surfaces near the ceiling. Normally, a sandblaster prepares a surface for painting. It is usually acceptable if a certain amount of the original paint is not removed, particularly on surfaces that are difficult to reach (e.g., tops of beams or trusses, or backside of support columns). On a decontamination job, these are the surfaces that must be cleaned as well as possible. Consequently, some of the structural steel surfaces had to be resandblasted.

In addition to the walls, ceiling, and structural steel, three bridge cranes were located in the high bay. A self-propelled, 60-ft manlift was required to reach the cranes for sandblasting and surveys. The two 5-ton cranes were relatively easy to decontaminate. The large, 75-ton crane had many surfaces that were not cleaned by sandblasting. Some surfaces required several applications of a chemical paint stripper followed by hand scrubbing with a wire brush to remove contaminated paint. More contamination was found in and behind electrical control panels mounted on the crane itself. Decontamination of the panels proved ineffective. They were removed and disposed as waste. The braided steel cable on the hoist was contaminated in several places and had to be removed and shipped to burial.

A final survey verified the removal of all contamination from within the high-bay interior.

4.4.16 Disposal of Radioactive Exhaust Systems

The SRE was equipped with three independent radioactive exhaust systems. Two identical units were mounted on the roof and exhausted air from the high-bay area. A separate single exhaust system for the hot cells was located directly above the metallurgical cell west of the high bay. During the decontamination activity, the roof units were used primarily during the sandblasting operation. The hot cell exhaust was disconnected from the two cells early in the decommissioning, and a new 18-in.-diameter exhaust line was routed into the high bay. The new duct provided a header to which several smaller diameter flexible or rigid exhaust lines could be connected. This radioactive exhaust system was used frequently during the SRE decommissioning. It was a vent for the sodium passivation, provided a negative pressure during reactor dismantlement and biological shield demolition, and was used during high-bay decontamination.

A radiological survey of the two roof units indicated they could be dismantled in place if the removable contamination could be "fixed" to the interior surfaces. This was accomplished with spray paint. Figure 76 shows the dismantling effort on the east roof exhaust. Both units were cut up into manageable pieces, wrapped in plastic, and lowered to the ground using an existing roof hoist. Figure 77 shows the removal of a portion of the roofing material adjacent to the roof penetration. Contaminated material was packaged for burial. The hot cell exhaust was dismantled starting with the ducting farthest from the blowers and moving toward the plenum. The contaminated components were packaged and shipped to burial. Noncontaminated items were sent to salvage. The exhaust stack was internally surveyed, found to be clean, and left in place for possible future use.

4.4.17 Decontamination of Buildings 163 and 041

Building 163 is a prefabricated, sheet metal building located just east of the SRE. The west end of Building 163 has served as a pipe spool fabrication shop, a machine shop, a radioactive waste staging area, and a radioactive waste size reduction and packaging facility. Decontamination of the west end of Building 163 was included in the SRE D&D activity.

A radiological survey indicated that most of the contamination in the building was located in the wall insulation material and in the concrete floor. All of the insulating material was removed from the ceiling and walls and disposed of as radioactive waste. A 2-ton bridge crane and its supporting structure were removed. The hoist was packaged for burial. The structural steel was decontaminated and sent to salvage. The concrete floor was scabbled to remove fixed contamination, and a small radioactive exhaust system was dismantled and shipped to burial.

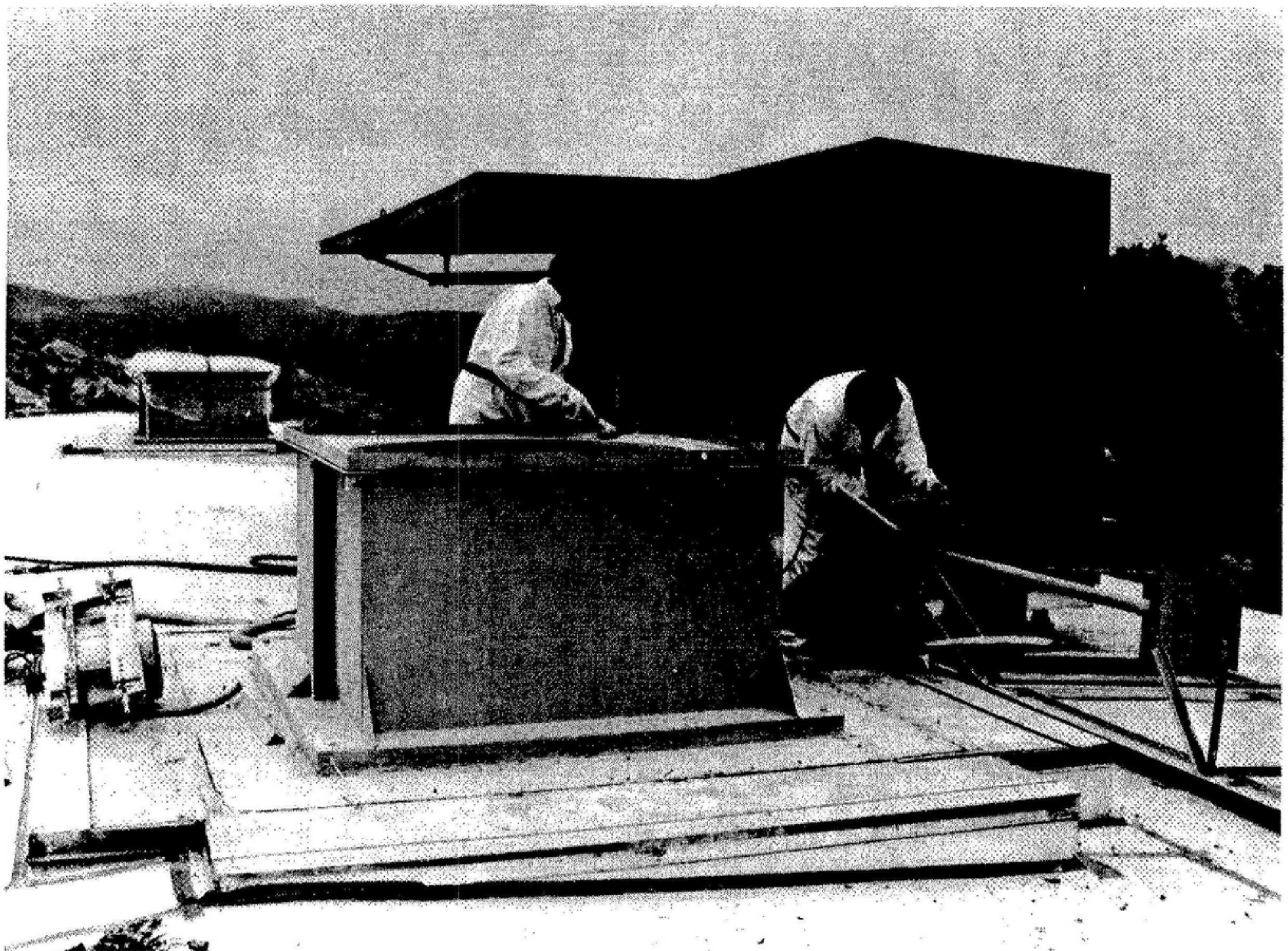

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Figure 76. Dismantling East Roof Exhaust

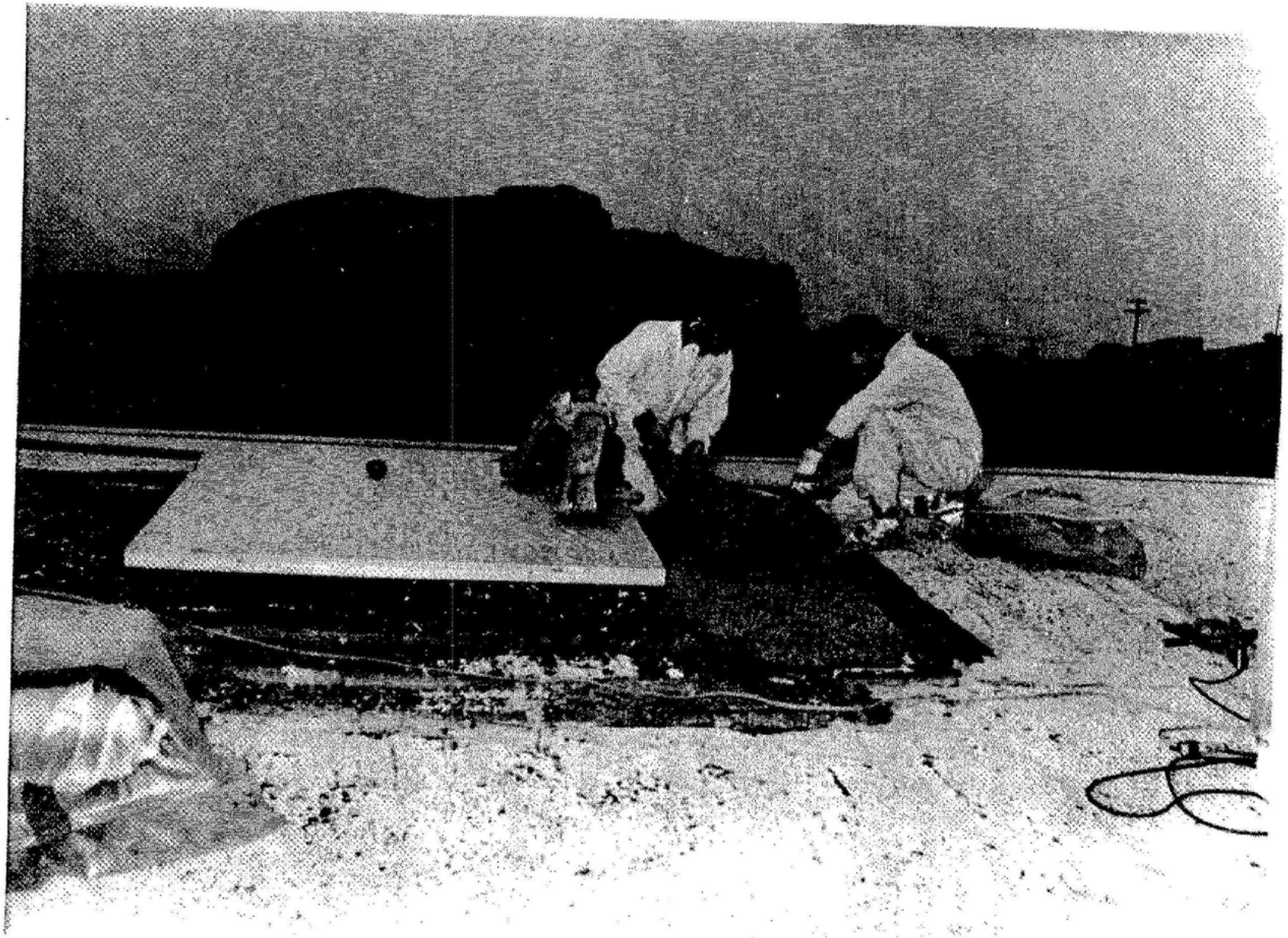

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Figure 77. SRE High-Bay Roof Decontamination

Building 041 was located within the SRE complex, west of Building 143. It had primarily been used for storage of radioactive waste prior to shipment. A small amount of fixed contamination was found on the concrete floor. Scabbling was used to remove the contamination.

4.4.18 Decontamination Equipment

Several pieces of equipment were found to be extremely useful throughout the SRE decomissioning project. A time-and-materials contract was established to provide concrete demolition services. The contractor had a large assortment of equipment available for use at the site, as well as a ready supply of experienced operators and laborers. The workhorse of the project was the backhoe/Hy-Ram combination. Figure 78 shows the Hy-Ram, a hydraulic jackhammer that could be mounted onto a backhoe in place of a bucket. The Hy-Ram could demolish concrete or bedrock many times faster than hand-held jackhammers. It could operate in any position, including 20 ft below the surface where the backhoe was parked. Despite its size, the Hy-Ram was easily maneuvered and could be used for selective material removal. The backhoe was used regularly at the SRE site. Various size buckets enabled the backhoe to excavate all but the deepest components at the site. The large backhoe shown in Figure 67 was used for the fuel element enclosure sleeves removal. It had the capability to excavate a hole 35 ft deep.

Concrete surface decontamination was a large part of the SRE D&D project. If a concrete surface could be decontaminated, the remaining material could be disposed of as clean rubble with a significant waste disposal cost savings. Many different methods and various pieces of equipment were tried with varying degrees of success.

The best and most versatile tool was found to be a scabbler. The scabbler is an air-driven, multiheaded concrete scarifying tool. Figure 79 shows two units: a three-headed hand-held model and a five-headed floor model. In actual use, the smaller hand-held unit was preferred. A guard was installed over the sides, and the hose from a portable radioactive vacuum system was

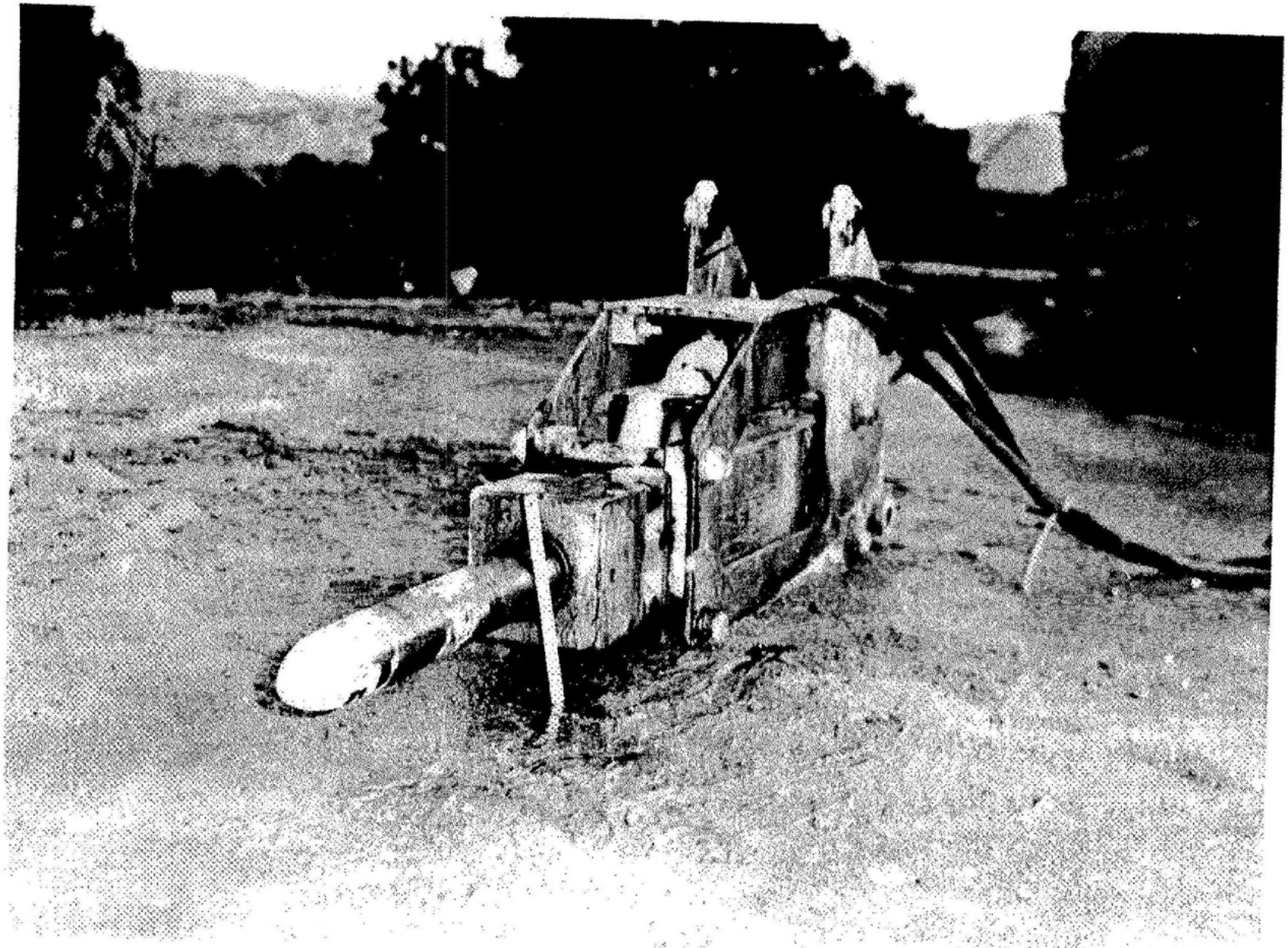

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Figure 78. Hy-Ram Used at SRE

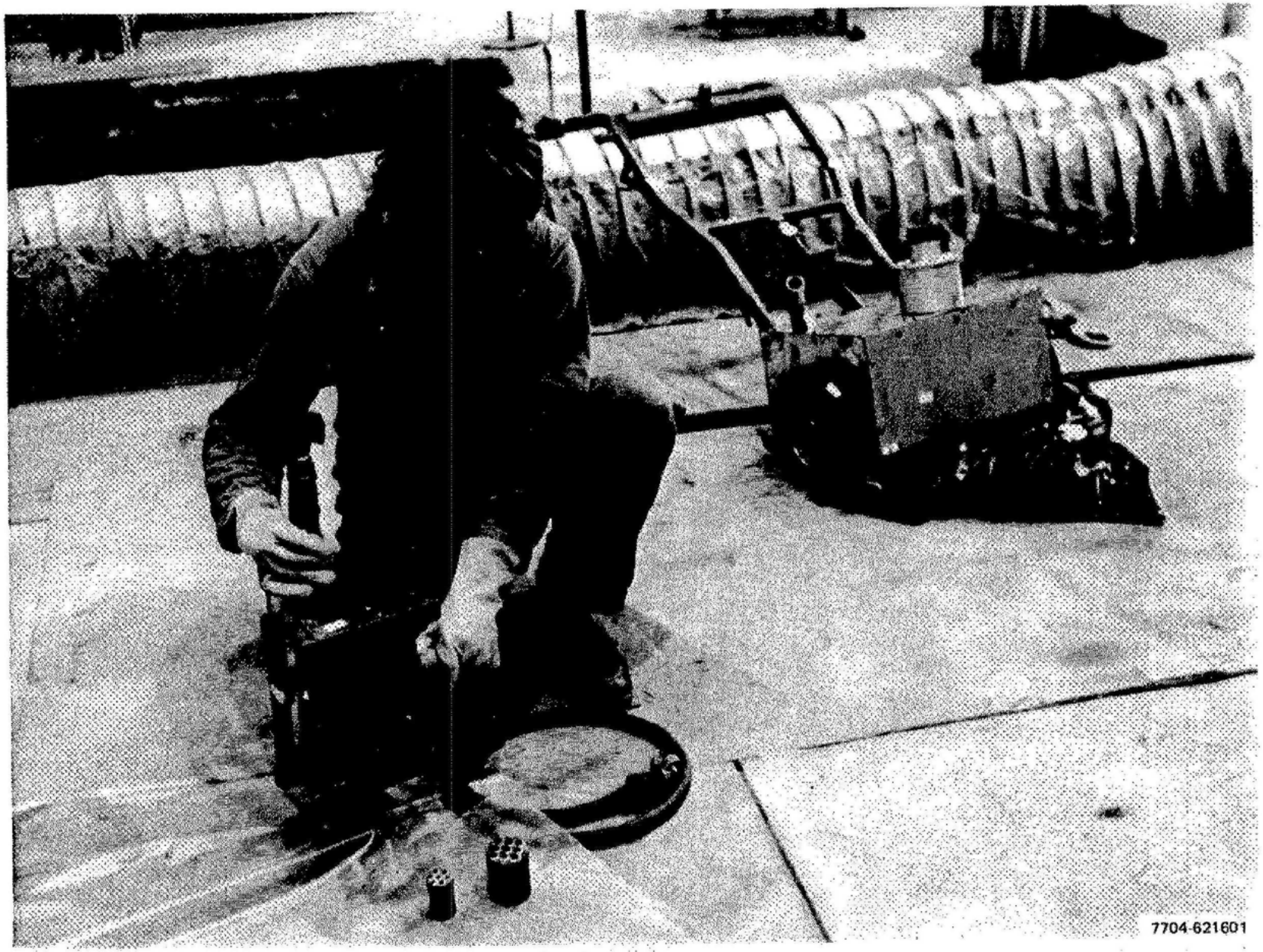

Figure 79. Floor Scabblers Used at SRE

attached. With the vacuum on, very little airborne dust escaped from the work surface. A single-headed "potato masher" scabbler was used in places the larger unit could not reach. Pneumatic tools, from 15-lb chipping hammers to 90-lb jackhammers, were used extensively for concrete and bedrock removal.

Portable vacuum cleaners for the removal or control of radioactive particulates were equipped with absolute filters and were used regularly at the SRE. Figure 69 shows a vacuum in use in Building 163.

4.5 WASTE DISPOSAL

4.5.1 Radioactive Waste Packaging and Handling

Most of the radioactive waste from the SRE was packaged onsite. Material or rubble identified as contaminated was packaged for burial as soon as possible. This was done for several reasons: first, it reduced the chance of cross contaminating a clean or recently cleaned surface; second, it provided access for further decontamination activity; and third, it reduced the radioactive field in a work area.

The selection of a container to package waste was based on several factors including type of material, volume to be packaged, and radiation level. Low specific activity contaminated soil, bedrock, and concrete rubble were packaged in cardboard, tri-wall King-Pac* containers. These containers were mounted on a plywood skid, held approximately 1 yd^3 each, and when loaded, had an average weight of 2000 lb. The King-Pacs had several advantages: they were inexpensive, the skids could be fabricated in advance and stored at the site, a box could be assembled in minutes, and even a loaded container was easy to handle. The primary disadvantage was the fragility of the cardboard. Great care was required when packaging or handling King-Pac containers. For example, no metal could be disposed of in a King-Pac. Large concrete pieces had to be packaged with a sufficient quantity of soil to prevent the rubble

*Registered trademark.

from shifting during transport and rupturing the sidewall of the container. Even scratches to the outer layer of cardboard were sufficient to cause a container to be rejected for shipment. A rejected box would have to be repackaged.

Low specific-activity contaminated steel or wood was packaged in strong, tight, wooden boxes. Each box held approximately 100 ft^3, and gross weight was limited to 6000 lb. Care was still exercised when packaging and handling a wooden box. If not packaged properly, the sidewall of a box could be split. Both King-Pac and wooden containers required indoor storage. Onsite, Building 041 was used for waste storage with overflow containers going to the Radioactive Material Disposal Facility.

Standardized shipping containers, like the King-Pacs and strong, tight, wooden boxes, helped organize the waste for shipment. Occasionally, oversize or custom packaging was required. The reactor vessel shield plug and the ring shield were both shipped to burial intact. The two FHMs and the one moderator-handling machine were also shipped to burial with only minor disassembly. With some large components, it was cost effective to perform a size-reduction operation prior to shipment. Figure 69 shows a size-reduction booth set up in Building 163. Items such as the fuel element enclosure sleeves and the dip leg were segmented in the booth, with a cutting torch or portable band saw, and placed directly into a shipping container.

Components having high levels of radioactivity required special packaging and handling. Lead or concrete shielding was used to reduce the surface dose rate on a container when shipping high-level waste. Dedicated shipping casks were used for the disposal of items that could not be packaged conventionally, even with shielding. The reactor vessel segments were an example of waste that required special containers.

Radioactive liquids were generated as part of the SRE decommissioning. Early in the project, it was permissible to ship low-level liquids in bulk quantities directly to a burial site. As transportation and burial guidelines became more restrictive, this was no longer permitted. Initially, contaminated liquids were acceptable if they were mixed with an absorbent medium, such as diatomaceous earth. This is how the 2500 gal of contaminated alcohol used in the sodium passivation process were disposed of. Eventually, the restrictions also prohibited this process. To comply with the new requirements, it became necessary to construct an evaporator. The unit was installed at the RMDF. Contaminated liquids were transported to the RMDF and processed in the evaporator. After processing, the remaining sludge was mixed with the proper quantity of cement powder and permitted to solidify in drums. The drums were acceptable at the burial site.

4.5.2 Radioactive Waste Transport and Burial

Transportation of radioactive waste from the SRE site was contracted to carriers licenced to receive and transport radioactive materials. Normally, a shipment was transported in a covered trailer 40 ft or 44 ft long. The quantity of each shipment was restricted by a 40,000-lb weight limit. Special transport vehicles were required to ship oversize or overweight loads. Figure 28 shows the reactor vessel shield plug being shipped to burial. Figure 80 shows the ring shield on a special transport vehicle. Radioactive waste from the SRE was shipped to two burial sites.

4.6 POST-DECOMMISSIONING RADIOLOGICAL SURVEY

The SRE facility was divided into several regions on the basis of past use, contamination history, and decommissioning operations. These regions, marked on Figure 81, were treated as geographical units in releasing the facility.

- Region I — This area contained the Hot Oil-Sodium Cleaning Facility, Building 724, and related structures, roadways, and drainage paths. Building 724 was relocated to Region IV and is now identified as Building 133. This building has been

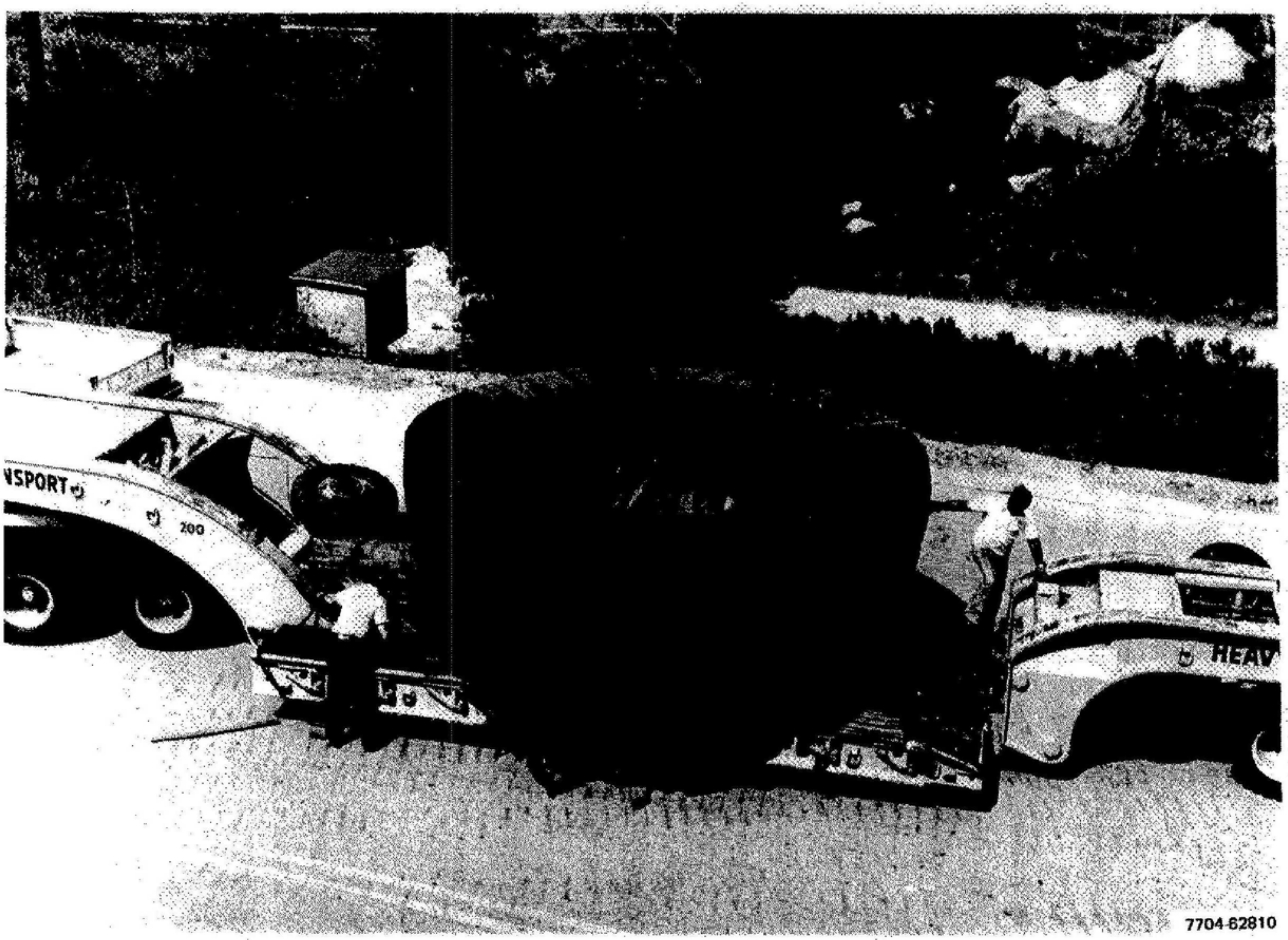

Figure 80. Ring Shield on Transport Vehicle

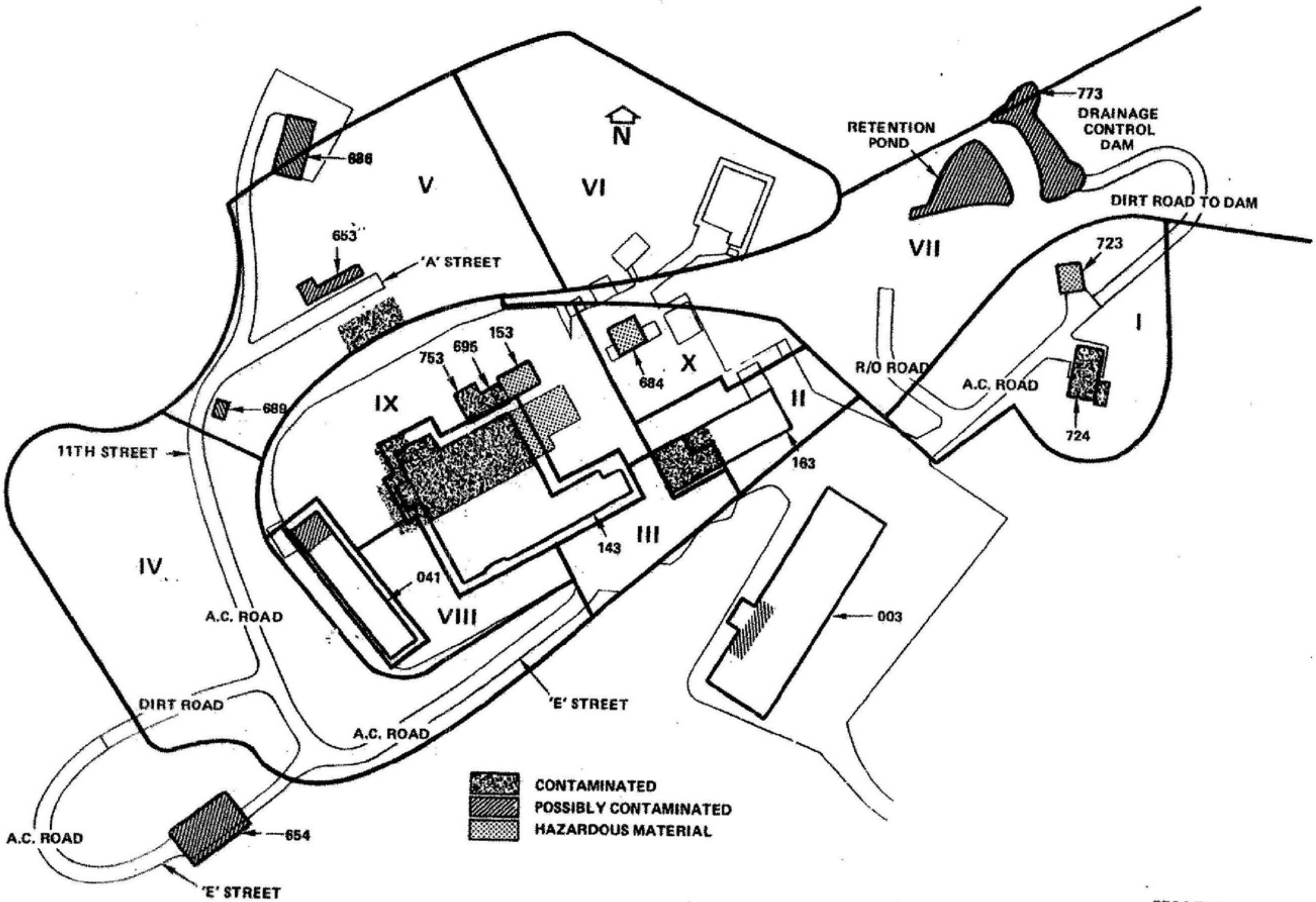

Figure 81. Radiological Survey Regions

released for unrestricted use. Survey data for this building is included in the report for Region IV.

- Region II — This area contains the Box Shop in the east end of Building 163 and also includes the surrounding paved surfaces.
- Region III — This area adjoins the contaminated work area of Building 163 and comprises the entrance approaches to the SRE and Region IV.
- Region IV — This area consists of the roadway from the SRE west parking lot and the slope to the west of the SRE and includes the building moved from Region I.
- Region V — This area contains the gas storage vault (Building 653) and the temporary radioactive waste storage area.
- Region VI — This area contains the water supply storage tank and some Southern California Edison Company structures.
- Region VII — This area contains the retention pond, the old leach field, the sanitary sewer pumping system, and the SRE drainage channel back to the fence line. It includes the retention pond overflow channel downstream for a distance of about 200 ft.
- Region VIII — This area consists of paving to the south and west of Building 143 to approximately the enclosure for the T1/T2 and T3 pits. It includes the drainage channel along the southwest to south edge of the paved area.
- Region IX — This area consists of the remainder of the paved area around Building 143 and includes the drainage path along the north side to the fence line at the northeast corner.
- Region X — This area was in use as a parking lot and includes the natural ground to the east of the parking lot.
- Building 163 — This area was the contaminated work area of the building and included the change room and the concrete ramp at the west entrance.
- Building 143 — This was the major reactor building and consisted of nonradioactive areas and areas with surface and/or

distributed contamination. The ground level and certain below-grade rooms are shown in Figure 3.

- Building 041 — The north portion of this building was used for interim storage of radioactive waste prior to shipment for disposal. The south portion was used for storage of controlled items.

As decontamination work in a region or building was completed, final survey activity began. A technical information (TI) report was prepared for each region and building as they were certified for final release to unrestricted use. The reports identify the area covered by the survey, the types of monitoring instruments used in the survey, and the results of the survey. In all cases, the level of radioactivity in the region or building was found to be below the acceptance criteria used in Table 3.

These reports have document numbers as follows:

N704TI990027, Region I
"Radiological Survey Results — Release to Unrestricted Use, SRE Region I (Building 724 Area)"

N704TI990028, Region II
"Radiological Survey Results — Release to Unrestricted Use, SRE Region II (Building 163, Box Shop)"

N704TI990029, Region III
"Radiological Survey Results — Release to Unrestricted Use, SRE Region III (SRE Entrance)"

N704TI990030, Region IV
"Radiological Survey Results — Release to Unrestricted Use, SRE Region IV (West Parking Lot)"

N704TI990031, Region V

"Radiological Survey Results — Release to Unrestricted Use, SRE Region V (Gas Storage Vault)"

N704TI990032, Region VI

"Radiological Survey Results — Release to Unrestricted Use, SRE Region VI (Water Tank Area)"

N704TI990033, Region VII

"Radiological Survey Results — Release to Unrestricted Use, SRE Region VII (Retention Pond)"

N704TI990034, Region VIII

"Radiological Survey Results — Release to Unrestricted Use, SRE Region VIII (SRE Front Lot)"

N704TI990035, Region IX

"Radiological Survey Results — Release to Unrestricted Use, SRE Region IX (SRE Back Lot)"

N704TI990036, Region X

"Radiological Survey Results — Release to Unrestricted Use, SRE Region X (SRE Parking Lot)"

N704TI990037, Building 041

"Radiological Survey Results — Release to Unrestricted Use, SRE Building 041"

N704TI990038, Building 043

"Radiological Survey Results — Release to Unrestricted Use, SRE Building 143"

N704TI990039, Building 163

"Radiological Survey Results — Release to Unrestricted Use, SRE Building 163"

5.0 SCHEDULE AND COST

5.1 SCHEDULE

Operation of the SRE as a nuclear power plant ended 15 February 1964. Modifications for a planned power expansion were completed 15 May 1965. At that time testing of the non-nuclear systems began. These systems were shut down in September 1967 after a decision was made to decommission the SRE.

A deactivation plan was implemented to put the facility in a "stored-in-place" condition. Deactivation of the facility was completed in 1968, and it was placed in a surveillance and maintenance mode.

An initial proposal for decommissioning the SRE was prepared in 1974. This proposal was prepared to get the project under way and was issued without having site characterization radiation data available (surveillance data from 1966 were utilized). The proposal requested funding for a 3-year period with a dismantlement plan to be prepared during the first year.

The dismantlement plan was prepared in 1975. It defined the methods to be used in removing contaminated equipment, systems, and materials, including cutting and removing the reactor vessels using a plasma torch. It also identified the need for development work and a test facility to establish and demonstrate cutting methods and parameters. This development work was accomplished in the 1975 through 1977 time period while auxiliary systems and structures were being removed. Reactor vessels were cut and disposed of in 1977 and 1978.

Removal of basement vaults, equipment embedded in the below grade structures, and substructure rock and soil extended from 1977 through 1981. Extensive contamination found deep in the bedrock added to the work and required extended time to complete.

The final schedule for decommissioning the SRE is shown in Figures 82, 83, and 84. The original 3-year funding period (1975 through 1978) was established to initiate the program. Subsequent schedules evolved to accommodate funding limitations and to meet the needs of changed conditions which expanded the work scope.

5.2 COST

The proposal submitted in 1974 to initiate the dismantlement covered a 3-year period and requested $6.9 million in 1975 dollars. The budget request was prepared before the dismantlement plans were prepared and without a radiation characterization survey.

The dismantlement plan had not been prepared when the original estimate was made. It was one of the first activities funded by the original budget request. The dismantlement plan identified the need for a test facility and a 2-year program to develop, test, and demonstrate plasma arc remote cutting capabilities to segment and remove the reactor vessels and internals.

Changing conditions encountered during the decommissioning added complexity and additional work to the project. As the work progressed, radiation surveys detected more contamination than anticipated in areas surrounding the reactor building, in radioactive waste systems, in the reactor building equipment vaults, and in the bedrock beneath the vaults. Contaminated water leaked into the bedrock. Extensive excavation was required to follow and remove contamination which seeped into cracks in the bedrock. Building foundations had to be temporarily braced and shored to prevent collapse.

As-built conditions differed from drawing information, resulting in added cost and time to perform additional work. Spills of radioactive material during reactor operations had been cleaned to less stringent criteria, resulting in additional cleaning and/or removal of material for burial in order to meet current criteria for release for unrestricted use.

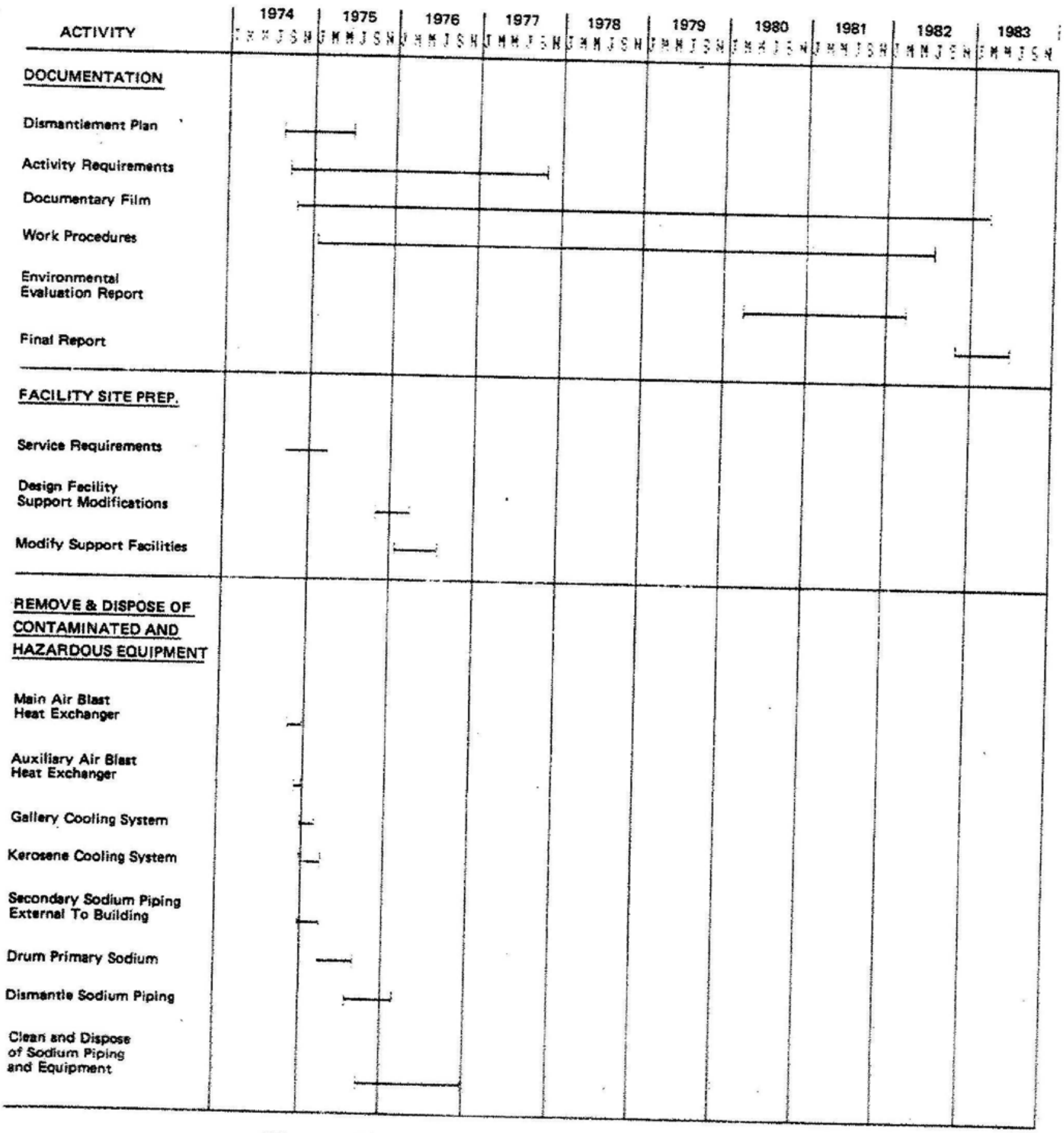

Figure 82. SRE Decommissioning Schedule

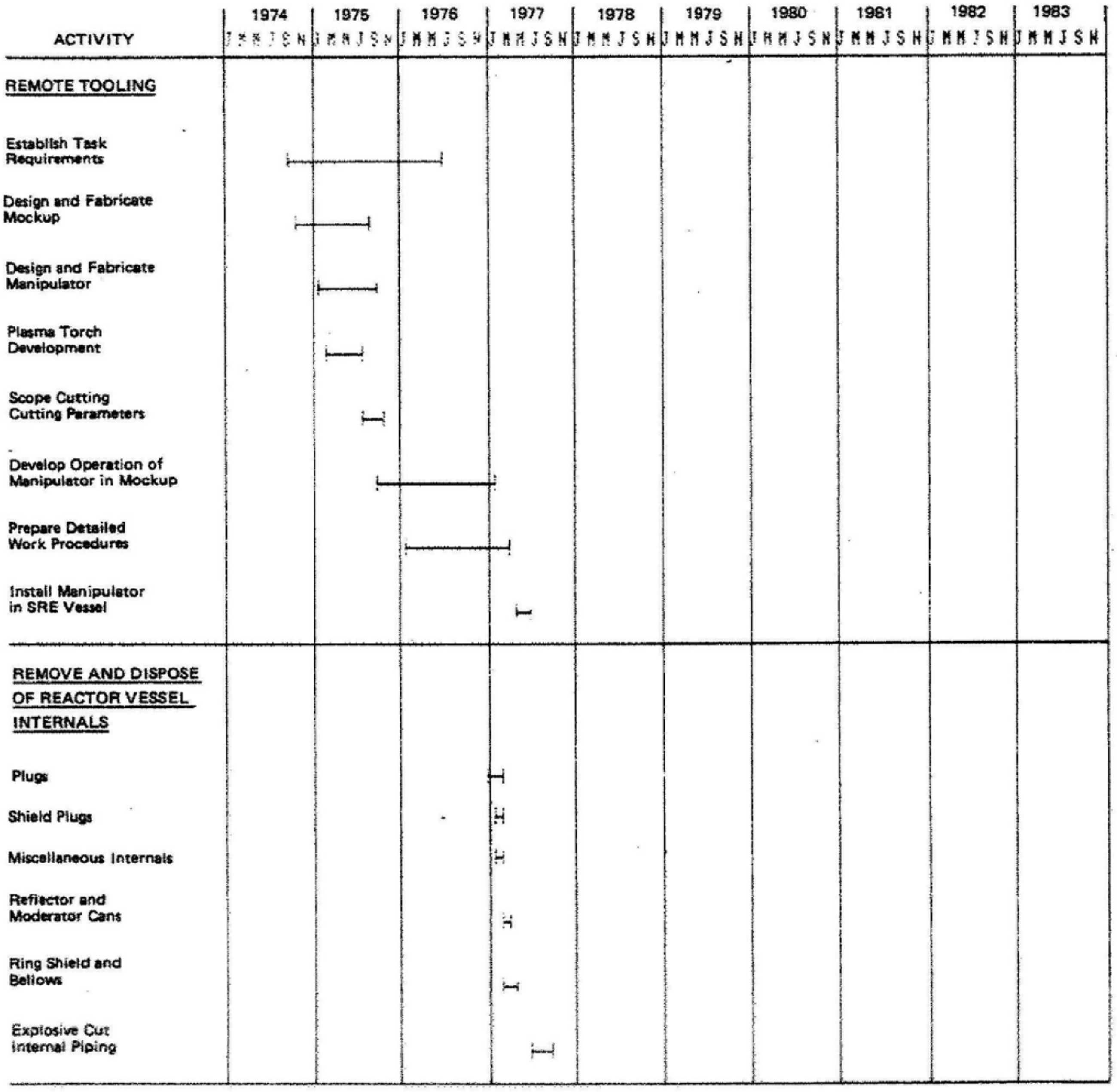

Figure 83. SRE Decommissioning Schedule

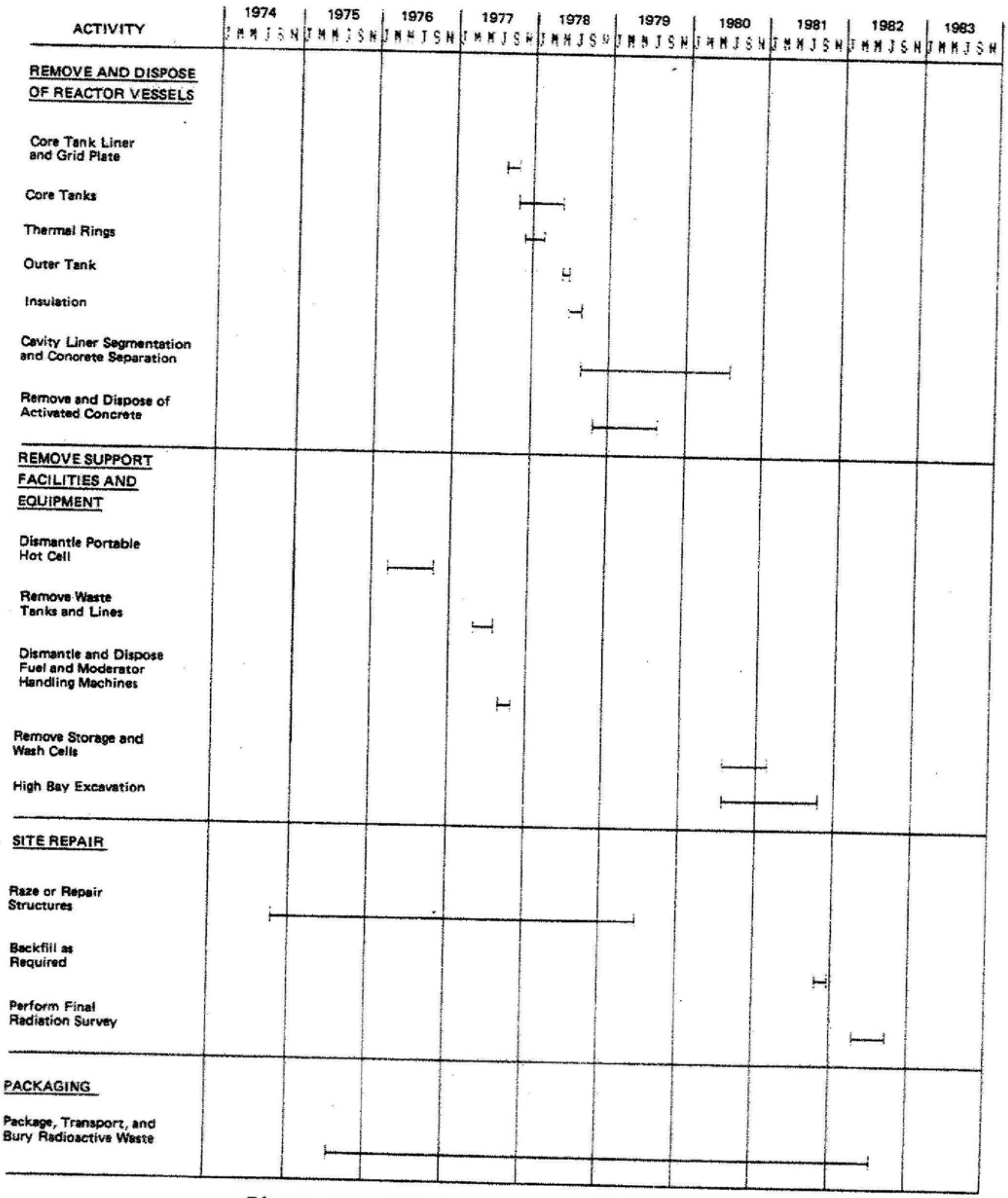

Figure 84. SRE Decommissioning Schedule

Requirements for radwaste disposal changed significantly during the contract period, and waste shipping and burial costs increased by a factor of 2-1/2 from 1974 to 1982.

An abnormally high inflation rate during the extended decommissioning period increased the costs. The original estimate of $6.9 million was in 1975 dollars. The final cost included approximately $4.3 million attributable to inflation.

The combined effects of changing conditions, increased work scope, increased waste burial costs, extended schedule, and the abnormally high inflationary period resulted in a final cost of $16.6 million in 1982 compared with the 1974 estimate of $6.9 million in 1975 dollars.

The SRE decommissioning project has shown that thorough and complete engineering studies, planning, and site survey data are needed at the onset of a major decommissioning project to allow more accurate development of cost/budget/schedule requirements.

The total SRE dismantlement costs, summarized by major cost elements, are listed below:

		Cost ($K) (Including Fee)
1.	Program Management, QA, and Planning	$2,410
2.	Development	1,465
3.	Reactor Structure	1,370
4.	Radioactive Heat Transfer Systems	1,175
5.	Reactor Building Substructure	2,805
6.	Reactor Building Superstructure	940
7.	Radwaste Systems	1,055
8.	Support Buildings and Structures	985
9.	Nonradioactive Auxiliary Systems	95

		Cost ($K) (Including Fee)
10.	Waste Shipment and Burial	2,650
11.	Rectification	465
12.	Health & Safety	1,220
	Total	16,635

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6.0 WASTE VOLUMES GENERATED

Types of waste and quantities generated in SRE D&D are shown below.

Type of Waste	Shipping Container Volumes, ft^3					Total Volumes (ft^3)
	King-Pac®	Boxes	Casks	Drums	Unboxed	
Activated vessel components		10,611	698		645	11,954
Contaminated components		51,490	1,729	1,025	595	54,839
Contaminated soil and concrete	61,874			1,481		63,355
Absorbed alcohol and other solidified liquids				4,993		4,993
Disposed liquid				1,270		1,270
Subtotal	61,874	62,101	2,427	8,769	1,240	
Total						136,411

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7.0 OCCUPATIONAL EXPOSURE TO PERSONNEL

At the beginning of the Decommissioning Facilities Program, an Operational Safety Plan[3] was developed. It provided the basic requirements and implementation for radiation safety, industrial safety, and industrial hygiene and was used throughout all the projects in the decommissioning program. All exposure to radioactive materials was under the surveillance of the Radiation and Nuclear Safety Group. The radiation protection standards established by the DOE Manual, Chapter 0524 were used. These standards limit individual occupational exposure to radiation to 3 rem in a calendar quarter and 5 rem in a calendar year for whole-body exposure. For the extremities (hands and feet), the limits are 25 rem per quarter and 75 rem per year; for the skin, the limits are 5 rem per quarter and 15 rem per year. In addition, a limit of 3 rem per year was used as a guide for controlling individual radiation exposures.

Film badges, processed by an independent laboratory, provided the legally documented record of external exposure. These badges were processed monthly during the early part of the project and quarterly later.

Direct-reading pocket dosimeters were used daily by each employee to monitor external radiation doses on a task. The dosimeters were charged at the beginning of each shift, and the indicated doses were recorded at the end of work that day. These records were summarized weekly and plotted for each employee by the health physics staff to provide a current and visible indication of exposure control.

Surface contamination in the work areas was monitored frequently by smear surveys, with the smears counted on automatic gas flow proportional counters.

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[3] J. D. Moore and E. L. Rody, "Operational Safety Plan for the AI Decontamination and Disposition of Facilities Program," SRR-704-990-001 Rev. B (October 1975).

Establishment of well-defined work areas with step-off lines aided in minimizing the spread of contamination. Airborne contamination was continuously monitored by use of continuous air monitors with automatic alarms. Airborne contamination was rarely a problem because of the control afforded by use of local containment and ventilation.

Application of special techniques to jobs that would normally create severe airborne contamination was very satisfactory. The plasma-arc cutting of the core vessel under water released a negligible amount of radioactive material. The outer tank was cut with the plasma arc in air. Airborne radioactivity from this operation was controlled by use of a temporary plastic enclosure exhausted by the facility radioactive exhaust system. Attachment of a vacuum cleaner hose to a concrete scabbling tool essentially eliminated any spread of dust from a very dusty operation. The vacuum cleaner exhaust was passed through a HEPA filter before release.

Internal exposures to radioactive material were determined by quarterly analysis of urine samples. Following suspected exposures, samples were also analyzed by an independent laboratory. Only one quarterly dose exceeded 1.25 rem, and that was allowable on the basis of prior exposure records.

Ambient radiation, particularly in areas subject to change in exposure rate, was monitored by a remote area monitor with an automatic alarm. Surveys were also performed by the health physics staff, and exposure rates were posted on a facility layout plan.

The number of the operating personnel varied in response to the type and amount of work. Radiation doses received at the SRE have been identified and recorded. The cumulative group dose for this project was 89 man-rem. It was well below the amount that would have been accumulated had each worker been exposed at a rate that would result in receiving the limit of 5 rem per year. In fact, it compares well with the cumulative group dose that would result from exposures at a rate consistent with the current DOE guideline of 1 rem per year to be used for the design of new facilities. This is shown in Figure 85.

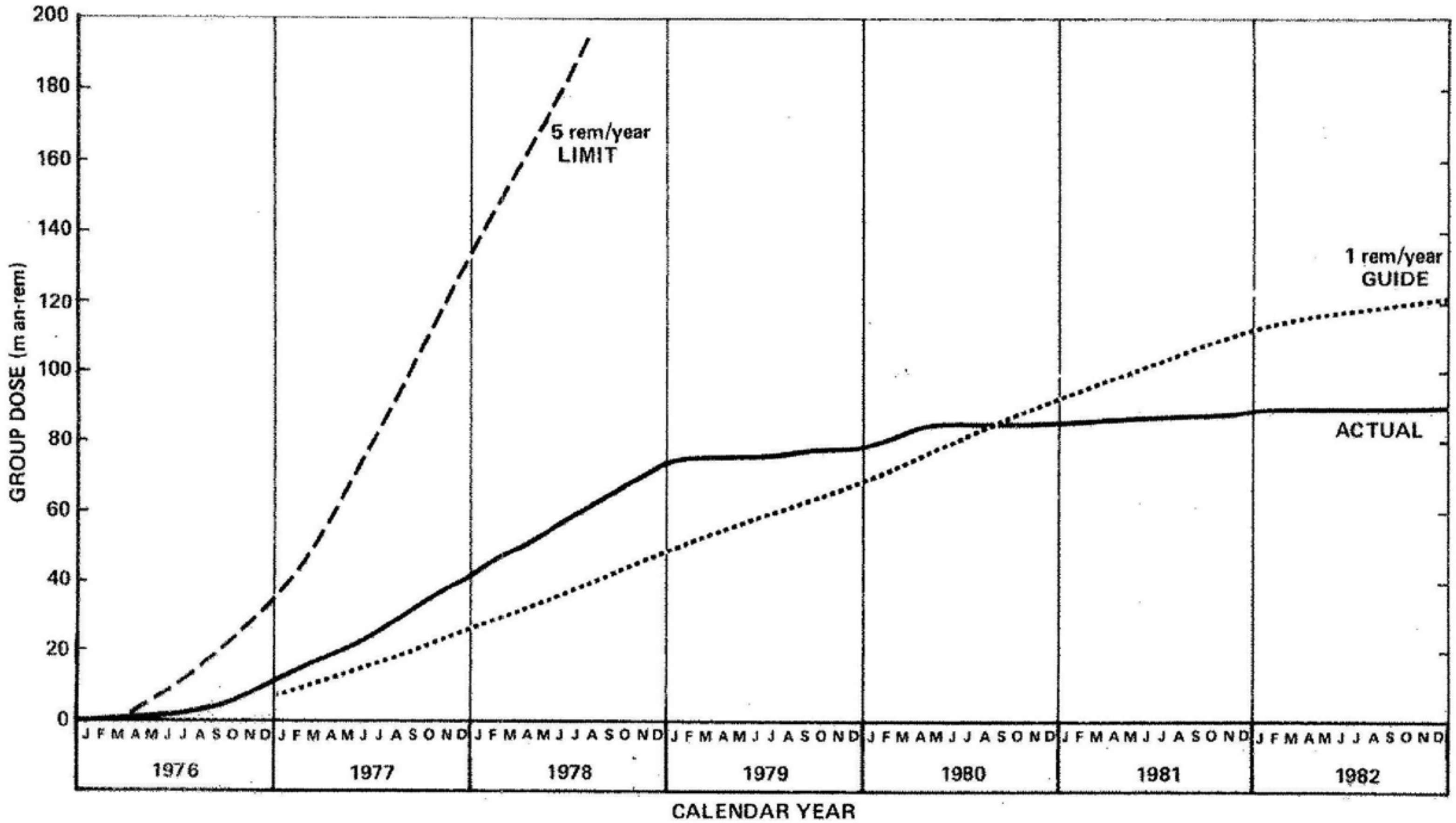

Figure 85. Cummulative Group Dose for All Personnel in Decommissioning the SRE

Much of the group dose was received in specific high-exposure operations. Disposal of the primary sodium auxiliary systems required considerable hands-on work, cutting and removing piping and components containing residual sodium. Removal of the core tank and core tank bottom involved transfers between the water-filled reactor vessel and a water-filled storage pit of components with exposure rates of 10-30 R/h at 1 m. Doses were controlled primarily by minimizing time and maximizing distance between the active pieces and the operators. The thermal rings produced a field of 4 R/h inside the ring, but operators were kept outside where the self-shielding of the 5-in.- thick steel reduced this to 400 mR/h. Decontamination of the water-filled storage pit after disposal of the activated material was another relatively high-exposure task.

Much of the work dealt with highly dispersible radioactive material: contaminated sodium and sodium compounds, contaminated water and alcohol, slag and dust from cutting activated steel, and contaminated or activated concrete and soil. In spite of this, controls were successful in restricting internal contamination of personnel by inhalation or ingestion. While the occurrence of positive bioassay results clearly suggested exposure episodes (and most of these clusters of positive indications were associated with incidents), no long-term depositions have resulted. Supplemental whole-body counts for gamma radiation showed Cs-137 burdens of 5 to 24 nCi, the largest value indicating less than 0.1% of an allowable body burden for this isotope. Assuming an equal amount of Sr-90 to be associated with this, but undetectable externally, the fraction of a body burden would be 1.2%.

All results of the radiation monitoring program showed that exposure was controlled well below established limits and, in fact, can be held to levels that are consistent with current design criteria for operation of new plants.

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8.0 FINAL FACILITY CONDITION

The SRE site, at the initiation of decommissioning, is shown in Figure 86, and the SRE site, at completion of decommissioning, is shown in Figure 87. Figure 88 is a plan view sketch of the SRE site.

The total site has been decontaminated and hazardous materials, primarily sodium, have been removed from the site. The disposition of the SRE support facilities or their present condition is as follows:

1) Temporary Hot Waste Storage 686. The above-ground facility was razed and the contaminated materials were packaged and shipped to a burial site. The area was surveyed and reported acceptable for unrestricted use in "Radiological Survey Results Release to Unrestricted Use, SRE Region V," Document N704TI990031.
2) Liquid and Gaseous Radwaste Waste Holdup and Decay System 653. The compressors, tanks, and piping were excavated and removed for shipment to burial. The remaining vaults were decontaminated and partially demolished. Contaminated rubble and soil were packaged as waste and sent to burial. The area was backfilled. The radiological survey of the area was also reported in Document N704TI990031.
3) Retention Pond and Drainage Control Dam 773. The retention pond was drained and contaminated silt and soil were removed. Recent rains have partially filled the pond. The water is noncontaminated. Water from the pond will be drained into the Simi valley as as soon as Rockwell's request for this action is approved by the State of California. The Radiological survey results are reported in "Release to Unrestricted Use, Region VII," Document N704TI990033.
4) Sodium Cleaning Pad 723. This facility was used to clean noncontaminated sodium from equipment and materials. The area is clean. Survey results are reported in "SRE Region I," "Document N704TI990027.

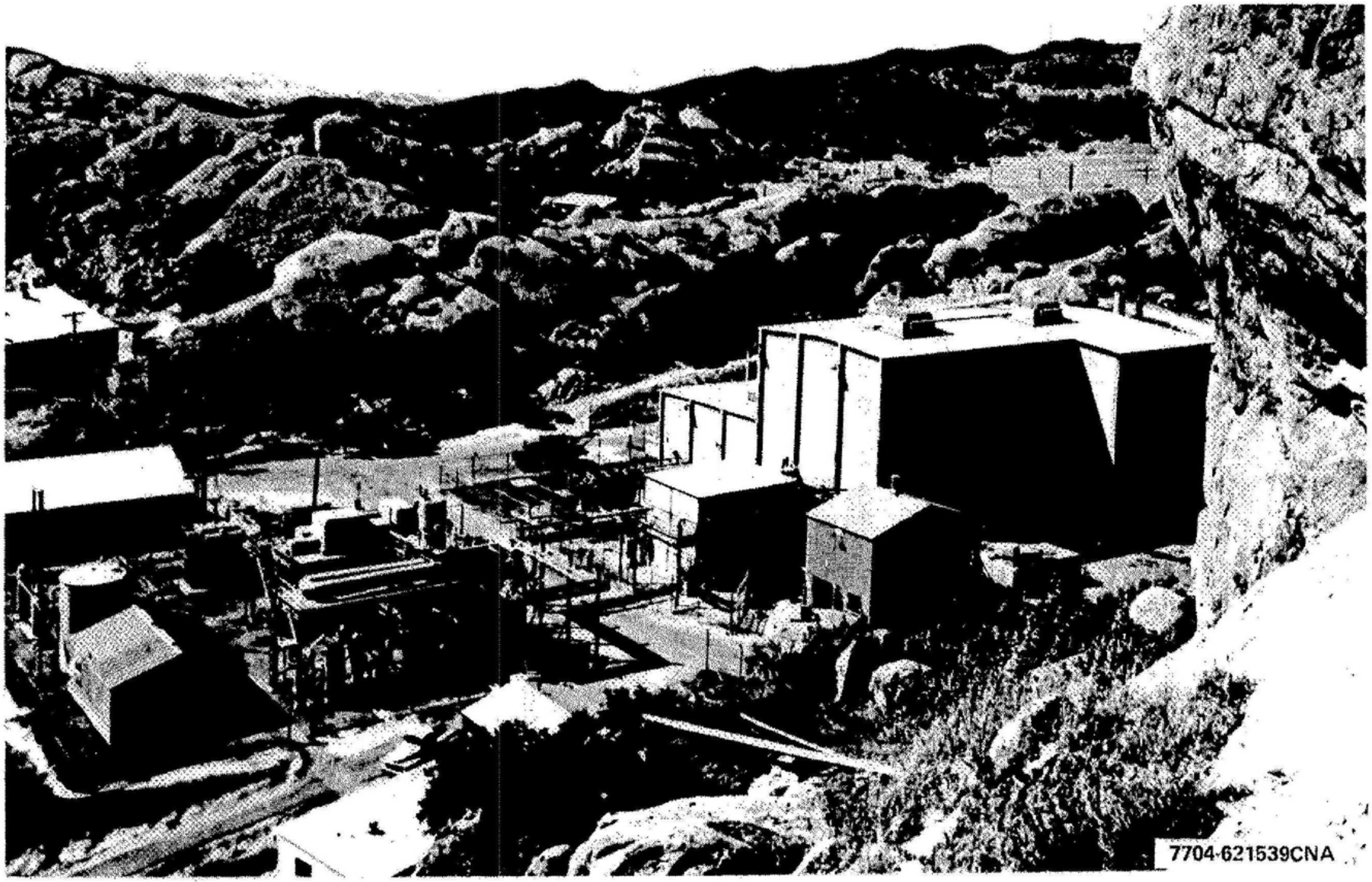

Figure 86. SRE at Initiation of Decommissioning

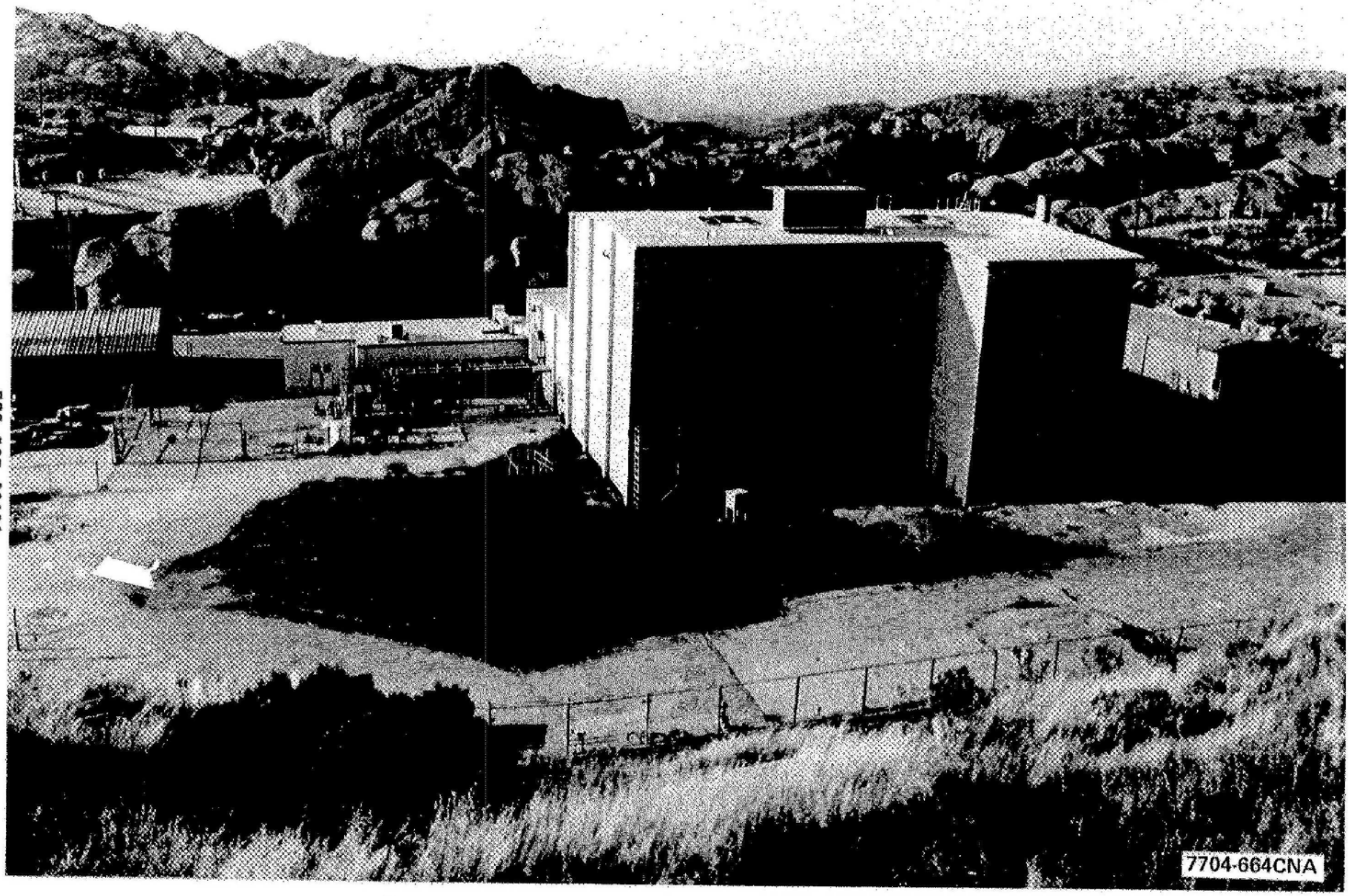

Figure 87. SRE at Completion of Decommissioning

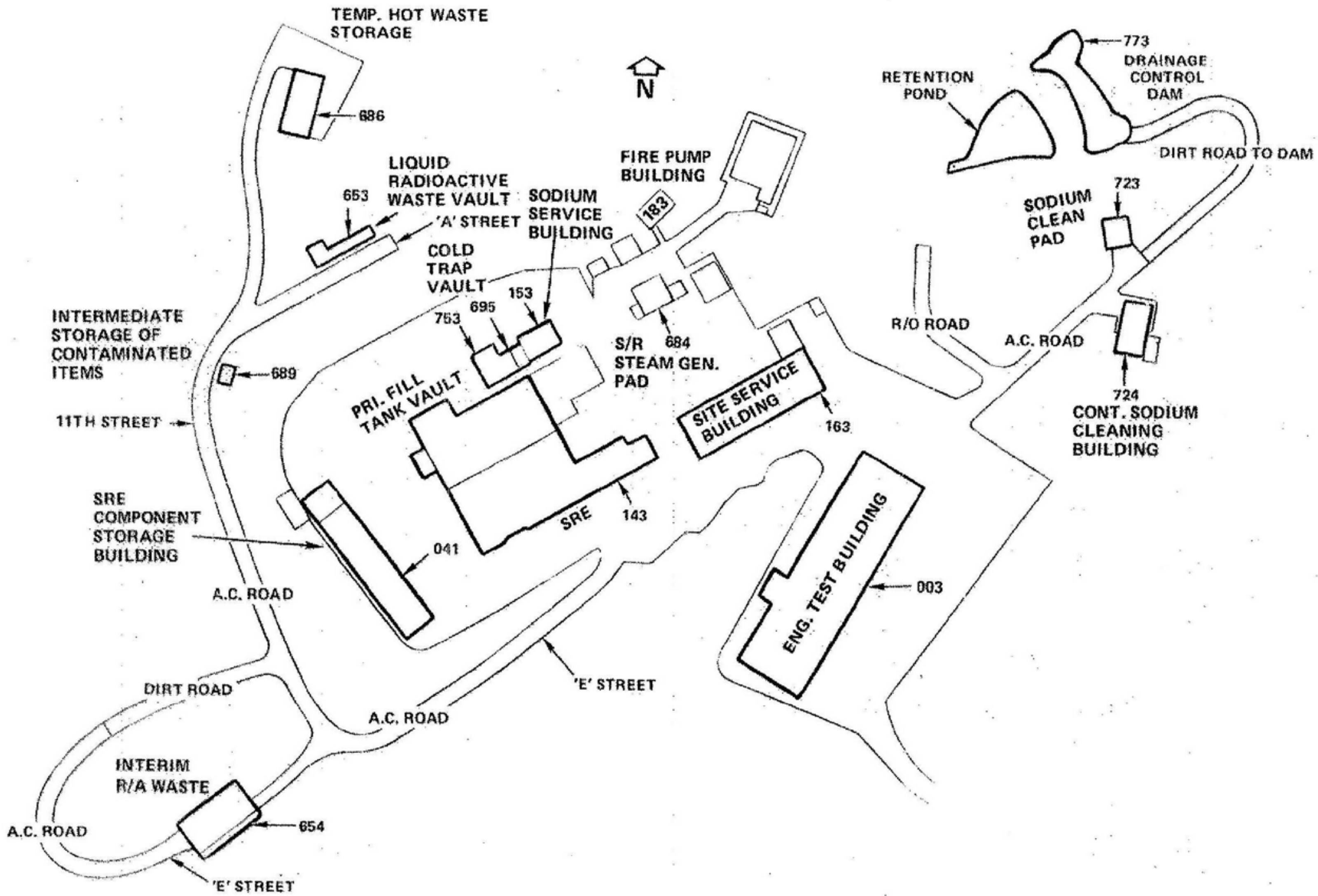

Figure 88. Plan View of SRE Site

5) Contaminated Sodium Cleaning Building 724. The building was decontaminated and transferred to another Santa Susana field laboratory site for use in cleaning sodium components. The remaining pad and surrounding area were decontaminated. Survey results are reported in "SRE Region I," Document N704TI990027.

6) Engineering Test Building 003 was used to support SRE and other programs activities. The decontamination of Building 003 was reported in a separate final report.

7) Interim Radioactive Waste Facility 654. This facility was operated in conjunction with the Radioactive Materials Disposal Facility (RMDF). All above-grade SRE materials and equipment have been removed, and the surface area has been decontaminated. The final disposition of the Interim Radioactive Waste Facility will be associated with the RMDF disposition.

8) SRE Component Storage Building 041. This facility was used to store waste during the SRE decommissioning. This decontaminated facility remains and will be used for clean storage. Radiological surveys of Building 041 are reported in "SRE Building 041," Document N704TI990037.

9) Steam Generator Pad 684. The steam generator pad and all the nearby concrete support structures for the nonradioactive systems associated with the production of electricity by Southern California Edison were demolished. The resulting clean rubble was used in the backfilling of the SRE building excavations. Radiological survey results of the steam generator area is reported in "SRE Regions II, VII, and X," Documents N704TI990028, N704TI990033, and N704TI990036.

10) Site Service Building 163. This facility was used to repair contaminated components. In recent years, the east end of the building was used for constructing shipping containers. The facility was decontaminated, and the basic structure remains for continued use as a box shop. Radiological survey results for Building 163 are reported in "SRE Region II," Document N704TI990028.

11) Intermediate Storage of Contaminated Items 689. This facility was totally removed prior to the SRE decommissioning. The contaminated blacktop in the area was removed and the area was repaved. The radiological survey results are reported in "SRE Region IV," Document N704TI990035.

12) The Primary Fill Tank Vault 753 and Cold Trap Vault 695. These were contaminated. The total below-grade structure was removed and the area was backfilled and paved. The radiological survey results are reported in Document N704TI990038.

13) Sodium Service Building 153. This building was razed. The concrete pad and footings were excavated to provide access for excavation equipment into the main SRE building. This area has been backfilled and paved. The radiological survey results are reported in Document N704TI990035.

14) SRE Reactor Building 143. The north portion of the SRE building contained the reactor and supporting systems. The contaminated systems were removed, contaminated soil and bed rock were removed, the excavations were surveyed, then backfilled and paved. After the building superstructure was decontaminated by sandblasting, it was painted. Lighting and fire detection systems were restored. The south portion of the building housed the control rooms, offices, restrooms, and electrical services. These areas were decontaminated as necessary. The final survey results of Building 143 are reported in Document N704TI990038.

15) SRE Complex. Only the reactor building, 143; the storage building, 041; the site service building, 163; and a fire pump building on the northeast end remain. The total area surrounding the building has been repaved.

Personnel access restrictions have been removed, and Buildings 041 and 143 are being used as warehouses.

The release of the SRE complex to unrestricted use will be contingent on the acceptance and approval of this final report and the report to be issued by Argonne National Laboratories survey team who conducted independent surveys at the site. In addition, the release to unrestricted use will be based on the considerations presented in the "Sodium Reactor Experiment Decommissioning Environmental Evaluation Report," DOE-SF-4, ESG-DOE-13367. This document, prepared by Rockwell ESG, states that the proposed action — release for unrestricted use — does not present any significant impact on the environment. Ground water will not be contaminated. Decontamination on various areas of the SRE has effectively reduced radioactivity in the soil to better than allowable limits. Contamination of water moving through these soils is highly improbable. Samples of surface and subsurface water has indicated radioactivity that is less than levels allowed for unrestricted areas. Radioactivity will not be introduced into the food chain from this pathway. Resuspension of radioactive materials into the atmosphere will not occur since material near the surface, which could become airborne, contains very low levels of radioactivity and no significant dose will result from inhalation of this material. Direct external exposure from the SRE will not reflect an increase above that naturally occurring at the site.

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9.0 LESSONS LEARNED

A review of the technical and management approaches taken to accomplish the SRE decommissioning indicates that, as in any program, the total performance could be improved if the project were to be repeated. This review has produced recommendations that will be useful in future programs. The SRE project has been divided into 11 major tasks. Each task is reviewed and analyzed, and recommendations are presented.

9.1 PLANNING AND ENGINEERING

The overall program incorporated plans for health and safety, training, and quality audit and assurance as well as development of approaches, responsibilities, and schedules. Beginning with a review of the facility design and operating history, a dismantling plan was prepared, followed by activity requirements and detailed working procedures for each task. Engineering was performed and control documents were developed for the tasks and for the development and special tooling designs. This intensive planning effort proved beneficial, both in technical performance and in effective control of costs. As decommissioning efforts proceeded, differences between design drawings and actual site conditions were found because facility drawings were not always updated. Available radiological survey data were insufficient for planning purposes, necessitating site characterization surveys to aid the planning effort.

<u>Conclusions and Recommendations</u>

1) Comprehensive radiological surveys should be performed prior to the establishment of schedules and cost estimates. Adequate work scope definition is impossible without thorough knowledge of the extent of radiological contamination.
2) Thorough engineering studies of alternatives and then comprehensive planning should be prepared as early as possible to adequately define the work to be done and permit accurate estimates and schedules to be prepared.

3) During reactor operations, records of incidents, radiological surveys, repairs, reconstruction, and any alterations should be maintained in sufficient detail to aid the decommissioning effort.
4) Facility drawings should be kept current.
5) Construction photographs should be taken and retained.
6) The design of nuclear facilities should incorporate decommissioning procedures.

9.1.1 Disposition of SRE Structures and Systems

The selected SRE decommissioning mode was the complete dismantlement of contaminated structures and systems. However, in the initial planning, it became apparent that the specific SRE facilities and buildings could be useful during the decommissioning procedure. Consequently, facilities such as the radioactive exhaust system and the personnel change room with its showers and radioactive waste holdup system were kept operable throughout the decommissioning procedure. In addition, the SRE reactor building provided a containment structure for airborne contamination generated by the decommissioning operations. The building also provided a health physics laboratory, office space for supervisory personnel, and restrooms and lunch rooms.

When the excavation of below-grade structures and systems began, the difficulty of excavating around building support columns and the need for shoring walls required a decision regarding the advisability of retaining the SRE superstructure. An engineering study showed that a schedular delay of several months would be necessary to dismantle the building, provide temporary containment structures for the decontamination operations, and relocate the health physics laboratory, personnel services, and supervisory offices, if the building was not retained.

9.2 DISPOSAL OF NONCONTAMINATED SRE SYSTEMS AND SUPPORT FACILITIES

The secondary sodium system, steam and electric generation facilities, airblast heat exchangers, water supply system, and external portions of the kerosene cooling system were the principal elements of the noncontaminated systems and facilities removed as the first decommissioning steps. A demolition and salvage contractor was hired to perform the removal. Because the work areas were physically separate from the contaminated areas of the SRE, the removal required no special techniques, other than industrial safety controls for the sodium and kerosene involvement and monitoring by Health Physics and Safety personnel. The cost for salvage contractor services was offset by the value of the materials removed.

By performing this work first, access to the contaminated systems of the plant was improved, and interference between work on contaminated and noncontaminated systems was prevented. The time spent removing noncontaminated systems was also used for planning and development work for the contaminated systems. It should be noted that safety precautions used by outside salvage contractors vary greatly, and therefore their operations must be monitored closely by the project onsite supervisor.

Conclusions and Recommendations

1) Maximize the use of conventional salvage contractors for noncontaminated work and provide separation from contaminated work areas.
2) Consider salvage value to offset decommissioning costs.
3) Schedule removal as early as possible to simplify access.
4) Assess contractor's safety procedures and safety record.

9.3 DISPOSAL OF CONTAMINATED SODIUM

During the deactivation process, 54,950 lb of slightly radioactive sodium (4 mR/h at the surface of each 55-gal drum of sodium) had been drained into the storage tank from the reactor and primary piping system. This sodium was later put into drums for shipment to Hanford, Washington, for possible use in other programs.

Residual sodium coating the interior of system components, piping, and the reactor vessel required special procedures for disposal. Sodium deposits and heels in piping, etc., were heated and drained into drums. Then, alcohol was added to react with the residual sodium films in piping, components, and the reactor vessel system. The alcohol was added slowly into the particular configuration, with control of the rate of flow based on the quantity of hydrogen generated by the reaction. Explosive mixtures were prevented by diluting the hydrogen with nitrogen. About 8,000 gal of alcohol were used. The resulting contaminated liquid was pumped into 55-gal drums containing diatomaceous earth, which absorbed the liquid and made it acceptable for burial. The drums were shipped to the licensed commercial burial site at Beatty, Nevada. (Current regulations do not allow such disposition of liquid wastes.)

Several sodium chemical passivation options were studied. The alcohol reaction was selected because it is comparatively slow and permits greater control. The sodium passivation procedure was carefully planned and conducted. Particular care was exercised to exclude air from the reactor vessel. Air contact with heated sodium can result in a fire.

Conclusion and Recommendation

Alcohol passivation of sodium films, although an effective and safe method, results in problems with alcohol disposition. Other sodium passivation methods such as nitrogen/steam reaction should be considered.

9.4 DISPOSAL OF CONTAMINATED SRE PERIPHERAL SYSTEMS AND FACILITIES

The next step in the decommissioning sequence was the disposal of the peripheral systems and facilities. Performing this step next in the sequence had the advantages of decreasing the area of operation in the shortest time, improving the familiarity of the crews with decontamination work, and providing better access for subsequent activities.

The peripheral systems and facilities disposed of were: (1) the gaseous and liquid waste holdup system on the hillside north of the reactor building, (2) the hot waste storage facility on the same hillside, (3) the secondary sodium storage handling and purification systems, and (4) the drainage retention pond. The vault walls of the liquid waste holdup system and the soil below the system components were contaminated. A hydraulically operated Hy-Ram was used to peel off several inches of concrete from the walls and floors. The soil below the tanks and several feet downslope was also removed and packaged for burial.

The capability and versatility of the Hy-Ram was developed in the concrete decontaminated operations. An early objective of the SRE decommissioning project was to minimize the total costs associated with the generation of contaminated waste. Whenever possible, selective rather than bulk removal techniques were used to minimize the waste to be packaged and sent to burial. The Hy-Ram could be equipped with chisel-like tools that could selectively peel off layers. It was also used to demolish the bulk noncontaminated concrete in vaults and walls. Consequently, its simplicity, versatility, accessibility, and cost effectiveness led to its evolution as the workhorse for the material removal operations.

The hot waste storage facility, essentially concrete and steel tank structures mounted on a concrete pad, were easily removed. The storage structures were above grade, and radiological surveys indicated that the soil had not been contaminated.

The secondary sodium systems, consisting of a sodium storage tank, sodium system loading facility, pumps, hot and cold traps, piping, and valves, were dismantled. Residual sodium in these components was reacted with steam. The cleaned components were free of contamination and were sent to salvage as scrap.

A radiological survey of the water in the drainage retention pond showed no contamination. The water was pumped into area drainage channels, and the silt in the pond was surveyed and sampled. Several slightly contaminated areas were detected; after these were removed, the area was resurveyed and found to be free of contamination.

Conclusions and Recommendations

1) Work on slightly contaminated peripheral systems should be used to train the work force and establish procedures.
2) Selective removal of contaminated materials is cost effective and should be used.
3) The Hy-Ram should be considered for both selective and bulk concrete removal.

9.5 DISPOSAL OF SUPPORT SYSTEMS

The support systems consisted of the machines for handling the fuel and moderator elements; the fuel storage, fuel wash, and examination cells; and the inert gas system. The large fuel and moderator handling machines were stripped of external appurtenances and then shipped to a burial site. Dismantling and decontaminating the basic structures would have been too time consuming and costly. This approach — intact shipment to burial — was used for disposing of all the large system components.

Fuel storage cells, fuel wash cells, and other cells located in the floor of the SRE high bay were excavated.

Some of the cells were located close to key building support structures and were deeply imbedded in bedrock. Removing these required techniques that would not damage the building structure or present a hazard to the personnel involved. To provide this protection, it was necessary to install shoring to prevent cave-ins. A consulting firm was hired to design and install the shoring. Holes were drilled from the grade-level floor to a depth of 60 ft to provide for the pouring of 2-ft-diameter reinforced concrete pilings. The pilings were slotted to accept timber spanners as excavation progressed.

To control contamination during dismantling and packaging for shipment, the storage and wash cells were filled with a solidifying foam and capped before being removed and later cut into manageable lengths.

The Hy-Ram was used to free the cells from their concrete support structures and to demolish the bulk concrete.

The fuel examination hot cell complex was also located below grade at a depth of about 20 ft. To decontaminate this system required removing hot cell windows, overboring pipe penetrations, cutting through concrete to free piping, removing stainless steel cell lining, and spalling off contaminated concrete surfaces.

The following procedure was used to remove the two storage tubes located in the floor of the examination cell (bottom of tubes, about 50 ft below grade):

1) A flat concrete base was poured from which a rock drill could operate.
2) Approximately 100 deep holes were drilled to weaken the bedrock.
3) The weakened bedrock was excavated using the Hy-Ram and a backhoe.
4) The storage tubes were pulled out.
5) The excavation was backfilled with grout to offset the effects of ground water.

Once set, the grout sealed the excavation and provided a firm base for further backfilling. Figure 89 shows the storage tubes imbedded in bedrock and the extent of the excavation necessary for their removal. The examination cells were partially dismantled, the inner cell liner was removed, and the drain lines were excavated.

The noncontaminated concrete structure of the hot cell complex was not completely demolished.

Figure 89. Storage Tubes Imbedded in Bedrock

Conclusions and Recommendations

1) Remove large components without major disassembly (fuel handling machines, plugs, shields, etc.) and transport to burial sites in one piece wherever possible since this may be most cost effective.
2) Use a solidifying foam internally to fix contamination in components so that they can be sectioned without spread of contamination.
3) Include provisions for ease of removal and for avoiding spread of contamination when installing system components into the bedrock.

9.6 DISPOSAL OF REACTOR VESSELS

The disposal of the reactor vessels, because of the significant induced radioactivity present in the metal, required development and use of remotely operated equipment and tooling. A manipulator with a plasma-arc torch-cutting head was used to remotely cut the vessels under water into manageable sections. These sections were remotely transferred to a water storage basin and then placed in cask liners for later disposal. Reactor vessel internals (such as downcomers and core clamps) were removed using shaped-charge explosives. Although explosives were used in removing the internals and proved to be very effective, it was shown later than the plasma-arc cutting technique could have been used also.

After the highly activated inner reactor vessels were removed, the thermal shield rings were lifted out. Since these were only slightly radioactive, they could be cut up for disposal safely with automated, remote, and oxy-acetylene cutting on the reactor room floor.

Removing asbestos insulation from between the vessels was a hands-on operation. After removal, it was sent to a burial site as low-level radioactive waste.

The engineering, tooling design, and cutting parameter development that preceded the use of the polar manipulator and plasma torch greatly facilitated this portion of the work. A mockup of the reactor vessel was constructed early in the project to permit development and training. The operators were adept at cutting before beginning work on the SRE. The vessel segmentation was conducted under water to cut 1-yd^2 sections from the vessel, remotely move these to a water-filled vault, and selectively stack the sections into cask liners.

The success of the vessel segmentation project was highly dependent on maintaining good underwater viewing. The TV camera attached to the manipulator was helpful as long as water clarity was maintained. A pump and filter system was used, and appropriate radiation shielding was provided. With proper maintenance, the unit produced good results.

Ground water was found in primary system vaults when they were first opened. A piping vault was also used for underwater segment storage. It was constructed of concrete with a few pipe penetrations. In preparing for the work, the vault was sealed water tight. The surfaces were cleaned, and the cracks were filled. The pipe penetrations were sealed, and the entire surface was coated with an epoxy material. Despite the preparation, a water leak developed. It may have resulted from shocks caused by the explosive cutting operation. As soon as the loss of shielding water was noted, a steel tank was fabricated to fit inside this vault and contaminated material and water were transferred to the tank. Water containing fission and activation products migrated into the soil and bedrock at the north and east quadrant of the building.

Samples were analyzed to determine the degree of activation of the concrete biological shield surrounding the reactor. This was found to be 10 in. into the shield from the inside. The lower portion of the shield was not contaminated and was buried in place. To minimize the generation of contaminated waste, the Hy-Ram was again found useful in accomplishing selective removal. In this case, the outside annulus of the concrete structure was removed (with close radiological surveillance) as noncontaminated material and saved for later use as backfill material. The inside contaminated concrete was reduced to rubble and packaged for waste disposal.

Conclusions and Recommendations

1) Careful planning, engineering, tooling development, mockup trial runs, and training are recommended for the successful completion of the task and to simplify the work.
2) Plasma-torch segmentation is recommended as a successful technique for remotely cutting highly contaminated reactor vessels.
3) Explosive cutting is feasible for remote underwater pipe cutting, but plasma-torch techniques should be considered.
4) The use of existing plant structures for critical operations such as storing of contaminated water should be avoided. New watertight structures should be engineered, fabricated, and installed for decommissioning processes.
5) Water clarity for viewing capability is essential for underwater operations. Therefore, an adequate filtration system is necessary.
6) Where access permits, the Hy-Ram should be used for selective removal of layers of the biological shield.

9.7 EXCAVATIONS

The SRE high bay was excavated to an average depth of 26 ft. The extensive excavation was necessary to remove the below-grade reactor structure, primary piping system vaults, fuel storage and cleaning cells, and the hot storage tubes.

In addition, an equivalent volume of soil and rock was removed from outside the north and east sides of the building. This excavation was necessary to remove the primary sodium storage vault, service system vault, and piping systems. Additional excavation was required to remove contaminated soil in the northwest quadrant of the building. The excavation extended beneath grade beams and column footings. Temporary bracing and shoring were installed to support local areas while the contaminated soil was being removed.

Two sources contributed to the extent of the soil contamination below the vaults. When the contaminated primary service vault was first opened, considerable water was found in the vault. This water either seeped in through the walls and floor slab from a ground water source or came in through the roof during rainy periods. The second source was the leak from the pipe vault pool used to store contaminated pieces from the reactor vessels.

Localized contaminated areas were decontaminated using manually operated tools. Large areas were excavated using the Hy-Ram. Since the SRE structure and some of the systems extended into underlying bedrock, some of the contamination in the soil extended into fractures in the bedrock. This necessitated some laborious machine and manual removal operations. After contaminated material from the below-grade areas had been removed, the area was surveyed and found to meet acceptance criteria, and the excavation was backfilled. Clean material removed from the excavation was returned. Additional backfill material was purchased from a nearby land development operation.

A consulting A&E firm was employed to prescribe and design bracing for the building columns during the period when they were extensively exposed by the excavation.

Conclusions and Recommendations

1) Carefully segregate noncontaminated materials to provide backfill and to reduce the volume of contaminated waste.
2) Give constant attention to safety considerations for personnel and remaining structures for the duration of the project.
3) Carefully assess engineering detail for all operations (including minor ones) during the progression of the job.

9.8 DECONTAMINATION OF STRUCTURES

Surface decontamination activities preceded most of the dismantling and removal operations. This decontamination was performed to reduce radiation exposures to personnel and to enable the bulk of structures or equipment to be disposed of as noncontaminated. In other cases, decontamination of the exterior of large items (such as the fuel handling machines) facilitated packaging and handling for disposition.

In a program to develop decontamination techniques, we used available literature, experiences of ourselves and others, and demonstration to produce an optimum set of techniques. Generally, we found that vacuuming, followed by applications of a foam containing decontaminating agents, was the best way to clean painted and metal surfaces and to initially clean various other surfaces. The approaches used in decontaminating concrete surfaces are described in Section IV. A scabbler device that spalls the concrete surface and is equipped with local vacuum and air cleaning proved quite effective.

On walls, ceilings, and the two high-bay cranes in the main building, contamination was fixed in the paint. The areas were decontaminated in two steps. First, paint, particularly from horizontal surfaces, was removed by sandblasting. Then, the few remaining spots were decontaminated by scrubbing or surface removal. Before sandblasting, all extraneous equipment, piping, and ducts were removed. No attempt was made to provide local aerosol control; instead, the entire high-bay area was sealed to contain contaminated dust and sand. All personnel in the area wore protective clothing and respiratory protection.

<u>Conclusions and Recommendations</u>

1) Pay careful attention to decontamination techniques to optimize contamination and exposure control, reduce waste volumes, and reduce cost.

2) Consider a foam decontamination approach for removal of loose contamination on walls. It minimized the generation of contaminated water and provided other benefits.

3) Decontaminate large surface areas of concrete floor with the scabbler.

4) Use sandblasting as an effective method for decontaminating large areas where contamination is fixed in paint. (A commercial contractor was used; however, since their usual objective is to clean in preparation for painting, and they neglect non-visible areas, the contractor's work required constant supervision.)

9.9 WASTE HANDLING

All materials leaving the SRE site were radiologically surveyed. Clean materials were sent to the salvage yard or removed by a salvage contractor. Contaminated materials were packaged in accordance with approved procedures and shipped on special trailers for land disposal. At first, these materials were shipped to a commercial site in Beatty, Nevada. Later in the program, such wastes were shipped to a DOE site at Hanford, Washington. Contaminated water was processed in an evaporator at the Radioactive Materials Decontamination Facility at Santa Susana. Sludges were solidified by mixing with concrete and then were shipped to burial.

With the large volume of slightly contaminated concrete and soil to be sent to burial from this project, the choice of suitable packaging was crucial to the achievement of optimum cost effectiveness. Tri-Wall Chemical King Pak™ containers (Tri-Wall Containers, Inc.) were found to be the most economical packaging for this category of waste. This is a fiberboard assembly about 1 yd^3 in volume. A typical loaded weight was about 2000 lb. The package was fastened to a shipping pallet. It met DOT requirements and was, until recently, acceptable to the Beatty site. It remains acceptable at some other disposal sites.

A total of 5050 yd^3 of contaminated solid waste was shipped for burial.

Conclusions and Recommendations

1) Uncertainty of commercial disposal site requirements and of state and federal waste transportation requirements greatly affect the cost, schedule, and technology of the waste disposition and should be carefully considered in early planning activities.

2) Radioactive waste generation must be carefully controlled and contained. Labor-intensive decontamination of components and materials is costly and leads to increased volumes of waste being sent to burial. However, the cost for burial is escalating, which changes the economics of decontamination practices. Trade studies are recommended.

9.10 RADIOLOGICAL SAFETY AND SURVEY CERTIFICATIONS

The SRE decommissioning operations were monitored and controlled by the Rockwell International Health and Safety Department. Decontamination and surveying were repeated until the radiological cleanliness criteria had been met. Radiological surveying and analysis were performed according to DOE, NRC, and California guidelines.

A quality assurance (QA) program, independent of Health Physics and the performing engineering department, supported the decommissioning program. In addition to being responsible for current calibration of instrumentation and inspections of waste shipments, QA established procedures for the statistical sampling and analysis of all decontaminated areas.

The Argonne National Laboratory's radiological survey team, assigned to the project by DOE, conducted surveys at various stages of the decommissioning and will provide overview and certification of the decontamination of the facility and site.

The commitment to ALARA principles was incorporated into the overall SRE operational safety plan and into the detailed working procedures. As a result, the total man-rem exposure for this project was controlled to approximately 75 man-rem. There were no individual exposures above the guidelines; most were considerably less than 3 rem/year.

The criteria for acceptable residual contamination levels that were applied are shown in Table 1. These values are slightly more conservative than those of Regulatory Guide 1.86 for surface measurements. In the absence of consensus or regulatory criteria for contamination, such as activation products distributed in materials, the project-specific values shown in Table 1 were developed. An environmental report was prepared that examined the possible effects of the residual levels and found them to be acceptable.

In the area of industrial safety, it is notable that no lost-time injuries occurred during the SRE decommissioning effort.

Conclusions and Recommendations

1) The radiological criteria for decontamination and for contamination and exposure control must be developed and formalized at the project planning stage.
2) Close operational surveillance by health physics personnel is essential to control contamination and exposure, to optimize decontamination work, and to assist in controlling the volume of contaminated waste.
3) Radiological control and certification planning is essential.
4) Quality assurance input is necessary in radiological status evaluation.
5) The participation of an overview and certification agency should be established early and the participation should be integrated into the project schedule.
6) An intensive industrial safety program is required for decommissioning activities.

9.11 FACILITY DESIGN

Decommissioning of any nuclear facility can be accomplished with existing technology. This has been demonstrated in the successful decommissioning of the SRE. It is apparent, however, in examining the technology and procedures employed in the decommissioning, that an in-depth review of the experience gained should be made by facility designers of future nuclear facilities so that problems can be avoided or at least mitigated. The designers can also incorporate facility features that will simplify the decommissioning procedure.

The more significant possibilities are considered and presented below.

9.11.1 Decontamination of Concrete Surfaces

Decontamination of concrete surfaces, particularly surfaces with cracks, expansion joints, and porous concrete, is difficult. Many techniques were tried, ranging from washing with solvents to total removal of the surfaces. None was wholly satisfactory. They all required an extensive use of manpower. Physical removal of the surfaces was usually accomplished with a concrete spalling tool (scabbler) that could remove surfaces to about 1/2 in. depth. Grit blasting was used chiefly for paint removal. Surfaces where permeation of the contamination was very deep (several inches) were removed by a hydraulically powered and positioned ram (Hy-Ram).

The difficulty of decontaminating concrete surfaces in areas where contamination is likely to occur, such as in vaults, trenches, pits, building columns, and walls, indicates a need for protection of surfaces. Metal liners with welded joints, continuous plastic material covers, paint, or hard, smooth coatings should be used to cover the concrete. In addition to permeability, the covering material selected should be sufficiently strong to withstand the potential for damage from maintenance traffic in the area. Metal liners, if used, should provide for ease of removal. Welded joints should be constructed to allow mechanical cutting and effect containment of cutting debris. The use of concrete expansion joints should be avoided unless an effective flexible sealer or cover can be specified for protection over the joints. Surface geometries should be optimized for cleaning. Rounded corners and edges should be used where possible.

9.11.2 Disposal of Massive Concrete Structures

Handling or demolishing of massive contaminated or activated concrete biological shields and support structures can be difficult and costly. These structures are usually only partially radioactive, and the radioactive materials are not easily separated from the nonradioactive materials because of the selective demolition required, the care necessary to keep from cross-contaminating, and the tedious radiological assessment procedures required. At the SRE, the other biological shield was demolished using the Hy-Ram. The upper portion of the shield was not significantly contaminated by induced radioactivity. However, the section near the reactor core line was activated, requiring packaging and shipment of the rubble to burial. Separation of the clean concrete from the activated concrete was not attempted for the concrete from the center section. Although this increased the volume of waste sent to burial, the cost for burial was less than the estimated separation costs.

The use of massive monolithic concrete designs in biological shields or other areas where concrete activation will occur should be reconsidered. Other shielding materials, for example, lead, steel shot, or iron pellets, in conjunction with hydrogenous shield material, might be used. Interlocking, modular concrete structures could be used. Where integrated concrete structures are necessary for containment or strength, means for easily removing or spalling the concrete surfaces should be included in the design. A two-layer biological shield structure could be used. The structure could consist of a physically independent outer layer for containment and an inner layer constructed to provide the major shielding requirements and contain all the induced activation expected during the reactor lifetime.

9.11.3 Disposal of Reactor Vessels

The disposal of the reactor vessel will be a major activity of decommissioning. If a plasma-torch manipulator is to be used to cut up the vessel, then design considerations of the following would simplify the torch operations.

1) Locate piping, grid plates, and other reactor internal structure with optimum access for cutting with the torch.
2) Provide for the installation of the manipulator; include manipulator support structure where possible.
3) Select material for vessels, pipe, and support structure with a concern for induced radiation effects.

9.11.4 Disposal of Waste Holdup Tanks

Excavation and removal of waste holdup tanks was relatively easy. However, leaky valves, tank fittings, and piping contaminated adjacent soil.

Consideration should be given to containing the radioactive waste tanks in isolated vaults with provisions for detecting and containing leaks. Tracks or guide structures should be considered for use on the tank outer walls to permit remote cutting and radiological surveys of the tanks.

9.11.5 Removal of Process Equipment

Process equipment such as heat exchangers, pumps, sodium purification traps, waste handling, and their support structures were removed without major difficulty.

Contamination in this equipment tends to collect in low spots and in cold spots. Design and installation of this equipment should enhance the tendency to concentrate the contamination. Dismantling of process equipment would be simplified if the larger system components were designed for ease of disassembly and for isolation of sections that are likely to be contaminated. Process system equipment installations should include adequate access for removal operations.

9.11.6 Disposal of Handling Machines

The 50- to 60-ton fuel moderator and plug-handling machines were stripped of clean, reusable exterior equipment and then shipped, intact, to the burial site. The cost for labor to dismantle the machines and decontaminate components was too great and was, therefore, not attempted.

Handling machine designs, which would permit easy disassembly and isolation of contaminated sections, would permit a greater salvage of material and a decrease in the waste volume for burial. Handling machines are usually at the center of most reactor operations and, consequently, are vulnerable to airborne contamination. An airtight shroud constructed of easy-to-wipe materials, covering the exterior wiring controls and instrumentation, would simplify decontamination of the exterior.

9.11.7 Decontamination of Facility Structures

Decontamination, rather than removal, of facility structures such as open beams and columns, electrical cable trays, conduits, exhaust ducts, etc., may be desirable to save the facility for future use. However, decontamination costs, in some instances, can exceed replacement costs.

Facility designs should recognize that radioactive spills will occur and that plant interiors, and especially horizontal surfaces, will become contaminated. Easily cleaned containment should be provided, and the routing of services through areas where spills may occur should be avoided.

9.11.8 Contamination Assessment

The radiological assessment of soil and concrete rubble, when working to essentially background levels, is a time-consuming process. Consequently, many cubic yards of soil with marginal contamination may be packaged and shipped to burial.

A well-kept record of radioactive spills and other plant construction and operating history is necessary. Radiological instrumentation-access spaces throughout the plant in concrete structure, shielding material, and soil would facilitate the plant contamination assessment.

9.11.9 General Recommendations

Perform comprehensive radiological surveys, engineering studies, and extensive planning prior to initiating the decommissioning work on site. The accuracy of the schedule and cost estimates are absolutely dependent on complete understanding and definition of the full scope of work. This scope can only be adequately defined after the completion of these activities.

The processes described can be anticipated before the decommissioning of many nuclear facilities. Solutions to problems may be made more difficult by the increasingly restrictive regulatory requirements, such as the contemplated decrease in the permissible radiation dosage for workers; the more restrictive requirements for packaging, transport, and burial of waste; and the growing emphasis on greater usage of waste volume reduction techniques.

Considerations for simplifying decommissioning not directly related to SRE experiences are presented as follows:

1) A decommissioning plan should be prepared concurrently with the conceptual design of the facility and should be revised in parallel with the development of the facility design.
2) The design of maintenance equipment and facilities should include capabilities for use in the decommissioning operations. Waste volume reduction capability such as arc cutters, shears, compactors, electropolishers, and liquid waste solidification should be provided.

3) Plant air exhaust systems should have the capability to handle airborne contamination generated during decommissioning. The plant should also have capability for containment of the liquid and solid generated during decommissioning.

4) Adequate space should be provided near the facility for decontamination, dismantling, packaging, storage. Also, adequate personnel and equipment access to the potentially contaminated areas is required.

These recommendations assume that decommissioning problems, as experienced today, will be similar to those 40 years from now when the facilities currently being designed will be ready for decommissioning. The projected physical size of plants is much larger now; the reactor designs, particularly the reactor internals, are much more complex; regulatory requirements for radiation worker radiation dosages are becoming more stringent; onsite burial of waste is being considered; and the possibility of a site being satisfactorily decontaminated to levels for unrestricted use is decreasing. The basic requirements for reducing contamination are not expected to change, but more of the decontamination work may be transferred to remotely operated machines.

10.0 LIST OF ABREVIATIONS

SRE — Sodium Reactor Experiment
PEP — Power Expansion Program
IHX — Intermediate Heat Exchanger
EM — Electromagnetic
FHM — Fuel Handling Machine
RMDF — Radioactive Materials Disposal Facility
CERF — Contaminated Equipment Repairs Facility
SFMPO — Surplus Facilities Management Program Office
DOE-RL — U.S. Department of Energy, Richland, Washington Area Office
DOE-SAN — U.S. Department of Energy, San Francisco, California Area Office
ESG — Energy Systems Group of Rockwell International Corporation
PCS — Performance Control System
PFT — Primary Fill Tank
MIHX — Main Intermediate Heat Exchanger
ORNL — Oak Ridge National Laboratory
JRC — Jet Research Corporation
DOT — U.S. Department of Transportation
UBC — Uniform Building Code
HEPA — High Efficiency Particulate Air
ALARA — As Low As Reasonably Achievable
DOE — U.S. Department of Energy
AEC — Atomic Energy Commission

APPENDIX

SUPPORTING DOCUMENTS

Document No.	Title
N704ACR990003	SRE Activity Requirement No. 005. Removal of Primary Sodium System Piping and Components
N704ACR990004	SRE Activity Requirement No. 009. Passivation of Residual Sodium in the Reactor Vessel
N704ACR990005	SRE Activity Requirement No. 008. Removal of Sodium Components from Sodium Service Building 153
N704ACR990006	SRE Activity Requirement No. 16. Decontamination and Dismantling of Demountable Maintenance Shield Assembly
N704ACR990007	SRE Decontamination and Removal of Storage and Wash Cells. SRE Activity Requirement No. 17
N704ACR990008	SRE Activity Requirement No. 10. Removal of SRE Reactor Vessel Loose Internals
N704ACR990010	SRE Activity Requirement No. 7. Removal of Primary Sodium Components from the Sodium Service Vault
N704ACR990011	SRE Activity Requirement No. 11. Cleaning of Sodium Components
N704ACR990012	SRE Activity Requirement Nos. 18 and 19. Decontamination and Dismantling of Mark I and Mark II Fuel Handling Machines
N704ACR990014	SRE Activity Requirement No. 10A - Removal and Disposal of the SRE Ring Shield
N704ACR990015	SRE Activity Requirement No. 20. Decontamination of Moderator Handling Machine
N704ACR990016	SRE Activity Requirement No. 16. Decontamination and Dismantling of the Hot Cell Facilities
N704ACR990017	SRE Activity Requirement No. 23 - Disposal of Radioactive Waste Systems Exterior to Building 143
N704ACR990020	SRE Activity Requirement No. 24. Decontamination of Building 163 (CERF)
N704ACR990021	SRE Activity Requirement No. 25. Decontamination & Dismantling of Building 724 and Pad 723

Document No.	Title
N704AACR990002	SRE Activity Requirement No. 14. Decontamination of Primary Fill Tank, Pipe & Sodium Service Vaults
N704ACR990023	SRE Activity Requirement No. 21. Removal of Activated and Contaminated Concrete Structure from the SRE
N704ACR990024	SRE Activity Requirement No. 27. D&D of Building 143 Retention Pond and Sanitary Sewer
N704ACR990025	Disposal of Building 143 (SRE) Stack and Vent System Activity Requirement
N704ACR990027	SRE Activity Requirement No. 29. Final Closeout of the SRE Facility
N704DP990001	Start-Up Safety Review for Plasma Torch System
DRR-704-990-001	Design Review Minutes for the ORNL Rotating Mast Manipulator Final Design
DWP-704-990-003	Procedure for Transferring Radioactive Sodium from Primary Drain Tank into Approved Cabinets
N704DWP990004	Procedures for Installing SRE Manipulator in SRE Vessel Mock-Up
N704DWP990008	Detailed Working Procedure for Removal of SRE Sodium System Components
N704DWP990009	Passivation of Remaining Sodium in SRE Core Vessel. Building 143 Detailed Working Procedure
N704DWP990010	Passivation of Remaining Sodium in SRE Primary Sodium Tank Detailed Working Procedure
N704DWP990011	Decontamination and Dismantling of SRE Demountable Maintenance Shield Assembly (DMSA) Detailed Working Procedure
N704DWP990012	Detailed Working Procedure for the Removal of SRE Reactor Vessel Loose Internals
N704DWP990013	DWP for Loading & Shipping SRE Declad Fuel
N704DWP990014	Removal of Primary Sodium Components from the Sodium Service Vaults
N704DWP990015	Detailed Working Procedure for the Removal of Sodium Systems & Components in Building 153

Document No.	Title
N704DWP990016	Cutting and Disposition of Primary Sodium Piping
N704DWP990017	SRE Core Liner Removal - Detailed Working Procedure
N704DWP990018	Core Clamp Band Removal - Detailed Working Procedure
N704DWP990019	Detailed Working Procedure for Explosive Removal of SRE Vessel Internal Piping
N704DWP990021	Detailed Working Procedure for the Removal of SRE Storage and Wash Cells Internals
N704DWP990025	Detailed Work Procedure for the Removal of the SRE Gridplate
N704DWP990026	Core Tank Removal Detailed Working Procedure
N704DWP990028	Detailed Working Procedure for the Passivation of Remaining Sodium in the SRE Components
N704DWP990029	Manipulator and Platform Installation and Alignment
N704DWP990031	Core Tank Bellows Removal
N704DWP990032	Main & Aux. Core Clamp Removal from the SRE Core Tank
N704DWP990033	SRE Core Tank Bottom Drilling
N704DWP990034	SRE Gridplate Nut Removal
N704DWP990035	Detailed Working Procedure for the Removal of the SRE Moderator Coolant Header
N704DWP990036	Guide Post Installation and Removal
N704DWP990037	Detailed Work Procedure for Removal, Transfer, and Reassembly of SRE Rotating Mast Manipulator and Platform
N704DWP990038	Detailed Working Procedure to Transfer SRE Internal Piping to Storage Pit
N704DWP990039	Detailed Working Procedure for the Cut-Up of the SRE Internal Piping
N704DWP990040	Detailed Working Procedure for Core Tank-To-Liner Attachment Ring Removal
N704DWP990044	Detailed Working Procedure for Removal of SRE Gridplate Perimeter Nuts

Document No.	Title
N704DWP990045	Detailed Working Procedure for Outer Tank Bellows Removal
N704DWP990046	Detailed Working Procedure for SRE Thermal Rings Removal and Cut Up
N704DWP990047	Detailed Working Procedure for Removal of Cutting Debris
N704DWP990048	Detailed Work Procedure for the Removal of the SRE Core Tank Bottom
N704DWP990049	Detailed Working Procedure for Outer Tank Removal
N704DWP990050	Detailed Working Procedure for Outer Tank Bottom Removal
N704DWP990051	Detailed Working Procedure for Super X Insulation Removal
N704DWP990053	Detailed Working Procedure for Scoring the Core Cavity Liner
N704DWP990054	Disposal of Radioactive Waste Systems at Building 653 and Building 143
N704DWP990055	Detailed Work Procedure for Operation of the SRE Shielding Water Filtration System
N704DWP990057	Decontamination and Dismantling of Building 724 Detailed Working Procedure
N704DWP990058	Removal and Shipment of Two Fuel and One Moderator Handling Machines
N704DWP990060	Deactivation of Building 143 Retention Pond and Sanitary Sewer System
N704DWP990062	Decontamination and Dismantling of the Hot Cell Facilities at SRE
N704DWP990063	SRE Site Survey Plan for Release to Unrestricted Use
N704DWP990065	Building 143 Detailed Working Procedure for Excavation of the SRE to Remove Below-Grade Contaminated and Activated Material and Structures
N704DWP990070	Final Radiological Inspection Detailed Working Procedure
N704DWP990071	Backfill and Compaction of the SRE High Bay Excavation, Detailed Working Procedure

Document No.	Title
TI-704-990-011	Remote Tooling Task Requirement 1.9. Core Tank Liner Removal Tooling
TI-704-990-012	Remote Tooling Task Requirement No. 1.10. Core Tank Removal Tooling
TI-704-990-013	Remote Tooling Task Requirement No. 1.11. In-Vessel Thermal Rings Removal Tooling
TI-704-990-014	Remote Tooling Task Requirement No. 1.12. Outer Tank Removal Tooling
TI-704-990-015	Remote Tooling Task Requirement No. 1.13. In-Vessel Thermal Insulation Removal Tooling
TI-704-990-016	Remote Tooling Task Requirement No. 1.14. Core Cavity Liner Removal
TI-704-990-017	Plan of Action for Technical Assistance Provided by ORNL in Support of Remote Tooling for Removal of SRE Vessels
TI-704-990-020	Soil and Concrete Activation Limits for Unrestricted Use of Former SRE Site
TI-704-990-021	Disposal of Primary Sodiuum
TI-704-990-022	Support Calculations for Rotating Mast Manipulator
TI-704-990-023	Passivation of Remaining Sodium in SRE Core Vessel
N704TI990025	Contamination Confinement Systems for Decontamination and Disposition of the SRE Core Vessel
N704TI990026	Technical Information on Decontamination of Radioactive Materials by Foam Application
N704TI990027	Radiological Survey Results - Release to Unrestricted Use, SRE Region I (Building 724 Area)
N704TI990028	Radiological Survey Results - Release to Unrestricted Use, SRE Region II (Building 163, Box Shop)
N704TI990029	Radiological Survey Results - Release to Unrestricted Use, SRE Region III (SRE Entrance)
N704TI990030	Radiological Survey Results - Release to Unrestricted Use, SRE Region IV (West Parking Lot)
N704TI990031	Radiological Survey Results - Release to Unrestricted Use SRE Region V (Gas Storage Vault)

Document No.	Title
N704TI90032	Radiological Survey Results - Release to Unrestricted Use, SRE Region VI (Water Tank Area)
N704TI990033	Radiological Survey Results - Release to Unrestricted Use, SRE Region VII (Retention Pond)
N704TI990034	Radiological Survey Results - Release to Unrestricted Use, SRE Region VIII (SRE Front Lot)
N704TI990035	Radiological Survey Results - Release to Unrestricted Use, SRE Region IX (SRE Back Lot)
N704TI990036	Radiological Survey Results - Release to Unrestricted Use, SRE Region X (SRE Parking Lot)
N704TI990037	Radiological Survey Results - Release to Unrestricted Use, SRE Building 041
N704TI990038	Radiological Survey Results - Release to Unrestricted Use, SRE Building 143
N704TI990039	Radiological Survey Results - Release to Unrestricted Use, SRE, Building 163
N704TI990045	Schedule to Complete Excavation of SRE in FY 1979 First Year Schedule of 2-Year Plan for Excavation of SRE in FY 1979
N704TI990047	Disassembly and Examination of SRE Sodium Heated Steam Generator
N704TI990050	References for Decontamination and Dispositioning Criteria
N704TI990051	Decontamination of Surfaces by Foam Cleaning
N704TI990057	Final Radiological Inspection of the Below-Grade Areas in the SRE Prior to Release for Unrestricted Use
N704TNP990001	Training Plan for the Decontamination and Disposition of Facilities
N704TP990005	SRE Mockup Operations Test Plan
N704TP990006	Test Plan for the Explosive Cutting Demonstration of SRE Vessel Internal Piping
N704TP990007	Manipulator Checkout and Test Procedure

Document No.	Title
N704DWP990087	SRE Radioactive Vent System Removal Detailed Working Procedure
N704ER990001	Evaluation of Cutting Methods for Removal of the SRE 5-1/2 Inch Carbon Steel Thermal Rings
N704ER990003	Radiation Levels Associated with Irradiated Metallic Components of the SRE
N704ER990005	Dose Rates Outside the ATCOR AL-33-90 Cask during the Shipment of SRE Stainless Steel Components
N704ER990008	SRE Biological Shield Removal Methods Trade Study
N704ER990009	Engineering Report for the Core Drilling and Radiometric Analysis of the SRE Reactor Biological Shield
FDP704990003	Facilities Dismantling Plan for SRE
N704DP990001	High Level Radioactive Waste Transfer
N704DP990004	Sodium Disposal Facilities Operating Procedure
N704DP990005	SRE Primary Piping Sodium Disposal
PP-704-990-001	Quality Assurance Program Plan for the Decontamination & Disposition of Facilities
PP-704-990-002	Decontamination & Disposition of Facilities Program
RPA-704-990-001	Release Plan of Action for the Decontamination & Disposition of Facilities Program
SRR-704-990-001	Operational Safety Plan for the AI Decontamination & Disposition of Facilities Program
SRR-704-990-005	Minutes of Isotopes Committee Review of the SRE Dismantling Plan
N704SRR990007	Minutes of Isotopes Committee Review of Decontamination and Disposition Program Detailed Working Procedures for STIR and SRE facilities.
N704SRR990008	Minutes of Isotopes Committee's Review of Application to Passivate Remaining Sodium in SRE Vessel Building 143 Detailed Working Procedure and an Operating Procedure for Calibration of Radiation Survey Meters in Building 100, Santa Susana

Document No.	Title
N704SRR990009	Minutes of the Isotopes Committee Review of the Detailed Working Procedure for the Proposed Sodium Passivation in the SRE Primary Tank
N704SRR990011	Minutes of Isotope Committee Review of the Detailed Working Procedures (DWP's) for Imminent D&D Operation
N704SRR990012	Minutes of Isotope Committee Review of the Detailed Working Procedure for Removal of SRE Reactor Vessel Loose Internals
N704SRR990014	Minutes of Isotope Committee Review of the Proposed Plasma-Torch and Explosive Cutting Operations at SRE
N704SRR990019	Summary and Comparison of ESG and ANL Radiometric Analyses at the SRE
TI-599-19-103	Post Retirement Plan for Radiological Decontamination of the SRE Site
TI-704-990-001	Activity Requirement No. 1. Remote Tooling for Removal of SRE Vessel
TI-704-990-002	Sodium Disposal Processes
TI-704-990-003	Remote Tooling Task Requirement No. 1.1. Initial In-Vessel Radiation Survey
TI-704-990-004	Remote Tooling Task Requirement No. 1.2. In-Vessel Viewing & Photo Survey
TI-704-990-005	Remote Tooling Task Requirement No. 1.3. SRE Core Cavity Liner Mock-Up
TI-704-990-006	Remote Tooling Task Requirement No. 1.4. Plasma-Torch Manipulator
TI-704-990-007	Remote Tooling Task Requirement No. 1.5. Plasma-Arc Cutting System
TI-704-990-008	Remote Tooling Task Requirement No. 1.6. Manipulator-Torch Control Console
TI-704-990-009	Remote Tooling Task Requirement No. 1.7. Underwater Cut-Up Tank
TI-704-990-010	Remote Tooling Task Requirement 1.8. Vessel Internals Removal Tooling

Document No.	Title
N704TP990008	Radiological Survey Plan, Support of D&D Program Operations at T-143 (SRE)
N704TR990003	Manipulator Console Systems Checkout and Calibration Test Report - Development
N704TR990004	SRE Vessel Internal Piping Explosive Cutting Development
N704TR990005	SRE Underwater Plasma Arc Cutting Development Test Report
N704TR990006	Report on Passivation of the SRE Hot Trap
N704TR990007	Report on Passivation of the SRE Reactor Vessel and Associated Components
N704TR990008	SRE Reactor Vessel Cutup and Disposal

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