FINAL DECOMMISSIONING OF THE UCLA BOELTER REACTOR FACILITY

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ABSTRACT

UCLA announced its intent to decommission the Boelter Research Reactor on June 14, 1984. The decommissioning of the Boelter Reactor was carried out in two phases. The first phase involved removal of the reactor fuel, core, graphite stack, and the majority of the concrete shield blocks. The second phase included demolition of the reactor monolith, removal of the remaining shield blocks, removal of all process equipment, decontamination of all remaining facilities, and a release survey. This paper describes the activities associated with this second phase of the project.

The University retained the services of Dames & Moore to provide a radiological engineer to supervise and oversee the D&D activities on a day to day basis. Actual decontamination and demolition activities were performed by Nuclear Energy Services (NES) through their subsidiary IES. All activities were performed with oversight by Dames & Moore on behalf of the UCLA Radiation Safety Office.

A baseline exposure rate survey was performed throughout the facilities. Additionally, a general area removable contamination survey was conducted to determine the protective clothing requirements. Using a teletector, the highest contact expose rate measured was 1100 mR/h. As D&D activities proceeded, routine radiation and contamination surveys were performed daily. No contamination outside of the monolith containment was ever detected by the routine surveys. The air samples collected during activated concrete demolition were all less than the maximum permissible concentration (MPC) for each radionuclide present. The dominant radionuclides detected were Eu-152 and Co-60. The total collective dose for the project was 1.17 man-rem, as determined from commercial film badge results.

The Boelter Reactor facility was surveyed to demonstrate compliance with the established release criteria. Several hot spots were identified during the reactor room floor survey and were decontaminated. A bushing hammer was used to scabble the concrete and the debris was vacuumed and disposed of as LSA radioactive waste. All other areas required little or no further decontamination.

The radioactive release criteria established for the Boelter reactor facility dismantlement included compliance with the surface contamination levels presented in the NRC Regulatory Guide 1.86, "Termination of Operating Licenses for Nuclear Reactors." In addition to the NRC Regulatory Guide 1.86 requirements, exposure rates were not to exceed 5 rem/h above background radiation levels, measured 1 meter from the surface of interest.

The primary forms of waste generated during the project were rubbled concrete, steel rebar, and miscellaneous paper and plastic. The concrete and rebar were segregated into clean and radioactive waste and disposed of accordingly. The radioactive material was sent to the low level radioactive waste facility in Beatty, NV. The resulting condition of the facilities is such that they are acceptable for release for unrestricted use. All remaining contamination levels are within the limits established prior to initiation of the decommissioning as acceptable for unrestricted release. Release of the facility for unrestricted use is expected in the Spring of 1993 following verification surveys by NRC.

BACKGROUND

UCLA announced its intent to decommission the Boelter Research Reactor on June 14, 1984. Chancellor Charles Young noted that the decommissioning decision was reached solely as a result of the changed circumstances affecting the academic benefits and escalating costs of continued operation of the reactor facility in a press release that day.

The decommissioning of the Boelter Reactor was carried out in two phases. The first phase involved removal of the reactor fuel, core, graphite stack, and the majority of the concrete shield blocks. The second phase included demolition of the reactor monolith, removal of the remaining shield blocks, removal of all process equipment, decontamination of all remaining facilities, and a release survey. This paper describes the activities associated with this second phase of the project.

Actual decontamination and demolition activities were performed by Nuclear Energy Services (NES) through their subsidiary IES. IES in turn hired subcontractors for concrete demolition (Penhall Company) and waste transportation (Environmental Management & Control). All activities were performed with oversight by Dames & Moore on behalf of the UCLA Radiation Safety Office. The University retained the services of Dames & Moore to provide a radiological engineer to supervise and oversee the D&D activities on a day to day basis.

OPERATING HISTORY

The operating history of the reactor extends from initial criticality on October 21, 1960 to the notice of intent to decommission by Chancellor Young on June 14, 1984. The facility was operated from the time of initial criticality until the decommissioning order for the purpose of research and reactor operations instruction. Due to the academic mission

of the reactor, it was operated "as needed" for class instruction and experimentation. As such, it was rarely operated for more than a few hours in any one day.

The reactor was licensed by the Nuclear Regulatory Commission (NRC) from initial criticality with a limitation on power output of 10 kilowatts (kW). Slight modifications were made to the reactor and licensing amendments were approved that allowed operation up to 100 kW in October of 1963. All licensing and operations records have been retained in the former control room.

DECOMMISSIONING ACTIVITIES

The objective of the decommissioning effort was to dismantle and remove the Boelter Research Reactor, decontaminate the reactor room and ancillary facilities, and release the facilities for unrestricted use.

Baseline Survey

A walk-through survey of the Boelter Reactor facility was performed prior to initiation of the final decommissioning to confirm radiological conditions reported by UCLA during the period between Phase 1 and Phase 2 activities.

A baseline exposure rate survey was performed throughout the facilities to determine the proper radiation area posting requirements. In addition, a general area removable contamination survey was conducted to determine the protective clothing requirements. Each shield block was surveyed for radiation and contamination levels and the results were documented. No smearable contamination was detected on any of the shielding blocks. The shielding block exhibiting the highest radiation level had a contact exposure rate of approximately 40 mR/h.

A detailed radiation survey was performed within the monolith containment to determine radiological conditions present during initial demolition in this area. A removable contamination survey was performed to identify the nature and extent of removable contamination within the monolith. Baseline air samples were also obtained from within monolith containment. Analysis of the smears and air samples confirmed that removable and airborne contamination were at background levels.

A radiation survey was performed to identify contact exposure rates on four structural steel rails within the pedestal of the monolith. Using a teletector, the highest contact expose rate measured was 1100 mR/h. This reading was in agreement with results of previous surveys.

Operational Surveillance

As D&D activities proceeded, routine radiation and contamination surveys were performed daily within the radiologically controlled area (RCA), as well as the count room, control room, storage room and reactor room ramp area (See Fig. 1).

These surveys were conducted to verify that contamination had not spread from the controlled surface contamination area (CSCA) during decommissioning operations. The surveys aided in the substantiation that administrative and engineering controls implemented during operations were adequate. No contamination outside of the monolith containment was ever detected by the routine surveys.

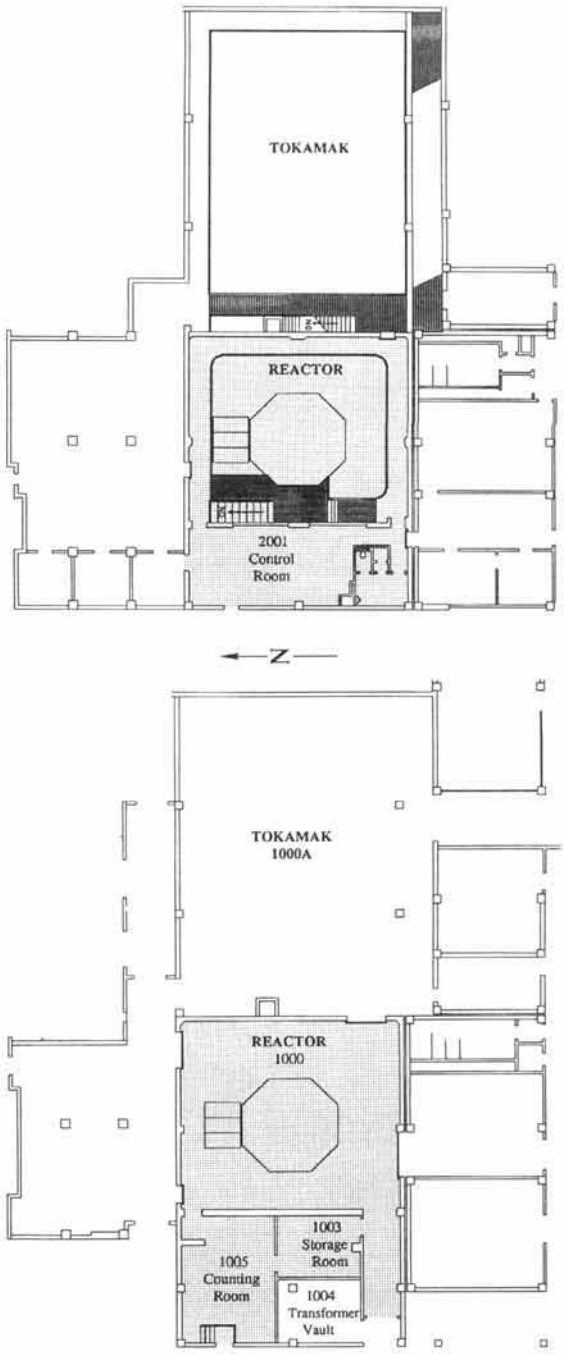

Fig. 1. Boelter Reactor Facility physical layout.

Air Sampling Surveillance

Fifty air samples were collected over the course of the decommissioning project. Air samples with initial results near or exceeding 1E-11 μCi/ml for alpha emitters and 1E-10 μCi/ml for beta/gamma emitters were recounted within 24 hours to allow for decay of short-lived naturally-occurring radionuclides. The air samples collected during activated concrete demolition were all less than the maximum permissible concentration (MPC) for each radionuclide present. The dominant radionuclides detected were Eu-152 and Co-60.

Eleven air samples that were collected during concrete demolition within the monolith containment were also

analyzed with a liquid scintillation counter (LSC) to determine the H-3 and C-14 concentrations in air. The LSC analysis resulted in overestimated quantities of H-3 and C-14 because of the presence of Co-60 and Eu-152 in the air samples. Even with the gross overestimate, the concentrations of H-3 and C-14 were significantly below their respective Maximum Permissible Concentrations (MPCs).

Personnel Exposure Monitoring

The University issued dosimetry and administered entry and exit whole body counts for all site personnel. The total collective dose for the project was 1.17 man-rem, as determined from commercial film badge results. The whole body counts were negative for all personnel on the decommissioning project.

FINAL SURVEY PROCEDURES

The Boelter Reactor facility was surveyed to demonstrate compliance with the established release criteria. Several hot spots were identified during the reactor room floor survey and were decontaminated. A bushing hammer was used to scabble the concrete and the debris was vacuumed and disposed of as LSA radioactive waste. All other areas required little or no further decontamination.

A graded approach was implemented consisting of dividing the surfaces (i.e., floor, walls, ceiling) into a predetermined grid pattern. Typically, the floors and lower walls (up to 2m) were divided into 1m by 1m grids, while the upper walls were 2m by 2m grids and the ceilings 3m by 3m grids.

Major Contaminants Identified

The major contaminants identified were products of neutron activation due to reactor operations. Based on laboratory characterization, Co-60 and Eu-152 were found to be in the highest concentrations. A concrete chip representative of the monolith was collected and analyzed. The analysis identified the following radionuclide content: Eu-152 (5481 pCi/g), Co-60 (2575 pCi/g), H-3 (1494 pCi/g), C-14 (502 pCi/g), Eu-154 (293 pCi/g), Eu-155 (45 pCi/g), and Cs-134 (3.82 pCi/g). A sample of the steel rebar from the monolith was also analyzed and resulted in 19,600 pCi/g of Co-60. Reactor fission products indicative of possible fuel failure were never identified during the project.

Guidelines Established

The Boelter reactor decommissioning was performed within the guidelines established in the consent order between UCLA, the NRC, and an intervenor group. The radioactive release criteria established for the Boelter reactor facility dismantlement included compliance with the surface contamination levels presented in the NRC Regulatory Guide 1.86, "Termination of Operating Licenses for Nuclear Reactors" (1). For beta-gamma emitters, the average fixed plus removable contamination levels could not be greater than 5000 dpm β-γ/100 cm^2 and removable contamination levels could not be greater than 1000 dpm β-γ/100 cm^2. Furthermore, the maximum surface contamination level, applied to an area of not more than 100 cm^2, could not exceed 15,000 dpm β-γ/100 cm^2.

In addition to the NRC Regulatory Guide 1.86 requirements, exposure rates were not to exceed 5 μrem/h above background radiation levels, measured 1 meter from the surface of interest.

Equipment and Procedures Selected

Survey measurements for fixed contamination, removable contamination and exposure rates (floor grids only) were obtained for each grid. A Tc-99 electroplated beta source (2060±80 dpm) was used to determine the efficiency of the GM pancake probes and the smear counter (refer to Appendix L). The Tc-99 source was chosen because it emits radiation of the level and type that was expected at the Boelter Reactor facility based on an isotopic analysis of the activated monolith. Tc-99 provided a conservative estimate of the GM pancake probe efficiency for the two prevalent radionuclides at the Boelter reactor site, Co-60 and Eu-152 . The conservatism resulted from the fact that the beta endpoint energy of Tc-99 (292 keV) is less than that of Co-60 (318 keV) and Eu-152 (696 keV). The higher beta energies of Co-60 and Eu-152 resulted in higher actual efficiencies than that determined with Tc-99.

Initially, a 100% surface scan survey was performed for each grid with a Ludlum 2221 ratemeter/scaler and 44-9 GM pancake probe. Five (5), 30 second direct beta-gamma contamination readings were then taken within each grid using a Ludlum 2221 meter and 44-9 GM probe. These measurements were uniformly spaced (i.e., similar to the pattern of a five on a die), with the scan survey serving to identify the highest direct contamination reading location for each of the five documented grid locations.

Two smears (1.75 in. diameter cloth sampling smears) were taken within each grid, one of which was taken at the location of the highest direct contamination reading. The smears were counted on a Ludlum 2929 phoswich detector for 30 seconds. In addition, one moistened paper smear was obtained per four grids for detection of low energy beta emitters with a liquid scintillation counter (LSC). The LSC analysis functioned primarily to verify that the surface contamination levels of H-3 and C-14 were below the release criteria.

The liquid scintillation smears were placed in 20 ml glass vials and prepared for counting. One milliliter of a 50%-50% water and alcohol solution was dispensed on the smear paper to facilitate elution of the collected activity. Approximately 10 ml of scintillation cocktail was added to each vial. The vials were shaken vigorously and stored for about an hour to allow for any photoluminescence to decay.

The vials were then analyzed on the LSC (Packard Model 2500 TR) with a dual-label protocol for H-3 and C-14 (named "3H-14C-OPEN WINDOW"). Three regions were established for the smear analysis, Region A (0 - 12 keV) for H-3, Region B (12 - 156 keV) for C-14, and Region C (150 -2000 keV) for higher energy beta emitters. This LSC counting protocol yielded accurate activity results as long as only H-3 and/or C-14 were present in the sample. However, when higher energy beta emitters were present (e.g., Co-60, Eu-152) H-3 and C-14 activities were overestimated due to the spilldown of counts into the lower energy regions. For this case, conservative activities were reported for H-3 and C-14.

Exposure rate measurements were taken for each floor grid (and the lower walls of the Reactor Room) with a Bicron Micro-Rem meter. The exposure rate measurements were taken at approximately 1 cm and 1 m from the surface.

SURVEY FINDINGS

Techniques for Reducing/Evaluating Data

The minimum detectable activity (MDA) was calculated for both the fixed contamination survey instrumentation (i.e., Ludlum 2221 and 44-9 GM pancake probes) and the smear counter (i.e., Ludlum 2929). The MDA was calculated by the following Eq. (2):

$$MDA = \frac{\frac{2.71}{T_s} + 3.29\sqrt{\frac{R_b}{T_b} + \frac{R_b}{T_s}}}{(\text{efficiency})\left(\frac{\text{probe area}}{100\ \text{cm}^2}\right)}, \qquad \text{(Eq. 1)}$$

where,

R_b = Background counting rate (cpm),

T_b = Background count time (min), and

T_s = Sample count time (min).

The MDA for the Ludlum 2221 and 44-9 GM pancake probe was calculated in the same units as the fixed contamination results (dpm/100 cm^2). As an example, the MDA for the Ludlum 2221 and 44-9 can be calculated for a background counting rate of 50 cpm:

$$MDA = \frac{\frac{2.71}{0.5\ \text{min}} + 3.29\sqrt{\frac{50\ \text{cpm}}{1\ \text{min}} + \frac{50\ \text{cpm}}{0.5\ \text{min}}}}{(0.18\ \text{c/dis})\left(\frac{15\ \text{cm}^2}{100\ \text{cm}^2}\right)} \qquad \text{(Eq. 2)}$$

or,

$$MDA = 1690\ \frac{\text{dpm}}{100\ \text{cm}^2}. \qquad \text{(Eq. 3)}$$

Thus, the MDA is approximately one-third of the releasable average surface contamination level (5000 dpm β-γ/100 cm^2) in NRC Regulatory Guide 1.86 (1).

The MDA was calculated in a similar manner for the Ludlum 2929 smear counter. However, no correction for probe area was necessary to convert to units of dpm/100 cm^2 since the smeared surface area was approximately 100 cm^2. Also, the background counting rate for the Ludlum 2929 was determined by a thirty (30) minute count (typical background was about 80 cpm). The MDA for the smear counter was approximately 320 dpm/100 cm^2, about one-third of the removable surface contamination level (1000 dpm β-γ/100 cm^2) in NRC Regulatory Guide 1.86.

The MDA for the liquid scintillation counter was extremely low due to the low background counting rates (e.g., 12 cpm for H-3) and high counting efficiencies (e.g., H-3 and C-14 efficiency of 67% and 96%, respectively). The minimum detectable activities found were about 8 dpm/100 cm^2 for H-3.

The average background count rate for each Ludlum 2221 and 44-9 GM pancake probe was determined by a series of three 1 minute counts. Each direct measurement of fixed contamination was thirty seconds in duration. If the direct measurement (corrected for a 1 minute count time) resulted in a value less than or equal to the background count rate, the net count rate was given a value of 1 cpm. For example, if the Ludlum 2221 and 44-9 probe had a background count rate of 50 cpm and a 30 second direct measurement resulted in 23 counts (gross count rate equals 46 cpm), the net count rate would be given a value of 1 cpm (as opposed to the actual net count rate of -4 cpm) and then converted to dpm/100 cm^2 by dividing by the efficiency and correcting for the probe area. Although this practice biases the average surface contamination results, the effect is the documentation of conservative survey results. The average of the five direct contamination measurements was calculated for each grid and compared to the average surface contamination level (5000 dpm β-γ/100 cm^2) for unrestricted release under NRC Regulatory Guide 1.86.

Comparison of Findings with Guideline Values and Conditions

The fixed contamination results for all grid locations were less than the releasable average surface contamination level (5000 dpm β-γ/100 cm^2) in NRC Regulatory Guide 1.86. The highest average surface contamination levels were found in the process pit sump, with readings of 2260±244, 2420±249, 2050±237, 2230±244, and 2600±253 dpm β-γ/100 cm^2, respectively, for the north, east, south, west and floor surfaces. Overall, there were very few fixed contamination readings that exceeded the MDA for the instrumentation.

The standard errors in each of the average surface contamination levels above were calculated by propagating the error in Equation (4). Specifically, the errors in the gross count rate and background count rate were obtained from the application of Poisson statistics and the error in the counting efficiency was determined in a consistent manner. No error in the active area of the probe was assumed.

The removable contamination survey consisting of the two cloth smears per grid resulted in all measurements less than MDA. No alpha contamination was identified on any of the smears. As stated earlier, one of the two smears per grid was taken at the location of the highest direct contamination reading. However, contradictions to this procedure occur for the reactor room floor survey. This is because the smears were taken prior to the "hot spot" decontamination, and the highest direct reading prior to decontamination was not always the highest direct reading following the final decontamination effort.

The LSC smear results were all below the removable surface contamination levels (1000 dpm β-γ/100 cm^2) in NRC Regulatory Guide 1.86. The highest tritium surface contamination level identified was 516±56 dpm/100 cm^2. The standard error in the tritium activity was calculated by assuming a conservative error in the LSC efficiency determination of 10% and assuming no error in a smeared area of 100 cm^2.

The exposure rate survey resulted in all measurements being less than 5 rem/h above background (13 μrem/h). Furthermore, the highest average exposure rate measurement was only 14.2 μrem/h.

Soil Sampling

Three soil samples were collected from beneath the concrete pedestal in the reactor room. A concrete core of the pedestal was removed at each of three locations and a sample of the undisturbed soil beneath the pedestal was collected. The soil samples were sent to an approved laboratory for gamma spectrometry and analysis for H-3 and C-14.

The water was distilled from each soil sample and analyzed for tritium. The measured tritium activity ranged from 1.6 E3 to 4.35 E3 pCi/l. For comparison, the EPA drinking water standard for tritium is 2 E4 pCi/l.

Carbon-14 was not detected in any of the soil samples and only naturally occurring radioactivity was identified by gamma spectrometry of the soil. Thus, the radionuclide concentrations in the soil indicate that the soil has not been contaminated by reactor operations.

Waste Disposal Activities

The primary forms of waste generated during the project were rubbled concrete, steel rebar, and miscellaneous paper and plastic. The concrete and rebar were segregated into clean and radioactive waste and disposed of accordingly. The radioactive material was sent to the low level radioactive waste facility in Beatty, NV. Clean concrete was sent to a concrete recycler for pulverization and future reuse. Clean rebar was disposed of at a commercial landfill. Paper and plastic goods were disposed of as either LSA or clean waste depending on level of contamination to the appropriate disposal facilities.

The total volume of waste generated included approximately 860 cubic feet of activated concrete and 2275 cubic feet of clean concrete. Rebar volume was not calculated since it was imbedded in the concrete. Contaminated waste paper and plastic goods were disposed of in the same LSA containers as the activated concrete and a volume was not determined, although it was relatively small. The packing efficiency of the LSA boxes used to ship the waste to the Beatty site was estimated at about 57%.

SUMMARY

The decontamination and dismantlement of the Boelter Research Reactor was carried out in a professional and timely manner. The resulting condition of the facilities is such that they are acceptable for release for unrestricted use. All remaining contamination levels are within the limits established prior to initiation of the decommissioning as acceptable for unrestricted release. Documentation of the D&D efforts was developed to meet the requirements of NUREG/CR-2082 (Ref. 3). Release of the facility for unrestricted use is expected in the Spring of 1993 following verification surveys by NRC.

REFERENCES

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