

ANL/D-D/TM--96/2

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**Decontamination of Hot Cells K-1, K-3,
M-1, M-3, and A-1, M-Wing,
Building 200: Project Final Report
Argonne National Laboratory - East**

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NOTATION

ACRONYMS, INITIALISMS, AND ABBREVIATIONS

AA	Argonne Area
ACWP	Actual Cost Work Performed
ADM	Action Description Memorandum
ALARA	As Low As Reasonably Achievable
ALI	Annual Limit on Intake
Anti-C	Anti-contamination
ANL-E	Argonne National Laboratory-East
BCWP	Budgeted Cost Work Performed
BCWS	Budgeted Cost Work Scheduled
Bq	Becquerel
CDR	Conceptual Design Report
cf	Cubic feet
CH	Chicago
CHM	Chemistry
Ci	Curie
cm	centimeter
CMT	Chemical Technology
CTZ	Central Time Zone
CY	Calendar Year
CX	Categorical Exclusion
D&D	Decontamination and Decommissioning
decon	Decontamination
DOE	Department of Energy
DOT	Department of Transportation
dpm	Disintegrations per minute
EA	Environmental Assessment Division
EE	Environmental Evaluation
EPA	Environmental Protection Agency
EMO	Environmental Management Operations
ESH	Environment, Safety and Health
EWM	Environmental Waste Management
FY	Fiscal Year

gal	Gallon(s)
Gy	Gray
>	Greater than
h	hour
HEPA	High Efficiency Particulate Air (Filter)
Hq	Headquarters
HP	Health Physics
IH	Industrial Hygiene
in.	Inch(es)
K	thousand
kg	kilogram
<	Less than
l	Liter
lb	Pound(s)
m	Milli (10^{-3})
m	Meter
μ	Micro (10^{-6})
n	Nano (10^{-9})
NEPA	National Environmental Policy Act
Oz	Ounce
p	Pico (10^{-12})
PAPR	Powered Air Purifying Respirator
PNL	Pacific Northwest Laboratory
PVC	Polyvinyl chloride
R	Roentgen
RCRA	Resource Conservation Recovery Act
RE	Reactor Engineering
rem	Roentgen equivalent man
SE	Safety Engineering
Sv	Sievert
T	Tera (10^{12})

TLD	Thermoluminescence Dosimeter
TRU	Transuranic
WM	Waste Management
WMO	Waste Management Operations

**DECONTAMINATION OF HOT CELLS K-1, K-3, M-1, M-3, AND A-1
M-WING, BUILDING 200: PROJECT FINAL REPORT
ARGONNE NATIONAL LABORATORY - EAST**

by

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EXECUTIVE SUMMARY

This is the final report for the Argonne National Laboratory-East (ANL-E) Building 200 M-Wing Hot Cells Decontamination Project. The purpose of the project was to practically eliminate the radioactive emissions of Rn-220 to the environment and to restore the hot cells to an empty restricted use-condition. About 96.2 TBq (2,600 curies) per year of Rn-220 was being emitted at the start of the project from the radioactive contaminants left in the hot cells at the end of the ANL-E Proof-of-Breeding program work in 1985.

Four of the five project Hot Cells (M-1, M-3, K-1, and K-3) had been used for Proof-of-Breeding research on irradiated thorium rods from the U. S. Navy's Shippingport Atomic Power Station thorium core breeder reactor research. The research involved precise shearing of the rods in Hot Cell M-3, dissolving of the samples in concentrated acids in Hot Cell M-1, preparing dissolver solution samples for radioassay in Hot Cell K-3, and pumping the waste dissolver solution to waste cementing stations in Hot-Cell K-1. Extensive equipment and structures in the hot cells needed to be removed as radioactive waste.

Hot Cell A-1 had been used for pulverizing irradiated reactor fuel specimens from the Zion Nuclear Power Station in Illinois for analyses to quantify breeding of fissile isotopes.

All five of the hot cells required remote disassembly and decontamination work prior to protected entry decontamination. Two pairs of heavy duty manipulators were procured to facilitate the remote disassembly and decontamination work. An existing radio-controlled rail cart system was used for moving remote-handled (>200 mrem/hr) radioactive waste.

The project was carried out by ANL-E personnel during the period June 1992 to April 1996 (46 months) at a cost of \$5.8 million. The total radiation dose to project personnel was about 74.5 person-mSv (7.45 person-rem). This was 80.1% of the total dose forecasted in the project

Action Description Memorandum. All radiation exposures were maintained below regulatory guidelines in all aspects.

The five hot cells were emptied and decontaminated for restricted use. The goal of practically eliminating radioactive emissions from the five hot cells was achieved by the project team. A total of 23.4 metric tons (25.8 tons) of radioactive waste was generated. Approximately 7.7 metric tons (8.5 tons) of radioactively contaminated lead shielding bricks were taken to ANL-E Waste Management for decontamination and recycling. Ten 208-1 (55-gal) drums of remote-handled waste were shipped to the Department of Energy disposal site by shielded cask truck transport. The contact-handled radioactive waste was shipped in steel bins by truck transport to the Department of Energy disposal site. The radioactivity in the waste totaled 110 curies, primarily of mixed fission products.

1 INTRODUCTION

Argonne National Laboratory-East (ANL-E) is a government-owned, contractor-operated, multiprogram research facility located 25 miles southwest of downtown Chicago on 689 hectares (1,700 acres) in DuPage County, Illinois. The location in the greater Chicago metropolitan area is shown in Figure 1.1. Building 200 is located at the west end of the ANL-E 200 area as shown in Figure 1.2.

The purpose of this project was to remove radioactively contaminated materials and equipment from the hot cells, to decontaminate the hot cells, and to dispose of the radioactive waste. The goal was to reduce stack releases of Rn-220 and to place the hot cells in an emptied, decontaminated condition with less than 10 $\mu\text{Sv/h}$ (1 mrem/h) general radiation background. The following actions were needed:

- Organize and mobilize a decontamination team.
- Prepare decontamination plans and procedures.
- Perform safety analyses to ensure protection of the workers, public, and environment.
- Remotely size-reduce, package, and remove radioactive materials and equipment for waste disposal.
- Remotely decontaminate surfaces to reduce hot cell radiation background levels to allow personnel entries using supplied air and full protective suits.
- Disassemble and package the remaining radioactive materials and equipment using hands-on techniques.
- Decontaminate hot cell surfaces to remove loose radioactive contaminants and to attain a less than 10 $\mu\text{Sv/h}$ (1 mrem/h) general background level.
- Document and dispose of the radioactive and mixed waste.
- Conduct a final radiological survey.

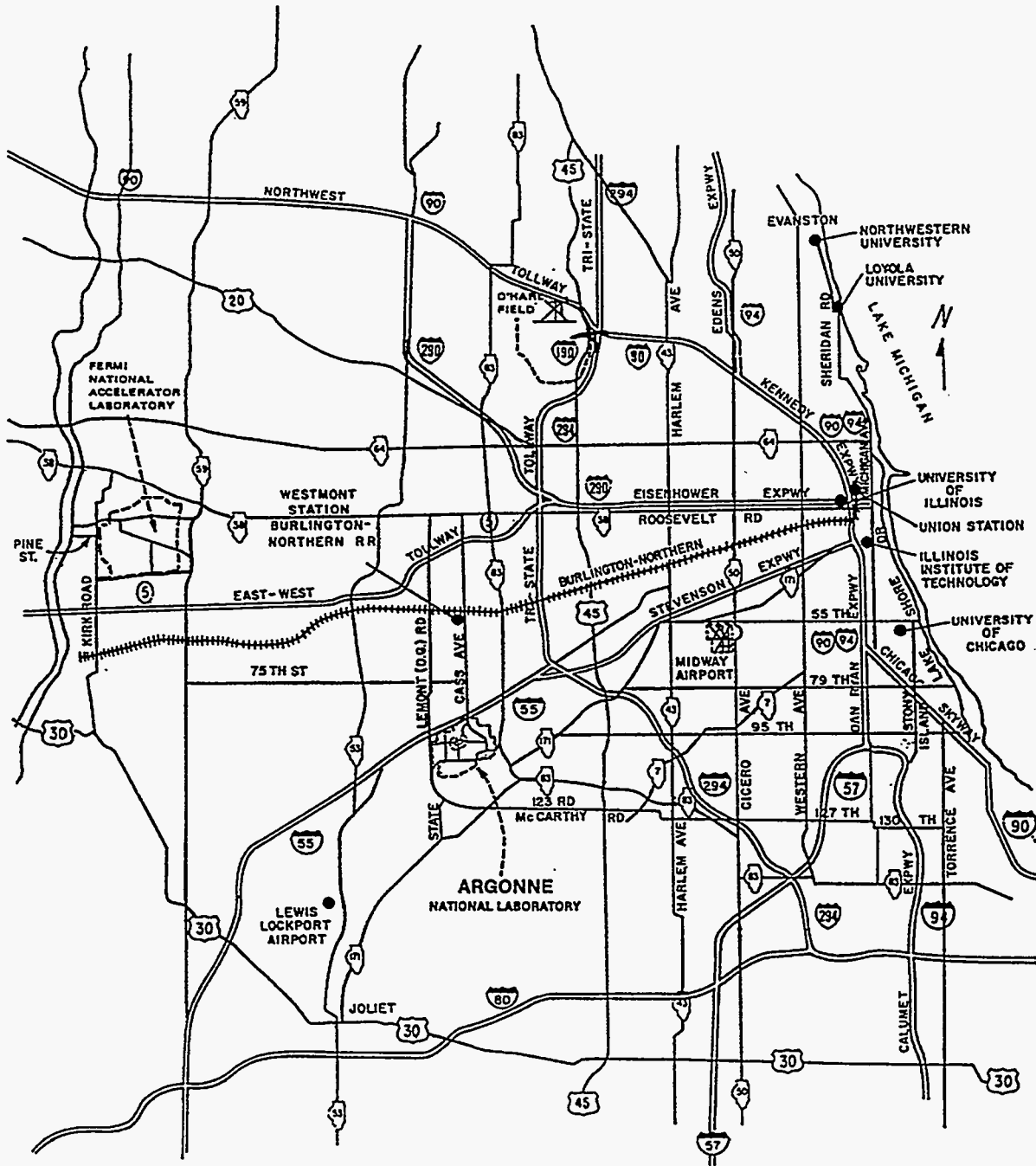


FIGURE 1.1 Map Showing ANL-E in the Greater Chicago Metropolitan Area

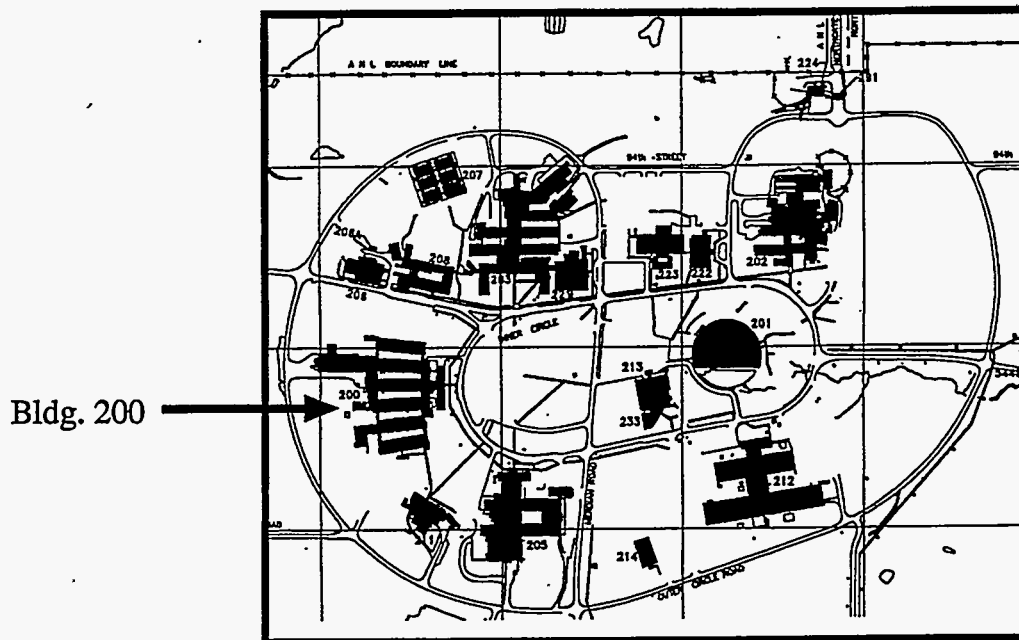
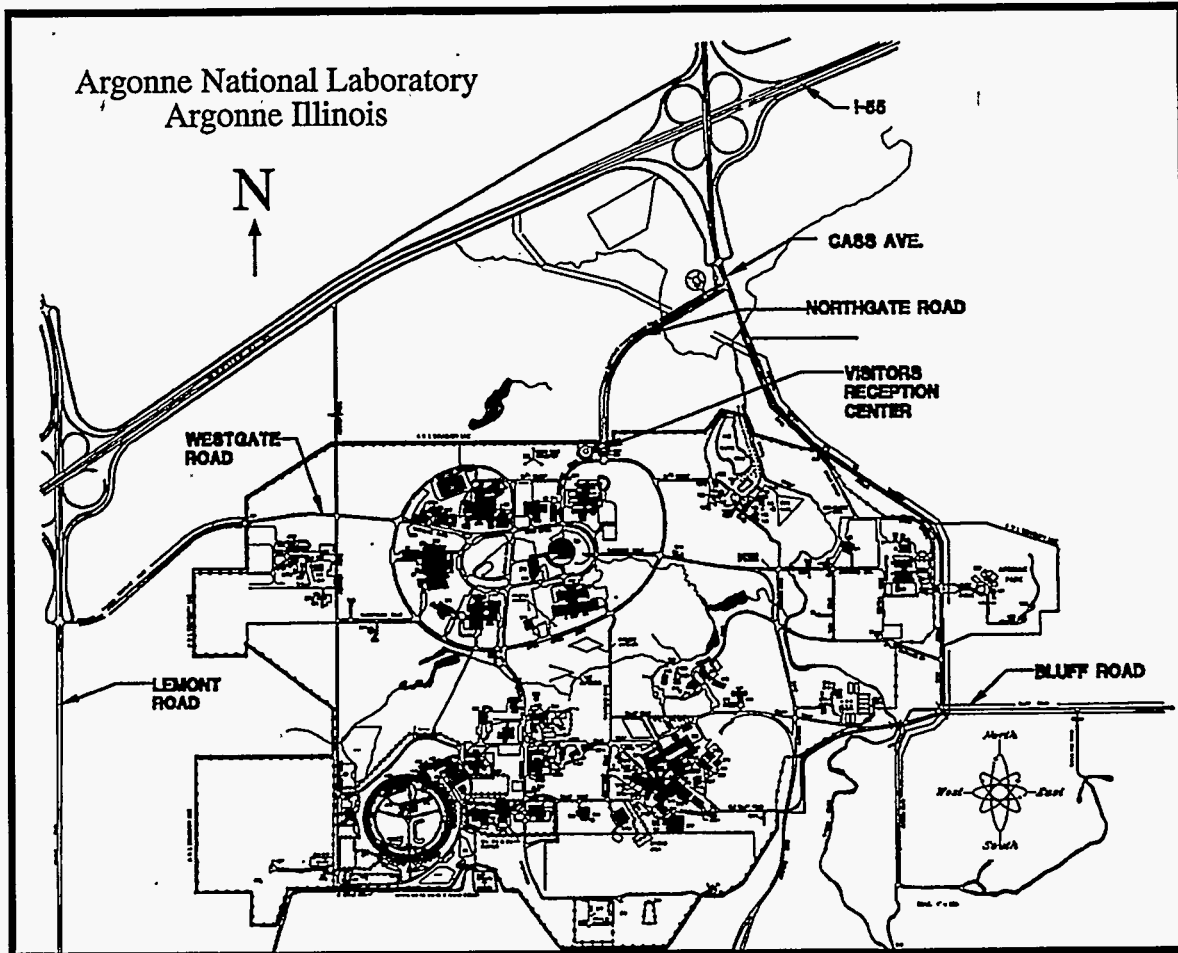


FIGURE 1.2 ANL-E Site Plan View Showing Building 200

Additional project objectives were to:

- Minimize radiation exposure, radioactivity intake, and potential injury to personnel.
- Minimize the volume of radioactive waste, particularly remote-handled and mixed waste.
- Minimize project costs within an As-Low-As-Reasonably-Achievable (ALARA) radiation exposure framework.
- Determine the most effective means for decontamination and other project activities.

The project was proposed by ANL-E to the Department of Energy Headquarters (DOE-HQ) in 1990 and again in 1991. It was funded by the DOE for startup in fiscal year (FY) 1992. Planning began in October 1991 and physical work in the hot cells began June 10, 1992. The project team was comprised of ANL-E technical operations and Environmental, Safety, and Health (ESH) Health Physics personnel who had hot cell operations and monitoring experience. The project technical support manager and the alternate technical support manager had work experience from the Proof-of-Breeding research project. The initial project work force was composed of 10 ANL-E personnel.

2 FACILITY BACKGROUND

The M-Wing hot cells addition to Building 200, occupied by the Chemistry Division, was built in 1961 for isotopes separation and research on heavy radioactive isotopes. Figure 2.1 shows a photograph of the M-Wing of Building 200. The M-Wing hot-cells facility consisted of four full-size megacurie hot-cells on the service floor level and eight kilocurie hot-cells (two full size, two half size, and four quarter size) in the same external space on the main floor. The megacurie hot-cells are shown in plan view in Figure 2.2; the kilocurie hot-cells are shown in plan view in Figure 2.3. The full-size hot cells are nominally 5.5 by 4.3 by 3.7 m high (18 by 14 by 12.25 ft high) internal dimensions. The megacurie hot-cell walls are 1.2 m (4 ft) thick and the kilocurie hot-cell walls are 0.7 m (2.33 ft) thick. Hot cell walls are constructed of high-density reinforced concrete.

In 1984-5 five of the M-Wing hot cells were used in support of the Navy's Proof-of-Breeding research program. Westinghouse Bettis Atomic Power Laboratory was to determine the end-of-life inventory of fissile uranium in the Shippingport Atomic Power Station Light Water Breeder Reactor. An irradiated-fuel assay gage for neutron interrogation and detection of delayed neutrons was used to examine a statistical sample of 500 end-of-life fuel rods. In support of these measurements ANL-E was to carry out destructive physical, chemical, and radiometric analyses on



FIGURE 2.1 Photograph of M-Wing, Building 200 (17551 K)

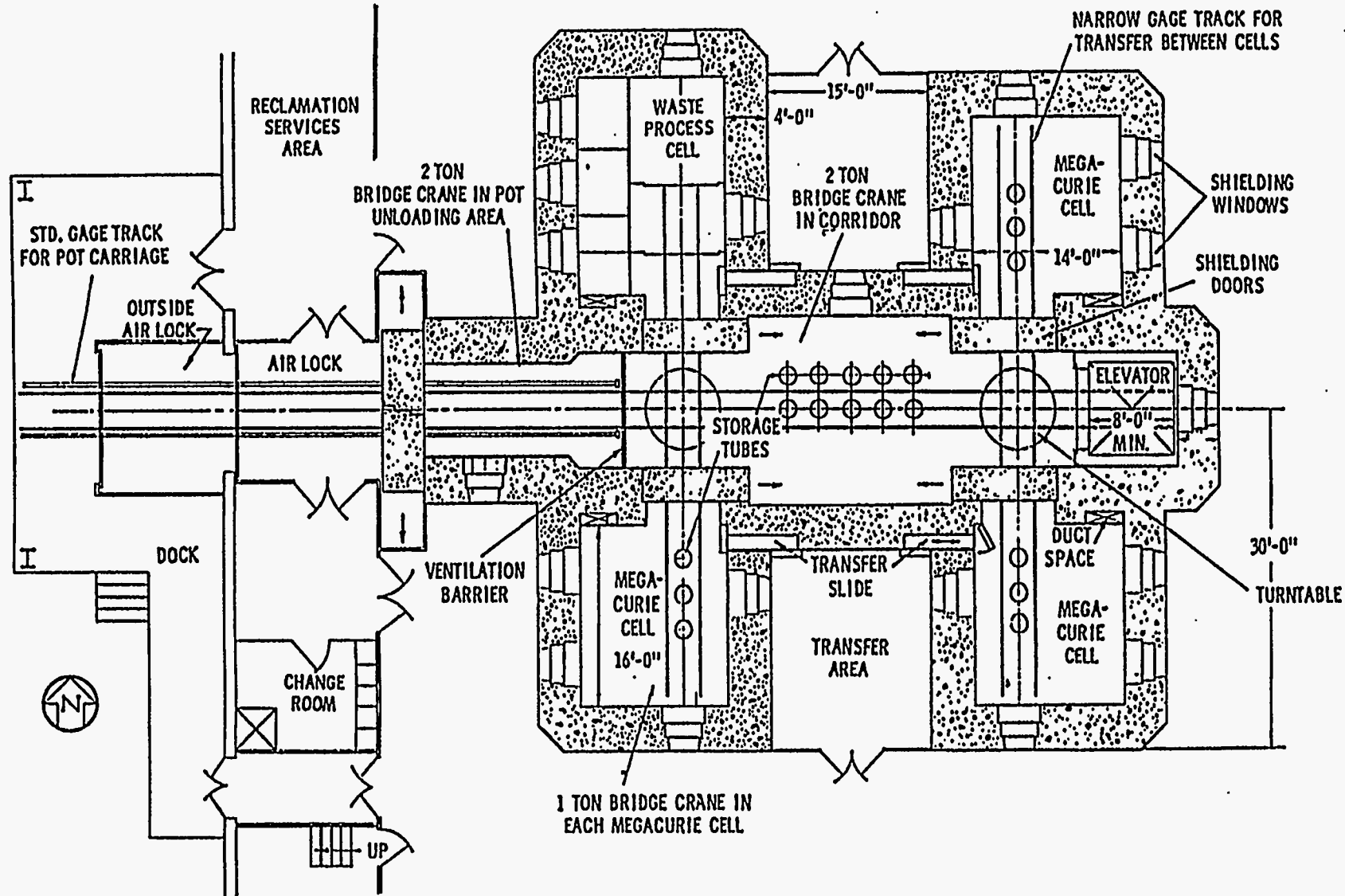


FIGURE 2.2 Plan View of Building 200 Service Floor Showing Location of the Megacurie Hot Cells

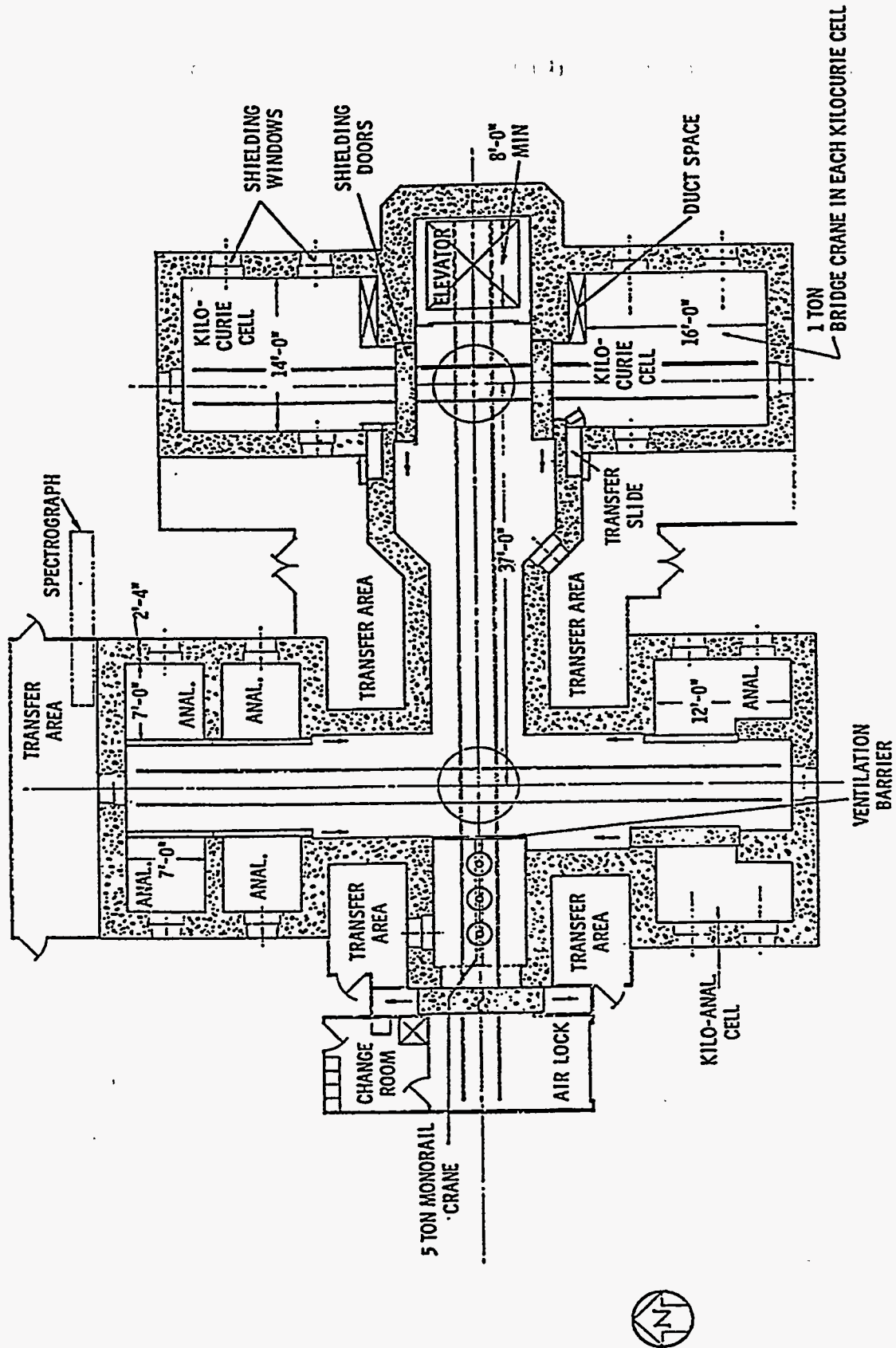


FIGURE 2.3 Plan View of Building 200 Main Floor Showing Location of the Kilocurie Hot Cells

7 end-of-life fuel rods that had been previously assayed. Hot Cell M-3 was set up for shearing the irradiated fuel rods into precise samples. Hot Cell M-1 was used for dissolving the fuel rod samples in concentrated nitric acid catalyzed with hydrofluoric acid. Hot Cell K-3 was used for preparing dissolver solution samples for analyses. The spent dissolver solutions were pumped up to Hot Cell K-1 (above Hot Cell M-1) for conversion to a cement waste form.

The Proof-of-Breeding research was conducted on irradiated Th-232 rods used to breed fissile U-233. Sheared samples of these rods were dissolved in acid. There had been dissolver acid solution leaks in Hot Cells M-1 and K-1.

Hot Cell A-1 (quarter size) had been used for examination of spent reactor fuel from the Zion Nuclear Power Station Pressurized Water Reactors. This hot cell contained pulverized irradiated reactor fuel samples. Remote shielded handling for transfer of irradiated reactor fuel specimens and remote decontamination were necessary prior to protected entry into the hot cell.

All five project hot cells were in shutdown status; however, two of the nonproject hot cells were in use. This required coordination with operating and support personnel but it did not prove to be an obstacle for conduct of the decontamination work.

3 DECOMMISSIONING OBJECTIVE AND WORK SCOPE

The majority of all Rn-220 emitted to the environment from DOE sites in 1993 was from ANL-E. (See Reference 10.) The project hot cells were the major source of the ANL-E emissions.

The objective was to clean out the project hot cells, decontaminate them to restricted use levels, and dispose of the resulting radioactive and mixed waste. The purpose of this work was to reduce the risks from the presence of the radioactively contaminated hot cells and the emissions of Rn-220 to the environment. The Building 200 Rn-220 monthly emissions in curies are plotted in Figure 3.1. The goal of reducing the Rn-220 emissions to less than the 5% of 1992 levels is shown near the baseline of Figure 3.1. At the completion of the decontamination the 5% goal was exceeded, as shown in the Figure 3.1, Feb 96 reading.

Increases in emissions during the project were due primarily to the seasonal weather conditions with the highest relative humidity and absolute moisture content in the hot cells' atmosphere in the summer. Emissions of Rn-220 are facilitated by the presence of moisture at the U-232 contaminant crystalline surface. The relative humidity and Rn-220 emissions from the hot cells were measured throughout the project and showed a strong correlation of increased emissions with an increase in relative humidity. The mechanism for increase of radon emissions is explained

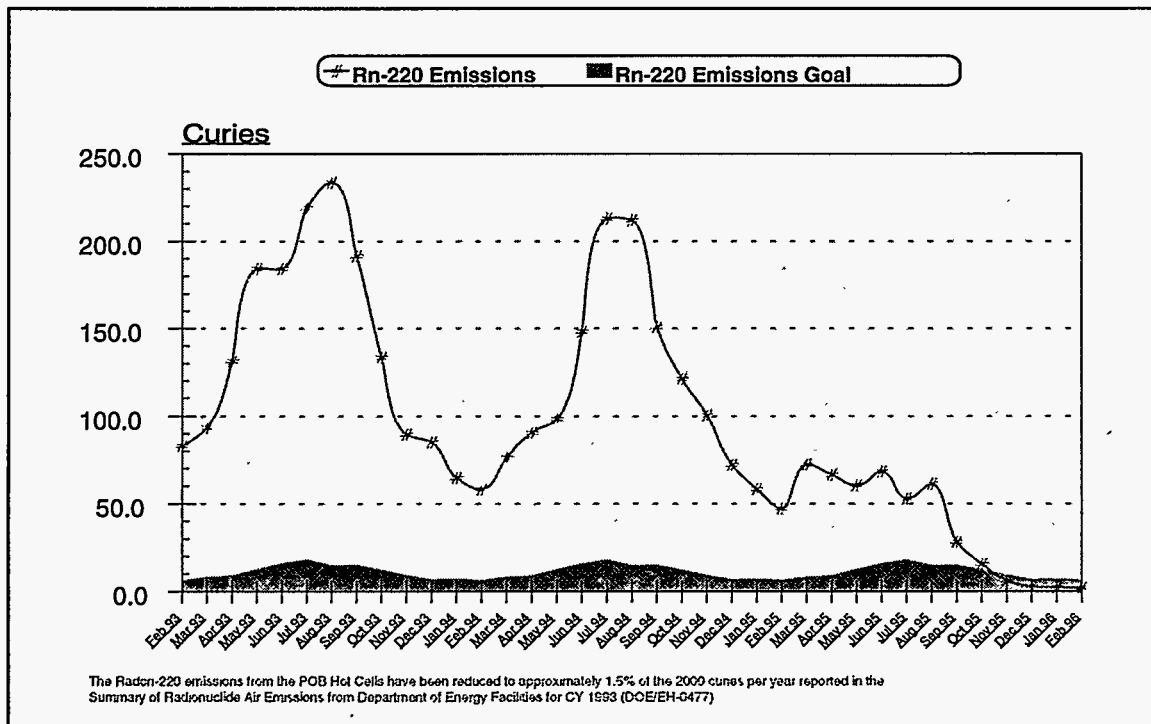


FIGURE 3.1 Building 200 Monthly Hot Cells Rn-220 Emissions

by A. B. Tanner in the "3rd DOE Natural Radiation Environment Symposium Proceedings," 1980 (Reference 9). He explains that "water is the most important agent in enabling radon isotopes to escape from solid material. Hydrating of mineral surfaces increases emanating power, and it decreases adsorption of radon on mineral surfaces."

The acid solution leaks in Hot Cells M-1 and K-1 lead to the formation of radioactive salts which have a hygroscopic nature. The hydration of the surfaces of these radioactive contaminants is reported to increase Rn-220 emissions.

The radioactive decay scheme for the formation of Rn-220 is depicted in Figure 3.2. The half-life of Rn-220 is only 56 seconds but that was sufficient for the transport of 2,600 curies of the gas through the exhaust ventilation high efficiency particulate air (HEPA) filters and to the environment in 1992. The M-Wing Building 200 hot cells emissions were the major radioactive emissions at the ANL-E site, as reported in Reference 12. The radioactive decay scheme for the Rn-220 to stable Pb-208 is shown in Figure 3.3.

The work scope (technical approach) was to:

1. Prepare the project documentation and mobilize a project team having the required qualifications, training, and experience.
2. Remotely remove radioactive waste and decontaminate the five project hot cells to allow protected entry decontamination.
3. Size-reduce equipment and structures and package them for radioactive waste disposal.
4. Decontaminate the hot cells to restricted-use levels of less than or equal to 10 $\mu\text{Sv/h}$ (1 mrem/h) general radiation background.
5. Characterize, document, and dispose of the radioactive waste.
6. Demobilize, leaving the project hot cells in an empty restricted-use condition.

The technical approach included the purchase, installation, and use of two sets of Central Research Laboratory heavy duty manipulators which were rated for lifting 22.7 kg (50 lb) with the hands and 45.4 kg (100 lb) with the arms. The existing manipulators were rated for lifting 6.8 kg (15 lb) with the hands and, due to the nature of the remote decontamination work, they were continually breaking down. The existing remote control rail cart system was used for movement and transport of remote handled radioactive waste. Tools such as abrasive wheel saws, saber saws, bolt cutters, wrenches, and shears were adapted for in-cell use. Various decontamination techniques were

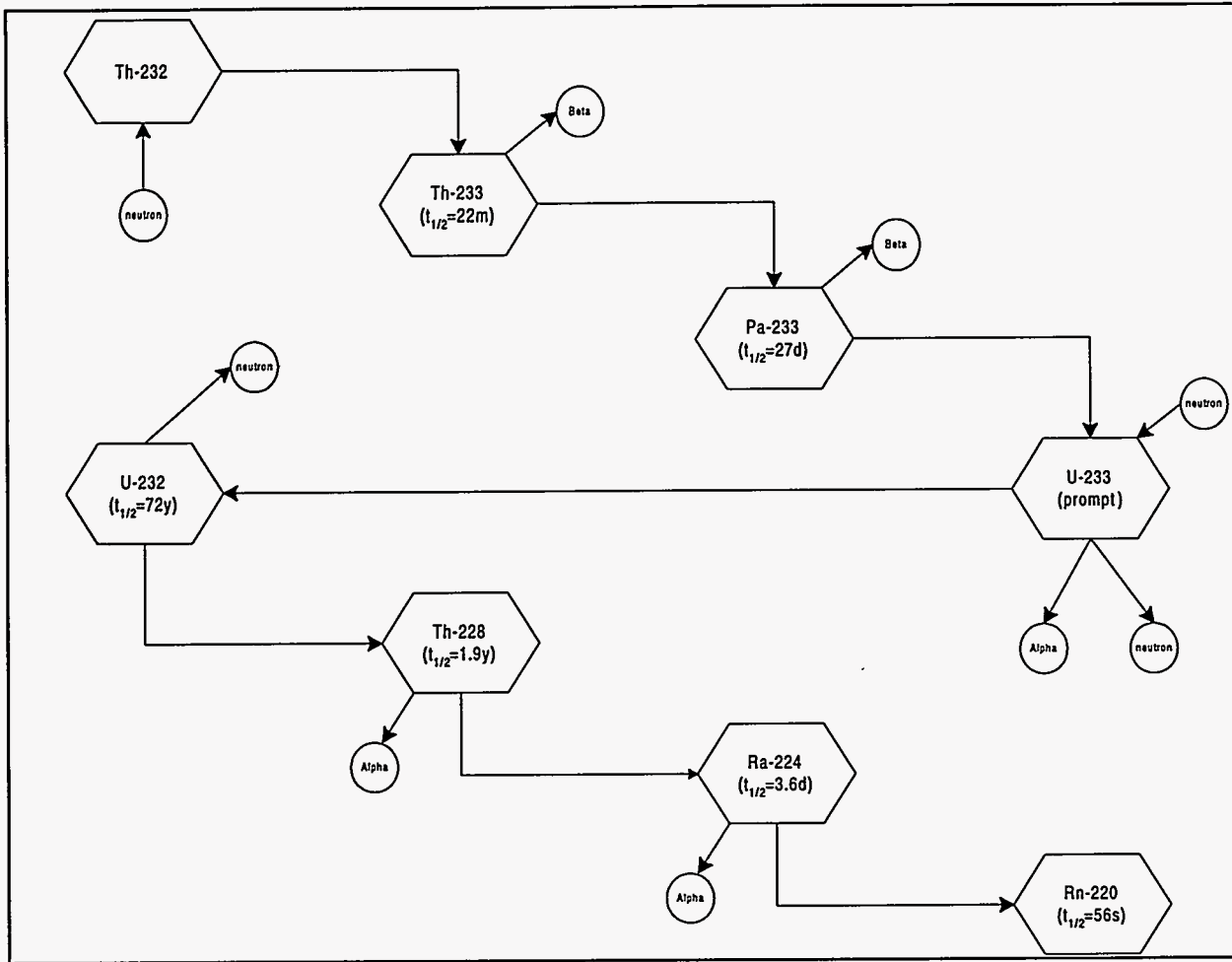


FIGURE 3.2 Predominant Radioactive Decay Pathway for Nuclear Reactor Irradiated Th-232 Containing 2.5% U-233 Leading to the Production of Rn-220

utilized including vacuuming, strippable paint, detergent wetted rags or paper wipes, electrical powered wire brush, and electrical powered needle scabber. A four-station breathing air compressor, compressed air cylinders, small worker-portable compressed backup air cylinders, full-face piece respirators, air distribution harnesses, powered air purifying respirators, and two-way radios were purchased and used for hot cell entries.

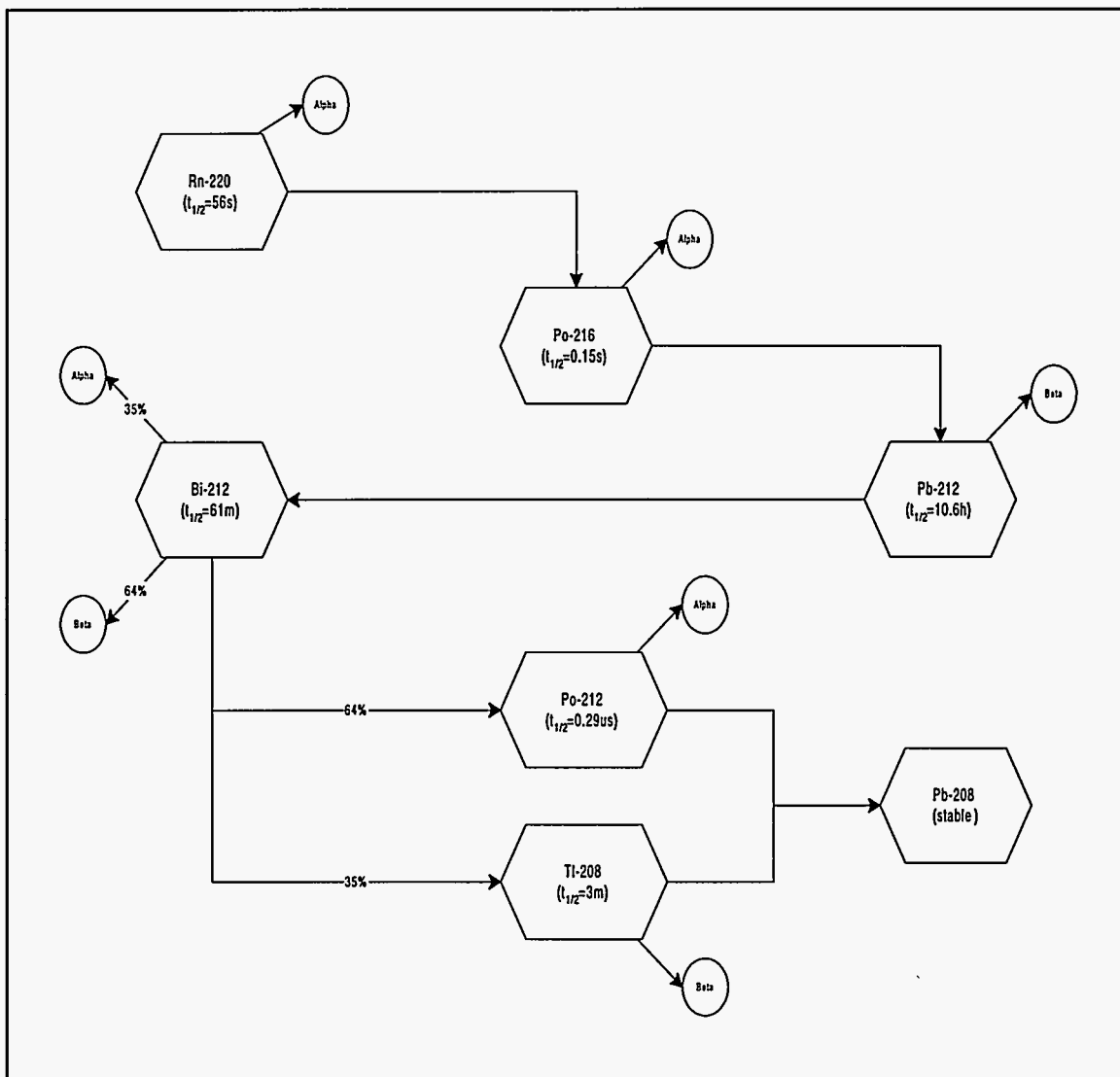


FIGURE 3.3 Rn-220 Decay to Stable Pb-208

4 WORK PERFORMED

4.1 PROJECT MANAGEMENT

The Conceptual Design Report (CDR) for the decontamination of the Proof-of-Breeding Hot-Cells was completed in August 1990. Funding was authorized by the DOE in 1991 and a draft Environmental Assessment (EA) was completed in September 1991. The draft Technical Management Plan was completed in December 1991. In January 1992 the EA was submitted to the DOE. In May 1992 the EA was revised in view of the DOE review comments and it was resubmitted as an Action Description Memorandum (ADM) under the National Environmental Protection Act (NEPA). A Categorical Exclusion was issued by the DOE as the NEPA determination for this project in September 1992.

The project team was assembled, office and storage space was assigned, materials and equipment were procured, and the remote decontamination work was started in June 1992. The project organization chart is shown in Figure 4.1. Before hot cell entry work was conducted, radiation worker training, baseline whole-body counts, hot cell entry decontamination procedures, mock-up training in use of the supplied-air suits and breathing air-compressor station, and Radiation Work Permits were completed. The Project Plan and the Decontamination Plan were revised whenever necessary. Specific procedures were prepared such as for transfer of irradiated reactor fuel samples from Hot Cell A-1.

Project reporting included Weekly Highlights reports, monthly Project Status reports, and Six Month Status reports to the DOE. In addition there were discussions and tours of the project work by DOE personnel and ANL-E ESH personnel. The ANL Nuclear Safety Committee and the ANL-E ALARA Committee had documented interaction on the project.

The hot cells nuclear facility classification was changed from "Category 3" to "Radiological Facility" after transfer of irradiated reactor fuel samples and removal of remote-handled radioactive waste met the requirements for this change. This change was made via a formal request to the DOE.

The project closeout included preparation of a final radiological survey procedure, final radiological survey report, demobilization, completion of the final project report, archiving of project closeout data, and notification of the closeout to the DOE.

4.2 PROJECT ENGINEERING

The project engineering task included planning of work, procurement of special tools, and modification of tools to facilitate remote decontamination and equipment size-reduction work. The

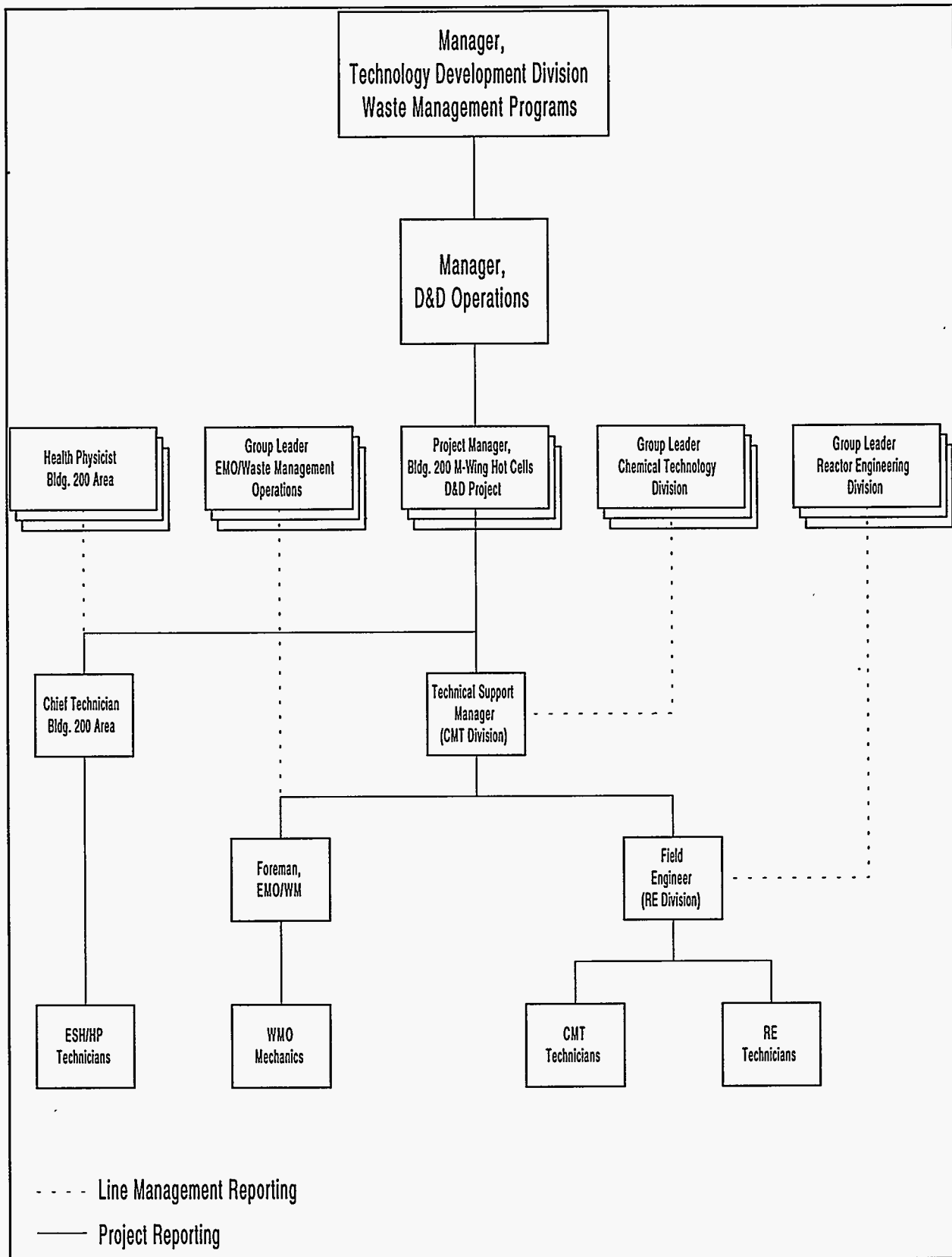


FIGURE 4.1 Project Organization Chart

hot cells already had a radio-operated rail cart system, manipulators, an elevator, and transfer ports in place and in operating condition. To improve the strength and load capabilities for the remote decontamination work, four rugged duty manipulators (two pairs) were purchased for remote size-reduction and handling of equipment in Hot Cell M-1 and other hot cells as needed. Our specifications for these manipulators did not require custom fabrication of parts. Portable tools, such as electrical powered saws and drills, were modified to facilitate handling with manipulator fingers. Cameras and radiation detectors were equipped for remote use in the hot cells to enable external determination of contamination conditions.

4.3 HOT CELL CHARACTERIZATION

Initial characterization was by remote radiation detector surveys of the interior surfaces of the hot cells, using a 0.6 m by 0.6 m (2 ft by 2 ft) grid system, to identify and map all hot spots. This provided radiation level mapping information for remote packaging of waste and decontamination work. The higher levels of radiation were above 1 Gy/h (100 R/h). Smear samples were remotely collected from selected surfaces and were submitted to the Argonne Analytical Laboratory for gamma spectroscopy and alpha radioactivity analyses. The predominant gamma emitter was Cs-137, with approximately equal amounts of the beta emitters Sr-90 and Y-90. U-234 and U-233 alpha emitters were found to be present at less than 1% of the Cs-137 activity level. The ratio of U-234 to U-233 was about three to one.

Radiation detector surveys and smear sampling and analyses were performed both remotely and later in protected entries to obtain information for decontamination and waste packaging. Surveys were often performed in repeated steps to determine the effect of decontamination measures. An on-line computer readout of the Hot Cell M-1, K-1, and M-3 Rn-220 emissions provided an indication of the progress in decontaminating these hot cells. Hot Cell M-3 exhaust stack monitoring was added after the project had started to provide emissions measurements for repackaging and staging of radioactive waste.

An area of radioactive contamination on the floor outside Hot Cell M-1 at the north hot cell window was surveyed with direct reading instruments and dry smears. It was then wipe cleaned and scabbled to a depth of about 2.5 cm (1 in.) in the concrete from the hot cell wall tapering out to the floor surface at about 0.6 m (2 ft) from the wall. This 1.8 m (6 ft) long area was resurveyed, filled in with concrete, and then painted over with red undercoat and top yellow paint to identify a residual fixed radioactivity of 375 Bq (22,500 dpm) beta-gamma/100 cm².

A sample of hard crust residue, about 2.5 cm (1 in.) thick, was remotely chipped out of the waste tanks in Hot Cell M-1 and was analyzed by wet chemistry for radionuclide content. It was found to have a U-233 content above the threshold for transuranic (TRU) waste (100 nCi/g) and was not soluble in concentrated nitric acid. This information led to removal by use of remote chipping

and an electrical powered wire brush. A HEPA filtered vacuum cleaner was used to remotely capture radioactive dust.

A concrete floor area of Hot Cell M-1 was found, by remote surveying, to be highly contaminated. Dissolver acid solution had leaked from the Proof-of-Breeding equipment and seeped through taped joints in the stainless steel sheets covering the concrete floor. After remote wipe cleaning, resurveying, entry wipe cleaning, surface scabbling, and resurveying, a high level of fixed radioactivity remained. This was characterized by coring a 6.3 cm (2.5 in.) diameter by 15 cm (6 in.) deep core sample for radionuclide content analyses. The core sample was sawed into a 7.6 cm (3 in.) lower section and three 2.5 cm (1 in.) sections above. The sections were analyzed by gamma spectroscopy and a chip was removed from the top surface for alpha spectroscopy measurements. It was found that the Cs-137 gamma spectroscopy measurements decreased from 3.33×10^5 Bq (2.0×10^7 dpm) in the upper 2.5 cm (1 in.) section to 1.8×10^2 Bq (1.1×10^4 dpm) in the second 2.5 cm (1 in.) section to 4.5 Bq (2.7×10^2 dpm) in the third 2.5 cm (1 in.) section. The penetration of alkali radionuclides such as Cs-137 into concrete is expected.

The uranium content of a chip from the top of the 15 cm (6 in.) core contained 1.66×10^3 Bq/g (9.95×10^4 dpm/g) alpha from U-232 and U-233, with 75% of the alpha radioactivity attributed to U-232. A chip from the bottom of the core sample contained 0.1 Bq/g (6.5 dpm/g) alpha from U-232 and U-233. The bottom sample may have been slightly contaminated by the process of coring and removing the concrete.

4.4 ALTERNATIVES ASSESSMENT

The principal alternatives for decontamination of the hot cells were to contract out for the work or to plan and do the work with ANL personnel. In view of having to do a significant amount of remote disassembly and decontamination work in order to characterize conditions, and in view of having the necessary internal resources, including a well-qualified technical support manager who had been a member of the Proof-of-Breeding research team, it was decided to do the work with ANL-E personnel. Knowledge of the Proof-of-Breeding work by the technical support manager was a valuable resource. The ANL-E ESH Health Physics personnel were knowledgeable of the hot cells and the radiation monitoring instrumentation.

Other alternatives assessments that were ongoing were the choices of methods used for size-reduction and decontamination work, as detailed in Section 4.6.

4.5 PREPARATIONS

Preparations for decontamination of the project hot cells included the following actions:

- Planning and assignment of project team members.
- Writing project plans and procedures.
- Training project personnel in updated ANL-E radiation control measures, operation of equipment, etc.
- Obtaining baseline bioassay and whole-body radioactivity measurements.
- Communicating with non project personnel in the area to coordinate activities.
- Arranging for office space, equipment storage space personnel dosimetry, bioassay monitoring, lockers, and personal protective equipment.
- Procuring needed tools, equipment, and waste containers.

4.6 DECOMMISSIONING OPERATIONS

The decontamination of the hot cells involved two major phases: remote decontamination and protected entry decontamination.

4.6.1 Remote Decontamination Phase

Due to the high levels of contamination, some measurements greater than 1 Gy/h (100 R/h) in Hot Cells M-1 and K-1, extensive remote decontamination work was required to get down to levels where supplied-air suit entries could be made for hands-on decontamination. Remote decontamination was carried out in each of the five hot cells. The hot cells ranked from most difficult to least difficult to decontaminate as follows: M-1, K-1, M-3, A-1, and K-3.

The initial work involved remote surveying, HEPA vacuum cleaning, wet wipe cleaning, dismantling of equipment, packaging, and segregating the radioactive waste. Conditions in Hot Cell M-1 are shown in Figure 4.2 during the remote decontamination work. Labeled containers contain high-gamma radioactive waste. Equipment in Hot Cell M-1 that has been remotely removed from mountings is shown in Figure 4.3. Wrenches were handled with manipulators to free the equipment.



FIGURE 4.2 Hot Cell M-1 with Labeled Containers of High-Gamma Radioactive Waste (18876K #5)

In order to reduce the background level of radioactivity to allow protected entries, it was necessary to remotely identify the locations and items of higher radioactivity. Remote surveying for radioactive hot spots was performed repeatedly. Figure 4.4 shows remote measurement of radiation levels in Hot Cell M-1. The remote surveying instrumentation was used by the decontamination personnel for remote work decisions. It was not used for personnel exposure measurements or for making decisions for hot cell entries. Health Physics personnel did all of the measurements for health protection with instruments calibrated under their control system.

A camera connected to an external video screen was used for remote observation of conditions that could not be seen from the hot cell windows. Camera observations are depicted in Figure 4.5. The flashlight style camera had a 1-lux light sensitivity, allowing effective observation of conditions inside of tanks without the use of special lighting.

During the remote work phase, highly radioactive waste was generally size-reduced for loading into 3.8-l (1-gal) or 19-l (5-gal) cans. Loading of a 19-l (5-gal) can in Hot Cell M-1 is shown in Figure 4.6. This waste was subsequently placed into 250-l (55 gal) Department of Transportation (DOT) 17C steel drums for remote handled waste shipment.



FIGURE 4.3 Hot Cell M-1 with Radioactivity Contaminated Equipment Remotely Removed from Mountings (18876K #9)

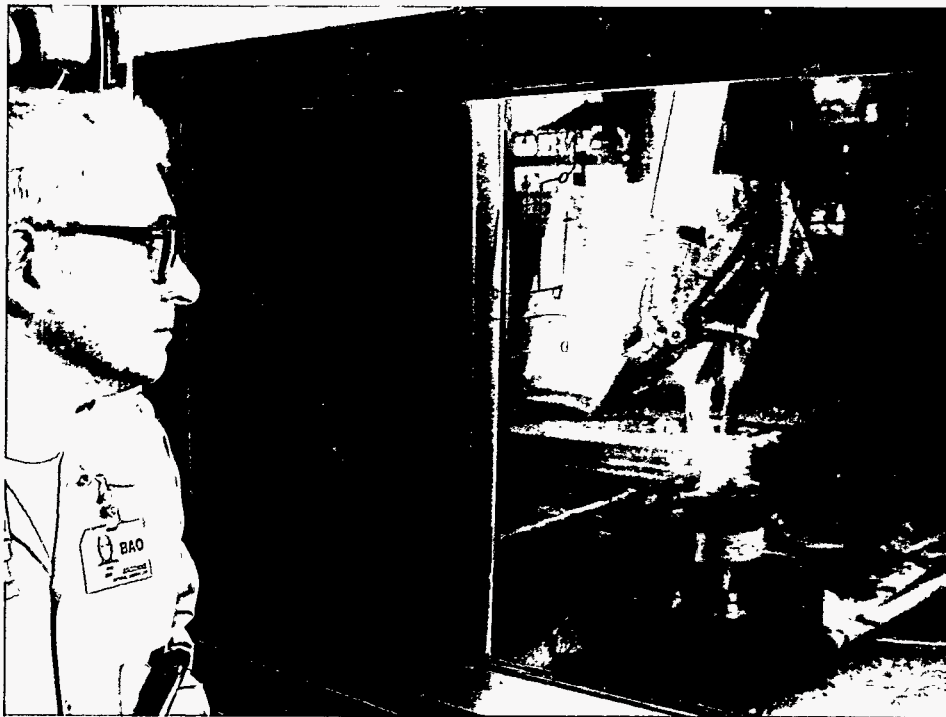


FIGURE 4.4 Remote Measurement of Radiation Levels in Hot Cell M-1 (14479 #33)



FIGURE 4.5 In-Cell Camera and External Video Monitor Viewing Remote Decontamination in Hot Cell M-1 (14479 #4)

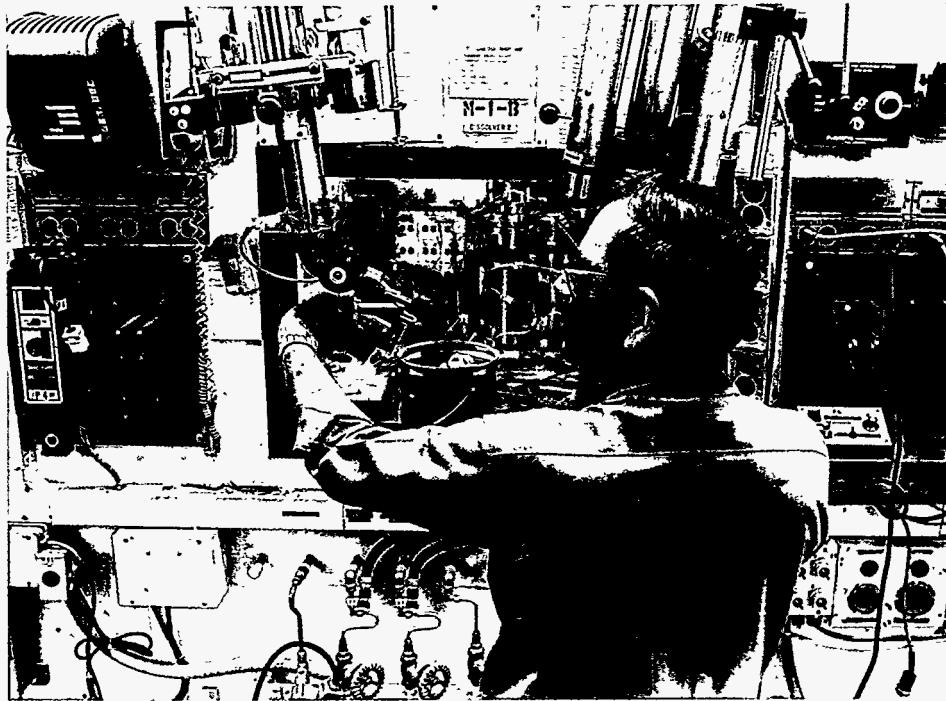


FIGURE 4.6 Remote Loading of Radioactive Waste into a 5-Gallon Can, Hot Cell M-1 (6951 #19)

Remote size reduction techniques included disassembly using wrenches, shearing, sawing, and bending. Remote use of a portable shear is shown in Figure 4.7. The large shear and steel I-beam shear bed in Hot Cell M-3 was difficult to remotely size-reduce. For fire safety reasons it was decided to not use a plasma torch or acetylene torch in the hot cells. Abrasive wheel saw cutting, as shown in Figure 4.8, was used for sizing heavy support framework. A saber saw was used for cutting apart the liquids transfer tanks, as shown in Figure 4.9.

After equipment items and structures were removed it was possible to resurvey and to decontaminate areas that had been inaccessible. Figure 4.10 depicts the remote removal of a mixing station used for concreting of liquid wastes. Repeated vacuuming with portable units that could be used with the manipulators, was required in the hot cells. Figure 4.11 shows remote vacuuming of radioactively contaminated surfaces in Hot Cell M-1. Wiping of contaminated surfaces with cotton rags or absorbent paper wipes that were dampened with an aqueous detergent solution was generally effective in decontaminating defined areas of surface contamination. An aqueous-base strippable decontamination paint was extensively used for decontamination both remotely and in the entry phase. It was applied mainly by paint spraying but also with rollers and brushes. The remote stripping of the decontamination paint is shown in Figure 4.12. It was generally ready to be stripped about eight hours after application.

Remote handling of equipment for removal from Hot Cell M-1 is depicted in Figure 4.13. The radio-controlled mule cart rail system was used to move remote-handled waste. The rail cart was able to transfer a 250-l (55 gal) drum shielding cask.

The remote decontamination phase of the work required continual maintenance work on manipulators. Breakdown of the manipulators was caused by exceeding the design capabilities. It was necessary to remove the dysfunctional manipulators in order to decontaminate and repair them. A manipulator ready for repair work is shown in Figure 4.14. Replacement and tensioning of tape drives on a manipulator are depicted in Figure 4.15. Other equipment, such as the rail-car turntables, also required repair work. Figure 4.16 shows repair of a radio-controlled rail-car turntable.

4.6.2 Protected Entry Decontamination Phase

The protected entries into the hot cells were delayed until remote decontamination work had lowered the radiation exposure levels to a point where the entry exposures were within the ALARA plan guidelines. It was more efficient to conduct the decontamination work by protected entries than by remote work. The procurement of appropriate protective clothing and equipment for entries and dress rehearsal training were carried out prior to work entries. The protective clothing and equipment used for entries is listed in Table 4.1.

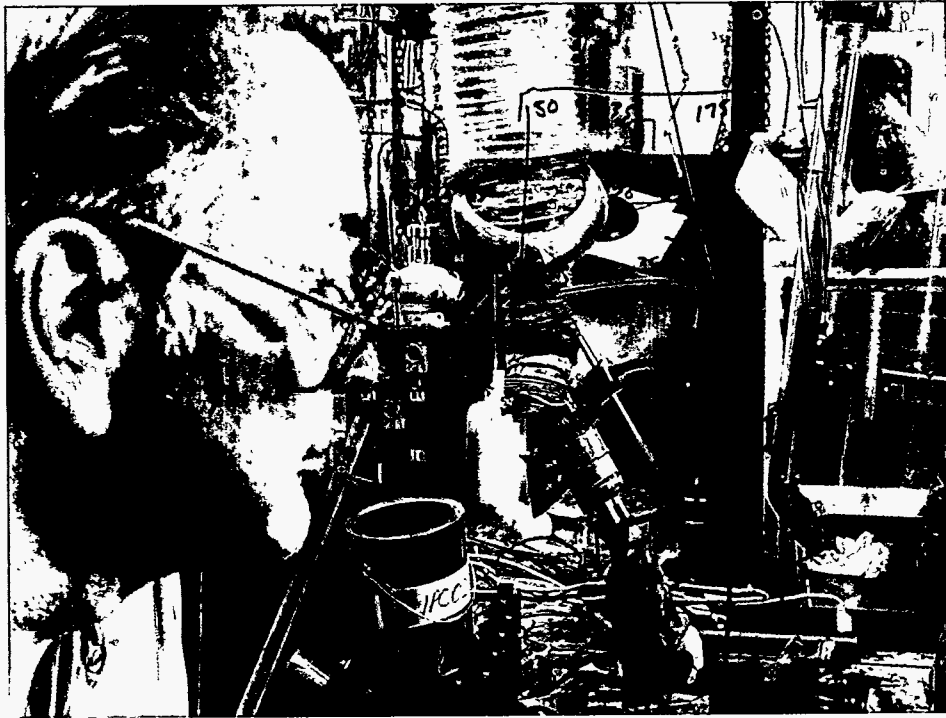


FIGURE 4.7 Remote Use of a Portable Shear Tool (14479 #23)

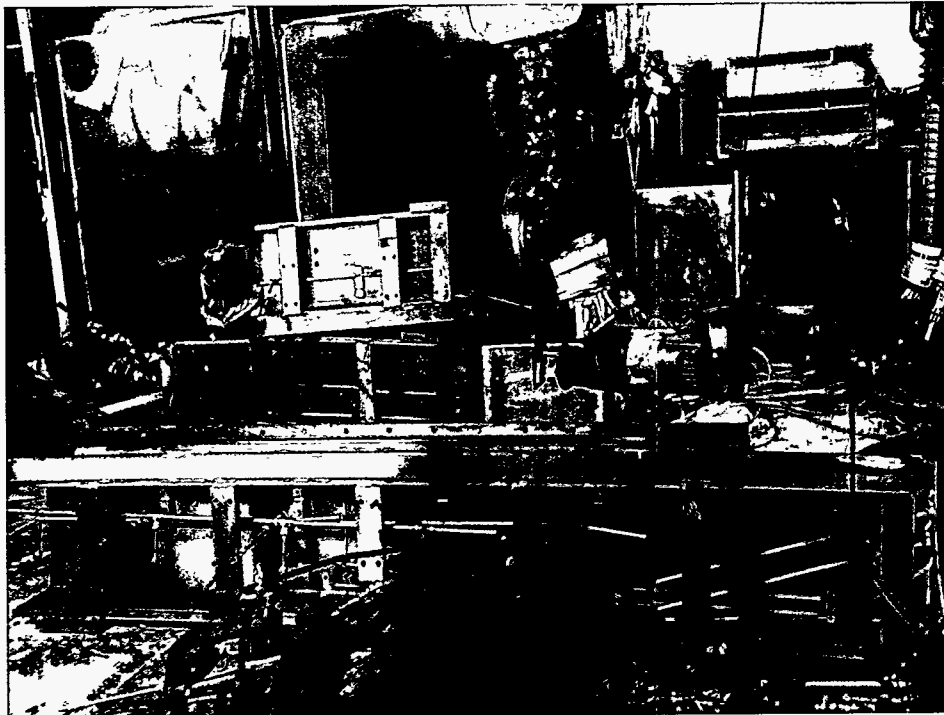


FIGURE 4.8 Remote Abrasive Wheel Circular Saw Cutting the Shear Bed in Hot Cell M-3 (15705 #13)

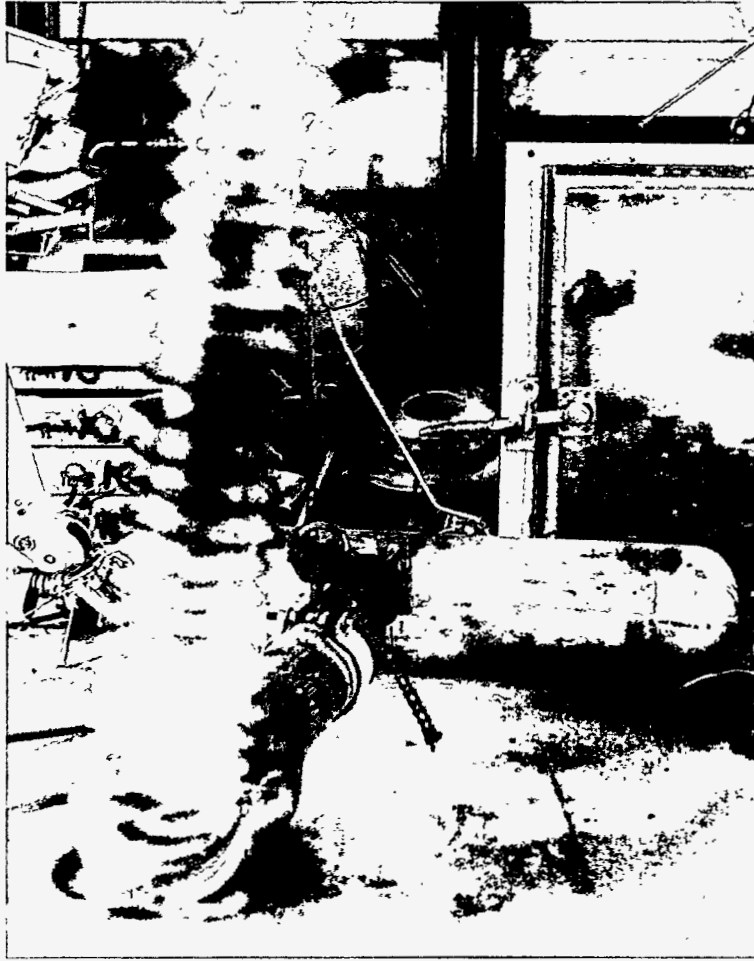


FIGURE 4.9 Remote Sawing of a Liquid Transfer Tank in Hot Cell K-1 (16065 #6)

Protective clothing and equipment are depicted in Figures 4.17 and 4.18. For an entry by two technicians at least five additional support personnel were used.

- One worker for observing through the hot cell window and giving directions to or receiving requests from the technicians inside.
- One worker who served as a valet to help the entry personnel in suiting up and checking their equipment. The valet wore protective clothing to facilitate bringing items to or assisting entry personnel with protective equipment problems even after they had entered the hot cells interior corridor.
- One worker for monitoring the breathing air compressor and compressed breathing air cylinders station, as shown in Figure 4.19.

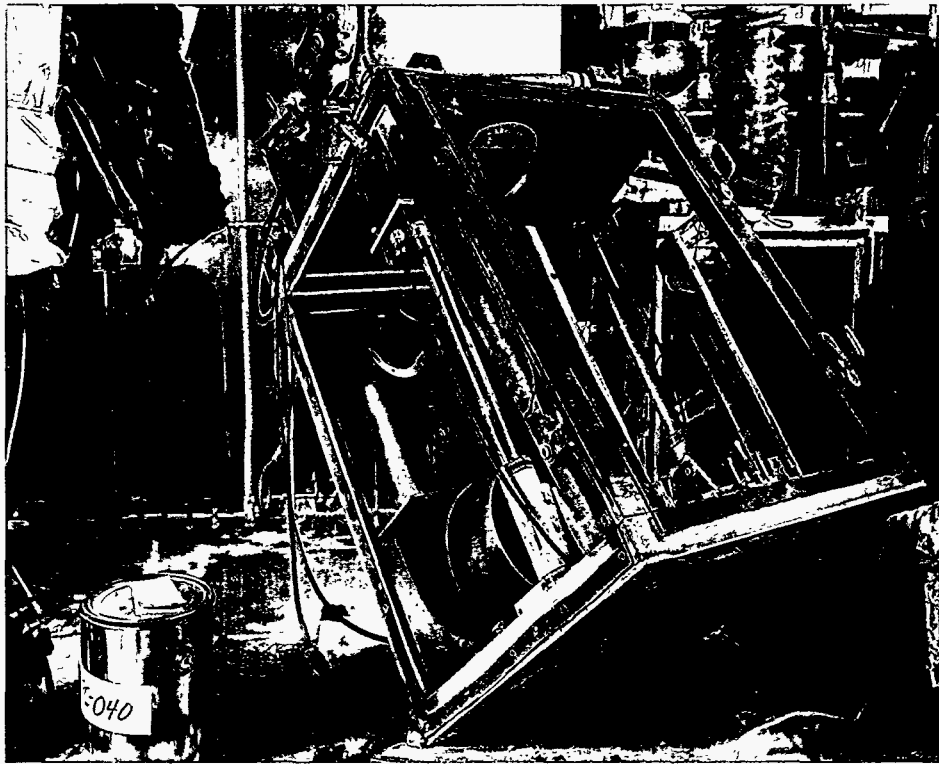


FIGURE 4.10 Remote Removal of a Concrete Mixing Station, Hot Cell K-1 (15705 #6)

- One worker fully suited and ready to enter as a backup entry person in case of an emergency need.
- One worker, the ESH Health Physics technician, who was ready with appropriate instrumentation to check personnel out of the hot cells and was ready for surveying and other assistance in the event of an emergency.

Entry into the hot cells was typically through an isolation tent at the doorway, as shown in Figure 4.20. Inflatable erection tents were used for efficiency of set up and removal. In order to minimize the risk of tearing protective air supplied clothing, sharp edges of equipment such as cut edges were taped as shown in Figure 4.21.

Entry decontamination techniques included HEPA filter vacuuming, and wiping with cotton rags or absorbent paper wipes wetted with an aqueous detergent solution. Strippable decontamination paint was used in repeated steps. Figure 4.22 shows the hands on stripping of decontamination paint. Where radioactive contaminants were fixed on the surface or had penetrated into the matrix, scabbling was applied. The use of a hand-held needle scabber (steel rods) is shown in Figure 4.23.



FIGURE 4.11 Remote Vacuuming of Radioactively Contaminated Surfaces in Hot Cell M-1 (14479 #28)

For more aggressive scabbling, an electrical powered jack hammer was used for the contaminated exterior concrete floor at the north wall of Hot Cell M-1.

Figure 4.24 shows a Health Physics technician monitoring a worker exiting from decontamination work in a Hot -Cell. The final stages of hot cell entry decontamination were carried out using powered-air-purifying-respirators (PAPR's), instead of the air supplied respirators, to provide comfort for workers. This was only after air sampling within the hot cell had shown the air contamination levels to be acceptable for the use of PAPR protective equipment. Figure 4.25 shows a Health Physics technician monitoring a shielding pot using an extended reach radiation detector. Final hand-and-shoe monitor check out from M-Wing is shown in Figure 4.26.



FIGURE 4.12 Remote Removal of Strippable Decontamination Paint, Hot Cell K-3 (16065 #9)

Figure 4.27 shows Hot Cell M-1 after the final clean out and the final radiological survey of conditions. The other four hot cells were also empty. The hot cells central interior corridor, after completion of final radiological surveys, is shown in Figure 4.28.

The external floor area at the north wall of Hot Cell M-1 had been contaminated during the period of research. It was wipe-cleaned and the concrete was scabbled out to a depth of up to 2.5 cm (1 in.) using an electric powered jackhammer. It was then filled in with new concrete, painted with red paint, over painted with yellow paint, and stenciled to indicate the remaining radioactivity. The final condition of this area is shown in Figure 4.29.

Digital dosimeter readout equipment, as shown in Figure 4.30, allowed the immediate assessment of doses received in each hot cell entry. These dosimeters also provided audible alarms at selected set-points for radiation dose rate and accumulated dose.

Thermoluminescence dosimeters and ring dosimeters were worn for monthly analyses.

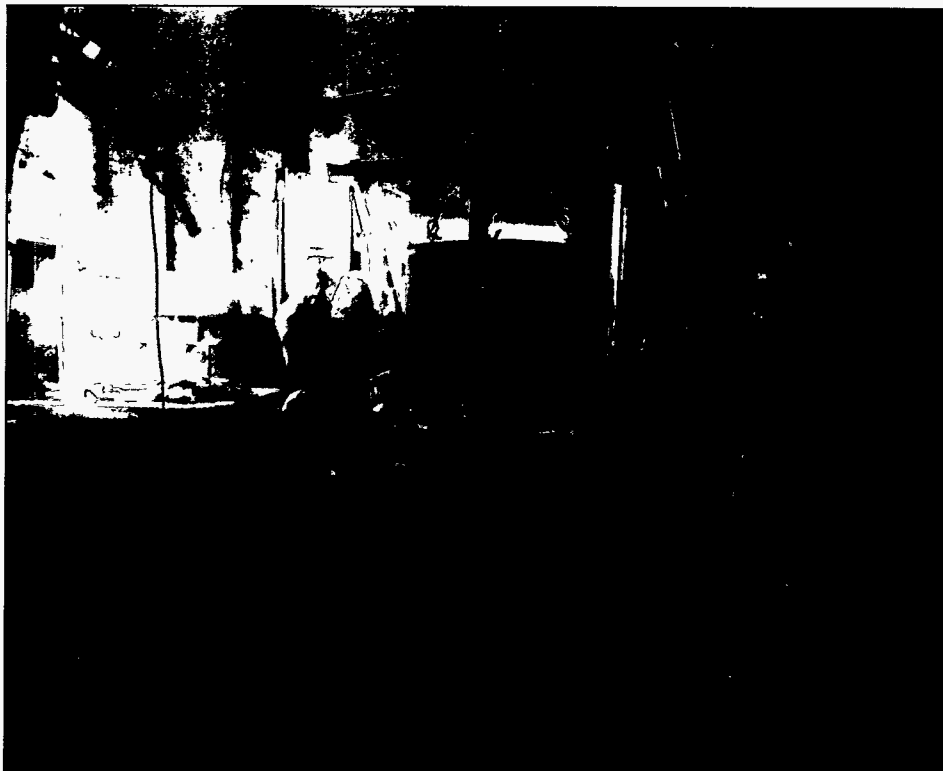


FIGURE 4.13 Technician Directing the Remote Loading of a Dissolver System Waste Tank into a Bin Liner (20537K #14)

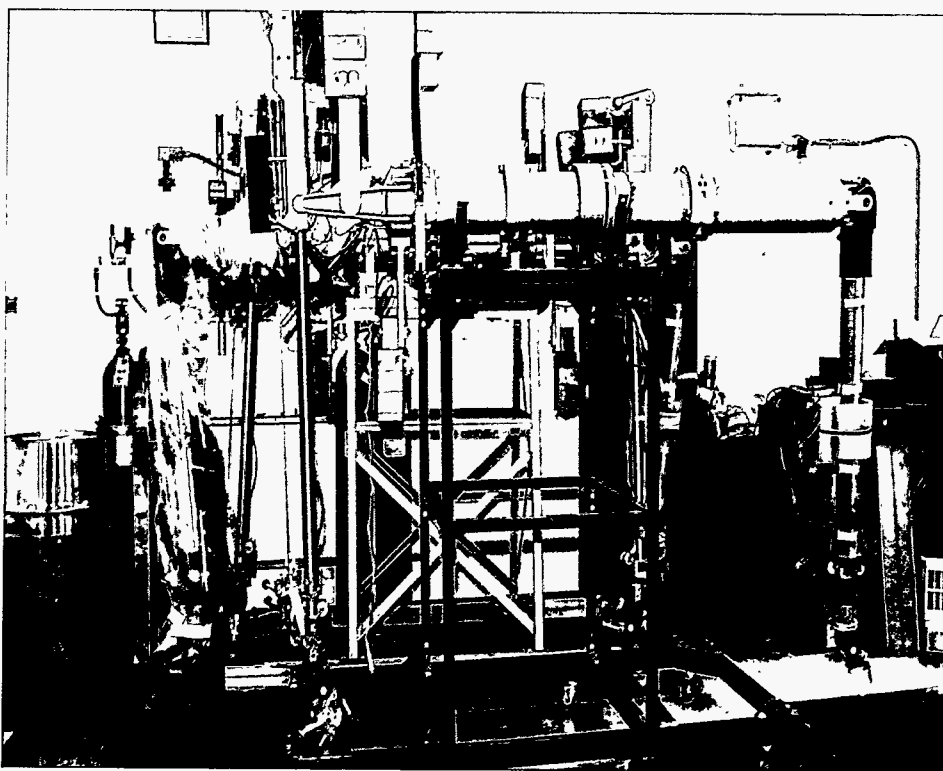


FIGURE 4.14 Manipulator Removed, Decontaminated, and Bagged for Repair (18875 #8)



FIGURE 4.15 Technician Repairing a Manipulator (14478 #7)

On-line computer readout instrumentation for monitoring of hot cells stack emissions, shown in Figure 4.31, was used for tracking progress in cleanup removal of radioactive contaminants.

4.7 WASTE DISPOSAL

Because of the mixed fission product contamination throughout the five hot cells, low level radioactive waste was the major type of waste. Because the gamma radiation from Cs-137 produced a peak reading of 1.45 Gy/h (145 R/h) on the surface of one of the drums, a small fraction of the volume of radioactive waste (2.7%) was remote-handled (>2 mGy or 200 mR/h at the surface of the waste package). Figure 4.32 shows the curie amounts of various radioactive isotopes in the total waste packages.



FIGURE 4.16 Repair of a Radio Operated Rail-Car Turntable in the Hot Cells Interior Corridor (16809 #8)

The radioactive waste was shipped to the DOE Hanford Site for disposal. Figure 4.33 depicts the removal of contact-handled radioactive waste from M-wing, building 200. Figure 4.34 shows the loading of remote-handled radioactive waste drums into a shielded transport cask for truck shipment to the DOE disposal site.

4.8 POSTDECOMMISSIONING RADIOLOGICAL SURVEY

The five project hot cells were not decommissioned but were emptied and decontaminated to restricted use condition. Health Physics did the final radiological survey in accord with their prepared procedure. The hot cells were chalk marked into 1 m square grids on the floors and walls starting in the southwest corners. The intersection of the grid lines was also marked on the floors with ink.

Each grid was directly surveyed for alpha radioactivity with a gas proportional survey instrument in the alpha mode. The hot spots and the general background measurements were logged onto a hot cell map by a technician recorder outside the hot cell. Radio communication was used between the technician inside and the technician recorder outside the hot cell. The recorder observed

TABLE 4.1 Protective Clothing and Equipment for Hot Cell Entries

Undergarments: cotton sports shorts and T-shirt. (It was planned to disrobe to undergarments for an emergency shower).
Anti-contamination (anti-c) coveralls: yellow 8.5 oz cotton with a wide opening at the neck for a step-in feature, a drawstring at the neck, and elastic at the wrists and ankles.
Full Tyvek suits, two worn over anti-c: white with integral boots and hood, zipper front, and elastic at wrists. These suits were taped at the wrists and neck.
Supply air distribution harness for distributing air to all areas of the suit, worn under anti-c.
Full facepiece air-supplied respirator.
Backup five-minute compressed breathing air-supply cylinder, worn under the two Tyvek's with a round handle valve that could be opened without disrobing.
Full vinyl bubble hood, with front and back bibs and with breathing air supply.
Two-way portable radio, with an ear microphone, worn under the two Tyvek's on a web belt over the anti-c with the transmit button operated with the Tyvek's over it.
Three pair of PVC shoe covers worn over the Tyvek boots.
Three pair of thin latex gloves and one pair of heavier outer gloves of rubber or leather.

Note: After experiencing penetration of water soluble radioactive salts through the Tyvek protective suits, a PVC/nylon apron and polyethylene tape over the knees and forearms of the outer Tyvek suit were added for subsequent entries.



FIGURE 4.17 Donning Protective Clothing for a Hot Cell Entry (15411K #11A/12)



**FIGURE 4.18 Technician Suiting-up for a Hot Cell Entry
(15411K #6A/7)**

the grid location through a hot cell window. Each grid was also directly surveyed for beta and gamma radioactivity with an ion chamber instrument that distinguished between beta and gamma.

In addition to the direct survey measurements, each grid was smear sampled over the entire grid area (1 m^2) with a single paper per grid. These large area samples were counted with an Alpha Beta ZnS(Ag) scintillation detector in the integrate mode for one minute for both alpha and beta-gamma radioactivity. Small area (100 cm^2) smear samples were taken near the center of each grid in separate entries and counted for radioactivity in the same way as for the large area smear samples.

4.9 POSTDECOMMISSIONING HAZARDOUS CHEMICAL CONDITION

There were no remaining hazardous chemicals. Eight and a half tons of contaminated lead bricks in Hot Cell M-1 were packaged into five wooden boxes and two 208-1 (55-gal) drums. The

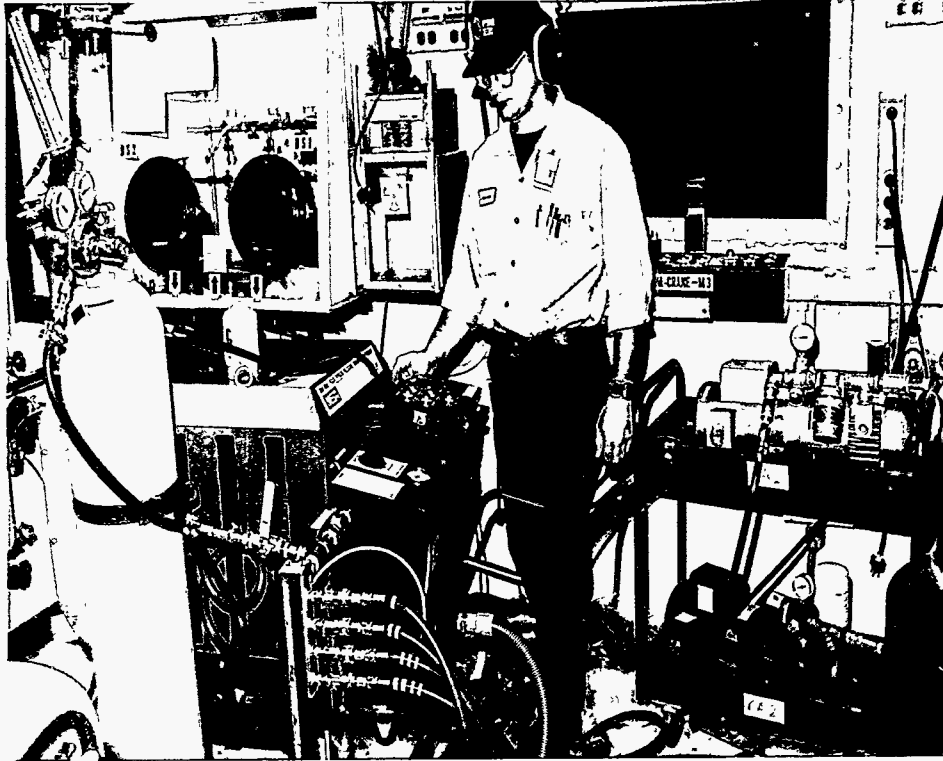


FIGURE 4.19 Technician Monitoring the Compressed Breathing Air Supply Station During a Hot Cell Entry (15409K #11)

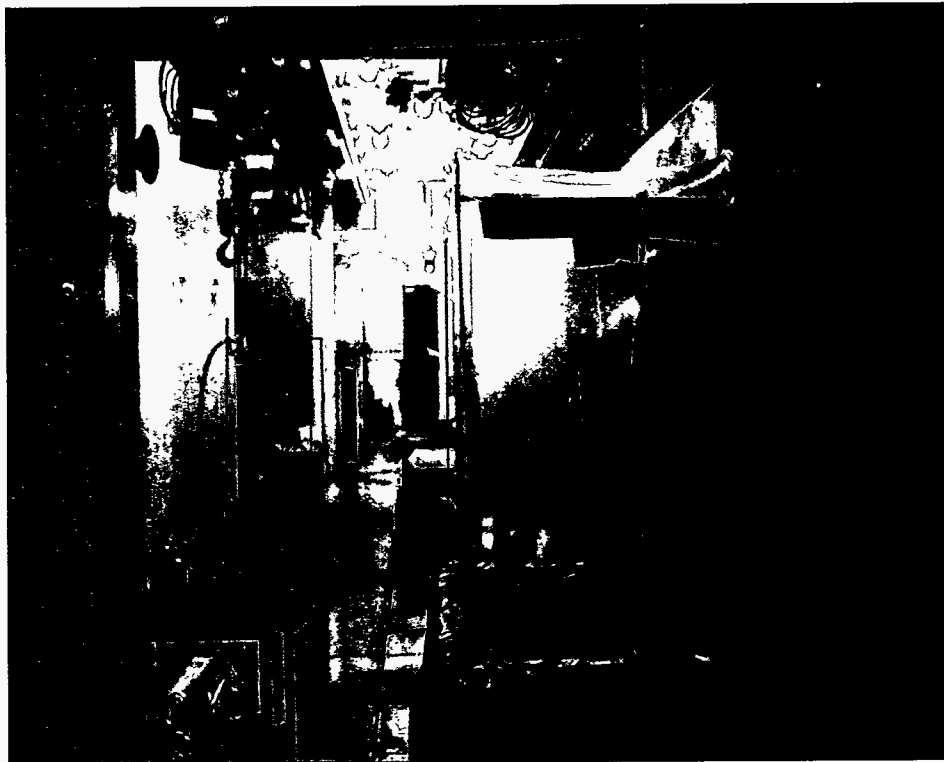
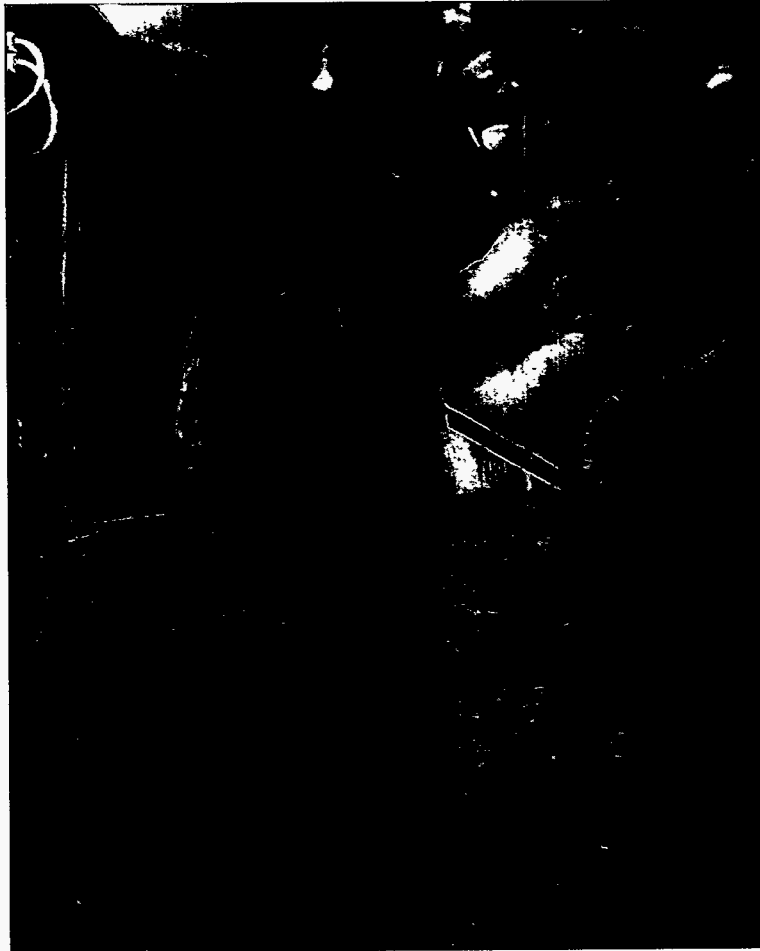


FIGURE 4.20 Technicians Making a Full-Suited Hot Cell Entry Through an Isolation Tent (19242K #6A)



FIGURE 4.21 Taping Sharp Edges of Size-Reduced Equipment (15410 #33)

packaged lead was transferred to ANL-E Waste Management Operations (WMO) for decontamination and recycling. Hot Cell M-1 was cleaned subsequent to the removal of the lead bricks. One 18.9-l (5-gal) metal can which was partially full of mixed waste was documented and taken to an ANL-E Waste Management storage space in compliance with the Resource Conservation Act (RCRA) regulations. This can contained mercury vapor lamps.



**FIGURE 4.22 Technician Removing Strippable
Decontamination Paint, Hot Cell K-3 (18874K #26)**



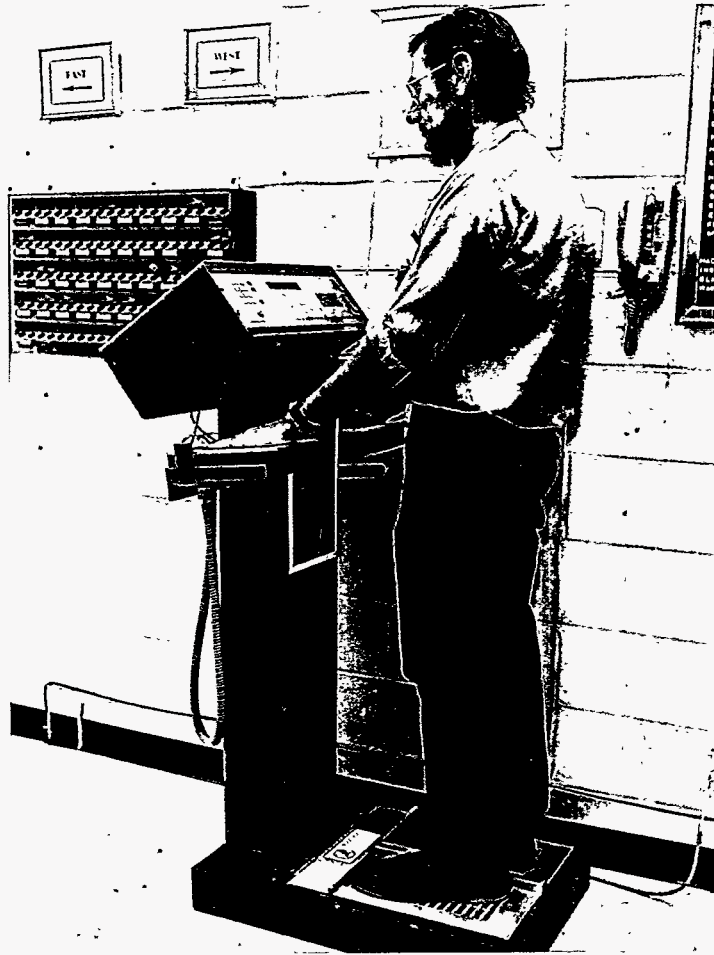
FIGURE 4.23 Technician Using Hand Held Vacuum Equipped Scabbler to Remove Fixed Radioactive Contamination from the Concrete Floor of Hot Cell M-1 (20728K #30A)



FIGURE 4.24 Health Physics Technician Performing a Hot Cell Exit Survey of a Worker After Removal of Outer Protective Clothing (16065 #32)



FIGURE 4.25 Health Physics Technician Using an Extended Reach Radiation Detector for Monitoring a Shielding Pot (16065 #30)



**FIGURE 4.26 Final Hand-and-Shoe Monitor Survey
(15705 #17)**

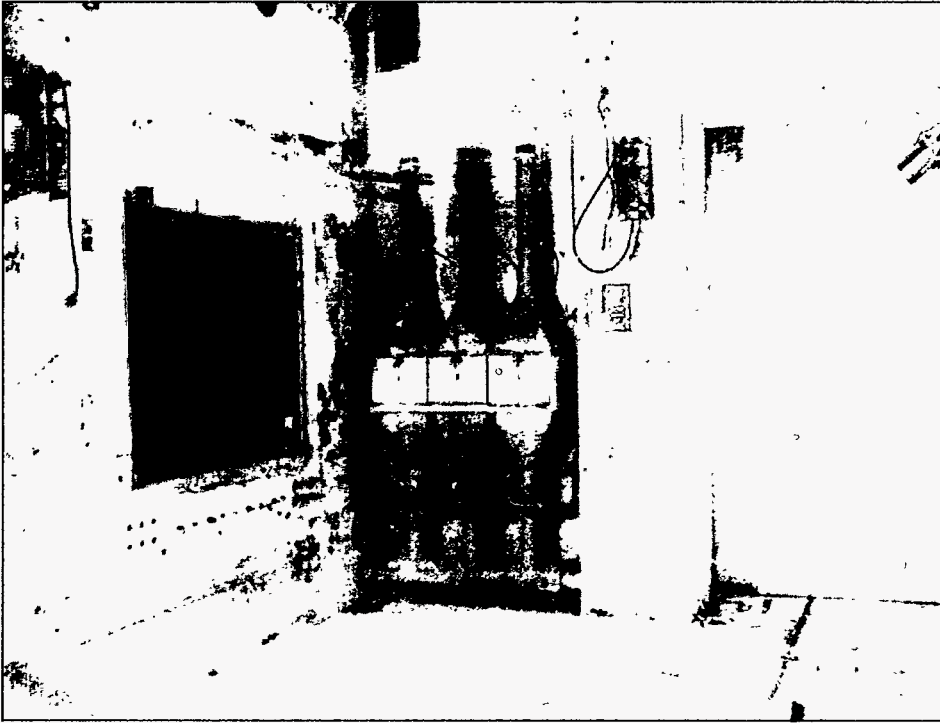


FIGURE 4.27 View of Hot Cell M-1 After the Final Radiological Survey (21249K #14)



FIGURE 4.28 View of Megacurie Hot Cells Central Corridor After the Final Radiological Survey (21249K #8)

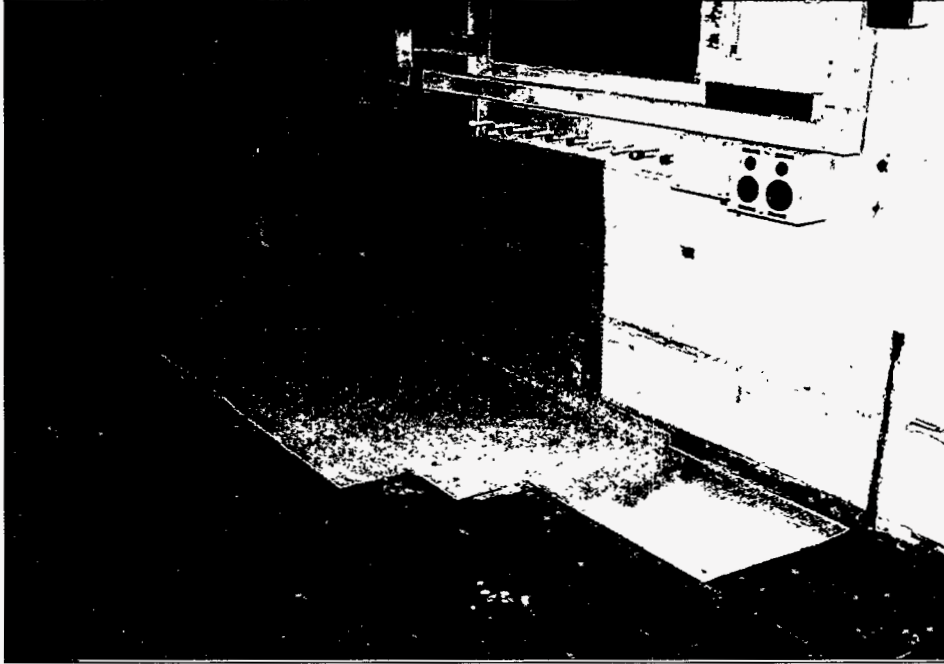
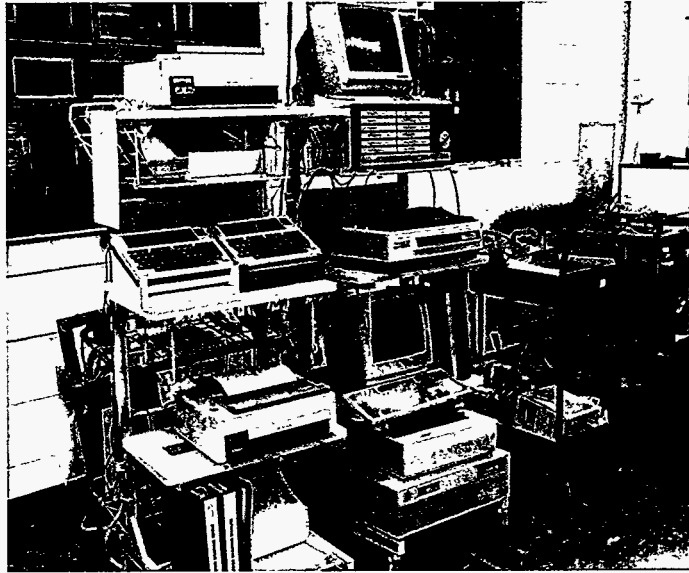


FIGURE 4.29 North Wall of Hot Cell M-1 Exterior Area After Scabbling, Concrete Patching, and Painting (21249K #3)



FIGURE 4.30 Dosimetry Readout Equipment (15705 #8)



**FIGURE 4.31 On-Line Computer Readout
Instrumentation for Monitoring Hot Cells Stack
Emissions (16065 #13)**

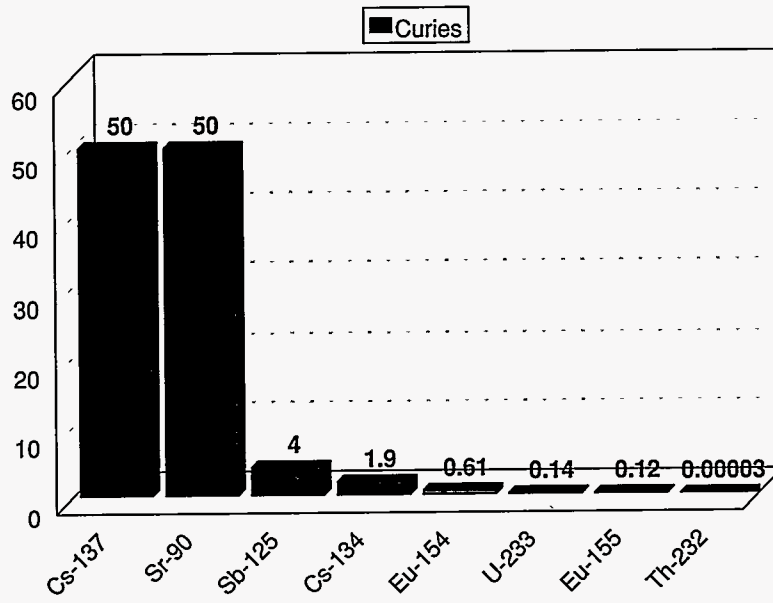


FIGURE 4.32 Radionuclide Distribution

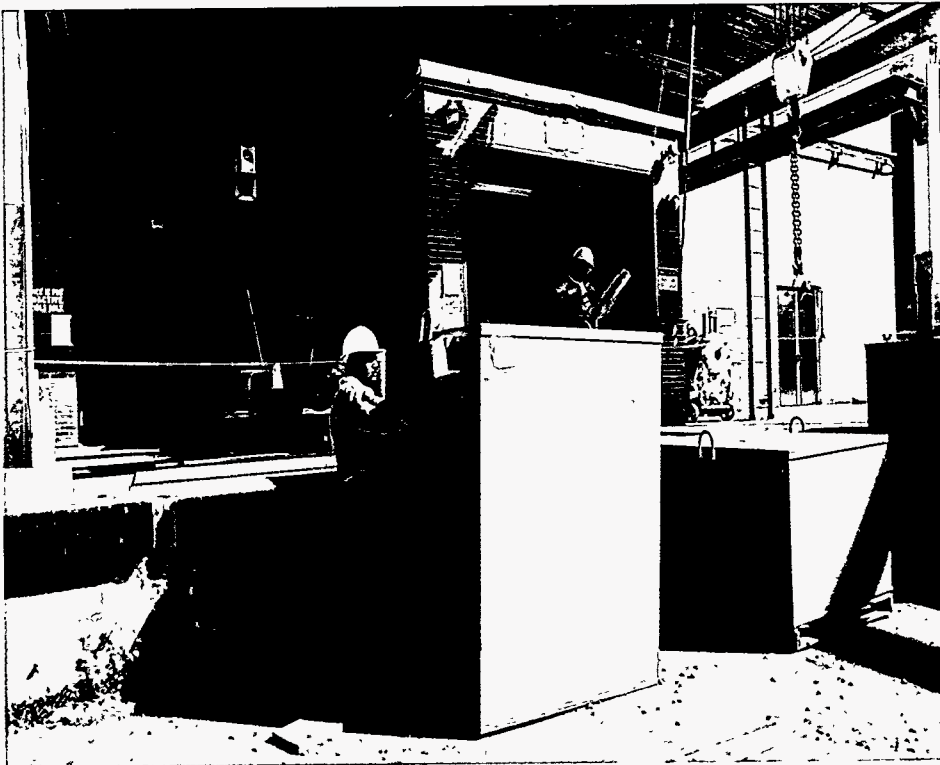


FIGURE 4.33 Removal of Packaged Radioactive Waste from M-Wing
(20536K #22)

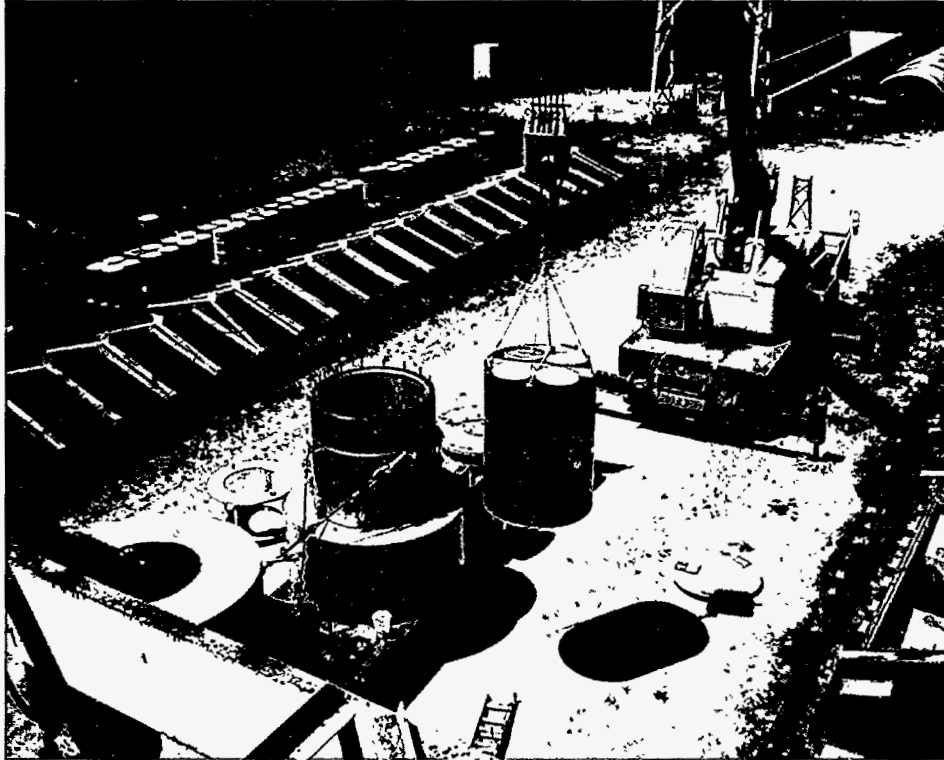


FIGURE 4.34 Loading of Remote-Handled Radioactive Waste Drums into a Shielding Cask for Truck Transport

5 COSTS AND SCHEDULES

The project costs were \$5.8 million with the estimated cost breakdown as shown in Figure 5.1 below. The cumulative earned value over the life of the project is shown in Figure 5.2.

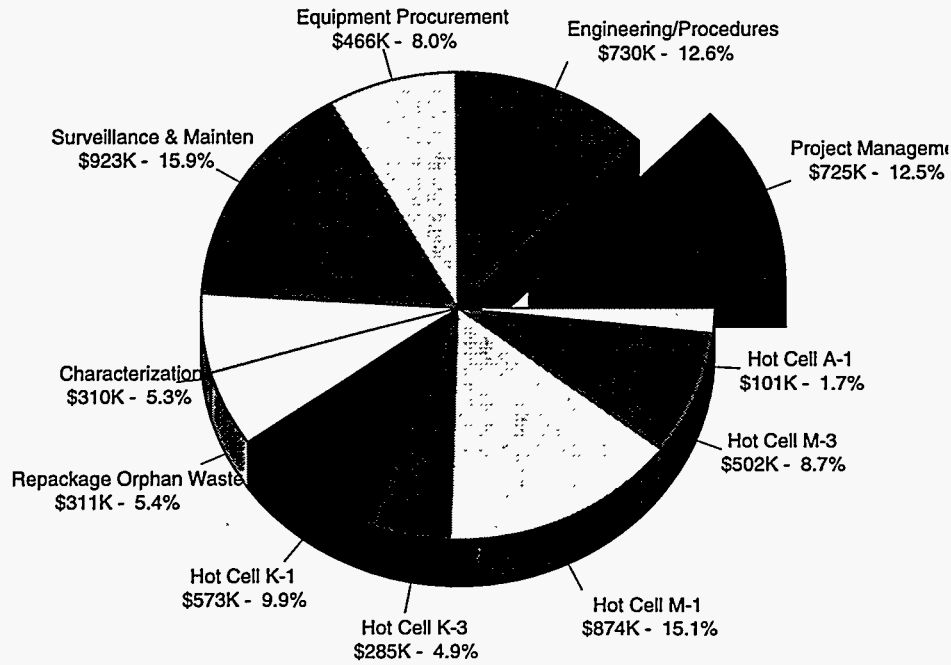
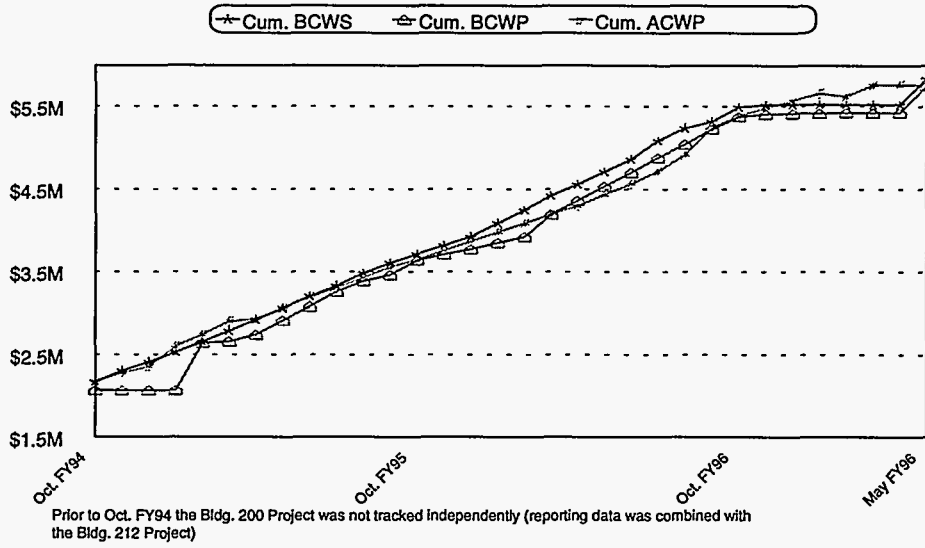


FIGURE 5.1 Activity Breakdown of Project Costs



ACWP: Actual Work Cost Performed
 BCWP: Budgeted Work Cost Performed
 BCWS: Budgeted Work Cost Scheduled

FIGURE 5.2 Cumulative Earned Value

Table 5.1 shows the project baseline schedule compared to the actual work performance.

TABLE 5.1 Project Schedule: Baseline/Actual^a

Activity	Planned		Actual	
	Start	Complete	Start	Complete
Technical Management Plan	b	b	12 Sep. 91	5 Dec. 91
Hot Cell M-1: Remote decon	7 Oct. 94	23 March 95	11 June 92	21 July 95
Hot Cell M-1: Entry decon	24 March 95	26 June 95	28 July 95	15 Dec. 95
Hot Cell M-3: Initial remote decon	b	b	18 June 92	19 March 93
Hot Cell M-3: Initial entry decon	b	b	25 March 93	24 Sep. 93
Hot Cell M-3: Final entry decon ^c	11 Aug. 94	18 Nov. 94	14 Aug. 95	30 Oct. 95
Hot Cell K-1: Remote decon	15 March 94	8 June 94	9 July 92	19 Aug. 94
Hot Cell K-1: Entry decon	9 June 94	23 Aug. 94	25 Aug. 94	17 March 95
Hot Cell K-3: Remote decon	22 Oct. 93	20 Dec. 93	18 Oct. 93	17 Dec. 93
Hot Cell K-3: Entry decon	21 Dec. 93	23 Feb. 94	10 Jan. 94	4 March 94
Hot Cell A-1: Remote decon	5 Jan. 94	19 April 94	4 Oct. 93	10 June 94
Hot Cell A-1: Entry decon	20 April 94	29 July 94	5 July 94	9 Sep. 94
Repackage Eight Waste Drums (remote)	15 Oct. 93	17 Dec. 93	25 Oct. 93	15 Dec. 93
Final Radiological Survey Report	14 Aug. 95	16 Nov. 95	16 Dec. 95	2 March 96

Note: Actual start dates for Hot Cells M-1, M-3, K-1, and A-1 remote decontamination (decon) work was earlier than the dates shown in the baseline plan. The remote decontamination work on these hot cells was deferred as other project work took precedence.

^a Delays occurred due to unplanned safety reviews and to needed extensive remote decontamination in Hot Cell M-1.

^b Completed prior to approval of the May 1994 baseline report.

^c Hot Cell M-3 was used for staging and sorting of remote handled radioactive waste after initial remote and entry decontamination. Final entry decontamination work was conducted about two years later.

6 WASTE VOLUMES

There were 156 containers of radioactive waste generated in this project with a total volume of 79.1 m³ (2,824 cf) and a total weight of 23,496 kg (51,753 lb). Ten 208-1 (55-gal) drums, having a total volume of 2.1 m³ (75 cf) and weight of 1,028 kg (2,265 lb), were remote-handled waste. The radioactive waste was all nonTRU waste with the highest U-233 content at 45 nCi/g (1.67 TBq), below the 100 nCi/g (3.7 TBq) threshold for TRU waste. A comparison of the amount of radioactive waste generated to the amount forecast is shown in Figure 6.1. Waste volumes, by category (contact handled or remote handled), and radioactivity content of categories are summarized in Table 6.1.

The contact-handled waste containers all read less than the 2 mGy/h (200 mR/h) limit at the container surface. The highest survey reading on the surface of a remote-handled waste drum was 1.45 Gy/h (145 R/h).

In addition to the radioactive waste there were 0.68 m³ (24.2 cf) of radioactively contaminated lead shielding bricks that were taken by ANL-E Waste Management for decontamination and recycling use. The weight of the lead shielding bricks was 7,759 kg (17,090 lb). These bricks had provided radiation shielding around the waste tanks in Hot Cell M-1.

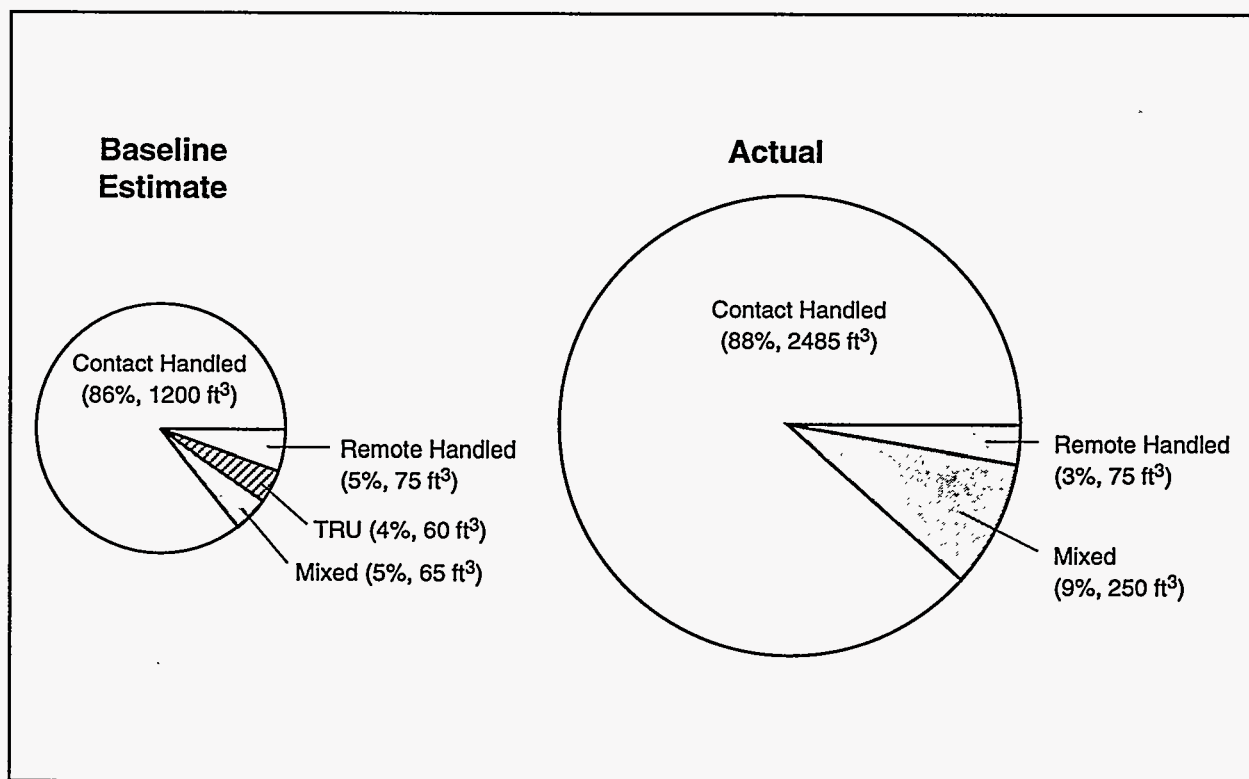


FIGURE 6.1 Comparison of Radioactive Waste Generated to the Amount Forecast

TABLE 6.1 Radioactive Waste

Waste Category	Volume	Radioactivity
Contact Handled		
10 full size M-3 bins	33.6 m ³ (1,200 cf)	
14 half size M-3 bins	26.3 m ³ (938 cf)	
39 drums	8.2 m ³ (292.5 cf)	
76 TV cartons	8.5 m ³ (304 cf)	
3 bags	0.3 m ³ (12 cf)	
2 small bags	0.03 m ³ (1 cf)	
2 cans	0.04 m ³ (1.4 cf)	
Subtotal	76.97 m ³ (2,748.9 cf)	0.283 TBq (7.65 Ci)
Remote Handled		
10 drums	2.1 m ³ (75 cf)	3.79 TBq (102.35 Ci)
Total	79.07 m ³ (2,823.9 cf)	4.07 TBq (110.0 Ci)

7 OCCUPATIONAL EXPOSURE TO PERSONNEL

The radiation doses to project personnel were well below regulatory guidelines. The collective dose for the entire project was approximately 74.5 person-mSv (7.45 person-rem) or 80.1% of the collective dose forecasted in the project ADM. Table 7.1 gives skin (shallow), extremity (finger), and whole-body estimated doses for hot cells decontamination and drum repackaging, and the total measured doses for the project.

The difference in the collective total measured dose and the estimated collective dose for the hot cells and drums repackaging are due to workers wearing dosimeters for all operations during one month. Part of the dose was then assigned to two operations. The total measured dose is the dose of record.

Figure 7.1 shows the cumulative radiation exposure to project personnel plotted on a time line as compared to the forecast radiation exposures. The low exposures in the early phases reflect the large proportion of remote decontamination work and the strategy of doing the least contaminated hot cells first. The steep slopes later in the project (from May 94 to Oct. 94 and June 95 to Oct. 95) resulted from protected entry decontamination work in Hot Cells K-1 and M-1.

TABLE 7.1 Project Collective Radiation Dose

	Shallow-skin		Extremity-finger		Whole Body	
	Estimated		Estimated		Estimated	
	mSv	rem	mSv	rem	mSv	rem
Hot-Cell A-1	8.4	(0.84)	6.5	(0.65)	3.3	(0.33)
Hot-Cell K-1	71.0	(7.1)	49.0	(4.9)	20.0	(2.0)
Hot-Cell K-3	3.0	(0.3)	3.7	(0.37)	0.4	(0.04)
Hot-Cell M-1	188.0	(18.8)	113.0	(11.3)	43.0	(4.3)
Hot-Cell M-3	30.0	(3.0)	19.0	(1.9)	5.0	(0.5)
Drums repack	4.4	(0.44)	4.7	(0.47)	4.0	(0.4)
Total (estimated)	304.8	30.48	195.9	19.59	75.7	7.57
	Measured		Measured		Measured	
Total (measured)	301.6	(30.16)	194.7	(19.47)	74.5	(7.45)

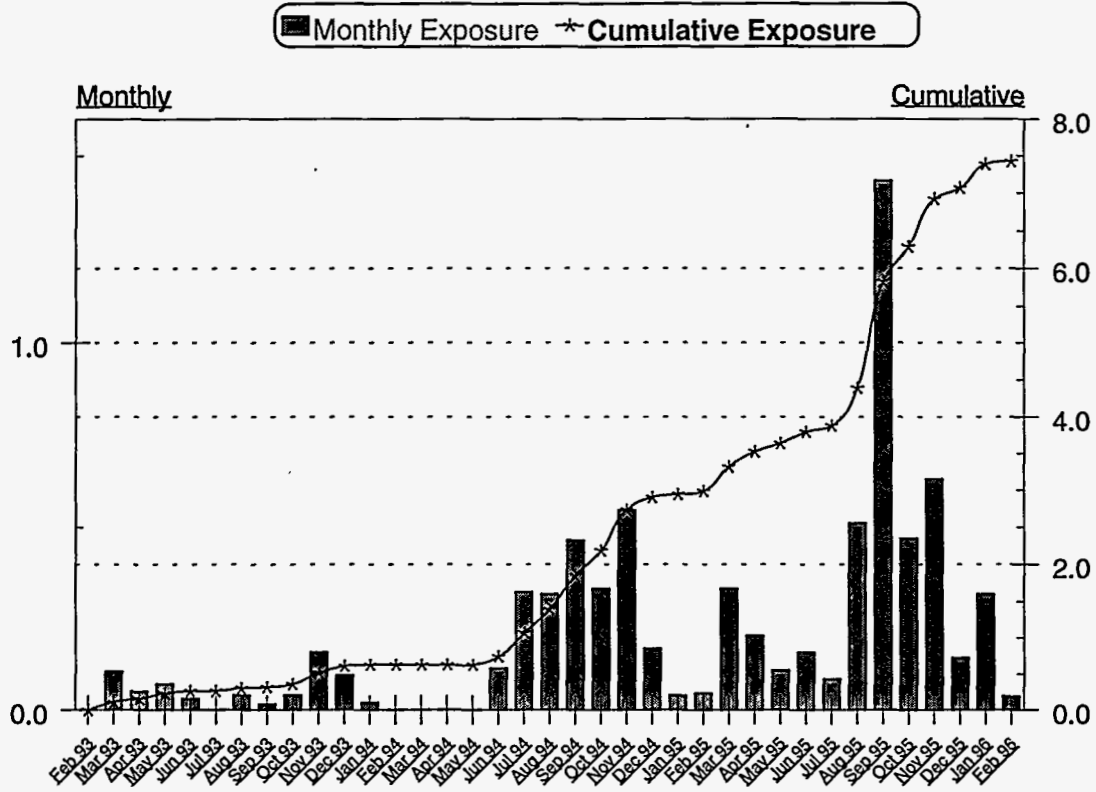


FIGURE 7.1 Cumulative Collective Radiation Dose

8 FINAL FACILITY STATUS

The five hot cells were emptied and decontaminated for restricted use status. The hot cells were left in restricted use status with general radiation levels at 1.75 m (5.75 ft) above the floor as follows:

Hot Cell K-3 <2 μSv (<0.2 mrem)/h

Hot Cell M-3 <2 μSv (<0.2mrem)/h

Hot Cell K-1 <5 μSv (<0.5 mrem)/h

Hot Cell A-1 25 μSv (2.5 mrem)/h

Hot Cell M-1 50 μSv (5 mrem)/h*

* Plastic encased lead blankets were left on the floor of M-1 over the area where radionuclides had penetrated into the concrete. The radiation level directly over the lead blankets at 1.75 m (5.75 ft) was 100 μSv (10 mrem)/h. Without the lead blankets the radiation level would be higher.

9 LESSONS LEARNED AND DOE REPORTABLE OCCURRENCES

This section describes lessons learned for accomplishing future decontamination work more safely and/or more effectively and describes DOE reportable occurrences for this project. Each of the occurrences were reviewed for lessons learned and to determine changes to avoid a recurrence.

9.1 LESSONS LEARNED

- Procedures for rechecking air line connections, etc., are needed to provide safety assurance. Supplied airline connections separated while personnel were working in a contaminated hot cell because connections had not been tightened sufficiently.
- Backup personal protective systems are needed for radioactive decontamination work. This was shown to be needed in the occurrence where supplied air lines became disconnected. The backup system of compressed breathing air cylinders was of no use because the air supply lines were disconnected. The secondary backup system of having personnel carry a small five-minute valved compressed air supply cylinder under the outer protective suit supplied breathing air for a safe evacuation. There was no intake of radioactivity.

A need for backup systems was also apparent when the breathing air compressor failed while personnel were suited-up, but prior to entry into a contaminated hot cell.

- It is important to establish effective procedures and controls to avoid spreading radioactive contamination when manipulators and other remote control devices are removed for decontamination and repair. Our initial procedure was to decontaminate the equipment in the hot cells interior central corridor area, wrap the parts having residual contamination with plastic sheeting, and then move the equipment to the area outside the hot cells for repair. It was found that this was not sufficient for the control of hot particles. Procedures were added to provide more extensive wrapping for transport, to have a Health Physics technician survey behind the equipment being moved, and to conduct frequent wide-area floor-smear surveys.
- It was found that using remote chipping, an electric drill powered wire brush, and a portable in-cell HEPA filtered vacuum cleaner was an effective method

for removal of a 2.5 cm (1 in.) hard crust layer of dried radioactive residue remaining inside two stainless steel dissolver tanks.

- Strippable aqueous-base decontamination paint was found to be effective for both remote and entry application in the contaminated hot-cells. It was visibly effective in removal of radioactive dirt from the cracks between steel plates forming the false floors of the hot cells. It was also effective for application over contaminated hot cell wall coverings (wall paper) for removal as a sandwich with the wall covering material to minimize recontamination of hot cell surfaces.
- Remote usage of an in-cell flashlight-style camera having 1-lux light sensitivity proved to be advantageous for remote viewing in hidden locations such as behind or underneath equipment and inside of tanks. The images were observed on a video screen located outside the hot cell at a window where the internal movements of the camera and the projected picture could be correlated. In this manner the video information can also be recorded if desired.
- Where there are soluble radioactive contaminants present it is prudent to cover protective clothing contact areas with impervious tape (or other suitable protection) to prevent contact of contaminants with protective clothing wetted by sweat. An alternative for knee areas would be to wear knee pads over the protective clothing to avoid contamination of the knees and to improve comfort while kneeling. Radioactive contaminants penetrated through intact protective clothing onto the skin of a worker's knees during decontamination of a hot cell floor because the clothing contact areas had become wetted with sweat and radioactive salts were present as contaminants.
- It is better to have automatic counting times at hand-and-shoe monitoring stations to help ensure that personnel will check out of the radiation control area properly. Our monitoring stations were upgraded during the project to avoid the administrative control problems involved in trying to avoid inadequate counting times.
- The usage of dosimeters with audible alarming at set points for radiation level and accumulated exposure was a good ALARA control measure. The immediate readout of the dosimeters following a cell entry provided information to the workers and the supervisor for exposure control planning. The supervisor was able to maintain a current record of individual exposures to compare to monthly exposure limits. Monthly readout of

thermoluminescence dosimeter (TLD) badges was supplemented by usage of the above dosimeters.

- It was important for workers to utilize the supplied air-distribution harnesses to distribute air throughout and to the extremities of their multiple-layer full-protective suits. This was needed to provide effective cooling and to reduce sweat moisture. Also the bubble hood had an air supply.
- By using inflatable containment tents at the doorways to the hot cells, the setup time was reduced to 25% of the time required for the non-inflatable type.
- It was effective to progress from the least contaminated hot cell to the most difficult to decontaminate. In this manner the decontamination procedures and the radiation control measures were improved for the more difficult work. Personnel became more proficient with time and were able to do tasks quicker when the higher levels of contamination were addressed, thereby minimizing exposure.

9.2 DOE REPORTABLE OCCURRENCES

There were five DOE reportable occurrences over the course of this project, as follows:

- CH-AA-ANLE-ANLEEW-1993-0004 Final Report dated 08/11/1993. This off-normal occurrence was radioactive contamination of work clothing trouser leg and of a work shirt. It was discovered at 1030 Central Time Zone (CTZ) on April 19, 1993. The source of the contamination was an air supply hose which brushed against a trouser leg following removal of two protective Tyvek suits. This occurred in an isolation tent at the entrance to Hot Cell M-3. The contamination was 500 Bq (30,000 dpm)/100 cm² beta-gamma assumed to be Cs-137 and Sr-90 based on characterization samples from the hot cell. There was no skin contamination detected. The work shirt was contaminated by brushing it with a contaminated respirator facepiece hose. The contamination level was 1,330 Bq (80,000 dpm)/100 cm² beta-gamma and no skin contamination was detected. Corrective actions included limiting the number of persons inside the hot cell entry/exit tent and adding a layer of anti-contamination clothing under the Tyvek protective suits. Training in disrobing techniques had been given prior to the occurrence.
- CH-AA-ANL-ANLEEW-1993-0005 Final Report dated 08/11/1993. This

off-normal occurrence was the accidental disconnection of supply air lines from two technicians during an entry in Hot Cell M-3. It was discovered at 1415 CTZ on April 21, 1993. The technicians were fully suited with protective clothing, full facepiece supplied-air respirators, bubble hoods with breathable air, and five-minute escape bottles. Technician one's supply air line became disconnected and he switched to the escape bottle air. One minute later technician two's supply air line became disconnected and he switched to the escape bottle air. The disconnections occurred between the female quick-disconnects and the threaded end of the hoses. An emergency exit from the hot cell was conducted with no contamination or uptake of radioactivity by either of the technicians. Corrective actions taken were: (1) revising the supplied air entry procedure to include a visual and "twist test" check of the air line connections before each use and (2) quick-disconnects were reassembled to hoses using 1.14 to 1.36 in kg (10 to 12 ft lb) of torque per the equipment supplier's recommendation provided after the occurrence. In addition, a scribe mark was placed on each fitting to aid in visual checking and lock-tight compound was placed on the threads.

- CH-AA-ANLE-ANLEEW-1993-0012 Final Report dated 01/04/1994. This off-normal occurrence was 292 Bq (17,500 dpm)/100 cm² beta-gamma (cesium-137) shoe contamination of a worker involved with removal, transport, and repair of hot cell manipulators. It was discovered at 1700 CTZ on October 4, 1993. A survey of the floor did not detect any radioactive contamination. It was concluded that a single radioactive particle had dislodged from the manipulator and then attached to the sole of the worker's shoe. The corrective actions included bagging of manipulator slave arms, modification of the manipulator transport procedure to have a Health Physics technician follow behind the transport cart to do wide-area floor smears, and institution of daily large area floor smear surveys in the hot cells exterior areas.
- CH-AA-ANLE-ANLEEW-1994-0001 Final Report dated 05/03/1994. This off-normal occurrence was radioactive contamination on the knee of Laboratory green work clothing. It was discovered at 1520 CTZ on March 14, 1994. The contamination was detected by Health Physics survey upon removal of two sets of protective Tyvek clothing by a decontamination and decommissioning (D&D) worker preparing to leave the interior corridor of the M-Wing, building 200, hot cells. There was no contamination of the outer layers of protective clothing. On further investigation it was found that the contamination was in a small piece of gum like material that was not able to be removed from the cloth. A small swatch cut out of the trouser knee (1 cm²)

contained 183 Bq (11,000 dpm) beta-gamma and there was no other contamination. The most likely source of contamination was thought to be an errant particle of gum material which may have escaped detection the previous day during removal of a hot cell manipulator. Corrective actions included improved plastic sheeting wrapping of manipulators when they are removed from a hot cell and improved personnel monitoring stations for frisking clothing before exiting the area.

- CH-AA-ANLE-ANLEER-1995-0010 Final Report dated 09/08/1995. This off-normal occurrence was contamination of a worker's left knee to 408 Bq (24,500 dpm) beta-gamma and right knee to 293.3 Bq (17,600 dpm) beta-gamma during an entry into Hot Cell M-3. It was discovered at 1030 CTZ on August 17, 1995. The contamination penetrated through four sets of anti-contamination clothing and based on characterization of the radioactivity it was approximately equal amounts of Cs-137, Sr-90, and Y-90. It is believed the penetration of fine salt dust contamination through clothing was due to water from profuse sweating which saturated the cloth. The removal of tape from steel plate joints of a raised floor involved extensive time on the hands and knees. The immediate action was to decontaminate the skin until a level of 13 Bq (775 dpm) was reached. It was then decided that further decontamination efforts would degrade the skin and that an acceptable decontamination had been achieved pending subsequent monitoring checks. The estimated skin exposure was 310 μ Gy (31 mR). Corrective actions were (1) the Radiation Work Permit procedures were revised to require water-resistant tape or other outermost barrier on the knees of protective clothing and (2) procedures and sequencing of work were reviewed with supervisors.

10 CONCLUSIONS AND RECOMMENDATIONS

Five radioactively contaminated hot cells, which were a source of discharge of 2,600 curies per year of Rn-220 to the environment, were emptied and decontaminated to restricted-use condition. This has reduced the radioactive emissions from these hot cells to <1% of the initial level.

The project was completed with the radiation dose to personnel held to 80.1% of the accumulated dose forecast in the project ADM.

The characterization of hot cells, similar to the project hot cells, needs to be a stepwise process throughout the project due to:

1. initially high background radiation levels which mask specific contamination problems and
2. disassembly or cutting apart of equipment and structures is needed to provide access for characterization.

This can lead to discovery of decontamination problems that had not been forecasted. It is a justification for a larger project funding contingency than for projects where characterization can be initially more complete.

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