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OFFICE OF ENVIRONMENTAL HEALTH AND SAFETY
THE CENTER FOR THE HEALTH SCIENCES
LOS ANGELES, CALIFORNIA 90024

September 5, 1980
ROS:C1705, 1712G

Docket No.
50-142

Robert L. Tedsco, Assistant Director
for Licensing
Division of Licensing
Office of Nuclear Reactor Regulation
Washington, D.C. 20555

Dear Mr. Tedesco:

Attached are UCLA's answers to the list of 14 questions received from your office dated July 31, 1980. As you can see we have gone to some great lengths to answer the questions in great detail, and hence have not been able to respond before this time.

We believe we have clearly answered all of the questions, but if you need clarification of any of our answers, please contact Neill Ostrander at (213) 825-2040.

Very truly yours,

Walter F Wegst by H.K Brown

Walter F. Wegst, Ph.D
Director of Research and
Occupational Safety

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September 5, 1980

This will certify that the following responses have been reviewed by Professors Catton and Pomraning, Messers Hornor and Zane; and by Dr. Wegst, and therefore by a majority of the Radiation Use Committee.

A. Zane, Secretary

Radiation Use Committee

Question 1. 8-22-80

In order to consider posting the roof of the Math/Science building as a "restricted area" it would be necessary to first consider relocating the meteorology laboratory facilities from that building. Is it conceivable for the meteorology facilities to be moved from the Math/Science building to another building. Would the astronomy facilities also have to be removed or are they principally utilized when the reactors is not operating?

Are there advantages to NEL in having the meteorology facilities located on the roof of the Math/Science building? Are student programs or University (reactor) programs incorporated in the use of this facility?

The meteorology facilities consist of special building features as well as the instrumentation. The original Math/Science building provided a ninth floor structure, the roof (tenth floor) of which bases much of the weather observation equipment. The station is located approximately 172 feet ENE of the reactor stack and is equiped with telescopic tracking and telemetry equipment. The Math/Science Addition includes a nine story (ca. 100 ft) precipitation shaft as an integral part of the building. The upper terminus of the shaft is located in a tenth floor structure approximately 46 feet north of the reactor stack. The relocation of these facilities is not practical.

The observatory facilities of the Astronomy Department are used only at night when the reactor is not operating. The planetarium, approximately 180 feet east of the stack is used for classes and discussion sessions during the daylight hours. Usage is scheduled by the Astronomy department and is 40 to 56 hours per quarter during the fall, winter, and spring quarters; 2 to 3 hours in the summer quarter. Taking three quarters at 60 hours and one quarter at 10 hours, the usage is 190 hours per year or 8.1% of the 45 hour/week, 52 week year.

The NEL uses the meteorological facilities infrequently to spot-check wind direction and speed. The station does not function as a publicly reporting weather station and does not compile tabular records of the strip chart recordings. There are no formal student programs in nuclear engineering that utilize the meteorological facilities.

Question 2. 8-27-80

When standing on the roof of the Math/Science building and looking at the reactor stack, it is not apparent that the ventilation system is operating. It is further not apparent that the reactor is operating. As the Math/Science roof area is an open access zone, it would appear that information attesting to the status of reactor operation would be helpful. Could a blinking red light be installed together with a permanent sign posted where it can easily be read from the roof of the Math/Science that (to wit) "when the red light is blinking the UCLA research reactor is in operation. Please do not loiter in this area."

The ventilation system operates 24 hours per day including weekends and holidays. Operation is evidenced at the roof top by the waving string tied to the exit grill. On the rare occasions that the system is down for maintanance, the reactor does not operate.

A blinking red light and sign are technically feasible. UCLA considers the helpfulness of that information to be questionable. It would obviously suggest unspecified hazards associated with the research reactor, a suggestion this is not compatible with the hazard level.

UCLA maintains that the research reactor is operated within the limits of 10 CFR 20.105. During the two-year environmental monitoring program (March 1976 through February 1978) the average value of dosimeters within 300 feet of the stack was about 9 mr/quarter or 36 mr/yr (γ-only). (See response to question 9.) If attributed entirely to reactor operations and scaled to the 1979 operating level, the projected γ dose rate would be 72 mr/yr. Assuming a semi-infinite cloud in which the γ-dose rate is 74.6% of the total dose rate, the estimated total $\beta + \gamma$ dose rate is about 97 mr/yr. Accordingly, none of the rooftop areas warrant posting under the 500 mr/yr provision of 10 CFR 20.105(a).

The reactor does not operate continuously and the shorter term limits of 10 CFR 20.105 should be considered. During the two year period 1976-1978, the reactor produced an average of 14.5 megawatt hours, or produced at 100 kw for an equivalent operating time of 145 hours. Assuming that this effective operating time yielded a rooftop dose rate of 36 mr/yr (γ), the hourly rate when the reactor is operating is 0.248 mr (γ) or 0.33 mr/hr ($\beta + \gamma$). This is well within the 2 mr/hr limit of 10 CFR 20.105 (b)(1).

The reactor operates much less than 45 hours a week, so that the weekly dose rate is less than $0.33 \times 45 = 15$ mr/week. This is well within the limit of 10 CFR 20.105(b)(2).

The UCLA policy in regard to defining restricted areas is expressed in the UCLA Radiation Safety Handbook, p.20, as:

> "Any areas such as corridors and waiting rooms which are open to non-restricted personnel shall have a radiation level less than .6 millirems per hour. If the level exceeds this, the area must be classed as Restricted."

This requirement is more stringent than the "Radiation Area" definition of 10 CFR 20.202(b)(2) which stipulates a limit of 5 mrem/hr or 100 mrem in any 5 consecutive days.

UCLA does not wish to provide signs or displays that may stir apprehensions about a particular facility when that facility is operating within legal limits and within the uniform and more restrictive campus policy.

Question 3. 8-22-80

To reflect the measures taken by UCLA, the Technical Specifications will specify that the roof containing the stack shall be declared a "restricted area".

UCLA will accept the declaration in some form with the understanding that the definition of "restricted area" is unrelated to the "Restricted Area" definition of 10 CFR 20.3(14). The phrasing of the declaration should be such as to avoid future misinterpretation of the declaration. One suggested form: "The eighth floor in the immediate vicinity of the ventilation exhaust stack is posted and controlled to a degree commensurate with the potential exposure risk involved upon entry of that area. It is not a Restricted area in the sense of 10 CFR 20.3(14)."

Presumably this statement will become another paragraph of the proposed Technical Specifications, 3.8.2 "Dose in Unrestricted Areas."

Question 4. 8-22-80

It was noted during the site visit that equipment for proposed Argon-41 holdup tanks are being obtained and stored. Please provide a schedule for completion of this facility.

There is no calendar schedule for the completion of the hold-up system. The pacing is dictated by the following events:

(a) Approval of License renewal.

(b) Approval of a construction plan by the Campus Architects and Engineers.

(c) Approval of the plan by the Radiation Use Committee.

(d) Preparation and presentation of the proposed Amendment before the Campus Radiation Safety Committee.

(e) Submission of the proposed Amendment to the Nuclear Regulatory Commission.

(f) Approval of the proposed Amendment by the Nuclear Regulatory Commission.

(g) Completion of the construction.

These steps are not entirely sequential and some overlap is possible in those steps internal to UCLA. The time lapse between steps (e) and (f) is quite uncertain, and not controllable by UCLA.

Question 5. 8-22-80

What is the reliability of emissions monitoring equipment and accuracy of calibration standards and methods? Who checks calibrations? How are records maintained?

Reliability of equipment: A 4.3 liter flow-through ion chamber manufactured by Carry is used to continuously monitor the ventilation system exhaust when the reactor is operating. The measuring device is a Keithley model 640 vibrating reed electrometer operated in the integrate current mode on the 1 volt range. The electrometer is of solid state design and is highly reliable. Past history of the above equipment shows only preventive maintenance performed during the semi-annual calibrations.

A gamma spectrometer standard model R-34 source kit manufactured by I.C.N. of Irvine Cal. was used to calibrate a 3 inch by 3 inch sodium iodide scintillator. This standard bears the serial number 534 and was calibrated in 1-7-73.

This kit was used to determine the efficiency of the scintillator from 60 KEV to 1.33 MEV. Two curves were determined. One for a disc source on the crystal face, and a second for a 545 ml gas sample bottle using the standards as theoretical point sources simulating the 545 ml gas sample bottle.

A steel cylinder of 1639 cubic centimeter capacity instrumented with ten gold foils was filled with pure argon to a pressure of 225 psig and irradiated in the thermal column for 30 minutes at 250 watts.

Grab samples of the gas were taken and counted on the scintillator. The gas sample was then passed through various ion chambers to be calibrated, and their readings and the time recorded. The gold foil data was collected using the scintillator and the average neutron flux determined. The concentration of Ar-41 was then determined and compared against the grab sample previously counted. A concentration vs instrument scale reading for the various ion chambers was thereby determined.

Three calibration runs as described above were conducted. The average measured efficiency of the scintillator was 1.20% with a confidence level to 1 sigma of .07%. This compares favorably with a theoretical model which predicted 1.2% at 1.29 MEV.

Since the preparation, the experiment, and the data reduction requires approximately 1 man week, an alternative calibration technique was developed using a tritium gas standard. This allows the tritium monitor and the argon monitor to be calibrated simultaneously and requires only 1/2 man day.

The experimental value determined from tritium gas is $(2.350 \pm .026) \times 10^8$ microcuries per milliliter per amp for the 4300 ml chamber. This compares favorably with a theoretical value of 2.354×10^8 microcuries per milliliter per amp. The large chamber captures nearly all of the energy of the tritium β's (18.61 kev max) and only a fraction of the energy of the argon-41 β's (1.20 MEV). Nevertheless, that fraction is much larger than the total energy of the tritium β's, and equal curie concentrations of tritium and argon-41 yield larger ion currents with argon-41. Thus, for the 4300 ml ion chamber

1 μCi/ml (tritium) → 4.255×10^{-9} amps

1 μCi/ml (Ar-41) → 3.425×10^{-8} amps

The currents are measured across a resistor of 10^{12} ohms and yield a practical scale factor of 2.92×10^{-8} μCi/ml per millivolt for argon-41. The tritium calibration checks the performance of ion chamber and electrometer. The electrometer alone can be (and is) checked against a standard current source.

The reactor supervisor has performed the tritium calibrations on a semi-annual basis as required by the Technical Specifications. Grab samples both in the exhaust fan intake plenum (on the eighth floor) and at the output of the ion chamber are also taken periodically and compared with the readings of the argon sampling system. This verifies the chamber calibration and allows a correction factor to be applied should the stack concentration differ from the sample line concentration.

The argon emissions are determined by the reactor supervisor who periodically reduces the data on the Ar-41 chart using a compensating polar planimeter and records this data in the reactor supervisor's documentation log.

Question 6. 8-22-80

What was the reliability of the instrumentation and sampling systems used for the SF_6 dispersion tests conducted by UCLA?

The SF_6 work performed at UCLA was analyzed by Dr. Fred Shair of the California Institute of Technology. Over the last eight years, he has done SF_6 dispersion tests for the EPA, the California Air Resources Board and others. Although a complete statistical analysis has not been performed, the stated accuracy with eight standards is within $\pm$10%.

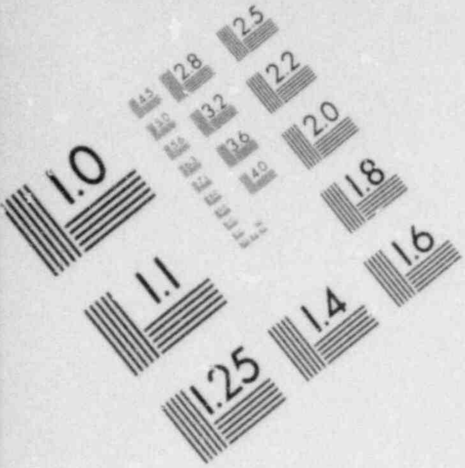
The sampling and analysis procedures are described in Chapter 2 of Mr. Rubin's thesis. A copy of that thesis is included in this response.

It is evident from the scatter in wind direction and speed data (Rubin, Figure 3) that turbulence is pronounced. The sampled concentrations show large fluctuations that might be expected under such turbulent conditions. In particular, the response to Question 8 indicates that none of the principle sampling locations (except the stack exit) were on the plume center line and large fluctuations should be expected in the fringe area. The data are highly consistent at the stack, and the general decrease in concentration with distance (as evidenced by averaged data) are powerful evidence of real fluctuations, not random experimental errors.

IMAGE EVALUATION
TEST TARGET (MT-3)

6″

MICROCOPY RESOLUTION TEST CHART



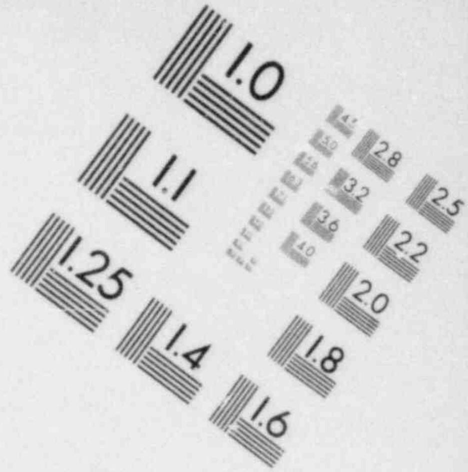
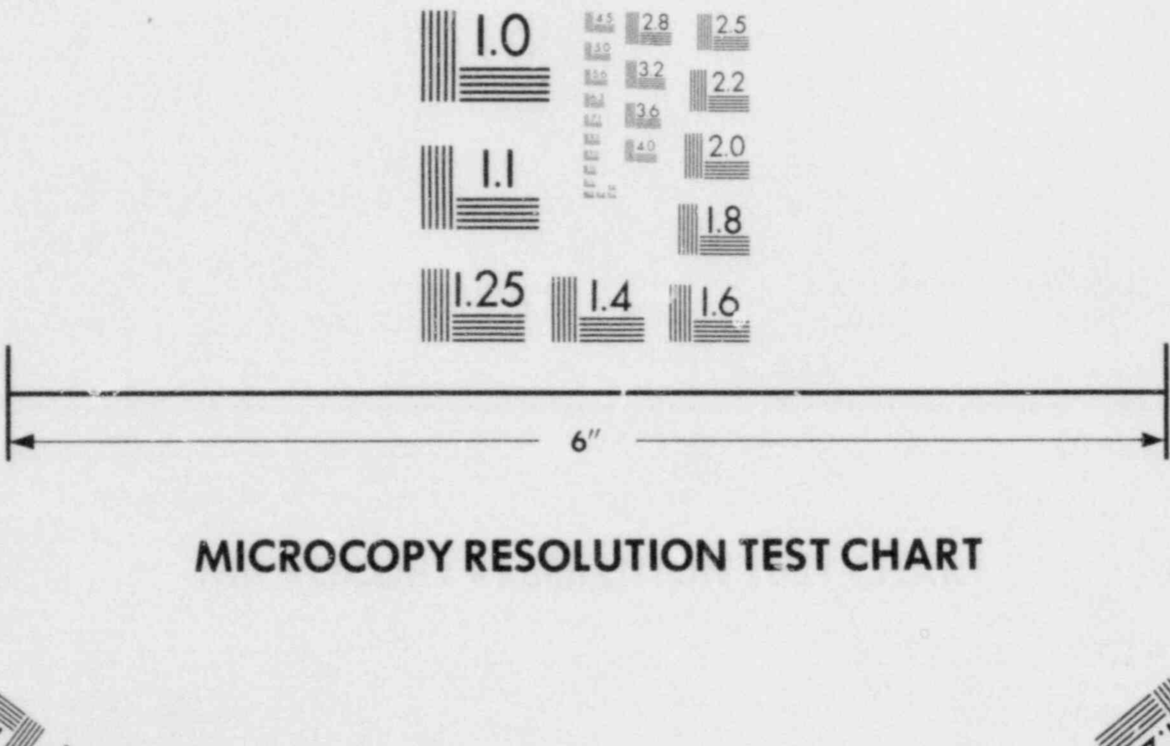
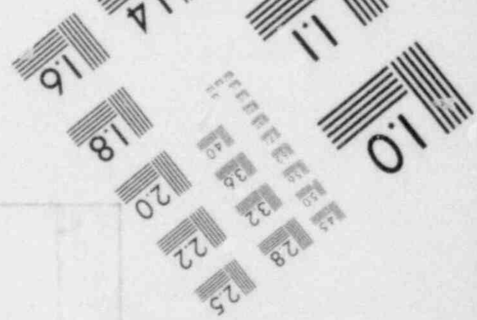


IMAGE EVALUATION
TEST TARGET (MT-3)



MICROCOPY RESOLUTION TEST CHART



Question 7. 8-22-80

What is the reliability and accuracy of the film badges at various levels and types of exposure used by UCLA?

Upon receipt of a new emulsion, calibration curves for γ and β exposures are constructed in the following way:

For γ exposures from approximately 10 mr to 3 R the calibration curve is established using a 20.16 mg Radium-226 needle. The needle was certified by Radium Corp. of America, Cert. No. 20412, 1962. The needle is placed on a board with ten test films in standard metal film badge holders which are placed at calculated distances from the needle. Films are exposed for varying lengths of time to obtain exposures from 17 mr to 3100 mr. (Actual points are 16.9, 25.4, 50.8, 102, 136, 254, 508, 1016, 3096 mr.) The films are processed with unexposed (background) films using a standardized development technique. A calibration curve, plotting calculated exposure vs film density, as read on a Photovolt densitometer, is then constructed. Shifts in emulsion performance (aging, etc.) are determined on a monthly basis by exposing five check films to 102, 254, 508 and 1016 mr as well as one exposure unknown to the film badge technician. Density readings of these films must agree within ±10% of the values on the calibration curve or a new ten point calibration curve must be constructed. The accuracy for the exposure range of 100 to 1000 mr is therefore ±10%. For γ exposures above 3000 mr, a number of films in metal holders, are exposed to Cesium-137 γ rays on the EH&S vertical calibration range. Exposures are measured with Condenser-R chambers. A calibration curve is established for high γ exposures approximately every three years.

β exposures: A set of 10 films are exposed to beta radiation from a thick slab of depleted uranium (dose rate at the surface of the slab was certified by supplier; Eberline Inc. Sept. 1972). The calibration curve covers beta exposures from 35 to 22000 mr.

Reliability in terms of badge recovery is nearly 100% for those badges issued to the nuclear energy laboratory. Bad film receipt is rare and is caught in the initial calibration stage. Processing errors are negligible. The threshold sensitivity is approximately 10 mrem (γ) and 20 mrem (β). Badges are changed either monthly or quarterly depending upon expected exposure. Thus for low radiation levels, the threshold dose rate is 10 mrem (γ) per quarter and 20 mrem (β) per quarter.

Question 8. 8-22-80

In the request for Amendment No. 10, UCLA utilized an overall emissions reduction of 460 that was calculated on the bases of reactor use, available meteorological dilution models, wind direction information, and building occupancy information. In the intervening years, meteorological stations have been established much closer to UCLA providing more applicable information, more rigorous meteorological mixing and transport models are available, UCLA has conducted meteorological studies and additional information is possibly available on building occupancy. With the use of this more current information, please prepare calculations to predict the concentration of Ar-41 at the Math/Science building from stack emissions due to reactor operation. Utilize the megawatt hours of operation in 1979 for reactor operating time.

Also please submit any actual release data available such as from smoke or vapor tests, and compare with the calculated results.

Use roof occupancy factors of 10% and 100%, and wind direction factors of 100% and 60%. Also consider infinite immersion, and non-infinite immersion factors indicated in the footnote associated with the calculations for Ar-41 concentrations provided in 10 CFR 20 Appendix B.

Meteorology

The distance from UCLA to reporting meteorological stations has not markedly altered from 1975 to today. The 1975 data was based upon an Air Pollution Control District (APCD) station located on Westwood Boulevard and Pico Boulevard, approximately 2.3 miles SSE of the reactor site. The availability of alternate and more proximate meteorological data was reviewed in late 1979. No new options could be identified. Available observations are in accord with older qualitative statements by the UCLA Department of Meteorology that a southwesterly wind prevails 60% of the daylight hours at the UCLA campus.

The assistance of the UCLA Department of Meteorology was sought in identifying and characterizing a transport model applicable to the NEL exhaust vent. Professor M. G. Wurtele kindly responded with the description following the text response to Question 8. The implications of that jet model are discussed in the following paragraphs. An alternative Gaussian model is described in subsequent paragraphs.

The Jet Transport and Related Models

The exhaust velocity from the stack is based upon 14000 CFM over a duct area 24 inches by 34 inches or 41.2 ft/sec (12.5 m/s). The average speed of the afternoon SW wind is 6.53 knots (3.36 m/s), at least as observed by Rubin in his 1976 study [1]. The vent exit radius is taken as $(A/\pi)^{1/2}$ where A is the cross sectional area. Hence $R_0 = 1.343$ feet (0.41 m).

The further numerical results are based upon a SW wind so that the plume departs to the NE. In Rubin's work [1], the average plume direction was more easterly (1 to 10°) and hence further from the MSA intake than assumed here.

For the bent-over jet, a location or observer is either within the plume envelope or is external to the envelope. More specifically, if a point P is located at perpindicular distance r from the jet centerline, then P(r) will be within the plume if $r < R$ and external to the plume if $r > R$. The plume radius is R computed as $\gamma z = .5 \cdot z$, where z is the plume elevation relative to the stack. The equations provided by Professor Wurtele have been evaluated for three locations; the location letter names of Rubin are adopted.

Location E. At the parapet, NE of the stack at a distance of 12.28 meters. The head of a six foot observer will be 7 feet (2.13m) above the stack.

Location G. The center of the MSA intake ventilator at an elevation of 3.5 feet (1.07m) relative to the stack exit. The location is 20.88 meters from the stack and 15° off (North) from the prevailing wind direction.

Location H. The head of a 6 foot observer standing on the highest level area of the meteorological station. The observer is [illegible]2 feet (52.42m) from the stack, the elevation is 6.95m relative to the stack, and the angular offset is 23° east of the plume path.

The following table presents the plume rise z, the radius R, the vertical component z-h and horizontal component Y of the distance r from the plume centerline. The distance r is given by $r=[(z-h)^2 + Y^2]^{\frac{1}{2}}$.

Jet Plume Geometry for Selected Observers

(All quantities in meters)

Location	z	R	z-h	Y	r	r-R
E	7.03	3.51	4.90	0	4.90	1.39
G	8.00	4.00	6.93	5.40	8.79	4.79
H	11.10	5.55	4.15	20.48	20.90	15.35

In all cases, $r > R$ and the locations (observers) are outside the plume. According to the theory, the concentration seen by the observers would be zero.

Gaussian Modification of the Jet Plume

With the simulant SF_6, Rubin found (and measured) down wind concentrations of SF_6 at each of the down wind locations. Eighteen samples were taken (6 per day, 3 different days), at each location. Although some were very low, none were zero.

Under the ocean breeze that characterizes the usual south westerly wind, the lower atmosphere is extremely turbulent. Wind speed and direction fluctuate markedly so that the jet plume is driven randomly in elevation and azimuth. On the basis of observed directional fluctuations ($\sigma = 29.5°$), the atmosphere would be classified as stability class A, extremely unstable.

With the assumption that the turbulence perturbes the uniform jet into a Gaussian radial (Rayleigh) distribution about the mean jet centerline, it is interesting to compare the radius of the jet with the Gaussian σ as given in Reg. Guide 1.111 at 100 meters.

$$R\ (\text{jet, 100m}) = 7.07\ \text{m}$$
$$\sigma\ (\text{class A, 100m}) = 16.20\ \text{m}$$

Evidently if the plume has significant Gaussian characteristics, its characteristic dimension is given by

$$\sigma = 2.3R.$$

The (inverse) dilution factor is then given by:

$$f^{-1} = \frac{c(r)}{c_0} = \frac{w_0}{2V}\left(\frac{R_0}{\sigma}\right)^2 \left[e^{-r^2/2\sigma^2} + e^{-r_1{}^2/2\sigma^2}\right]$$

The distribution extends to infinity and the second term represents an image plume at elevation $-(z+h)$ relative to the observer.

The preceding equation for the dilution factor yields results that compare well with average values of the Rubin work.

Comparison of Guassian Model With

Experimental Observations (Rubin 1976)

Location	σ	r	r_1	f(Eq)	f(Exptl)*
E	8.07	4.90	9.16	154	198
G	9.20	8.79	10.56	235	303
H	12.76	20.90	27.30	1430	1670

*Rubin uses the reciprocal dilution factor. The value here is the reciprocal of the mean value of 18 dilution factors (f^{-1}) at each location.

Considering the complexity of the actual geometry, the agreement is really excellent. The Gaussian model will slightly over-predict the downwind concentrations relative to the observational data.

The foregoing results are not directly comparable to the emissions reduction factor of 460 calculated in the application for Amendment 10. The 460 figure represented an over-all average effect that included a reactor utilization factor, wind factors (speed and direction frequencies), and occupancy factors. In calculating the concentration at the ventilator intake of the Math-Science Addition, the predicted direct dilution at that location was estimated to be 1/0.0411 = 24.3 with the wind from the SW, the reactor operating, and the occupancy 100%. The 24.3 figure may be compared with the 235 to 303 figure shown in the preceeding table for location G. The latter results indicate a 10-fold reduction in concentration relative to that used in the application for Amendment 10.

Assuming 5% operating time, and using the more conservative dilution factors of the Gaussian model, the effective dilution factors and annually averaged concentrations of argon-41 at the three locations are:

	Dilution Factor f	Concentration μCi/ml
E (at the parapet)	2340	5.1×10^{-9}
G (Vent Intake)	4700	2.6×10^{-9}
H (Met Station)	28600	4.2×10^{-10}

These assume a SW wind frequency of 100% and 100% occupancy. The concentrations are relative to 1.2×10^{-5} μCi/ml at the stack, and would be proportionately lower for reduced wind frequency and/or occupancy.

Immersion in semi-infinite clouds of these concentrations would yield the following dose rates.

E (at the parapet)	:	64 mr/yr
G (Vent Intake)	:	33 mr/yr
H (Met Station)	:	5 mr/yr

Again, these are for 5% reactor utilization, 100% SW wind, and 100% occupancy.

For the interior occupants of the Math Science Addition, the annual average concentration is assumed to be uniform and equal to the concentration at the ventilation intake (2.6×10^{-9} μCi/ml.) The β-dose rate is largely due to the local concentration and is therefore estimated to be:

$$127(2.6 \times 10^{-9}/4 \times 10^{-8}) = 8.3 \text{ mr/yr } (\beta)$$

The gamma dose rate depends upon the size of the cloud (room). If a sphere of radius R contains uniformly distributed sources emitting S photons/cm^3-sec., the photon flux at the center of the sphere is F = SR. If the source strength is given in µCi/ml, and converting from photon flux (of 1.29 Mev argon-41 photons) to dose rate, the equivalent numerical equation is

$$D(mr/hr) = 82.6 \cdot C \cdot R$$

C is in µCi/ml and the radius R is in centimeters.

The 1975 application for Amendment 10 subdivided the Math Science Addition into 13 cells each characterized by the radius of an equivalent volume sphere. A large room will have a larger dose rate than a small room, and is also likely to contain more people. Thus an effective average radius is a person-weighted radius.

$$\overline{R} = \sum N_i R_i / \sum N_i$$

R_i and N_i are the radius and population of the $i^{\underline{th}}$ cell. From the 1975 data, $\overline{R}$ = 683 cm. The average gamma dose rate is

$$\begin{aligned} D(\gamma) &= 82.6 \times 2.6 \times 10^{-9} \times 683 = 1.5 \times 10^{-4} \text{ mr/hr} \\ &= 1.3 \quad \text{mr/yr } (\gamma). \end{aligned}$$

The total dose rate is 9.6 mr/yr ($\beta + \gamma$). Reactor utilization is 5%, SW wind frequency and occupancy are both 100%. From the definition of $\overline{R}$, the total person-rem dose rate is the individual dose rate multiplied by the population.

Reference

1. Rubin, Mark Philip "Atmospheric Dispersion of Argon-41 from the UCLA Nuclear Reactor," a UCLA Master's Thesis, School of Engineering, 1976.

The Non-Buoyant Bent-Over Plume

The use of Turner Workbook formulas in the present problem is not appropriate, and they cannot be expected to yield reasonable results. The only applicable simple model is that of the "bent-over" plume, discussed by Briggs in Chapter 4 and by Csanady in Chapter 6, especially section 6.12 and Appendix to Chapter 6, A.6.1. Most discussions of plumes issuing from chimneys are concerned with a predominance of buoyancy, since most plumes are emitted at a temperature considerably greater than ambient. In the present case, the temperature may be taken as equal to ambient and the plume becomes a "jet" in conventional terminology, with an initial condition of a momentum excess, characterized by vertical velocity w_0 and an initial radius (i.e. radius of chimney R_0).

This jet is emitted vertically into an atmosphere with horizontal velocity V. Two assumptions then apply, as follows.

1) The atmosphere may be turbulent, but it is assumed that the entrainment of air into the jet is "self-generated" by the jet, just as if the air were smoothly flowing. The fact that the jet begins vertically and the airflow is horizontal is taken into account only by the use of an increased entrainment coefficient of 0.5, in contrast to the value of about 0.08 for a plume moving horizontally with the wind.

2) Mathematically, it is assumed that one can translate in time according to $t = x/V$, where x is the horizontal distance traversed by a particle in the jet, even though time is required for the jet to be accelerated to the horizontal wind speed. Similarly, it is assumed that the differential equations for vertical structure can be transformed into differential equations for horizontal structure by the relations

$$\frac{d}{dz} = \frac{d}{dx} \cdot \frac{dx}{dz} = \frac{V}{w}\frac{d}{dx}$$

where V is constant and w variable.

These assumptions are not really satisfactory, but I know of no simple theory that avoids them. The similarity theory, which derives essentially from Morton, Taylor, Turner (Proc. Royal Soc. A234, 1956) - yields the results cited by Briggs on p. 33 and Csanady on p. 219: the height Z of the jet centerline, and the expanded radius R of the jet are given in terms of the initial variables R_o, w_o, V, and the horizontal distance x. (The stability of the atmosphere does not enter for such short distances. Of course, this stability will greatly affect the turbulence of the atmospheric flow itself; but, as mentioned above, this does not enter.)

The relevant formulas are

$$Z = 2.3(w_o^2 R_o^2)^{1/3} V^{-2/3} x^{1/3}$$

$$= 2.3(w_o/V)^{2/3} (R_o x)^{1/3}$$

Plume radius is propo tional to height by similarity theory:

$$R = \gamma Z \qquad \gamma = \text{entrainment coefficient}$$
$$= 0.5$$

so that dilution of contaminant is inversely proportional to

$$\frac{R^2}{R_o} = (2.3)^2 \left(\frac{w_o}{V}\right)^{4/3} \frac{(R_o x)^{2/3}}{R_o^2}$$

$$= 1.3\left(\frac{w_o}{V}\right)^{4/3} \left(\frac{x}{R_o}\right)^{2/3}$$

The conservation of contaminant requires that

$$c_o w_o R_o^2 = CVR^2$$

c_o is the concentration at the stack release point, and C is the downwind concentration where the plume has expanded to radius R and the velocity V is close to the mean wind speed. Consequently the dilution factor is:

$$\frac{c_o}{C} = \frac{R^2 V}{R_o^2 w_o} = 1.3 \left(\frac{w_o}{V}\right)^{1/3} \left(\frac{x}{R_o}\right)^{2/3}$$

These formulas must be interpreted as follows. Take the mean wind direction and plot it on a horizontal map with stack as origin. If at a distance of 22 meters, the intake is further that a distance R from the mean wind direction, theory says intake is outside polluted plume

Similarly, determine Z at a distance of 22 m. If the difference (Z - R) is still greater than intake height, intake is outside plume. If the plume has not risen to the height of the 9th floor of M.S., the theory fails, of course, and a complicated flow situation arises.

If intake is <u>within</u> plume, concentration of pollution is reduced to C from c_o at chimney exit.

Thus, in this example this simple theory says that either (1) the air intake is within the plume, in which case it is receiving a high concentration, or (2) it is outside the plume and receives a concentration of zero. There is probably some validity to the concept of a very sharp gradient of concentration (rather than the continuous gradient of the Gaussian plume) so near to the exit. It would be nice to have continuous readings over time at the intake.

However, the assumption that all entrainment is due to the plume motion is very important here. In the typical sea-breeze regime, which is the one that produces the pollution problem in question, this assumption is quite invalid. The air is highly turbulent, gusting with eddies that will distort the plume and give highly variable concentrations at the intake over periods of 10 seconds to a few minutes. The meaningful value of concentration under such conditions would be a mean over a time scale--say, 20 minutes--sufficient to average out these eddies, but smaller than the time scale of variation of the mean wind V, or of the statistical intensity of the atmospheric turbulence. Such data are not now available.

The next step upward in modeling sophistication would take into account the turbulence of the atmosphere and the transition from a vertical to a horizontal plume. Numerical procedures and a large computer would be required. Teske et al. (1978) present a two-dimensional model useful for many purposes, but not applicable, as they note, to the simulation of plume-bending in a moving atmosphere. The appropriate model for the problem under discussion is that of Bennet and Golay (1979), a full three-dimensional, higher-order closure code. Several simulation runs using this code would produce interesting and useful results.

M.G. Wurtele
August 1980

References

Bennet, R.G. and Golay, M.N., 1979: "Numerical Modeling of Buoyant Plumes in a Turbulent Stratified Atmosphere," MIT-EL 79-002, M.I.T.

Briggs, G.A., 1969: Plume Rise, U.S.A.E.C.

Csanady, G.T., 1973: Turbulent Diffusion in the Environment, D. Reidel Pub. Co.

Teske, M.E., Lewellen, W.S., Segur, H.S., 1978: "Turbulence Modeling Applied to Buoyant Plumes," E.P.A. Report 600/4-78-050.

Question 9. 8-28-80

In regard to the environmental study conducted by UCLA, what would have been the results if more of the TLD's were considered in the analyses. As indicated during the site visit, do not utilize the TLD's that were located at distances appreciably upwind from the discharge stack that were initially placed to determine the effects of off-site and potentially super-imposed fugitive sources.

The av... value of all 16 TLD locations within 300 feet of the stack was 8.86 mr/quarter. Of these 16 locations, ten were in the 90° northeast quadrant which contains the prevailing wind quadrant. The average value for these ten stations was 9.31 mr/quarter. There was only one other test location in the NE quadrant, TLD #18 was approximately 780' NE of the release point on an elevator structure above the Physics Building. The average value at that station was 8.9 mr/quarter. If included 'th the ten others in the NE quadrant, the overall average for the N' quadrant is 9.27 mr/quarter.

The TLD on the stack (11. 6 mr/quarter) is included in all of the averages reported above.

Question 10. 8-27-80

Your May 13, 1980 response to question #2 indicated that the calculated reduction of a factor of 200 due to installation of a hold-up tank is expected to show a factor of 10 reduction in reality due to "seep" into the reactor room and "some losses" from operation of the pneumatic sample transport system. This is a large loss in effectiveness. How much do you estimate is due to each of these effects? Could a non-activating gas be used in the pneumatic system, where it might provide some relief from argon escaping the core extract line while not involving large amounts of pressurized gas handling?

An improved estimate of the effective capture is about 96%. The loss distribution is estimated to be:

Leakage to room	2.75%
Pneumatic transfer system	1.36%
Delayed release	0.16%
Total Losses	4.27%

The losses by delayed release depend somewhat on the operating cycle. The loss cited above assumes 8 hours of operation, 15 hours of holding, and 1 hour to release (depressuring).

The largest loss (leakage to the room), is the least certain but is an upper bound estimate. It is based upon a concentration of 5×10^{-7} μCi/ml. This number is the estimated detection threshold of the Triton model 855 that has been used on several occasions to attempt argon-41 detection in that room. The null result of these measurement attempts indicates that the argon-41 concentration is less than 5×10^{-7} μCi/ml in that room.

Unless the estimated loss to the room proves to be considerably overestimated, the cost-benefit ratio is not very attractive to inert gas utilization in the pneumatic transfer system.

Question 11. 8-27-80

During the reactor lifetime and since AMF has stopped manufacturing Argonaut reactor components, what has been the UCLA experience in regard to repair and replacement parts for reactor facility components that have malfunctioned or required replacement? What would be expected in the future?

If parts are no longer available off the shelf, could they be fabricated, manufactured, substituted for. Are as-built and fabrication drawings and specifications available for the various components or component parts that may have to be replaced.

Although AMF was the prime contractor for the UCLA reactor, the mechanical work was done by Levine and McCann, the electrical work (equipment) largely by Honeywell. The mechanical components (control blades, shafts, bearings, gears, couplings, clutches and drives) are a combination of purchased and fabricated parts. The mechanical assembly was never an off-the-shelf item. The system is very simple and although exact replacement of some purchased parts might be difficult today similar components exist and could be re-engineered into the existing equipment.

The only mechanical components of the control system that have been replaced are bearings.

The most significant repair/replacement work on the UCLA reactor was the replacement of the fuel boxes and related plumbing. This was done in 1971 because of exterior corrosion of the aluminum piping that had been cast into the concrete base. The effort required plumbing and sheet metal crafts, but not sophisticated engineering. Parts procurement problems were non-existent.

Over the years, major components of the control console have gradually been replaced with improved equipment. Because of solid state circuitry, the reliability is probably better now than with the vacuum tube units of the original console.

A reasonably complete set of construction drawings by General Nuclear Engineering and AMF exists. There may have been unrecorded field changes, and in general, core maintenance requires entry to assess the problem, and a part would not be fabricated without examination of that part to determine the appropriate fix.

Question 12. 8-27-80

What is the present status of the permanent fix for the control rod withdraw event of December 1979? Has the Radiation Use Committee made a decision? Has installation of the fix been completed?

The Radiation Use Committee approved the modification (by signature on individual letters) and unanimous approval was reported to the Committee at the March 20, 1980 Meeting. At the June 17, 1980 Meeting, the Reactor Supervisor reported the installation and testing had been completed and that the performance was entirely satisfactory.

Question 13. 8-27-80

Figures III-1, -2, -3, -6 of the license renewal application do not clearly show the operation of the control rods. How do they operate in relation to the core in the event of an earthquake? Discuss the effects on control blade operability of any seismic shake tests performed on the reactor core/control system. Has there been any reactor operating experience during seismic events. If so, describe control rod activities.

The four control/shim blades are firmly fixed to horizontal drive shafts which rotate to swing the blade through a maximum arc of about 45 degrees. The blades are rotated in a vertical plane. When at the lower extremity of the 45° arc they are horizontal and between adjacent fuel boxes. Control blade withdrawal is effected by rotating the drive shafts so that the blades rotate upward and away from the core center.

Blade withdrawal is measured/indicated as a percent of the maximum (45°) rotation. It is typically less than 50% indicating an elevation of less than 22.5 degrees from the horizontal.

The blades rotate within closed magnesium shrouds, the space surrounding the shrouds is stacked graphite. The shrouds define the clear path for the blade rotation as well as the graphite stacking geometry.

Control blade operability under earthquake has not been tested or experienced. If the earthquake precursor is sensed by the seismic scram interlock before any large effects occur, then the blades will fall (rotate downwards) by gravity. A sudden sharp jolt could conceivably shift the graphite relative to the foundation and shroud. Binding of one or more control blades by deformation of the shroud is conceivable. No such event was observed in connection with the seismic shake tests.

Results of the seismic shake tests were reported at the Winter Meeting of the American Nuclear Society in 1968 [1]. It was reported that no immediate adverse effects were observed, however a possible delayed effect was observed approximately six months later. The delayed effect was the failure of a "drop rod" test during a pre-start check off. The failure was attributed to shifting of the lead shielding in the rod-drive shaft clearance space. Although not provably related to the seismic test, the coincidence did not go unremarked. More importantly, the lead shot arrangement was recognized as a potential high-friction situation and remedial action was undertaken.

There is no experience with reactor operation during an earthquake.

In regard to the "frozen-blade" scenario with all four blades locked, it may be remarked that the reactor has been operated in a simulation of this mode for many consecutive hours. Nominally in the manual mode, the power level is stabilized by the negative temperature coefficient of reactivity.

The actual behavior under a quake induced "frozen blade" scenario depends upon the propagation of various multiple failure sequences. The seismic interlock should demand "full-scram" including the "dump water" command.

Execution of the latter command adds approximately 25 dollars of negative reactivity to the core. If the interlocks fail, and the reactor is super-critical, an over-power scram would be called, again including the "dump water" command. Failure of the electrical and/or air utility would similarly result in opening the dump valve.

Because of the variety of possible signals to "dump water", the simplest approach to a worst-case scenario is to hypothesize that the dump valve is stuck in the closed position.

In mild cases, the operating staff can intervene. A "stuck" dump valve can be levered open, and a control blade can be torqued down with a pipe wrench. These are not highly sophisticated maneuvers, but the reactor is not a highly sophisticated device.

A most drastic case assumes that the blades are frozen, the dump valve is stuck, and that the entire 8 story structure has collapsed through the roof of the reactor building, burying the reactor in a mass of rubble. All of the utilities are off but the fuel boxes and dump line remain intact. If super-critical, the core water inventory would be driven to the boiling point. Evaporation of 10 to 20% (3 to 6 gallons) of core water would render the core subcritical in 3 to 6 minutes. This time scale is based upon an initial excess reactivity sufficient to drive to reactor to a void limited power level of 150 kw. No fission product release attends the scenario.

References:

1. Smith, C.B., and Matthiesen, R.B., "Vibration Testing and Earthquake Response of Nuclear Reactors" Presented at the Winter Meeting of the American Nuclear Society, Washington D.C., November 1968.

Question 14. 8-27-80

Page V/1-3 of the renewal application defines "secured experiment". What is the status of a "secure experiment" in the event of an earthquake?

Secured experiments rest on a spacer supported by a graphite plug at the bottom of a vertical port. The spacer elevates the sample to the mid plane of the core, the region of maximum flux. The sample is laterally constrained by the sample hole liner, and is vertically supported by the spacer.

Neither the sample, the core, nor the top shielding are secured against vertical downward accelerations greater than 1 g. Cohesive forces sufficient to produce downward accelerations greater than 1 g are unlikely, the building and all of its contents would fall at no more than 1 g. The sample would not move relative to the core.

ENCLOSURE

1. In order to consider posting the roof of the Math/Science building as a "restricted area" it would be necessary to first consider relocating the meteorology laboratory facilities from that building. Is is conceivable for the meteorology facilities to be moved from the Math/Science building to another building. Would the astronomy facilities also have to be removed or are they principally utilized when the reactors is not operating?

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   Are there advantages to NEL in having the meteorology facilities located on the roof of the Math/Science building? Are student programs or University (reactor) programs incorporated in the use of this facility?

2. When standing on the roof of the Math/Science building and looking at the reactor stack, it is not apparent that the ventilation system is operating. It is further not apparent that the reactor is operating. As the Math/Science roof area is an open access zone, it would appear that information attesting to the status of reactor operation would be helpful. Could a blinking red light be installed together with a permanent sign posted where it can be easily read from the roof of the Math/Science building that (to wit) "when the red light is blinking the UCLA research reactor is in operation. Please do not loiter in this area". OK WW

3. To reflect the measures taken by UCLA, the Technical Specifications will specify that the roof containing the stack shall be declared a "restricted area".

4. It was noted during the site visit that equipment for proposed Argon-41 holdup tanks are being obtained and stored. Please provide a schedule for completion of this facility.

Terry E.

5. What is the reliability of emissions monitoring equipment and accuracy of calibration standards and methods? Who checks calibrations? How are records maintained?

6. What was the reliability of the instrumentation and sampling systems used for the SF_6 dispersion tests conducted by UCLA? Perhaps contact Prof. Fred Shair @ Caltech.

7. What is the reliability and accuracy of the film badges at various levels and types of exposure used by UCLA?

   See Harmor and Rad. Saf. Prog. determinat of minim detectable (amount, [illegible]

8. In the request for Amendment No. 10, UCLA utilized an overall emissions reduction of 460 that was calculated on the bases of reactor use, available meteorological dilution models, wind direction information, and building occupancy information. In the intervening years, meteorological stations have been established much closer to UCLA providing more applicable information, more rigorous meteorological mixing and transport models are available, UCLA has conducted meteorological studies and additional information is possibly available on building occupancy. With the use of this more current information, please prepare calculations to predict the concentration of Ar-41 at the Math/Science building from stack emissions due to reactor operation. Utilize the megawatt hours of operation in 1979 for reactor operating time.

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Also please submit any actual release data available such as from smoke or vapor tests, and compare with the calculated results.

Use roof occupancy factors of 10% and 100%, and wind direction factors of 100% and 60%. Also consider infinite immersion, and non-infinite immersion factors indicated in the footnote associated with the calculations for Ar-41 concentrations provided in 10 CFR 20 Appendix B.

9. In regard to the environmental study conducted by UCLA, what would have been the results if more of the TLD's were considered in the analyses. As indicated during the site visit, do not utilize the TLD's that were located at distances appreciably upwind from the discharge stack that were initally placed to determine the effects of off site and potentially superimposed fugitive sources.

10. Your May 13, 1980 response to question #2 indicated that the calculated reduction of a factor of 200 due to installation of a hold-up tank is expected to show a factor of 10 reduction in reality due to "seep" into the reactor room and "some losses" from operation of the pneumatic sample transport system. This is a large loss in effectiveness. How much do you estimate is due to each of these effects? Could a non-activating gas be used in the pneumatic system, where it might provide some relief from argon escaping the core extract line while not involving large amounts of pressurized gas handling?

No, but mention experiments to be done with N_2 in core.

11. During the reactor lifetime and since AMF has stopped manufacturing Argonaut reactor components, what has been the UCLA experience in regard to repair and replacement parts for reactor facility components that have malfunctioned or required replacement? What would be expected in the future?

If parts are no longer available off the shelf, could they be fabricated, manufactured, substituted for. Are as-built and fabrication drawings and specifications available for the various components or component parts that may have to be replaced.

12. What is the present status of the permanent fix for the control rod withdraw event of December 1979? Has the Radiation Use Committee made a decision? Has installation of the fix been completed?

13. Figures III/5-1, -2, -3, -6 of the license renewal application do not clearly show the operation of the control rods. How do they operate in relation to the core in the event of an earthquake? Discuss the effects on control blade operability of any seismic shake tests performed on the reactor core/control system. Has there been any reactor operating experience during seismic events. If so, describe control rod activities.

14. Page V/1-3 of the renewal application defines "secured experiment". What is the status of a "secure experiment" in the event of an earthquake?

Tony

15. Questions concerning "security" will be posed under separate cover.

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UNIVERSITY OF CALIFORNIA

LOS ANGELES

Atmospheric Dispersion of Argon 41 from the UCLA Nuclear Reactor

A thesis submitted in partial satisfaction of the requirements for the degree Master of Science in Engineering

by

Mark Phillip Rubin

1976