a pipe cutter (if there is room to use a pipe cutter). Make the second cut completely and wrap tape around the cut and clamp the two pieces back together with the pipe clamps to keep the sections rigid. Complete the first cut and remove the cut section after removing the pipe clamp and tape. Immediately after removing the cut out section, clean the exposed ends with alcohol to remove residual NaK. Plug both of the open ends of the pipe with the rubber bladders expanded to tightly seal the pipes. The ends can be chamfered for welding a new section in with the plugs in place.
- d. To re-install the section, remove the plugs and follow the removal sequence in reverse, substituting welding for cutting. Use a constant low-pressure-argon flow to shield the weld root when welding.

5.2 Alkali Metal System Decontamination

- (1) General. Alkali metal decontamination may be required to change, repair, replace or decommission equipment. Removal of alkali-metal dregs and perhaps relatively large amounts of oxide will be required. In general, this is done by chemical reactions. Fitting the cleaning technique to the cleaning requirement will eliminate many problems.
- (2) NaK Decontamination. NaK containing equipment and/or piping shall be decontaminated as soon as possible after removal of the NaK to minimize the possibility of potassium superoxide formation.
- (3) Protection from the Atmosphere. A drained NaK system should be protected from atmospheric contamination pending initiation of cleaning procedures. Atmospheric contamination can result in formation of hard crusts over free alkali metal, increasing the difficulty of cleaning and result in the formation of potassium superoxide.

(4) Cleaning Agents and Their Use

Cleaning agents are solvents and reactants such as water, steam, or alcohol. Table V shows some physical properties of various cleaning agents.

TABLE V
PROPERTIES OF CLEANING AGENTS

Agent	Boiling Point (°C)	Solubility in Water @ 20°C (g/100 ml)	Reaction Products	Solubility of Reaction Products in Water (g/100 ml)
CH ₃ OH	64.7	∞		
C ₂ H ₅ OH	78.5	∞		
i-C ₃ H ₇ OH	82.3	∞		
C ₄ H ₉ OH	117.7	7.9		
Ethylene glycol	197.2	∞		
Liquid NH ₃	-33.8	90 @ 0°C		
H ₂ O	100	--		

↑

metal adds to the alcohol group, releasing hydrogen

↓

metal dissolves but can form MNH₂

↑

Decompose

↓

Li	17.5 @ 100°C
Na	347 @ 100°C
K	178 @ 100°C
Rb	180 @ 15°C
Cs	395 @ 15°C

- a. By Solution. Liquid-ammonia cleans by dissolving the alkali metal, however the method requires refrigeration, which makes it difficult to use on large-scale systems. For small systems, and special application, the advantages can outweigh the disadvantages of the refrigeration requirement. No hydrogen is formed and there is no overheating. The color of ammonia solutions can be used as a rough indication of cleaning progress. A blue color denotes low concentration of metal; a bronze color develops in more concentrated solutions. Table VI gives some solubilities of

TABLE VI

SOLUBILITIES IN ALKALI METALS AND COMPOUNDS IN LIQUID AMMONIA

Values are g/100g NH ₃ at -33.8°C					
	<u>Li</u>	<u>Na</u>	<u>K</u>	<u>Rb</u>	<u>Cs</u>
Metal	11	25	47	107	173
Hydroxide	--	0.25 mg ⁻⁴⁰	--	--	--
Monoxide	--	--	--	--	--
Chloride	0.5	4	0.13 ⁻¹⁵	0.3	--

alkali metals and their compounds in liquid ammonia.

Because liquid ammonia cleans by solution it may be used to remove alkali metal residue from delicate equipment or from sensitive surfaces such as those to be examined metallurgically. Penetration into alkali-metal-filled crevices is perhaps superior to any other agent.

Ammonia will not dissolve such impurities as sodium oxide and sodium hydroxide. However, these impurities can be removed by reaction with two to five percent ammonium chloride which may be added to ammonia after the bulk of sodium has been removed. Reaction of ammonium chloride with these contaminants produces sodium chloride, which is soluble to about four percent by weight in liquid ammonia. Corrosion by liquid-ammonia cleaning procedures is low. The cleaning agents are normally injected at the lowest level of a large system.

Mercury has been used to clean alkali-metal systems, generally as an expedient to permit analysis of residues for oxygen. This may be considered for small components in specialized cases, but it is cumbersome and not recommended as a general procedure.

- b. By Reaction. Alcohol, water, steam, and concentrated aqueous hydroxides are examples of cleaning agents that perform by reaction. They all release hydrogen during reaction with the alkali metal. The reaction rate of

alcohol with the alkali metal decreases with increase in molecular weight and complexity of the alcohol molecule, going from normal through secondary and tertiary alcohols. Reaction of the alcohols with alkali metals is somewhat self-controlled as alcohol is evaporated when the reaction becomes too vigorous. In addition to the hydrogen hazard, the flammability hazard of the alcohol itself must also be considered. Another undesirable feature of the alcohols is production of the alkali-metal alcoholates, which may form insoluble crusts over free alkali metal and slow further reaction. A word of caution is warranted on the use of alcohol as a cleaning fluid for systems containing potassium, rubidium, or cesium. The highest oxides formed by exposure of lithium and sodium to air are the peroxides (M_2O_2) which will react violently with organic compounds. Also, any free alkali metal can react with the organic cleaning fluids, produce a local temperature increase, and thus initiate the peroxide reaction. Potassium, will form higher oxides (MO_2 or superoxides) on exposure to air. The superoxide is explosively reactive with organic compounds, and the need of excluding alcohol from systems that contain these higher oxides is mandatory.

Steam cleaning has been used on large equipment, including steam generators with multitube arrangements where a steam lance has proven to be a suitable tool. There are a number of advantages to steam cleaning. First, the alkali metals, with the exception of lithium, will be liquid at the steam temperature, providing greater possibility for complete reaction. Second, the flammability hazard is reduced with steam.

There are disadvantages, however. The limited amount of water available during initial stages of cleaning may lead to caustic-soda formation which, in the dry form, can cause plugging of small channels or lines. Furthermore, as the heat capacity of steam is low, temperature excursions can be expected. Care must be taken not to allow steam to condense before contacting the metal.

An effective technique of steam cleaning is to dilute the steam with an inert gas. The initial stage of cleaning may entail the use of a mixture of, for example, 5 vol% steam and 95% inert gas. As the reaction continues, the steam content can be enriched, leading to faster reaction until ultimately it will be 100% steam. A similar technique involves the use of an inert gas with high moisture content. This working media can be prepared by bubbling inert gas through water. The water-vapor content of the working media can be controlled by the inlet temperature of the inert gas or by the length of the path that the inert gas must travel.

If a system is suspected or known to contain superoxides, a number of washout techniques are available other than those using alcohols. First, the higher oxides can be reduced to lower oxides by heating to approximately 800°F in the presence of pure alkali metal. The alkali metal must be in contact with the higher oxides to effect decomposition. Second, steam cleaning rather than alcohol flushing can be employed. Reaction of steam or water with the higher oxide is less violent than with the pure metal, however if free metal is present, hydrogen gas will be formed. Concentrated NaOH has been used to clean sodium systems, although its use has been rather limited. This technique depends upon the common-ion effect of the hydroxyl ion in the solution limiting the rate of reaction between the water and the alkali metal. The technique normally consists of using saturated NaOH solution during the initial stages of washout followed by the addition of more dilute solutions, until pure water is being put through the system. One of the advantages of this technique is the elimination of the fire hazard present with the use of alcohols. Furthermore, the reaction rate is low, and higher temperatures can be tolerated because of the higher boiling point of the caustic solution. This eliminates evaporation of the cleaning fluid and residue that may

plug small lines or channels. Some of the disadvantages include the inability to determine the degree of cleaning, at least during the initial stages of washout, and the potentially greater degree of corrosion of structural materials.

(5) Hazards

- a. Alkali Metal Pockets. Alkali-metal pockets can lead to large localized temperature and pressure excursions. These pockets are ideal locations to collect or form reaction products that form protective coatings over the residual pool of alkali metal. Subsequent solution during a water wash will expose free alkali metal. Pocketing areas also complicate flushing procedures after initial reactions, because they tend to retain cleaning fluid high in caustic content. Density differences between water and NaOH inhibit mixing of the two fluids. Equipment which cannot be drained free of large alkali metal pockets should be removed from the system and cleaned with steam on the EBR-I NaK disposal pad. If the equipment cannot be removed as is the case with the EBR-I NaK drain tanks, saturated GN_2 at high velocity shall be used to create turbulence in the residual NaK thus preventing the formation of protective coatings and allowing the water-NaK reaction to continue to completion.
- b. Hydrogen Explosion. A hazard during washout is the potential of a hydrogen explosion if air has been admitted to the loop. Hydrogen-air mixtures will explode between about 4 and 80 vol% hydrogen (at 100°F). As the reaction proceeds, hydrogen will flush out any trapped air so the danger is most pronounced during initial phases. To minimize the danger of a hydrogen gas explosion an inert-gas flush should be used, prior to washout, and the hydrogen evolved should be ignited at the system vent by a constant pilot light. A flame arrester is also recommended if the back pressure is not unduly increased. The most effective flame arrester is a GH_2 water bubbler.

- c. Pressure Excursions. Pressure excursions have been discussed earlier. The need for sufficient venting during washout cannot be overemphasized.

(6) Stepwise Cleaning Procedures

Examples of Stepwise Cleaning Procedures are shown in Table VII which follows:

TABLE VII

STEPWISE CLEANING PROCEDURES

Alcohol Cleaning

1. Completely drain the system. Cool to below alcohol boiling point.
2. Fill system with nitrogen or other inert gas. Equip high-point vent line with pressure-relief valve or check valve. Maintain slight inert-gas bleed.
3. Add 95% ethyl alcohol and allow alcohol to reflux. Methyl alcohol, which reacts at a slightly higher rate, can also be used.
4. Add additional increments of alcohol each time the alcohol temperature falls below the boiling point. Continue until system is completely filled.
5. Circulate or agitate alcohol.
6. Drain.
7. Cut alcohol to 20% water.
8. Fill, repeat circulation or agitation.
9. Drain and refill with water and circulate.
10. Soak and drain.
11. Verify system is dry prior to placing back in service.

Steam Cleaning

1. Drain alkali metal system and fill with inert gas. Preheat system to prevent steam condensation.
2. Add dry or slightly superheated steam at approximately 15 psi gage pressure
3. Maintain gas bleed through vent lines until steam venting is observed. Inert gas flow can now be stopped.
4. Vent steam through all openings and through all paths, each in turn.
5. Remove system heat, introduce wet steam, permit condensation.
6. Fill system with water, allow water to issue through each path and through each vent
7. Verify system is dry prior to placing back in service.

TABLE VII (contd.)

GN₂ Cleaning

1. Drain the alkali metal system and fill with inert gas
 2. Apply temperature indicating tabs to the system
 3. Add moist GN₂ at approximately 15 psi gage pressure
 4. Maintain gas bleed through vent lines until GN₂ venting is registered.
 5. Vent moist GN₂ through entire system
 6. Continue moist GN₂ purge until reaction of water with the alkali metal is completed
 7. Fill system with water, allow water to circulate through the system.
 8. Drain and refill the system. Continue until flushing fluid is free of caustic.
 9. Drain system
 10. Dry system with dry GN₂.
-

5.3 Routine Spill Cleanup

Continual monitoring of the facility will dictate the need of routine cleanup and disposal of alkali metal contamination.

Appropriately designed drip pans or containers under equipment can frequently provide adequate control for small leaks. Their main purpose is to contain or confine the alkali metal and prevent its contact with concrete or combustible materials, and to minimize the spread of contamination.

In the case of a NaK spillage which does not burn, no immediate danger exists providing the NaK spill is covered with approved fire extinguishing agent (see Table VIII). Minor leakage or droplets should be scraped up and placed in a container to await disposal. Larger spills should be ringed by a dike of dry sand and blanketed with a fire-fighting material such as Met-L-X, and scooped up for removal to the disposal area. If burning occurs, the heavy white oxide smoke emitted acts as an irritant to the eyes, throat, and skin. In this case the spill will be handled as an emergency, as described in Section 7.

Disposal of the alkali metal remaining after a fire can be as hazardous an operation as the fire fighting, however it is a relatively safe operation if adequate personnel protection is used and proper precautions are observed in handling the residual metal and extinguishment powder.

As soon as possible after an alkali metal fire, the residue, which will consist of unburned metal, hydroxides, oxides, and fire extinguishment should be shoveled into a dry metal container. Since disturbing the residue may cause the metal to re-ignite, the operation should be carried out as quickly as possible, and a blanket of fire extinguishment spread over the surface to exclude oxygen and extinguish any fire.

5.4 Disposal of Alkali Metal Wastes

- (1) General. Assurance of safe disposal of Sodium or NaK metals, residues, or NaK contaminated equipment, usually requires that the alkali metals be converted to a nonreactive form. This can be accomplished under controlled flame burning, slow oxidation with air or chemical reaction with reagents such as water, aqueous hydroxides, alcohol and steam. Neutralization of converted wastes may be necessary if corrosion of containers is a concern. This may be accomplished through adequate dilution or pH adjustment with acids.
- (2) Radioactivity. If sodium or NaK contains radioactive contamination, special precautions must be taken to prevent excessive radiation exposure of personnel performing the operation (e.g., anti-C clothing, ventilation, respiratory protection, dosimetry and health physics monitoring, etc). Care must be exercised to prevent spreading of contamination to other equipment, facilities or personnel through spills, fires, or explosions. Use drip pans, fire extinguishments, tanks, ventilation control, and filters to confine or control activity.

Excessive release of radioactivity to the environment from both waste handling and disposal operations must be prevented. The rules and regulations of AECM Chapter 0524 should be used as a guide.

(3) Conversion Methods

(a) Nonradioactive

1. Small amounts (gm batches) of alkali metal may be converted by burning in a heavy metal dish under a hood, using a gas flame or reacting with alcohol or water. Residues may be disposed of by flushing with water to normal waste systems.
2. Larger amounts (1 or more lb) of alkali metal may be burned by flame or reacted with chemicals such as water, dry steam, or hydroxides if controlled and isolated.

- (b) Radioactive. Contaminated NaK shall be reacted or burned under controlled atmospheric conditions. The oxide fumes shall be passed through a filtration system to remove radioactive solids. The NaK residues shall be collected and disposed of as a radioactive contaminated solid waste at the NRTS Burial Ground.

(4) NaK Conversion Guidelines

- (a) Conversion of alkali metal and/or residues in the open (outside of the NaK processing equipment) shall be supervised by an officer of the NRTS Fire Department.
- (b) Conversion shall be accomplished at approved NRTS sites which are: The NRTS Fire Department training field, the EBR-II Sodium Disposal Pads, the EBR-I NaK disposal pad and the acid disposal pit (non-radioactive residue).
- (c) Two men shall be present during any or all conversion actions.
- (d) All men directly involved in the conversion shall wear complete liquid metal protective clothing and gear during loading, unloading, and conversion operations.
- (e) Special procedures shall be prepared for conversion of radioactive contaminated alkali metal.

5.5 Transportation of NaK

- (1) NOS Appendix 6.4 A-5 shall govern the preparation and transportation of NaK.
- (2) Annex L shall apply for onsite shipment of radioactive alkali metals.

- (3) If evaluation of the alkali metal condition determines that an explosion possibility exists during transportation activities the following precautions shall be observed:
1. A motor pool truck shall be modified to provide adequate protection of the driver and assistant from the explosive hazard.
 2. Two men shall ride the vehicle to the disposal area.
 3. Material to be disposed of will be placed in a container to alleviate jarring or movement in transit.
 - a. Sand makes a good packing material.
 - b. Container(s) shall be adequately secured to the disposal vehicle. (Metal bodied dump truck preferred.)
 4. A fire crew escort or follow-up fire apparatus shall accompany the disposal vehicle.
 5. Safety precautions shall be commensurate with the degree of danger.
- (4) All alkali metal shipping procedures must be approved by the Safety Division and ANC shipping coordinator.

6.0 PERSONNEL PROTECTION

6.1 General

Protection of personnel engaged in handling liquid metals shall be afforded by a combination of individual hygiene, protective clothing and equipment, a planned medical program, and by detailed formal instruction in alkali metal methods and procedures.

6.2 Personnel Safety Equipment

The following are considered minimum requirements for alkali metal protective gear:

- (1) Coveralls (fire resistant) Nomex
- (2) Hard hat with full face shield
- (3) Goggles (Jones type or chemical splash)
- (4) Gloves (leather or PVC) long gauntlet
- (5) Leather boots with chrome leather leggings
- (6) Scott Air pack respiratory protection, if required.

6.3 Precautions in the use of Personnel Safety Equipment

- (1) Eye protection shall be provided and used.
- (2) Gloves and roll down sleeves shall be provided and used.
- (3) Alkali metals are very destructive to wool and synthetic clothing
- (4) Loose clothing that is easy to remove shall be worn
- (5) Eliminate clothing features which can catch and hold alkali metal
- (6) Protective clothing should be worn to cover the whole body
- (7) Cloth gloves are ignited rapidly, therefore, use only chrome leather or PVC long gauntlet
- (8) If hot or liquid metal is splashed onto leather gloves, remove as quickly as possible, as conduction of heat is rapid. The gloves should then be decontaminated because diffusion of alkali metal reaction products through the leather can produce chemical burns,
- (9) Avoid rubber boots
- (10) Respirators may be used in emergency situations when approved by ANC Industrial Hygiene
- (11) Use Scott Air packs if there is any question of a hostile atmosphere.

7.0 EMERGENCY PROCEDURES AND PROTECTIVE EQUIPMENT

7.1 General Definition

An emergency exists in EBR-I if any event occurs that can affect the safety of personnel or lead to the destruction of government equipment or facilities. A precursor of emergency exists if there is any doubt as to the outcome of an action. Therefore emergency procedures are established to guide personnel trained in handling alkali metals. The following procedure will ensure maximum safety and eliminate loss of property.

7.2 EBR-I Potential Emergencies

- (1) NaK spill
- (2) NaK fire
- (3) Thermal and caustic burns to personnel
- (4) Hydrogen (GH_2) explosion
- (5) NaK/ KO_2 /organic explosion.

7.3 Emergency Response

At the first sign of an incident, the cognizant engineer, foreman or worker shall initiate the emergency alarms and spread the word to other workers for immediate area evacuation upwind, and to the appropriate safety monitors and emergency crews for fire and first aid. Shutdown procedures will consist of stopping system pumps, motors and electrical gear, venting system pressure, opening dump valves and draining the NaK back to the drain tank. The Warning Communications Center, the Manager of Environmental and Waste Management and Manager of CF/PBF Safety Branch shall be notified of any emergency. In applicable instances, the CF Dispensary and Ambulance shall be notified.

7.4 Emergency Protection Equipment

- (1) Emergency protection equipment shall be provided for those personnel who must enter or remain in an alkali metal designated emergency area. Reasons for entering or remaining in this area include: shutdown of equipment, rescue, evacuation, fire fighting or cleanup.
- (2) A list of equipment and procedures to be used under applicable emergency situations is as follows:
 - (a) Emergency Plan for EBR-I
 - (b) Fire alarms and firefighting equipment

- (c) Safety showers (Haws steel safety shower Model 3620 with eye wash device)
- (d) Eye fountains
- (e) Scott Air packs
- (f) Emergency panels containing first aid kits, stretchers, towels and blankets. (Blankets should be labeled "Warning Do Not Use to Smother NaK")
- (g) Emergency signs and placards
- (h) Telephones and radio with applicable numbers and names.

7.5 Alkali Metal Fire

7.5.1 General. Fires may initiate when alkali metals are exposed to the atmosphere. Circumstances most conducive to burning include high temperature, high state of subdivision, splatter, and high humidity.

NaK is more reactive than either sodium or potassium alone.

7.5.2 Burning Characteristics of NaK

- (1) Reacts easily at room temperatures, but will not ignite spontaneously without moisture until its temperature reaches about 239°F.
- (2) Temperature of the metal may reach 1618°F.
- (3) Flames, if there are any, are small and may not be readily visible.
- (4) Hot spots of burning metal are a brilliant yellow.
- (5) Produces large volumes of thick white smoke.
 - (a) Although the voluminous white smoke produced from the burning metal looks threatening, there is no danger of explosion from the burning metal itself.
 - (b) The white smoke is dangerous because the hot oxide particles will combine with the moisture in the air or on the skin to form alkali hydroxide which is a strong caustic (lye) that will burn the skin, eyes, and lung tissue.
 - (c) Alkali oxides and hydroxides are readily soluble in water; consequently, washing affected areas with large volumes of water is immediately beneficial treatment for exposed areas.

7.5.3 Comparative Heat Release

NFPA guide for smoke and heat ventilating industrial ventilation:

Material	Heat Release BTU per minute per square foot of floor area
Gasoline	25,000
Wood pallets in pile 8 ft high	8,000 to 10,000
Sodium, burning in air	40,000 Btu/hr

7.5.4 Types of Fire

- (1) Seepage from high temperature systems. Most alkali metal systems are operated above 500°F. This temperature is sufficient for auto ignition of metal upon contact with atmosphere. The leakage rate will determine the severity of the fire. Pipe insulation will absorb considerable quantities of alkali metal which can produce what is best described as a smoldering fire. Such leaks around insulation are difficult to locate because the metal may travel for some distance before coming through the insulation.
- (2) Jet stream. Jet stream leaks will cause scattering of the alkali metal and promote rapid burning because of the small particles. Jet stream ignition will depend a great deal upon temperature and humidity. The leakage rate from the system will depend on inert cover gas pressure and size of leak. Reduction of system pressure should be the first step in fire fighting. Maintaining vent lines free of solidified alkali metal is very important.
- (3) Drip pans. Easiest fires to fight are those contained in metal drip pans. The pan acts as a heat sink and contains the NaK within a limited area. The pan helps to retain the fire extinguishment.

7.5.5 Fire Extinguishments

Fire extinguishments are shown in Table VIII which follows:

TABLE VIII
FIRE EXTINGUISHMENTS

<u>Extinguishment</u>	<u>Composition</u>	<u>Best for</u>					
		<u>Li</u>	<u>Na</u>	<u>K</u>	<u>Rb</u>	<u>Ca</u>	<u>NaK</u>
UL Approved Na_2CO_3	Na_2CO_3		X	X	X	X	X
Graphite ^[a]	Carbon	X	X				
Met-L-X ^[b]	Resin-covered NaCl		X	X	X	X	X
Pyrene G-1	Resin-covered NaCl		X	X	X	X	X
Soda ash	Free-flowing Na_2CO_3		X	X	X	X	X
CaCO_3	CaCO_3		X	X	X	X	X
TEC powder ^[b]	Ternary eutectic chloride mixture		X	X	X	X	X
Lith-X	Graphite base	X	X				
Polyurethane foam ^[c]	--		X	X	X	X	X
Purple K	Free-flowing KHCO_3			DO NOT USE			
Sand	Dry SiO_2		X	X			X
ABC powder	---			DO NOT USE			
Dry powder	Free-flowing NaHCO_3			DO NOT USE			
Carbon dioxide	CO_2 -reignites, may produce CO			DO NOT USE			
Carbon tetrachloride	CCl_4 -explodes			DO NOT USE			
Water	H_2O -explodes			DO NOT USE			
Water-based foams	-explodes			DO NOT USE			

[a] Used for Na, K, Rb, Ca, NaK in small leaks

[b] Extinguishment/metal weight ratio is 1/2 to 1/3 for TEC and Met-L-X

[c] Must be applied before temperature reaches 800°F

7.5.6 Extinguishing An Alkali Metal Fire

The rules for extinguishing an alkali metal fire are basically the same as for any other burning material: use of the proper extinguishment; and exclusion of air. Five basic steps to be followed in extinguishing an alkali metal fire are: (1) be familiar with the fire plan (2) use the proper protective clothing (3) contain the alkali metal (4) extinguish the fire and (5) clean up the residue.

- (1) Fire Plan. The operator and fire brigade response should be as follows:
1. Sound the alarm (pull box preferred to phones).
 2. Minimize the hazard by securing the system, removing pressure and dumping the NaK to dump tanks as applicable.
 3. Don protective clothing and use approved fire fighting equipment and materials.
 4. Use the buddy system; do not enter hazardous areas without backup.
 5. All brigade and fire department response to an EBR-I fire alarm should consider the possibility of a NaK fire event though the fire alarm may have been actuated by a conventional fire.
 6. The fire brigade captain will remain in charge of all fire fighting efforts until he has fully advised the Fire Department officer of the particulars and hazards involved.
 7. The brigade should then assist the Fire Department as requested by them.
 8. Immediate cleanup efforts should follow any NaK fire, since if allowed to stand, the residue will absorb water from the air and make cleanup more hazardous.
 9. Appropriate first aid should be given immediately to anyone receiving NaK burns.
- (2) Protective Clothing. The recommended protective clothing to be used in combating an alkali metal fire include the following: hard hat with full face shield, Jones or chemical goggles, dry PVC or chrome leather long gauntlet gloves, flame proof (Nomex) coveralls without cuffs (to avoid catching liquid metal), high quality leather shoes and chrome leather leggings, coat, full length chrome leather, and self-contained air packs.
- (3) Contain the Alkali Metal. If the alkali metal is molten (NaK is liquid at ambient temperature down to 10°F) it must be contained prior to attempting to extinguish the

fire. The metal can be contained in drip pans designed for use under liquid metal containers piping and equipment, or it can be contained by diking with sand or extinguishment.

(4) Extinguishing the Fire

The technique for application of fire extinguishment is important both in minimizing spread of the burning material and properly smothering the material with a minimum amount of extinguishment. Too rapid application of the extinguishment can cause spread of the burning metal incomplete coverage of some of the burning areas, and over loading of other areas which may cause sinking of the crust. The extinguishment may be administered to the burning surface with either a commercial extinguisher (which uses inert gas as a propellant) or with a shovel or scoop. Better control of spreading of the extinguishment and freer application is generally attainable with a shovel. The extinguishing cover should be built up slowly and uniformly. For difficult places, such as vertical lines or dripping horizontal lines, extinguishments are ineffective. Once complete coverage has been attained, there is no guarantee that re-ignition will not occur. An indication of potential re-ignition is a darkening of the extinguishment surface. This is the result of a localized hot spot causing degradation of the resin coating on the extinguishment. Immediate application of a fresh coating to this area will prevent re-ignition of the fire. When the fire has been permanently extinguished, the alkali-metal and extinguishment residue should not be disturbed until it has cooled below the melting point of the alkali metal.

(5) Cleanup the Residue

Cleanup of alkali-metal residue is a far from pleasant task, as re-ignition may occur. However, it is generally preferable that fire residues be collected and

disposed of as soon as possible (after cooling). Alkali metal residue and extinguishment is best shoveled into a dry metal container fitted with a lid. The residue should be covered with a layer of extinguishment and the lid closed before transportation to the disposal area.

After the bulk of the residue has been removed from the drip pan or fire area, additional cleanup is required. Good judgment, based on training and common sense, must be used to determine what should be done. If little alkali metal and fire risk is present, careful flushing with water can be used. If a large amount remains, it should be scraped from the surface before water is used to flush the area. After the area has been flushed of free alkali metal, a continued water flush should be used to remove as much caustic as possible. Caustic will adhere to all surfaces and is difficult to remove by flushing alone, hence a dilute acetic-acid wash can reduce cleanup time. Neutralization is essential if caustic residues are present on easily corroded surfaces. Any insulation that has been exposed to leaking alkali metal should be removed and replaced with new insulation. Piping must be cleaned and neutralized with an acetic-acid swabbing.

Non-radioactive contaminated alkali metal residue from a fire or spill shall be disposed of by water reaction at the NRTS acid pit. Radioactive residue from a fire or spill shall be disposed of by heating the residue in an open receptacle to complete the oxidation of the alkali metal. The product of oxidation shall then be packaged for disposal at the NRTS Burial Ground.

7.6 Major NaK Spill

In the case of NaK spill the main concerns will be for the possible resulting fire, the air contamination by the oxide-filled smoke and the spraying of hot metal. All of these potential NaK dangers are visually apparent.

The philosophy in handling NaK spills and resulting fires if they occur, consists of keeping the spillage to a minimum, localizing the spillage and retarding liquid metal burning by the partial or total exclusion of oxygen.

NaK spills can vary in seriousness from droplets escaping from a system to a total container failure which may dump the entire system volume. The emergency procedures after a major NaK spill will be to:

- (1) Alert all personnel to evacuate upwind, determine the conditions and notify the proper departments; i.e., fire department, fire brigade, Manager of Environmental and Waste Management Branch, -WCC, Manager of CF/PBF Safety Branch.
- (2) Shut down all systems, dump the NaK to storage tanks if applicable and vent system pressures.
- (3) Upon accomplishing shut down, two men, fully protected with emergency equipment and with backup personnel standing by, will approach the area in question and determine the nature of the emergency. Advise EBR-I Project Engineers and proceed to apply indicated emergency fire fighting or cleanup and disposal procedures.

7.7 Injuries to Personnel

7.7.1 General Instructions:

In the event of serious personal injury, the Emergency Number 1515 shall be dialed and a request placed for ambulance, and a doctor if deemed necessary. The worker making the call must give explicit instructions as to the exact location of the emergency. The ambulance and the First Aid trained attendant shall report to the designated EBR-I Emergency Area. If possible, a man shall go to the emergency area in order to direct the attendants to the injured person.

7.7.2 First Aid Station:

A standard first aid cabinet shall be mounted on a wall in a readily accessible location near each operating area. Contents of the cabinet should consist of at least the following: bandages, sterile gauze, compacts, acetic acid, tourniquet, splints, tweezers, and spatulas. Fire retardant blankets should be provided at the First Aid Station for care of shock victims.

7.7.3 Immediate First Aid for Liquid Metal Burns:

Appropriate prevention and treatment of alkali metal burns requires proper use of protective clothing, available first aid equipment and personnel thoroughly trained in its use. Eye protection and treatment should be given primary consideration if a NaK hazard exists. Extreme care should be taken when removing all protective equipment because of the possibility of residual NaK contamination. Protective clothing contaminated with alkali metal will protect for a very short period of time. Protective gear is not designed for sustained alkali metal contact.

If NaK has come in contact with clothing, flesh or hair, brush off or remove with protected hand, tweezers or spatulas. All clothing should be removed, and the person showered in a safety shower for 10 min. If there is a definite caustic burn or fire the individual should immediately enter the shower and disrobe while showering, even though NaK entrapped in the clothing will produce hydrogen gas in the reaction with water. Burn areas other than the eyes may be flooded with three percent acetic acid solution after water irrigation.

If metal has come in contact with the eyes they should be washed for 10-15 min with low pressure water stream. Aid should be given to the injured person to help maintain open eyelids during irrigation. Boric acid dispensed by the Medical Dept. may be installed in the eyes if available. Injured personnel should be sent to the Central Facilities Dispensary for follow-up treatment. A water filled pan may be used as a eye wash, with the injured person immersing the forehead and blinking the eyes, during transportation to the dispensary.

7.7.4 Personal Injuries. All persons injured or exposed to concentrated toxic fumes must report promptly to the dispensary for treatment. Also, the injury shall be reported to the individual's supervisor as soon as possible.

- (1) Walking Injured. Injuries in this classification comprise minor cuts, abrasions, contusions, burns, etc., wherein the victim is able to get to the dispensary

under his own power. Person inhaling concentrated metal fumes are not to be considered as walking injured.

- (2) Serious. These injuries are such that the victim will have to be removed from the area by ambulance to the dispensary or hospital. The patient must not be moved except by medical personnel unless further injury may result because of failure to be moved.
- (a) Fumes. Remove the victim from contact with fumes so as to avoid further injury. The patient should lie down and be treated for shock.
- (b) Shock. Shock may accompany any serious injury. All seriously injured persons must be treated for shock in addition to treatment for the specified injury. Treatment for shock consists of keeping the injured person warm, quiet and lying down.
- (c) Burns from Alkali Metal. If a person's clothing is on fire, his burning clothing should be removed and his body cleaned of all metal and metal residues. First aid treatment as outlined in 3 (a) should be followed.

8.0 TRAINING

8.1 Administration of Program

Training in the handling of alkali metals will be performed as a formal training course under the guidance of the ANC Environmental and Waste Management Branch.

8.2 Contents of Course

The training program should include, as a minimum, the following techniques and topics:

(1) Classroom preparation

- (a) Physical properties of sodium potassium and NaK
- (b) Toxicology of sodium, potassium and NaK
- (c) Protective clothing requirements
- (d) Respiratory equipment and fitting
- (e) Discussion of known accidents
- (f) Documentary Sodium fire films
- (g) Fire protection and fire fighting
- (h) First Aid
- (i) Emergency equipment and procedures.

(2) Field demonstration and/or practical application

- (a) Physical examination of sodium, potassium and NaK
- (b) Reaction of Sodium with:
 - Hard stream of H_2O
 - H_2O fog
 - steam
- (c) Reaction of sodium with ethyl alcohol (includes discussion of toxicology and demonstration of protective clothing and respirators)
- (d) Demonstration of effects on a sodium fire using:
 - Metal-X extinguishment powder.
 - CO_2
 - Na_2CO_3
 - ABC fire extinguishment powder
 - Graphite
 - (including participation of trainees)

- (e) Demonstration of safety shower and eye wash fountain including the location of these items at EBR-I.
- (3) Study and demonstration of First Aid techniques (including trainee participation)
- (4) Study and consideration of conceivable accidents and preparation for emergency procedures. (EBR-I)
- (5) Final written examination and certification.

APPENDIX H

DESIGN CRITERIA FOR THE
REMOVAL OF NAK AT EBR-I

J. L. Commander 5/60/74
Program Approved

D. P. H. 123 J. H. K. C. H. M.
Safety Approved

Design Criteria for the Removal of NaK at EBR-I

I. Introduction

To make the EBR-I Complex safe for the public use and enjoyment as a National Monument, decontamination is required. This includes the removal of approximately 5000 gallons of sodium-potassium eutectic alloy (NaK) coolant from drain tank T-3 (primary coolant), drain tank T-6 (secondary coolant), and the associated piping and components.

This document presents the conceptual approach, design limits, safety standards, system operation limits, system requirements, and sequence of removal operations.

II. Design Basis

Current and pending criteria specify the requirement that the NaK in drain tanks at EBR-I be removed. The following presents the design basis for the NaK removal.

1. Conceptual Approach - The NaK shall be pressurized out of the two storage tanks to holding tanks external to the EBR-I building and then through NaK processing equipment. Clean-up of the EBR-I tanks and plumbing will follow the completion of NaK processing.
2. Design Limits - The NaK removal system, which must interface with the existing EBR-I NaK and argon systems, shall have pressure, temperature and materials design limits compatible with the requirement for removal of the NaK from the EBR-I drain tanks; however, in no case will the design limits of the existing systems be exceeded. If the existing system capabilities are inadequate to satisfy the required design limits, the NaK removal design limits shall be revised accordingly.
3. Safety Standards - These standards are available in the Alkali Metals Safety Handbook.
4. System Operation Limits - The system operation limits are imposed by line sizes, pressure source and volume, mechanical joints, and cleanliness requirements.
5. System Requirements - System requirements shall include pressurizing gas, electrical power, a transfer line and related components.

6. Sequence of Removal Operation - The sequence of removal operations shall include prerequisites, precautions (personnel) and operating procedures.

III. Design Requirements

The requirements of design are based on the design basis statements in Section II, plus the applicable requirements of the Standard Health and Safety Requirements Report No. IDO-12028, General Design Criteria AEC Manual Appendix 6301, and AECM 0550. The emergency actions that will be taken in the event of line blockage, line rupture or other anomaly shall be identified in the EBR-I Alkali Metals Safety Handbook and in the detailed operating procedures.

1. Conceptual Design - The conceptual design provides for transfer of the NaK that is stored in drain tanks T-3 and T-6 located in the basement to NaK feed tanks outside of EBR-I. This will be performed by pressurizing the tanks using the existing Argon gas manifold, causing the NaK to flow (after proper valve operation) through the primary (or secondary) fill line to the transfer line and into the feed tanks. The NaK in the feed tanks will then be pressurized and transferred to a process tank for processing; Reference: The Design Criteria for the EBR-I NaK Disposal Facility. The tanks, plumbing and associated components of both systems (primary and secondary) as well as the complete process system shall be purged clean of all traces of NaK during decontamination operations which will be covered by a separate design criteria.
2. Design Limits - The ambient temperature necessary to perform the removal of NaK will have to be above 10⁰F to avoid freezing the NaK, therefore, this task must be scheduled for the summer months.

The maximum temperature and pressure for the NaK removal system shall be based upon the expected operating temperature +10⁰F to +120⁰F, and the pressure required to fill the feed tank at a rate of 10 liters per minute against a feed tank pressure of 2 psig, however, the pressure or temperature shall not exceed the maximum safe operating pressure or temperature of the existing system.

3. Safety Standards - The Alkali Metal Safety Handbook shall be made available to personnel involved in the NaK removal operation. In addition, for all those persons involved in the NaK removal, there will be a formal training class presented to educate these persons on the hazards, general safety, handling and storage, compatibility, fundamental procedures, personnel protection, emergency situations/procedures, and emergency protection equipment.
4. System Operation Limits - The NaK transfer line from the EBR-I fill line to the feed tanks shall be 3/8-inch diameter stainless steel tubing, unless Engineering determines that the diameter is too small to obtain a flow rate of 10 liters per minute with a nominal pressure drop. The

argon gas system which exists at EBR-I and is operational shall be utilized to pressurize the ullage space over the NaK in the EBR-I drain tanks. The pressure required to overcome pipe and component friction losses and to provide a NaK transfer flow rate of 10 liters per minute shall be calculated, however, the pressure shall not exceed the maximum safe operating pressure of the existing system. Mechanical joints shall be kept to a minimum, and where used, shall be supplied with a catch pan to catch any leakage from the joint. The transfer system will be cleaned and dried prior to acceptance for use in the NaK transfer operations.

5. System Requirements - The NaK transfer system requirements will be satisfied as follows: (1) The transfer line between the NaK fill valves and the NaK feed tanks shall be designed and fabricated to provide a flow rate of 10 liters per minute. (2) The existing EBR-I primary and secondary transfer system (Argon gas) shall be used to pressurize the NaK from the drain tanks to the transfer line. Valves which must be operated to effect the transfer shall be evaluated to insure this operability prior to acceptance of the transfer system for operation. Unacceptable valves shall be replaced prior to acceptance of the systems for operation. The existing EBR-I power system shall be utilized to provide the electrical power needed for the transfer operation.
6. Sequence of Removal Operation - The prerequisites for the removal of NaK require that a detailed procedure be developed and approved prior to any movement of NaK stored in the two tanks, also a sample of the cover gas to verify the Argon, Oxygen, Nitrogen, and Hydrogen content in the system. The personnel involved directly with the removal operation will attend an Alkali Metal Training Class to become certified in the safety, handling, and emergency situations with NaK. The pilot plant operation shall be completed and evaluated with the items of value noted during the pilot plant run incorporated in the main process plant design. The NaK from drain tank T-6 (secondary coolant) will be removed first, then the NaK from drain tank T-3 (primary coolant). Radiation hazards and controls will be discussed in the SAR and special protective procedures defined in the detailed operating procedures.

APPENDIX I

EBR-I SUPPORT SERVICES
REACTIVATION CRITERIA

by

E. W. Kendall

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Approved
W. P. Halls 2-7-74
Safety Approval

SUPPORT SERVICES REACTIVATION CRITERIA FOR EBR-I COMPLEX

I. Introduction

EBR-I Complex, having been designated a National Monument, will require Support Services Reactivation Design to provide for public safety and comfort as well as support of the D&D program. This will include the Plant Water System which has only been partially deactivated, the boiler plant, if feasible, or some other means of heating economically, portions of the electrical light and power system, and the heating and ventilating system.

II. Design Basis

Current and pending criteria specify requirements for reactivation of the support systems which include water, portions of power, portions of lighting, heating and ventilating, materials handling and evolvement of reactivation requirements. The following items describe the individual support system:

1. Water (potable system) - Reactivation of the fire protect system, well, reservoir, waterlines, except that in annex lunch room, and some component replacement. When water is turned on, it will be necessary that Industrial Hygiene be called in to sample the system for bacteria. Any restrooms not reactivated will have to be locked.
2. Power (electrical) - Reactivation of systems including main substation, switch gear, high lines, etc.
3. Lighting - Replacement of defective, worn out or damaged components, label switches and breaker boxes.
4. Heating and Ventilating - High-bay, basement and some rooms require heating. Ventilation is based on maximum exhaust during warm weather and minimum during the cold season.
5. Materials Handling - Reactivation of overhead bridge and monorail crane. Some revisions will be necessary to meet present day standards.
6. Evolvement of Reactivations - Items that may unfold or become disclosed by the growth and change of reactivated systems or components.

III. Design Requirements

The requirements of reactivation design are based on definition of items in Section II and in addition the applicable requirements of the Standard Health and Safety Requirements Report No. IDO-12028, General Design Criteria AEC Manual Appendix 6301, and AECM 0550.

1. Water (potable system) - The potable water system reactivation will supply the EBR-I septic system washrooms, water fountains, and outside water connections.

2. Power (electrical) - Sufficient power from the main substation will provide energy for required systems and components, and also for the NaK processing equipment and operations.
3. Lighting - The EBR-I facility will contain sufficient lights for use as an approved public installation. In addition to normal light, a number of battery powered emergency lights strategically located shall be installed for use in case of a power failure. ANC Industrial Hygiene will have to make a lighting survey to verify a minimum of thirty candle power.
4. Heating and Ventilating - Sufficient electric or gas space heaters will be installed in the facility high-bay, basement, restrooms, and offices to be used to maintain an inside temperature of 60°F with an outside temperature of -20°F. Emergency power or standby unit shall be considered to avoid freezing or some other adverse effect. Ventilation as such will not be installed since intermittent circulation can be provided by the space heaters, door traffic, and air changes through leaking.
5. Materials Handling - The bridge and monorail crane will be used provided it is economically feasible to meet present day applicable standards (OSHA).
6. Evolution of Reactivation - During the reactivation of systems and components, additional items that have not been addressed may be noted. These items may be required for system operation such as additional design and procurement of piping or valves to complete or close up a system.

IV. Safety Requirements

1. Strategically placed smoke detectors and alarm boxes are presently in the facility to detect and alarm a fire, should one occur. Hand fire extinguishers are also available in the facility for use against a fire; however, these systems and equipment will have to be reactivated. In addition, an existing hose station is located near the facility which will require a properly equipped Fire Hose House.

APPENDIX J

SAFETY ANALYSIS OF THE
PILOT TEST NAK PROCESSING EQUIPMENT

Program Approved

Safety Approved

SAFETY ANALYSIS OF THE
PILOT TEST NAK PROCESSING EQUIPMENT

I. General Description of Test

1.1 Purpose

The purpose of the test is: (1) to demonstrate startup, shutdown and restart sequence; (2) to demonstrate that the NaK lines can be kept dry prior to operation; (3) to investigate the injection of NaK through various nozzles; (4) to investigate injection of water; (5) to obtain pressure readings due to reaction, and observe the NaK/caustic environment; and to demonstrate clean-up procedures for NaK contaminated systems. The nozzles proposed for the NaK processing have been flow-tested using both oil and mercury as the test fluid injected into water. It is desired to flow test the nozzles using NaK as the test fluid injected into 14 molar caustic solution. Injection of cold water into 200°C caustic will cause the water to flash to steam and the violence of this injection caused turbulence needs to be investigated.

1.2 Location

The test will be conducted on the NaK disposal pads located approximately 100 feet west of EBR-I. The pad has a concrete block safety shelter with heavy glass shielded observation port and water lance ports. The pad was designed for disposal of small quantities of NaK, and was used for that purpose in the past.

1.3 Description of Equipment

The test equipment will consist of:

- (1) One semi-scale process vessel, constructed from a 55-gallon drum, with ports for nozzle entry, temperature probes, and open top.
- (2) One standard 55-gallon NaK drum from the 37 noncontaminated NaK storage drums, and a 78-gallon run vessel, WC-103, design pressure 60 psig at 1500°F.
- (3) One small vacuum pump, laboratory size.
- (4) One propane heater.
- (5) Two Argon bottles (221 SCF each).
- (6) One propane bottle (250 gallon) and flare nozzle.
- (7) Interconnecting piping, valves and fittings.
- (8) Mirror for observing the solution surface for turbulence, appearance of NaK on the surface, GH_2 burn off, etc.
- (9) Instrumentation including thermocouples and strain gauges.

The equipment will be assembled on the NaK Disposal Pad in accordance with the flow diagram and equipment layout as shown in Figures J-1 and J-2.

1.4 Waste Disposal

Waste caustic from the NaK/Caustic Reaction is not radioactive and can be disposed of at the acid pit. Standard caustic handling procedures (ACC 4.10.5 and 4.12.9) will be observed during the handling of waste caustic. Protective clothing, as described in Section 4.3.3, will be used.

1.5 Flow Diagram and Equipment Layout

1.5.1 Pilot Test Flow Diagram - Figure J-1

1.5.2 Pilot Test Instrumentation Diagram and NaK Nozzle Detail - Figure J-2

2. Interaction with Existing Plant Facilities and Operations

ANC is responsible for the maintenance, operation and safety of the experiment.

2.1 ACC Process and Support Technology

The ACC Process and Support Technology Branch is responsible for research and development of the NaK processing equipment. This experiment will be directed by ACC, using ANC-C&SS maintenance craftsmen to assemble and operate the equipment. The operations will be detailed on MJRs and will require safe work permits prior to initiation of each days work.

2.2 ANC-C&SS Maintenance Branch

The ANC-C&SS Maintenance Branch will provide the crafts and equipment required to assemble the NaK reaction pilot test. The craftsmen directly involved in operation of the test equipment will have received Liquid Metals Handling and Safety instructions.

3. Principal Design Criteria

3.1 Seismic

The test equipment is a temporary out-of-door installation which will not be required to withstand horizontal or vertical accelerations due to seismic activities, however, Argon gas battles and pressure lines will be restrained in accordance with OSHA requirements.

3.2 Fire

The maximum potential fire will be due to a NaK feedline break which would produce a NaK flow of 10 liters per minute. A leak can be discovered and the feed valve can be closed in one minute from the remote position behind the barrier. Therefore, a maximum fire equivalent to 10-liter of NaK is postulated, which will require maintaining at least 200 # of Met-L-X or Soda Ash on hand to extinguish the potential NaK fire. The postulated accidental spill would be a surface spill of no appreciable depth.

3.3 Explosion

The explosive hazards associated with the test can be divided into two categories:

(1) the hazard due to NaK and potential KO_2 contamination in the NaK storage drums; and (2) the hazard associated with the GH_2 produced during the NaK caustic chemical reaction.

3.3.1 NaK/ KO_2 Explosive Hazard

The NaK/ KO_2 hazards evaluation has not been completed, therefore, the answer to specific questions concerning the propagation rate of the NaK/ KO_2 reaction and the TNT equivalency ratio have not been answered. However, the mechanism postulated for development of the hazard is known. KO_2 doesn't form as a direct reaction between NaK and O_2 , nor can KO_2 exist in direct contact with NaK. All investigators concede that the KO_2 , if formed, must form above the NaK surface supported upon a film of stable oxides of sodium and potassium. Should the film or crust be broken by vibrations or dynamic movement of the liquid below the crust, the KO_2 could be thrust into the NaK, reacting with potentially explosive speed.

The heat generated by the reaction could cause the cover gases to expand rapidly in the enclosed container causing an explosive rupture of the container.

3.3.2 GH_2 Hazards

The reaction of NaK with water produces $\text{NaK OH} + \text{GH}_2$ and heat. The GH_2 produced in the pilot test will bubble to the surface through 26 inches of caustic. At the surface GH_2 could combine with atmospheric oxygen to produce potentially explosive mixtures. The rate of GH_2 production will be approximately 20 scfm. If it were possible to constrain the 20 scf of GH_2 in the immediate vicinity of the test area, an explosive potential equivalent to 0.104 # of GH_2 , would exist. This would be equivalent to 6.2 # of TNT as a worse case, based upon a theoretical GH_2 air explosive TNT equivalency of 6.6. However, the density of GH_2 relative to air is equal to 1: 14.38. Therefore, the GH_2 from the reaction will rise rapidly through the denser atmospheric air much as a bubble of air will rise in water. The rate of rise of GH_2 in air is approximately 8/ft/sec (Report No. 3861 Exp. Research Lab, Bureau of Mines, Pittsburgh, Pa.), therefore, in a nonenclosed out-of-door experiment, the 20 scf of GH_2 will have dispersed approximately 480 feet vertical in one minute. Only the amount within 50 feet of the experiment creates an explosive hazard to the operators. This means that $\frac{50}{480} \times 6.2$ #TNT is available as an explosive hazard, or approximately 0.65 #TNT at an average concentration approximately 25 feet above the ground. During normal operation, this potential hazard will not exist, since the GH_2 evolved will be flared at the caustic surface using a continuous propane fired flare nozzle.

3.4 Waste Disposal

The NaK used for the pilot test will not be radioactively contaminated, therefore, radioactive waste will not be generated. Chemical waste consisting of $(\text{NaK})\text{OH}$ will be generated during the pilot test. It will be drained into 5-gallon polyethylene bottles and disposed of at the acid disposal pit.

3.5 Safety Shut-Down

The pilot test will be designed so that the NaK-NaOH H₂O reaction can be safely shut down by closing the NaK feed valve with a reach rod from a protected position behind the NaK disposal pad barrier. Other essential control valves, including the vent valves, will also be located behind the barrier for safe operation.

4. Control Methods and Procedures

4.1 Process Control

- 4.1.1 Set up equipment, nozzles and instrumentation as shown in Figure 1 and 2. Fill NaK run vessel WC-103 (design pressure of 60 psig at 1500°F) with approximately 25 gallons of NaK from a NaK storage drum, by pressurizing the drum to 2 psig with Argon. NOTE: NaK storage drum design pressure is 10 psig.
- 4.1.2 Prepare 40 gallons of 14 M caustic in the pilot test vessel by adding 50 pounds of technical grade NaOH to 34.8 gallons of H₂O and purging with N₂ or A until it is all dissolved.
- 4.1.3 Evacuate the water inlet pipe jacket using a vacuum pump.
- 4.1.4 Purge the NaK feedline and the atomizing nozzle line with hot Argon (A) before use.
- 4.1.5 Start recorders for instrument readout.
- 4.1.6 Increase pressure on atomizing gas line to 31 psig of A.
- 4.1.7 Set flow rate of A on water line purge at 0.3 scfm.
- 4.1.8 Set flow of A on NaK purge line at 1 scfm.
- 4.1.9 Close by-pass valve and set pressure at 10 psig. Open valve to pressurize NaK run vessel to 10 psig, then open NaK valve to feed NaK and slowly reduce the flow of A on the purge line to zero.
- 4.1.10 Increase pressure on NaK run vessel to 20 psig.
- 4.1.11 Increase pressure on NaK run vessel to 30 psig.
- 4.1.12 Increase pressure on NaK drum until 2 L/min flow rate is achieved, not to exceed a maximum pressure of 40 psig.
- 4.1.13 After (NaK) OH solution reaches 200°C, start H₂O feed at 4 L/min.
- 4.1.14 Repeat step 4.1.8 and shut off NaK.
- 4.1.15 Open NaK feed valve and slowly reduce the flow of A on the purge line to zero.

- 4.1.16 Repeat steps 4.1.14 and 4.1.15.
- 4.1.17 When the temperature reaches 200°C turn off the water, turn on the Argon purge to NaK line (1 scfm) and then turn off the NaK flow.
- 4.1.18 Turn on the water flow to 4 L/min. until the water/caustic reaction can be observed, and then turn off the water flow.
- 4.1.19 Purge NaK from line, disconnect line at filter screen and carefully remove NaK spray nozzle from tank. Replace with new nozzle and repeat test starting with step 4.1.8.
- 4.1.20 Add enough water to (NaK) OH to reach 14 M.
- 4.1.21 Clean out system by passing water saturated A through lines that contain NaK for 4 hours. Connect dry steam line and steam out lines, and then flush with water.
- 4.1.22 Transfer (NaK) OH to 5-gallon polyethylene bottles for disposal at acid disposal pit.

4.2 Engineered Safety Features

The pilot test equipment will be arranged to allow start-up and shutdown of the test from a safe position behind the protective barrier. Argon gas will be used to purge all systems and to blanket the test vessel in order to eliminate any chance of atmospheric air (O_2) mixing with the CH_2 generated until after the CH_2 leaves the test equipment and is flared. The Argon purge will also insure that water or caustic cannot backflow into the NaK lines or container under normal conditions. Instrumentation will be provided to register temperatures and turbulence resulting from the reaction. If the temperature or degree of turbulence exceeds expectations, the test can be terminated remotely.

4.3 Special HP, Industrial Hygiene, Safety and Fire Protection Procedures

No special HP surveillance will be required since radioactive materials will not be involved in the pilot test. Special industrial hygiene, safety and fire protection procedures will

be required for the pilot tests. These will include: Liquid Metals Training; Handling procedure for NaK 55-gallon drums (Nonradioactively contaminated); protective clothing use; fire protection; and caustic handling procedures.

4.3.1 Liquid Metals Training

All personnel involved in the pilot test will receive a formal course in Liquid Metals Handling and safety procedures. The course will be particularly slanted toward safety in the handling and operation of NaK systems associated with EBR-I.

4.3.2 Handling Procedure for NaK 55-Gallon Drums

The 37 NaK drums which contain residual amounts of NaK were blanketed with Argon at the time they were placed in storage. The drums are intact, however, possible leakage from the two head valves over the past 20 years could have depleted the Argon blanket pressure to a point where atmospheric air could leak into any or all of the drums. We will, therefore, assume that all the drums have been violated by atmospheric air and that KO_2 has had an opportunity to form on the residual NaK surface.

Each drum to be moved from storage to the NaK processing pad will have heat indicating tabs installed and will be marked with heat indicating crayon. The drum will then be manipulated remotely by means of a 100-foot length of rope looped around the drum head to a horizontal position taking care not to damage the two head valves. The manipulation will cause the residual NaK to come in contact with potential films of KO_2 . Should KO_2 exist, the reaction can only occur as a deflagration or fire.

In either case, the quantities of KO_2 postulated would not be sufficient to create drum rupturing over pressures. The heat tape and crayon marks will provide a visual report of drum skin temperature changes in the range from 100° to 400° F. Knowing the original temperature of the drum and contents, any change in temperature will indicate the occurrence of a chemical

reaction. Rough order calculations could then determine an approximation of the quantities of reactants involved in the reaction. After the reaction, or in the event no reaction occurs, it will be safe to move the NaK drum to the NaK disposal pad using a fork lift equipped with a drum handling device.

4.3.3 Protective Clothing

Protective clothing will be utilized by the craftsmen involved in handling or operating the pilot test equipment. Clothing will include fire resistant momex coveralls, hard hat with full face shield, Jones goggles, chrome leather gloves, chrome leather leggings, and half mask respiratory protection. Scot Air Packs will be available for fire fighting.

4.3.4 Fire Protection

Fire protective equipment will be provided at the test site and will include an adequate supply of Met-L-X, a Met-L-X extinguisher, long handled shovels, and a metal container with a lid. In the event of a NaK fire, the pilot test equipment will be shut down in accordance with the process control procedure, and when the system has been purged, the fire will be extinguished if potentially damaging, other wise, it will be allowed to burn out.

4.3.5 Caustic Handling Procedures

Caustic material will be handled in accordance with standard safety procedures (ACC 4.10.5 and 4.12.9) will be observed during the handling of waste caustic. Protective clothing, as described in Section 4.3.3, will be used. equivalent protection from caustic materials involved in the pilot test program.

4.4 Personnel Training

Personnel training will include eight hours of class room and field instruction in NaK and KO₂ safety procedures. The instruction will stress first aid, fire

fighting, handling and protective clothing and will require passing a written test in order to qualify for working around or operating the pilot test equipment or for moving NaK containers from storage to the test pad.

5. Safety of Normal Operation

In normal operation, the pilot test equipment will be considered a hazardous operation, therefore, operations will be conducted remotely from the NaK disposal pad safety shelter. The action of the liquid surface in the test vessel will be observed by viewing mirror. Temperature and strain gauge indicators will be located near the safety shelter for safe viewing. Only personnel in protective clothing will be allowed to directly observe the NaK/Caustic reaction in the pilot test vessel. Argon purge gas will prevent backup of caustic or water through the NaK process nozzles, therefore, all NaK/Caustic reactions will take place in the pilot test vessel under normal conditions of operation.

6. Discussion and Evaluation of Abnormal Occurances or Conditions

The abnormal occurances or conditions postulated during the conductance of the pilot test operations are as follows: GH_2 detonation; loss of Argon purge and backup of caustic into NaK containment drum; NaK leak in system; equipment overturn due to unknown external forces, i.e. seismic, wind, or over-pressure due to detonation; and a guillotine break in the NaK feed line.

6.1 GH_2 Detonation

The design criteria limits the GH_2 detonation to that resulting from a concentration of GH_2 and O_2 equal to the equivalent of 0.65 #TNT at a point approximately 25-feet above the ground. The over-pressure at ground level resulting from the design criteria detonation would be less than 2 psig, which is acceptable from the standpoint of personnel safety. Since the detonation would be uncontained,

no shrapnel or missile debris would be produced to endanger personnel. The GH_2 detonation would require termination of the test to evaluate damage to equipment, however, injury, if any, to test personnel would be slight since they will be protected by the concrete block protective barrier. Overpressure calculations follow:

$$P_s = \frac{4120}{Z^3} - \frac{105}{Z^2} + \frac{39.5}{Z}$$

where $Z = \frac{r}{w^{1/3}}$ $r = \text{dist. in feet and } w = \text{\#TNT}$

$$Z = \frac{25 \text{ ft}}{0.65^{1/3}} = \frac{25}{0.86} = 29$$

$$P_s = \frac{4120}{29^3} - \frac{105}{29^2} + \frac{39.5}{29} = 0.17 - 0.12 + 1.36 = 1.41 \text{ psi}$$

The resultant over-pressure is approximately equivalent to that experienced, due to a 70 mile-per-hour wind.

6.2 Loss of Argon Purge

Should the Argon purge be lost, caustic or water could back up in the NaK feed line and into the NaK run vessel. The caustic or water would immediately react with the NaK producing GH_2 pressure inside the vessel. The pressure buildup in the vessel would stop the back flow and the reaction of the caustic and NaK would terminate when the caustic was exhausted. The accident is, therefore, self-terminating at some low pressure buildup exceeding atmospheric. Then the pilot test operations would be terminated. The GH_2 trapped in the NaK run vessel would then be purged by dilution with Argon provided through a revised piping arrangement. Operations would not be continued until the GH_2 concentration in the NaK vessel had dropped to less than 4%, and until it could be established that caustic had not plugged the dip leg in the NaK run vessel.

6.3 NaK Leak in System

The NaK leak postulated would be a small leak at a weld joint or component producing less than 0.5 liters per minute. The pilot test equipment would be shut down and the leaked NaK contained with a dam of Met-L-X. The system would be purged and the leak repaired. The NaK contaminated Met-L-X would be shoveled into a metal container for disposal at the acid pit near the Burial Ground. If a fire should occur in conjunction with the NaK leak, it would be extinguished in accordance with the Alkali Liquid Metal Safety Procedures handbook for EBR-I. Disposal of residue from the fire would be accomplished in accordance with the Alkali Liquid Metals Safety Procedures.

6.4 Equipment Overturn Due to Unknown External Forces

The probability of equipment overturn, due to unknown external forces, is extremely low, however, in the event of equipment overturn, the pilot test experiment will be brought to a close. Overturn of the NaK run vessel will cause no problem unless the feed line, Argon blanket line, or any of the vessel shut off or relief valves rupture or break loose. In that event, the worse case accident would be an open spill of less than 25-gallons of noncontaminated NaK, which would be contained in a catch pan. If the NaK ignited, the fire would be extinguished with Met-L-X per Alkali Liquid Metal Safety procedure. If the NaK did not ignite, it would be placed in five- gallon containers and removed to the acid disposal pit for disposal by water reaction with the NaK. The equipment would require cleanup and repair prior to continuance of the pilot tests. Hazard to personnel will be no greater than that involved in fighting a NaK fire in a shallow collection pan. Overturning of the pilot test vessel would involve a spill of approximately 50 gallons of hot, noncontaminated caustic. Workers would be protected by protective clothing and by a carbon steel protective barrier. Non-working observers will be located behind the concrete block protective barrier. This is not considered to be an extremely hazardous situation.

6.5 Guillotine Break in the NaK Feed Line

A guillotine break in the NaK feed line while a test was in progress could result in a spraying leak from a 30 psig system. The leakage rate could approach 10 liters per minute or about the flow rate from a household water faucet. Corrective action would involve closing the NaK run vessel gate valve as quickly as possible (Less than one minute required to close). Cleanup operations would be instigated as in the previously discussed accident cases. Workers in protective clothing would not be exposed to a pressurized stream of NaK since the run vessel feed gate valve can be closed remotely. Observers would be safe behind the NaK disposal pad barrier or at an adequate separation distance from the test equipment.

7.0 Discussion of Design Basis Accident

The design basis accident is considered to be the overturn of equipment due to unknown external forces. During this event, the NaK drum could overturn, causing a feed line break at a pressure of 30 psig or a gate valve break which would potentially produce a 25 gallon spill of noncontaminated NaK. The pilot test design will include a catch pan capable of containing 150% of the design basis accident spill.

APPENDIX K

PROCEDURE FOR LOADING AND TRANSFER OF THE EBR-I CUP BASE
FROM EBR-I TO INEL BURIAL GROUND

REVISION I

Approved: T. H. Stickley 1/2/75
T. H. Stickley Date

INTRODUCTION:

The purpose of this procedure is to provide the necessary step by step instructions for removal of the EBR-I cup base ring from the EBR-I, repair cell No. 1, load into a shipping box, and transfer to the INEL burial ground.

REFERENCES:

- Sketch: Lifting sling assembly for cup base removal at EBR-I.
- Sketch: Containment box to bury cup base.
- Drawing: Argonne National Laboratory EB-1405 cup base, EB-1400 cup assembly.
- Drawing: Argonne National Laboratory sheet EB-2 basement plans.

bcc: JCCommander
EWKendall - w/o attachment
SJKeating - w/o attachment
WKoutnik
THStickley

MATERIALS AND EQUIPMENT:

1. Swab
2. Bucket of Water
3. Blotting Paper
4. Heavy Plastic Bags (3) Minimum of 3'6" diameter.
5. Lifting Sling Assembly
6. Two 3/8" sling assemblies
7. Containment Box
8. Truck Tie Down (cables and shackles)
9. Lead Sheeting
10. Portable Crane (secure from TAN - call E. L. Krogh, ext. 6349)
11. Masking Tape
12. Two 4' x 4's x 4' long
13. Hammer
14. Metal Plate, 3-1/2' x 5' x 1/8"
15. Hot Waste Disposal Boxes
16. Plastic Sheeting

GENERAL:

The cup base is presently located in EBR-I repair cell No. 1 in the EBR-I basement and is positioned over a spool piece. Several dowel pins may position the cup on the spool piece. The flange is highly contaminated (approximately 30,000 cpm) and is reading approximately 10 R/hr on contact. The access aisle way in the cubicle is 4' wide by 5' high. Several hot waste boxes should be provided near the repair cell. The calculated weight of the cup base is 650 pounds. Representation from Safety Engineering and Health Physics must be in attendance during the removal and rehearsal!

PREPARATION:

- 1) Prior to actual removal of cup base, conduct a dry run practice using the individual participants and actual removal hardware. This will be conducted in repair room No. 2. The weight of 650 lbs will not be simulated for this dry run activity.

- 2) Prepare cell access area at shielded doorway of repair room No. 1 (10' x 10' blotting paper minimum). Basement floor area below access hatch must be covered.
- 3) Locate open cup base containment box with plastic sheet liner installed and 3/8" slings threaded thru on blotting paper below open hatchway. The cover, with nails started in each corner, must be within arms' reach from the radiation barrier.
- 4) Tape wheels of mobile hoist to prevent contamination.
- 5) Prepare the dump box of the hot waste dump truck in accordance with Standard Practices for transportation of hot waste to contaminated waste disposal area.
- 6) Verify the appropriate Anti-Contamination clothing and respirator equipment is available.
- 7) Remove basement access hatch from reactor room floor and place at east side of hatchway.
- 8) Place safety rope barrier to include open hatchway, hatchcover and truck.

REMOVAL OF CUP BASE FROM REPAIR ROOM NO. 1

- 1) All participants must be properly clothed and equipped.
- 2) Move repair room No. 1 shield door to far left (west) for full open position.
- 3) Lay metal plates 3-1/2' x 5' x 1/8" over door track and cover with blotting paper.
- 4) Lay prepared roll of blotting paper in access doorway so that it may be rolled out into the repair room and tape the loose end securely to the floor.
- 5) With a long-handled mop, swab top surface side of cup base to a level deemed satisfactory by H.P.
- 6) Have H.P.'s make cubicle radiation and contamination survey.
- 7) With a felt marker pen, mark three "z" holes spaced at 120° (see drawing ANC EB-1405).
- 8) Place the mobile hoist at the access doorway with cable and hook directed toward the repair cell interior and so that when the hoist is moved into the cell, it will cause the blotting paper of step 4 to unroll inward.

- 9) Attach lifting sling to hook of portable crane.
- 10) Roll portable lifting crane into repair cell. Lower crane chain and position lifting sling hooks opposite three "z" holes previously marked. Take slack out of lifting sling.
- 11) Begin lifting cup base from spool piece. It may be necessary to jiggle the sling to permit the base to easily slide away from the dowel pins.
- 12) When the cup base has been lifted clear of the spool piece, pull portable crane away so cup is clear of spool piece and cover the cup with plastic. Secure sheeting at ring of lifting bale with tape.
- 13) Pull portable crane from cubicle. Center cup under open hatchway.
- 14) Lower cup into containment box.
- 15) Disconnect sling from mobile hoist hook and leave in box.
- 16) Seal outer plastic sheeting (box liner).
- 17) Nail cover onto box.
- 18) Attach the sling eyes to the hook of the five-ton facility crane.
- 19) Hoist the enclosed cup base through the hatch and onto the prepared hot waste truck.
- 20) Prepare the load for transport to RWDSA in accordance with H.P. guidance and Annex L.
- 21) Notify RWDSA personnel at least 15 minutes before the transport vehicle leaves the EBR-I confines, so that all traffic from the RWDSA can be halted while the transport is in progress.
- 22) Haul cup base to RWDSA.
- 23) Survey portable crane for contamination. Decontaminate as necessary.
- 24) Remove from basement and return to TAN (contact E. L. Krogh, TAN-606 ext. 6349).
- 25) Survey warm area, remove blotting paper and decontaminate floor as necessary.
- 26) Close hatchway and remove safety barrier.

SKETCH 1 EBR-I Mock up CUP BASE

APPENDIX L

FINAL RADIATION SURVEY

ZPR-III FACILITY

March 25, 1975

Mr. George Wehmann, Director
Office of Waste Management
Idaho Operations Office - ERDA
Idaho Falls, ID 83401

EBR-I D&D TASK 2 COMPLETED AND CERTIFIED - HIC-105-75

Task 2, D&D of the Zero Power Reactor (RTF-601-ZPR-III) was completed in accordance with the EBR-I Program Plan, and has been certified free of radioactive contamination by the CF/PBF Safety Branch.

The contaminated material located in the high bay area, hood room, and vault has been removed and transferred to the RWMC. The ZPR-III reactor was decontaminated, disassembled and reassembled at EBR-I.

The ZPR-III High and Low Bay D&D was completed on schedule and certified to be contamination free on November 4, 1974. A copy of the ZPR-III Survey Summary is attached for your information.

Original Signed By
J. C. Commander *JCV*

W. W. Hickman, Manager
Waste Management Program Division

EWK:ec

Attachment - as stated

cc: RMNelson
FHTingey

ZPR III SURVEY SUMMARY

All smears were $<1000 \text{ d/m/100}^2\text{cm } \beta \gamma$ and $<200 \text{ d/m/100}^2\text{cm } \alpha$ with direct radiation $<0.1 \text{ mR/hr}$ at contact. This meets the criteria set forth in the letter to T. H. Stickley by E. W. Kendall, EWK-2-74, "Decontamination Criteria for the EBR-I Complex."

S. J. Keating,
Health Physicist

RADIATION SURVEY REPORT

LOCATION: Office area - section one

DATE: 12-19-74

SURVEYOR: S.S. Keating

TIME: 0950

RESULTS: < 1000 d/m/100²cm Bx and < 200 d/m/100²cm² with < 0.1 m²/hr direct radiation

INSTRUMENTS USED:

- ☐ PIC 6
- ☒ GM
- ☒ RM-14
- ☒ Other

AIR SAMPLE TAKEN:

☐

Yes

☒

No

RESULTS:

Was Respiratory Equipment Used?

☐

Yes

☒

No

Type:

L-5

DATE 12-19-74		TIME 1420		UNIT AREA SMEARED 100 ² cm		REMARKS 130 d/m/100 ² cm B8 6 d/m/100 ² cm L .05 m ² /Hk direct							
ROOM Office section #1				SMEAR AREA A Whatman 50's									
SAMPLED BY S.J.K.		COUNTED BY S.J.K.		Wet ☒ Dry ☐									
Location Smeared	Date Counted	Time Counted	Count Time In Minutes	Counts per Minute Gross	Background Counts per Minute	Counts per Minute Net	Counter eff.	Disintegrations per Minute per Unit Count	Unit Area	Type of Activity Counted	Initials		
1	12-19-74	1430	1	0 12	1 9	0 3	33% 10%	0 30	100 ² cm	α B8	S.J.K.		
2				0 16		0 7		0 70					
3				0 9		0 0		0 0					
4				0 22		0 13		0 130					
5				130 13		0 4		0 40					
6				1 12		0 3		0 30					
7				2 7		1 0		3 0					
8				0 5		0 0		0 0					
9				0 17		0 8		0 80					
10				0 12		0 3		0 30					
11				0 18		0 9		0 90					
12				0 21		0 12		0 120					
13	↓	↓	↓	0 6	↓	0 6	↓	0 60	↓	↓	↓		

Location Smeared	Date Counted	Time Counted	Count Time In Minutes	Counts Per Minute Gross	Background Counts Per Minute	Counts Per Minute Net	Counter Eff.	Disintegrations Per Minute Per Unit Count	Unit Area	Type Of Activity Counted	Initials
14	12-19-75	1430	1	19	19	0	33%	0	100%	88	J.J.K.
15				0 11		0 2		0 20			
16				0 16		0 7		0 70			
17				1 9		0 0		0 0			
18				3 20		2 11		6 110			
19				0 12		0 3		0 30			
20				0 12		0 3		0 30			
21				0 16		0 2		0 70			
22				0 14		0 5		0 50			
23				1 18		0 9		0 90			
24				2 10		1 1		3 10			
25				0 17		0 8		0 80			
26				0 14		0 5		0 50			
27				0 13		0 4		0 40			
28				0 5		0 0		0 0			
29				0 9		0 0		0 0			
30				0 19		0 10		0 100			

Location Smeared	Date Counted	Time Counted	Count Time In Minutes	Counts Per Minute Gross	Background Counts Per Minute	Counts Per Minute Net	Counter Eff.	Disintegrations Per Minute Per Unit Count	Unit Area	Type of Activity Counted	Initials
31	12-19-74	1430	1	0 23	0 1	0 14	33 102	0 140	100 cm ²	8	J.P.K.
32				0 18		0 9		0 90			
33				1 19		0 10		0 100			
34				0 14		0 5		0 50			
35				4 12		3 3		9 30			
36				0 19		0 10		0 100			
37				0 17		0 8		0 80			
38				2 21		1 12		3 120			
39				0 21		0 12		0 120			
40				1 23		0 13		0 130			
41				1 16		0 7		0 70			
42				1 13		0 4		0 40			
43				0 15		0 6		0 60			
44				0 18		0 90		0 90			
45				0 16		0 7		0 70			
46				1 19		0 10		0 100			
47				0 20		0 11		0 110			
48				0 21		0 12		0 120			

RADIATION SURVEY REPORT

LOCATION: *Office area - Section two*

DATE: *12-19-74*

SURVEYOR: *S.J. Keating*

TIME: *1030*

RESULTS: *4000 d/m/100cm² B8 and 200 d/m/100cm² with
0.1 mR/hr direct radiation*

INSTRUMENTS USED:

- ☐ PIC 6
- ☒ GM
- ☒ RM-14
- ☒ Other

AIR SAMPLE TAKEN:

☐
Yes

☒
No

RESULTS:

Was Respiratory Equipment Used?

☐
Yes

☒
No

Type:

DATE 12-19-75		TIME 1530		UNIT AREA SMEARED 100 ² cm		REMARKS 190 d/m/100 ² cm P8 9 d/m/100 ² cm α .08 mR/hr direct radiation					
ROOM Office section #2				SMEAR MEDIA Whatman 50's							
SAMPLED BY S.J.K.		COUNTED BY S.J.K.		Wet ☐ Dry ☒							
Location Smeared	Date Counted	Time Counted	Count Time In Minutes	Counts per Minute Gross	Background Counts per Minute	Counts per Minute Net	Counter eff.	Disintegrations per Minute per Unit Count	Unit Area	Type of Activity Counted	Initials
1	12-19-75	1530	1	0 5	1 9	0 0	33% 102	0 0	100 ² cm	α P8	S.J.K.
2				4 26		3 17		9 170			
3				1 17		0 8		0 80			
4				0 19		0 10		0 100			
5				0 12		0 3		0 30			
6				0 19		0 10		0 100			
7				1 16		0 7		0 70			
8				0 14		0 5		0 50			
9				1 17		0 8		0 80			
10				0 21		0 12		0 120			
11				0 23		0 14		0 140			
12				2 14		1 5		2 50			
13	↓	↓	↓	1 9	↓	0 0		0 0	↓	↓	↓

Location Smeared	Date Counted	Time Counted	Count Time In Minutes	Counts Per Minute Gross	Background Counts Per Minute	Counts Per Minute Net	Counter Eff.	Disintegrations Per Minute Per Unit Count	Unit Area	Type Of Activity Counted	Initials
14	12-19-75	1530	1	18 18	1 9	0 9	32% 10%	0 90	100 ² cm	2 B8	SJK
15				3 22		2 13		6 130			
16				1 17		0 8		0 86			
17				2 20		1 11		3 110			
18				4 21		3 12		9 120			
19				0 16		0 7		0 70			
20				0 12		0 3		0 30			
21				0 12		0 3		0 30			
22				0 20		0 11		0 110			
23				1 28		0 19		0 190			
24				1 14		0 15		0 150			
25				1 19		0 10		0 100			
26				0 13		0 4		0 40			
27				0 15		0 6		0 60			
28				1 15		0 6		0 60			
29				3 12		2 3		6 30			
30	↓	↓	↓	2 21	↓	1 12	↓	3 120	↓	↓	↓

RADIATION SURVEY REPORT

LOCATION: *Office area - section three*

DATE: *12-20-74*

SURVEYOR: *S. J. Keating*

TIME: *1330*

RESULTS: *< 1000 d/m/100²cm² β and < 200 d/m/100²cm² α with
< 0.1 mR/hr direct radiation*

INSTRUMENTS USED:

- ☐ PIC 6
- ☒ GM
- ☒ RM-14
- ☒ Other

AIR SAMPLE TAKEN:

☐ Yes ☒ No

RESULTS:

Was Respiratory Equipment Used?

☐ Yes ☒ No

Type:

DATE 12-23-74		TIME 0830		UNIT AREA SMEARED 100 ² cm		REMARKS 170 d/m/100 ² cm P8 12 d/m/100 ² cm - 2 .1 m/HR direct radiation							
ROOM Office section #3		SMEAR MEDIA Whatman 50's											
SAMPLED BY SJK		COUNTED BY SJK		Wet ☒ Dry ☐									
Location Smeared	Date Counted	Time Counted	Count Time In Minutes	Counts per Minute Gross	Background Counts per Minute	Counts per Minute Net	Counter eff.	Disintegrations per Minute	per Unit Count	Unit Area	Type of Activity Counted	Initials	
1	12-23-750840	1	0	12	2	11	0	33%	6	100 ² cm	2 P8	S.J.K.	
2			1	10		0	0	0	0				
3			0	13		0	2	0	20				
4			0	11		0	0	0	0				
5			0	17		0	6	0	60				
6			2	19		0	8	0	80				
7			0	18		0	7	0	70				
8			1	12		0	1	0	10				
9			1	8		0	0	0	0				
10			0	21		0	10	0	100				
11			0	20		0	9	0	90				
12			2	11		0	0	0	0				
13			1	15		1	4	0	40				

Location Smeared	Date Counted	Time Counted	Count Time In Minutes	Counts Per Minute Gross	Background Counts Per Minute	Counts Per Minute Net	Counter Eff.	Disintegrations Per Minute Per Unit Count	Unit Area	Type Of Activity Counted	Initials
14	12-23-78	0540	1	2 23	2 11	0 12	33%	0 120	100%	8	81.2
15				4 19		2 8		6 90			
16				3 17		1 6		3 60			
17				1 23		0 14		0 140			
18				0 26		0 15		0 150			
19				0 18		0 7		0 70			
20				0 18		0 7		0 70			
21				1 23		0 12		0 120			
22				1 20		0 9		0 90			
23				2 23		0 12		0 120			
24				1 16		0 5		0 60			
25				0 15		0 4		0 40			
26				6 22		4 11		12 110			
27				0 13		0 2		0 20			
28				0 9		0 0		0 0			
29				0 11		0 0		0 0			
30				1 14		0 3		0 30			

RADIATION SURVEY REPORT

LOCATION: *Control room and adjoining office area* DATE: *12-20-74*

SURVEYOR: *S.J. KEATING*

TIME: *1400*

RESULTS: *< 1000 d/m/100²cm Bx and < 200 d/m/100²cm² with
< 0.1 mR/hr direct radiation*

<p>INSTRUMENTS USED:</p> <p>☐ PIC 6</p> <p>☒ GM</p> <p>☒ RM-14</p> <p>☒ Other</p>	<p>AIR SAMPLE TAKEN: ☐ Yes ☒ No</p> <p>RESULTS:</p> <p>Was Respiratory Equipment Used? ☐ Yes ☒ No</p> <p>Type:</p>
--	--

DATE 12-23-74		TIME 0920		UNIT AREA SMEARED 100 ² cm		REMARKS 200 d/m/100 ² cm B8 15 d/m/100 ² cm α 0.1 mR/hr direct radiation						
ROOM Control room + office				SMEAR MEDIA								
SAMPLED BY S.J.K		COUNTED BY S.J.K		Wet ☒ DRY								
Location Smear	Date Counted	Time Counted	Count Time In Minutes	Counts per Minute Gross	Background Counts per Minute	Counts per Minute Net	Counter eff.	Disintegrations per Minute per Unit Count	Unit Area	Type of Activity Counted	Initials	
1	12-23-74	0930	1	28	11	17	33%	6	100 ² cm	α B8	S.J.K	
2				3	24	1	13	3				
3				6	19	4	8	12				
4				2	18	0	7	0				
5				4	28	2	17	6				
6				3	22	1	11	3				
7				0	16	0	5	0				
8				0	17	0	6	0				
9				3	21	1	10	3				
10				3	20	1	9	3				
11				4	19	2	8	6				
12				2	15	0	14	0				
13	✓	✓	✓	0	21	0	10	0	✓	✓	✓	

Location Smeared	Date Counted	Time Counted	Count Time In Minutes	Counts Per Minute Gross	Background Counts Per Minute	Counts Per Minute Net	Counter Eff.	Disintegrations Per Minute Per Unit Count	Unit Area	Type Of Activity Counted	Initials
14	12-23-74	0930	1	2 16	2 11	0 5	33% 10%	0 50	100 ² cm	α Bd	J.J.K
15				3 28		1 17		3 170			
16				0 19		0 8		0 80			
17				0 19		0 8		0 80			
18				6 25		4 15		12 150			
19				3 27		1 16		3 160			
20				2 25		0 14		0 140			
21				1 19		0 8		0 80			
22				5 20		3 9		9 90			
23				7 31		5 20		15 200			
24				9 18		1 7		3 70			
25				0 19		0 8		0 80			
26				0 22		0 11		0 110			
27				1 23		0 12		0 120			
28				2 25		0 14		0 140			
29				0 17		0 6		0 60			
30	✓	✓	✓	5 21	✓	3 10	✓	9 100	✓	✓	✓

RADIATION SURVEY REPORT

LOCATION: *Vault and Hood room*

DATE: *12-20-74*

SURVEYOR: *S. J. KEATING*

TIME: *1535*

RESULTS: *< 1000 d/m/100² cm Bx and < 200 d/m/100² cm d with
< 0.1 mR/hr direct radiation*

INSTRUMENTS USED:

- ☐ PIC 6
- ☒ GM
- ☒ RM-14
- ☒ Other

AIR SAMPLE TAKEN:

☐

Yes

☒

No

RESULTS:

Was Respiratory Equipment Used?

☐

Yes

☒

No

Type:

DATE 12-23-74		TIME 1035		UNIT AREA SMEARED 100 ² cm		REMARKS 200 d/m/100 ² cm Bx 15 d/m/100 ² cm d						
ROOM vault and hood rm.		SMEAR MEDIA Whatman 50's										
SAMPLED BY S.J.K.		COUNTED BY S.J.K.		Wet ☒ Dry ☐								
Location Smeared	Date Counted	Time Counted	Count Time In Minutes	Counts per Minute Gross	Background Counts per Minute	Counts per Minute Net	Counter eff.	Disintegrations per Minute per Unit Count	Unit Area	Type of Activity Counted	Initials	
1	12-23-74	1035	1	6 28	2 11	4 17	33% 102	12 170	100 ² cm	Bx	S.J.K.	
2				4 31		2 20		6 200				
3				7 27		5 16		15 160				
4				5 25		3 14		9 140				
5				5 27		3 16		9 160				
6				2 25		0 14		0 140				
7				2 21		0 10		0 100				
8				2 18		0 7		0 70				
9				3 23		1 12		3 120				
10				2 29		0 18		0 180				
11				0 17		0 6		0 60				
12				1 15		0 4		0 40				
13	✓	✓	✓	0 19	✓	0 8	✓	0 80	✓	✓	✓	

[illegible]

RADIATION SURVEY REPORT

LOCATION: *Reactor room*

DATE: *12-30-74*

SURVEYOR: *S.S. Keating*

TIME: *1015*

RESULTS: *<1000 d/m/100²cm² Bx and <200 d/m/100²cm² with
<0.1 mR/hr direct radiation*

INSTRUMENTS USED:

- ☐ PIC 6
- ☒ GM
- ☒ RM-14
- ☒ Other

AIR SAMPLE TAKEN:

☐ Yes ☒ No

RESULTS:

Was Respiratory Equipment Used?

☐ Yes ☒ No

Type:

DATE 12-30-74	TIME 1230	UNIT AREA SMEARED 100 ² cm	REMARKS 200 d/m/100 ² cm B ⁸ 14.2 d/m/100 ² cm α 0.1 mR/hr direct radiation									
ROOM Reactor Room.	SMEAR MEDIA Whatman 50's											
SAMPLED BY S.J.K	COUNTED BY S.J.K	Wet ☐ Dry ☒										
Location Smeared	Date Counted	Time Counted	Count Time In Minutes	Counts per Minute Gross	Background Counts per Minute	Counts per Minute Net	Counter eff.	Disintegrations per Minute per Unit Count	Unit Area	Type of Activity Counted	Initials	
1	12-30-74	1230	1	17	.3	.7	35%	2.1	100 ² cm	α	S.J.K	
2			2	15		1.7	1	5.1				
3			4	19		3.7	5	11.2				
4			0	29		0	15	6				
5			0	34		0	20	0				
6			0	25		0	11	0				
7			1	17		.7	3	2.1				
8			5	15		4.7	1	14.2				
9			0	9		0	0	0				
10			3	20		2.7	6	8.2				
11			1	28		.7	14	2.1				
12			1	32		.7	18	2.1				
13	✓	✓	✓	1	30	✓	.7	16	✓	2.1	✓	

Location Smeared	Date Counted	Time Counted	Count Time In Minutes	Counts Per Minute Gross	Background Counts Per Minute	Counts Per Minute Net	Counter Eff.	Disintegrations Per Minute Per Unit Count	Unit Area	Type Of Activity Counted	Initials
14	12-30-74	1230	1	3 / 22	.3 / 14	2.7 / 8	33%	8.2 / 90	100 ² cm	α / βγ	S.J.R.
15				2 / 24		1.7 / 10		5.1 / 100			
16				1 / 19		.7 / 5		2.1 / 50			
17				5 / 17		4.7 / 3		14.2 / 30			
18				3 / 23		2.7 / 9		8.2 / 90			
19				2 / 28		1.7 / 14		5.1 / 140			
20				0 / 19		0 / 5		0 / 50			
21				0 / 24		0 / 10		0 / 100			
22				1 / 17		.7 / 3		2.1 / 30			
23				0 / 29		0 / 15		0 / 150			
24				2 / 31		1.7 / 17		5.1 / 170			
25				0 / 20		0 / 6		0 / 60			
26				0 / 18		0 / 4		0 / 40			
27				3 / 16		2.7 / 2		8.2 / 20			
28				0 / 23		0 / 9		0 / 90			
29				1 / 25		.7 / 11		2.1 / 110			
30	✓	✓	✓	1 / 17	✓	.7 / 3	✓	2.1 / 30	✓	✓	✓

RADIATION SURVEY REPORT

LOCATION: *MEZZANINE FLOOR*

DATE: *8 1-6-75*

SURVEYOR: *S. S. KEATING*

TIME: *0900*

RESULTS: *<1000 d/m/100²cm B₈ and <200 d/m/100²cm α with
40.1 mR/hr direct radiation at contact*

INSTRUMENTS USED:

- ☐ PIC 6
- ☒ GM
- ☒ RM-14
- ☒ Other

AIR SAMPLE TAKEN:

☐ Yes ☒ No

RESULTS:

Was Respiratory Equipment Used?

☐ Yes ☒ No

Type:

DATE 1-6-75	TIME 1300	UNIT AREA SMEARED 100 ² cm	REMARKS 140 d/m/100 ² cm B γ 15.5 d/m/100 ² cm α 0.1 m μ /hr direct radiation									
ROOM MEZZANINE		SMEAR MEDIA Whatman 50's										
SAMPLED BY SJK	COUNTED BY SJK	Wet ☐ Dry ☒										
Location Smeared	Date Counted	Time Counted	Count Time In Minutes	Counts per Minute Gross	Background Counts per Minute	Counts per Minute Net	Counter eff.	Disintegrations per Minute	per Unit Count	Unit Area	Type of Activity Counted	Initials
1	1-6-75	1300	1	14	.2	.8	33%	2.4	50	100 ² cm	α B γ	SJK
2				0	8	0	0	0	0			
3				0	17	0	8	0	80			
4				0	19	0	10	0	100			
5				2	12	1.8	3	5.4	30			
6				1	13	.8	4	2.4	40			
7				0	18	0	9	0	90			
8				1	9	.8	0	2.4	0			
9				1	10	.8	1	2.4	10			
10				0	8	0	0	0	0			
11				0	19	0	10	0	100			
12				0	16	0	7	0	70			
13				0	15	0	6	0	60			

Location Smeared	Date Counted	Time Counted	Count Time In Minutes	Counts Per Minute Gross	Background Counts Per Minute	Counts Per Minute Net	Counter Eff.	Disintegrations Per Minute Per Unit Count	Unit Area	Type Of Activity Counted	Initials
14	1-6-75	1300	1	2 16	.2 9	1.8 7	33% 10%	5.4 70	100 ² cm	α β	8JK
15				3 18		2.8 9		8.4 90			
16				0 21		0 12		0 120			
17				1 18		.8 9		2.4 90			
18				2 17		1.8 8		5.4 86			
19				3 13		2.8 4		8.4 40			
20				0 19		0 10		0 100			
21				0 19		0 10		6 100			
22				4 15		3.8 6		11.5 60			
23				5 23		4.8 14		15.5 140			
24				1 10		.8 1		2.4 10			
25				1 19		.8 10		2.4 100			
26				1 17		.8 8		2.4 80			
27				1 20		.8 11		2.4 110			
28				0 16		0 7		0 70			
29				2 18		1.8 9		5.4 90			
30	✓	✓	✓	1 17	✓	.8 8	✓	2.4 80	✓	✓	✓

APPENDIX M

ARGONNE FAST SOURCE REACTOR CONTAINMENT
DEMOLITION PLAN

J. L. Commander 8/21/74
Program Approved Date

Lee P. Halls 8-27-74
Safety Approved Date

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1.0 PURPOSE

The demolition and removal of the Argonne Fast Source Reactor (AFSR) containment is part of the program plan for the decontamination and decommissioning of the EBR I complex.

This document outlines the procedures, both operational and safety, that will be in effect during the demolition of the AFSR containment.

2.0 REFERENCES

ID Manual 0500-1 Annex K
TM 9-1910 Military Explosives
FM 5-34 Engineer Field Data
Dupont Blasters Handbook
Federal Register 1926.900, 1910.109.

3.0 RESPONSIBILITIES

The responsibilities as outlined in ID Manual 0500-1 Annex K, will govern the use of explosives on the AFSR demolition.

4.0 PROCEDURE FOR DELIVERY AND PROCUREMENT OF EXPLOSIVES

ID Manual 0500-1 Annex K will govern.

5.0 TRANSPORTATION OF EXPLOSIVES

ID Manual 0500-1 Annex K will govern.

6.0 GENERAL HANDLING OF EXPLOSIVES

ID Manual 0500-1 Annex K will govern.

7.0 STORAGE OF EXPLOSIVES

ID Manual 0500-1 Annex K will govern.

8.0 DESCRIPTION OF EXISTING AFSR FACILITY

8.1 AFSR Location

The AFSR is located within the EBR-I Complex, approximately 100 ft from ZPR-III and 300 ft from EBR-I (see Figure 1).

Figure 1. EBR-I Complex

8.2 AFSR Component Description

The AFSR building and the AFS reactor have been removed as have all the control instrumentation and electrical gear. Remaining are the below-grade basement; source storage vault and withdrawal hardware; and the above-grade steel-lined concrete shielding structure with view ports and access ports to the centrally located reactor cell.

8.3 AFSR Dimensions and Weights

The 1/4 in. steel-lined above-grade concrete shielding structure is approximately 12 ft long, 9 ft high and 11 ft wide. Volumetric analysis of this structure yields approximately 570 ft³ of high density concrete weighing 215 lb/ft³. Therefore, the weight of this structure is approximately 62 tons.

8.4 Radiation/Contamination Status

8.4.1 Direct Radiation

Basement 0.05 mR/hr (General Field)

Basement ceiling 0.1 mR/hr @ Contact (see Figure 2)

Reactor support ring 1 mR/hr @ Contact (see Figure 2)

8.4.2 Contamination Smear Survey (see Figure 2)

AFSR Basement <60 d/m B γ /100 cm²

<20 d/m α /100 cm²

Reactor support ring 1050 d/m B γ /100 cm²

<20 d/m α /100 cm²

8.4.3 Water Samples

The surface water that had seeped into the AFSR basement was sampled and analyzed.

02/11/74

Figure. 2

BASEMENT: 4.05 mR/hr

$\leq 60 \text{ d/m} \beta / 100 \text{ cm}^2$
 $\leq 20 \text{ d/m} \alpha / 100 \text{ cm}^2$

The contamination levels are as follows:

$\text{Ru}^{106} \quad 1.33 \times 10^{-7} \text{ } \mu\text{Ci/ml}$

$\text{Cs}^{137} \quad 8.45 \times 10^{-8} \text{ } \mu\text{Ci/ml}$

$\text{Cs}^{134} \quad 2.24 \times 10^{-8} \text{ } \mu\text{Ci/ml}$

$\text{Co}^{60} \quad 2.0 \times 10^{-8} \text{ } \mu\text{Ci/ml}$

Gross Beta $2.28 \times 10^{-7} \text{ } \mu\text{Ci/ml}$

Gross Alpha $3.5 \times 10^{-8} \text{ } \mu\text{Ci/ml}$

These levels, in all cases, are less than the unrestricted waste levels as specified in AEC Manual Chapter 0524, Table 2.

9.0 AFSR DEMOLITION

9.1 General Objective

Demolish the above-grade portion of the structure down to the concrete grade level slab; fill all open spaces in the basement with sand; pour concrete plugs in openings in the slab; and create a terrain feature by covering the slab with five feet of native soil and rock.

9.2 Comparison of Different Removal Plans

9.2.1 AFSR Bisectioning

This plan would involve fracturing the above-ground reinforced concrete structure into two sections of approximately 30 tons each. Less than 5 lb of explosive would be used to establish a longitudinal fracture plane in the reinforced concrete monolith. The two concrete sections would then be rigged, lifted and transported to the sanitary landfill (<0.1 mR) or the Idaho National Engineering Laboratory (INEL) Radioactive Waste Disposal and Storage Area (RWDSA) (>0.1 mR at contact). The degree of effort, low amount of explosives required and the minimum dispersal of the concrete waste make this the optimum plan.

9.2.2 AFSR Mechanical Breakup

This plan involves pneumatic tools and labor support to fracture the concrete monolith. This would require a high degree of effort in man-hours and equipment.

9.2.3 AFSR 100% Breaching

This plan defines breaching in military terms; that is, complete breakup of the obstacle. This requires internal emplacement of at least 20 charges totaling at least 130 lb of explosive at a loading ratio of 8.5 lb/yd³. The closeness of EBR-I and ZPR-III, in terms of ground shock and air blast, make this plan impractical.

9.2.4 AFSR Fragmentation to 1-5 cu ft Pieces

This plan utilizes the same number of internal charges and loading configurations as the breaching plan but requires less than 10 lb explosive at a loading ratio of 0.5 lb/yd³. There is a considerable degree of effort in the core drilling of the more than 20 holes. There would be a greater degree of "mucking up" of small aggregate concrete which would increase the costs of interment in the sanitary landfill. The primary circuits would be more complicated and the checking of fired charges upon completion of the demolition would be much more involved.

9.2.5 AFSR Monolith Hydrodynamic Blast

This plan involves unseating the whole above-grade steel lined concrete shielding structure so that it could be transported in one piece to the landfill.

Explosives would be emplaced in the basement under the monolith to cut the "mud dogs" and to give the necessary lift to break the dry concrete bond between the foundation and the monolith.

Water or sand could provide the required tamping factor. The primary drawback would be the inability of on-site cranes to lift the 62 ton monolith.

9.2.6 The Cost/Benefit Analysis for the preceding demolition plans was based upon the following factors:

- (1) Mission requirements
- (2) Man-hours and equipment time
- (3) Cost of explosives and associated equipment
- (4) Damage potential to adjacent buildings
- (5) Personnel safety
- (6) Transportation
- (7) Interment costs
- (8) Total time for planning and implementation.

The analysis resulted in the following order of preferences:

- (1) AFSR Bisectioning
- (2) AFSR Fragmentation to pieces 1-5 ft³
- (3) AFSR Monolith blast
- (4) Mechanical breakup.

9.3 AFSR Bisectioning

9.3.1 Objectives:

- (1) To decontaminate the reactor access hole
- (2) To establish a bisection fracture plane in the steel liner by making a longitudinal cut with an acetylene torch
- (3) To drill five holes or cuts into the concrete monolith

- (4) To detonate five explosive charges (60% gelatin dynamite) to break the monolith into two pieces and unseat the monolith from the concrete slab foundation
- (5) To rig, lift by crane, and transport by low bed truck and trailer, the two concrete bisections to the sanitary landfill
- (6) To fill in the basement voids with native soil, grade and create a terrain feature.

9.3.2 Decontamination of AFSR Access Hole

The void within the monolith that enclosed the AFSR is contaminated to the levels 2 mR/hr and 1050 d/m B γ /100 cm² smearable. To decontaminate the void, a container will be placed within the AFSR basement under the access hole and high-pressure water spray injected through the top of the monolith into the reactor access hole. The water washout will be caught in the container and then transported to CF-669 laundry hot drain for disposal. A resurvey of the access hole will then be conducted, and if necessary, stronger decon agents will then be used to adjust the contamination level to 1 mR/hr @ contact and less than 1000 dpm B γ /100 cm² and less than 20 dpm α /100 cm² smear.

9.3.3 Bisection Fracture Plane

A fracture plane will be established in the 1/4 inch metal shell of the concrete monolith. This will be accomplished by acetylene torch. Air line respirators will be used during cutting. The longitudinal cut will be from the thermal column access, over the top of the monolith, in and out of the access hole B liner, and to the beam hole access plug on the other side. In this manner the metal shell

of one bisection will be completely free of the metal shell of the other. The fracture plane will aid in stress relief at those points that lie in the plane (see Figure 3).

9.3.4 Drilling of Cuts Into the Monolith

Five holes will be drilled into the concrete monolith (see Figures 4 and 5) for the purpose of loading the explosive charges. Both the cuts and the explosive charges will be noted by the letters E1, E2, E3, A1, A2, and preceded by the words, cut, or charge, whichever is applicable.

The location, depths, diameters and angles of the five cuts are as follows:

(1) Cut E1

Location: 10 in. from the access hole B liner on
the longitudinal midplane

Diameter of Cut: 2 in.

Angle of Cut: 16° from the perpendicular

Depth of Cut: 3 ft 4 in.

Rb = breaching radius = 1.834 ft

(2) Cut A1

Location: 1 ft 10 in. from the access hole B liner
on the longitudinal midplane

Diameter of Cut: 2 in.

Angle of Cut: vertical 90°

Rb = 1.834 ft

[illegible]

Fracture Plane Bi-Section Figure 3

Figure 4

(3) Cut E2

Location: 12 in. from the beam hole access plug

Diameter: 2 in.

Angle: horizontal

Depth: 1 ft 4 in.

Rb = 1.16 ft

(4) Cut E3

Location: internally located 3 ft 4 in. from out-
side face of beam hole access plug

Diameter: 2 in.

Angle: vertical

Depth: 11 in.

Rb = 0.667 ft

(5) Cut A2

Location: 6 in. from the thermal column vertical
midplane

Diameter: 2 in.

Angle: horizontal

Depth: 1 ft 5 in.

Rb = 0.5 ft

9.3.5 Explosive Charge Calculations

(1) Given:

Rb = breaching radius or radius of rupture

Charge Notation: Ch E1, Ch E2, Ch E3, Ch A1,
Ch A2

K = material factor

C = tamping factor

Loading ratio = the ratio of explosive to volume
of concrete

Explosive = medium strength

Dupont straight gelatin

60% grade

1-1/4 in. x 8 in. @ (1) stick

density 96 cart./50 lb (0.52 lb/cart.)

velocity $\approx$ 19,000 ft/sec

Note: This explosive was chosen because of its high detonation velocity, high loading density and plasticity.

(2) An explanation of the three types of explosive calculation methods is as follows:

(a) Title: Commercial Explosive Loading Ratio

Calculation

Primary Use: Commercial blasting of masonry and concrete with explosives used in loading ratios of 0.25-0.5 lb explosive per cu yd of concrete

Principal Technique: Commercial blasting agents are used to produce large aggregate fragmentation of construction materials so that the "burden" may be "mucked up" by machinery or personnel.

Purpose of Calculation: This calculation will form the basis for the explosive demolition of AFSR.

(b) Title: Military Breaching Calculation

Primary Use: Military breaching of obstacles

Principal Technique: Military blasting agents are employed in much larger amounts than commercial agents to completely breach an obstacle so as to aid the passage of troops and equipment.

Purpose of Calculation: This calculation was performed to establish the maximum explosive loading that would fulfill the mission requirement 100%. Air blast, ground shock and blast fragmentation are not considered. The amounts of explosive required for a particular degree of concrete breakup will be found between the commercial blasting calculation value and the military breaching calculation value. The breaching requirements for the 1/4 in. metal shell are not determined by this calculation.

A relative effectiveness calculation is made to adjust to the different efficiencies of various blasting agents.

(c) Title: 1/4 in. steel plate explosive breaching

Primary Use: Explosive breaching of metal plates or members

Principal Technique: Explosives that possess high detonation velocities and "brisance" may be used to cut metals.

Purpose of Calculation: This calculation produces an explosive quantity value that is required to breach the 1/4 in. steel plate along a fracture plane. Because the fracture plane will be made by acetylene torch cutting of the metal, this calculation will not be used. Its purpose is to help establish a slightly larger explosive value than that given by the commercial loading ratio calculation.

(3) Charge E1

(a) Concrete fragmentation charge @ loading ratio of 0.5 lb/yd³

V = volume of concrete @ Rb = 1.834 ft

$$\begin{aligned} V &= 4.189 Rb^3 \\ &= \frac{4.189(1.834)^3}{27} \\ &= 0.957 \text{ yd}^3 \end{aligned}$$

$$0.957 \text{ cu yd} \times 0.5 \text{ lb exp/cu yd} = \underline{0.478 \text{ lb 60\% Gelatin}}$$

(b) Military Breaching Charge

$$K = 0.070$$

$$C = 1.25$$

$$P = Rb^3 K C$$

$$= (1.834)^3 (0.70) (1.25) = 5.39 \text{ lb TNT}$$

$$+10\% \text{ for charges } < 50 \text{ lb exp} = 5.93 \text{ lb TNT}$$

$$\text{Relative effectiveness 60\% gelatin dynamite} = 0.76$$

$$5.93 \text{ lb TNT} / 0.76 = \underline{7.8 \text{ lb 60\% Gelatin Dynamite}}$$

(c) Explosives in contact of metal required for shearing steel plate

$$L(\text{length of } 1/4 \text{ in. steel plate @ Ch}^{E1}) = 15 \text{ ft}$$

$$P = 3/8 A_{(\text{in}^2)} = 3/8 (0.25) (15 \text{ ft}) (12) = 16.87 \text{ lb TNT @ contact of plate length}$$

$$\text{Rel Eff} = 16.87 \text{ lb TNT} / 0.76 = \underline{22.19 \text{ lb 60\% Gelatin}}$$

(4) Charge A.

Same calculation as ChE1 because the breaching radius is the same.

(5) Charge E2.

(a) Concrete fragmentation charge @ loading ratio of 0.5 lb/yd³.

$$V = \text{Volume of concrete @ } Rb = 1.16 \text{ ft}$$

$$V = 4.189 Rb^3 \\ = \frac{4.189(1.16)^3}{27} = 0.242 \text{ yd}^3 \text{ concrete}$$

$$0.242 \text{ yd}^3 \times 0.5 \text{ lb/yd} = \underline{0.12 \text{ lb 60\% Gelatin}}$$

(b) Military Breaching Charge

$$\begin{aligned}P &= Rb^3 K C \\&= (1.16)^3 (0.70) (1.25) \\&= 1.36 \text{ lb TNT}\end{aligned}$$

+10% for charges <50 lb = 1.49 lb TNT

$$1.49 \text{ lb TNT} / 0.76 = \underline{1.96 \text{ lb 60\% Gelatin}}$$

(c) Explosives in contact required for shearing
steel plate

L(length of 1/4 in. steel plate @ E2) = 4 ft 5 in.

$$\begin{aligned}P &= 3/8 A \\&= 3/8 (0.25) (4.4) (12) = 4.95 \text{ lb TNT}\end{aligned}$$

$$4.95 \text{ lb TNT} / 0.76 = \underline{6.51 \text{ lb 60\% Gelatin}}$$

(6) Charge E3

(a) Concrete fragmentation charge @ loading ratio
of 0.5 lb/yd³

V = volume of concrete @ Rb = 0.667 ft

$$\begin{aligned}V &= 4.189 Rb^3 \\&= \frac{4.189 (0.667)^3}{27} = 0.046 \text{ yd}^3 \text{ concrete}\end{aligned}$$

$$0.046 \text{ yd}^3 \times 0.5 \text{ lb/yd}^3 = \underline{0.023 \text{ lb 60\% Gelatin}}$$

(b) Military Breaching Charge

$$\begin{aligned}P &= Rb^3 K C \\&= (0.667)^3 (0.70) (1.25) \\&= 0.259 \text{ lb TNT}\end{aligned}$$

$$\text{Rel Eff } 0.259 / 0.76 = \underline{0.340 \text{ lb 60\% Gelatin}}$$

(c) Explosives in contact required for shearing
steel plate.

L(length of 1/4 in. steel plate @ E3) = 5 ft 7 in.

$$P = 3/8 A = 3/8 (0.25) (5.8) (12) = 6.27 \text{ lb TNT}$$

$$\text{Rel Eff} = 6.27 \text{ lb TNT}/0.76 = \underline{8.25 \text{ lb 60\% Gelatin}}$$

(7) Charge A2

(a) Concrete fragmentation charge @ loading ratio
of 0.5 lb/yd³

V = volume of concrete @ Rb = 0.5 ft

$$\begin{aligned} V &= 4.189 Rb^3 \\ &= \frac{4.189(0.5)^3}{27} = 0.0194 \text{ yd}^3 \text{ concrete} \end{aligned}$$

$$0.0194 \text{ yd}^3 \times 0.5/\text{yd}^3 = \underline{0.0099 \text{ lb 60\% Gelatin}}$$

(b) Military Breaching Charge

$$\begin{aligned} P &= Rb^3 K C \\ &= (0.5)^3 (0.70) (1.25) = 0.109 \text{ lb TNT} \end{aligned}$$

$$\text{Rel Eff} = 0.109 \text{ lb TNT}/0.76 = \underline{0.143 \text{ lb 60\% Gelatin}}$$

(c) Explosives in contact required for shearing
steel plate

L(length of 1/4 in. steel plate @ A2) = 3 ft 3 in.

$$P = 3/8 A = 3/8 (0.25) (3.25) (12) = 3.65 \text{ lb TNT}$$

$$\text{Rel Eff: } 3.65 \text{ lb TNT}/0.76 = \underline{4.8 \text{ lb 60\% Gelatin}}$$

(8) Explosive Quantity Comparison

<u>Charge</u>	<u>Commercial</u>	<u>Military Breach</u>	<u>Steel Cut</u>	<u>AFSR</u>
Ch E1	0.478 lb	7.8 lb	22.19 lb	1.0 lb
Ch A1	0.478 lb	7.8 lb	22.19 lb	1.0 lb
Ch E2	0.12 lb	1.96 lb	6.51 lb	0.25 lb
Ch E3	0.023 lb	0.340 lb	8.25 lb	0.25 lb
Ch A2	0.009 lb	0.109 lb	4.8 lb	0.25 lb

9.3.6 Blasting Format

(1) Preparation of the Blasting Area

- (a) The Blasting Area is that area surrounding the AFSR in which personnel could be injured or equipment damaged by blast or fragmentation. This will be defined as a 500 ft radius around the AFSR.
- (b) Entry of personnel or vehicles to the EBR-I area will be limited to those individuals that are necessary during the preparation and blasting period.
- (c) The EBR-I evacuation siren will be the Blasting Warning System. The system must be checked and verified ready for operation.
- (d) The explosive materials for the AFSR operation will be stored at the CF Explosive Magazines. They will be transferred to the AFSR the day of scheduled blasting.
- (e) The explosives transport vehicle must be readied to comply fully with Annex K transportation requirements.
- (f) The drilled cuts in the AFSR must be checked for depth, location, and size.
- (g) All required blasting equipment should be accounted for and tested for reliability.

A list is as follows:

1. Blasting machine 10 cap min.
2. Blasting galvanometer
3. 500 ft firing lines (equal to or greater than 14 B&S gauge)
4. Wooden tamping rod
5. Sand/clay stemming
6. Cap crimpers or dynamite punch
7. Tape
8. Log book

(2) Priming

- (a) The 60% gelatin and EBCs will be delivered to the AFSR.
- (b) A single qualified person will prime and load the cartridges. #8 instantaneous EBCs will be used.
- (c) The gelatin will be visually checked for signs of degradation and the EBCs will be checked for conductivity. The leg wire shunts will be maintained up until the charges are wired in series and connected into the main firing lines.
- (d) The firing line will be shunted on both ends until final connections are made. Conductivity checks will be made.
- (e) The blasting machine will be in possession of the powderman.

- (f) The gelatin dynamite will be center punched and the EBC inserted the full cap length into the primer cartridge along its longitudinal axis.
 - (g) The leg wires of the EBC will not be subject to harmful strain; the leg wires will be immobilized by two half hitches about the primer cartridge.
 - (h) As each primer cartridge is made it will be inserted into the cut, the placement being indirect, that is, the EBC end of the cartridge will be inserted first.
- (3) Loading and Stemming
- (a) The primer cartridges will be gently loaded in cuts as they are made up.
 - (b) Wet holes will not be primed.
 - (c) The charges will not be tamped. The tamping rod may be used to ensure the charge being fully seated in the cut.
 - (d) With leg wires pulled firmly tight, stemming, a mixture of moist sand and clay, will be injected into the cut and gently tamped.
 - (e) All charges will be loaded and stemmed before any electrical circuits are established.
- (4) Connecting blasting circuits
- (a) Upon removal of the leg wire shunts a conductivity check will be made with the blasting galvanometer.

- (b) The leg wires of the explosive charges will be connected with Western Union Pigtail splices and in simple series.
 - (c) Before connecting the branch line into the main firing line, a conductivity test will be made.
 - (d) Connect branch line into main firing line.
 - (e) Personnel will evacuate to a safe area inside the west wall door of EBR-I.
- (5) Firing
- (a) A conductivity check of the main firing line will be made and the shunt replaced.
 - (b) An accounting of all personnel will be made.
 - (c) EBR-I guard gate will be locked and sufficient guards employed to control access to the blast area.
 - (d) Adequate cover will be insured for all personnel.
 - (e) The evacuation siren will be activated. Three 10 second sounds will be used as a positive warning signal.
 - (f) The blasting machine will be tested and cranked five times before being connected into the firing circuit.
 - (g) The firing line will be deshunted and the blasting machine connected.
 - (h) The charges will be fired.
- (6) Return to the blast area.
- (a) Only the powderman will be allowed to initially reenter the blast area. The main firing line

will be shunted and the blasting machine carried.

- (b) Reentry will be allowed only when smoke, fumes and dust has cleared.
- (c) Each detonated or misfired charge must be accounted for.
- (d) Burning holes (evidenced by smoke or irregularity) must not be approached until at least an hour after the smoke has subsided.
- (e) A vocal "all clear" signal may be given after the powderman has checked the area and found it free of all explosive hazards.

(7) Emergency Action for Misfires

- (a) Should a blasting misfire occur, ANC Safety Division Management and ID Occupational Safety shall be contacted before proceeding.
- (b) Misfires shall be handled under the direction of the person in charge of the blasting.
- (c) Do not attempt to investigate a misfire too soon. For nonelectric and electric primed charges an hour wait is required.
- (d) Burning holes should not be approached for at least an hour after the burning has subsided. Fumes from burning dynamite are very toxic and the burning may result in an explosion called a "hang fire".

- (e) There are no specific instructions for handling all misfires. Each situation must be judged upon its own safety conditions. Under most conditions the safest way to dispose of a misfire is to shoot it.
- (f) If EBCs are involved in the misfire, disconnect the leading wires from the source of power before returning to the blast area. If the leg wires of the misfired priming cartridge are accessible, test the cap with the blasting galvanometer and if it shows a circuit, reconnect the leg and lead wires and fire it in the usual manner.
- (g) Explosives shall not be extracted from any hole that has once been charged or has misfired unless it is impossible to detonate the unexploded charge by insertion of a fresh additional primer.
- (h) For EBC shots that fail the second time, for nonaccessible EBC leg wire situations, and for holes that contain only 12-15 in. of stemming; try to shoot the hole with a fresh primer.
- (i) If the procedure as stated in (h) fails or is impractical, stemming may be removed by means of a wooden spoon, jet of water if the

misfired charge is water resistant, or a stiff rubber hose and compressed air. The distance from the top of the misfired charge to the collar of the hole should be known from the loading data. With the aid of the wooden tamping rod one can determine hole access to within 12 in. of the misfired charge. When sufficient stemming has been removed, the stemming left in the hole should be moistened and a new high velocity primer inserted and fired. A careful search shall be made for unexploded material in the debris of the second charge.

- (j) When stemming entry is not possible, the missed hole may be opened by benching.
- (k) Missed holes may be handled by drilling a new hole no nearer than two feet from the misfired charge. It is preferable to place the second hole so that both holes lie in a plane parallel to the face or so that the second one is in front of rather than behind the missed hole in order to prevent throwing unexploded dynamite into the broken rods from the blast. This is a hazardous procedure and should be used only as a last resort.

- (l) For large diameter holes or sprung holes, it is neither safe nor practicable to drill another hole near them to blast out the charge. This is due to the fact that drill holes drift to a surprising degree in certain types of ground, and to some degree in concrete.
- (m) Partially detonated charges in a borehole should be handled in the same manner as those involving the entire charge.
- (n) Unexploded dynamite spread about an area or lying in a "muck" pile should be collected, placed in a storage magazine or secured and disposed of in a manner approved by the manufacturer. ANC Safety Division Management will be notified of the details prior to implementation.
- (o) Workers reentering the blasting area should be briefed on the hazards and visual qualities of unexploded dynamites or detonating caps. A suspicious "find" by anyone should be immediately reported to the blasting supervisor.
- (p) An investigation of a misfire will usually disclose the cause of the trouble, such as improperly made primers, defective or deteriorated explosives, the use of nonwater resistant explosives in wet work, improper

loading practices, injuries to leg wires, detonater explosive disengagement, failure to light the fuse or connect the electric cap in the circuit, improper electrical hookup, improper power source, cutoffs, direct priming, improperly trimmed fuses, improper use of delays, or improper blasting design.

9.3.7 Rigging, Loading and Transportation of the AFSR Bisections.

- (1) Upon completion of the AFSR blasting, an analysis shall be made as to the efficiency of the bisection breakup.
- (2) Cutting torches may have to be used to cut reinforced rod and sheet metal.
- (3) A crane and tractor may be required to separate the bisections.
- (4) Once the bisections are separated, they will be rigged with wire rope through the beam holes and lifted onto low bed trailers where they will be securely fastened.
- (5) The CF Safety Engineer will check and approve the rigging of the loads.
- (6) The Bisections will then be transported to the RWDSA or the sanitary landfill.
- (7) The AFSR basement voids will then be filled with clean concrete, rubble, and dirt.

(8) A terrain feature will be made at the site of the AFSR.

9.4 Ground Shock to ZPR-III and EBR-I

There is general agreement among seismic vibration investigators that the maximum particle velocity in the seismic wave train is the measured parameter which best correlates with structural damage. Several states have promulgated regulations limiting the size of blasting charges permitted on this basis. The state of New Jersey was one of the leaders. Their regulation (Safety Reg. No. 23 Governing the Use of Explosives, State of New Jersey Dept. of Labor and Industry) states that the maximum total peak particle velocity allowable in the most critical location is 1.92 in. per sec.

In the absence of seismic measurements the New Jersey regulation (page 45, par. 10.4.2, 10.4.3) provides the following limits: for a 60 to 200 foot distance from a blast area to nearest building or structure in feet, a 1/4 lb explosive per foot of distance may be employed. The closest point of the ZPR-III building is 95 feet from the AFSR. Therefore a maximum quantity of explosives per shot for instantaneous firing or per delay, for delay firing, is 23.7 lb.

9.5 Air Blast and Fragmentation

A Quantity -- Distance Standard for Explosives taken from the Ordnance Pamphlet 5, U.S. Bureau of Ordnance, 1957, states that the safe distance from an explosive charge not exceeding 50 lb in an unbarricaded magazine to an inhabited building is 300 ft or to a public highway, is 180 ft.

This standard does not account for fragmentation. The total AFSR charge will not exceed 3.5 lb explosive.

As a precaution, the windows of ZPR-III shall ^{be} opened to avoid
breakage due to overpressure. Personnel shall take cover during
blasting to avoid any fragmentation exposure.

9.6 Safety Approval and Blasting Permit

This procedure must be approved by ANC Safety Division and AEC Occupational Safety. The powderman must be evaluated by AEC and issued a blasting permit.

APPENDIX N

PROCEDURE FOR REMOVAL OF NAK
FROM EBR-I STORAGE PIT

Approved

Safety Approved

N-2

EBR-1 NaK Storage Pit

1.0 SCOPE

This procedure details the requirements for moving two drums and two vessels, containing NaK, from the NaK Storage Pit at EBR-I to temporary storage at the Air Force Re-Entry Vehicle Facility Site (ARVFS) Bunker. These items are to be handled remotely, using approved and demonstrated methods, to prevent exposure of potential chemical reaction and to radioactive material. An explosive test report on NaK/KO₂ prepared by Cook and Associates provides conclusive evidence that NaK and KO₂ cannot be made to detonate. If KO₂ is present in the NaK containers, the only reaction possible as a result of moving the containers will be an exothermic reaction and a resulting increase in temperature of the contained NaK. In the unlikely event of a container rupture or leakage from the container during the handling operations, personnel involved in the handling operations shall be protected by protective gear in accordance with the Alkali Metals Safety Handbook for EBR-I. Radio contact with WCC will be provided by a security escort, who will have instructions concerning who to contact in the event of an accident.

1.1 The emergency procedure in the event of a NaK spill shall be to: Contain the NaK in accordance with the EBR-I Alkali Metals Safety Handbook, and to evacuate the BORAX V office. Notify the Burial Ground employees to stay clear of the EBR-I road and to barricade Highway 20 at the entrance to the CFA and at the Lost River Bridge until clean-up of the spill is achieved.

2.0 PREREQUISITES

2.1 Remove wood/transite partitions and lighting fixtures from ARVFS Bunker.

2.2 Prefab closure panels for front of Bunker from 1/8" steel sheet reinforced with 2" x 2" steel angle stiffeners and weld cable tray closure plate.

2.3 Modify steel box container for top loading, and install lifting eyes.

2.4 Additional equipment and/or personnel to be on hand:

- a. 20-ton low-boy and tractor with tie-down rigging.
- b. Four pieces 2" sch. 40 pipe 8-feet long for rolling container into bunker.

- c. 25-ton mobile crane with 80-foot boom.
- d. Two special drum clamps with handling tool.
- e. Dump truck with 10 cubic yards of dry sand and tail-gate spout for loading sand hopper.
- f. 10-ton forklift for rolling dumpster container into bunker.
- g. Portable welding outfit to tack weld steel over front of bunker.
- h. Security escort for the transfer from EBR-I to the ARVFS Bunker.
- i. Fire Department escort.
- j. Protective clothing per ANC Alkali Metals Safety for EBR-I.
- k. Temperature indicators (Tempilstik⁰) rated at 200⁰F, and reach rod.
- l. Constant air monitor.
- m. HP personnel with radiation monitoring equipment.
- n. Mirror for indirect observation of the NaK pit contents.

3.0 PROCEDURE

An HP with radiation monitoring equipment will be present at all phases of this operation, and a fire department escort will be required during the removal and transfer operations.

3.1 Loading at EBR-I

Check equipment requirements and have the needed items ready at the work location. Start CAM.

3.2 Remove lid from the NaK disposal pit with the 25-ton crane.

3.3 Mark container sides and top with Tempilstik⁰ (200⁰F) using a reach rod to avoid personnel entry into the pit.

3.4 Using reach rod, affix the drum clamp to the NaK drums and lifting hook through the vessel lifting eyes. Use two tag lines to control swinging during the lift.

3.5 Using the 25-ton crane, shake the containers individually and observe the Tempilstik⁰ marking for change of temperature. Use a mirror to avoid direct line of sight into pit.

3.6 If Tempilstik⁰ doesn't indicate 200⁰F, wait 30 minutes and continue with procedure, steps 3.8 through 3.13. Analysis indicates that the potential temperature and/or pressure rise will not break the containers.

3.7 If Tempilstik⁰ indicates a temperature rise to greater than 200⁰F, delay operations until the container skin temperature drops to below 200⁰F as evidenced by use of Tempilstik⁰.

3.8 The steel box container will be located and tied down on the rear of the low-boy deck. Lift drums one at a time with 25-ton crane and place in container leaving clamps and rigging in place on the drums. Tie the vessel rigging to keep the individual vessel lifting cables together. Then lift vessels by placing lifting hooks in through the vessel lifting eyes with a handling tool. Lift and place vessels in container.

3.9 Place dry sand in container using crane and hopper. Sand level to be about twelve inches over tops of drums and vessels. (Verify tag lines are attached.)

3.10 Proceed to ARVFS Bunker with container mounted on low-boy, travel time approximately one hour.

NOTE 1: The calculated radiation level at contact with the surface of the container will be between 250 and 420 mR/hr. The radiation level at the driver's compartment (excluding lead shielding) will not exceed 40 mR/hr. Lead shielding will be used to limit the driver's compartment to 2 mR/hr.

NOTE 2: Do not exceed 15 mph in route to ARVFS Bunker.

3.11 Attach rigging and lower the loaded container with 25-ton crane to rest on pipe rollers at front of bunker. Start CAM and check for radiation.

3.12 Pull container into bunker using cable sheave arrangement and leave pipe rollers under container for ease of removal at a later date.

3.13 Place steel sheets at front of bunker using crane and tack weld sheets and angles in place.

3.14 Verify dike has been repaired prior to leaving the area.

4.0 REHEARSAL

This procedure will be rehearsed and witnessed by a cognizant safety representative.

4.1 The simulated loading will be performed at the CF equipment yard instead of EBR-I.

4.2 A dummy drum filled with sand will be substituted.

4.3 Welding of the bunker cover plates will not be rehearsed.

5.0 SAFETY ANALYSIS REPORT

5.1 General Description of Program - The removal of four containers of contaminated NaK (residues from the EBR-I Mark II core meltdown in November, 1955) from the EBR-I NaK storage pit to an engineered interim storage area at ARVFS is one part of the D&D of the EBR-I Complex program plan.

5.2 Interactions with Existing Plant Facilities - The only interaction in the transfer of the NaK containers is between two excessed AEC facilities, EBR-I and the ARVFS. Approval has been received from AEC-ID to use the ARVFS Bunker for temporary storage of the four containers. Revisions to the ARVFS Bunker include removal of a stud wall partition with a 1/4-inch carbon steel plate closure, tack welded to the edge of the armco arch sections which form the bunker. The EBR-I NaK storage pit will be demolished as described in the EBR-I D&D Program Plan.

5.3 Principal Design Criteria - This section is not applicable since there are no new facility designs or modifications.

5.4 Control Methods and Procedures - This section is applicable to the handling and transfer operations and associated safety procedures, which have been discussed in Sections 1.0 through 4.0. In addition, the requirements of Annex-L will apply to this on-site shipment.

5.5 Safety Aspects of Normal Operation - Expected radiation doses to operating personnel have been calculated. The maximum radiation measured at contact with any of the NaK containers was 7R. Therefore, these containers will be placed inside of a steel box container and shielded with dry sand. The steel box container will then have a calculated radiation level at the surface of the steel sides of 250 to 420 mR/hr. The radiation level at the tractor driver compartment will not exceed 40 mR/hr and the trip from EBR-I to ARVFS should not take more than one hour at a rate of 15 miles per hour. Therefore, expected dose rates will not exceed the Administrative Exposure Guides (AEG).

There will be no processing activities, therefore, no releases of radioactivity would be expected during the transfer operations. Likewise, there should be no contribution to overall plant effluents under normal transfer conditions.

5.6 Discussion and Evaluation of Abnormal Occurrences or Conditions -

Concern has been expressed in the past that potassium superoxide (KO_2) may have formed in the NaK containers over the period of some 13 years since the NaK was encapsilated; and that a NaK/ KO_2 mixture might be explosive under certain conditions of shock or sudden contact of the one compound with the other. Therefore, an explosive hazards analysis and evaluation of NaK and KO_2 was conducted which proved that: (1) liquid or solid NaK- KO_2 mixtures do not explode in the "drop test" or "impact test", (2) liquid NaK- KO_2 mixtures will ignite but with no gas generation, and (3) the NaK- KO_2 reaction does not fulfill either the high pressure or loud noise criterion. We therefore conclude that handling or movement of the contaminated NaK containers will not result in gas generation or overpressures sufficient to cause container rupture.

It could be postulated that a container would be dropped during the lifting operation in which case a rupture of the container or shearing of the head valves or lines would be possible. However, the lifting equipment and procedures have been tested with similar shaped packages, and have a safety factor of greater than 8 for the lifts involved. Moreover, the operators involved have dry run the entire handling and transfer operation, thus minimizing the human error factor.

Assuming, however, that a highly unlikely accident resulted in a rupture of the largest container (a 55-gallon drum) which reads 7R, we would be faced with at worst, a NaK fire which could be confined and extinguished. If additionally, it were assumed that the fire could not be extinguished, we would be faced with contaminated NaK oxide dispersal to the atmosphere of a portion of the fission product and plutonium inventory contained in the Mark II core melt down. An analysis by H. K. Peterson, enclosure to OB-169-73, concluded that even if the entire inventory of contaminated NaK at EBR-I were to be consumed in an uncontrolled fire, doses to personnel at CFA, CPP and TRF would be low whether the New Lung Model or the ICRP Report of Committee II Model were used for comparison.

Discussion regarding criticality is not appropriate since the maximum inventory of Pu postulated is due to the 10.5 gram experiment specimens which were not recovered during disassembly of the Mark II core, and are assumed to be in the contaminated NaK contained in the four containers. Since the maximum amount of fissile material in the containers would be several orders of magnitude less than critical mass, no criticality accidents can occur.