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MEMORANDUM FOR: James Miller, Chief, Standardization and Special Projects Branch, DOL

FROM: R. Wayne Houston, Chief
Accident Evaluation Branch, DSI

SUBJECT: ACCIDENT ANALYSIS FOR SAFETY EVALUATION FOR LICENSE RENEWAL - UNIVERSITY OF CALIFORNIA AT LOS ANGELES TRAINING REACTOR

Plant Name: University of California at Los Angeles (UCLA) Training Reactor
Docket No.: 50-142
Responsible Branch: Standardization and Special Projects Branch
Project Manager: H. Bernard
Review Status: AEB - Complete

The Accident Evaluation Branch (AEB) has completed its accident analysis for the Safety Evaluation for license renewal for the University of California at Los Angeles Training Reactor (Enclosure 1). Analysis of a conservative fuel clad damage accident was performed, assuming extremely adverse meteorology. The radiological accident consequences were a small fraction of the limits of 10 CFR Part 100. AEB, therefore, concludes that continued reactor operation is not inimical to the public health and safety.

R. Wa[illegible] Houston, Chief
Accident Evaluation Branch
Division of Systems Integration

Enclosure:
As stated

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cc: D. F. Ross
W. E. Kreger
D. Eisenhut
W. F. Pasedag
T. R. Quay
H. Bernard
M. Wohl

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OFFICE	DSI:AEB	DSI:AEB	DSI:AEB				
SURNAME	MWohl:jk	WFPasedag	RWHouston				
DATE	3/11/81	3/15/81	3/[illegible]/81				

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FOR INCLUSION IN THE SAFETY EVALUATION BY THE
OFFICE OF NUCLEAR REACTOR REGULATION
SUPPORTING AMENDMENT NO. ______ TO LICENSE NO. ______

UNIVERSITY OF CALIFORNIA
UNIVERSITY OF CALIFORNIA AT LOS ANGELES TRAINING REACTOR
LICENSE NO. R-71
DOCKET NO. 50-142

Introduction

By letter dated February 28, 1980 the University of California at Los Angeles (the licensee, UCLA) requested renewal of the license for operation of the one hundred kilowatt UCLA Argonaut research reactor at the University of California at Los Angeles campus. This evaluation addresses potential consequences of postulated accidents.

Discussion and Evaluation

The reactor site is located in the Westwood district of the City of Los Angeles, California, in the western section of Los Angeles County (Figure 1). The reactor is housed at the Nuclear Energy Laboratory, in the center of the campus of the University of California at Los Angeles (UCLA) as seen in Figure 2. The campus is located south of the southern base of the Santa Monica Mountains on a coastal plain about 5 miles east of the Pacific Ocean.

The reactor, an Argonaut type, is water-cooled and moderated, graphite reflected, contains 93% enriched uranium in the fuel, and is licensed for a maximum core thermal power of 100 kilowatts. It is used primarily for activation analysis, class instruction, and research. Important fail-safe cc physics parameters are relatively large negative moderator void and temper. coefficients of reactivity. Additionally, the substantial prompt neutron lifetime, largely a function of graphite reflect[illegible] the quantity of reactivity insertion required to achieve a given [illegible], thereby providing an increased measure of safety.

Since the water acts as both coolant and moderator, loss of coolant would drive the reactor subcritical, not only by creating large voids and consequent fuel temperature rise, but also by loss of moderator. The reactivity worth of all the core water is approximately 1[illegible]% $\Delta k/k$. In general, core mechanical rearrangements or deformations result in negative incremental reactivity.

The Reactor Facility, shown in Figure 3, is a two-story, reinforced structure about 75 by 49 feet in plan and about 2[illegible] feet high. The reactor room is bounded on the north, east, and south sides by space controlled by the Nuclear Energy Laboratory and shared with the Tokamak Fusion Laboratory. There is a clear space of two stories above the reactor room, and three stories of building above the clear space. Reactor-related air conditioning and water demineralization equipment are located within a fenced-in structure on the reactor room roof, which is in the clear space between structures. No vital equipment is located in this area.

The reactor high bay area is served by a separate 14000 cfm ventilation system. A negative pressure is maintained in this area relative to its surroundings. The reactor is interlocked so that it cannot be operated unless the ventilation fans are on.

Prior to defining a Design Basis Accident for the UCLA reactor, five broad areas of potentially credible accidents were considered. These are (1) rapid or stepwise insertion of reactivity, (2) mechanical core rearrangement, as from a seismic event, (3) metal-water reaction, (4) graphite fire, (5) fuel damage. Each of these possibilities will be examined briefly below.

(1) Excess Reactivity Insertion: Though not considered to be feasible, calculations were done for an inadvertent step insertion of the total maximum theoretical excess core reactivity. The maximum excess reactivity available for an inadvertent step insertion is 2.3% $\Delta k/k$. Though not possible, if all the available reactivity were inserted instantaneously, a prompt period of 7.2 msec would result, producing a maximum calculated energy release of 1.[illegible]. Even if all the energy released in the excursion is assumed to heat the fuel plates, the temperature of the fuel would be on the order of 500° C or less, well below the melting point of the fuel eutectic or the cladding. Based on the estimated peak temperature produced in the SPERT-I destructive test, the fuel hot spot temperature would be approximately 590° C, still well below the melting points of both the fuel eutectic and cladding.

Since conduction heat transfer will occur through the graphite in reality the actual fuel temperatures will be somewhat less.

Since the above results are based on the instantaneous insertion of all the available excess reactivity, any credible accident would produce a maximum fuel temperature no greater than and in all likelihood much less than the maximum of 590° C estimated on the basis of highly conservative assumptions. Therefore, no melting or cladding perforation would result from this accident and no fission product release would occur.

(2) Mechanical Core Rearrangement/Crushing Accident. Fracturing the cladding and fuel eutectic would allow the escape of some fission products, as discussed in the "Design Basis Accident" section, from the fuel plates. One source of the compressive/tensile stresses that could cause such fuel damage would be a massive object dropped on the unshielded assembly. The Argonaut uses large, cast concrete blocks for shielding purposes. These blocks must be removed to gain large-scale access to the fuel elements as would be required by a fuel unloading operation. While the most severe scenario might be droppage of the heaviest shield block, the shield assembly configuration may require that the heaviest block be removed while the core is still well structurally shielded. Thus, the block could not be dropped directly onto the core, since the shield blocks would protect against this possibility.

Another source of possible large mechanical loads applied to the core would be those occurring in a seismic event. If an extreme seismic acceleration of 1 g is assumed in such an event, the maximum compressive stress to which the graphite reflector and stringers are subjected is still less than 1/10 of its compressive strength. Because the blocks are not interlocked, tensile stresses should not occur. Horizontal acceleration can cause the graphite blocks to impact against the metal fuel boxes and, if the impact is severe, it will partially crush the box and fuel elements laterally. The likelihood and extent of crushing cannot be predicted without dynamic structural analysis. The core might also suffer partial crushing in the vertical direction, but would be largely protected in this mode by the massive removable concrete shield blocks.

In summary, some core crushing in the lateral direction seems possible under very severe accelerations. Vertical crushing is less likely. Any crushing that takes place will tend to result in the removal of air from between the fuel plates such that conduction from the surrounding graphite will be improved relative to that in the uncrushed state.

Heat transfer analyses were performed to examine the effects of partial seismic core crushing on fuel thermal behavior. The reactor is assumed to be at a uniform temperature of 311° K, operating initially at a 100 kw power level. It is assumed that an equilibrium inventory of fission products exists in the core. At time zero, the core water is completely drained in less than one second. The reactor shuts down immediately and the transient heat transfer calculation begins with the dry core condition. Stagnant air is in the spaces between fuel plates. The calculated peak fuel temperatures following this sudden removal of core water are summarized in the table below:

Calculated Peak Fuel Temperature in 100 kw Argonaut Following

Sudden Loss of All Core Water

Core Air Configuration	Core Condition		
	Uncrushed	Crushed	
Natural Convection Flow	396° K	478° K[a]	410° K[b]
No Air Flow	631° K	527° K[a]	460° K[b]

a. Coolant gap between fuel plates reduced to one-half normal value.

b. Coolant gap reduced to 25 percent of normal value.

It can be seen that fuel melt is not plausible for any of the above tabulated cases, the melting point being approximately 940°K.

(3) Metal-Water Reaction: Studies of the U-Al fuel plate and water reaction show that a heat input of 174 cal/gm of fuel plate is required before both damage is apparent and reaction products can be ascertained. (Ref. _______). This is equivalent to 7.24 x 10^{-4} MW-sec/gm of fuel plate, or .156 MW-sec/fuel plate. With the nominal core loading of 240 fuel plates, the 12 MW-sec pulse generated from an inadvertent maximum reactivity insertion would produce an average of only .05 MW-sec/fuel plate. A hypothetical maximum nuclear excursion might deposit one-fourth of its energy in the central one-sixth of 40 plates of the core. These plates would thus experience .08 MW-sec/plate from the pulse, or about half the energy required to initiate the reaction. Or, looking at this from another perspective, a total of 40 x .156 = 6.24 MW-sec would have to be deposited in the central one-sixth of the core and this would require a burst energy release of 25 MW-sec, or about twice that available from the maximum credible excursion. Thus, since the minimum energy which initiates the reaction is approximately two times that available from an inadvertent pulse, the Al-H_2O chemical reaction could not occur from such an accident.

(4) Graphite Fire: In order to assess the likelihood of a self-sustaining graphite fire, the three critical parameters of oxygen source, fuel, and an ignition source were investigated. Oxygen sources considered were oxygen in argon dilution air flow, in room air with the shield blocks removed, in failed beam tubes, a failed rabbit tube, and in experimental gas flow. Fuel sources considered were reactor graphite, liquid fuels, gaseous fuels, and solid fuels. Ignition sources considered were Wigner Effect, electrical malfunction, pyrophoric material, friction, explosive material, nuclear heating, power excursion, external flame, and a building fire.

building fire during an off-shift experimental period could be postulated, while the reactor concrete shield blocks are removed and some reactor graphite is exposed. The fire could spread, given an appropriate ventilation/air flow pattern, to whatever flammables were available around the reactor work area. Since the open shield would expose the graphite to room air, it can be ignited. Appropriate smoke detection systems must be available to give warning to security guards/fire fighters that such a fire is in progress, so that available fire-fighting equipment may be employed to extinguish the fire. Appropriate technical specifications will require the installation of adequate smoke detection/alarm equipment.

(5) Design Basis Accident: The type of accident most likely to lead to release of radioactivity from fuel, excluding partial fuel melt/reassembly, which is not considered credible in any of the previously discussed scenarios, is an accident where fuel clad is compromised. This could occur in an out-of-core fuel handling accident, where an element might be dropped and damaged in some manner. It might also occur, for instance, as a result of mechanical damage in a seismic event. In order to conservatively bound these possible scenarios, a non-mechanistic DBA is defined with the following assumptions:

Reactor type:	Argonaut
Steady-state Power Level:	100 kw (for 1 yr.)
Exposed Fuel Surface Area due to Clad Damage	10,500 cm^2 *
Breathing Rate	3.47×10^{-4} m^3/sec
Short-term X/Q at reactor room wall (no holdup or removal in room)	7×10^{-3} sec/m^3

Radionuclide Inventories[**]

Noble Gases	Inventory, Ci	Inventory Released, Ci	Whole Body Dose, mrem
^{85m}Kr	78.5	2.2	28.7
^{85}Kr	1.1	0.03	0.21
^{87}Kr	140.0	3.8	295.4
^{88}Kr	215.0	5.9	--
^{133m}Xe	11.2	0.31	--
^{133}Xe	4.0	11.0	85.4
^{135m}Xe	62.0	1.7	32.9
^{135}Xe	397.0	11.0	--
		Whole Body Total, Noble Gases:	443 mrem

Radioiodines	Inventory, Ci	Inventory Released, Ci[***]	Thyroid Dose, rem
^{131}I	164	4.5	15.5
^{132}I	244	6.7	0.8
^{133}I	399	11.0	10.6
^{134}I	424	12.0	0.7
^{135}I	327	10.0	2.9
		Total, Thyroid:	30.5 rem

[*] Equivalent to the nominal exposed fuel surface area of all the plates of one element if all clad is stripped away.

[**] Assumed that all activity produced within the range of the recoil particles (1.37×10^{-3} cm) escapes; referenced to that fuel element containing the maximum inventory; steady-state operation for one year (inventories much smaller for 8-30 hr. duty cycle); uncorrected for burnup; instantaneous release assumed.

[***] The volume of fuel from which the radionuclides escape is

$$V_{esc} = 1.37 \times 10^{-3}\ \text{cm} \times 10{,}500\ \text{cm}^2 \approx 14\ \text{cm}^3$$

The total fuel volume/element is 526 cm^3. Thus, conservatively assuming a uniform volume distribution of fission products, the fraction of escaped radionuclides is 14/526 ≈ .027 or 2.7%.

The computed thyroid dose is a small fraction of the 10 CFR Part 100 limit. The whole body dose is very low (< 1 rem).

Conclusions

We have considered as hypothetical accident scenarios the following: (1) Excess reactivity insertion, (2) Mechanical core rearrangement, (3) Metal-Water Reaction, and (4) Graphite fire. None of these were found to result in releases leading to appreciable offsite radiological consequences. In order to have a release resulting in such consequences, substantial quantities of fuel clad must be compromised.

Using appropriately conservative release fractions and meteorological modelling, the staff finds that, even in the event of the occurrence of a fuel handling or seismic accident leading to substantial compromise of the fuel clad, the radiological consequences in the near vicinity of the reactor building are a small fraction of the limits of 10 CFR Part 100.

We have concluded that (1) because license renewal for operation of the University of California at Los Angeles training reactor (Argonaut) does not involve a significant increase in the probability or consequences of accidents considered and does not involve a significant decrease in a safety margin, it does not involve a significant hazards consideration, (2) there is reasonable assurance that the health and safety of the public will not be endangered by operation in the present manner and (3) continued operation of the reactor will not be inimical to the common defense and security or to the health and safety of the public.

FIGURE 1 AREA MAP - WEST LOS ANGELES

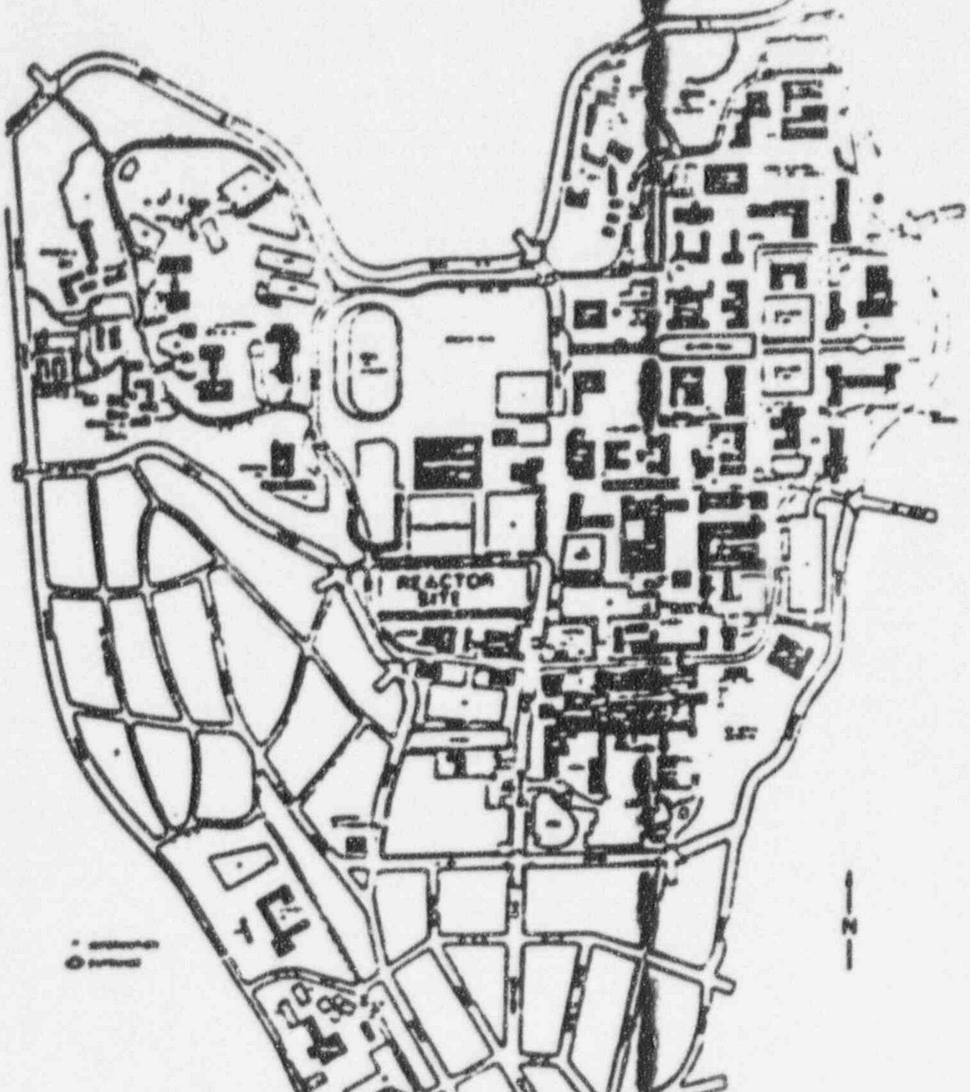
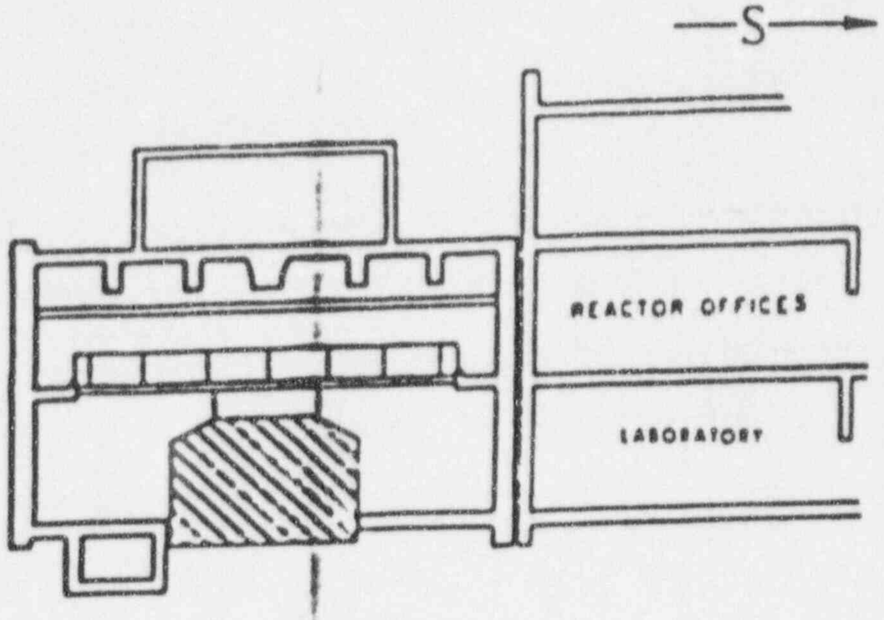
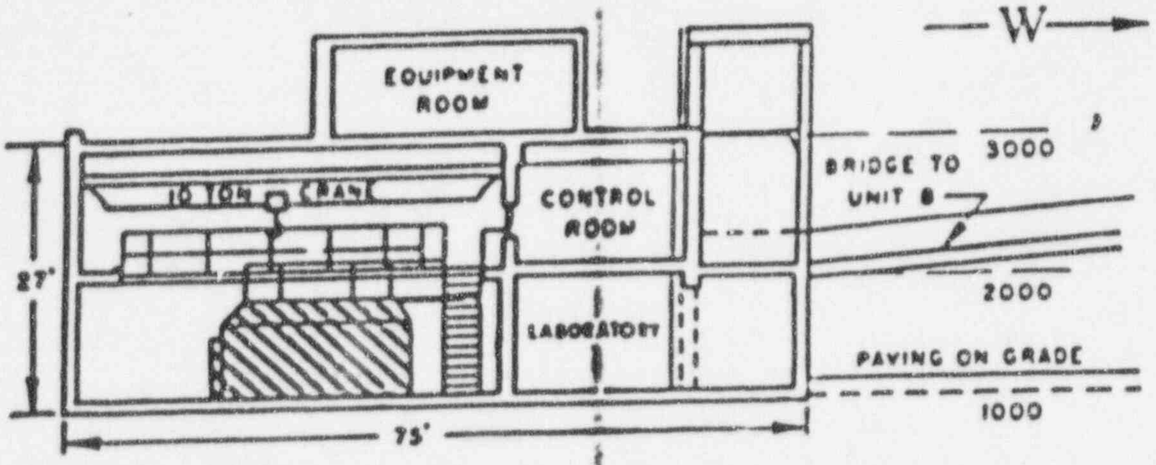


FIGURE 2 UCLA CAMPUS MAP

POOR ORIGINAL



SECTION VIEWED FROM THE WEST



SECTION VIEWED FROM THE NORTH

FIGURE 3 · REACTOR BUILDING - ELEVATION SECTIONS