APPENDIX

U.S. NUCLEAR REGULATORY COMMISSION
REGION IV

NRC Inspection Report: 50-128/88-03 License: R-83

Docket: 50-128

Licensee: Texas A&M University (TAMU)
Nuclear Science Center
College Station, Texas 77843

Facility Name: Nuclear Science Center (NSC) - TRIGA Reactor (1 Megawatt)

Inspection At: TAMU-NSC, College Station, Texas

Inspection Conducted: April 11-12, 1988

Inspector: for H. D. Chaney, Radiation Specialist, Facilities Radiological Protection Section — Date 5/25/88

Accompanied By: B. Murray, Chief, Radiological Protection & Safeguards Branch

Approved: R. E. Baer, Chief, Facilities Radiological Protection Section — Date 5/25/88

Inspection Summary

Inspection Conducted April 11-12, 1988 (Report 50-128/88-03)

Areas Inspected: Routine, unannounced inspection of the licensee's Radiation Protection Program, radiological surveys including an independent radiation spectrum measurements of reactor Beam Port No. 1 and a review of high radiation area controls for experiments, and interview with personnel associated with the neutron diffraction (ND) experiment at the NSC during the period August through December 1987.

Results: Within the areas inspected, one apparent violation (see paragraph 3) on training and indoctrination was identified. No deviations were identified. Two previous inspection findings (apparent violations) concerning a possible overexposure (128/8801-01) and inadequate radiological surveys (128/8801-05) were found to not warrant classification as violations, and will not be included in any subsequent enforcement action.

DETAILS

1. Persons Contacted

TAMU

*F. Jennings, Executive Director, Office of University Research
D. Deere, NSC Senior Nuclear Engineer
M. Kalyanasundaram, Nuclear Engineering Student
D. McDonald, NSC Reactor Operator
*C. Meyer, Senior Health Physicist, NSC
*J. Reuscher, Director, Research Reactor Programs
L. Rodriquez, NSC Health Physicist
T. Salamonca, Mechanical Engineering Student
*G. Schlapper, Associate Professor, Nuclear Engineering Department
*J. Simek, Assistant Radiation Safety Officer

*Indicates those present at the exit interview.

2. Followup to NRC Inspection Report 50-128/88-01 (92702)

a. Possible Personnel Overexposure Review

The NRC inspectors and the licensee conducted comparative dosimetry and portable radiation survey instrument evaluations on the radiation beam emanating from the NSC reactor Beam Port No. 1 (BP1). These evaluations were designed to characterize the radiation components and intensities of the beam during reactor operations at 1000 kilowatts power and in a reconstruction of the equipment setup similar to that used during the neutron diffraction (ND) experiment that was carried out during the period of August through December 1987.

b. Background

When the NSC reactor is operated in the pool stall location, radiation given off by the reactor can be directed to one or more beam ports that pass through the reactor pool wall. These beam ports can be provided with shutoff devices if needed. A beam shut off device was not installed until December 1987. The licensee set-up BP1 in early August 1987 for conduct of a proposed experiment involving ND. The experiment called for the placing of a steel plate approximately 1 inch thick by 8 inches wide by 12 inches long on a precision rotating machinist vise at approximately 70 inches from the BP1 opening. BP1 is equipped with a 4.5-inch thick shield door. During the ND experiment, the BP1 door is swung open so that an unattenuated radiation beam strikes the edge of the plate as it is rotated manually, in increments of a few degrees at approximately 2-minute intervals, through a 180-degree arc. The plate is

periodically removed for annealing or hardening. As is shown in Attachment 1, the orientation of the equipment and the counting station required personnel to pass through the attenuated beam to get to and manipulate the equipment. The NSC senior health physicist (SHP) understood that the ND experiment was initially only supposed to take approximately 1 or 2 weeks to complete. Several different TAMU radiation safety office (RSO) health physicists (HPs) were involved at various times with the experimenters.

The following factors (determined during the licensee's overexposure investigation) were used by the licensee and the NRC inspectors in evaluation of dosimetric data to determine if an overexposure of one or more of the experimenters had occurred.

- Total time in beam, most exposed experimenter: 7.1 minutes
- Percent of time in beam attributable to fourth-quarter exposure: 65 percent
- Beam transit factor (beam size, average beam intensity, and whole body movement through beam): 0.5
- Thermal neutron equivalent dose rate: 60 millirem per minute
- Neutron dose rates: 407-530 millirem per minute
- Gamma dose rates: 260-547 millirem per minute

c. Comparative Measurements

The NRC inspectors obtained both neutron and gamma radiation measurements. Attachment 2 contains a listing of the dosimetry and portable survey instruments used by the NRC and the licensee. All portable instruments were determined to be in proper calibration. Dosimetry use by the NRC in this comparison were supplied by two different vendors. Both vendors have successfully participated in the National Voluntary Laboratory Accreditation Program. One of the personnel dosimetry vendors also provides personnel dosimetry services to the NRC. Neither vendor was aware of the purpose of the dosimeters submitted to them for processing. Due to type of dosimetry provided by one vendor, it was necessary to inform the vendor that the dosimetry was exposed to a mixed radiation field (gamma and neutron).

The dosimeters were irradiated in the radiation beam from BP1 while attached to the front surface of a phantom, approximating the one referenced in American National Standard N13.11-1983, "Personnel Dosimetry Performance - Criteria for Testing." The phantom (approximately 40 X 40 centimeters square with a thickness of 15 centimeters) consisted of eight water filled plastic jugs with a

thin plastic plate for support of the dosimetry attached to the front of the phantom surface. Each dosimeter was placed on the phantom at the radiation beam's center. The beam's relative center point was determined by beam imaging on photographic film.

(1) Portable Radiation Survey Instrument Results

The NRC inspectors compared their portable gamma (geiger-mueller [GM] and ion chamber) and neutron (remmeter) dose rate measurement instruments to similar instruments used by the licensee. The licensee's portable instrumentation was similar to the NRC's with the exception of a GM instrument which the licensee did not include. A comparison of survey results for the NRC's GM (with a probe relatively small compared to the 6-inch diameter beam at the point of transit) and ion chamber (with a probe volume relatively large compared to the beam size) instruments showed that the GM instrument over responded by approximately 30 percent as expected. The NRC's neutron radiation measuring remmeter also showed that it under responded to the licensee's remmeter by a factor of approximately 3. Considering the different neutron calibration sources (moderated Californium and unmoderated Plutonium/Beryllium) used in calibrating the two instruments this is expected. Due to the design of both remmeters (spherical 9-inch diameter moderator and the relatively small detector within it), it is very difficult to ensure that the beam and detector are in alignment. Absolute dose rate results of both instruments would be suspected unless precision alignment of the remmeter detector to the beam center were assured.

The NRC inspectors determined that the licensee's documentation of the radiation levels associated with the beam in the early part of the ND experiments were adequate, even though marginal in detail, and provided sufficient information for the assessment of the radiological hazards associated with the beam. Apparent violation 128/8801-05 will not be included in the enforcement package being prepared for NRC Inspection Report 50-128/88-01 findings.

(2) Personnel Dosimeter Results

The NRC inspectors irradiated 15 personnel dosimeters at the point of transit of the experimenters and other personnel during the licensee's ND experiment. The licensee only irradiated three personnel dosimeters during this evaluation. The licensee had performed extensive dosimetry exposures involving the beam in March 1988. Attachment 3 compares the licensee's March 1988 dosimetry study results with the results obtained both by the licensee and the NRC during this study.

The NRC's dosimetry irradiation results favorably agreed with those reported by the licensee in their potential overexposure investigation report issued to the NRC and dated March 31, 1988.

Even though there existed a very high potential (dose rates of 50 Rem per hour combined gamma and neutron radiation without any attenuators in the beams path) for an individual to exceed the 10 CFR Part 20.101 exposure limits while conducting the ND experiment there is reason to believe that most of the in beam activities were conducted in such a fortuitous manner that exposure was minimized. The steel plate in the beam path effectively reduced (by a factor of 10) the dose rates to personnel passing through the beam (most personnel bent over during their passage through the general beam area), plate removals were conducted with the BP1 shielded door closed (the area in the immediate vicinity of the plate would still be approximately 750 millirem per hour), and personnel extremities and major body portions were maintained out of the beam path for the most part. Based on a lack of suitable dosimetry measurements for any participant in the ND studies, acceptance of the licensee's maximum gamma and neutron radiation dose rates (at the transit point), their time and motion studies of the person with the most transits of the beam, and their overexposure investigation, it is of the NRC inspectors opinion, based on all available facts, that the exposure limits of 10 CFR Part 20.101 were not likely exceeded. Therefore, apparent violation 128/8801-01 will not be included in the enforcement package being prepared for NRC Inspection Report 50-128/88-01 findings.

d. High Radiation Area Controls

The NRC inspectors reviewed the licensee's high radiation area controls that were purportedly in place during the licensee's ND experiment for compliance with the requirements of 10 CFR Part 20.203(c)(2). The licensee places primary reliance on procedures and the lead experimenter for controlling access to high radiation areas associated with their experiments. In addition, the licensee utilizes a system of warning lights, alarmed doors (annunciated in the reactor control room), loud speaker announcements, and random oversight by the HP staff to ensure high radiation areas are properly controlled. These controls are referred to as C-2 controls. Interviews with personnel associated with the ND experiment and the review of reactor plant operating logs indicated that the licensee's control over the high radiation area associated with the ND experiment did not meet the requirements of 10 CFR Part 20.203(c)(2).

Inadequacies in the licensee's high radiation area controls for BP1 and the ND experiment are.

- Personnel not associated with the ND experiment at BP1 were allowed to transit the high radiation beam area (approximately 5 Rem per hour) on the authority of student experimenters that had little if any knowledge of the beam's radiological hazards.

- The lead experimenter did not ensure that associate experimenters (four) were aware of their responsibilities regarding control of the high radiation area when he left them in charge of the experiment. The experimenters, collectively, were not provided sufficient information on high radiation area controls and the maintenance of them.

- During the early part of the ND experiment (August 19-31, 1987), the area adjacent to BP1 was left unattended (with BP1 shielded door closed) for various periods of time (total of 4 hours) with no apparent high radiation area demarkation in effect and with accessible whole body radiation (neutron and gamma) dose rates in the general area of BP1 exceeding 5 Rem per hour. On August 31, 1987, a temporary enclosure (5-foot high wire fence) was placed on each side of BP1 to enclose/isolate the ND experiment/equipment area. This fenced enclosure was posted as a high radiation area but the two access gates were not locked or alarmed. The fence is depicted in Attachment 1. Permanently installed C-2 warning lights and intrusion alarms were located at the normal accesses to the NSC lower level. Following installation of the fenced enclosure (between August 31 and September 8, 1987), the area was again left unattended, during approximately 21 hours of reactor operations, with radiation dose rates external to BP1 exceeding 5 Rem per hour. Portable shielding (paraffin blocks) for BP1 were not evaluated and required to be used until approximately September 8, 1987. This shielding, when used with BP1 door closed, reduced the general area radiation dose rates to below 100 millirem per hour. Statements from licensee personnel indicate that on one or more occasions following the implementation of the portable shielding radiation dose rates were found to be abnormally high (greater than 100 millirem per hour) in the immediate area of BP1. These high dose rates were created when personnel left the portable shielding out of the void between the beam tube end and the BP1 door when securing the experiment and closing the BP1 door.

- Reactor operators routinely relocated (by electrical switching) the C-2 alarms and warning lights from the lower level stair well entrance door (outer perimeter of the reactor containment building), inward to the alarms situated on the individual beam port doors. The licensee could not produce any records showing that radiation surveys were performed verifying that the radiation dose rates in the area adjacent to BP1 were less than

100 millirem per hour prior to reduction of the C-2 high radiation area controls. The licensee frequently conducts off-hours reactor operations without onsite HP coverage.

- The licensee's standing procedures for extraction of radiation from reactor beam tubes/ports (Experiment Authorization No. E-3 and 11-1) reference the need to provide shielding, personnel access control, and reduction of radiation dose rates to levels specified by the RSO. Neither the primary experimenter nor the SHP were fully familiar with these procedures or radiological hazards associated with beam port operations. Positive controls over reduction of dose rates external of BP1 were not fully implemented until approximately November 30, 1987.

The NRC inspectors confirmed the finding of NRC Inspection Report 50-128/88-01 in that the licensee failed to properly implement adequate high radiation area controls or implement standing procedures associated with the extraction of radiation from reactor BP1. The licensee's reliance on the primary experimenter was found to be inadequate, since the primary experimenter was not always in control of the ND experiment activities at BP1, especially during times that no ND experiment work was being accomplished at BP1 and dose rates in the area adjacent to BP1 were above 100 millirem per hour. The licensee also failed to implement positive controls that would insure personnel were not inadvertently exposed to high levels of radiation during these periods. A possible root cause of this incident is the lack of a committee type review of beam port experiments. The lack of experience on the part of the experimenters and the RSO HPs compounded the initial failings of inadequate experiment review. The NRC inspectors noted that the basement area of the facility is normally not a high traffic area but is routinely accessed by experimenters and staff personnel.

3. Briefing of Workers on Radiological Hazards

The NRC inspectors conducted interviews with selected licensee employees and student experimenters involved in the ND experiment during August through December 1987. The NRC inspectors reviewed the licensee's 10 CFR Part 19.12 required training and indoctrination of workers.

10 CFR Part 19.12 requires that all individuals working in or frequenting any portion of a restricted area shall be kept informed of the storage, transfer, or use of radioactive materials or of radiation in such portions of the restricted areas. These instructions are required to include procedures to minimize exposure and the purpose and functions of protective devices employed.

The NRC inspectors determined on April 12, 1988, that due to the significant degree in the lack of specific knowledge (concerning the radiological hazards associated with the ND experiment beam) possessed by the personnel involved, the licensee had not adequately briefed or kept

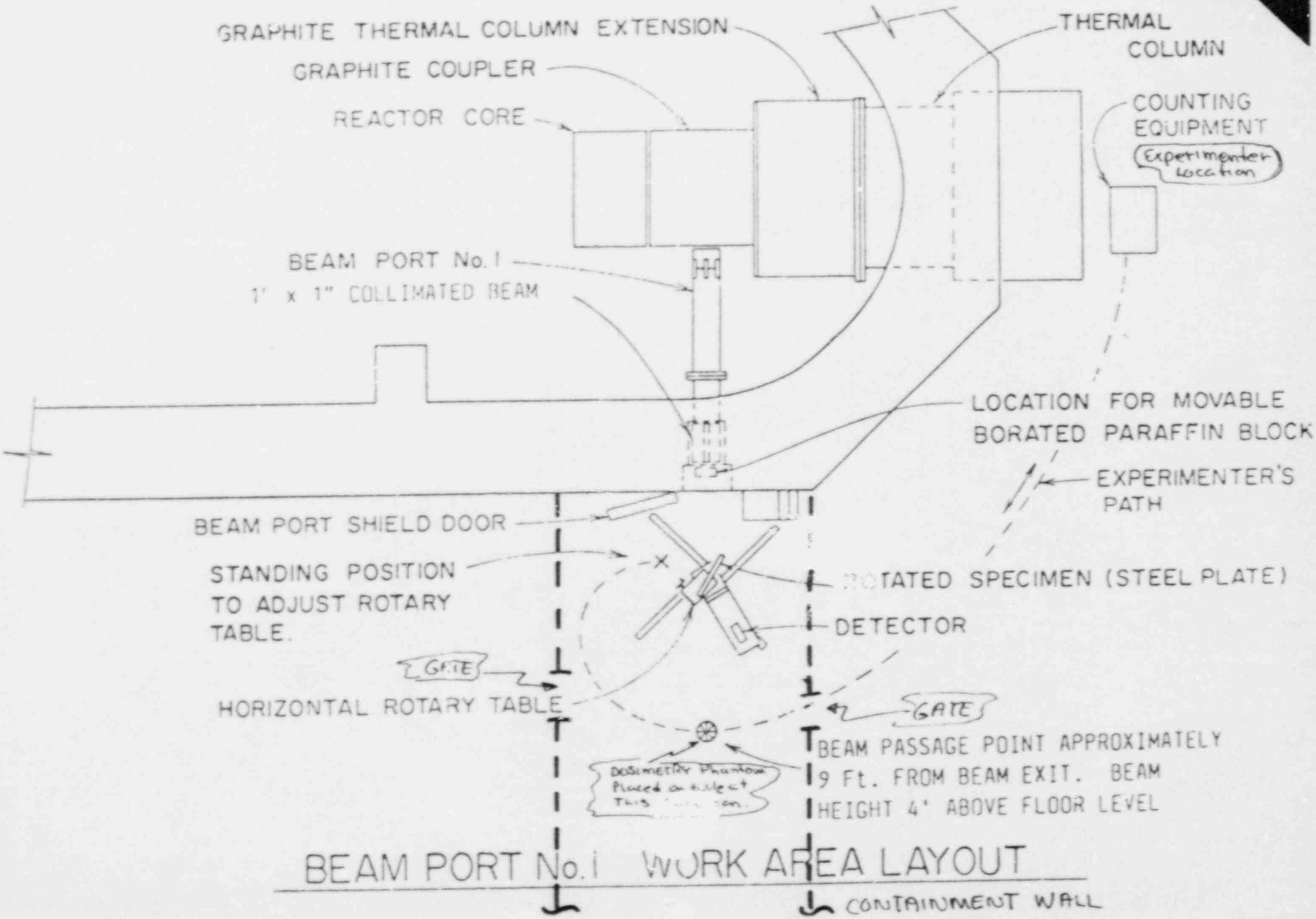
all personnel informed of the radiological hazards associated with the ND experiment. Additionally, these personnel were not properly informed as to the location that personal dosimetry was to be worn to ensure that accurate personnel whole body monitoring was accomplished. At the time of this inspection, at least two experimenters were not aware of their exposure or the significance of their passing through the radiation beam from BP1 during their portion of the ND experiment. Due to the lack of frequent HP oversight, the experimenters used, on their own volition, available portable dose rate measuring instrumentation in an attempt to evaluate the general area radiation dose rates.

The failure to provide adequate information to personnel concerning the radiological hazards associated with the ND experiment at BP1 is considered an apparent violation of the requirements of 10 CFR Part 19.12. (128/8803-01)

4. Exit Interview

The NRC inspectors met with the licensee representatives identified in paragraph 1 of this report at the conclusion of the inspection on April 12, 1988. The NRC inspectors summarized the scope and the inspection findings. Subsequent to the exit interview on April 15, 1988, the NRC confirmed, via a telephone conversation with the licensee, that (a) the NSC will establish the necessary procedures to ensure that proper preplanning is conducted before experiments/work activities begin, and that personnel have a clear understanding of the scope of the work and the proper radiological controls to be implemented; and (b) NSC HP personnel will perform periodic reviews of ongoing work activities to ensure proper radiological controls are being followed. A Confirmatory Action Letter (88-03A) was issued to the licensee on April 20, 1988, confirming the above matters.

ATTACHMENT 1



BEAM PORT No. 1 WORK AREA LAYOUT

ATTACHMENT 2

INVENTORY OF PORTABLE RADIATION MONITORING
AND
PERSONNEL DOSIMETRY

NRC Equipment:

Number and Manufacturer	Model	Type	Detector	Range
(2) Xetex	305B	Beta/gamma	GM	.1mr/hr to 99.9R/hr
(1) Eberline	R02A	Beta/gamma	IC	.2mrem/hr to 50 Rem/hr
(1) Eberline	PRS-2P/ NRD	Neutron	BF_3+	.2mrem/hr to 20 Rem/hr

(6) TL-100 beta/gamma/thermal neutron personnel dosimeters
(6) Hankins Albedo type gamma/neutron dosimeters (TL-600/700)
(3) TL-100 beta/gamma personnel dosimeters

TAMU Equipment:

Manufacture	Model	Type	Detector	Range
N. Wood/Ludlum	1237/16	Neutron	BF_3(9)	.2mrem/hr to 240,000 cpm
Radector	III	Beta/gamma	IC	.1mrem/hr to 100 KRem/hr*

(3) TL-100 beta/gamma personnel dosimeters

Legend: GM - Geiger-mueller tube (thin walled, halogen quenched)
IC - Ion Chamber
BF_3+ - Borontrifluoride tube inside a 9-inch cadmium loaded polyethylene sphere (with a Rascal PRS2 control unit)
BF_3(9) - Borontrifluoride tube inside a 9-inch cadmium loaded polyethylene sphere (with a modified Ludlum 16 control unit)
TL - Thermoluminescent
* - The licensee limits this instrument's use to 100 Rem/hr due to calibration limitations.

ATTACHMENT 3

DOSIMETRY MEASUREMENT RESULTS

Date and time of measurements: April 11, 1987, 11:30 a.m. to 3:30 p.m.

Location: Texas A&M University Nuclear Science Center, Beam Port #1

Reactor Status: Operating in the reactor pool thermal column stall position at 1 megawatt power level.

Background: A dosimetry phantom approximating the type referenced in ANSI 13.11 was created from thin plastic jugs filled with drinking water. This phantom was placed approximately 109 inches ± .10 inches from the face of beam port #1 door, which approximates the location that personnel transitted during the August to December 1987 neutron diffraction experiments. The center of the phantom was located approxiamtely 48 inches above the floor, which is the height of the radiation beam emanating from beam port #1 (BP1). The dosimeter irradiations were performed without any attenuators in the beam and with a 3/4-inch thick steel plate in the beam. Dosimetry was placed at 48, 50, and 52 inches high on the phantom's vertical center line. All dosimeters were aligned faced forward except one which was aligned so the beam struck it from a side edge. This orientation would represent the orientation of the badge when attached to shirt pocket with its holding device.

TAMU results include measurements performed in March 1988 and reported to the NRC as part of a potential overexposure investigation performed by TAMU Radiation Safety Office.

The licensee had determined that the fluence rate of thermal neutron component of the radiation beam from BP1 was 1.3E6 neutron per square centimeter per second.

A. (Position and Attenuator) - 48 inches high and no plate

Method of Measurement	Date	Type Radiation	TAMU (Rem per hour)	NRC (Rem per hour)
TLD (TL-100)	(3/88)	Gamma/neutron*	450	---
TLD (TL-100)	(4/88)	Gamma/neutron*	458	414
TLD (TL-100)	(4/88)	Gamma/neutron*	---	405
Albedo TLD	(3/88)	Neutron (e/f)	32	---
Albedo TLD	(4/88)	Neutron (e/f)	---	24
Film	(3/88)	Gamma	16	---
Albedo TLD	(4/88)	Gamma	---	33

B. 48 inches high with plate in beam.

TL-100	(4/88)	Gamma/neutron*	24	25
TL-100	(4/88)	Gamma/neutron*	---	18
Albedo TLD	(4/88)	Neutron	---	2.5
Albedo TLD	(4/88)	Gamma	---	3.0
TL-100 (on edge)	(4/88)	Gamma/neutron*	---	8.2

Method of Measurement	Date	Type Radiation	TAMU (Rem per hour)	NRC (Rem per hour)
C. 50 inches high with plate in beam.				
TL-100	(4/88)	Gamma/neutron*	17	12
Albedo TLD	(4/88)	Gamma	---	1.7
Albedo TLD	(4/88)	Neutron	---	1.7
D. 52 inches high with plate in beam.				
TL-100	(4/88)	Gamma/neutron*	---	1.5
Albedo TLD	(4/88)	Gamma	---	.23
Albedo TLD	(4/88)	Neutron	---	.44

*TL-100 when exposed to a mixed field of gamma and thermal neutron radiation will exhibit a significant overresponse when evaluated for gamma equivalent dose during processing. These values are used for relative accuracy determination of only.

e/f = epithermal and fast