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November 5, 1980

Region III, Office of Inspection and Enforcement
U.S. Nuclear Regulatory Commission
799 Roosevelt Road
Glen Ellyn, Illinois 60137

Attn: James G. Keppler, Director
Ref: Docket No. 50-186
Docket No. 30-2278

Gentlemen:

Upon review of your letter of October 15, 1980, and following discussions with our staff members, I have reinforced and restated the University's policy to provide for independent oversight of the health physics operations conducted under license R-103. This responsibility is assigned to the University-wide Radiation Safety Office; in fact, John Tolan is responsible for the oversight and monitoring function for all the NRC licenses. This responsibility is clear to all operational units. I will continue to assure that the needed resources are available to perform this oversight function.

In keeping with this assignment, I have asked John Tolan to investigate the circumstances of the exposure cited in Appendix A of your letter and to assign a dose attributable to the exposure that reflects his interpretation of the various measurements that were made by others.

A copy of Mr. Tolan's assessment of the exposure is attached. The over exposure did occur, but Mr. Tolan advises me that it was impossible to pinpoint a dose with reasonable confidence in the quantity. While it is certainly within the range of possible values, Mr. Tolan believes the NRC assessment of the dose to be too high in view of uncertainties in the survey data and in consideration of the Oak Ridge data on intercomparisons of neutron detectors as referenced in his report. He has proposed the assignment of a neutron dose of 1500 mrem to add to the 750 mrem gamma dose reported by Landauer for an incident total of 2250 mrem and an accumulated quarterly total of 2400 mrem. This quantity is in excess of the limit specified by 10 CFR 20.101(a) for a quarterly dose.

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John Tolan derived this dose assignment from the following steps:

1. Not a single number of all that were generated has any more validity than any other. That is, every one of them is faulty in some respect.
2. We know for certain only that conditions existed for an exposure of significant magnitude to occur.
3. We know approximately what the upper and lower limits of the exposure to the detector were. That is, we can be fairly confident the exposure was not less than the 750 mrem gamma dose and 180 mrem neutron dose reported by Landauer, and we can be fairly confident the exposure was not more, or much more, than the 480 mrem gamma dose and 1700 mrem neutron dose reported by Teledyne.
4. The exact value of the exposure is not important as long as we can be reasonably certain it was not so high as to produce clinical manifestations of excessive exposure.
5. What is important is that we recognize a failure in our control measures and take steps to prevent a recurrence of the same failure and be increasingly alert to possible failures elsewhere.
6. Any number for the neutron dose within the order of magnitude of 200-2000 mrem is equally supportable. I have selected a number toward the high end of this range in keeping with the usual conservative nature of an estimate made within a wide range of values with each having an equivalent validity.
7. No adjustment is claimed for the geometrical conditions that suggest the true whole-body dose may have been one-half or less of the dose recorded by the detector.

Independently, MURR staff members have undertaken an evaluation of the thermal neutron dose determination provided by the Landauer detector and the characterization of the neutron radiation environment with Bonner spheres. The preliminary results independently agree with the dose signment made by John Tolan. We will be pleased to furnish a copy of this report when it is completed if it would be useful. Thus the Director of MURR, Dr. Robert Brugger, agrees to the dose level as given by John Tolan. The experience gained was instructive and will provide an incentive to improve our overall monitoring program.

With respect to your evaluation of our previous responses contained in Appendix B of your letter of October 15, 1980, most of your concerns are directed to the dose assessment that you found to be inadequate. I hope that the assessment provided by Mr. Tolan and agreed to by Dr. Brugger will be more nearly satisfactory to you. Regarding the question of the adequacy of our program for air sampling, bioassays, and laboratory surveys, we plan to implement a recommendation made by Norman Sunderland, then our Assistant Radiation Safety Officer, in his audit report of February 6, 1979, in which he proposed that a senior-level health physics technician be added to the staff. This added staff member was intended to serve a supervisory role to assign duties, schedule operations, maintain records, and so on, to free the Manager, Reactor Health Physics, from routine tasks so that more time could be devoted to developing health physics procedures, a formal ALARA program, and an improved training program. I believe this additional staff member will strengthen the conduct of our radiation control program at the Reactor Faciltiy.

Please let me know if I can provide further information.

Sincerely,

Melvin D. George

Melvin D. George
Vice President for
Academic Affairs

MDG:mk
Enclosure

cc: Robert M. Brugger
Thomas C. Collins
Robert L. Carter
C. W. Tompson
John H. Tolan

Assessment of the Dose to be Assigned To the Personnel Monitoring Record of Employee A

Purpose

As has been requested, I have undertaken a review of the circumstances relating to the exposure of Employee A last November with the intent of determining a quantity for the dose to be assigned to his exposure record. In this review, I should point out, I was seeking substance in the use of a measurement system (the film or TLD detector) in which I have very little confidence. It is much easier to describe the many ways one can be misled by the measurement obtained in this way than it is to demonstrate accuracy.

Several essentially independent parameters were considered, but only a few of them are significant as will be explained. I am personally distressed that the incident occurred, but it did have a positive result without producing too serious a consequence. The real value of the monitoring device is as a mobile, integrating indicator of the efficacy of our control measures. We found from this incident that previously unknown but correctable weaknesses in these control measures existed, and they have now been corrected.

Comparison of detectors

Not having used the Teledyne detector myself, I was unfamiliar with its operating characteristics. I telephoned the Company in New Jersey and spoke to Tom Pelton, their dosimetry supervisor, to learn how the detector works. He explained that the detector used to monitor neutrons is a lithium fluoride TLD, which is also sensitive to gamma rays. To distinguish neutron dose from gamma dose, the LiF detector is paired with a calcium sulfate (dysprosium) TLD that is supposed to be sensitive only to gamma rays. If both detectors register the same dose, it is all gamma; if the LiF detector registers a higher dose, the difference is the neutron dose. With respect to sensitivity of the LiF to neutrons as a function of neutron energies, I was told it was highly sensitive to thermal neutrons and less, much less, sensitive to fast neutrons.

The NTA film used in the Landauer detector has an entirely different response as a function of neutron energy. Recoil tracks from neutron interactions are produced as latent images in the emulsion of the film. After developing the film, the fixed images of the tracks are counted individually by an operator as they are viewed through a microscope. The number per unit area of the tracks is a measure of the number of neutrons incident on the film and to the dose. A neutron less than 1 MeV in energy is less likely to produce a visible track, so there is a sharp reduction in sensitivity to neutrons less than 1 MeV. Landauer provides at the customer's option an independent measure of dose from thermal-energy neutrons. Employee A's badge was equipped with this optional feature. Relative to the measure of neutrons, one detector measures apples and the other detector measures oranges. Segal's Law* states: "A man with one watch knows what time it is. A man with two watches is never sure."

Evaluation of the conditions of the exposure

To begin the evaluation, I visited the area of beamport F where the incident occurred so that I could get an impression of the spatial relationships and of the position occupied by Employee A during his cleanup of the water spill. He is a very large man. I can only guess at his dimensions, but he must be 6'-3" tall and weigh about 250 pounds. I mention this only to emphasize that not very much of him could squeeze into the available space and manipulate a mop. He had to stand at the entranceway to project his upper body and arms into the space to perform the cleanup. Because he attached his monitoring device to the garment covering the front center of his chest, the detectors were substantially closer to the source of radiation than was the bulk of his body.

It was explained that the emerging beam in the space is normally a sharply collimated cylinder of about 1" diameter projecting into the space coaxially with the beamport. Only because of the displacement of

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* Arthur Bloch, *Murphy's Law and other reasons why things go ɓuoɹʍ !* Price/Stern/Sloan, Los Angeles, 1977.

the beam tube and of the bismuth filters did this beam diverge away from its normal position. Unfortunately, this diverging beam cannot be reproduced, so its exact intensity and location are unknown. There is a shroud shield, however, around the beam that would have partially absorbed some of the diverging beam. This shroud, no doubt, reduced the exposure detected from that which would have been experienced in the absence of the shroud.

There is an uncertainty about the distribution of the energies of the neutrons emerging from the beamport under these unusual conditions. If my understanding of the purpose of the bismuth filters is correct in that they are intended to suppress the gamma intensity and the number of intermediate-energy neutrons in favor of the fast neutrons, the displacement of the filters along the length of the tube would not render them completely ineffective for this purpose, since they remained athwart the beam. If this be so, the energy distribution of neutrons in the center of the emerging beam would remain skewed toward the high-energy end. This would not be so, however, for the neutrons scattered from the displaced filter. The quality factors of the thermal-energy and intermediate-energy neutrons that then emerge are less than they are at 1 MeV, which reduces the dose production per unit energy absorbed.

The significance of the quality factors is that the dose equivalent in rem varies by a factor of five per unit absorbed dose in rad from thermal neutron to 1-MeV neutrons. The monitoring system measures something proportional to absorbed dose, and the detector vendor must supply through his calibration procedure an adjustment necessary to convert to dose equivalent. To be accurate in the assessment of dose equivalent, the vendor must calibrate with exactly the same energy distribution as the monitoring device is exposed to. In a practical sense, this is very difficult to do.

Assessment of the exposure measurements

I struggled with an attempt to derive some intelligence from the numbers generated as dose indicators from the two monitoring devices and from the survey instrument. The NRC is in a quandary about measurements of neutron dose for personnel monitoring purposes. Regulations require that monitoring be performed, but everyone knows it cannot be done accurately at a cost within reason. In an attempt to shed some light on this problem, the NRC has commissioned the National Sanitation Foundation in Ann Arbor, Michigan, to develop standards of performance and to intercompare measurement systems. The contract terms do not address dosimeter design. After two years of work, it has been established that the commercial suppliers are unable to deliver consistently accurate results. Development of the standards of performance are more nearly complete.

Very little progress has yet been made on a solution of the problem of energy dependence of the neutron detectors. Only the recently developed track-etch-in-plastic detectors offer some hope that a reliable and reasonably accurate monitoring device can be produced at an affordable price. The NTA film used by our supplier of monitoring devices (and by most other suppliers until recently) has always been deficient in two respects: it does not respond to thermal- or to intermediate-energy neutrons and it suffers from latent-image fading so that the use interval is abbreviated to about two weeks. Now that track-etch detectors are commercially available, the Reactor Facility converted to this system in July 1980.

The licensee is in a very awkward position with respect to compliance with the personnel monitoring requirements of the Federal regulations when neutron exposure is likely. Neutron dose can be measured accurately but not by an instrument that is pinned to a shirt. What the licensee must do is to so characterize and control the neutron-radiation environment that individual exposures will be small enough that errors in the range of a factor of two in the interpretation of the personnel monitor will not matter. In the Employee A exposure, the control measures were breached, and we now must attempt to be more accurate in our evaluation of his dose than the measurement system permits.

He was a short-term employee but even in this brief tenure he demonstrated a propensity to accumulate higher than normal exposures on his film badge. He received a 260 mrem gamma dose in the third, two-week interval of his employment. In our developing ALARA program, this report should precipitate an investigation and a special instruction on proper procedure. Reports for the next three, two-week intervals showed reduced exposures of 40 mrem, minimal, and 40 mrem gamma dose respectively. These are more representative values for the duties performed.

Next came the interval of October 29 to November 11, 1979, during which the beamport incident occurred, that resulted in a dose of 750 mrem gamma and 180 mrem fast neutron as recorded by the Landauer badge. With the detector sent in for processing on November 8, the day of the incident, a two-week interval was essentially completed. since only one working day and the weekend intervened before the next two week interval commenced on November 12. The Teledyne detector was sent in for processing the same day, but this detector was exposed over a different time span. For three days in October (29, 30, & 31), the Landauer badge was worn with a different Teledyne badge. Some exposure to gamma radiation could have occurred that was recorded on the Landauer badge but not on the Teledyne badge. The Teledyne report for October 1 to October 31 did show a dose of 35 mrem gamma, but the Landauer report for October 15 to October 28 showed a dose of 40 mrem gamma and the Landauer report for October 1 to October 14 showed a minimal reading. Thus, it would seem the overlap in use intervals is accounted for.

To attempt to learn if there was a consistent difference between the Landauer and Teledyne interpretation for gamma or neutron dose, the reports for two other staff members were compared. For one individual over the four-month interval of October 1979 through January 1980, the Landauer report showed a dose of 560 mrem for gamma and a minimal dose for neutrons while the Teledyne report showed 365 mrem for gamma and 20 mrem for neutrons. For the other individual, the Landauer report showed 430 mrem for gamma and a minimal dose for neutrons while the Teledyne report showed 330 mrem for gamma and 25 mrem for neutrons. The ratios of the Landauer to Teledyne reports for gamma dose were about the same as for the report on Employee A's detector: about 1.5:1. This is not to say either is correct but that the difference is uniform. It is also interesting to note the Teledyne reports for the two individuals showed small doses attributable to neutrons while the Landauer reports showed none. The report of neutron dose is questionable.

Attempting to make some sense out of these numbers when they are based on a very shaky foundation is not much more than informed guesswork. At this time, the NRC-sponsored study at the National Sanitation Foundation is incomplete. No licensee can afford to perform an independent study, but I wondered if maybe a government laboratory had worked on the problem. Upon inquiry, John Auxier and Steve Sims of the Oak Ridge National Laboratory supplied data from a series of intercomparison measurements made there over a period of several years using the health physics reactor as the neutron source. Distilled from the formal reports, the Teledyne detector was shown to register dose too high by a factor of 1.77 for neutrons. The Landauer detector (NTA film) was shown to register dose too low by a factor of 1.6. Of course, the spectrum was not the same and other factors that might influence the readings were not the same, but these data are, nevertheless, indicative of the differences in interpretation that may occur.

If the Teledyne reported neutron dose of 1700 mrem is divided by 1.77 and the Landauer reported neutron dose of 180 mrem is multiplied by 1.6, we have adjusted figures of 960 mrem and 290 mrem respectively. These are still pretty far apart but, allowing for the uncertainties of the conditions prevailing in Employee A's exposure, they seem more reasonable. Strangely, the Oak Ridge study found the Teledyne interpretation of gamma dose to be too high also and the Landauer interpretation of gamma dose to be low. If the gamma interpretations had been the other way, that is Teledyne low and Landauer high, the adjustments of the neutron doses would be easier to accept.

Next consider the data obtained with the survey instrument, which usually produces a more satisfying group of measurements. Using the dose rate measured with the instrument, the ratio of fast-neutron dose rate to gamma dose rate was 3.2:1. Multiplying this ratio by the gamma dose reported by Landauer, the product is 2400 mrem or higher than the value reported for neutron dose by Teledyne. Suppose the 750 mrem gamma dose reported by Landauer was too high for some reason. If the assumed 3.2:1 ratio of neutron-to-gamma dose rate is multiplied by the 480 mrem for gamma reported by Teledyne, the neutron dose would be 1540 mrem. This is near the Teledyne reported value, but it is much higher than if the Oak Ridge correction factor of 1.77 were applied to the original report from Teledyne. Unfortunately, the survey data were taken under less than ideal conditions with instruments not calibrated specifically for the energy distribution of the radiations encountered. No great reliance can be placed upon the measurements recorded.

The neutron survey was performed with a Victoreen 488A instrument calibrated against the emissions of an unmoderated plutonium-beryllium source that had been standardized with a similar instrument returned from Victoreen after repair and calibration. This is not bad, but it is hardly good enough to serve as the basis for a dose determination. The gamma survey was performed with an Eberline R03-A instrument calibrated locally against the emissions of cesium-137 standardized with a Victoreen R-meter calibrated for the same radiations. Gamma measurements were likely to be more reliable. The survey was performed in an atmosphere of great excitement and anxiety with many people milling about. Dose rates to be measured were in the several rem-per-hour range, a condition that precludes careful and deliberate measurements. The surveyor reported that he entered the beamport area only briefly to take one reading and came out immediately to report to his associate who was recording. After repeating the in-out maneuver several times, the set of readings constituting the survey was complete, and the reactor was shut down. All of this took but a few minutes, and the surveyor's Landauer badge recorded only 20 mrem gamma dose and no neutron dose for the entire two-week period. A Teledyne badge had not been issued. Retrospectively, we might conclude that more measurements should have been taken, but they were not; and we can record our afterthoughts in the experience-gained column of the ledger.

It is clear that the numbers available permit a wide range of interpretations, and the likelihood of identifying the correct one is very small. To cast aside one of the Landauer reported values on the basis of presumed inaccuracy is to say that none of the 17 years of accumulated Landauer reports are correct. Teledyne is the new player in the game and we have no experience with them, but the Oak Ridge data show the Teledyne detector to be subject to substantial error. Furthermore, the same Oak Ridge reports show the Landauer detector to be correct in every instance when the neutron spectra were known. Perhaps now that the neutron spectra at the Reactor Facility are being established, we can expect to receive more accurate reports from Landauer than they were able to supply in the past. Also, we are now using the improved track-etch detector, and better results are expected from it. Meanwhile, I think we have to accept as fact that the Landauer report of 180 mrem neutron dose for the Employee A exposure was too low for reasons we do not know.

Even the survey data show a higher fast-neutron dose than the Landauer report. Measured at waist level, the fast-neutron dose rate was measured at 1600 mrem/hour. For a 10.5-minute exposure, the fast-neutron dose was calculated to be 280 mrem. Keeping in mind the position of the detector relative to the waist and to the source of radiation, the detector should have registered a dose possibly twice as high as that calculated from the survey measurement. The survey measurement also indicated a thermal-neutron dose component. The Teledyne detector integrates the thermal dose with the fast neutron and the Landauer detector registers them separately, but the Landauer detector in use did not show a measurement of thermal neutrons.

Conclusions

Employee A was exposed to neutrons in our establishment while in our employ in an incident that was partly his own fault. Responsibility for the incident is not at issue here. We don't know the exact magnitude of the exposure, but it is likely to be between 180 mrem and 1700 mrem as reported independently by two detectors. He is no longer employed here, and the number we assign to his monitoring record will have very little bearing on his health or on his future employment. The conditions that permitted the exposure to occur have been corrected, and increased vigilance and application of ALARA principles will reduce the likelihood of excessive exposure in the future. I propose, therefore, an assignment of 1500 mrem neutron dose to the permanent record of Employee A instead of the 180 mrem neutron dose that now appears on his record for the interval of October 29 to November 11, 1979, with all other entries kept the same, except for the appropriate adjustment of the accumulated dose. A copy of this adjusted monitoring record should be supplied to Employee A.

This proposed dose assignment is derived from several determinations as follows:

1. Not a single number of all that were generated has any more validity than any other. That is, every one of them is faulty in some respect.
2. We know for certain only that conditions existed for an exposure of significant magnitude to occur.
3. We know approximately what the upper and lower limits of the exposure to the detector were. That is, we can be fairly confident the exposure was not less than the 750 mrem gamma dose and 180 mrem neutron dose reported by Landauer, and we can be fairly confident the exposure was not more, or much more, than the

480 mrem gamma dose and 1700 mrem neutron dose reported by Teledyne.

4. T! exact value of the exposure is not important as long as we can be reasonably certain it was not so high as to produce clinical manifestations of excessive exposure.

5. What is important is that we recognize a failure in our control measures and take steps to prevent a recurrence of the same failure and be increasingly alert to possible failures elsewhere.

6. Any number for the neutron dose within the order of magnitude of 200-2000 mrem is equally supportable. I have selected a number toward the high end of this range in keeping with the usual conservative nature of an estimate made within a wide range of values with each having an equivalent validity.

7. No adjustment is claimed for the geometrical conditions that suggest the true whole-body dose may have been one-half or less of the dose recorded by the detector.

Respectfully submitted,

John H. Tolan

John H. Tolan
Radiation Safety Officer

JHT:mh

Distribution:

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References:

1. ORNL/TM-7137, February 1980, by H.W. Dickson. Teledyne detectors identified as Group 17.

2. ORNL/TM-4786, January 1976, by H.W. Dickson, W.F. Fox, and F.F. Haywood. Landauer detectors identified as Group C-2.

3. ORNL/TM-5672, December 1976, by L.W. Gilley, H.W. Dickson, and D.J. Christian. Landauer detectors identified as Group H.
4. ORNL/TM-6114, January 1979, by H.W. Dickson and L.W. Gilley. Landauer detectors identified as Group BA.