VI

UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of THE REGENTS OF THE UNIVERSITY OF CALIFORNIA (UCLA Research Reactor)	Docket No. 50-142 (Proposed Renewal of Facility License)

DECLARATION OF LOUIS E. FOSTER

I, Louis E. Foster, do declare as follows:

1. From 1975 through 1979 I was employed by the Nuclear Environmental Services Division of Science Applications, Inc. My duties were primarily in radiation safety and environmental protection in and around nuclear facilities. These duties included implementation of radiation monitoring systems at numerous nuclear power plants throughout the country. A statement of professional qualifications is attached.

2. In cooperation with colleagues at the Southern California Federation of Scientists, I have reviewed existing radiation monitoring data from the UCLA research reactor.

3. Based on that review, I have concluded that the results of the radiation monitoring program established by UCLA are not reliable as to their accuracy. Furthermore, even if one assumed the data were reliable, the results indicate radiation doses to the public that are unacceptable from a safety standpoint. In other words, the data acquired and the estimates made by UCLA to date are suspect because of inadequate monitoring and calibration practices and faulty monitoring program design and dispersion model design. But even were the data correct, the doses indicated thereby are unacceptable from a public health standpoint, and clearly violate the requirements to keep radiation doses As Low As Reasonably Achievable (ALARA). Significant reductions

in radiation exposure are reasonably achievable at this facility through any of a number of means, and the radiation monitoring program and calibration programs need very significant improvement before adequate protection of the public could be considered to be reasonably provided.

4. Although questions had been raised by the Atomic Energy Commission about the adequacy of UCLA's Argon-41 monitoring system, and the ability to keep the Argon-41 effluents within permissible limits, even before the reactor received its initial license in 1960 and at various times thereafter, it was not until the reactor had been operating for fifteen years that the Commission learned that calibration and instrumentation errors had led to a gross underestimation of the Argon-41 effluent concentration. Inspectors had determined (1) that UCLA had lost its maintenance log, which included the calibration procedures and methodology of its derivation, and (2) that UCLA had failed to calibrate the radiation monitors at the required intervals. Both of these were serious violations with potential for impacting upon public safety. To compound the problem, UCLA notified the NRC that it had initially detected a factor of 10 error in the calibration of its Argon-41 monitor, but stated that they were "convinced these calculations are correct." (inspection report 75-01, p. 7). However, further recalibration and re-instrumentation led to the finding that the error was actually of several hundred-fold. (see letter of Charles E. Ashbaugh III of UCLA to David Jaffee of NRC, dated April 23, 1975, correcting previously reported annual effluent releases, by a factor of between 200 and 400.) The estimates of actual Argon-41 concentration at the point it enters the environment were revised to approximately 2×10^{-5} µc/ml, as opposed to the previously reported concentration of 6.8×10^{-8} µc/ml. (Ashbaugh letter, ibid.) The level is currently estimated to be around 1.65×10^{-5} (SER p. 11-5).

5. The Maximum Permitted Concentration of Argon-41 is 4×10^{-8} µc/ml (10 CFR 20, Appendix B, Table II). Thus, the calibration and instrumentation errors put the emitted concentration far in excess of the MPC (over 400 times MPC, if one uses the 1.65×10^{-5} concentration, higher even than that if one uses the Ashbaugh figure).[1/] The NRC, correctly, found UCLA to be in violation of both its Technical Specifications and the requirements of 10 CFR 20. (See memo of enforcement conference, April 22, 1975, in docket).

1/ In addition to the calibration and maintenance log problems, the University was cited for the stack being too short, the accelerator nozzle removed, and failure to dilute the effluent to 14000 CFM. Only the last item has been corrected

6. It was determined that annual averaging was permissible, so a reduction factor of .188 was approved to reflect the licensed utilization limit (p. 3, Safety Evaluation, NRC Office of Nuclear Regulation, for Amendment 10 to the license). Thus, concentrations of Argon-41 at the point of entry into the environment (the only place where those concentrations have actually been measured), even when annual averaging is factored in, would remain $1.65 \times 10^{-5} \times .188 = 3.1 \times 10^{-6}$. Thus, even when averaged over a year the concentration remains approximately 78 times the Maximum Permitted Concentration of Argon-41, as defined in 10 CFR 20 Appendix B.

7. The University asserts it may ignore the concentration at the point where the effluent enters the environment and add a further reduction factor for presumed dispersion of the plume before it passes the wall of the Math Sciences Building, a few feet from the reactor stack. 10 CFR 20.106 (d) expressly indicates that the concentration is to be determined, for purposes of complying with the Appendix B MPC limits, "at the point where the material leaves the conduit." Only where the conduit is located in a restricted area, as defined in 10 CFR 20.3(a)(14), can dispersion factors be included; the reactor roof area where the stack is located is not a restricted area as so defined, in that essentially nothing prevents public access to the area. As noted in "The UCLA Reactor: Is it Safe?", there are seven unlocked doors and two elevators that open onto the Boelter Hall/Math Sciences roof complex, and the roof area contains planetarium, meteorology labs, observatories, a seminar room, and even a public restroom. It is not a locked or fenced-off rooftop but rather a public, readily accessible location. The concentration must be considered at the point it leaves the stack and enters the environment.

8. But, assuming for the sake of argument that one consider dispersion to the area the University argues is the boundary of the restricted area, the nearby Math Science Building wall, the concentration at that point remains many times the Maximum Permitted Concentration. UCLA calculated dispersion

according to the standard NRC dispersion model for such releases, determined the dilution factor to be .115, which the NRC approved in granting Amendment 10. There are some non-conservative elements in this calculation, particularly because the dispersion model begins at distances greater than 100 meters and UCLA's extrapolation to the much shorter distances in this case may tend to overstate the amount of dispersion that actually occurs. However, taking UCLA's calculated dispersion factor, based upon the NRC model and approved by the NRC Staff, the concentration on the Math Sciences roof would be 3.1×10^{-6} uc/ml x .115 = 3.6×10^{-7} uc/ml. This is nine times the Maximum Permitted Concentration of 10 CFR 20.

9. A student associated with the UCLA reactor attempted a student project to demonstrate the conservative nature of the dispersion model used. (It should be noted, of course, that a dispersion model for safety analysis is supposed to be conservative.) Dr. Lyon has, in his declaration, provided a summary critique of the Rubin student project, with which I concur. The study can, perhaps, provide some level of support for the appropriateness of the original dispersion calculation used in obtaining Amendment 10, but it most assuredly cannot be used to substitute for it or for true measurements of the Argon-41 in a controlled, scientific study.

10. UCLA was required to undertake a TLD study to confirm the conservatism of the Amendment 10 calculations. Unfortunately, the TLD data indicate doses still most unacceptable from an environmental protection standpoint and very much above ALARA. The study is flawed (as Dr. Lyon notes, the use of a "control" hundreds of miles away when the nearby TLD on Pauley Pavilion read consistently lower is hard to fathom). However, taking the readings, which were consistently substantially above even the Sunnyvale "background" quarter after quarter at virtually all of the locations surrounding the exhaust stack, doses of about 130 mrem/year gamma are indicated at the licensed level of operation (approximately 8 hours per 45 hour work week). The beta dose, as we shall see below, would add substantially to that. But, even taking the University's reading and ignoring beta radiation, doses equivalent to about 4½ additional chest X-rays per year are indicated; put another way, doses 26 times the limiting conditions for the big power reactors I used to do radiation monitoring for. This is far in excess of ALARA, and significant reductions are readily achievable.

11. Film badges at the stack read 425 mrem per year beta radiation (Application, F. II/2-1a), which would indicate considerably higher beta doses at the authorized operating level of 438 full power hours per year. The Annual Report for 1979, p. 15, reports a correlation between the high beta measurements on the film badges and direct measurements of 2-4 millirem/hr; the direct measurements would thus indicate beta doses of from 876 to 1752 mrem per year at the authorized operating level (2 x 438 = 876; 4 x 438 = 1752). Obviously the beta dose will be substantial at other locations as well. An indication of how substantial will be given below.

12. The NRC Staff, in addition to (a) employing a dispersion factor to reduce the effluent concentration when no such dispersion consideration is permitted due to the unrestricted nature of the area where the Argon-41 is released, and (b) using a dispersion factor two orders of magnitude less conservative than the official NRC regulatory guide mandates, further attempts to add a reduction factor for plume geometry. No such reduction factor is permitted in 10 CFR 20 Appendix B, which they cite as their basis. Furthermore, the source of their actual numerical value used for the reduction was not intended for the purposes to which the Staff are putting it. But, given the fact that no reduction factor for plume geometry is authorized in the regulations, and given the fact that the specific reduction factor utilized by the Staff is of questionable and undemonstrated validity in this situation, for the point of argument let us consider the result that would ensue from its use.

13. The NRC Staff, in the Attachment to the April 11, 1980, Memorandum from Robert Reid to Samuel Bryan regarding CBG's charges on the Argon-41 matter, estimates gamma doses of 24 mrem/yr inside the Math Sciences Building. One should note that this is 17 times higher than the dose estimated by the Staff in the SER (p. 11-6) for the roof area. It would mean that individuals within the Math Sciences Building, consisting of many hundreds of people, would have been getting the equivalent each of an additional medical chest X-ray annually, year after year, which is totally unacceptable, given the lack of medical benefit from such exposure, the risks involved, and the unnecessary nature of the exposure to begin with. The calculation ignores a number of factors which tend to indicate far higher doses. For example, it assumes that the only radiation received is from the Argon-41 in the room in which one is located, ignoring the contribution from the Argon on floors above and floors below and from the Argon surrounding the building,

some of which has clear line-of-site through office and classroom windows. Argon-41 is a very strong gamma emitter, with a gamma intensity (1293 kev) greater than that of Cobalt 60 (1173) according to the Handbook of Chemistry and Physics. NRC Staff Regulatory Guide 1.109 (p. 68) indicates an attenuation factor to account for shielding provided by residential structures of 50% for the general public, less than that attentuation for the maximally exposed individual. The Staff's assumption of 100% attentuation of the penetrating gamma is inappropriate, and thus their estimate based on the dose received from just the Argon-41 in the same room, or even floor, is extremely low.

14. However, taking the gamma estimate of 24 mrem per year inside Math Sciences as put forth by the Staff based on a correction factor of .03 for the plume size inside, what would be the beta dose? As UCLA in its answer #8 (September 5, 1980) to NRC Staff questions indicated, at MPC the gamma-beta ratio in a semi-spherical infinite cloud of Argon-41 is 3:1, for a beta dose at MPC of 127 mrem/yr. As UCLA observes, "The β-dose rate is largely due to the local concentration" and is therefore a simple function of the fraction, or multiple of MPC of Argon-41 within a few meters of the individual (because of the few meter range of beta in air). The Staff in its 24 mrem calculation assumed a stack concentration of 1.6×10^{-5} uc/cc, a dilution factor of .115, and an operating factor of .05, producing a concentration inside Math Sciences pulled in by the ventillation system of 9.2×10^{-8}, or 2.3 times the Maximum Permitted Concentration, WITHIN the Math Sciences Building. The Staff was able to estimate a low radiation dose from such a concentration by only considering the contribution from the room or floor on which the individual was located, thus using a correction factor of .03, and by ignoring beta. However, the beta dose for such a concentration is, as UCLA indicated, unaffected by the plume size because the beta dose is of local origin; thus the beta dose received by hundreds of people within that building would be, assuming the Staff estimate of 24 mrem gamma is correct, an additional 2.3 x 127 or 292 mrem/yr at the authorized level of operations (about 8 full power hours weekly). This would be unacceptable. So, even were the NRC Staff assumptions correct (and numerous non-conservative assumptions have been identified), doses that are unacceptable would be the result. (I note also that using the Staff calculation for within the building, gamma doses on the roof would be 5 times as high, or 120 mrem gamma, because Staff uses a plume size correction factor of .03 for inside the building and .15 for on top because of the assumption of a larger plume outside. It is interesting to note that

the actual gamma measurements by the TLDs are in very tight agreement with that figure; thus doses on the roof, by TLD extrapolation and from the NRC calculation, would be approximately 120 gamma and 292 beta, for a total of 412 mrem annually. This is all based on a series of very non-conservative assumptions by UCLA and the NRC Staff which are very questionable, so actual doses could be much higher, in the Rem range. As indicated earlier, concentrations on the roof, given the dispersion factor assumed by UCLA and NRC Staff in Amendment 10, are several times MPC.)

15. I would note also that UCLA's monitoring system is so poor that accurate readings just have not been made. The film badge system, for example, has minimum detection limits so high (20 mR for gamma and beta each and 40 mR for neutron) that very significant doses would be reported as zero (particularly for the badges changed monthly; doses of nearly a rem annually could be reported as zero.)

16. A few comments on UCLA dismissing the results of its own TLD program. The TLD study was supposed to demonstrate that doses unmeasurable above background were being produced by the Argon-41 emissions and thus justify permitting the facility to release concentrations far in excess of the MPC. Unfortunately, quarter after quarter and location after location, the recorded doses were significantly above background. UCLA first attempted to explain away the high readings by claiming other radiation sources on campus (Nuclear Medicine, the animal incinerator at the Med School, etc.) were responsible rather than the reactor. It has since settled on the assertion that the TLDs were picking up radiation from the concrete rather than the Argon-41 plume.

17. To attempt to "prove" this justification for rejecting its own measurements, UCLA has performed a rather childish exercise. It placed several of the roof-top TLDs on lead bricks, and placed others in cracks in concrete in a parking structure. The results were what anyone who has even a rudimentary acquaintance with radiation monitoring would predict--the doses recorded on the TLDs placed on lead went down, whereas the doses recorded on the TLDs in physical contact with concrete on several sides went up. UCLA says, QED, it is the concrete, not the Argon-41 plume, that is responsible for the elevated TLD readings on the Math Science roof.

18. What is wrong with this "experiment" need hardly be detailed. Background radiation, of course, has two primary components--terrestial and cosmic. The cosmic component, obviously, affects a TLD from above, while the terrestial component, composed of radiation from soil, building materials, etc., affects the TLD from below. Putting a lead brick under any TLD, no matter where, will cause the recorded dose to go down, because the lead brick blocks out normal terrestial radiation.

19. If UCLA were to assert that the 40 mrem per year recorded above background by the TLDs (at considerably less than full licensed operating level) were coming from "hot" concrete (i.e., that the concrete was 40 mrem more radioactive than normal background as seen by the TLD), then placing a lead brick under the TLDs must necessarily cause the elimination of the 40-50 mrem/year normal terrestial component of background plus the 40 or so mrem/year above background recorded by the TLDs and asserted by UCLA to be coming from the "hotter-than-normal" concrete. In other words, for UCLA to be right, the TLD reading would have to go down about 80 mrem/year when placed on a lead brick, which would block out both normal terrestial radiation and the effect of the concrete.

20. However, UCLA's data show that the TLD readings only went down about 25-35 mrem/year when placed on lead bricks, not the 80 or so necessary to prove them right. In other words, the concrete, if anything, is less radioactive than normal background and cannot be the source of the elevated TLD readings. I note also that the recent NRC Staff measurement on the Math Science roof reported in the June 9, 1982, despite its questionable usefulness in determining Argon-41 doses (discussed below), does appear to demonstrate that the concrete on the roof is not a source of greater-than-background radiation, because the measurement made of background on the roof corresponds to the background used in the TLD study.

21. An additional word is probably not necessary about the TLD-in-the-crack-in-the-wall. It is well known that naturally-occuring radioiosotopes are found in concrete and that by placing a detector so that it is essentially in physical contact on all sides will elevate the recorded dose because of the geometry and physical proximity. To do so in a parking structure says absolutely nothing about the Argon-41 dose on the Boelter/Math Sciences roof.

22. The single measurement by the NRC Staff reported in the June 9, 1982, inspection report is of little value. First of all, the measurements conducted at the Math Sciences air inlet are, by the inspectors' own admission, useless for anything except a measurement of background, because the wind was in the other direction then. The other measurement was conducted at an unidentified location. Without knowing where the measurement was taken, the geometry and shielding relative to the plume and so forth, the reading is useless. Furthermore, however, a single reading at a single location on a single day is of far less statistical significance than even one TLD, which integrates over several months, let alone a dozen or so pairs of TLDs with consistent results quarter after quarter.

23. A few other comments about that inspection report. That report makes clear that the problems identified in the mid 1970s--failure to adequately calibrate, no calibration procedures, lack of familiarity with one's own Technical Specifications, underestimation of actual radiation releases and so on--continue to this day and appear to be actually considerably aggravated. The picture one gets of the radiation protection program at the UCLA reactor from this inspection report is one of a very lackadaisical approach to radiation protection. It is incomprehensible to me how a health physicist could get away for a year with calibrating devices without any calibration procedure, how not a single calibration label could match with the records, how supervisorial personnel would not catch the calibration errors, how a facility could operate without acceptance criteria, etc. Perhaps the most telling finding of all is the lack of any reported exposure on the part of the health physicist, when his predecessor consistently had such exposures and his duties are such that exposures would be inescapable if he was doing the monitoring required. The radiation protection program, the monitoring, calibration, administrative controls, obedience to regulations and license conditions, are all dangerously deficient, posing a substantial threat to public health and safety.

24. I understand that the NRC Staff has asserted that radiation doses in the reactor room are about 1 mrem/hour. My review of the radiation data indicates that is incorrect by two orders of magnitude

data indicates that that assertion is incorrect by two orders of magnitude. The Application (p. III/5-5) indicates doses of 200 mrem/hr. in areas of the reactor room. The annual radiation surveys that I have reviewed confirm this. Furthermore, readings taken outside the reactor room (for example, on the 3rd floor above the reactor) indicate doses many times that asserted by the NRC Staff as the maximum within the reactor room. This is of concern particularly for the snack bar/cafeteria a few feet from where these measurements were taken; I have seen however,no record of an attempt by UCLA to monitor in that populated area. There is also a substantial concern for the people in the offices and classrooms on the 5th floor above the reactor. The hourly doses recorded on the 3rd floor are the equivalent of many Rem per year, even if one assumes that the radiation is present only when the reactor is operating, which of course would not be the case. Even with attenuation through the floor, people on the 3rd and 5th floors could be getting very substantial doses, considerably in excess of regulatory limits.

25. Furthermore, as Mr. Pulido indicates in his declaration, there are a number of penetrations in the reactor room ceiling for airducts and the like; the doses streaming through those penetrations could be substantially higher yet. And when the experimental vertical holes in the reactor are opened, shielding rolled away, to insert or remove experimental samples, the dose could be extraordinary. The radiation exposure incident reported in the April 1965 inspection report involved an exposure of a worker to a 50 R/hr beam from an opened port while the reactor was shutdown and an experiment being inserted or removed. Assuming 50 R/hr from such beams through the vertical ports when samples are loaded or unloaded, very substantial doses could be received by the people on the floors above.

26. In conclusion: the monitoring at UCLA has been and appears to remain very inadequate. The calibration errors and other failures of the radiation protection system appear to put at risk substantial numbers of the public. The concentration of Argon-41 in unrestricted areas, given the data available from the Applicant and the Staff, far exceeds the Maximum Permitted Concentrations of 10 CFR 20 Appendix B. Doses from the Argon-41 to members of the public far exceeds acceptable levels and clearly is not as low as reasonably achievable. Gamma and neutron "shine" from the reactor likewise appear to constitute a very significant public health threat, particularly to those on floors above. The attitude evidenced in the radiation protection record, and the lack of adequate managerial controls and supervision, are seriously deficient. The public health and safety has not been, and remains, not well protected by the radiation monitoring and control program at the UCLA reactor.

I declare under penalty of perjury that the foregoing is true and correct to the best of my knowledge and belief.

Louis E. Foster

Executed at Los Angeles, California, this 7th day of January, 1983

Statement of Professional Qualifications

LOUIS FOSTER

My name is Louis Foster. From 1975 to December 1979 I was employed by the Nuclear Environmental Services Division of Science Applications, Inc., involved primarily in radiation safety and environmental protection in and around nuclear facilities.

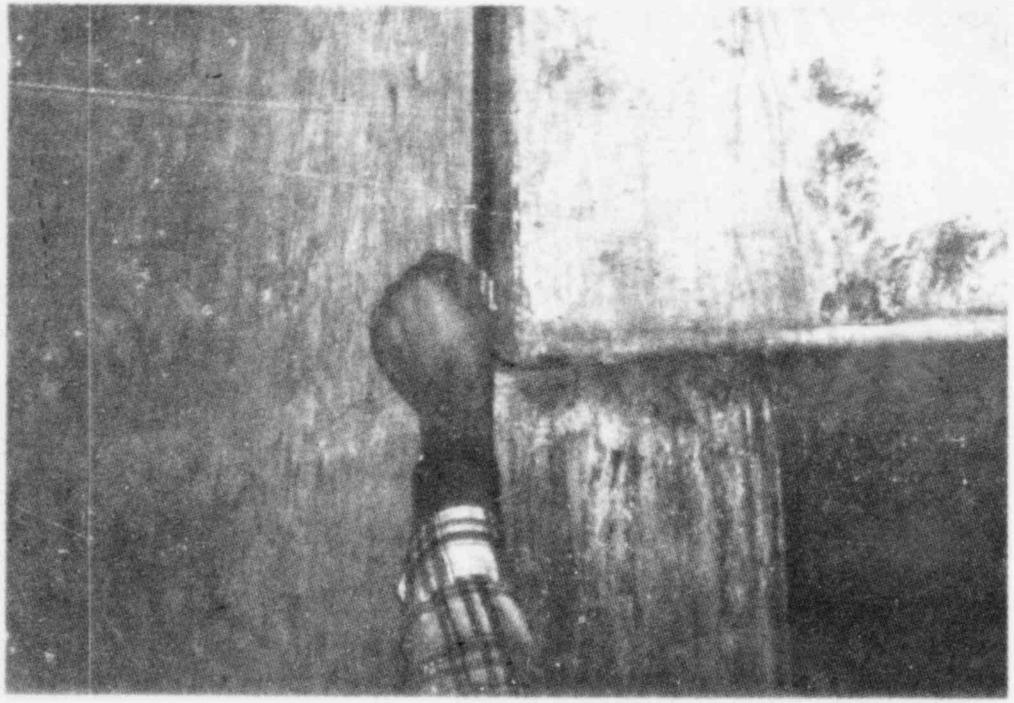
My duties at SAI included implementation of radiation monitoring systems to determine levels of gamma and beta emitting nuclides in effluent streams and in environmental samples.

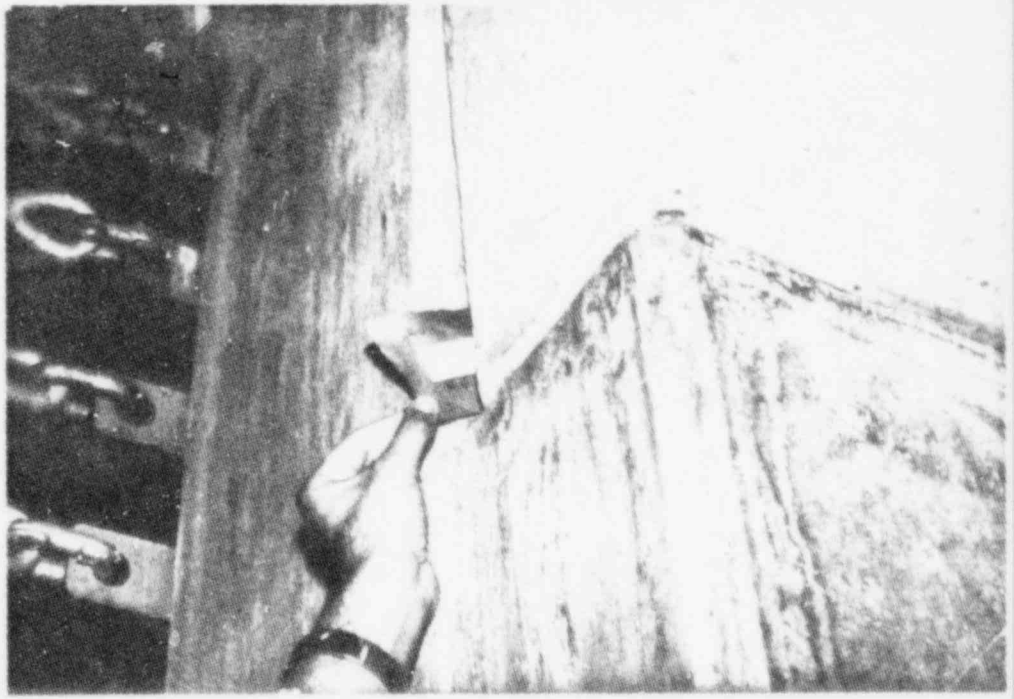
I was assigned through SAI to implement radiation monitoring systems at the nuclear power plants at Calvert Cliffs, Oyster Creek, Salem, Peach Bottom, Three Mile Island, Ginna, Indian Point, Vermont Yankee, Main Yankee, Quad Cities, Dresden, Zion, and others.

I have extensive experience in field and lab radiation measurements and quality analysis/quality assurance testing.

When I left SAI I was the Technical Supervisor for the SAI field research team involved with radiation safety monitoring as well as experimental research on radioiodine differentiation and concentration as part of the Three Mile Island Unit 2 cleanup.

I received my Associate of Arts degree in Environmental Science and Technology in 1977 from Montgomery College in Maryland, and thereafter completed numerous courses at the University of Maryland relating to my radiation protection work at SAI. Since 1980 I have been associated with Citizens' Campaigns, Inc., an organization concerned with energy, environmental and related issues.



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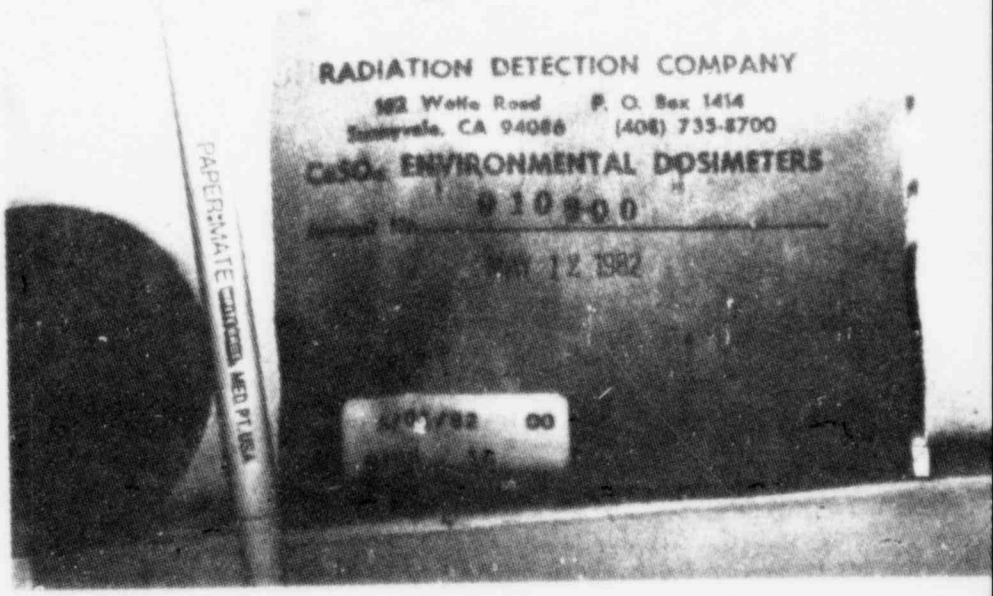
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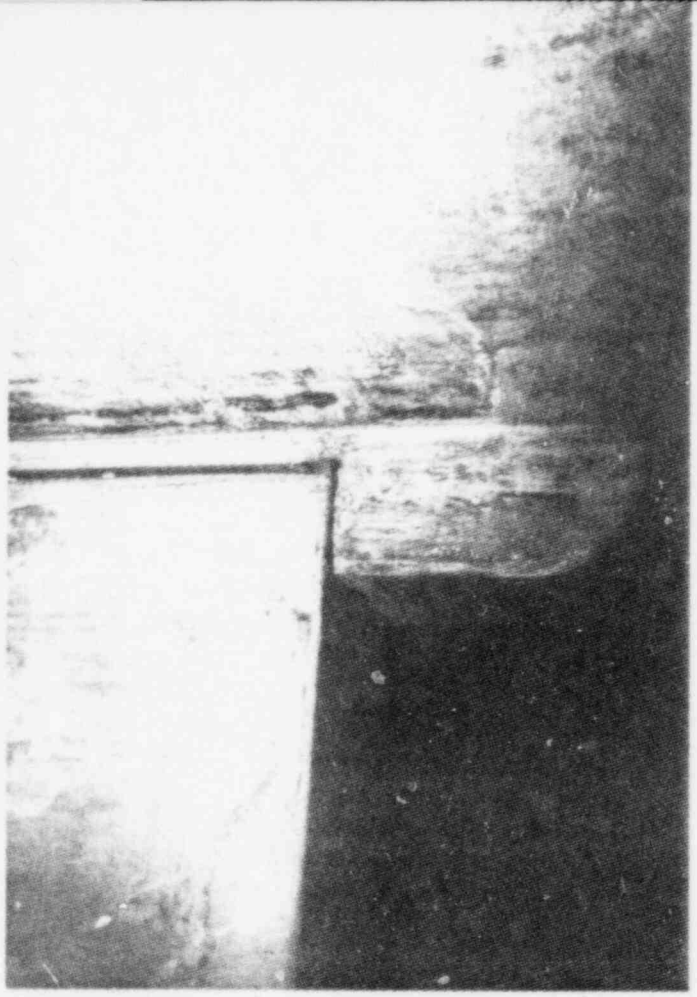

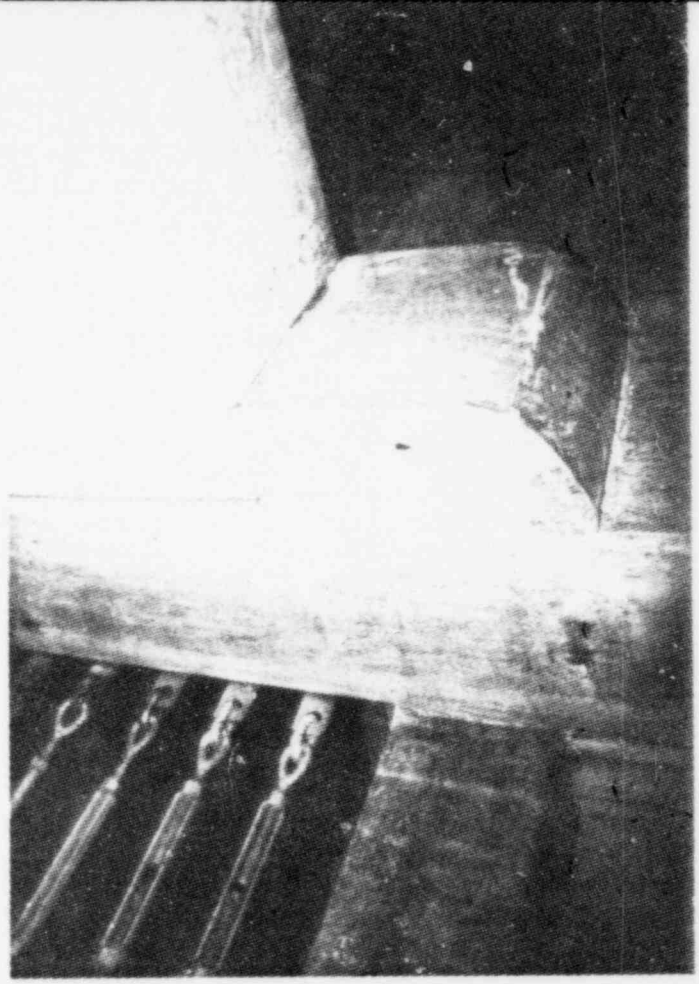

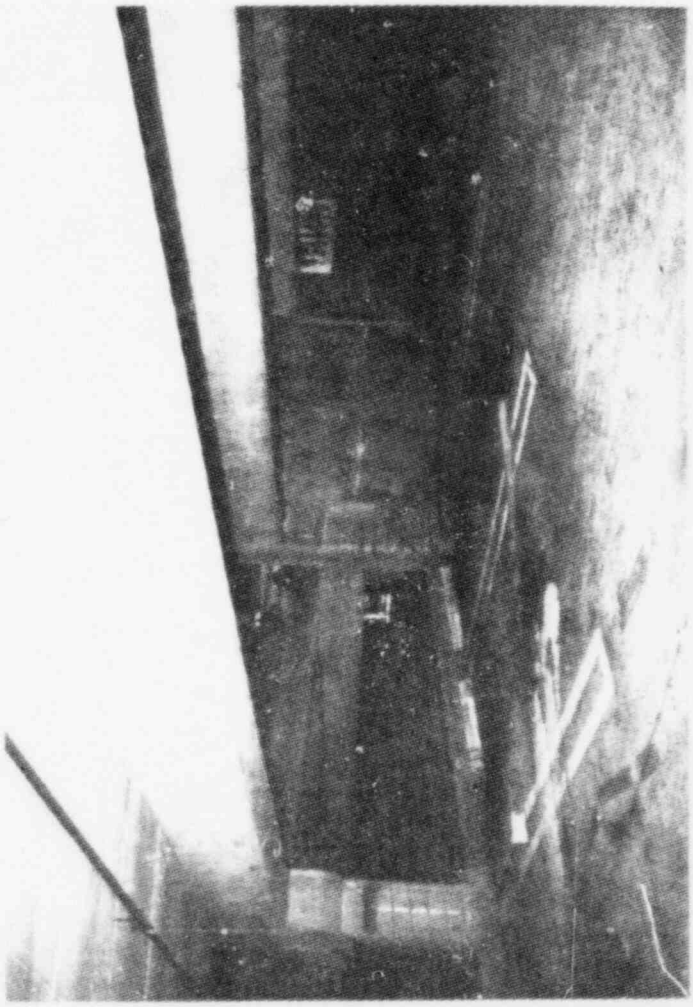

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NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

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OFFICE OF THE SECRETARY
D.C.

April 11, 1980

Docket No. 50-142

(P)

MEMORANDUM FOR: Samuel E. Bryan, Assistant Director, Division of Reactor Operations Inspection, OIE

FROM: Robert W. Reid, Chief, Operating Reactors Branch #4, Division of Operating Reactors, NRR

SUBJECT: NRR INPUT FOR RESPONSE TO PETITION FROM THE COMMITTEE TO BRIDGE THE GAP (CBG) CONCERNING THE UCLA RESEARCH REACTOR

Enclosed is a discussion of CBG charges contained in its October 3, 1979, petition concerning the UCLA research reactor. The specific CBG charges discussed are those which allege deficiencies in our review procedures used to support Amendment 10 to the UCLA operating license.

It is expected that further NRR input will be necessary to assure that all issues raised by the CBG have been properly covered. Please contact Mr. Hal Bernard (X27435) for assistance.

Robert W. Reid, Chief
Operating Reactors Branch #4
Division of Operating Reactors

Enclosure:
Discussion of CBG Charges

cc w/enclosure:
DEisenhut
WGammill
DGarner
HBernard
SBlock
RBachmann, OELD
JBuchanan, I&E
GKlinger, I&E
GKnighton

Attachment

Calculations have been made for estimating the dose that could be received by a "maximum individual" occupying a room in the math-science building. We will define a "maximum individual" as one who occupies this room for the entire year during which time the reactor is at power (i.e., 8.4 hrs/week), and is subjected to the same ^{41}Ar concentration as is on the roof of the math-science building (e.g. We assume the same concentration in the room as is at the intake to the ventilation system supplying air to the room).

From Regulatory Guide 1.109 "Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50 Appendix I", table B-1 provides the total body gamma dose factor for exposure to a continuous semi-infinite cloud of ^{41}Ar as 8.84×10^{-3} $\frac{\text{mrem/yr}}{\text{pci/m}^3}$. Using this dose factor, the paramenters of the UCLA reactor effluent, and a geometry correction factor, we get the following:

$$^{41}Ar \text{ dose factor} = \frac{8.8 \times 10^{-3} \text{ mrem/yr}}{\text{pci/m}^3} \times \frac{10^6 \text{pci}}{\text{uci}} \times \frac{10^6 \text{cc}}{\text{m}^3} = 8.8 \times 10^9 \frac{\text{mrem/yr}}{\text{uci/cc}}$$

UCLA parameters:

^{41}Ar emission concentration = 1.6×10^{-5} uci/cc
Dilution factor at Math-Science ventilation intake = 0.115
Reactor utilization factor = $\frac{8.4 \text{ hrs/week} \times 52 \text{ weeks/yr}}{8760 \text{ hrs/yr}} = 0.05$

Since the ^{41}Ar dose factor is based on a semi-infinite hemisphere, a correction factor must be used for a finite room volume. From the report "The Atmospheric Diffusion of Gases Discharged from the Chimney of the Harwell Pile (BEPO)", N.G. Stewart, et. al., AERE HP/R 1452, a correction factor for a room of 9 meter radius is about 0.03.

Collecting terms we get:

$$\frac{\text{mrem}}{\text{yr}} = 8.8 \times 10^9 \frac{\text{mrem/yr}}{\text{uci/cc}} \times 1.6 \times 10^{-5} \frac{\text{uci}}{\text{cc}} \times 0.115 \times 0.05 \times 0.03 = 0.0024 \times 10^4 = 24 \text{ mrem/yr}$$

This value is in reasonable agreement with the approximate 40 mrem/yr dose measured by an independent contractor on the roof. It would be expected to be smaller since the roof dosemeters would be "seeing" a larger plume of ^{41}Ar.