DECOMMISSIONING PLAN:

Phase I: Dismantlement and Radiological Assessment of the UCLA Argonaut Reactor Facility

License R-71
Docket 50-142

October 1985

School of Engineering and Applied Science
University of California, Los Angeles

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DECOMMISSIONING PLAN

Phase I: Dismantlement and Radiological Assessment
of the UCLA Argonaut Reactor Facility

1.0 Plan Background and Management

Phase I of the Decommissioning Plan (DP) pertains to dismantlement of the nuclear research reactor located in Boelter Hall on the campus of the University of California at Los Angeles (UCLA). The objective of Phase I is to define the radiological status of the facility by gaining access to the interior of the biological shield and assessing the distribution of neutron induced activity in the foundation, side walls, and removable shield blocks. The work is to include surveys of the fuel storage pits, the floor drains, and the decontamination facilities. The format of the Plan follows the outline of the Standardization and Special Projects Branch of the U. S. Nuclear Regulatory Commission (October 15, 1984).

The scope of dismantlement is to include removal and disposal of the reactor core-reflector, graphite thermal column, shield tank, and certain peripheral equipment. Phase I is to culminate with a report discussing final decommissioning alternatives, DECON and SAFSTOR. This report is to provide the basis for selecting the ultimate Decommissioning Plan to be implemented in Phase II.

1.1 Summary Description

The UCLA Argonaut reactor was water-cooled, water-moderated, and graphite-reflected. It was operated from October 1960 until it was shut down in January 1984. Operations were by the Nuclear Energy Laboratory (the NEL) within UCLA's School of Engineering and Applied Science. It was operated to provide student instruction and in support of research.

The first license period extended from 1960 to March 30, 1970. Technical Specifications were then added and the license was extended to March 30, 1980. A timely application for renewal was filed in February of 1980, and the license was automatically extended pending NRC action. In June 1984, University informed the NRC that University intended to withdraw the renewal application and decommission the reactor.

The most recent licensing action (Amendment 14) deleted the license to possess Special Nuclear Material and the attendant requirement for a Physical Security Plan. It also eliminated the Operator Training requirements of 10 CFR Part 55. A request for related changes to the Technical Specifications has been submitted to the Nuclear Regulatory Commission.

The preferred Decommissioning Plan (DP) is DECON, but SAFSTOR is regarded as a possible alternative mode to be elected if a radiation survey at the close of Phase I discloses any exceptional circumstances. The Phase I project will retain the concrete shield blocks to provide the primary barrier for SAFSTOR until such time as that mode is rejected as a logical continuation.

Dismantlement is to include removal of non-essential external equipment, unstacking removable concrete blocks, removal of core contents (generalized to include the thermal column and at least part of the shield tank), packaging of radioactive materials for transport, and disposal of those materials.

The assay of residual activity will include core sampling of the concrete as well as wipe tests of the fuel storage pits, drain lines, and decontamination facilities. The work is to be done in sufficient detail to characterize the decontamination requirements and the costs attendant to final decommissioning.

The cost of completing the Phase I dismantlement is estimated to be approximately $65,000 exclusive of internal administrative and supervisory costs.

UCLA expects that the unstacking and packaging of core materials can be accomplished in two to four weeks unless complications arise in characterizing the materials as they are removed. The core sampling, analyses, report preparation, and preparation of the Final Decommissioning Plan are to be accomplished in the subsequent six to eight weeks.

The principal items subject to quality assurance are: radiation worker dosimetry; worker environmental protection; control of air-borne radioactivity and spreadable contamination; and compliance with packaging, transport, and burial regulations.

UCLA experience in major core maintenance (dismantlement and reconstruction) is described in Appendix C. That experience which included fuel handling and core entries within three weeks after shut down, yielded exposures of 35 to 45 man-rem. The fuel is gone and the reactor has been shut down since January, 1984. UCLA does not expect total exposures to exceed 10 man-rem.

1.2 Facility Operating History

The reactor operated at a maximum power of 100 kw(thermal), with a 24 year time-average power of about 2.5 kw(t). The corresponding time-average thermal flux near core center is about 3.75 E10 per sec per sq cm. The reactor last operated in January of 1984.

If one knew the concentration of trace elements such as cobalt in steel and stainless steel, europium in graphite and concrete, and silver in lead, it might be possible to theoretically calculate the distribution of activation products in those materials. However, those concentrations are unknown, and the flux has never been mapped throughout the core-reflector region.

UCLA favors the use of a radiation survey to define the decontamination requirements; i.e. the volume of concrete to be removed, the status of the fuel pits, the drain lines, and the decontamination facilities.

There are no known radioactive spills that might aggravate the decontamination and decommissioning. However, the possibility of activation by neutrons streaming through the control blade shrouds, the horizontal pipeways of the primary water lines, and down the vertical drain line below the reactor core center is recognized.

1.3 Current Radiological Status of Facility

Samples of graphite, lead, and concrete have been taken from the reactor core-reflector region. The findings of this work are described in Appendix B.

There are no known gaseous radionuclides at the site except for those which occur naturally.

There are several gallons of water in the sump and some sludge resulting from the wet core sampling of graphite. Eu-152 may be present.

The principal radioisotopes in the solid materials are due to trace elements not normally specified in describing the composition of materials. Mn-54, Fe-55, Co-60, and Zn-65 are expected in the metallic core parts. The principal products identified in the graphite are Eu-152, Eu-154, and Co-60. The lead is known to contain Ag-108 and Ag-110. The major radionuclides found in the magnetite concrete are Eu-152, Co-60, Eu-154, Mn-54 and Cs-134. The first two of these account for about 94% of the neutron induced activity in the concrete.

The inventory of radioactive material in the facility is estimated in Table P-1.

Table P-1: Radionuclide Inventory

Metallic Components	~ 1.5 Ci
Graphite	< 4.2 Ci
Lead	< 0.1 Ci
Concrete	~ 1.5 Ci

The quantity of metallic components near the core center is small relative to the graphite and lead. Thus, although they are expected to be more intensely radioactive, the total inventory may be no more than that in all of the other materials combined. The graphite and lead estimates are based upon samples taken near the core center, and the same concentration in those materials was conservatively assumed (high-side estimate) to prevail independently of where they were located in the reactor.

The induced activity in the concrete was estimated using the observed 2.2 inch attenuation length calculated in Appendix B at B.2 and taken perpendicular to an area of 240 sq ft at a surface concentration of 377 nano-Ci per gram. The assumed area is 2.4 times the area of the four faces of the five-foot core-reflector cube that are adjacent to the concrete. The factor of 2.4 arises from edge and corner effects which engage a larger volume than that which is projected perpindicularly to the faces of a cube.

1.4 Decommissioning Alternative

The purpose of the Phase I program is to define the feasibility, environmental acceptability, and cost, of DECON versus SAFSTOR. The interest in SAFSTOR follows from the fact that a seven story structure rests upon the reactor room foundations, and the decommissioning activities may have implications that go beyond the reactor facility.

1.5 Decommissioning Organization and Responsibilities

Many divisions of UCLA may be peripherally involved in the dismantlement work. The principal organizational lines that will be directly involved are shown in Table P-2.

UCLA will provide a manager and a Health Physicist at the site whenever work is in progress.

Table P-2: Dismantling Organization

```
                         ____________
                        |Chancellor|
                        |__________|
                              |
           ___________________|___________________
           |                                     |
  _________|_________                   _________|_________
  |    Executive    |                   |Administrative   |
  |Vice_Chancellor  |                   |Vice_Chancellor  |
           |                                     |
  _________|_________                   _________|_________
  |Dean, School of  |                   |    Assistant    |
  |__Engineering____|                   |Vice_Chancellor  |
           |                                     |
  _________|_________                   _________|_________
  |    Director     |                   |    Director     |
  |_____NEL_________|                 __|____OROS_***_____|
           |                       *             |
           |                  *                  |
  _________|_________    *              _________|_________
  |    Manager      |                   |   Radiation     |
  |_____NEL_________|                   |Safety_Officer___|
     |
     |    _____________                 ___________________
     |_ _| Assistant  |                 |     Health      |
     |   |__Manager___|                 |_Physicist(s)____|
     |
     |    _____________
     |_ _| Temporary  |
         |___Techs____|
```

*** For the dismantling operations, the manager of the NEL will take direction from the Director of the Office of Research & Occupational Safety (OROS).

1.6 Regulations, Regulatory Guides, and Standards

Dismantlement, decontamination, and decommissioning will be governed by the applicable Federal and State regulations, regulatory guides, and Standards. These include the following:

Table P-3: Regulations, Guidance, and Standards

Radiation Protection And Surveys	10 CFR 20 Reg Guide 1.86 NUREG 2082	Protection Standards Decon Standards Termination Survey
Worker Safety	Title 8, CAC (Cal OSHA)	Worker Health & Safety
Environ-mental	EPA-NEPA (40 CFR) NUREG 0586	Environ Impact Statement " " " "
Transport of Radioactive Material	10 CFR 71 49 CFR (DOT)	Packaging & Transport Packaging & Transport

Most UCLA employees, including some employees working in areas adjacent to the NEL, are under 17 CAC and the requirements of 1335-70 (July 1984). This Plan pertains to the NEL site and to the federal regulations governing the packaging, transport, and burial of radioactive materials.

1.7 Training and Qualifications

UCLA will use experienced radiation worker-technicians, and will provide orientation and training for the UCLA facility. This is to include a brief review of radiation properties, handling of radioactive materials, personnel dose and contamination control, applicable permissible doses, radiation work permits, and an introduction to the physical structure of the UCLA Argonaut reactor.

2.0 Occupational and Radiation Protection Programs

The Director of the Office of Research and Occupational Safety (OROS) is responsible for all matters relating to occupational safety at UCLA, and he will be the Director of the dismantlement work. The Radiation Safety Officer (RSO) who heads the campus Radiation Safety Office, is directly responsible to the OROS Director. A qualified Health Physicist reporting to the Radiation Safety Officer will be present (full-time) to assure that appropriate contamination control procedures are used; to monitor all materials packaged for disposal or released for other use: to prepare appropriate records and shipping papers; and to generally assure that all radiation exposures are maintained ALARA.

8.1 Radiation Protection Program

The radiation protection program for dismantling and decommissioning will be an extension of the supervisory role which the Radiation Safety Office normally exercises over the use of radioisotopes at UCLA. The practices will conform with the procedures specified in the UCLA Radiation Protection Manual.

All workers will wear personnel dosimeter film badges and pocket dosimeter ionization chambers. The ionization chambers will be read and doses recorded daily. All workers will be given pre- and post- dismantlement whole body counts. Based upon presently available data, extremity dosimeters will not be required, but should that judgment prove wrong such dosimeters are available.

The radiation monitoring equipment normally available at the reactor site is shown in Table P-4. The Radiation Safety Office will provide back-up emergency instrumentation and services if necessary. The emergency instruments will not necessarily duplicate any of the instruments identified in the Table.

Table P-4: Radiation Monitoring Equipment

Portable Survey Meters	1	Ludlum Model 3 with shielded pancake probe Model 44-40 and unshielded probe 44-9
	1	Ludlum Model 3 with pancake GM probe
	1	Ludlum Model 14C with shielded pancake probe Model 44-40
	1	Ludlum Model 14C with side window GM probe
	1	Eberline RO-2 ionization chamber
	1	Eberline alpha survey meter
	1	Teletector Model 6112B, 0-1000 R/hr (must be operated in horizontal plane)
Wipe Counters	4	Technical Associates Multiscalers with thin end-window GM tubes
	1	Nucleus Multiscaler with thin end-window GM tube
Gamma Spectroscope		ND-66 (4096 channel) with 110 cu cm GeLi crystal (Princeton Gamma-Tec)
Particulate Monitors		Stack Effluent Monitor, fixed filters, changed and counted weekly
		High Volume Air Sampler
Personnel Monitors		Film Badges by Landauer
		Pocket Dosimeters plus charger and case
		6 0- 200 mr
		3 0- 500 mr
		2 0-1500 mr
	1	Hand & Foot Counter, HMF2

2.2 Industrial Safety and Hygiene Program

The Office of Research and Occupational Safety (OROS) includes specialists in toxic materials, electrical safety, machine safety, and fire protection. The Director of that Office has been a physicist and nuclear engineer and is a Certified Health Physicist. He will direct the dismantlement operations.

Some operations will involve the use of half-face dust respirators. These respirators will be fitted and leak tested by the Industrial Hygienist of the OROS staff. Only NIOSH/MSHA approved respirators will be used and air sampling will be done to determine the extent of any air borne contamination.

2.3 Contractor Assistance

The dismantlement will be done by temporary technicians under the direction of the UCLA staff. Technicians will receive training as described in paragraph 1.7 and will be provided with protective garments, safety shoes, safety glasses, and respirators as necessary. UCLA plans to use a consultant for the concrete core sampling.

2.4 Cost Estimate and Funding

UCLA estimates the cost of dismantlement to range from $50,000 to $65,000 depending upon the cost of disposing of the graphite and lead (burial versus transfer to a licensed recipient).

3.0 Dismantlement Tasks and Schedules

3.1 Tasks

The major tasks of Phase I are identified in Table P-5.

Table P-5: Task Identification

1 Planning and Review
2 Mobilization
3 Removal of External Equipment
4 Disassemble Reactor Core
5 Package Materials for Transport
6 Transport Materials from Site
7 Assessment of Radiological Status
   a. Biological shield (concrete coring)
   b. Fuel storage pits
   c. Floor drain lines
   d. Decontamination facilities
8 Prepare Report and Final Decommissioning Plan

3.2 Schedule

UCLA expects that the unstacking and packaging of core materials can be accomplished in two to four weeks unless complications arise in characterizing the materials as they are removed. The core sampling, analyses, report preparation, and preparation of the Final Decommissioning Plan are to be accomplished in the subsequent six to eight weeks.

Schedules are subject to unforeseeable delays due to approvals and/or other events beyond the control of UCLA.

3.3 Task Analyses

3.3.1 Planning:

UCLA has been actively engaged in planning. Procurement of special shipping containers, and of garments for workers has been initiated, and a source of experienced radiation worker/technicians has been identified. The general unstacking procedure is largely dictated by the geometry of an Argonaut reactor, i.e. one must work from the top and thermal column face toward the core center.

3.3.2 Mobilization:

A source of radiation worker technicians has been identified and UCLA expects to use the first three scheduled work days in orientation, training, garment fitting, and bioassays. A reasonable number of shipping containers will be on the site. No special tools or equipment will be required other than a heavy duty fork truck for moving containers. Such fork trucks can be rented locally.

3.3.3 Removal of External Equipment:

Peripheral reactor equipment, external to the core and non-essential to the prosecution of decommissioning, is to be surveyed and classified as either radioactive or non-radioactive. Non-radioactive material is to be removed from the site. Radioactive material (if any) is to be either decontaminated or packaged and shipped to a licensed disposal site. Non-essential peripheral equipment is listed in Table P-6.

Table P-6: Non-Essential Equipment

1. The dump tank and internal heat exchanger.
2. Primary water circulation system (except for primary pump) including flow meters, control valves, and demineralizer circuit components.
3. Secondary water system.
4. Air lines and gas vent lines.
5. Shield tank water purification system.
6. The shield tank (non-essential, but physical removal is impractical prior to core disassembly).

Items 1 through 4 are located in the process pit. Air and water supply lines are to be removed to a convenient shut off valve location.

3.3.4 Disassembly of the Reactor Core:

Disassembly involves the unstacking of concrete blocks, lead, and graphite, the unbolting of flanges and control rod mechanisms, and the cutting of tubing and piping to convenient packaging lengths. The shield tank is to be cut flush to the top of the biological shield, and the well covered with temporary decking. This will provide more work space on the reactor top and will facilitate removal of the west lead wall which resides in the shield tank. The principal embedded component in the core (other than piping and drain lines) is the control blade support structure. It is built of five-inch, 6.7 lb channel, and it will not be removed unless it interferes with the core sampling work to follow.

UCLA experience with core disassembly is described in Appendix C. As the circumstances of those disassemblies were quite different from the present circumstances, the radiation exposures of that experience are not applicable to the present conditions.

3.3.5 Package Materials for Transport:

This task is to proceed concurrently with core disassembly. The materials are to be surveyed and catagorized in sufficient detail to provide a shipper's description of the materials and, when applicable, to satisfy burial site requirements. It should be noted that large variations in specific activity are to be expected because of the spatial distribution of the reactor flux. Where appropriate the self-shielding properties of these materials will be used to reduce the surface radiation level of packages. The available information characterizing the radioisotopes in these materials will be found in Appendix B.

Removal of metallic parts (fuel boxes, control blade system components, piping, etc) is to include removal of the protruding portions of embedded piping where such piping can be removed by non-abrasive cutting (shearing or sawing). Torch cutting is not contemplated in Phase I.

3.3.6 Transport Materials from Site

Most, if not all, of the external equipment is expected to be non-radioactive. Possibly some of the graphite from the thermal column will also be non-radioactive. Such materials will be disposed of as non-radioactive material.

The metallic parts are expected to be the most radioactive and the most likely to interfere with the radiation survey attendant to defining the radiological status of the facility. These materials are to be promptly shipped to burial at a licensed burial site.

The graphite and lead are expected to be of low specific activity and some may be non-radioactive. The cost of disposal of those materials has been estimated to be about $42.50 per cubic foot (burial cost included).

3.3.7 Radiological Assessment Survey

The Survey is to assess the radioisotopic composition (qualitative and quantitative) in the concrete biological shield and embedments, and to determine the extent and kind of radioactivity (if any) in the drains, the fuel storage pits, and other facilities as necessary to estimate the requirements and cost of decontamination and ultimate decommissioning.

3.3.8 Report:

At completion of Task 7, a report is to be prepared describing the cost of decontamination and decommissioning the reactor. The report is to describe specific decontamination requirements including the extent (area, volume, and type) of material to be removed. The report is to consider both DECON and SAFSTOR modes in the context of satisfying the regulatory requirements of those alternatives.

The report is to be used by UCLA to provide the basis for selecting the mode of decommissioning, and for soliciting bids for the DECON mode of decommissioning.

The report is to include an estimate of the cost of completion of DECON and implementation of SAFSTOR. Cost is to include removal, transport, and burial of radioactive material, and cost of the termination survey. The estimated cost of SAFSTOR is to be based upon the assumption of current regulations and dollars; and is to include initial cost, annual cost, and termination cost.

3.4 Safe_Storage

A prolonged period of safe storage would be invoked only under exceptional circumstances. The provisions here pertain to either: (1) an interim SAFSTOR period to adjust to new and unexpected findings; or (2) a long term SAFSTOR if the DECON continuation would imply structural damage to the building or unacceptable environmental effects.

4.0 Safeguards and Physical Security

There is no fuel on the site and there are no 10 CFR 73 Safeguards or Physical Security requirements. Normal industrial security measures will be retained. The physical security system may be used in connection with the SAFSTOR mode if that becomes necessary.

5.0 Radiological Accident Analyses

With no fuel on the site, there is no significant potential for radiological accidents that might affect the public. The potential for worker over-exposures is always implicitly present when handling radioactive materials, but this is a matter to be managed by a combination of worker training and radiation protection practices. See sections 1.7 and 2.1.

6.0 Radioactive Materials and Waste Management

There are no gaseous radioisotopes present other than those which occur naturally. A small amount of liquid waste (water) will be generated in concrete coring and tool decontamination. The vast bulk of radioactive material will be the solid components removed from the core. Those materials will be packaged and removed from the site in accordance with all applicable regulations.

6.1 Fuel_Disposal

Not applicable, there is no fuel on the site.

6.2 Radioactive Waste Processing

Wet core sampling will generate some contaminated waste water. If cross-contamination problems are not prohibitive, the volume of such water may be reduced by using a settling system to recover recycle water. Residual sludge will be solidified and treated as solid waste.

Past UCLA experience indicates that water for tool decontamination is used in quite small amounts, and the waste water is generally within the limits of 10 CFR 20 for discharge to the sanitary sewer. When outside those limits, a modest dilution will suffice to bring the water within prescribed limits.

The solid waste consists of three distinct types of material: metallic components (aluminum, magnesium, cadmium, structural steel, and stainless steel); graphite; and lead. Estimates of the volumes and masses of these materials are summarized in Table P-7.

Table P-7: Estimated Radioactive Waste

	Cu Ft	Lbs
Metallic Components	26.5	1325
Graphite (reflector)	120	12,000
Graphite (thermal column)	86	8,600
Lead bricks	22.4	15,900
Lead sheet	16.7	11,860
Lead shot	2.7	1,910
TOTAL	274	61,600

The total volume of radioactive material is not well known. In Table P-7 it is assumed that the metallic components consist of the known core parts (780 lbs) and 545 lbs representing one-fourth of the shield tank mass. For the metallic parts, the volume is based upon an assumed packaging density of about 50 lbs per cu ft. The graphite and lead masses are based upon volume estimates converted to mass using intrinsic (maximum) densities.

The following equipment is considered to be essential:

Table P-8: Essential Equipment

1. Sump pump
2. Holding tanks
3. Decontamination facilities
4. Primary pump
5. Ten ton bridge crane
6. Ladders, stairways, walkways, platforms
7. Ventilation system

Items 1 through 4 are potentially useful to the management of liquids generated in the Phase I work and are to be retained for similar service in the Phase II program. The remaining items are regarded as assets to decommissioning and to the subsequent use of the building.

7.0 Technical and Environmental Specifications

The total volume of radioactive material estimated in Table P-7 is less than 20% of the radioactive material annually generated by UCLA and is well within UCLA's capacity to manage. The Technical Specifications; the project organization; adherence to the applicable federal and state regulations governing worker exposure, packing, transport, and burial of radioactive materials; all contribute to assurance that dismantlement can be accomplished without significant impact upon the health and safety of the public.

8.0 Proposed Termination Radiation Survey Plan

This is not a final Decommissioning Plan and a Termination Radiation Survey will not be undertaken.

END

APPENDIX A

LICENSE AND TECHNICAL SPECIFICATIONS

(Amendment Requests)

for

Docket 50-142
License R-71

A request for License Amendment 14 was submitted to the NRC by letter of Wegst (UCLA) to Denton dated August 30, 1985. A request for corresponding changes to the Technical Specifications was submitted by letter of Wegst to Denton dated September 25, 1985.

Those submittals are hereby incorporated in this Plan by reference and are not reproduced herein.

October 28, 1985

School of Engineering and Applied Science
University of California, Los Angeles

APPENDIX B: PRELIMINARY RADIATION SURVEY

B.1 ACTIVATION PRODUCTS IN GRAPHITE AND LEAD

Samples of graphite and lead from the reactor core have been examined with a GeLi detector and multichannel analyzer to determine specific activities and radioisotopic composition.

Graphite stringers taken from the central region of the reactor core in March of 1985 exhibited surface radiation levels from 20 to 50 mr/hr near the center of those vertical four-foot stringers. At a perpendicular distance of one foot from the center of the stringers, the level fell to 5 to 8 mr/hr. Samples of graphite taken from locations within the central region near core mid-height were found to contain 13.6 year Eu-152 as the principal radioisotope. Observed specific activities ranged from 0.3 to 0.45 micro-Ci per gram (3-20-85). Eu-154 and Co-60 were also observed, each at a specific activity about one order of magnitude less than that of the Eu-152.

The lead above the reactor core consists of two layers of lead bricks, each layer is two inches thick. Samples from the upper layer at a corner of the reactor were measurably radioactive (0.5 mr/hr on the surface), and silver-110 was identified at a concentration of about 240 pico-Ci per gram. Bricks taken from the lower course in the vicinity of the fuel boxes were appreciably more radioactive (5 mr/hr on the surface). The principal isotopes are silver-108 (127 yr) and silver-110 (252 day). The results for six samples, three from each of two bricks, are shown in table B-1.

Table B-1: Activities in Lead (5-13-85)

Sample		Ag-108	Ag-110
1-1	11.3 gms	110	2510
1-2	30.3 gms	186	3410
1-3	17.4 gms	158	3100
	Average	164	3100
2-1	38.0 gms	91	2300
2-2	20.5 gms	87	2600
2-3	20.3 gms	173	3600
	Average	110	2670

Activities are in pico-Ci per gram, the "averages" are the mass-weighted average for each brick.

B.2 ACTIVATION PRODUCTS IN CONCRETE

The reactor beam port plugs are composed of concrete cast in aluminum sleeves. Samples taken from the south beam port plug and counted on May 15, 1985, showed the following activation products (in order of dominance):

Table B-2: Activation Products in Concrete (5-15-85)

	Isotope	Activity*	%
1.	Eu-152, 13.6 y	183	52
2.	Co-60, 5.3 y	157	42
3.	Eu-154, 8.6 y	19	5
4.	Mn-54, 312 d	9	2
5.	Cs-134, 2.1 y	9	2
	TOTAL	377	100

*Activities are in nano-curies per gram. The results in Table B-2 pertain to a sample taken one inch from the interior face of the plug (four inches into the core from the biological shield).

The total activity, as a function of distance from the inner face of the biological shield was found to be:

Table B-3: Specific Activity, Concrete (5-15-85)

Distance, inches	Activity, n Ci/gm
-4	377
-2	229
0 (Note 1)	203
2	126
4	36.6
7	11.5
13	1.46 (Note 2)
19	Background

Note 1: Zero is taken as the inner face of the concrete biological shield.

Note 2: At the 13 inch depth, Eu-154 and Cs-134 were not discernible. The sum of the other isotopes identified in Table B-2 was divided by 0.93 to obtain the activation product concentration of 1.46 nCi/gm. In that same sample a number of short-lived radium-thorium daughter products appeared.

A least-squares best fit of an exponential to the five points from zero to nineteen inches indicates a relaxation length (e-folding distance) of about 2.2 inches for the activation products in this concrete.

The concrete was black in color, evidently the plugs are filled with magnetite concrete. It is premature to assume that the samples are representative of all of the concrete and higher levels of activity may appear due to streaming neutrons through the control blade shrouds or along pipeways. This question cannot be answered without unstacking the core.

B.3 RADIATION SURVEY OF THE SOUTH BEAM PORT

A radiation survey (by Teletector) of the south beam port in December of 1984 yielded the following readings as a function of distance from the internal end. The "zero" distance is 16 inches interior to the inner face of the biological shield; i.e. the 16 inch measurement is at the inner surface of the biological shield.

Table B-4: South Beam Port Observations

Distance, inches	Radiation, m rem/hr
0	3000
8	2000
16	650
28	55
52	4.5

The high readings correspond to locations within a few inches of the steel blade drive support bearings and structure.

B.4 RADIATION MEASUREMENT IN CORE CENTER VOID

The reactor core was uncovered to the top of the fuel boxes in March 1985 for a radiation survey and to collect samples. Fifteen vertical graphite stringers (4 inches by 4 inches by 4 feet) were removed thereby creating a void 12 inches by 20 inches in horizontal cross-section and four feet deep. The radiation field in the void was observed to have a nearly uniform value of one rem per hour.

B.5 ACTIVATION OF CORE METALLIC PARTS

Other than lead, aluminum is the predominant metallic core component. The fuel boxes, the shield tank, and various plumbing and tubing are composed of aluminum. The vertical port liners are composed of type 6061 aluminum which according to NUREG/CR-1756, vol 2, Table E.1-1, contains 0.25% zinc. A small sample of a vertical port liner examined with the GeLi detector showed both Zn-65 (244 day) and Co-60 (5.27 yr) in the atomic ratio of about 2:3. The calculated total activity based upon the reactor operating history followed by 20 months decay is about six micro-

Curies per gram. The calculated result agrees well with a measured radiation field of 10 mR/hr at a distance of three inches from the tube center line at a location far from either end of the tube.

The highest concentrations of radioisotopes are expected in the structural steel and the small amount of stainless steel in the core. Calculated values for these activities, based upon the spatial-maximum, time-averaged neutron flux, are shown in Table B-5.

Table B-5: Calculated Activities in Steels

Structural Steel	Fe-55	1.2 mCi/gm
Stainless Steel	Fe-55	0.8 mCi/gm
	Co-60	0.3 mCi/gm
	Ni-63	0.1 mCi/gm

The majority of the steel parts are not in the highest flux region of the reactor, and the indicated values are high upper-bound estimates.

APPENDIX C: UCLA CORE DISMANTLEMENT EXPERIENCE

The UCLA staff, aided by student volunteers, has dismantled the core for maintenance on a number of occasions. Typically, a three week interlude between shutdown and core entry was used for planning, preparation, and procurement. The general plan of entry is straightforward, the planning and preparation related to finding volunteers, garment selection, procurement of special materials, review of special tooling requirements, and instrument checking.

During this phase, holding tank and sump waters were tested for release to the sanitary sewer to accommodate any new liquid waste that might arise. Common air conditioning filters were fixed to the reactor room exhaust grill with duct tape. Controlled areas were defined within the reactor room, paper was laid, and entry points were established.

Core entry is initiated by removing the top concrete blocks, removing the fuel box cover plugs, and transferring the fuel to dry storage. A third layer of top blocks, the east face blocks, the graphite thermal column, and the lead wall are successively removed. A concrete block (process pit cover block) is then rigged to the crane and used as an elevator to transport lead and graphite from the core top to the floor level. The work was done with two people at the core top, two unloaders at the floor level, a crane operator, a "gopher," and a surveillant health physicist. The gopher remained in the clean area to fetch and deliver materials and tools to the controlled area boundary.

Because of exposure considerations, student help was limited to unstacking and restacking the upper courses of lead and graphite and to floor operations outside the core.

Personnel were rotated on a three-to-four hour basis. Typical radiation exposures were 35 to 45 man-rem distributed over a twenty to thirty man work force in a period of approximately three months. Fuel handling and reactor reassembly were significant contributors to the total exposure. Neither are now required. All fuel has been removed from the site, and the ex-core packaging of materials for transport should be easier than the in-core reassembly of the same components to demanding tolerances.

It might be possible to improve upon the procedures used by UCLA, particularly in man-power utilization. Reactor dismantlement normally commenced about three weeks after termination of normal operations. Now, nearly two years after the termination of operations, the radiation exposure conditions should be much more benign.