Figure 4

PNPF Reactor Complex Showing Regions of Radioactive Materials
DECONTAMINATION OF A HIGHLY RADIOACTIVE CHEMICAL PROCESSING FACILITY

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Aiken, SC 29801

ABSTRACT

Five modules of the highly radioactively contaminated "hot canyon" in one of the chemical processing plants for irradiated fuel at Savannah River Plant were successfully decontaminated for installation of a new process. Decontamination was completed in about one year at a cost of about $150,000. The various techniques employed, equipment used, and the overall job plan are described.

BACKGROUND

Building 221-F, typical of two "canyon-type" chemical processing plants at the Savannah River Plant, was completed in 1954 for processing irradiated fuel elements as part of the production cycle for $^{239}$Pu. The building is of steel reinforced concrete, about 800 feet long x 120 feet wide x 70 feet high (figure 1). Chemical processing is carried out in stainless steel equipment in two canyons, referred to as hot and warm. Each canyon is about 600 feet long, 15 feet wide, and 25 feet deep below the cell covers. One canyon is located on each side of the building, and the center section between the two canyons includes servicing areas, offices, control rooms, etc., on four separate levels. The walls of the hot canyon are of 5-1/2-foot-thick steel-reinforced concrete for shielding the high levels of radiation. The warm canyon, with lower levels of radiation, has 2-1/2-foot-thick walls. The canyons are maintained at a negative air pressure with respect to the rest of the building. The canyon exhaust air is filtered by a sand filter prior to dis-
Canyon processing equipment is installed in modules arranged in a repetitive pattern for pipe transfer routes, instrumentation, and required services. Equipment includes tanks, evaporators, dissolvers, centrifuges, mixer-settlers, and centrifugal contactors which are handled remotely by overhead bridge cranes employing hoists, impact wrenches, and special tools. Observation in the hot canyon is by periscopes installed on the crane and viewed from a heavily shielded cab. The warm canyon can be observed directly, using binoculars if required, from the shielded crane cab (figure 2).

After "hot" processing began in 1954, personnel did not enter the hot canyon until 1971 when entry was made in connection with the work described here. Fixed radiation levels up to 1000 rads are encountered in the hot canyon after billions of curies of fission product activity have been processed. Maintenance of equipment is done remotely. Although pipe jumpers and equipment are now routinely decontaminated for direct maintenance, several years were required to develop methods for recovering failed equipment.

When the need for a new, relatively small multipurpose facility (employing master-slave manipulators and bulk shield windows) for processing highly radioactive materials became apparent in 1969, consideration was directed toward using part of the north end of the hot canyon in Building 221-F because equipment in this space was no longer needed and functions could be reassigned to other canyon equipment (figure 3). Design studies showed that the new facility could be economically installed in the last five modules in the north end of the Building 221-F hot canyon provided that this portion of the canyon could be decontaminated to levels that would permit construction personnel to work directly in the canyon. A goal of a general
radiation level of 25 mR and no appreciable smearable or airborne contamination was established for this decontamination effort.

DECONTAMINATION

Overall Plan

The plan developed for this decontamination effort included (1) removal of the former processing equipment, (2) remote decontamination of canyon walls and floor using the hot canyon crane, (3) isolation of the five modules to be cleaned from the rest of the canyon, (4) penetration of the 5-1/2-foot-thick wall for personnel entry, (5) direct decontamination as required — e.g., chipping out contaminated concrete, and (6) concrete replacement and painting. Work started in February 1970 and was completed in February 1971 (figure 4).

Remote Phase

Four tanks and associated pipe jumpers located in modules 17.4, 18.1, 18.2, and 18.3 were all extensively flushed and relocated. After the tanks were removed, remote decontamination of the canyon walls, floor, and all other surfaces began; this work continued from March through July 1970. A "Tigar Jet"* suspended from the crane sprayed hot solutions (80°C) of water, 10% nitric acid, 10% caustic, and 10% nitric acid with hydroxylamine acid sulfate through rotating spray nozzles at a pressure of 135 psig. An 8-inch-diameter hole was core drilled through the wall in module 18.4 for radiation surveys and observation. A grid system of radiation levels was used to record the progress of the job so the "Tigar Jet" could be positioned where needed to reduce radiation levels. Piping embedded in the concrete walls was flushed using a special manifold to flush several pipes simultaneously. All flushing and spray solutions

(approximately 200,000, gallons) were collected in the section 17 and 18 sumps and moved to waste evaporators for concentration and disposal. Radiation levels were reduced from the initial levels of 230 rads maximum and 68 rads average to 1.3 rads maximum and 500 mrads average (table 1). Another 8-inch hole was core drilled in the wall in module 18.2 for additional radiation surveys and direct observation. Lights were installed in the canyon to provide better visibility. During July 1970, in preparation for personnel entry into the canyon, a 2-1/2-foot-thick steel reinforced concrete shielding wall was installed between modules 17.3 and 17.4. This installation served to isolate the portion of the canyon being cleaned from the rest of the canyon where normal Purex processing continued.

Personnel Entry and Direct Decontamination Phase

Penetration of the 5-1/2-foot-thick steel-reinforced concrete hot canyon wall was accomplished by core drilling techniques. Except for the 8-inch-diameter holes used for special observation, all holes were 4 inches in diameter. A total of eight "windows" were cut to accommodate the master-slave manipulators and bulk shield windows required for the new process. About 100 4-inch-diameter holes were drilled to outline each window, and the block of concrete thus cut out was hydraulically pushed into the canyon for removal. Each block weighed approximately 25 tons and was removed using the hot canyon crane. The total of 4-inch hole length drilled was about one mile. Diamond tip core drills were used. After the first window was opened to the canyon, an air lock was set up and personnel wearing air-supplied plastic suits entered the canyon and continued with direct decontamination using a high pressure jet nozzle. The high pressure system was the "Water Blaster"* which was operated at 4500 psig.

* American Water Blaster model WBG-110, manufactured by American Water Blaster Company, PO Box 55343, Houston, Texas 77055.
using a hand-held jet lance. Jackhammers were used to chip out contaminated concrete. Localized areas of contamination (or "hot spots") were cleaned by hand or by the high pressure jet. Conditions continued to improve gradually and, by February 1971, working times increased to greater than 8 hr per day. After the area was painted, the need for respiratory protection was eliminated. The final radiation level averaged about 20 mR per hr, with no smearable or airborne contamination (figure 5). During the work, no contamination was spread to the clean work area in the center section of the building and no personnel were overexposed to radiation.

CONCLUSIONS

In conclusion, the following achievements were demonstrated:

- Decontamination of a highly radioactive contaminated canyon-type chemical processing facility.
- Remote spraying of water, acid, and caustic to effectively reduce initial high radiation levels.
- Penetration of thick reinforced concrete walls by diamond-tipped core drills.
- Direct decontamination by personnel to remove localized areas and hot spots in the final phase.
- Removal of concrete surfaces by chipping, and refinishing and painting to fix any remaining contamination for the desired optimum conditions.
Figure 1. Separations Building

Figure 2. Separations Building Cross Section

Figure 3. Separations Building Hot Canyon, Sections 17 & 18

Figure 4. Decontamination Schedule

Figure 5. Finished Cell
## Table 1. Decontamination of Hot Canyon*

<table>
<thead>
<tr>
<th></th>
<th>Radiation Levels in Canyon (rad/hr)</th>
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<tbody>
<tr>
<td></td>
<td>Average</td>
</tr>
<tr>
<td>Before Equipment Removal</td>
<td>68</td>
</tr>
<tr>
<td>After Equipment Removal</td>
<td>1.5</td>
</tr>
<tr>
<td>After Remote Decontamination</td>
<td>0.50</td>
</tr>
<tr>
<td>After Manual Decontamination</td>
<td>0.02</td>
</tr>
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</table>

* Overall DF = 3.4 x 10³
FIGURE 1. SEPARATIONS BUILDING
FIGURE 2. SEPARATIONS BUILDING CROSS SECTION
FIGURE 3. SEPARATIONS BUILDING HOT CANYON SECTIONS 17 & 18

FIRE CURTAIN

17.1  17.2  17.3  17.4  18.1  18.2  18.3  18.4

10 x 11  8 x 11  DECANTERS  10 x 11  10 x 11  8 x 11  8 x 11

SHIELDING WALL  FIRE CURTAIN

PIPE RACK
FIGURE 4. DECONTAMINATION SCHEDULE

- EQUIPMENT REMOVAL & DECONTAMINATION
- REMOTE DECONTAMINATION
- CELL ENTRY
- DIRECT DECONTAMINATION & TURNOVER
FIGURE 5. FINISHED CELL
DISPOSITION OF TA-33-21,
A PLUTONIUM CONTAMINATED EXPERIMENTAL FACILITY

ABSTRACT

This report discusses the decontamination, demolition and disposal of a plutonium contaminated experimental physics facility which housed physics experiments with plutonium from 1951 until 1960. The results of preliminary decontamination efforts in 1960 are reported along with health physics, waste management, and environmental aspects of final disposition work accomplished during 1974 and 1975.

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</table>
1. History

The facility described in this report was acquired by the U. S. Atomic Energy Commission in April, 1951, at a cost of $40,819.00. During the period from 1951 until 1960, it was used for numerous physics studies, some of which involved plutonium. Most internal surfaces of the building and surfaces of experimental equipment items became contaminated on April 13, 1960, following an accidental release of approximately 300 milligrams of plutonium ($^{239}$Pu) oxide powder from an experimental apparatus in the process section of the main building. Soon after this accidental release occurred, preliminary decontamination efforts were initiated. Removal of contaminated equipment items and materials, and repeated washing and painting of surfaces removed and/or fixed the plutonium contamination allowing release of the building for occupancy on May 2, 1960. Due to programmatic changes, the facility was not placed back into service and it remained an excess contaminated facility until October, 1974, at which time final decontamination and demolition work was begun. Final disposition of the facility was achieved in June, 1975.

2. Description of Facility

The facility which is referred to in this report as TA-33-21 was located in Technical Area No. 33 (TA-33). The main building was designated as Building 21 or Structure No. TA-33-21 for engineering and maintenance reference.
TA-33 is a remote technical area located along State Road 4 bordered by National Park Service Land, Indian Land, and by other LASL technical areas. The site, shown in Fig. 1, is approximately 9.6 kilometers southeast of the main Los Alamos Technical Area. TA-33-21 was located approximately 100 meters southwest of the main TA-33 office and Laboratory facilities. It was referred to as the "Cut Off Building" in early Laboratory communications and drawings.

In addition to Building 21, the facility included a small compressor shed, a septic tank, a manhole structure, and several hundred meters of underground drain lines and chain link security fences. These structures, identified in Fig. 2, are:

- Structure No. TA-33-32 Septic Tank
- Structure No. TA-33-55 Compressor Building
- Structure No. TA-33-74 Manhole
- Structure No. TA-33-83 Vacuum Pump Base

As shown in Figs. 3 to 6, Building 21 was a combination concrete and wooden structure with approximately 100 square meters of floor area. The concrete portion had approximate dimensions of 11 x 5.4 x 4.2 meters and was constructed of 0.2 meter thick monolithic reinforced concrete. It had a poured concrete floor with wire reinforcement. The wooden section had approximate dimensions of 8.7 x 3.9 x 3.0 meters and was constructed of frame with sheetrock paneling on the
inside and gypsum board siding on the outside; this section was supported on wooden beams. The foundation consisted of concrete piers reinforced with heavy steel bars and was insulated with rock wool. As shown in Fig. 7, Building 21 consisted of six rooms: a counting room, a process room, shower and clothes change areas; a restroom, and a utility room. The counting room was equipped with laboratory benches located around the exterior walls. The process room housed two single gloveboxes and a sink. These rooms were ventilated by two once-through forced air heating systems located in the utility room. There were also several exterior wall exhaust louvers. The building was enclosed in its own perimeter security fence.

Building 21 was served by three liquid waste drain systems: 1) a contamination free drain line that served a sink, a floor drain and a safety shower in the counting room; 2) a sanitary sewer system that served restroom and change room lavatories, urinals, and commodes; and 3) a contaminated industrial waste system that served the sink, shower, and glovebox drains in the process room and an adjacent hot change room. The industrial waste system drained to a drain field located approximately 16 meters south of Building 21. The sanitary sewer system drained to a drop manhole, TA-33-74, which drained to a septic tank, TA-33-32. Overflow from the septic tank surfaced a few
meters southwest of the septic tank. Figure 8 shows the manhole, a section of the security fence around TA-33-21, and the fenced industrial waste drain field area.

3. Decontamination of Building 21

Following the accidental plutonium release which occurred on April 13, 1960, decontamination efforts were begun to allow personnel occupancy and beneficial use of the building. The general sequence of this decontamination effort was:

1) Removal of most material and equipment items from the process room.
2) Removal of material and equipment from the other rooms.
3) Scrubbing of surfaces in the process room.
4) Sealing of duct openings and outside door from process room and removal of all remaining movable items from process room.
5) Final scrubbing of rooms and equipment surfaces.

Decontamination efforts terminated on May 2, 1960. Removable contamination remained on the cracked and buckled linoleum flooring and in inaccessible ducts and cracks. All other surfaces were free of removable contamination. Several small areas of fixed contamination (<400 dpm/60cm²) remained on the west wall of the process room. Surfaces not entirely accessible for decontamination were painted.
Although the building could be occupied by personnel following this preliminary decontamination effort, it was abandoned due to program redirection. The doors were secured to prevent unauthorized access and the facility became an excess contaminated facility awaiting final disposition.

An extensive survey was conducted on July 18, 1972, to re-establish contamination levels on accessible surfaces in Building 21. Results of this survey are listed in Table 1. No attempt was made to survey inside ducts and drain lines. Results of the July 18, 1972 survey indicated that some recontamination of interior surfaces had occurred since 1960. There was also evidence that the building was deteriorating structurally making final decontamination and disposal desirable, primarily to prevent accidental plutonium dispersal in the event of a fire or natural disaster.

In October, 1974, final decontamination efforts were begun with special program funding from the ERDA Division of Waste Management and Transportation. The following decontamination efforts were initiated to reduce the potential for plutonium dispersal during subsequent demolition phases:

1) Removal of gloveboxes, equipment items and miscellaneous materials remaining in Building 21.
2) Removal of some contaminated air ducts and fixtures.
3) Resealing of duct openings.
4) Scrubbing of floors and bench tops.
Figure 9 shows the sink unit and a portion of the process room prior to final decontamination. Surface contamination levels following final decontamination work were significantly less than levels measured in 1972.

During the period from October 1974 until March 1975, final demolition and disposal plans and work orders were developed to accomplish final disposition.

4. Demolition and Disposal

Demolition work started on March 31, 1975 and continued until May 8, 1975. This effort was divided into the following phases:

1) removal of remaining fixtures and equipment items;
2) dismantling and disposal of wooden section of Building 21 which included the process and hot change room;
3) demolition and disposal of concrete section of Building 21; and
4) removal and disposal of underground drain lines, manhole and septic tank.

To best utilize equipment and manpower, phase four was carried out intermittently throughout the complete operation. The work accomplished during each of the four phases and contamination levels that were encountered are described.
Phase 1. Removal of Fixture and Equipment Items

Items removed from inside the building consisted of light fixtures, sinks, cabinets, commodes and duct work. Exterior items consisted of exhaust blowers, piping, and light fixtures. The contamination levels detected ranged from several hundred to 100,000 dpm/60cm². After removal work was completed, the interior wall and floor surfaces were scrubbed and painted to further reduce the potential for plutonium dispersal. This resulted in conditions shown in Fig. 10.

The furnace, compressor, and other small equipment items located in the utility room were cleaned, painted, dismantled and repainted. This operation produced the highest levels of surface and airborne contamination encountered during the project. The highest surface and airborne contamination levels were 100,000 dpm/60cm² and 40 \times 10^{-12} \mu Ci/cm², respectively.

All persons engaged in removal work wore full face respirators equipped with ultra-high efficiency filter canisters and anti-contamination clothing.

Phase 2. Removal of Wooden Structures

This phase involved the dismantling and removal of the wooden section of Building 21. This section housed the process and hot change room and was the main source of the remaining contamination. All interior wall paneling, ceiling, flooring and insulation were removed with the
exterior walls intact to prevent possible contamination release to the atmosphere.

Contamination levels detected ranged from 4,000 dpm/60cm² under the linoleum to 12,000 dpm/60cm² on the walls. After removal of the paneling and insulation, the interior surfaces of the remaining walls and floor were repainted. A backhoe was used to remove underground piping and foundations. TA-33-55, the compressor shed, was also removed during this phase of demolition work, leaving conditions shown in Fig. 11.

Phase 3. Removal of Concrete Section

A large crane equipped with a "wrecking" ball was required for demolition of the concrete section as shown in Fig. 12. All perimeter fencing was removed to allow the equipment to maneuver. After each initial crushing of a portion of the wall and roof, an extensive radiation survey was conducted. Water spray was used for dust and contamination control. No contamination was detected on the debris or the heavy equipment used. The absence of loose contamination allowed use of conventional demolition techniques, thus avoiding high cost and time delay.

During phases 2, 3 and 4, a full set of anti-contamination clothing was required. Full face respirators were used at the discretion of the health physics surveyor in charge.
On several occasions, demolition was curtailed due to extreme windy conditions.

Phase 4. Removal of Underground Drainlines, Septic Tank and Manhole

As was mentioned earlier, the removal of the underground items were conducted concurrently with the demolition of Building 21 to best utilize manpower and equipment. The uncontaminated lines, i.e., the drainline from the count room and the septic tank system were removed first; no contamination was encountered. These items were easily removed using a backhoe and manual labor.

The tile field which received the industrial wastes from Building 21 was removed last to minimize spreading of contamination. Details of this drain field are shown in Fig. 13. Expectations were that the entire distribution and collection systems as well as the gravel between them would be highly contaminated requiring hand excavation and packaging of the materials. The excavation and removal of the 1.2 m sections of 10.2 cm clay pipe began at the outfall in hopes that this would be uncontaminated because wastes entering the field may not have reached this point.

It was soon evident that the entire collection system had never been exposed to contaminated wastes. This fact was verified by monitoring the inside of the pipe and by collecting and measuring soil samples under pipe joints. The
collection system was removed in a fashion similar to the removal of the two uncontaminated drain systems. A typical trench, after removal of the clay pipe, is shown in Fig. 14.

The next step was the removal of the distribution system. Excavation was begun at the ends most distant from the junction shown in Figs. 13 and 15. All four east-west laterals were removed without encountering any contamination.

Contamination was encountered in the north-south lateral of the distribution system. As shown in Fig. 13, approximately 10 m of trench were contaminated to levels of approximately 80 pCi/gm gross alpha. Approximately 2.5 m$^3$ of contaminated soil from this trench and all of the clay pipe were sent to the contaminated waste burial ground and buried as non-retrievable waste. Sampling and analyses of the soil will be described in Section 8.

The fact that the contamination in the tile field was not as extensive as expected can probably be explained in this manner: Contamination from the 1960 accidental spill did not enter the field, and volumes of waste from normal operations prior to 1960 were small enough that the wastes did not migrate to very long distances from the entrance to the field.

The demolition portion of this operation required 28 working days and about 1700 manhours of on-site craft and
Approximately 200 manhours were required for pre-demolition decontamination work; hence, final disposition consumed a total of about 1900 manhours. No incidents occurred except for an uncontaminated minor scratch on the face of one man which occurred while he was helping dismantle the perimeter fence.

5. Health Physics

A standard operating procedure that established health physics provisions was prepared prior to starting final decontamination and demolition work. Trailer facilities shown in Fig. 16 were located approximately 30 meters east of Building 21. These trailers provided space for health physics monitoring, change rooms, and eating facilities. Provisions established for health physics included:

1) Personnel assigned to work at TA-33-2l were quantitatively fitted with full face respirators and sampled for urinary plutonium before they could work at the site.

2) A complete change into protective anti-contamination clothing was required for workmen and health physics personnel actively engaged in decontamination and demolition work. This included socks, underwear, safety shoes, booties, coveralls, surgeon's cap, gloves, and hard hats.
3) No personal items such as rings, wrist watches, cigarettes were allowed on personnel engaged in decontamination work.

4) Health physics monitoring was provided continuously and workers were provided film badges even though only background beta-gamma levels existed.

5) All workmen were surveyed for contamination at noon and at the end of the work shift. More frequent surveys were conducted during the final decontamination phase.

6) Nasal smears were taken at the end of each work shift as a minimum.

7) Workmen were required to take shower baths at the end of the work shift.

8) Any injury was reported to health physics for proper monitoring.

9) Tools and equipment used in the area were monitored for contamination prior to removal.

10) All dump trucks were monitored for contamination after being loaded at TA-33-21 and after each load was dumped at Area G, TA-54.

11) Daily air samples were collected in work areas during the entire operation.

12) Workers were placed on a routine plutonium urine sampling program to assure post work sampling.
Minimal airborne and personnel contamination control problems were encountered during final decontamination and demolition phases of the project because prior decontamination efforts in 1960 had removed and/or fixed most of the original plutonium contamination.

Airborne plutonium levels exceeded $2 \times 10^{-12} \mu\text{Ci}/\text{cc}$ in the utility and process rooms on four days during final decontamination work. The highest measured concentration was $40 \times 10^{-12} \mu\text{Ci}/\text{cc}$ which equals the concentration guide for insoluble plutonium. The highest single nasal smear activity was 8 dpm and no contaminated injuries occurred during the job.

6. Waste Management

All structures, fences, and underground tanks and lines at TA-33-21 were removed and disposed of at the LASL's radioactive solid waste disposal site as nonretrievable, < 10 nCi/g, plutonium contaminated solid waste. These waste materials were packaged in different ways depending on size and contamination level to make transport and disposal safe. Contaminated small items were placed in plastic bags and 0.56 m³ cardboard boxes; the bags and boxes were sealed with tape. In addition to the boxed waste, large items and structural materials were taken to the disposal site in covered dump trucks as shown in Fig. 17. Fixing the contamination on large items with several coats of paint allowed
handling, transport, and disposal without vehicle or personnel contamination problems. Ninety-seven truck loads, or about 450 m$^3$ of contaminated debris were removed from the site.

Waste packages and unpackaged items were monitored for plutonium contamination with portable alpha survey instruments prior to removal from the site.

7. Environmental Air Monitoring

Environmental monitoring of the demolition operation was conducted with a special on-site air sampling program. Two trailer-mounted, gasoline-powered generators were used to provide electrical power at the site. Each of the generators powered two environmental air samplers. A sampler and a generator can be seen in Fig. 18. The sampler locations are shown in Fig. 19.

The samplers drew air through a 78-mm Microsorban filter with an efficiency of about 99.8% for 0.3μm dioctylphthalate (DOP) particles (a standard test aerosol for determining filter efficiency) at a rate of about 70  l/min.

The samples were collected weekly. This schedule was not intended to provide an early detection of a plutonium release, but was to document the magnitude of an accidental release.

Each week's samples were composited for plutonium analyses to determine environmental plutonium levels during the demolition. For comparison, the sampling program was
begun three weeks prior to start-up and was continued two weeks after completion of the demolition operations. The weekly concentrations of atmospheric $^{239}\text{Pu}$ including the predemolition and post demolition periods are listed in Table 2.

8. Soil Sampling and Analyses

An extensive soil sampling program was effected in the tile field. Samples were collected under pipe joints at intervals of approximately 1.2 meters. The samples were homogenized by mixing in the plastic collection bags. A 100 x 15 mm plastic petri dish was filled with soil. The dish and its contents were dried under a heat lamp for five minutes and then allowed to cool. Gross alpha measurements were made on each sample with a ZnS alpha counting system.

Alpha activity levels were considered to be significant if the gross counts were greater than 3σ above the approximately 20 counts per 5 min observed on a background sample of the type of soil found at TA-33-21. The equation used was:

$$A = 1.33 \left( G - 20 \right)$$

where

- $A$ = alpha activity in pCi/gm
- 1.33 = calibration factor obtained from a 2 nCi/gm standard
- $G$ = gross counts for five minutes
- 20 = background counts for five minutes.
With a gross count of 35 counts/5 min, (just above the 3\sigma level of significance), the significant alpha activity level was 20 pCi/gm.

Ninety percent of the samples (48 out of 53) taken from under clay tile distribution and collection systems contained less than 20 pCi/gm gross alpha. The remaining five samples, taken from the area where the soil was removed, ranged from 25 to 80 pCi/gm.

Samples taken from the area where soil was removed (after the removal of the contaminated soil) indicated that the remaining soil contained less than 20 pCi/gm gross alpha. Four surface samples collected in the area of TA-33-21 after the demolition but prior to back filling with top soil also contained less than 20 pCi/gm gross alpha activity.

Ten soil samples collected during the removal of the tile field lines were selected for plutonium analyses to confirm the gross alpha measurements made with the ZnS system. The Pu concentrations ranged from 0.01±0.01 to 0.10±0.01 pCi/gm for soil left in place. The highest measured Pu concentration for soil removed for burial was 130±10 pCi/gm.

9. Final Site Condition

The 10 to 15 cm depression remaining after the removal of Building 21 and its related structures was backfilled with top soil to restore the site to its original contour. The area (approximately 2000m²) was planted in blue gramma and
stream wheat grasses, and fertilized with ammonium nitrate and super triple phosphate. Figure 20 shows the site following site grading, seeding, and fertilizing operations.
Table 1

Building TA-33-21 Survey Results 18 July 1972

<table>
<thead>
<tr>
<th>Room</th>
<th>Location</th>
<th>Maximum Contamination Levels</th>
<th>Direct α (dpm/60cm²)</th>
<th>Removable α (dpm/100cm²)</th>
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<tbody>
<tr>
<td>Process Room</td>
<td>Outside airlock floor</td>
<td></td>
<td>3,000</td>
<td>90</td>
</tr>
<tr>
<td>Process Room</td>
<td>Floor under glovebox</td>
<td></td>
<td>&gt;40,000</td>
<td>29,000</td>
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<td>Process Room</td>
<td>Water pipe, south wall</td>
<td></td>
<td>2,000</td>
<td>500</td>
</tr>
<tr>
<td>Process Room</td>
<td>Floor, center</td>
<td></td>
<td>2,000</td>
<td>180</td>
</tr>
<tr>
<td>Process Room</td>
<td>Floor, under sink</td>
<td></td>
<td>1,500</td>
<td>269</td>
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<tr>
<td>Process Room</td>
<td>Floor, under bench</td>
<td></td>
<td>1,000</td>
<td>150</td>
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<tr>
<td>Hot Change Room</td>
<td>Top of door</td>
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<td>20,000</td>
<td>160</td>
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<td>Floor</td>
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<td>90</td>
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<td>Restroom</td>
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<td>Restroom</td>
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<td>Count Room</td>
<td>Floor</td>
<td></td>
<td>1,000</td>
<td>100</td>
</tr>
<tr>
<td>Count Room</td>
<td>Floor</td>
<td></td>
<td>3,000</td>
<td>170</td>
</tr>
<tr>
<td>Utility Room</td>
<td>Pipes</td>
<td></td>
<td>36,000</td>
<td>1,000</td>
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Table 2

Environmental Air Sampling Data

<table>
<thead>
<tr>
<th>Week</th>
<th>Status of Project</th>
<th>$^{239}$Pu Concentration ($10^{-18}$μCi/ml)</th>
<th>% of ERDA CG**</th>
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</thead>
<tbody>
<tr>
<td>1*</td>
<td>Background Air Sampling</td>
<td>56±30</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>2</td>
<td>Background Air Sampling</td>
<td>33±9</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>3</td>
<td>Background Air Sampling</td>
<td>57±11</td>
<td>&lt;0.01</td>
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<tr>
<td>4</td>
<td>Final Building Decontamination</td>
<td>1821±66</td>
<td>0.18</td>
</tr>
<tr>
<td>5</td>
<td>Final Building Decontamination</td>
<td>922±40</td>
<td>0.09</td>
</tr>
<tr>
<td>6</td>
<td>Building Demolition</td>
<td>245±24</td>
<td>0.02</td>
</tr>
<tr>
<td>7</td>
<td>Building Demolition</td>
<td>70±12</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>8</td>
<td>Building Demolition</td>
<td>80±24</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>9</td>
<td>Building Demolition</td>
<td>124±18</td>
<td>0.01</td>
</tr>
<tr>
<td>10</td>
<td>Background Air Sampling</td>
<td>58±8</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>11</td>
<td>Background Air Sampling</td>
<td>58±8</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

*Sampling began March 5, 1975.

**Concentration guide for uncontrolled area for insoluble $^{239}$Pu in air equals $1 \times 10^{-12}$ μCi/ml.
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<tr>
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SEPARATIONS CANYON DECONTAMINATION FACILITIES

J. H. Hershey

E. I. du Pont de Nemours and Company
Savannah River Plant
Aiken, South Carolina 29801

Abstract

Highly radioactive process equipment is decontaminated at the Savannah River Plant in specially equipped areas of the separations canyon buildings so that direct mechanical repairs or alterations can be made. Using these facilities it is possible to decontaminate and repair equipment such as 10- X 11-ft storage tanks, 8- X 8-ft batch evaporator pots and columns, 40-in. Bird centrifuges, canyon pumps and agitators, and various canyon piping systems or “jumpers.” For example, centrifuge or evaporator pots can be decontaminated and rebuilt for about 60% of the 1974 replacement cost. The combined facilities can decontaminate and repair 6 to 10 pieces of major equipment per year. Decontamination time varies with type of equipment and radioactivity levels encountered.

Discussion

CURRENT OPERATING PRACTICE

Highly radioactive process equipment is decontaminated at the Savannah River Plant (SRP) in Separations Department Buildings 221-F and 221-H. Each building has two processing areas known as the hot and warm canyons and a center section that includes space for offices, control rooms, pipe galleries, service areas, etc. (figures 1 and 2). The canyon zones are each about 600 ft long, 15 ft wide, and 25 ft deep below one-foot-thick concrete cell covers. Chemical processing operations involving highly radioactive solutions are performed remotely in stainless steel equipment in both canyons. The center section is shielded from radiation by thick reinforced concrete walls. Process equipment is decontaminated to levels that permit equipment to be moved out of a canyon building for external storage at the SRP storage and burial ground.

Space has been provided in both the hot and warm canyons of Buildings 221-F and 221-H for equipment decontamination and repair work. The hot canyon contains a decontamination cell, a shop, and a swimming pool (essentially a stainless-steel-lined tank built into a canyon module). The warm canyon contains a decontamination cell and shop area, both used for repair activities. A shielded overhead traveling crane is provided in each canyon for remote handling of contaminated equipment. Using these facilities it is possible to decontaminate and repair process equipment such as a 10- X 11-ft canyon storage tank (figure 3), an 8- X 8-ft batch evaporator pot or column (figure 4), a 40-in. Bird centrifuge, a large continuous evaporator and associated reboiler tubes (figures 5 through 8), canyon piping systems or jumpers (removable canyon piping), and miscellaneous pumps and agitators from canyon or waste storage facilities.

Time required for and cost of decontamination and subsequent repairs varies with type of equipment and radioactivity levels encountered. The service history of a failed piece of equipment largely determines radioactivity levels. Failed canyon equipment is stored in canyon cells for as long as is feasible to allow highly radioactive, short half-life isotopes to decay. Most decontamination activities are intermittent operations with work being done when manpower is available and as canyon processing schedules permit.
Equipment to be decontaminated is moved remotely by an overhead canyon crane to the hot canyon decontamination cell for a series of full-volume flushes with caustic/permanganate and with hydroxylamine sulfate/nitric acid solutions. Personnel do not enter the hot decontamination cell; all solutions are added to or sprayed on vessels remotely. Initial decontamination of a canyon batch evaporator pot, for example, would consist of a full-volume flush with 24,000 lb of 2% NaOH/2% KMnO₄ solution followed by 24,000 lb of 3% hydroxylamine sulfate/3% HNO₃ solution. After a series of such flushes the evaporator pot is moved to the hot canyon shop for visual inspection and radiation survey. Chemical flushing during this initial decontamination phase can range from 200,000 lb to 1.4 M lb of NaOH/KMnO₄ and HAS/HNO₃ solutions. These flushes are disposed of through existing waste processing facilities. A hundred gallons of flush solution generates about one or two gallons of solid waste for permanent storage. The choice of chemicals used for initial decontaminations is limited to those compatible with solutions routinely processed in canyon waste evaporators so that these large volumes of solutions can be evaporated in canyon equipment.

Instead of using full-volume flushes the interior of a process vessel can be decontaminated by spraying heated solutions at 135 psig through a rotating jet assembly held suspended in the vessel by the canyon crane, or mounted on an adaptor flange on the vessel. The discharge head rotates 360° in both horizontal and vertical planes. Hydraulic pressure to operate the spray is supplied by a pump on the third level of the center section of the building.

Small equipment such as pumps, agitators, or reboiler tubes can be set in a modified open top 10- X 11-ft tank and allowed to soak in warm decontaminating solutions. Solutions can be backflushed through pumps using a special canyon jet assembly.

Equipment being decontaminated is periodically moved to the hot canyon shop for radiation survey. If the survey shows radiation to be greater than 500 rads/hr at 2 ft, the equipment is returned to the decontamination cell for additional cleaning. If radiation is less than 500 rads/hr at 2 ft, the equipment is moved to the swimming pool for second-stage decontamination using detergents as well as chemicals.

The swimming pool is equipped with a remotely operated manipulator, various steam/spray cleaner units, and a shielded work area with viewing windows. Some direct-contact hand decontamination can be done in this area if radiation exposure levels permit. Solution volumes used for decontamination in this facility are small. Use of detergents or other chemicals incompatible with normal canyon waste solutions is permissible because the waste generated is isolated and processed through a general-purpose evaporator outside the canyon building. Decontamination efforts continue in the swimming pool until the radiation level is reduced to less than 100 mR/hr body exposure at 1 ft.

When radiation is reduced below this level, equipment is moved, using a railroad car and a flat-bed truck, from the hot canyon swimming pool to the warm canyon shop or to the warm canyon decontamination cell for final decontamination and subsequent repair or modification. When moving between the hot and warm canyons, the equipment is either completely wrapped in plastic or placed in a transport box. The external surface of the plastic wrapping or of the transport box must be free of transferable contamination while the equipment is in transit.

Final decontamination may include direct-contact hand cleaning or physical removal of parts or sections that resist decontamination efforts. By these means, and by selective use of lead shielding for isolated high-radiation spots, body exposure rates are reduced to the point that contact maintenance and repair is possible. For repair of a major piece of canyon equipment, the total accumulative radiation exposure to personnel will be about 1 R.

1 Tiger Jet Tank Scrubber, Vici Jet, Inc., Narberth, PA
2 Clayton Hydro-steam Cleaner, Clayton Mfg. Co., El Monte, CA
3 Sellers Hydraulic Jet Cleaner, Sellers Injector Corp., Philadelphia, PA
Both the warm shop and warm decontamination cell are supplied with breathing air for plastic suit work, power for centrifuge operation, and welding facilities. Both are equipped for functional testing, run-in tests, and layout checks.

HISTORY

As originally designed, the hot canyon was provided with a decontamination cell, a swimming pool area, and a repair shop. The warm canyon was provided with a decontamination cell and a repair shop. These facilities were intended to operate independently in serving the individual canyons. Canyon equipment was to be decontaminated remotely by external and internal flushes in the decontamination cells to acceptable radiation levels for transfer to an onsite burial and storage area, or to levels that would permit inspections and minor repairs in the canyon shops. The swimming pool was provided so that equipment could be placed underwater for radiation shielding and the repairs accomplished with special long-handled tools. No major overhaul or repair was originally contemplated; failed major equipment pieces such as centrifuges or evaporator pots were to be decontaminated to acceptable limits for burial or storage and replaced with new equipment.

Deficiencies in the original concept became obvious promptly. Some of the difficulties or deficiencies encountered were as follows:

- The wall-mounted sprays in the decontamination cells proved to be ineffective in reducing contamination levels on external surfaces.
- Underwater repairs in the swimming pool facility were found to be impractical because radioactive materials leached out of equipment into the shielding water and tended to stratify in layers exposing personnel to excessive radiation levels. Manipulation of the long-handled tools was difficult and prolonged repair time.
- Holding or suspending major pieces of equipment underwater proved difficult. Positioning of equipment underwater with canyon cranes was not feasible.
- No shielded observation areas were originally provided. Inspections of failed equipment involved considerable radiation exposure.
- Facilities for removing transferable smearable contamination and for handling alpha-contaminated equipment were inadequate.
- Facilities for repair work were inadequate.
- No provisions were made for handling and repairing pumps, agitators, and miscellaneous small equipment.

It also became apparent that a major repair and modification capability was needed to overcome high replacement costs, long delivery times, and reduce spare part inventories.

MODIFICATIONS TO ORIGINAL FACILITIES

Decontamination Cells

In Buildings 221-F and 221-H, the canyon decontamination cells occupy two modules in section 4 of both the hot and warm canyons. These cells are fully stainless steel lined and equipped with trunnion guides and wall connectors for remote installation of canyon equipment. Fixed wall sprays no longer used, are provided in the cell walls for external spraying of vessels. Both cells have concrete covers. A canyon crane removes these covers as necessary and remotely installs equipment in the cells. The hot and warm decontamination cells were essentially identical as originally built.
The decontamination cells are 22 ft long, 15 ft wide, and 24 ft deep. Original services included: chemical addition lines from third-level tank 5E; 150-psig steam supply for heating solutions and for solution transfers by jet; cooling water supply; condensate/water-out lines; power supply for agitators and pumps; thermohm connections; liquid level instrumentation; lube lines; sample lines; waste transfer lines; floor spray lines; vessel spray nozzles; and fire water supply lines.

Over the years, the warm decontamination cell has been converted to a direct maintenance/repair facility and only incidental decontamination is performed there. In modifying the warm decontamination cell for direct maintenance, a personnel access door was provided in the south wall of the cell and all chemical addition lines, steam, and water lines were blanked out of service. Other items added or provided include: an electrically-driven one-ton crane; steam and water service for steam cleaning units; breathing air supply for plastic suit work; welding facilities; power supply for operation and run-in of centrifuges; equipment testing capability; layout platforms; additional lighting, and a supply of conditioned air.

Swimming Pool

The swimming pool is located in section 3 of the hot canyon. The pool is 16 ft wide, 25 ft long, and 23 ft deep, and is fitted with concrete cell covers. The stainless steel liner is about 15 ft high and the observation/work catwalks are about 14 ft above floor level. Catwalks on south and east walls, a movable maintenance platform, two small jib cranes, submerged wall lights, and personnel access from second level were originally provided.

The pool was designed to hold submerged the majority of canyon vessels so that repairs could be made by use of special long-handled tools. Underwater repairs were found to be impractical and the pool is no longer filled with water. It is now used as a secondary decontamination and equipment inspection area. When initial decontamination efforts in the hot decontamination cell have reduced radiation levels to less than 500 rads/hr at 2 ft, equipment is moved into the swimming pool where operators using remotely controlled steam-cleaning lances continue decontaminating until radiation levels are reduced to less than 100 mrad/s/hr at 1 ft. Decontaminating solutions are made up in third-level tankage and added to or sprayed on equipment being cleaned. Detergent solutions can be made up in a small tank permanently located in a corner of the pool. Accumulated waste solutions are normally transferred to a general-purpose evaporator outside the canyon building. Solutions containing detergents are not compatible with routine waste solutions generated by canyon processing operations.

Modifications of the swimming pool facility include: abandonment of water shielding; installation of breathing air manifolds for plastic suit work; replacement of original jib cranes with two 1-ton electric hoists; removal of the traveling maintenance platform; modification of the south catwalk to serve as a shielded work/observation area with controls for manipulator operation; installation of an air lock for access to east catwalk; installation of a remotely controlled manipulator for a steam-cleaning lance; installation of a high pressure water spray system; and repair and reinforcement of the pool floor to ensure against solutions leaking out of pool area.

Canyon Shops

Both the hot canyon shop and the warm canyon shop were originally intended for maintenance and repair of contaminated canyon equipment. The shops are located in section 3 of the respective canyons. The hot canyon shop is 15 ft wide, 21 ft long, and approximately 21 ft deep below 3-ft-thick concrete cell covers. The warm canyon shop is 15 ft wide, 24 ft long, and approximately 24 ft deep below 1-ft-thick concrete cell covers. Equipment is remotely positioned in canyon shops with overhead canyon cranes. Personnel enter the hot shop by a stairwell from second level and the warm shop from an air lock in first-level corridor. At 221-H, an additional air lock access and observation area for the hot canyon shop has been provided.
Each shop was originally equipped with breathing air manifolds, electric power outlets, compressed-air hose bibs, flush-mounted wall lights, and safety showers. Both shops have stainless steel floors with built-in sumps for collection of liquid wastes. Accumulated waste solutions are transferred by jet to canyon waste processing stations.

The hot canyon shop is used principally for equipment surveys and inspections following initial decontaminations in the hot decontamination cell. Normally, equipment placed in the hot canyon shop is too radioactive for more than limited direct maintenance or contact decontamination with steam-cleaning units. Some repairs are still done in the hot canyon shop on jumpers, canyon pumps and agitators, and miscellaneous minor equipment.

The warm canyon shop is used routinely for direct maintenance, modification, overhaul, functional checking, mockup, layout, and run-in. Some final decontamination is also performed in the warm canyon shop—direct contact decontamination by hand cleaning and the physical removal of parts or sections that have resisted decontamination efforts.

Modifications to the hot canyon shop include: addition of a chainfall hoist; installation of a Clayton steam-cleaning facility; and added piping to supply flush and decontamination solutions from a third-level tank.

Modifications to the warm canyon shop include: improved welding facilities; power for centrifuge run-in and functional check; two chainfall hoists; observation window in north wall; and provisions for equipment testing and layout.

TYPICAL DECONTAMINATION EXPERIENCE

The sequence of a decontamination program and the extent of decontamination or repair required varies with each item of canyon equipment handled. A piece of canyon equipment is seldom decontaminated, repaired, and returned to service as a continuous operation. Normally, failed equipment is replaced with an item from the spare equipment inventory. During repair operations it is not unusual to experience delays in obtaining replacement parts. Typical decontamination/repair time, in months, is as follows:

<table>
<thead>
<tr>
<th></th>
<th>Decontamination</th>
<th>Repair/Modification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Centrifuge</td>
<td>4 to 8</td>
<td>2 to 6</td>
</tr>
<tr>
<td>10- × 11-ft storage tanks</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>8- × 8-ft evaporator pot</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>

Examples

Decontamination of Evaporator Pot in Hot Decontamination Cell. The coils failed in this pot in February 1972 while the pot was in high activity waste service. Full-volume flushes began in January 1973 and continued over a four-month period. There were five hydroxylamine sulfate/nitric acid and three caustic/permanganate flushes—each consisting of about 25,000 lb of solution. The pot was moved in August 1973 to an onsite burial ground for above-ground storage pending final decontamination and coil replacement.

Decontamination of Evaporator Pot in Swimming Pool. Decontamination of this pot was performed in the swimming pool because the hot canyon decontamination cell was not available. The pot coils failed in high activity waste service in February 1971. Decontamination took about 3½ months starting in April 1972, using caustic/permanganate and hydroxylamine sulfate/nitric acid solutions. After a series of full-volume flushes, a number of flushes were made with a rotojet pressurized spray. Some external cleaning was also done with detergents and a Clayton steam-cleaner unit. About 340,000 lb of flush solution was used. In September 1972, the pot was moved to an
onsite burial ground in a transport box for above-ground storage. At this time radiation levels were 800 mrad/hr at 1 ft on external surfaces and 2000 mrad/hr at 1 ft on internal surfaces. Maximum smearable contamination levels on external surfaces was 40,000 c/m beta-gamma and 1000 d/m alpha. The pot was moved to Building 221-F canyon for final decontamination and repair in October 1972. Repairs were completed in March 1973 and the pot was returned to canyon service in April 1974.

Decontamination of De-entrainment Section of Continuous Evaporator. The procedure for remote decontamination of a de-entrainment section of a continuous high activity waste evaporator consists of a series of chemical flushes on various sections of the unit. The first series of flushes are made with hot caustic/permanganate and with hot hydroxylamine sulfate/nitric acid solutions alternately sprayed on the bubble-cap area. These flushes are followed with a hot water flush. Next, a "Tigar Cub" rotojet is used to clean the Hackman hat (feed control area), the internal parts of the de-entrainment area, and the reboiler section (with the bundle removed). When the de-entrainment section is cleaned below the bubble-cap zone, the rotojet is fitted with a flexible hose connection to permit access to this area. A series of chemical flushes followed by a hot water rinse are also made on the external surfaces of the unit. Each flush consists of about 8000 lb of solution; a total of about 224,000 lb is used for the entire decontamination sequence. This usually reduces radiation levels sufficiently to permit transfer of equipment to above-ground storage at an onsite burial ground. Some additional direct decontamination is necessary before modifications and repairs can begin. Since 1960, six de-entrainment units have been repaired with minimal exposure to repair personnel.

Cost Summary

The following table shows estimated costs for decontamination and repair of major pieces of canyon equipment in the 221-F/221-H facilities during 1974.

<table>
<thead>
<tr>
<th>Building 221-F</th>
<th>Estimated Replacement Cost (1974)</th>
<th>Cost of Repair and Decontamination&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous evaporator</td>
<td>$200,000</td>
<td>$118,700</td>
</tr>
<tr>
<td>Replace coils sealed in tank</td>
<td>58,000</td>
<td>15,500</td>
</tr>
<tr>
<td>Mate new tubesheet to old flange</td>
<td>125,000</td>
<td>82,000</td>
</tr>
<tr>
<td>Canyon pumps (7)</td>
<td>140,000</td>
<td>35,000</td>
</tr>
<tr>
<td>5-hp agitator</td>
<td>8,000</td>
<td>6,400</td>
</tr>
<tr>
<td>20-hp agitator (2)</td>
<td>50,000</td>
<td>14,600</td>
</tr>
<tr>
<td>Total</td>
<td>$581,000</td>
<td>$272,200</td>
</tr>
</tbody>
</table>

<sup>a</sup> Includes waste storage costs.
## Building 221-H

<table>
<thead>
<tr>
<th>Item</th>
<th>Estimated Replacement Cost (1974)</th>
<th>Cost of Decontamination&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Cost of Repair</th>
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<tbody>
<tr>
<td>Ion exchange column</td>
<td>$45,000</td>
<td>$2,000</td>
<td>$500</td>
</tr>
<tr>
<td>Centrifuge</td>
<td>200,000</td>
<td>60,000</td>
<td>75,000</td>
</tr>
<tr>
<td>Centrifuge</td>
<td>200,000</td>
<td>20,000</td>
<td>75,000</td>
</tr>
<tr>
<td>Install coils in evaporator pot</td>
<td>97,000</td>
<td>10,000</td>
<td>45,000</td>
</tr>
<tr>
<td>Reinsulate dissolver column</td>
<td>35,000</td>
<td>5,000</td>
<td>16,000</td>
</tr>
<tr>
<td>Evaporator columns (3)</td>
<td>135,000</td>
<td>24,900</td>
<td>60,000</td>
</tr>
<tr>
<td>Waste transfer pump</td>
<td>80,000</td>
<td>10,000</td>
<td>16,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$792,000</strong></td>
<td><strong>$131,900</strong></td>
<td><strong>$287,500</strong></td>
</tr>
</tbody>
</table>

<sup>a</sup> Includes waste storage costs.

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Figure 1. Separations Building
Figure 2. Separations Building Cross Section
Figure 3. Standard 10 × 11-ft Canyon Tank
Figure 4. Modified-Coil Batch Evaporator and Column
Figure 5. Continuous Evaporator
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FIGURE 3. STANDARD 10 x 11-FT CANYON TANK
FIGURE 4. MODIFIED-COIL BATCH EVAPORATOR AND COLUMN
FIGURE 5. CONTINUOUS EVAPORATOR
FIGURE 6. CONTINUOUS EVAPORATOR. Condenser column and reboiler tubes removed. DPSPF 10701-6.

FIGURE 7. SIDE VIEW OF REBOILER SECTION AND STEAM CHEST. DPSPF 15690-2.
FIGURE 8. STEAM CHEST. Cut from tube bundle section for tubesheet replacement. DPSPF 11966-6.
A SUMMARY REVIEW OF MOUND LABORATORY'S
EXPERIENCE IN D & D OF RADIOACTIVE FACILITIES,
1949-1973

J. M. Garner & W. P. Davis

Mound Laboratory*
Miamisburg, Ohio 45342

ABSTRACT

The objective of Mound Laboratory's Decontamination and De-
commissioning (D&D) projects has been the effective termina-
tion of radioactive material processing facilities with no
significant personnel exposures or environmental releases.
This objective must be met with available resources and
manpower.

Mound has effectively decontaminated and/or decommissioned
four major facilities in the 1949 through 1973 time period.
Many minor areas were also decontaminated and/or decommis-
sioned during this period. The major D & D projects involved
the following isotopes: polonium-210, radium-226, actinium-
227, and plutonium-238.

To achieve a D & D status, Mound has employed several control
and decontamination techniques such as: "Navy Cocooning",
entombment, removal, foaming, bagging, tents, chutes, port-
able exhausters, dry ice, vents, bubble suits, three-zones,

*Mound Laboratory is operated by Monsanto Research Corporation
for the U. S. Energy Research and Development Administration
fire watches, painting and sealing, in-line cleaning, high pressure water blaster, and chemical cleaning.
Introduction

Mound Laboratory has completed four major Decontamination and Decommissioning (D & D) projects of ERDA facilities over the years in addition to several minor D & D projects.

The four major D & D projects were:
1. Two polonium-210 processing facilities.
3. A plutonium-238 processing facility.

The details of these four major projects are described in the following sections.

Polonium-210 Facilities

Units III and IV were used to process polonium-210 from 1944 through 1949. Unit III contained approximately 35,000 ft.² of contaminated floor space and was Decontaminated and Decommissioned from 1949 to 1950 under the direction of AEC/Oak Ridge by conventional scrubbing and removal techniques. The main building was returned to the original owners (the Dayton Board of Education) in 1950. The outer smaller buildings were removed (including footer), and the area was backfilled.

Unit IV was approximately 16,000 ft.². The building was decontaminated as much as possible by conventional scrubbing
and removal techniques. The structure and footer were then removed, and the area was backfilled. The site was returned to the original owner (the Talbott family) in 1950.

Monitoring included air samples, wipe and direct contamination surveys, water and urine samples. End results of D & D was N/D (nondetectable) removable alpha and less than $5 \times 10^3$ dis/min/100 cm$^2$ fixed alpha ($5 \times 10^4$ on Unit IV). Followup surveys shows N/D due to the short (138-day) half-life.

Personnel protection included clothing and respiratory (half and full face masks) protection. Clothing was basically two-piece whites, coveralls, gloves, control shoes, shoecovers, and booties.

Radium-226 and Actinium-227 Facility

The "Cave" and associated waste disposal facilities were used to process radium-226 and actinium-227 from 1952 to 1954. The Cave and associated facilities contained approximately 4,000 ft.$^2$ of contaminated floor space and was D & D'd under the direction of the AEC/DAO by conventional scrubbing, removal, "Navy Cocooning", and entombment techniques. The D & D was performed during the 1955 through 1957 time period (equipment in "Navy cocoons" was on hold until 1957) with available manpower. A portion of the Cave structure (where high level material was processed) was entombed in 12 in. of concrete. The remainder of the facility was decontaminated
to N/D removable and less than 400 dis/min/100 cm² fixed alpha contamination. This portion is now used for other programs.

Monitoring included air samplers, radon sampling, wipe and direct contamination surveys, gamma surveys, and urine samples.

Personnel protection included clothing and respiration protection (half and full face supplied-air masks, bubble suit). The Mound-Snyder supplied-air bubble suit was developed and used on this project.

**Plutonium-238 Facility**

The SM Facility was used to process plutonium-238 for space programs from 1961 to 1968.

The SM Facility contained approximately 15,000 ft.² of contaminated floor area (585 linear feet of gloveboxes) and was D & D'd under the direction of the AEC/DAO office by employing several control and decontamination techniques such as: removal, foaming, bagging, tents, chutes, portable exhausters, dry ice, vents, bubble suits, three-zones, fire watches, painting and sealing, in-line cleaning, high pressure water blaster, and chemical cleaning. The facility is now awaiting final disposition by ERDA. The D & D was performed during the 1968 through 1972 time period (work emphasis on later years).
Monitoring included air samplers, wipe and direct contamination surveys, γ-n surveys, soil and water samplers, nosewipes, urine samples, WBC, film badges, etc. The current contamination level inside the facility is less than 10,000 dis/min/100 cm² removable alpha and less than 400,000 dis/min/60 cm² fixed alpha. (Painting was not used.)

Personnel protection included clothing and respiratory protection. This protection included: two-piece whites, coveralls, two-piece plastic suits, two-piece supplied-air bubble suits, shoecovers, booties, control shoes, head covers, and filtered and supplied-air respiratory protection.

A Third Polonium-210 Facility

The "T" facility was used to process polonium-210 for commercial sale and space programs to 1972.

The radioactive processing section was approximately 32,000 ft.² for two floors (236 linear ft. of gloveboxes) and was D & D'd under the direction of the AEC/DAO office by conventional scrubbing and removal techniques. The D & D was performed during the 1971 through 1973 time period. The facility is now used for both radioactive and nonradioactive work.

Monitoring included air samples, wipe and direct contamination surveys, γ-n surveys, soil and water samplers, urine samples, WBC, film badges, etc. The area was decontaminated
to N/D removable alpha and N/D fixed. Painting was allowed only on surfaces less than 4,000 dis/min (decayed to N/D by end of project).

Personnel protection included clothing and respiratory (filtered and supplied air) protection.

**Special Techniques**

Several techniques were found to be effective in controlling and reducing the spread of contamination during decontamination and decommission work.

- Equipment and structures contaminated with short half-life material were removed for storage at a controlled area until decay had reduced contamination levels to N/D.
- Sealing equipment and structures were used for containment purposes. The Navy cocooning method was used in the earlier days, but has now been replaced with foaming. Other materials such as asphalt, concrete, and paint can be used on items that are to be discarded or are contaminated with a short half-life material.
- Containment can be achieved by using plastic bags and enclosures. These enclosures were especially helpful when working outside the building.
- Temporary access methods such as a chute improved efficiency.
- Portable exhaustors such as Spencer turbines and large industrial vacuum cleaners with absolute filters provided added negative differential to small work areas.
• The use of dry ice to remove tile minimized the spread of contamination.

• Small respirator filters were used as vents when equipment was foamed.

• The Mound-Synder supplied-air bubble suit provided personnel with maximum respiratory and contamination protection.

• The use of three separate zones of contamination levels proved to be effective in contamination control.

• A 24-hr, seven-days a week, "fire watch" was provided on occasion to increase ability (in addition to automatic alarms) to detect potentially hazardous conditions.

• In-line glovebox cleaning and separation of equipment proved to be very successful. Even high pressure washing can be used if the gloveboxes are not deteriorated.

• A variable high pressure water blaster was used to reduce decontamination time. Wet sandblasting was used on a limited basis because of problems with lines and drains plugging.

• Chemical cleaning such as paint removers and acid solutions also reduced decontamination time. Mechanical paint chippers were used only on a limited basis because they were time consuming.

The exact methods used for D & D work will depend on an evaluation of several factors: half-life of contaminants, type, specific activity, quantity of contamination, the presence of other radioactive and nonradioactive contaminants, location, and desired end result.
Summary

In conclusion, Mound Laboratory has completed four major Decontamination and Decommissioning projects. These projects were accomplished in an effective manner by use of these contamination control techniques, procedures, and decontamination techniques. As a result, there were no significant personnel exposures and no significant impact on the environment as verified by data from the following monitoring programs: stack sampling, on-site and off-site monitoring stations, bioassay sampling, and dosimetry data.

The D & D projects were also completed with minimum impact on operational resources and manpower.
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1. Report No. 3 of Steering Committee for Disposal of Units III and IV, MLM-461, Mound Laboratory, April 17, 1950.

THE DECOMMISSIONING OF THE FISSION PRODUCT DEVELOPMENT LABORATORY AT HOLIFIELD NATIONAL LABORATORY

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ABSTRACT

The decontamination of the Fission Product Development Laboratory at Holifield National Laboratory was initiated in FY 1975 after 17 years of processing fission product waste streams to produce commercial quantities of $^{90}$Sr, $^{137}$Cs, $^{144}$Ce, and $^{147}$Pm. The objective of the decommissioning program is the removal of all radiation and contamination areas in the facility to a level which will be compatible with the environment in the foreseeable future.

*Operated by Union Carbide Corporation for the Energy Research and Development Administration.
INTRODUCTION

The fission product research and development work at Holifield National Laboratory (HNL) leading to the construction of the Fission Products Development Laboratory (FPDL)\(^1,2\) began in 1948 with the investigation of a number of methods for removing long-lived fission products from waste solutions. Fission products were first separated in curie quantities in laboratory glassware using ion-exchange processes. Later, hundred curie quantities were separated in small stainless steel vessels. Finally in 1958, the FPDL facility (Fig. 1) went on stream to separate kilocurie amounts of \(^{137}\)Cs, \(^{90}\)Sr, \(^{144}\)Ce, and \(^{147}\)Pm from Redox and Purex type waste streams. This program was successfully demonstrated during the first two years of operation, and kilocurie quantities were made available for worldwide distribution.

With the advent of the AEC's Systems for Nuclear Auxiliary Power (SNAP) and increased demand for \(^{137}\)Cs gamma sources, the requirements for \(^{137}\)Cs, \(^{144}\)Ce, and \(^{90}\)Sr were increased to a level of megacuries per year. To meet this demand, concentrates of \(^{137}\)Cs, \(^{90}\)Sr, and \(^{144}\)Ce were shipped from the Hanford Atomic Products Operation (HAPO) to the FPDL for preparation of the fuel compounds used in the SNAP program. The FPDL facility\(^3\) was modified in 1963 to allow the continuous production of three product streams as follows:
1. A semi-pure fraction of $^{137}\text{Cs}$ from HAPO was chemically purified at the FPDL and converted to $^{137}\text{CsCl}$ powder. This powder was cold pressed into pellets which were doubly encapsulated in stainless steel; the capsules were tested for leaks and then shipped to the customer.

2. Purified $^{90}\text{Sr}$ was received from HAPO and converted to $^{90}\text{Sr}$ titanate. This material was then compacted by vacuum hot press techniques to form a high density pellet. The pellets were encapsulated, usually in Hastelloy "C", and the capsules were tested for leaks and decontaminated before being loaded into a thermoelectric generator for shipment to the customer.

3. A mixed rare earth fraction was received from HAPO; the $^{144}\text{Ce}$ was separated by solvent extraction and converted to $^{144}\text{Ce}$ oxide. The powder was cold pressed and sintered and then sealed in compatible containers for shipment to the customer.

A total of 10.0 megacuries of fission product material was successfully processed at the FPDL during the past decade. During this period, in-cell maintenance requirements were at a minimum and only six cells were decontaminated for the installation of new equipment or repairs to existing equipment. Thus, the decommissioning of 25 individual cells (Fig. 2) highly contaminated with three potent long-lived fission products presented a formidable task for the operating personnel.
DISCUSSION

The decontamination program at the FPDL was divided into four distinct phases.

I. Removal and encapsulation of $^{90}$Sr products.

II. Decontamination of the manipulator cells used for powder preparation.

III. Decontamination of the process cells which contained the vessels and associated piping used in the purification processes.

IV. Decontamination of the tank farm cells and cell ventilation system.

The original FPDL decontamination proposal was to accomplish this effort in two years based on a 3-shift operating crew of 25 chemical operators. Due to a limited budget in FY 1975, the crew was reduced to ten chemical operators. This reduction in personnel drastically reduced the flexibility of rotating personnel on work in radiation zones while maintaining the minimum practical individual radiation exposure. The crew was placed on a day shift schedule and all work assignments were made on the basis of >75% remote operations to limit radiation exposure. The initial goals for each cell were to reduce the radiation and contamination level to <5 R/hr to allow direct access to the cell for maintenance personnel to remove contaminated equipment to the HNL Solid Waste Storage Area.
REMOVAL OF STRONTIUM-90 PRODUCTS

Approximately 500,000 curies of $^{90}$Sr titanate powder was stored in the FPDL facility at the beginning of FY 1975. A physical inventory of the powder was made by weighing each batch and determining the $^{90}$Sr content calorimetrically on a representative sample from individual batches. The powder was then loaded into stainless steel cans (25,000 Ci/can) and sealed with a press fit cap. The inner container was cleaned to a smear level of <10 mr/hr and placed into an outer stainless steel container. The outer containers were Tungsten Inert Gas (TIG) welded, leak tested, and cleaned to a smear tolerance of <10,000 dis/min. The sealed containers were placed in AEC-DOT approved shipping containers and are being held for future customer orders.

DECONTAMINATION OF MANIPULATOR CELLS

After the removal of the $^{90}$Sr products, it was possible to remove all solid waste from nine of the manipulator cells and transfer it to the HNL Solid Waste Storage Area. A typical manipulator cell and its associated equipment are shown in Fig. 3. The solid waste consisted of glassware, tygon tubing, calorimeters, balances, blenders, graphite die bodies, manipulator-operated tools, ceramic filters, and all equipment that could be disassembled with the manipulators. This material was thoroughly washed in the cell and placed in a plastic-lined 55-gallon drum. The drum was
sealed with a standard ring using special tools designed for manipulator operation. The drums were decontaminated in the manipulator cell with high pressure soap spray equipment and then wiped to a smear tolerance of <1 mr/hr. A total volume of 200 ft³ of solid waste was transferred in a shielded drum waste carrier to the HNL Solid Waste Storage Area and lowered into holes for storage.

Large pieces of equipment, such as a vacuum hot press (Fig. 4), were dismantled in the cell with the aid of specially designed tools that could be operated with manipulators. The highly contaminated parts were transferred to the HNL Solid Waste Storage Area. The stainless steel vacuum chambers were cleaned in the cell with high pressure soap solutions and chemicals to remove the insoluble particles of SrO. The cells were then cleaned using the same techniques by spraying through a 12-in.-diam opening in the top of the cell.

When the radiation level in the cell was reduced to <10 R/hr, the top blocks were removed and a 3-in. armor plate shield was placed in the cell block opening. This shield was equipped with a 2-in.-thick plexiglass shield approximately 3.5 ft in diameter. Since the remaining contamination in the cell was Sr (CsCl dissolves readily in hot water), the plexiglass was adequate shielding for the soft beta radiation emitting from the cell opening. The shield had various sized holes with removable plugs that would permit the access of high pressure spray equipment to
reach a large portion of the cell surfaces. The large diameter of the plexiglass allowed excellent line of sight to all areas of the cell.

When the radiation level in the cell was reduced to <5 R/hr and the contamination level <500 mr/hr, the shield was removed and large pieces of equipment were removed from the cell and decontaminated by hand to a level acceptable for reuse. Permanent equipment, (Fig. 5) such as a vessel mounted on the cell wall and its associated piping, was decontaminated during the initial cell clean up work. This was accomplished by flushing the system repeatedly with hot solutions of 1 N HNO₃, 1 N NaOH, versene, Turco 4501, oxalic acid, and water flushes between each chemical addition. Analyses of the decontamination solutions would generally indicate a few millicuries of beta activity after the third cycle of the chemical treatment. If the vessel and piping were reading <5 R/hr, maintenance personnel would hot rod the piping and the equipment brackets with a carbon graphite-copper clad cutting electrode on a long rod from the top of the cell. The small pieces were removed from the cell by the use of manipulators to transfer the material to the drum waste station. Large vessels (~100 gal) were lifted through the top of the cell into plywood containers and transferred to the HNL Solid Waste Storage Area for underground storage.

After the removal of piping, conduits, and instrument lines, additional hot spots were found that would require decontamination or lead shielding to reduce the cell background to <1 R/hr for direct access to the cell.
As of June 30, 1975, four manipulator cells were decontaminated to a background of 1 R/hr, and direct access for maintenance personnel was approved. The remaining five manipulator cells have a radiation background ranging from 10 R/hr to 100 R/hr and are expected to require approximately ten man-years of effort to make them accessible for direct maintenance. Exposure to operating personnel during this period was maintained below the ERDA limits of 5 Rem per year of penetrating dose (Dc) and 15 Rem per year of skin dose (Ds). The skin dose became the controlling factor due to the beta component of 90Sr. The ratio of Ds:Dc ranged from 5:1 to a high of 30:1 and limited our ability to decontaminate with open access to the cell. Special shields, tools, and spray systems were required to limit the Ds dose to the operator on top of the cell bank.

DECONTAMINATION OF THE PROCESS CELLS

The decontamination of the nine FPDL process cells (Fig. 6) during FY 1975 was used as a non-exposure operation to balance the work on the manipulator cells involving exposure to personnel. The process cells contain centrifuges and stainless steel vessels for precipitation, evaporation, crystallization, solvent extraction and storage of fission product cuts. This system was operated from panelboards in non-exposure areas. All vessels and approximately 95% of the transfer lines were operable at the beginning of the decontamination cycle.
A series of hot chemical flushes similar to those used in the manipulator cells were passed through all of the equipment a total of five times. The final decontamination solution contained less than 100 mCi of beta-gamma activity. This was the expected result since the process system had contained fission products in a chemically soluble form.

During the chemical flushes, all vessels were heated to the boiling point of the solution and the vapor allowed to escape to the vessel off-gas system. The vapor flows through the off-gas lines and then is condensed in the vessel off-gas dehumidifier and chilled scrubber system. After the decontamination solution samples indicated a low level of activity in the process system, the main off-gas header was valved-off and chemical solutions were gravity flowed into the off-gas High Efficiency Particulate Air (HEPA) filter chamber. Since the filter chamber is the highest elevation point in the system, the decontamination solutions filled the vessel off-gas scrubbers, dehumidifiers, and lines and overflowed into the process vessels. The off-gas HEPA filter chamber was decontaminated to <1 R/hr and placed in operation with new HEPA filters to contain any residual activity during final phases of decommissioning.

The results of the decontamination of the process system are unknown at this time because removal of the process cell blocks to obtain radiation surveys would involve excessive exposure to personnel. Based on previous decontamination campaigns, the general background in the process cells
should be <10 R/hr with hot spots up to 100 R/hr on lines that could not be cleaned due to in-cell valve failures. An additional five man-years of operating effort are expected to be required to reduce the nine process cells to a radiation level which will permit the direct access of maintenance personnel to remove the process equipment and piping.

DECONTAMINATION OF TANK FARM CELLS AND CELL VENTILATION SYSTEM

The final phase in the decommissioning program will consist of decontaminating the process pipe tunnels to the tank farm cells and then decontamination of the four large tank farm cells. All piping and tankage will be removed and the cells cleaned to a low smear tolerance for painting.

The cleaning of the vessels and piping is actually in progress as all decontamination solutions from the process vessels and cell floor drains must pass through the tank farm cells on the way to the HNL ILW system. It is estimated that five man-years operating effort will be required to complete this work.

The cell ventilation system will be cleaned as each cell is decontaminated. Each cell has an individual cell ventilation duct and these are high pressure sprayed before cell entries are approved. The decontamination solutions flow down the main ducts to the primary cell
ventilation filter pit. This pit contains stainless steel Neva Clog roughing filters plus twelve 1000-cfm HEPA filters.

Decontamination of the cell ventilation filter pit is in progress as this time. The filters have been removed and access is available from the upstream side. Due to erosion of the concrete floor on the downstream side of the filters, we have not been successful in entering this area due to the high radiation readings in the concrete. After decontamination, this area will be reconcreted and painted. New HEPA filters will be installed until the completion of the decommissioning program.

The secondary cell ventilation filter house contains nine HEPA filters which can be replaced in an 8-hour period. Some decontamination and painting will be required to place this system in a surveillance mode of operation.

CONCLUSIONS

The initial phase of the decommissioning of the Fission Product Development Laboratory has been accomplished by reducing the radioactive content in the facility by a factor of $10^3$. The intermediate phase of reducing the curie quantities of fission products by an additional factor of $10^3$ will require considerable personnel exposure and direct contact
type of operations. The final phase of shielding and sealing to acceptable levels of radiation and contamination can be accomplished with a minimum of personnel exposure. A substantial monetary investment will be required to allow a complete shutdown of the facility.

ACKNOWLEDGEMENTS

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REFERENCES


FIGURES

1. Fission Product Development Laboratory, Holifield National Laboratory

2. Isometric View Fission Product Development Laboratory

3. Typical FPDL Manipulator Cell

4. Vacuum Hot Press

5. Manipulator Cell Process Equipment

6. Typical FPDL Process Cell
Fig. 1. Fission Product Development Laboratory Holifield National Laboratory
Fig. 2. Isometric View Fission Product Development Laboratory
Fig. 3. Typical FFDL Manipulator Cell
Fig. 4. Vacuum Hot Press
Fig. 5. Manipulator Cell Process Equipment
Fig. 6. Typical FPDL Process Cell
ABSTRACT

This paper discusses the experience obtained from Decontamination and Decommissioning of the Experimental Breeder Reactor No. 1 located at the Idaho Nuclear Engineering Laboratory, Scottsville Idaho. The paper will address the planning, preparation and operations associated with the removal and processing of radioactively contaminated sodium-potassium eutectic alloy (NaK) from the First Experimental Breeder Reactor (EBR-I) facility systems plus the decontamination and decommissioning of same.

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INTRODUCTION

In October 1973, Aerojet Nuclear Company (ANC) initiated the first maneuver involving actual Decontamination and Decommissioning (D&D) program for EBR-I facility at the Idaho Nuclear Engineering Laboratory (INEL). The program provided for the removal and processing of the EBR-I alkali metal coolant, the eutectic alloy of sodium and potassium (NaK); the decontamination of all radioactive contaminated portions of the facility, the demolition and removal of those portions which could not be made safe, and relinquishing EBR-I safe for the public use and enjoyment as a Registered National Historic Monument.

This paper presents a portion of the program plan as performed by Aerojet Nuclear Company, assisted by Allied Chemical Corporation (ACC) and Argonne National Laboratories (ANL-West).
GENERAL DESCRIPTION

The D&D of EBR-I is complete, thus marking a first in action taken at INEL to comply with the ERDA directive concerning excessed radioactive contaminated facilities.

Figure 1 locates the EBR-I complex in the southwestern portion of the site and identifies the complex as part of a considerable inventory of excessed INEL facilities which meet the ERDA-D&D criteria. The facilities which at one time made up the EBR-I complex are shown in Figure 2; however, ancillary structures have been removed from the site leaving two major structures: EBR-I, 601 building which housed the first Experimental Breeder Reactor; and RTF-601 building which contained the ZPR-III, a split table zero power reactor. The split table zero power reactor has been decontaminated and transferred to the EBR-I facility for public display. The facilities as they appear today are shown in Figure 3.

PURPOSE

The EBR-I produced the first usable electric energy from nuclear fuel, demonstrated the principle of breeding fuel and proved that the consequence of a core meltdown was not necessarily catastrophic. As a result of these "First in History" demonstrations, the EBR-I was declared a Registered National Historic Monument. The registration ceremonies, over which the late President Johnson presided, were conducted in 1966 as shown in Figure 4. The condition of the facility however, radioactive contamination and hazardous accumulations of NaK, has prevented public access to the Historic Monument. Therefore, the purpose of this program is to provide the EBR-I complex
safe for the public use and enjoyment, and in a condition acceptable for
transfer to the National Park System.

SCOPE OF WORK
The EBR-I has been converted to a safe condition and its physical appearance
as an operational reactor facility has been maintained. The building RTF-601
has been decontaminated and the contained ZPR-III reactor structure has been
dismantled, decontaminated and transferred from the ZPR-III complex to EBR-I,
where it was re-assembled. Plant services required in support of the National
Historic Monument, such as the water, fire protection and sanitary systems
have been restored and reactivated.

D&D EXPERIENCE
The removal and disposal of NaK from the EBR-I primary and secondary
coolant systems were considered as major challenges in decontamination of
the facility. The primary and secondary NaK coolant systems are shown in
Figure 5. The primary system contained 4400 gallons of NaK which was
contaminated with 16.2 Ci of 137Cs residue from the 1955 EBR-I Mark II core
meltdown. The NaK was processed in a plant designed, fabricated and
installed outside of the EBR-I building.

The secondary system contained 1100 gallons of uncontaminated NaK which
was disposed of first over a several day period in order to check out the
system, equipment, and procedures.

The NaK disposal process was preceded by an explosive hazards analysis
and evaluation of the eutectic solution of sodium and potassium (NaK) and
potassium superoxide (KO₂). This analysis was performed by Cook Associates Inc. in Salt Lake City, Utah. The analysis was to render the following:
(1) determine conditions and properties under which KO₂ becomes an explosive hazard, (2) evaluate the explosive parameters of any XKO₂ mixture, compound or hazard situation and (3) compare the magnitude of the particular explosive hazards with other well-known explosives in order to evaluate the total hazard potential associated with decontamination of the EBR-I facility.

The results and conclusions obtained from the testing are summarized as follows:

1. Dry KO₂ can be mixed at ambient temperature with liquid or solid NaK without an immediate reaction, yet such mixtures will ignite spontaneously (but will not explode) after an induction period (e.g., 18 minutes after a vial of 50 cc of NaK was ruptured into dry KO₂ under a dry argon atmosphere). There is no explosion hazard connected with dry KO₂-NaK mixtures, but upon ignition they may react, at rates comparable to those occurring in explosions (but with no generation of gas) via a non-explosive thermite-type, solid-phase burning reaction. Liquid or solid NaK-KO₂ mixtures ignite but do not explode in the "drop-weight" or "impact" test. (By "explosion" is meant a very fast reaction producing high pressure and loud noise. The NaK-KO₂ reaction does not fulfill either the high pressure or loud noise criterion, but it is an extremely fast condensed-phase nonexplosive reaction).

2. NaK and water, of course, react spontaneously and explosively upon contact. However, the rate of pressure development in the NaK-water reaction is relatively slow, as in explosive deflagrations, and a great deal slower than in detonations. When NaK was poured into excess water the observed explosion showed an energy release of
somewhat less than 400 calories per gram of NaK. This compares with roughly 1000 calories per gram for an average high explosive such as TNT. It is about one-third the heat of explosion of nitroglycerin. However, if involved in large quantities, the hydrogen produced in this reaction may be ignited and react explosively with the atmosphere to increase the explosion potential of the NaK-water reaction theoretically to as high as 1380 calories per gram of NaK, comparable to the explosion potential of an equal weight of nitroglycerin.

3. Moisture in KO₂ reduces the induction period for spontaneous ignition of mixtures of NaK and KO₂. On the other hand, even when the moisture content is high enough for instantaneous ignition, the NaK-KO₂ mixture still does not explode even though the condensed-phase combustion is extremely rapid and hot (white-hot in air).

4. Mixtures of KO₂ and liquid hydrocarbon, e.g., No. 2 fuel oil (FO), can be mixed safely at ambient temperature. (This is not true of all organic compounds, some of which react spontaneously with KO₂ at ambient temperature, e.g., acetone). The KO₂-FO mixture has an autoignition temperature (i.e., explodes spontaneously) of 207°C and is very sensitive to impact and friction. The impact sensitivity of dry KO₂-FO is comparable to that of PETN, one of the most sensitive of the solid secondary high explosives. The balanced (91/9) KO₂-FO mixture explodes with an incomplete (explosion) energy release with a No. 5 electric blasting cap (EBC), the next size cap smaller than the standard (No. 6) commercial detonator. This mixture detonated with complete energy release with a No. 8 EBC. The ignition hazards of balanced KO₂-FO is so great that it flashes nonexplosively when initiated with a No. 4 EBC. High explosives are seldom this sensitive to ignition, i.e., they either detonate or else, when the
cap is too small to produce a detonation, they simply fail completely. (Detonations are the fastest and most intense of the explosion reactions. They are orders of magnitude faster and higher in pressure than explosive deflagrations. All detonations are explosions, but explosions are not necessarily detonations).

Balanced (91/9) KO$_2$-FO ignited but did not detonate when a vial of NaK was broken into it by a blasting cap.

5. The most important conclusion of this study is that uncontaminated NaK-KO$_2$ mixtures do not possess an explosion hazard even though they are extremely sensitive to ignition. Explosions in this system referred to in the literature were evidently caused by organic or moisture contamination. Yet even moist KO$_2$ does not explode when it comes into contact with NaK, but upon contact with NaK it will spontaneously and immediately ignite.

6. The NaK-KO$_2$-FO system will ignite spontaneously just like the NaK-KO$_2$ system. However, the presence of FO might be expected to cause explosions under some conditions, even though only a non-explosive reaction was observed in this investigation when a 50 cc vial of NaK caused ignition of about 400 grams of balanced (91/9) KO$_2$-FO.

7. One of the important safeguards against explosion in the EBR-I decontamination project is the fact that the NaK-KO$_2$ mixture self-ignites in a relatively short time even when no moisture is present. Therefore, the only way KO$_2$ could be present in NaK after prolonged storage is to exist at surfaces or interfaces and to be buffered from the NaK by intermediate oxides. And, since the EBR-I NaK systems had Argon cover gas, it is very unlikely that KO$_2$ would be present in EBR-I in significant amounts.
NaK PROCESSING

The NaK in its original form was both a liquid and a potential fire hazard which was not acceptable for storage at the INEL Radioactive Waste Management Complex (RWMC). This situation required the processing of the NaK, converting it to a solid, non-pyrophoric material in order to qualify for storage. NaK processing will be discussed later per the program agenda by Dr. L. C. Lewis.

SYSTEM DECONTAMINATION

When the greater part of the NaK had been removed from the primary and secondary coolant systems drain tanks, the residual heels, films of NaK and oxides had to be removed to complete the decontamination. The approach taken by Waste Management Projects Branch was to process the residual NaK in the secondary system first to obtain all the data and experience possible prior to processing the primary system, since the secondary was a non-contaminated system. The method used was to inject a moist N₂ purge (10-12 psig) through the NaK fill line to the drain tank. When the purge was established and stable (pipe surface was noted to be 100°F or less, detected by using templistick markings), water droplets were injected at a rate of 60 drops per minute and maintained at that rate until the audible reaction in the drain tank had ceased or the vent line temperature indicated 400°F as noted by the templistick marking which was placed on the pipe prior to starting the reaction. Since an exotherm develops when reacting the NaK, the N₂ purge exiting from the drain tank carried the water vapor on through the vent path causing a reaction of the NaK film on the pipes and tanks up stream of the drain tank. To vent the drain tank, the path selected was through the pressurization line into the receiving tank.
From the receiving tank, the path selected was either through the superheater and steam generator or straight to the flame arrestor outside the building. Both paths were opened in the event that a spike in pressure should occur as it could be easily lowered by the available piping tankage. The rupture disc assembly was removed and valved to give a straight path to the atmosphere. The purging was done on a 24-hour basis; however, the water droplet injection was secured overnight and weekends. When the heat indicator (templistick) and audible activity was no longer detectable, water at 5 gpm was injected into the purge to dilute the caustic in the drain tank. This was done at one minute intervals to verify the NaK reaction was complete. A heat rise of over 100°F but less than 200°F was noted on the vent line of the drain tank for approximately one hour and there was no audible reaction detected. The water injection was secured after 300 gallons had been delivered to the drain tank. The next injection point was on top of the filter piping where it was known, due to the filter configuration, NaK would exist. The vent path selected for this component was through the pump and receiving tank. There were two paths - either through the pump or through the bottom of the receiving tank-and from there to atmosphere through the same path as noted above for the drain tank. When the reaction was complete in the filter, valving was performed to allow moist N₂ to travel through the heater, heat exchanger, superheater and steam generator to atmosphere. This 8 psig N₂ purge was initiated and left on over a 64 hour period. The caustic water vapor that was discharged to atmosphere through the flame arrestor was visible and fairly steady when the area was secured for the weekend; however, upon returning Monday, there was no visual sign of reaction. Valving was again performed to allow the Moist N₂ to flow for one hour through each fin tube cooler and on through...
the economizer to the atmosphere. There was an audible reaction each time another cooler was 'valved in to accept the moist N$_2$ purge, however, this was no more than you get when slowly opening a cold leg on a steam line. When all the fin tube coolers were purged with moist N$_2$, valving was changed to start a water injection purge through the filter, pump, and to drain tank with no audible reaction noted. We then changed the valving to go through the filter, pump, heater and heat exchanger back to the receiver tank, venting to the atmosphere. When it was evident that water was draining into the receiver tank, the valving was changed to push the water through the superheater, steam generator and economizer. Each time the water made a turn in the piping of these units, audible reaction was detected and the water valve was closed to avoid a stepped reaction, however, the only reaction noted was just at the change in flow direction.

By drilling out a thermo-well for water injection and proper valving, the fin tube coolers were flooded one by one. The reaction was a very small, thump and only at the beginning of each fin tube cooler operation. This was felt to be due to a small amount of NaK at the upstream side of the valve. The fin tube coolers were filled with water and drained to receiver tank. The complete secondary system was drained to the drain tank and then the system was completely flooded and drained again. The caustic solution from the drain tank was then moved by pressure to an external holding tank and then transferred to the INEL acid pit. A total of 2,125 gallons of caustic solution was removed from the drain tank.

Prior to initiating the moist N$_2$ purge, the primary system required: a modification of the off-gas piping to incorporate filtration, adapters welded to the filter for purging; and the flame arrestor installed. Upon completion
of the modification, the valving was positioned to initiate a moist N₂ purge (10 psi) into the drain tank as well as the EM transfer pump at the base of the drain tank. This purge was started in the morning, remained on overnight and the next morning water droplets were injected into the Moist N₂ which increased the reaction rate. This was noted by a rise in temperature of the vent pipe and a boiling type sound. When the temperature returned to ambient, and no sound was detected when injecting the H₂O at a higher rate, i.e. 20-30 ml/min., the reaction was considered complete. A moist N₂ purge line was then attached to a filter. The valving was such that the venting was through the drain, receiving and gravity tanks, then through the filters and flame arrestor to atmosphere. Again, the injection rate and completion was the same as noted on the primary drain tank. It is estimated that each filter had approximately one pint of NaK to be reacted due to the configuration of the filter. The cold trap was valved in next with a moist 8 psi N₂ purge left on over the weekend. Upon return on Monday, the water droplets were initiated into the N₂ purge and by mid-afternoon, the reaction was complete. It is estimated that approximately 11 gallons of NaK was reacted in the cold trap by this method. A minor problem occurred while working the cold trap near the end of the reaction period when the oxides and hyroxides plugged the 1" discharge line. After trying N₂ pressure, water and hammering pipe walls, it was necessary to break the flanges and inject a 1/4" SS tube into the solid plug making a path for water to tunnel. When this was done, the pipe flanges were re-assembled and the discharge lines were cleaned by water flushing. Flushings were, in all cases, drained to the primary drain tank. Prior to processing the NaK in the reactor vessel, a dip tube was installed in the reactor flange for use in removing the reaction
product after processing. The moist $N_2$ purge was then connected to a 1/2" pipe installed in the top of the reactor flange, the purge initiated and all valving was opened on piping to or from the reactor to insure a good vent path. There were approximately 27 gallons of NaK in the bottom of the reactor to be processed. The reactor has two view ports in the top flange which were used to verify the reactor was completely flooded with demineralized water when the reaction was finished. The caustic solution in the reactor was drained to within three feet of the bottom through the primary side of the heat exchanger on down to the primary drain tank. The expansion tank was also flushed while performing the above operation. The reactor vessel was filled twice with demineralized water and then drained to the primary drain tank. A considerable amount of rinsing was performed and by valving and connecting the water line to various attachment points in the system, the direction of flow was controlled to assure all lines had been flushed thoroughly. Approximately 1500 gallons of demineralized water was pumped to the gravity tank and drained to the drain tank.

The gas purification system, filter trap, and ballast tank were purged with moist $N_2$, then flushed with $H_2O$ to verify any film or puddle of NaK would be passivated. Upon completion of water flushing of the primary system all valves were opened and system was allowed to drain to the primary drain tank until the NaK process plant was modified and ready for boil-off operations. The NaK process tank required the installation of heaters and the attachment of a vent gas line directly to the filter elements. The boil-off operation required the caustic solution in the primary drain tank to be transferred to the NaK process vessel where boiling down the solution to a 25M caustic solution would assure a solid waste product
upon cool down. Eight day shifts were expended on boil-off before a round
the clock 8-day operation was initiated. 3,300 gallons of caustic solution
were boiled down to a molarity that assured a solid upon cooling (347°F).
The decontamination, decommissioning, and isolation activities were con-
tinued throughout the NaK processing operations. The process plant
product remained in the reaction vessel as a solid after cool down. All
lines were capped or plugged on the vessel to isolate the caustic solid
from the atmosphere. The vessel plus all the associated components and
piping were contaminated; therefore, the entire NaK processing plant was
disassembled, packaged and transferred to the RWM C.

The approach taken on rooms or areas that had smearable contamination
was to generate a grid on all the surfaces and number or letter same. This
provided a method for expediting completion and acceptance per criteria
requirements of a cell, room or area. The clean-up methods used were
manual in most cases. However, a concrete electric chipping hammer was
required to remove pieces of concrete that contained impregnated contami-
nation.

The criteria for acceptance was that the facility items and areas must
not exceed the contamination levels shown in the following table.
ACCEPTABLE SURFACE CONTAMINATION LEVELS

<table>
<thead>
<tr>
<th>NUCLIDE</th>
<th>AVERAGE</th>
<th>MAXIMUM</th>
<th>REMOVABLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>U-nat, U-235, U-238 and associated decay products</td>
<td>5,000 dpm a/100 cm²</td>
<td>15,000 dpm a/100 cm²</td>
<td>1,000 dpm a/100 cm²</td>
</tr>
<tr>
<td>TRANSURANICS, Ra-226, Ra-228, Th-230, Th-228, Pa-231, Ac-227, I-125, I-129</td>
<td>100 dpm/100 cm²</td>
<td>300 dpm/100 cm²</td>
<td>20 dpm/100 cm²</td>
</tr>
<tr>
<td>Th-nat, Th-232, Sr-90, Ra-223, Ra-224, U-232, I-126, I-131, I-133</td>
<td>1000 dpm/100 cm²</td>
<td>3000 dpm/100 cm²</td>
<td>200 dpm/100 cm²</td>
</tr>
<tr>
<td>BETA-GAMMA EMITTERS (nuclides with decay modes other than alpha emission or spontaneous fission) EXCEPT Sr-90 AND OTHERS NOTED ABOVE</td>
<td>5000 dpm β-γ/100 cm²</td>
<td>15,000 dpm β-γ/100 cm²</td>
<td>1000 dpm β-γ/100 cm²</td>
</tr>
</tbody>
</table>

The areas that required isolation were narrowed down to two rooms; the washroom and the conveyor room both located in the basement. The conveyor room had a 25 R/hr reading at contact that was impractical to remove and the washroom had a 15 mR/hr reading at contact which would have required extensive removal of load bearing wall surfaces and would have been prohibitively costly to decontaminate. The conveyor room had sodium vapor lights and three observation windows, therefore, tourists could view it.
from the outside and it was considered unnecessary for them to enter the room. These two rooms were sealed up rather than being decontaminated.

There were areas that after chipping or removing concrete required some lead sheeting in the bottom covered by a thin film of polyethylene before filling with grout. This proved very successful in meeting the required criteria. The contaminated cleaning liquids generated during decontamination were mixed with absorbent materials in an open top 55-gallon drum, sealed when full and transferred to the RWMC. For the most part, the cleaning agents used were: TURCO 4324-OR, METHYL-CHLOROFORM, M-68 cleaning foam and commercial laundry soap.
SUMMARY OF PROGRAM

In retrospect, the EBR-I project management activities such as: structuring the task force, personnel training, writing D&D procedures and producing a Safety Analysis Report, as well as the technical research and development effort, were completed with no major difficulties. The NaK/KO₂ hazards evaluation was successfully completed and provided assurance that the NaK removal operations could proceed without danger of a NaK/KO₂ explosion. The hazard existed only when a third ingredient containing hydrocarbon was present and the EBR-I systems were known to be free of hydrocarbon. The final engineering drawings for the NaK processing equipment were generated by ANC Design Engineering Division. They used the conceptual sketch generated by ACC personnel who were called upon primarily as chemical and instrumentation consultants. The EBR-I facility with the exception of two areas (the conveyer room and washroom, which were isolated), was decommissioned and decontaminated to the level requirements that allows free access by the general public to any area so selected by the National Park Service. The facility was transferred to the National Park Service on June 10, 1975 which allowed for an earlier opening date, then originally scheduled for NPS public tours.
FIGURES

1. Idaho National Engineering Laboratory
2. EBR-I Complex Plan View
3. Photo of EBR-I Complex
4. President Johnson Dedicating EBR-I
5. Simplified Pictorial of EBR-I Coolant Flow
Fig. 1 Idaho National Engineering Laboratory.
Fig. 2 EBR-I Complex Plan View
Fig. 3  Photo of EBR-I Complex.
"On this very spot the United States produced 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-1 for its technical feats.

Fig. 4 President Johnson Dedicating EBR-1.
Fig 5  Simplified Pictorial of EBR-I Coolant Flow
PROCESSING EBR-I NaK TO PRODUCE A STORABLE SOLID

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L. C. Lewis

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Idaho Falls, Idaho 83401

ABSTRACT

Approximately 5500 gallons of fission product – contaminated liquid metal coolant (eutectic sodium-potassium alloy – NaK), was removed from the EBR-I reactor system, reacted with caustic solution to produce a solid 25 M potassium hydroxide-sodium hydroxide mixture suitable for storage at the Idaho National Engineering Laboratories RWMC. Considerations that went into the design and operation of the processing unit will be discussed.
PROCESSING EBR-I NaK TO PRODUCE A STORABLE SOLID

INTRODUCTION

Late in 1973, Allied Chemical was asked to develop a process for disposing of the contaminated liquid metal coolant from the EBR-I reactor and the rinsings from the reactor's coolant loops. Several alternative treatment methods for the disposal of the liquid metal (NaK) were considered which included reaction with organic solvents such as alcohols, burning in air, or reaction with steam as well as methods to purify the NaK without changing it from the elemental form.

Several constraints were inherent in the task. These included the natural constraints of handling the relatively hazardous liquid metal safely, the constraint caused by the presence of radioactive fission product contaminants arising from a 1955 core melt down, and finally the constraint of leaving the facility, as closely as possible, in a historically accurate configuration, since it had been designated a National Historical Landmark.

The process concept that was developed was the reaction of the NaK with concentrated aqueous caustic. In this concept, the NaK was transferred from the reactor systems to a pair of feed tanks and then sprayed under pressure into the caustic in the reactor vessel through atomizing nozzles. The finely divided droplets reacted with the water in the aqueous caustic and produced hydrogen and more caustic. The pertinent reactions are:

\[ \text{2 Na} + 2 \text{H}_2\text{O} \rightarrow \text{2 NaOH} + \text{H}_2 \]
\[ \text{2 K} + 2 \text{H}_2\text{O} \rightarrow \text{2 KOH} + \text{H}_2 \]
Quantities and properties of the NaK feed and the caustic product are shown in Table 1.

TABLE 1
NaK PROCESS STATISTICS

<table>
<thead>
<tr>
<th>Volume of NaK Reacted</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Secondary System:</td>
<td>1100 gallons</td>
</tr>
<tr>
<td>Primary System:</td>
<td>4400 gallons</td>
</tr>
<tr>
<td>Total</td>
<td>5500 gallons</td>
</tr>
</tbody>
</table>

Radionuclides Processed with the Primary NaK

<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{137}$Cs</td>
<td>16.2 Ci</td>
</tr>
<tr>
<td>$^{90}$Sr</td>
<td>2.1 mCi</td>
</tr>
</tbody>
</table>

No other fission products were detected

Proposed Processing Rate: 120 liters per hour

Projected Caustic Concentration 25 Molar (OH$^-$)

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiling Point</td>
<td>$\sim$ 200°C</td>
</tr>
<tr>
<td>Freezing Point</td>
<td>$\sim$ 100°C</td>
</tr>
</tbody>
</table>

The liquid metal coolant used in EBR-I was the eutectic alloy of sodium and potassium which has a composition of 78% potassium and 22% sodium. The freezing point of NaK is $-12.6\,^\circ$C. It is chemically more reactive than sodium and has a density and viscosity approximately 90% that of water. It reacts with water and oxygen to produce various oxides and hydroxides. The thermodynamically stable oxides from complete oxidation by air are sodium peroxide and potassium superoxide both of which are powerful oxidants. The oxides are insoluble in the liquid metal.
The most desirable product for the disposal process would be an insoluble solid. However, the alkali metals do not conveniently produce insoluble compounds. The best compound for radioactive waste management purposes that can be readily produced is the solid hydroxide. By reacting the NaK in a very concentrated caustic, the rate and violence of the reaction would be much slower since the liquid metal would have to compete with the caustic for water. In addition, the caustic will freeze at a reasonably high temperature. The high concentration of caustic product is required also to avoid stress corrosion cracking of construction materials. Reinoehl and Berry\(^1\) reported that caustic would cause stress corrosion cracking of carbon steel but only in that certain temperature-composition region shown in Figure 1. This region could be avoided by operating at a high concentration of caustic.

The operating concentration chosen was 25 M hydroxide ion. At this concentration, each mole of hydroxide crystallizes with one mole of water upon cooling. Its freezing point is around 100\(^\circ\)C, and the boiling point is about 200\(^\circ\)C. It is a white deliquescent solid which has a large thermal contraction upon cooling from the boiling point to the freezing point. The chemical material balance flow sheet for the process is shown in Figure 2.

**NaK Feed System**

The feed system was used to receive the NaK from the reactor storage vessels and deliver it to the NaK processing system at the proper pressure. All parts of the NaK feed system were constructed of Type 304 or 316 stainless steel which are suitable materials for containing the
NaK. In order to minimize valve failure and leakage, only bellows sealed valves were used in the NaK feed system.

To avoid the problems inherent to pumps, all NaK transfers were accomplished by pressurizing the tank with nitrogen and withdrawing the NaK through a line that reached the bottom of the vessel. Transfers from the reactor system to the feed tanks were low pressure (15 psi) transfers, while for feeding to the processing system, higher pressures (40 psi) were required.

The two feed tanks have capacities of 328 and 68 gal, respectively. When feeding NaK from a tank it was pressurized to 40 psig to give the proper flow of NaK. When NaK was not being fed from the tank, it was filled by pressurizing the NaK drain tanks in EBR-I while venting the feed tank. To prevent loss of NaK in the event of an overflow, the two feed tanks were vented into a 78 gal NaK feed relief tank.

The NaK on leaving a feed tank passed through one of two filter screens to remove particles larger than the nozzle orifice. The redundant filter screens were installed in an inerted glove box so that they could be replaced quickly if they became plugged, without interrupting the processing of NaK.

Two atomizing spray nozzles were used for injection of NaK. This type of nozzle was found to give the smoothest reaction of NaK with caustic in the pilot plant test. The nozzles were fabricated from Type 304 stainless steel (a nickel plated brass nozzle was used for the processing of the secondary system NaK).

REACTION VESSEL AND CAUSTIC COLLECTION SYSTEM

The reaction vessel was constructed of carbon steel. It was a tall
vertical vessel, 15 ft. 2 in. from tangent line to tangent line with a 30 in. diameter. The vessel was anchored in the vertical position to three I-beams by turnbuckles.

The two NaK atomization nozzles were mounted in a flange 2 ft. above the bottom tangent line, and the water injection nozzle was mounted on a flange 10 in. above the bottom tangent line. Because of the extent of atomization of the NaK, most of the reaction took place at the level that the NaK was sprayed into the vessel.

Caustic product was removed from the reaction vessel through a line leading from the bottom of the vessel. For a safe positive shut off, this drain line had both a remotely- and a manually-operated valve. The outlet of the line was tightly connected to the large hole in a standard 55-gal drum with a HEPA filter attached to the small hole. The depth of caustic product in the drum was indicated by a strip of welders dye check painted the length of the side of the drum. As the hot caustic filled the drum, the dye check burned off the barrel giving an unambiguous level indication as the drum filled. After the drum was full, the caustic drain line was removed and the large hole in the drum sealed with a screw cap. The HEPA filter in the small hole was removed and replaced with a molecular sieve-filled tube so that only dry air could be drawn into the drum while cooling. After the caustic had completely frozen, the molecular sieve tube was removed, and the drum sealed.

**INSTRUMENTATION**

Process control instrumentation was relatively simple. Level indication in the reaction vessel was achieved by weighing the vessel and contents with load cells. Pneumatic instruments for level measuring
were not suitable because of the turbulence. Composition control of the reaction mixture utilized a measurement of the boiling point. An automatic control valve which opened on an increase in the boiling temperature, injected water which diluted the solution in the reaction vessel and reduced the boiling point.

NaK flow was measured by two electromagnetic flow meters. One flow meter was installed in the line from the drain tanks in the reactor system to the feed tanks. This flowmeter merely indicated that flow of NaK was taking place during the transfer of NaK from the storage tanks in EBR-I to the feed tanks. The other flowmeter was installed between the feed tanks and the injection nozzles. It gave an accurate indication of the volume of NaK injected. The output from this flowmeter was continuously recorded.

The NaK feed tanks were equipped with electrical level sensing rods. An electrically insulated rod formed a complete circuit when NaK was in contact with it and the walls of the tank. The rods were set at three levels in the tank. The lowest level was indicative that the tank was essentially empty. The second rod was placed to indicate that the tank was filled. The topmost rod served as a redundant fill indicator and warned of impending overflow of the tank into the NaK feed relief tank. All three indicators were fitted with both visual and audible warning devices to indicate when the NaK had reached their control point.

Thermocouples were installed at various points in the system to give an indication of the operation of the system. In addition to the several locations in the reactor system, temperature measurements were made in the off-gas system, and on the caustic drain line.
The off-gas system was directly monitored by condensing a side stream from the main off-gas line down stream from the HEPA filters. The pH of this condensate was continuously recorded in order to detect sudden changes in the amount of caustic passing the HEPA filters which would signal a breach in the filters. In addition, the gas stream out of this condenser was passed through a constant air monitor (CAM), a hydrogen monitor, and an oxygen monitor.

All inert gas and water lines were equipped with flowmeters and pressure gauges. The flows were balanced to provide sufficient pressure and flow to keep the lines open and the system flushed with nitrogen.

**PROCESS SUPPORT SYSTEMS**

There were several process support systems required for the NaK process plant. The inert gas system was a nitrogen system. The non-reactive nitrogen gas was used to sweep the oxygen from the reaction vessel and the off-gas train as well as to provide an inert atomizing gas at the nozzles and to provide the force to move the NaK. Nitrogen was supplied from a large liquid nitrogen reservoir equipped with a vaporizer. In addition, there was a back-up bottled gas system for an emergency supply.

Water was supplied to the system at two points. The water injection nozzle was located near the bottom of the reaction vessel. A demister installed at the top of the vessel was sprayed with a small stream of water to wash the caustic that was removed by the demister back into the process.

To minimize the amount of chloride in the feed water, which is known to cause or contribute to stress cracking of carbon steel, demineralized
water was trucked from the Test Reactor Area and stored in a large tank beside the processing system. This water was then pumped from the reservoir as required for the process.

The off-gas train consisted of the demister installed in the top of the reaction vessel, a scrubber to remove most of the entrained caustic, a knockout vessel to remove the entrained liquid from the scrubber, redundant roughing filter/HEPA filter combinations, followed by a flashback arrester and the propane torch at the top of the stack. Caustic solution from the scrubber and from the condensation which occurred between the filters and the top of the stack was recycled into the reaction vessel. After the initial startup of the scrubber unit, the liquid level in the scrubber was maintained by condensation of water from water vapor in the off-gas stream. Excess liquid was recycled to the reaction vessel. The filter boxes were heated to a temperature above the saturation temperature of the off-gas stream to keep them from being breached as the result of condensation increasing the pressure drop across them.

The flashback arrester was installed to prevent an explosive mixture of hydrogen and air from causing any damage to the processing system. In order to insure ignition of the hydrogen, a propane torch was installed on top of the stack.

To provide for the possibility of overfilling the feed tanks an overflow tank was provided on the vent line from the feed tanks. When the feed tanks were in use, the valves in the line to the overflow tank and to the EBR-I systems were closed and the feed tank pressurized to 40 psi. The atomizing gas pressure was also 40 psi. Figure 4 shows the NaK processing unit in operation.
PROCESS STARTUP

Because of the possibility that particles of oxide would plug lines and the nozzles, precautions were taken to insure that the lines and vessels were dry and had been swept clear of oxygen. This was accomplished by heating and purging all lines with nitrogen for a day to remove all traces of water. While the purging was taking place, the start-up solution of 14 M sodium hydroxide was introduced into the vessel through the caustic drain line. Water was added to the scrubber such that any entrained caustic would be removed before the off-gas reached the filters.

OPERATION OF THE NaK DISPOSAL UNIT

A number of conditions had to be met before the NaK could begin flowing to the reaction vessel. These included the oxygen in the off-gas system being below the lower explosive limit, temperature on the filters exceeding the maximum expected off-gas temperature, flare torch operating, CAM and pH meter operating, load cells, flowmeters, and their readout devices operating, tanks filled, and purge and atomizing gas flows at the proper level and pressure. At that point the NaK flow could be started.

No product was removed until the caustic weight in the reaction vessel reached 5000 pounds and the reaction temperature reached \( \sim 200^\circ \text{C} \). The NaK flow was brought up slowly to the operating rate. It took approximately 24 hours to build the hydroxide level up to the operating level.

During operation, the sound of the reaction was about like an idling internal combustion engine. Some vibration was noted as the result of both the addition of water and of the NaK. The vibration increased as the atomization air flow decreased due to plugging of the nozzle.
During the entire processing period for the primary system NaK, the pH of the condensate never exceeded 12 and was rarely above 11.5. Samples of the off-gas and the condensate were periodically taken for chemical analysis. These samples and the pH readings formed the basis for the release estimates from the off-gas stack of $1.3 \times 10^{-2} \mu \text{Ci/m}^3$ for $^{137}\text{Cs}$ and $1.4 \times 10^{-5} \mu \text{Ci/m}^3$ for $^{90}\text{Sr}$. The stack was located approximately 100 ft. from the processing plant which kept the airborne contamination at very low levels in the working areas.

The secondary NaK was used for the feed to the NaK processing plant for an operational check out. Proper values for many of the operating parameters were identified at that time as well as the necessity to install the scrubber/knockout drum system ahead of the HEPA filters. Approximately one hundred gallons of caustic from the cold operation was used as the startup solution for the hot run. Approximately 18 drums of caustic were produced during the processing of the secondary NaK.

The processing of the primary NaK resulted in filling 93 drums of caustic. Some of the process performance statistics are shown in Table 2.

**TABLE 2**

**NaK PROCESS PERFORMANCE STATISTICS**

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimated time for reaction of primary NaK based on proposed NaK processing rate</td>
<td>138.8 hours</td>
</tr>
<tr>
<td>Actual Elapsed Time</td>
<td>140.9 hours</td>
</tr>
<tr>
<td>Reaction Produced:</td>
<td></td>
</tr>
<tr>
<td>25 million Kcal of heat equivalent to:</td>
<td>900 gallons gasoline</td>
</tr>
<tr>
<td>6100 cubic meters of hydrogen gas equivalent to:</td>
<td>980 standard cylinders</td>
</tr>
</tbody>
</table>
Average radionuclide releases from off-gas stack:

\[
\begin{align*}
^{137}\text{Cs}: & \quad 1.3 \times 10^{-2} \text{ Ci/m}^3 \\
^{90}\text{Sr}: & \quad 1.4 \times 10^{-5} \text{ Ci/m}^3
\end{align*}
\]

55 gallon barrels of solid caustic produced:

- **Secondary:** 18 barrels
- **Primary:** 93 barrels

---

**CONCENTRATION OF REACTOR SYSTEM RINSINGS**

After all the NaK had reacted and the caustic drained from the reaction vessel, one of the original banks of heaters was reinstalled and other external wrap-around heaters were placed on the vessel. It was then used as an evaporator to concentrate the aqueous rinsings from the EBR-I primary coolant system. The rinsings from the EBR-I primary system were accumulated in the old NaK drain/storage tanks at the lowest point in the reactor system. The dilute caustic produced by the reaction of the rinse water with residual NaK in the system was then transferred into the evaporator vessel along the same route and in the same manner that the NaK was during the NaK processing phase.

In order to effectively evaporate the rinsings, the system was modified by removing the scrubber/knockout drum system and by decreasing the length of piping to the stack such that little condensation would occur in the off-gas line. The flare and the flame arrester had been previously removed for other work in the decommissioning operation.

After all the rinsings had been evaporated, the heaters were turned off and the vessel contents allowed to solidify. All lines to the vessel were cut and capped and the vessel and its contents taken to the
Radioactive Waste Management Complex. The decommissioning of the processing plant will be discussed in somewhat more detail in the paper by E. W. Kendall presented at this conference.

The success of this operation, the present existence of large quantities of contaminated liquid metal wastes (such as from the Hallam and Fermi reactors and the Sodium Reactor Experiment as well as smaller quantities from reactor experiment loops), and the anticipated large quantities to be generated as the Liquid Metal Fast Breeder Program expands, prompted Allied Chemical to suggest two techniques to deal with these wastes. One proposal for construction of a mobile processing plant was based on the design of the plant described in this paper. It would have the capabilities of treating the liquid metal present at the site and concentrating reactor system rinsings and other aqueous wastes generated during the decontamination/decommissioning of a radiochemically contaminated liquid metal facility.

This type of operation is suitable if the quantities of liquid metal are small and the radionuclide contaminants are short-lived. However, because sodium containing wastes do not lend themselves to long-term storage, a second proposal was made to evaluate the technology and to construct a facility which would allow recycle of waste liquid metal back to the liquid metal cooled reactors. The product would be of sufficient purity to be suitable for use in a reactor system with a residual radioactivity due to traces of $^{134}$Cs, $^{137}$Cs, and $^{22}$Na. Implementation of this program would prevent the accumulation of large volumes of liquid metal wastes and the consequent problems and expenses associated with waste management of large volumes of liquid metal or alkali metal based
aqueous waste as well as assuring a continuing supply of reactor grade liquid metal.

SUMMARY

Numerous constraints on the design, timing, safety, and environmental effects of processing a large volume of radionuclide contaminated liquid metal from the EBR-I reactor were faced and successfully dealt with in converting the 4400 gal of primary NaK and 1100 gal of secondary NaK to a solid caustic. The operation proceeded as planned with minimal environmental effects.
REFERENCES

FIGURES

1. Caustic Cracking Zone for Carbon Steel Data from Reinoehl and Berry(1).
2. Material Balance Flowsheet for Processing the EBR-I NaK.
4. Removing a Drum of Caustic Product from the NaK Processing Unit.
Figure 1. Caustic Cracking Zone for Carbon Steel
Data from Reinoehl and Berry(1).
Figure 2. Material Balance Flowsheet for Processing the EBR-I NaK.
Figure 3. Equipment flowsheet for the EBR-I NaK Conversion Process.
Figure 4. Removing a drum of caustic product from the NaK Processing Unit.
DISMANTLING AN ALPHA-CONTAMINATED FACILITY

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Abstract — The difficult task of removing large pieces of highly contaminated equipment from an obsolete plutonium-239 facility was completed in a seven-month operation that included structural alteration of the process building. Detailed job planning, job execution and contamination control were major factors in accomplishing the task.

INTRODUCTION

A decision was made to convert an unused plutonium-239 recovery room in a separations building to other use. The room (Figs. 1 and 6), midway between the third and fourth levels of the four-story structure, is approximately 85 ft long, 20 ft wide, and 18 ft high with a partial balcony on one side. It contained:
- one large wet chemistry cabinet enclosing 19 vessels,
- one smaller wet chemistry cabinet enclosing several small vessels,
- five sections of dry chemical cabinets, and
- associated piping, electrical conduit, air ducts, etc. for each cabinet and vessel.

On the balcony were several cold feed tanks and one wet chemistry cabinet containing two process vessels.

Removal was complicated by internal transferable contamination levels up to $10^8$ d/m alpha per ft$^2$ and the absence of a route between the room and a loading dock two levels below that could accommodate the large pieces to be moved.

SPECIAL PREPARATIONS

A series of meetings of production, health physics, and construction personnel produced a four-phase job plan:

**Phase I** — Remove nonprocess piping and other equipment which is virtually uncontaminated

**Phase II** — Remove intermediately contaminated equipment (2 to $3 \times 10^7$ d/m alpha per ft$^2$) (Transferable contamination determined by paper towel smear)

**Phase III** — Remove highly contaminated equipment (above $3 \times 10^7$ d/m alpha per ft$^2$) (Determined as above)

**Phase IV** — Remove equipment from the balcony.

Equipment contamination required that breathing air-supplied respiratory protection be worn on all but a few jobs. The following additional protective clothing was specified with air-supplied hoods and plastic suits:

With hoods
- 2 pair coveralls
- 2 pair gloves (rubber)
- 3 pair shoe covers (cloth boots, plastic shoe covers, and rubber overshoes as outer pair)
With plastic suits
- Coveralls
- Gloves
- 3 pair shoe covers (cloth boots, plastic shoe covers under suit, and rubber overshoes as outer pair)

To establish an equipment removal route, an 8-foot-square hole (Fig. 2) was cut in the floor of the office at the south end of the room and the wall between the office and room was removed. On the level below, the corridor wall was modified to give adequate space under the opening. Walls between the corridor and other affected rooms were removed.

As expected, the additional airflow upward through the floor opening into the old recovery room upset the air balance, pressurizing the room. To solve this problem, the regular air supply to the room was cut off and all available exhaust utilized. A large air lock with doors adequate to permit passage of equipment was constructed in an unused area on the level below to control airflow to the work area. Due to the size of the building and other variables, air control problems could not be accurately forecast. Air balance remained critical throughout the job and the least deviation from control instructions would cause an air reversal. All high efficiency particulate air (HEPA) filters in the exhaust system were replaced prior to start of work.

CONTAMINATION CONTROL

To prevent spread of contamination, the bag method was used on all duct and process line breaks except those made inside cabinets. (The bag method is the separation of lines, ducts, etc. inside a plastic bag or sleeve that completely encloses the area of the line break then squeezing the bag together between the two separated pieces, taping and cutting at taped area, thereby leaving each end of the break fully covered with plastic.)

The following additional precautions were taken in packaging equipment for delivery to the burial ground:
- Plywood covers were placed over all ventilation duct openings.
- Process pipe openings were sealed with rubber plugs or blank flanges and gaskets.
- Vessel openings were covered with blank flanges and gaskets.
- All contaminated equipment was wrapped in plastic until transferable surface contamination was less than 5000 d/m alpha per ft², then it was removed from the room and placed in special plastic-lined, reinforced ¾-in. plywood boxes (Fig. 3) to withstand burial in concrete.
- Transferable contamination levels on exterior surfaces of all boxes were less than 500 d/m alpha per ft² before they were shipped to the burial ground.
- Relatively clean equipment with external transferable and/or fixed contamination of less than 500 d/m alpha per ft² was placed in skip pans on the third level. The pans were enclosed with plastic prior to shipment to the burial ground.

Manpower Requirements

Initially, two Health Physics inspectors were assigned to cover work in the area. As work progressed, a third inspector was required — two inside covering process line breaks and one in the air lock at the south end of the room to check personnel as they exited. A Health Physics supervisor was present at the job site approximately 75% of the time.
REMOVAL OF EQUIPMENT

For several reasons, the concentrated feed cabinet on the west side of the room was first to be removed. This cabinet was the largest and heaviest (approx 3500 lb) single piece of equipment in the room and served as an excellent test of the method and equipment (triple chain hoist) used to lower items through the 8-foot-square opening to the air lock below. The cabinet was 16 feet long, 5 feet high, and 2 feet wide with top and ends fabricated from laminated lead and iron. The space occupied by this cabinet was needed to provide a clear passage for other equipment to be removed.

After the following preparations the cabinet was moved without incident:
- Cabinet was stripped of all external piping and ductwork.
- Front panel frames were tack-welded to cabinet.
- An angle iron frame with lifting bails was welded around entire cabinet.
- Front panels and duct stub openings were covered with plywood which was strapped to the cabinet with metal bands.
- Cabinet was wrapped in several layers of plastic and tape.

Next to go were the dry chemistry cabinets. After removal of all external piping and ductwork, the cabinets were separated into three sections using the bag method. Interiors had been previously swept as clean as possible. All waste had been removed and heavy equipment in cabinets had been secured in place; then all interior surfaces were sprayed with “Krylon” (a clear plastic) to fix any loose contamination. All openings (glove ports, bag ports, etc.) were covered with ½-inch plywood and banded. The cabinets were covered with plastic and tape before they were lowered to the air lock on the level below. All equipment in the air lock was resurveyed by Health Physics before it was moved to the loading dock and placed on trucks for shipment to the burial ground.

The large wet chemistry cabinet, containing 19 vessels and associated piping, required extensive preparation. It was 60 feet long, 5 feet wide, and 7 feet high with three high hats approximately 6-feet high. A large plastic containment hut with air lock was erected around the cabinet (Figs. 4 & 5). The sumps were cleaned and the piping removed by removing cabinet panels (maximum of three at one time) and physically entering the cabinet. All interior surfaces were spray-painted with a water base latex paint using a low pressure sprayer to fix the contamination. Water-base paint was selected because of the large quantity needed and because of the explosion potential in spray propellants. Panels were replaced with plastic taped to the cabinet frame. This was necessary to control the airflow. Cabinet framework and ends were then cut away, leaving the vessels in place over the sump pans. Airflow had to be continuously adjusted during this work. The vessels were riged on chainfalls suspended from the ceiling and extended down through the roof of the hut to the cabinet area. The vessels were disconnected from all bracings and mounts and moved from the sump area. While still suspended on the chainfalls, vessels were wrapped in plastic and taped until transferable contamination on the outer covering measured less than 5000 d/m alpha per ft². The vessels were placed on a cart, removed from the hut through the air lock, and lowered to special made-to-order boxes in the air lock below. Actual removal of the large wet chemistry cabinet framework and the vessels required only eleven working days other than preparation time. The concrete around the edges of the sump pans was removed with jackhammers. The pans were cut into five sections, wrapped, and removed following the same procedures used for the vessels. At one stage of this job, airflow into the hut was practically lost. Maximum contamination spread to the hut surfaces during the work was $3.5 \times 10^6$ d/m alpha per ft². The containment hut was cleaned and removed.

The small wet chemistry cabinet on the balcony was cleaned and painted in the same manner as the large wet chemistry cabinets. Panels, framework, piping, and vessels were removed following the same procedures outlined for the large cabinets except that no containment hut was employed.

The remaining cold piping, cold feed vessels, ductwork, and electrical conduit was removed. This
essentially completed the work except for cleanup and refinishing of the room (Fig. 6).

A survey of the room before final cleanup established these transferable contamination levels:

- walls, less than 1000 to 10,000 d/m alpha per ft²
- floor, 2000 to 3000 d/m alpha per ft²
- overhead piping and cuts left in place, 1000 to 50,000 d/m alpha per ft²
- light fixtures, $2 \times 10^5$ d/m alpha per ft²

The room was cleaned until transferable contamination was less than 1000 d/m. Floor tile was taken up and fixed contamination removed by chipping. The floor was regrouted and the room repainted.

SURFACE AND AIRBORNE
ALPHA CONTAMINATION EXPERIENCE

Transferable contamination on the room floor did not exceed 40,000 d/m alpha per ft² and was generally less than 5000 d/m alpha per ft². Air-supplied respiratory protection was worn at all times in the room so the contamination level was not considered serious but was kept as low as possible. Airborne alpha contamination ranged from $5 \times 10^{-12}$ μCi/cm$^3$ to $50 \times 10^{-12}$ μCi/cm$^3$ except for two incidents: air activity reached approximately $1500 \times 10^{-12}$ μCi/cm$^3$ in one and greater than $2000 \times 10^{-12}$ μCi/cm$^3$ in the other. (RCG = $2 \times 10^{-12}$ μCi Pu/cm$^3$ air)

The one instance in which activity exceeded $2000 \times 10^{-12}$ μCi occurred while the sump pans were being removed inside the containment hut. Use of a jackhammer to remove concrete produced considerable airborne concrete dust. The southeast corner of the old dissolver sump had been jacked or pried from its supports and was being cut along the seam with a power saw equipped with an abrasive blade. Airflow into the hut was low but thought to be adequate. There were eight men in the hut and one man in the air lock. When the high level was revealed by air samples, work in the hut was halted. Plastic suits were removed at the entrance to the hut air lock and a breathing air hood was then worn from the hut to the room exit. All personnel were asked to submit nasal smears because of the dust on the plastic suits. Three of the nine persons showed positive alpha nasal contamination levels and were administered a chelating agent and a cathartic by Medical personnel. All nine were counted on the whole body counter and submitted bioassay samples. The persons having nasal contamination had confirmed plutonium assimilations less than 5% MPBB. No skin contamination was detected.

There were no indications that nasal contamination occurred while plastic suits were being worn. Apparently contamination occurred while suits were being removed. A survey of the inner surfaces of the suits (after the fact) showed no contamination but outer surfaces were contaminated to $10^5$ d/m transferable alpha per ft² and were heavily covered with concrete dust. Had suits been wiped down with a wet towel before removal, contamination would probably have been avoided.

SUMMARY

In the seven months required to complete the job, 415 six-mil and 60 twelve-mil air-supplied plastic suits were used along with approximately 2900 air-supplied hoods. The 12-mil suits were worn for entry of the wet chemistry cabinets. Two thousand man-hours of Health Physics inspector coverage and 700 man-hours of Health Physics supervisory time were required. Excellent radiation protection in all phases of the job resulted from extensive preplanning and the continuing cooperation of Health Physics, Production, and Construction personnel.

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Figure 1. Plutonium-239 Recovery Room at Beginning of Equipment Removal Project. West wall at left.

Figure 2. 8 x 8-ft Hole in Floor of Adjoining Office. Opening was made to provide an evacuation route through the level below.

Figure 3. Specially Constructed Burial Boxes. Sides of 3/4-inch plywood reinforced to withstand burial in concrete.

Figure 4. Exterior of Plastic Containment Hut with Airlock Portion in Foreground

Figure 5. Interior of Plastic Containment Hut. Wrapped and partially removed vessel in background.

Figure 6. Plutonium-239 Recovery Room at Conclusion of Equipment Removal Project
Fig. 1. Plutonium-239 recovery room at beginning of equipment removal project. West wall at left.

Fig. 2. 8 x 8-ft hole in floor of adjoining office. Opening was made to provide an evacuation route through the level below.