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PORTER-GERTZ CONSULTANTS, INC.

TECHNICAL REPORT - 175

DOSE ASSESSMENT FROM THE AUGUST 28, 1979 ENTRY INTO THE TMI UNIT II FUEL HANDLING BUILDING NORTH MAKE-UP VALVE ROOM

November 30, 1979

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DOSE ASSESSMENT FROM THE AUG. 28, 1979 ENTRY INTO THE TMI UNIT II FUEL HANDLING BLDG. NORTH MAKE-UP VALVE ROOM

ABSTRACT AND SUMMARY TABLE

This report describes the work performed to assess the doses received by the six persons who entered the Three Mile Island Nuclear Generating Station Unit II North Make-Up valve room on August 28, 1979 to repair leaks in the packings of some of the valves in the room. All of them wore multiple personnel monitors (TLD badges and self-reading dosimeters in various combinations and distributions over the body).

The TLD badges worn by the workers indicated far higher beta readings than had been expected on the basis of the gamma survey performed with a "Teletector" survey instrument prior to commencement of the repair work. This procedure has been changed to require beta surveys prior to all Unit II radiation work in areas where any appreciable beta fields may be expected to exist.

The reportable overexposures,as per 10 CFR Part 20, resulting from the valve room entry are presented below. As indicated, there were two reportable cases of extremity overexposures and six reportable cases of skin of the whole body overexposures. All of the overexposures were due to nonpenetrating, or beta, radiation, and are therefore to be considered as overexposures to the skin.

In order to perform the dose assessments, extensive studies, both theoretical and experimental, were performed to evaluate the response of the TLD badges to mixed beta fields from the primary coolant. Some of the results of this work are presented in this report, but additional details will be presented in a separate technical report dealing with the problem of personnel monitoring for beta exposures using TLD badges. Comprehensive interviews,detailed mock-ups, and TLD irradiations in the Make-Up valve room were also undertaken in an effort to obtain information on the field distribution in the valve room, and also to obtain details on the clothing and personnel monitoring equipment worn by the workers during the valve room entry. Our standard primary coolant beta source was calibrated by NBS.

The table below gives a summary of the overexposures. The doses are to be considered as skin doses. The units are in rads.

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Summary of Radiation Overexposures Recieved by TMI Workers During the August 28, 1979 Entry into the Unit II Fuel Handling Building North Make-Up Valve Room

WORKER	Organ Overexposed	Dose (rads) August 28, 1979		Dose (rads) Rest Third Quarter, 1979		Total For Third Quarter(rads)
		Beta	Gamma	Beta	Gamma	Beta Plus Gamma
H.P. Foreman A	Skin (both legs)	39	0.6	0.3	0.35	40
Aux. Operator C	Skin (left leg)	25	1.0	0.0	0.2	26
Aux. Operator D	Skin (left leg)	12	0.8	0.0	0.4	13
Aux. Operator E	Skin (right leg)	28	0.8	0.0	0.03	29
Aux. Operator I	Skin (right leg)	165	0.8	0.0	0.26	166
	Skin (left hand)	81	0.8	0.0	0.26	82
Aux. Operator J	Skin (right leg)	160	0.5	0.0	0.3	161
	Skin (left hand)	37	0.5	0.0	0.3	38

Note : Doses to the skin of the legs are considered doses to the skin of the whole body and are therefore subject to the quarterly limit of 7.5 rads. Doses to the hands are considered to be extremity doses and are therefore subject to the quarterly limit of 18.75 rads. The relative standard deviations on the total doses are 15%.

DOSE ASSESSMENT FROM THE AUGUST 28, 1979 ENTRY INTO THE
TMI UNIT II FUEL HANDLING BUILDING NORTH MAKE-UP VALVE ROOM

A. - INTRODUCTION

On August 28, 1979, six persons made individual entries into the North Make-Up Valve Room to evaluate and repair leaks from some of the valve gaskets. Preliminary surveys, using a survey meter, indicated a gamma field of 10-15 R/hr in the room and around the piping and valves. All individuals involved, except the H.P. Foreman, wore multiple TLDs and/or one or more self-reading dosimeters. The H.P. Foreman wore one TLD and two self-reading dosimeters.

The TLDs were subsequently read out and some of them indicated doses received that appeared to be above the allowable limits, particularly the beta doses, or as it is sometimes referred to, doses due to non-penetrating radiation. Based on these high readings, a dose assessment study was initiated to determine the extent of overexposure, if any, to each individual.

B. - AVAILABLE DATA

The data on which the dose assessment was based is presented in the Tables attached. Table (1) shows the initially reported TLD readings for each of the individuals, together with the staytimes in the valve room. The protective clothing worn by each individual is shown in Figure (1), and the total thickness of clothing is summarized in Figure (2). In this figure the clothing thickness over each part of the body is shown on the left hand diagram in units of mg/cm^2. The right hand diagram shows the thickness of clothing that was worn under each TLD in units of mg/cm^2, where applicable. The clothing thicknesses used to calculate these numbers are shown in Figure (3).

Summaries of interviews conducted with each individual are given in the Appendix. These interviews were conducted in order to determine and supplement

information on number and types of clothing worn, number of TLDs and self-readers used, clothing under the TLDs, and type and location of work performed. Also given in the Appendix are copies of the calibration certificates for the "Teletector" survey instrument used in making the surveys in the valve room. One of the calibrations shown was performed 36 days before the August 28, 1979 valve room entry and the other was performed 14 days after the entry.* The normal calibration interval for this type of instrument is three months. A floor plan and elevation view of the Make-Up Valve Room is included with the interviews to assist in visualizing the events described.

O. - PRELIMINARY TECHNICAL CONSIDERATIONS

The TLD badges worn by the individuals into the Make-Up Valve Room are the standard two-chip Harshaw badges. The two chips are sealed between two teflon sheets and mounted on a TLD card which fits into the badge. Each of the teflon sheets is 16 mg/cm^2 thick. The chips are extruded lithium fluoride of a thickness of 0.035 inch. Based on a density of 2.64 mg/cm^3 for LiF, the chip thickness is 234 mg/cm^2. The card utilized two Harshaw 700 chips.

When placed in the badge, the TLD card positions one chip, which shall be referred to as the beta chip, behind an open window (or collimator). The opening is covered on the outside of the badge by a paper name plate about 16 mg/cm^2 thick making the total material covering the beta chip 32 mg/cm^2. The second chip, which shall be referred to as the gamma chip, is positioned behind an aluminum filter of 230 mg/cm^2 nominal thickness. Adding the thickness of the paper name plate brings the total up to about 245 mg/cm^2.

Examination of the TLD readings and of the radioisotopic analysis of the primary coolant indicated that the beta fields from the coolant contained components sufficiently energetic to penetrate the gamma chip filter and contribute to the reading of that chip. Table (2) shows the results of an analysis of the primary coolant performed on September 10, 1979 by Babcock and Wilcox. The sample was representative since it was taken on August 29, 1979. Also shown are the yields, endpoint energies, and maximum ranges of the beta emissions.

Suggestions were put forward that the two TLD chips in the badge should be referred to as chips recording penetrating and non-penetrating radiation rather than gamma and beta radiation respectively. Although there is some merit in this usage, it was felt that the distinction based on type of radiation rather than penetrating ability is more fundamental, especially since the two types of radiation are attenuated by different mechanisms and, therefore, follow different attenuation laws. Of course, a borderline area is encountered at very low photon energies where it becomes difficult to separate the photon and beta radiations. However, at such low photon energies it is usually not important to separate the effects of the two types of radiation, and the purposes of radiation protection and dose assessment are probably adequately served by treating very low energy photons as betas of the same energy and treating the higher energy photons as gamma rays. It was decided that attempting to correct the gamma chip readings for beta penetration through the filter would be very difficult and the results

*See comments and qualifications in Appendix III.

would contain too much uncertainty to be of use in dose assessment. The gamma chip readings were therefore not used in this study. Gamma dose estimation is described in the next section, followed by a discussion of beta dose estimation.

D. - EVALUATION OF THE GAMMA DOSES

As mentioned in the last section, the TLD gamma chip readings were not used in gamma dose assessment because of probable interference from beta rays penetrating the filter in front of the chip. The gamma dose rates obtained from the TLD readings were not consistent and showed large variations by as much as a factor of 16 for the chest TLDs. Of course, such variations could have been due to a non-uniform field in the room, but other data to be presented shortly does not support this possibility. Also, an experiment performed using the primary coolant as a source showed that at an absorber thickness of 245 mg/cm^2 the response of the TLD corrected for gamma contribution drops by less than 90% compared to the unshielded response. The large variations in gamma dose rate could be explained by assuming varying degrees of beta penetration depending upon the orientation of the badge with respect to the source. An angular orientation increases the effective shield thickness and reduces beta penetration.

The gamma dose estimates are based on the survey performed prior to commencement of work in the Make-Up Valve Room. The survey was performed using a "Teletector" survey meter (calibration certificates presented in the Appendix). This survey indicated a uniform gamma field of 10 R/hr. throughout most of the room, rising to 15 R/hr. close to the floor and to the leaking MU-V-155. A hot spot of 25 R/hr. was found at one point on the floor. Supporting evidence for these field values were obtained from the self-reading dosimeters worn by the individuals who entered the Make-Up Valve Room. Table (3) gives the readings of these dosimeters, the staytimes, and the exposure rates based on the readings and staytimes. It should be noted at this point that the self-readers probably respond to beta fields to some extent because the chamber walls are not thick enough to stop the higher energy betas (thickness of about 350 to 400 mg/cm^2). Therefore, the exposure rates shown in Table (3) probably contain some beta contributions. On the other hand, the staytimes include walking from the point of entry to the work area and back. The vicinity around the point of entry is a low field area and the walk back to the point of entry involves some shielding of the self-readers by the body, which, in this configuration is between the source (pipes and valves) and the dosimeter. These effects are comparatively small, however, since the total entrance and exit times are estimated to make up about 7% of the total staytime.

The above considerations and data indicate that the use of 10 R/hr. for the gamma field above about waist level and 15 R/hr. below that level is probably a good estimate of the existing field, if not a conservative one. The gamma dose to each individual is based on these values together with the estimated staytimes.

E. - BETA DOSE ESTIMATION

After correcting the beta chip reading for gamma contribution, as calculated above, the dose obtained is equal to the average beta dose over the thickness of the chip. Since it is necessary to obtain the entrance dose rather than the average

dose, a factor is used to multiply this average to convert it to an entra
In view of the fact that the source of beta radiation in the Make-Up Valv
is made up of a mixture of beta emitters, the conversion factor, which wi
referred to as the beta Sensitivity Index, SI, will depend on the relativ
concentration of the beta emitters. The index will therefore be time dep
because the beta emitters have widely differing half-lives. Also, since
beta endpoint energies are quite different for the different emitters, it
be expected that the characteristics of the composite beta spectrum would
with depth of penetration into an absorber. This results in the Sensitiv
Index being a function of depth at which the dose is evaluated. (Referenc

It was mentioned in a previous section that the TLD badges used du
entry into the Make-Up Valve Room were worn under a variety of protective
thicknesses, and in some cases there was also some clothing worn under th
This means that different badges would require different sensitivity indi
estimate the beta entrance dose to the skin. In view of the fact that th
experimental equipment was not available to make measurements to determin
required index values, it was decided to calculate them. The Lovinger eq
for a thin infinite planar source was chosen for evaluating the depth dos
Sensitivity Index is defined as,

$$SI = \frac{D(e)}{\bar{D}}$$

where $D(e)$ = entrance dose

$$\bar{D} = \frac{1}{\Delta x} \int_{x_1}^{x_2} D(x)dx$$

$$\Delta x = x_2 - x_1$$

$D(x)$ is the depth dose function given by the Lovinger equation. x_1 and x
the entrance and exit coordinates of the TLD chip with respect to x, the
for the entrance dose. Since the chip is covered by a total of 32 mg/cm^2
the limits of integration would be,

$$x_1 = x + 25$$

$$x_2 = x_1 + 234$$

The 25 number in the first equation is 32 minus 7 mg/cm^2 represent
skin epidermis. Thus, if the TLD is not covered by any protective clothi
Sensitivity Index for 7 mg/cm^2 thickness is used. 32 is the thickness of
covering the beta chip.

In order to determine the extent of the validity of this method, a
experiment was performed in which the response of the TLD chip was measur
a function of absorber thickness. Aluminum absorbers were used and the s
was made by depositing a matrix of primary coolant drops onto a steel pla
5" x 7" in size. The TLD card was irradiated outside the badge and was h
place 6" above the source by a suitable jig which was designed to also ho

the absorbers. The dose rate at the chip location was measured at about 1500 mrad/hr. at the time the source was made.

The results of the experiment are shown in Figure (4) together with a plot of the calculated mean dose at various depths. It is evident from the figure that the agreement is quite good. It was also possible to measure one value of the Sensitivity Index. A TLD reading was made with no absorber and the dose rate at the TLD position was measured using an extrapolation chamber. This latter measurement gives an entrance dose rate and when divided by the TLD rate, the result is the Sensitivity Index.

The index was calculated for the same conditions as those in the measurement. The measured value was 3.6 and the calculated value 4.5. The standard deviation of the measured value is estimated to be between 15-20% and hence the difference between the calculated and measured values is not significant at the 90% confidence level.

Curves showing the variation of SI with absorber thickness are shown in Figure (5) for Sr-89, Y-90, and the coolant mix corrected in composition to the day of the Make-Up Valve Room entry.

Based on the above results, the procedure used for beta dose calculation was the following. For each TLD, the reading was attenuated to allow for clothing worn between the TLD and the skin using the curve in Figure (4). The Sensitivity Index was next determined using the curve for the coolant shown in Figure (5), at the point corresponding to the total clothing thickness worn at the TLD site. Finally, the dose is obtained by multiplying the TLD reading by the Sensitivity Index. This was repeated for all the TLDs worn into the Make-Up Valve Room.

The results of this procedure are shown in Table (4) which gives the estimated gamma and beta doses to each of the individuals who entered the Make-Up Valve Room on August 28, 1979. Since only a limited number of dosimeters were worn by any individual, some doses, at locations not covered by dosimeters, had to be estimated. The bases for these estimates in each case are given in Table (5). Appropriate adjustments were made in each case for differences in clothing over and under the TLDs. It should be noted in this connection that the choice of the most appropriate TLD to use for estimating the dose to an organ not covered by a TLD was aided by a series or re-enactments of the work done in the Make-Up Valve Room. These were done by the operators themselves using a mock-up of the room and piping. Photographs illustrating this phase of the analysis are presented in the Appendix.

In the case of the gonadal doses, a tissue thickness of 300 mg/cm^2 was used between the surface of the gonad and the seminiferous tubes (as per medical consultant's letter to that effect in the Appendix). The gonadal dose was obtained by averaging the dose from that depth into the gonad up to the maximum beta range in the gonad.

F. - ESTIMATION OF STATISTICAL UNCERTAINTY

The gamma doses were obtained on the basis of "Teletector" surveys. Since the instrument was certified to have been in proper calibration before and after * the August 28, 1979 entry, the systematic errors in the readings are relatively small. The random errors are estimated to be less than 10%.

*See comments and qualifications in Appendix III

Experimental measurements on a series of TLDs showed that, in the lower beta dose ranges shown on the badges worn into the Make-Up Valve Room, the random errors in the chip readings are on the order of 4-5%; therefore, 5% is used for the relative standard deviation of the beta chip reading.

The beta dose is calculated using the formula,

$$D = (B - G) A \times F$$

where, D = beta dose
B = reading of TLD chip (open chip)
G = gamma dose as calculated in section E
A = attenuation factor to allow for protective clothing
F = beta sensitivity index

An uncertainty of 10% is assigned to A and 10% to F. These numbers are based on preliminary sensitivity studies of the two factors.

Based on the above considerations, the uncertainty in the beta dose is estimated to be 15%.

G. DISCUSSION and CONCLUSIONS

1. Basic Assumptions : the basic assumptions used in arriving at the doses to the workers considered in this report were that the survey performed on initial entry using a survey meter adequately mapped the gamma field, that the beta TLD chip registered a quantity that is proportional to the skin entrance dose, and that the beta field energy spectrum in the Make-Up Valve Room is closely represented by the field from the isotope mix found in the sample of primary coolant on August 29, 1979, one day after entry into the valve room.

The first assumption appears to be adequately confirmed by the self-reading dosimeters worn by the workers, and is probably also on the conservative side. The self-readers did not, in any case, show a gamma field greater than 15 R/hr In two cases, however, the dosimeters appeared to have reached their maximum dose reading which in these two cases give dose rates of 15 R/hr. and 10 R/hr. Unfortunately these two cases involved self-readers attached to the wrists and the closest TLD chips were beta ring badges; therefore no gamma chip reading is available close to the self-readers. The closest gamma chips in both cases were in the chest badges. In the apparently worse of the two cases mentioned above, the chest TLD gave 1.05 rads gamma and 52.37 beta. Based on the attenuation curve shown in figure (4), the beta dose after passage through the gamma filter is about 12% of the unfiltered beta dose. Applying this factor to the beta chip readings and then subtracting from the gamma reading gives a gamma dose rate of about 18 R/hr. Thus the dose rate actually used, namely 15 R/hr., is not much in error if the 18 R/hr figure is accepted as exact, which it should not be since the correction for beta interference is only approximate.

The assumption that the beta chip gives a reading proportional to the entrance dose to the skin and that the proportionality factor is obtainable analytically or experimentally is valid only if it is assumed that the collimation provided by the TLD badge does not materially affect the chip reading or, if it does, it affects it in a constant and predictable way. This is probably never entirely true, but it is a fairly good approximation for a diffuse field (i.e. not a directional beam). Based on experimental irradiations in the Make-Up Valve Room, the field does appear to have been diffuse, and on this basis no corrections were made for possible badge collimation effects. It must, nevertheless,be pointed out that some small effect is inevitable and that the effect is in the direction of underestimating the dose received.

The assumption that the beta energy spectrum from the coolant is similar to that existing in the Make-Up Valve Room forms the basis of the calculation of the beta sensitivity index, the factor used to convert the beta chip reading to skin entrance dose. Survey TLD exposures in the Make-Up Valve Room, after the August 28, 1979 entry,did not yield any conclusive information on the energy spectrum of the beta field,and relatively more sophisticted measurements were needed to map the energy distribution of the field. However, it was decided that the benefits to be gained from such an effort did not justify the risk of additional personnel overexposures. Also, even if such measurements were made it would still have been necessary to assume that the field had not changed after completion of the repair work. This may not have been a valid assumption because the repairs stopped the leaking of primary coolant into the room. Preliminary calculations also indicated that the bremsstrahlung fields that may have been generated by the beta emitters probably did not make a significant contribution to the doses received. In view of these considerations, the assumption made above regarding the beta energy distribution appeared to be the most reasonable.

2. Future Personnel Monitoring : based on the experience gained from the Make-Up Valve Room entry and the subsequent dose assessment studies, important changes are planned in the area of personnel monitoring and radiation field surveys.

It became evident from the studies made in connection with the dose assessment that survey instruments are not handled with the care necessary in utilizing measuring instruments of this kind. The limitations of the instruments in terms of their ability to measure radiation fields of different qualities also do not appear to be widely understood and the response curves are not readily available for inspection by the users. This is especially true in the case of beta surveys which, under the best of conditions, are difficult undertakings to perform and correctly interpret. Educational programs are needed as well as stricter accountability for the proper upkeep of survey instruments.

A search has been initiated for beta survey instruments with a sufficiently high dose rate range to permit surveys prior to any work in potentially high radiation areas. Preliminary findings indicate that very few commercially available instruments have a high enough range for the required application. Serious problems are anticipated in the calibration and response

characterization of any instrument selected. The reason is that there are few well calibrated high intensity beta sources available covering the required energy range.

The study also indicated that the response of the TLD badge to the fields from the primary coolant from TMI Unit II is not adequately understood and quantified. Therefore, further experimental and theoretical work is underway to correct this situation and to re-design the TLD badge to a form more suitable for use in mixed gamma/high-energy beta fields.

3. Further Reports : it is anticipated that the technical findings resulting from implementation of the above recommendations will be presented in further reports.

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TABLE (1)

Early Reported TLD Readings (9/29/79) and Staytimes In The Valve Room For Each Of The Individuals Involved On 9/28/79

WORKER	DOSES REGISTERED BY TLDs, RADS							
	Left Hand	Right Hand	Chest	Left Knee	Right Knee	Left Foot	Right Foot	Staytimes,Min.
A	-	-	0.55 γ 15.89 β	-	-	-	-	2.5
C	3.1 β	8.4 β	0.27 γ 3.4 β	-	-	1.74 γ 38.6 β	0.8 γ 7.2 β	3.8
D	7.0 β	2.4 β	0.42 γ 1.72 β	-	-	1.36 γ 10.58 β	0.79 γ 7.51 β	3.0
E	2.0 β	0.85β	0.26 γ 8.58 β	-	-	0.41 γ 5.02 β	0.59 γ 8.59 β	3.25
I	40 β	27 β	1.05 γ 52.37 β	4.47 γ 119 β	6.69 γ 149 β	-	-	3.0
J	18 β	3 β	0.43 γ 4.92 β	3 γ 67.28 β	6.16 γ 143.66 β	-	-	2.0

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TABLE (2)

Radioisotopic Composition of the Primary Coolant
On September 10, 1979 and the Associated Beta
Yields, Energies, and Ranges

ISOTOPE	ACTIVITY µCi/ml	BETA ENDPOINT MeV*	YIELD %	MAXIMUM RANGE mg/cm^2
Sr-89	171	1.463	100	660*
Sr-90	27	0.546	100	185
Y-90	27	2.284	100	1100*
Cs-134	15	0.662	71	240
		0.410	1	125
		0.089	28	10
Cs-137	73	1.176	6	505*
		0.514	94	170
Ba-140	0.15	1.020	62	420
		0.830	4	325
		0.590	10	205
		0.460	24	145
La-140	0.15	2.164	8	1030*
		1.680	18	775*
		1.365	46	605*
		1.150	19	490*
		0.857	4	340
		0.510	5	170

* Maximum range exceeds gamma chip filter thickness

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TABLE (3)

Dose Indications on Self-Reading Dosimeters Worn
By Individuals Entering the North Make-UP Valve Room

INDIVIDUAL CODE	POSITION OF DOSIMETER	READING mR	STAYTIME Minutes	EXPOSURE RATE R/hr
A	Chest	265	2.5	6.4
	Wrist	300	2.5	7.2
C	Chest	250	3.8	4.0
	Wrist	350	3.8	5.5
D	Chest	180	3.0	3.6
	Wrist	425	3.0	8.5
E	Chest	175	3.25	3.2
	Wrist	350	3.25	6.5
I	Chest	650	3.0	13
	Wrist	>500	3.0	>10
J	Chest	410	2.0	12.3
	Wrist	>500	2.0	>15

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TABLE (4)

DOSES TO UNIT II WORKERS FROM MAKE-UP VALVE ROOM FIELDS

WORKER		H.P. Foreman A	Aux. Operator C	Aux. Operator D	Aux. Operator E	Aux. Operator I	Aux. Operator J	
Left Hand	γ	0.6	0.6	0.5	0.5	0.8	0.5	
	β	7	6.7	12	5	81	37	
Right Hand	γ	0.6	0.6	0.5	0.5	0.8	0.5	
	β	7	15	4.1	2.1	55	6.1	
Chest	γ	0.6	0.6	0.5	0.5	0.8	0.5	
	β	12	2.5	1.2	6.4	51	32	
Eyes	γ	0.6	0.6	0.5	0.5	0.8	0.5	
	β	0	0	0	0	0.1	0.1	
Left Leg	γ	0.6	1.0	0.8	0.8	0.8	0.5	
	β	39	25	12	3.2	128	74	
Right Leg	γ	0.6	1.0	0.8	0.8	0.8	0.5	
	β	39	4	7.1	28	165	160	
*Left Foot	γ	0.6	1.0	0.8	0.8	0.8	0.5	
	β	3.6	5.1	1.5	0.4	13	7.4	
*Right Foot	γ	0.6	1.0	0.8	0.8	0.8	0.5	
	β	3.6	0.8	0.8	3.3	16	16	
Gonads	γ	0.6	1.0	0.8	0.8	0.8	0.5	
	β	0.4	0.3	0.1	0.3	1.5	1.4	

Doses in Rads

Beta doses are skin doses except for Gonad & Eye Beta dose.

*Beta dose is dose to skin of ankles since all operators wore street shoes in addition to protective clothing.

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TABLE (5)

Locations of TLDs Used to Estimate Doses To
Organs Not Covered By a Dosimeter

ORGAN	Location of TLD On Which Dose Is Based					
	A.	C	D	E	I	J
Eye	Chest	Chest	Chest	Chest	Knee	Knee
Gonads	Knee	Knee	Knee	---	L. Knee	L. Knee
Left Foot	Knee	---	---	---	R. Knee	R. Knee
Right Foot	L. Foot	---	---	L. Foot	---	---
Left Leg	Average L. Knee (I)&(J)	L. Foot	L. Foot	R. Foot	---	---
Right Leg	L. Leg	R. Foot	R. Foot	---	---	---
Left Hand	Chest	---	---	---	---	---
Right Hand	L. Hand	---	---	---	---	---

(1) The chest TLD of Operator (I) was used because there are some indications that the chest TLD of Operator (J) was shielded by his respirator.

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FIGURE (1)

Protective Clothing Worn by Individuals
Entering the Make-Up Valve Room

__H.P. Foreman A

Head:	SCBA, stocking cap, cloth hood
Hands:	1 pair cotton gloves, 1 pair surgical gloves
Whole Body:	1 pair shorts, 1 pair cotton coveralls, 1 pair paper coveralls
Feet & Ankles:	6 pair plastic boots, 1 pair rubber boots, 1 pair socks

__Operator C

Head:	SCBA, surgical cap, cotton hood, plastic hood
Hands:	1 pair cotton gloves, 1 pair orange rubber gloves
Whole Body:	1 pair cotton coveralls, 2 pair coverall wet suits, 1 pair shorts
Feet & Ankles:	1 pair socks, 1 pair shoes, 1 pair plastic boots, 1 pair rubber boots

__Operator D

Head:	SCBA, surgical cap, eye glasses, cotton hood, plastic hood
Hands:	1 pair cotton gloves, 1 pair surgeon's gloves, 2 pair rubber gloves
Whole Body:	1 pair shorts, 1 pair cotton coveralls, 2 pair coverall wet suits
Feet & Ankles:	1 pair socks, 2 pair shoes, 1 pair rubber boots, 8 pair plastic boots (right foot), 9 pair plastic boots (left foot)

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FIGURE (1)

(cont.)

__Operator E

Head:	SCBA, cotton hood, plastic hood
Hands:	2 pair cotton gloves, 1 pair surgeon's gloves, 2 pair rubber gloves
Whole Body:	1 pair shorts, 1 pair cotton coveralls, 1 pair paper coveralls, 2 pair coverall wet suits
Feet & Ankles:	1 pair socks, 1 pair shoes, 8 pair plastic boots, 1 pair rubber boots

__Operator I

Head:	SCBA, cotton hood, plastic hood, surgical cap
Hands:	2 pair cotton gloves, 1 pair surgeon's gloves, 2 pair rubber gloves
Whole Body:	1 pair shorts, 1 pair cotton coveralls, 2 pair coverall wet suits
Feet & Ankles:	1 pair socks, 1 pair shoes, 1 pair rubber boots, 10 pair plastic boots

__Operator J

Head:	SCBA, surgical cap, cloth hood, plastic hood
Hands:	2 pair cotton gloves, 2 pair rubber gloves
Whole Body:	1 pair cotton coveralls, 1 pair shorts, 2 pair coverall wet suits
Feet & Ankles:	1 pair socks, 1 pair shoes, 1 pair rubber boots, 10 pair plastic boots

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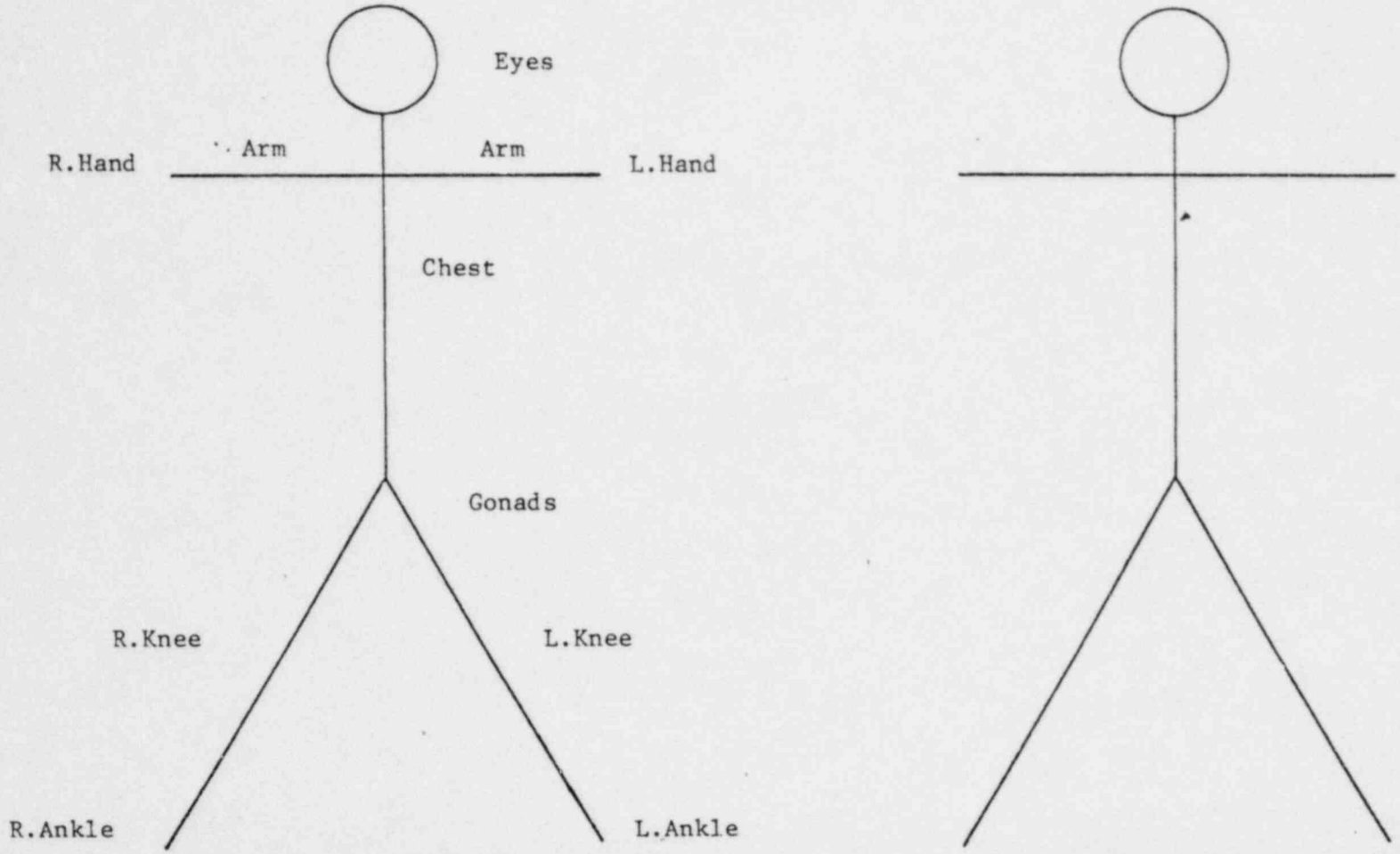
Key To Figure(2)



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November 30, 1979

NOTE: The right hand diagrams show the effective thicknesses of materials through which the TLD dose readings were attenuated. These thicknesses do not represent the actual clothing thicknesses worn under the TLDs because adjustments to these thicknesses were made in cases where the TLD badges were wrapped in masking tape.

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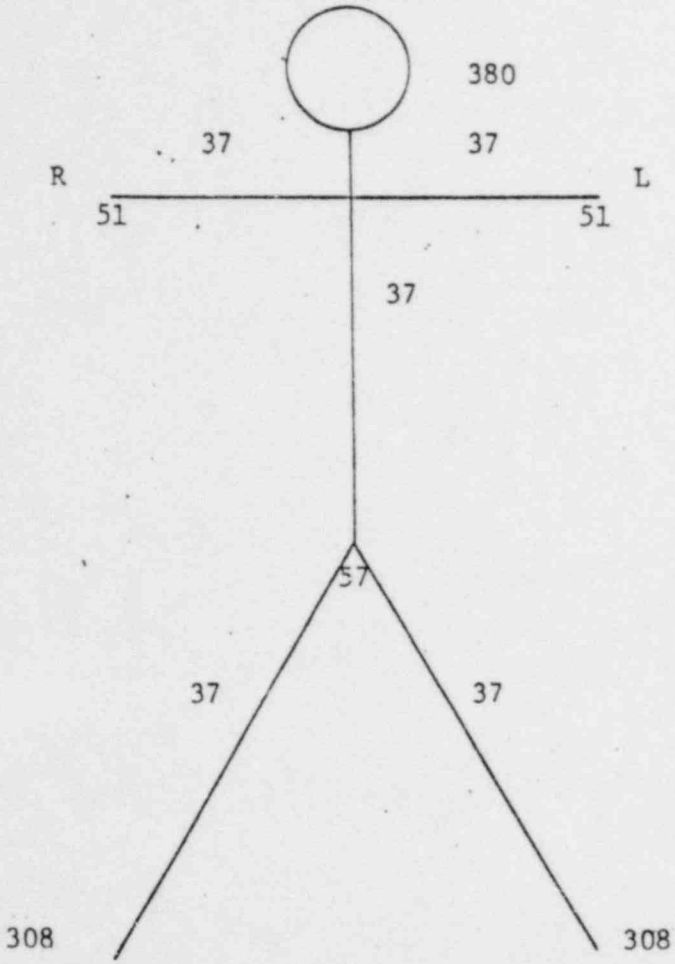
Figure (2)
(cont.)

HP Foreman A



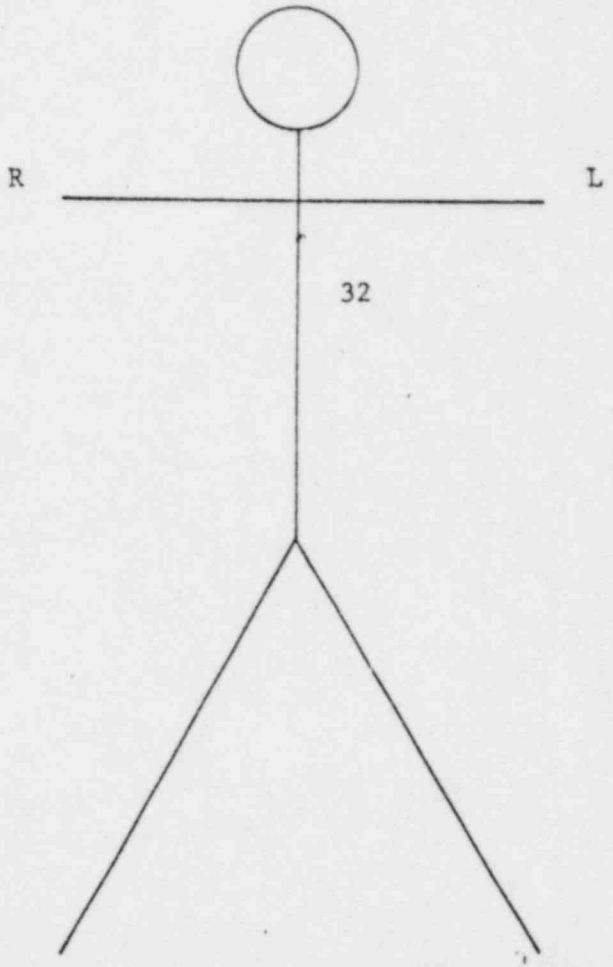


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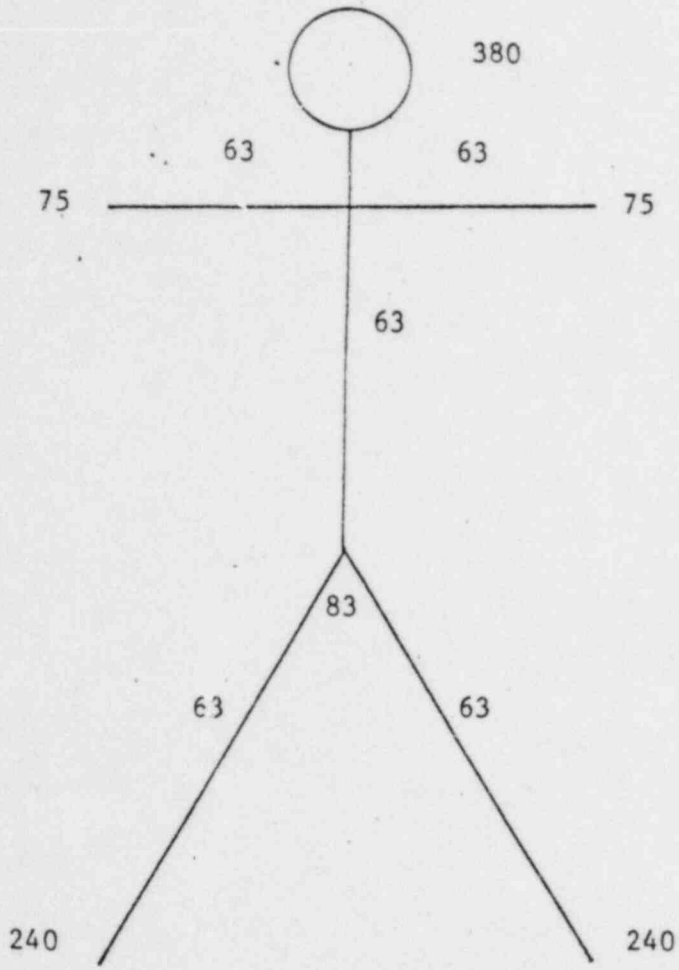
Figure (2)
(cont.)

Operator C



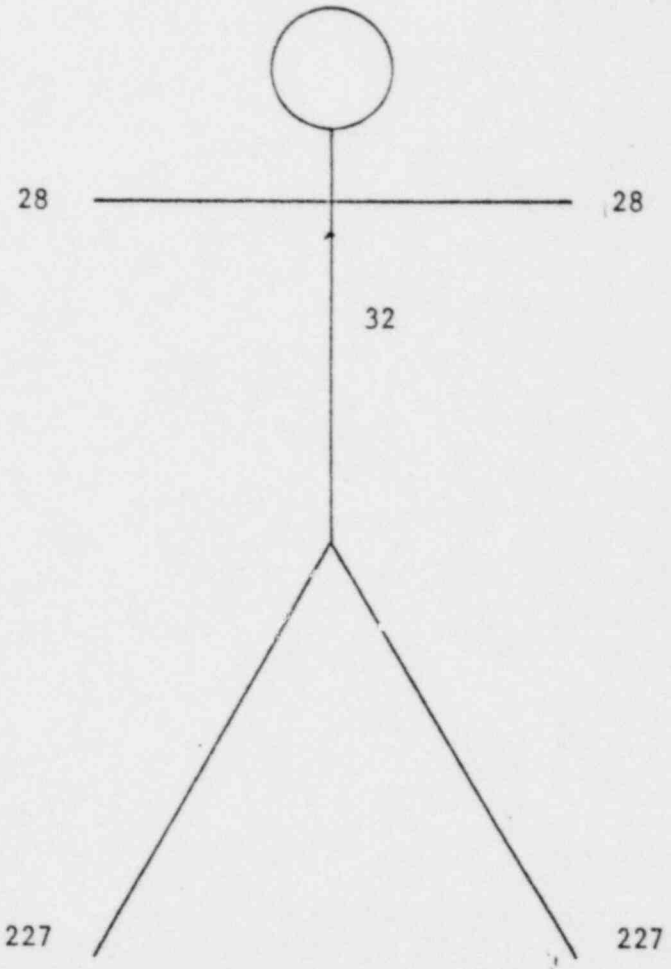


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Figure (2)
(cont.)

Operator D

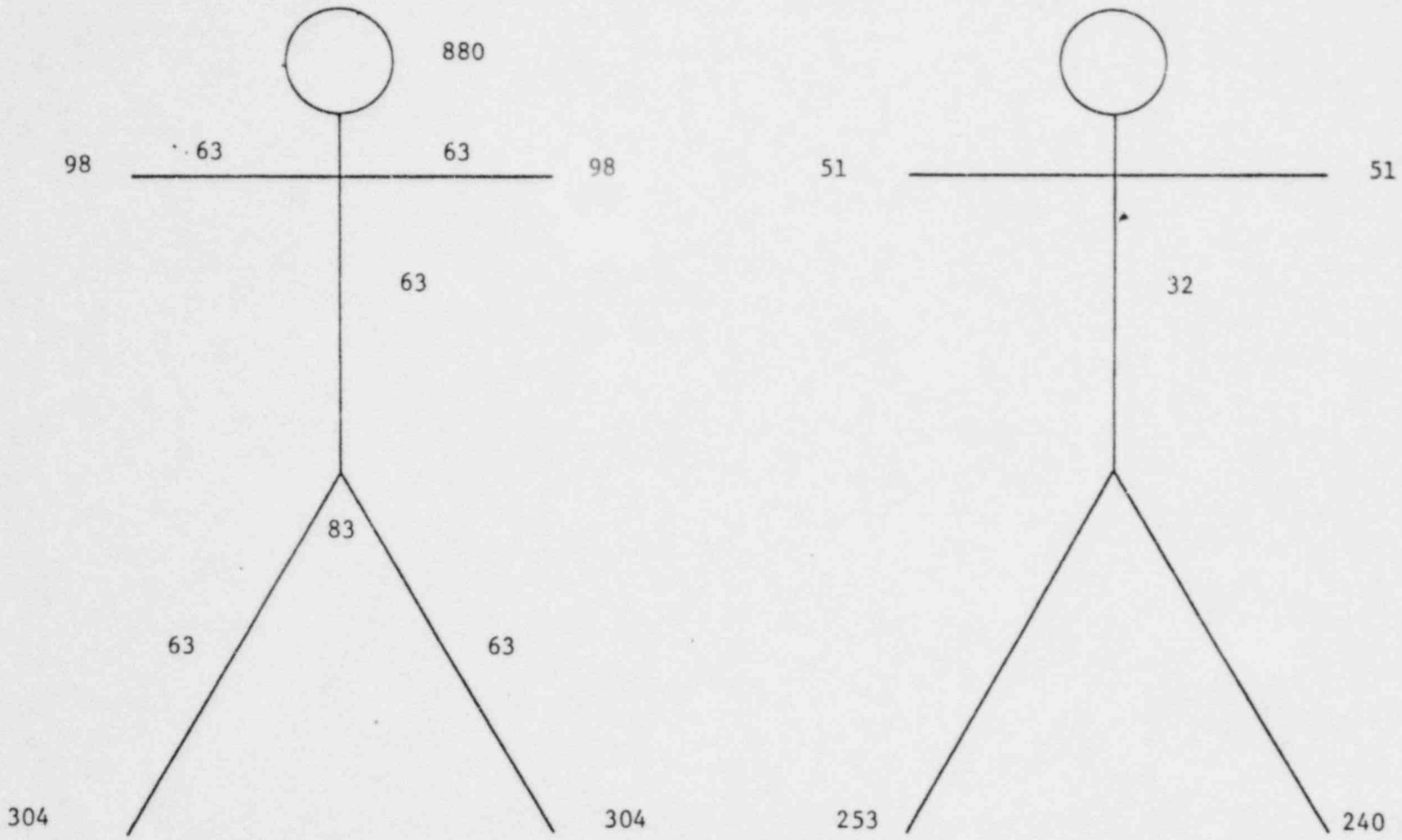

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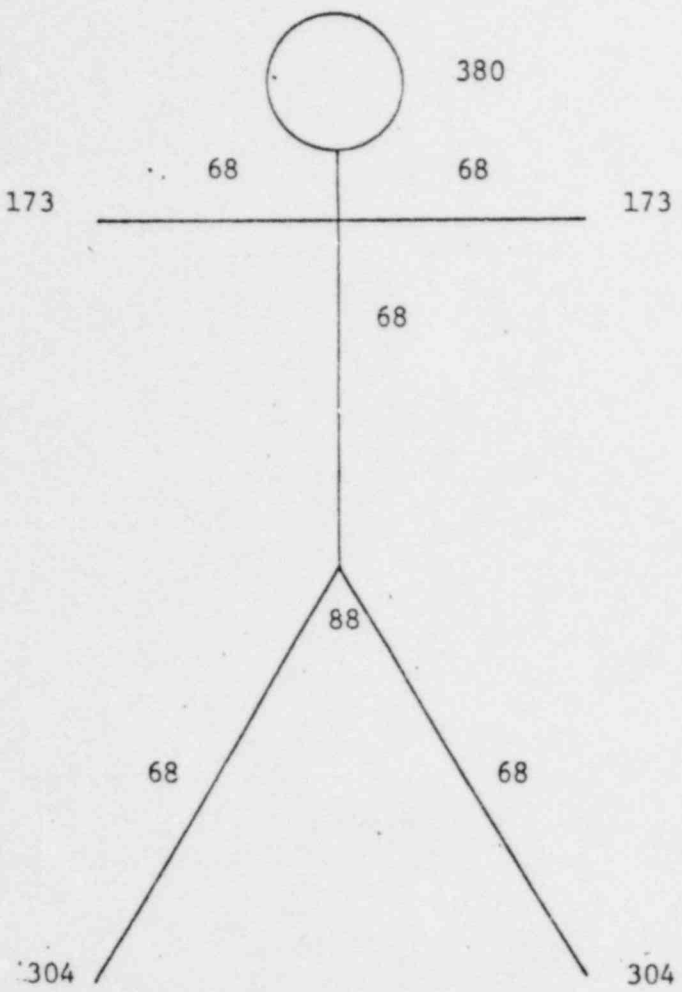
Figure (2)
(cont.)

Operator E



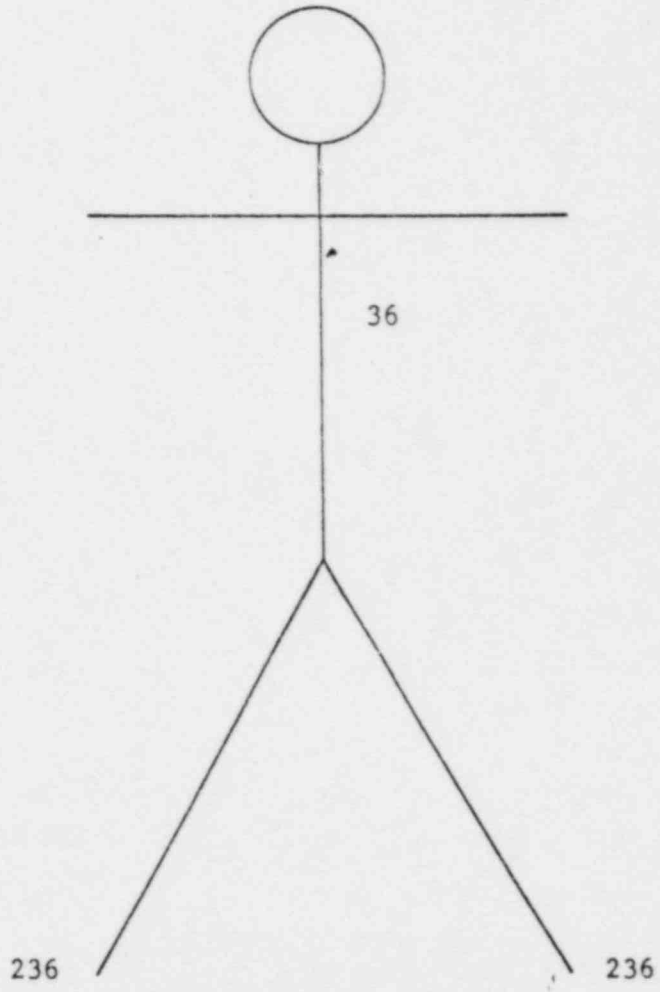


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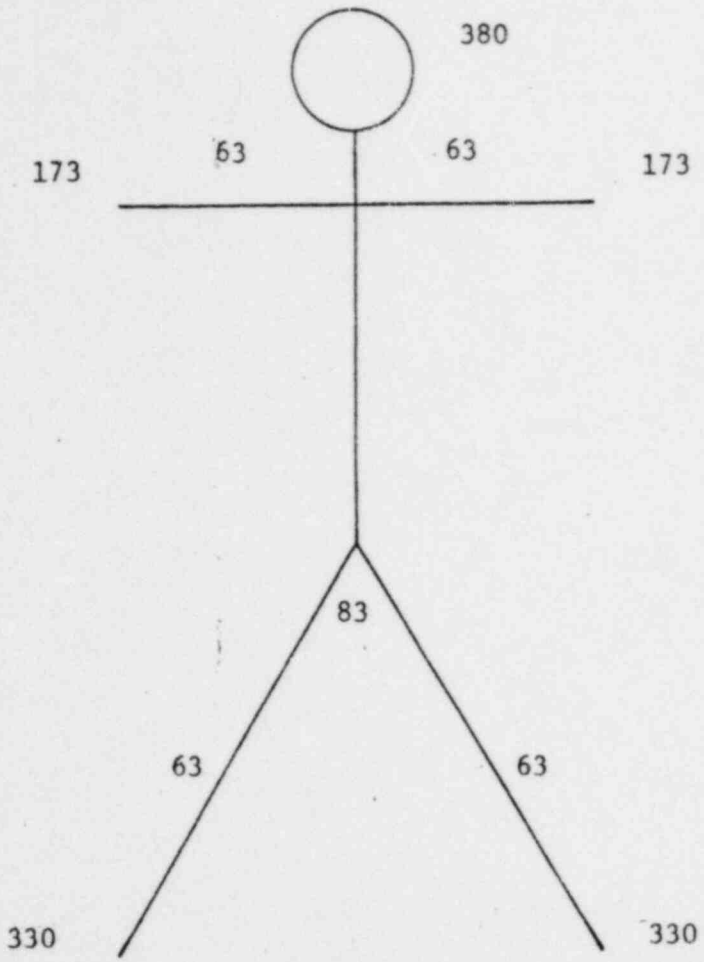
Figure (2)
(cont.)

Operator I



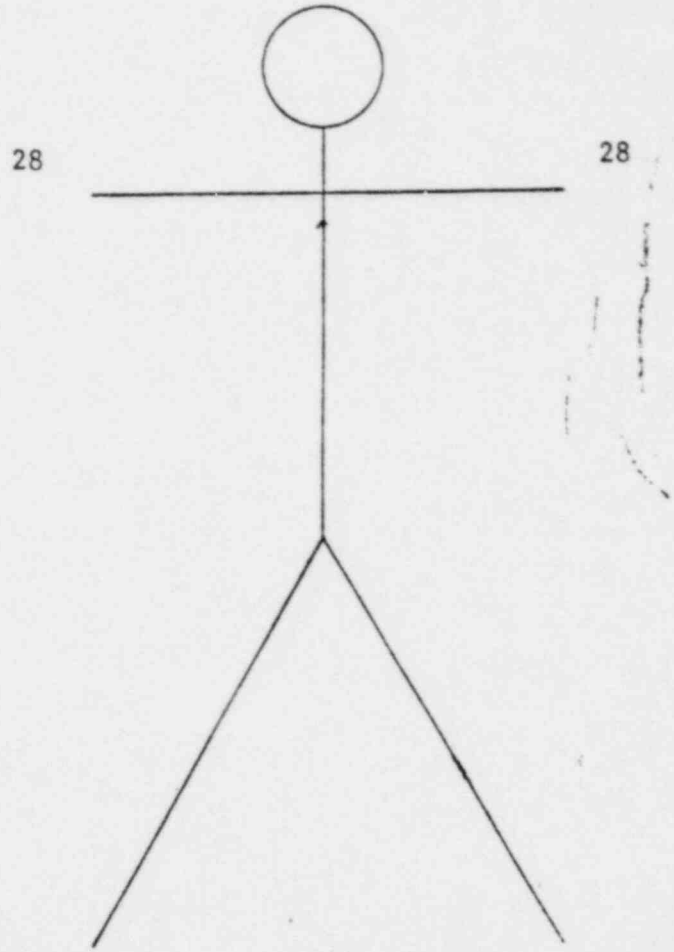


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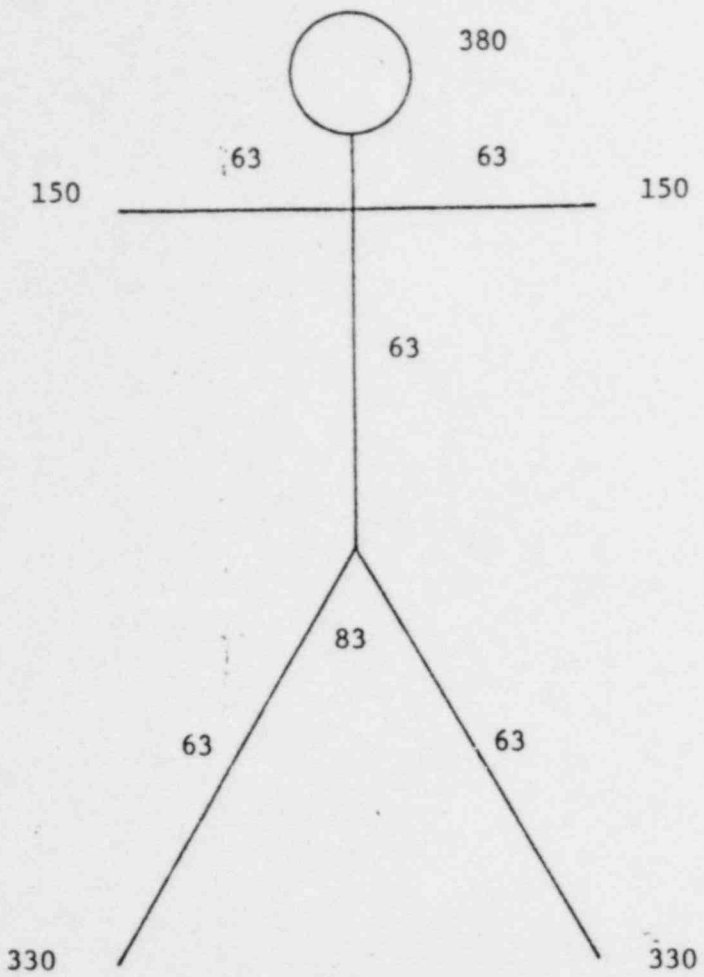
Figure (2)
(cont.)

Operator J



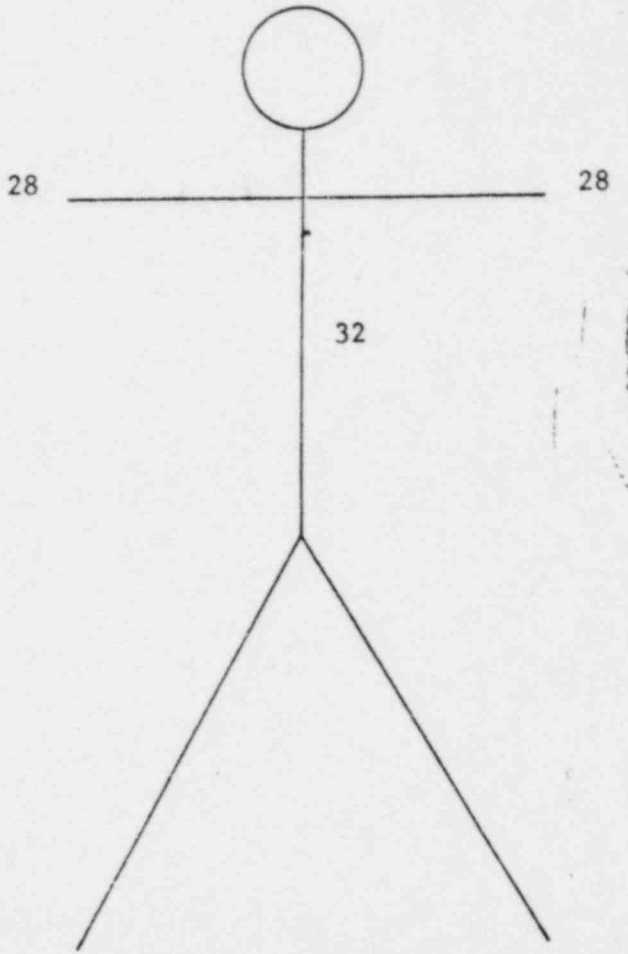


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FIGURE (3)

Thicknesses of Protective Clothing In
mg/cm^2 Worn In Different Combinations
By Individuals Entering the Make-Up Valve Room

SCBA Face Mask	380
Shorts	20 (estimated)
Coveralls	
Cotton	32
Paper	4.6
Wet Suit	15.5
Gloves	
Cotton	28
Rubber	47
Surgical	23
Socks	30 (estimated)
Boots	
Plastic	13
Rubber (sides)	200
Rubber (bottom)	500 (estimated)
Eye Glasses	500 (estimated)
Masking Tape	10 (estimated)

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FIGURE (4)

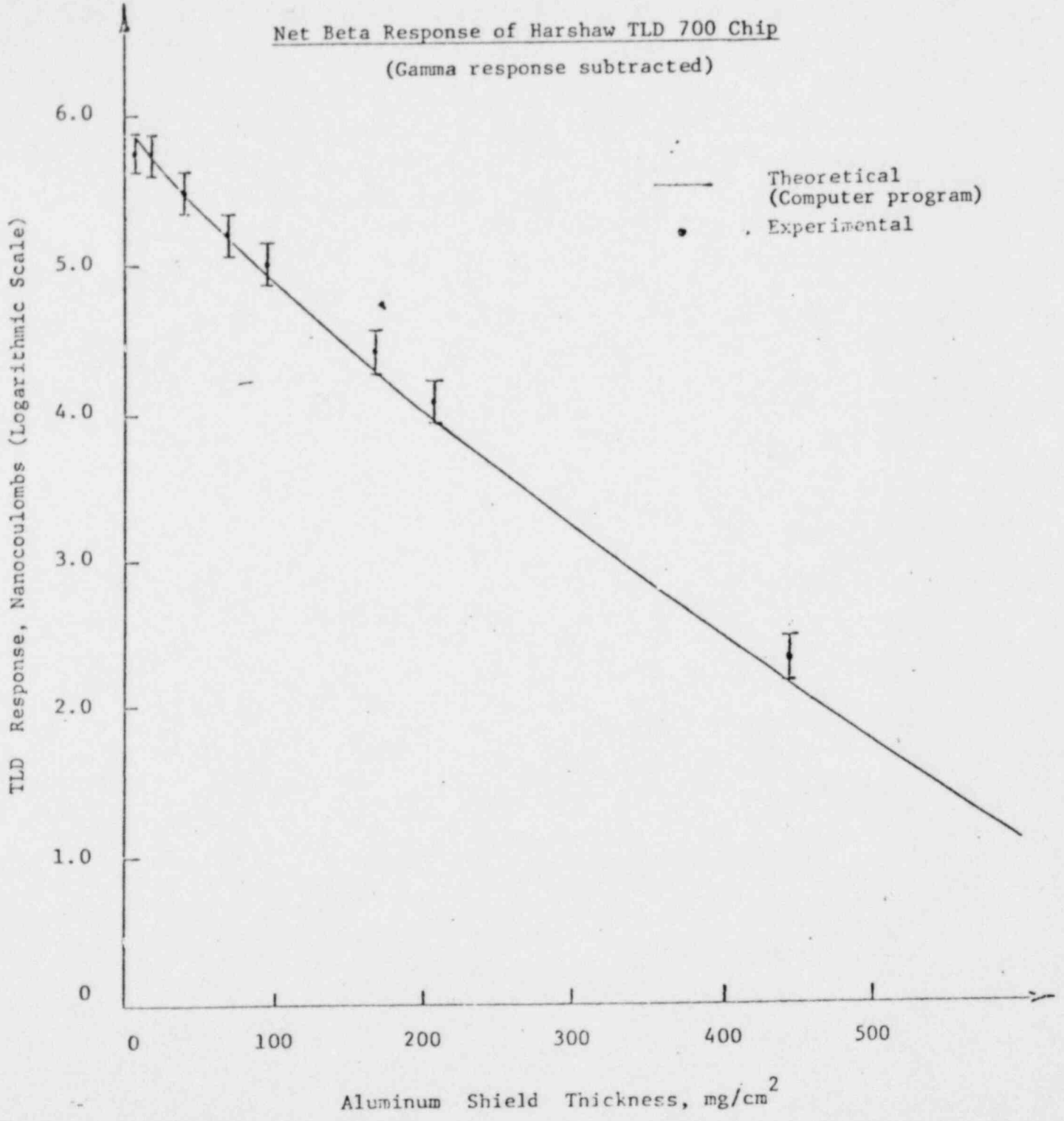
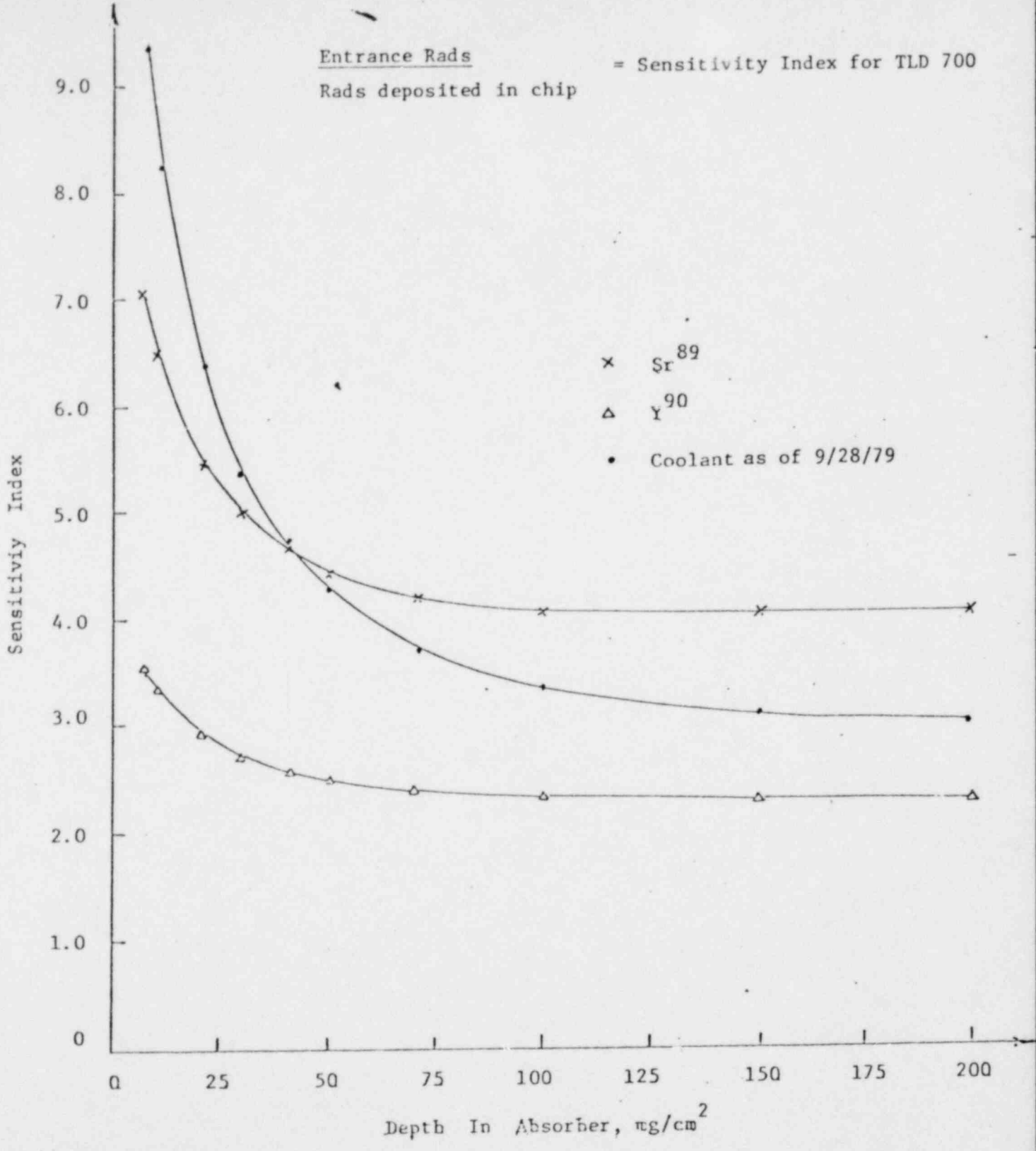


FIGURE (5)



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November 30, 1979

Dose Assessment From the August 28, 1979 Entry Into The TMI Unit II Fuel Handling Building North Make-Up Valve Room

I. - APPENDICES

I) Interviews With Individuals Involved In The Repair Work In The Make-Up Valve Room (enclosed)

II) Sketches Showing Dimensions and Pipe Layout In The Make-Up Valve Room (enclosed)

III) Calibration Certificates For The Survey Instrument "Teletector" Used To Survey The Gamma Field In The Make-Up Valve Room Prior To Entry For Repair Work (enclosed)

IV) Photographs Of The Mock-Ups Performed To Re-enact The Entry Into The Make-Up Valve Room And The Work Done On The Valves (enclosed)

V) Medical Evaluations Of The Overexposures By The Met-Ed Medical Consultant. Medical Evaluation Of The Inherent Shielding Of The Gonad (enclosed)

VI) Late History Of The Make-Up Valve Room Investigations (approximately September 8, 1979 to October 25, 1979) (not enclosed)

VII) Early History Of The Make-Up Valve Room Investigations September 7, 1979 (not enclosed)

VIII) Overexposure Letter To Each Of The Six Workers (not enclosed)

DOSE ASSESSMENT FROM THE AUGUST 28, 1979 ENTRY INTO THE TMI UNIT II

FUEL HANDLING BUILDING NORTH MAKE-UP VALVE ROOM

APPENDIX I

Interviews With Individuals Involved
In The Repair Work Done In The MU
Valve Room

Porter-Gertz Consultants, Inc.
76 RITTENHOUSE PLACE
ARDMORE, PA. 19003
215-896-5353

TO: File (14-Sept-79)

SUBJECT: Interview with H.P. Foreman: Description of North M-U Valve Room Entry of August 28, 1979 (Revised 8-Oct.-79)

That morning I checked the Aux and FH Building instrument panels for venting problems, the flow seemed normal. At approximately the same time, an assistant was going over the old survey data from March 23, 1979, five days prior to the accident. It looked like a primary water valve had not been repaired, the water was leaking at 255 ml per minute near MU-V-17. Decided to enter North Valve Room to check for leak, no leaks had been seen in South Valve Room in July. Got H.P. Gerry Spires to go with me (he stayed out in the corridor) and I entered the valve room approximately 9:30-10:00 A.M., at 10:10 A.M. air sample was finished. Entered part way in toward MU-V-255, could see leaks in MU-V-155 and MU-V-233A when surveyed. The air sample read about $1X10^{-6}$ uCi/cc.

Dose rate of 15R per hour on MU-V-155, near the packing, using a teletector. The general area was 10R per hour, a steady field throughout the room. MU-V-233A showed 10R per hour near the packing. The water on the deck towards the drain read 10-12R per hour as well.

Left the room with teletector and checked with the H.P. who had stayed in the corridor near the entrance to the valve room for safety, and then went back into the room to look at the valves again so that I could draw a picture from memory, also to retrieve air sample, it was 10:20 A.M. My total time in the room was 1½ to 1 3/4 minutes with dosimeter readings at about 265mR using two SR dosimeters. Notified the Operations people of what was leaking. At that time Mr. Mulleavy and Mr. Neely, NRC, got involved and decided that a crew would go back in to repair the leaks. Had people enter within one hour, reported that MU-V-233A had been leaking at about 500 ml/min and that they had secured the total packing so that it was just dripping. In the middle of the afternoon one man went into the room to stop the leak.

At approximately 4:00 P.M., I returned to the room to retrieve the air samples 305 and 328, in the FH Building, and inspect valve leaks. MU-V-155 was still leaking through the packing. I was in the room for approximately 30 seconds. Read 100mR on personal dosimeter. (NOTE: no analysis data was found. The sample log book showed 305 #6 and 328 #4 to read 600mRad and 2 RAD respectively).

After coming out that afternoon, another crew was sent into the room at 8:00 P.M. to fix the leak on MU-V-155. The leaking on MU-V-155 was a steady drip, no puddle. The floor next to this valve room reads 25R per hour so I expected this area to read the same. The dose rates were so even around the room, I did not consider that there would be a problem.

The men who went into the room to fix the valve wore two wet suits of heavy rubber and one set of cloth under the wet suits. The inner wet suit was dry but the outer suits were quite wet. They read 2R per hour gamma with the teletector. Noted about 50R per hour beta (did not specify instrument for this reading). I do not know where their badges were on their bodies since badge placement is not uniform.

MU-V-155 looked like it had been leaking for a long time but MU-V-233A looked like the leak had originated 8 to 10 hours before original entry, somewhere between 8:00 PM, 8/27 and 8:00 AM, 8/28. I was amazed to see a leak of such magnitude as that of MU-V233A. I have a gut feeling that this may have been a very tiny leak for awhile but had developed into a large one over a short period of time.

I was the only one in the room more than once.

Primary coolant is in the one inch, 2-½ inch, and four inch lines, and in the MU-Vs. I did not observe any heavy deposits indicating old leak residues on piping in general although I did not look at all the piping very carefully. Did see a few white spots (boric residue) near slow drips. Should be able to see floor drain in glossy of print #160. Should check plant specs for detailed piping composition. Am sure that the floor drain position shown in the drawing is too far away from MU-V-155. The water appeared to be running down pipe and wall then towards drain. No actual "puddles" seen.

I may be reached at Unit II H.P., ext 8093.

NORTH MU VALVE ROOM ENTRY 28-AUG-79

OPERATOR C (H,K,) INTERVIEW 4-OCT-79

1. Dressed out in protective clothing and dosimetry as depicted on the attached sheet. He was pretty sure that the TLD was <u>not</u> covered by the SCBA Regulator.

2. Entered the MU-Valve room looking for the leaking valve (~12 sec)

3. He noticed that the leaking valve was MU-V233A, which was different from the one he was led to believe.

4. He noticed that there was some water on the floor and that there was a lot of boric acid on MU-V-233A and also on MU-V-155.

5. He stood on 2½" pipe and leaned across hand wheel to MU-V-154 and with crescent wrench in right hand tried to turn top nut on right side of MU-V-233 and then changed over to left side to tighten packing. At first it did not budge. Finally nuts began to turn and tighten packing. This did not stop leak completely (~120 sec).

6. Next he gripped the hand wheel with both hands and with a great deal of effort began to turn the wheel (~90 sec).

7. He exited the room immediately when informed by Operator D that his time was up (~6 sec).

8. Figures 1 and 3 depict the two positions he was in while working on MU-V-233A and MU-V-154 hand wheel, respectively.

9. The relative positions of his various body areas to potential radiation sources are depicted on the attached sheet.

NORTH MU VALVE ROOM ENTRY (28 Aug 79)

OPERATOR D. (R.J.) INTERVIEW 4-Oct-79

1. Worked with Operator C to stop leak on MU-V233A; Close MU-V-154.

2. Suited up primarily by himself. Used two (500mR) self-reader dosimeters because H.P. Tech told him that they were all they had available. Did not think that the regulators covered his dosimeters because it was hanging low.

3. Waited at the door to Valve Alley while Operator C worked on MU-V-233A and MU-V-154. After Operator C exited Valve Alley, they discussed what must be done to stop the leak.

4. Entered Valve Alley and checked tags on other valves before going on to MU-V-154. Saw a lot of Boric Acid along the length of the 4" pipe back to the wall. (~10 sec).

5. While standing with both feet on the floor, gripped the hand wheel and tried to close MU-V-154. (~60 sec).

6. Stood on 4" pipe while straddling MU-V-155 Reach Rod and leaning back to jerk the hand-wheel was able to turn it and close MU-V-154 (~90 sec).

7. When he thought his stay time was up, he exited Valve Alley immediately. (~8 Sec.).

8. Figures 4 and 5 depict the two positions he was in while working on MU-V-154.

9. The relative positions of his various body areas to potential radiation sources are depicted on the attached sheet.

NORTH MU VALVE ROOM ENTRY (28-AUG 79)

OPERATOR E: INTERVIEW - 4- OCT-79

1. Entered North valve room and went directly to MU-V-233A. (~6 sec).

2. Stood with right foot on 2½" pipe and left foot on Reach Rod directly above MU-V-155. While in that position, leaned across hand wheel of MU-V-154 to tighten packing not on MU-V 233A with crescent wrench (~120 sec).

3. Changed foot positions with right foot on Reach Rod directly above MU-V-155 and left foot on Reach Rod at the wall. Gripped hand wheel to turn (close) MU-V-154 (~60 sec).

4. Exited valve alley immediately. Did not remember seeing any water on the floor.

5. Outside the room he checked himself for contamination after removal of his protective clothing and found none with the hand and foot monitor and portable survey meter.

6. Figures 2 and 3 depict the two positions he was in while working on MU-V-233A and MU-V-154 hand wheel respectively.

7. The relative position of his various body areas while performing these operations are as listed on the above page.

NORTH MU VALVE ROOM ENTRY (28 AUG-79)

OPERATOR I (W.S.) INTERVIEW BY J. ROY 4-Oct-79

1. Worked with Oper. J. Told to go into valve alley and stop leak on MU-V-155.

2. Understood what his task was. Had been in that area several times before.

3. Had been briefed by H.P. as to the radiation levels.

4. Suited up primarily by himself. Checked self reader dosimeters and confirmed that they were zeroed.

5. The only item he carried into the valve room was a crescent wrench (10-12 inches).

6. Entered the valve room with operator J at the door to relay signal from H.P. Tech when his 3-4 minutes stay time up (~ 6 sec.).

7. He noted MU-V-155 was leaking (oozing) and the floor was wet from MU-V-155 to floor drain near MU-V-273.

8. Began working on MU-V-155 by squatting all the time (~ 120 sec)

   a. Had to clear boric acid off R Nut; L. Nut was clean
   b. Inspected packing with arms resting on his knees.
   c. Flipped the wrench from right to left nut to tighten packing.
   d. About 2/3 way thru operations he leaned in close to the valve to count the threads. Both hands around the valve. Eyes about 6" away from valve. Remained in this position until tapped on the shoulder by Operator to indicate that his stay time was up (~30 sec)

9. Exited valve alley with Operator J immediately (~6 sec).

10. Outside the room, checked his SR dosimeter (wrist) and wasn't surprised to see that it was pegged (> 500 mR).

11. Discussed with Operator J. how to approach the problem of finishing the job of stopping the leak from MU-V-155. Stayed at the door to notify Operator J. when H.P. Tech signaled that his stay time was up.

12. Went in and tapped Operator J. on the shoulder when his time was up. They both exited immediately (~12 sec).

13. After removal of protective clothing, frisked himself and didn't recall being contaminated.

14. Recalled that he had several high exposures already on his TLD from other RWP's (200mR)

15. Figures 6 and 9 depict the two positions he was in while working on MU-V-155 and inspecting it, respectively.

16. The relative positions of his various body areas to potential radiation sources are depicted on the attached sheet.

NORTH MU VALVE ROOM ENTRY (28-Aug-79)
OPERATOR J (D.S.) INTERVIEW BY J. ROY
4-Oct-79

1. Worked with Operator I. Told to go into valve alley and stop leak on MU-V-155.

2. Understood what his task was. Had been in that area before several times.

3. Had been briefed by H.P. as to the radiation levels.

4. Suited up primarily by himself. Noted that his self-reader (wrist) had about 150mR on it before going into valve alley.

5. Waited at the door to Valve Alley while Operator I worked on MU-V-155. When signaled by the H.P. Tech, went in and tapped Operator I on the back to indicate that his time was up, they both exited immediately (this took about 12 Sec.)/

6. After discussions with Operator I went into valve alley and immediately began to work on MU-V-155. Used crescent wrench to tighten nut on both sides while standing near reach rod (~ 72 sec).

7. He squatted to inspect packing on valve. His knee TLD's always faced the pipes or MU-V-155 (~30 sec.). Remained in this position until tapped on the shoulder by Sawyer to indicate that his time was up.

8. Exited Valve Alley with Sawyer immediately (~ 6 sec).

9. Outside the room checked his SR dosimeter (wrist) and noted that it was pegged (>500 mR).

10. After removal of protective clothing, frisked himself and didn't recall being contaminated.

11. Additional Comments

    a. Had whole body count the next day. Didn't know results yet.

    b. Recalled that he had several exposures on his TLD on previous RWP's during the month.

    c. Submitted a urine specimen next day.

    d. Knows that his TLD was covered by his SCBA regulator at least part of the time.

12. Figures 7 and 10 depict the two positions he was in while working on MU-V-155 and inspecting it, respectively.

13. The relative positions of his various body areas to potential radiation sources are depicted on the attached sheet.

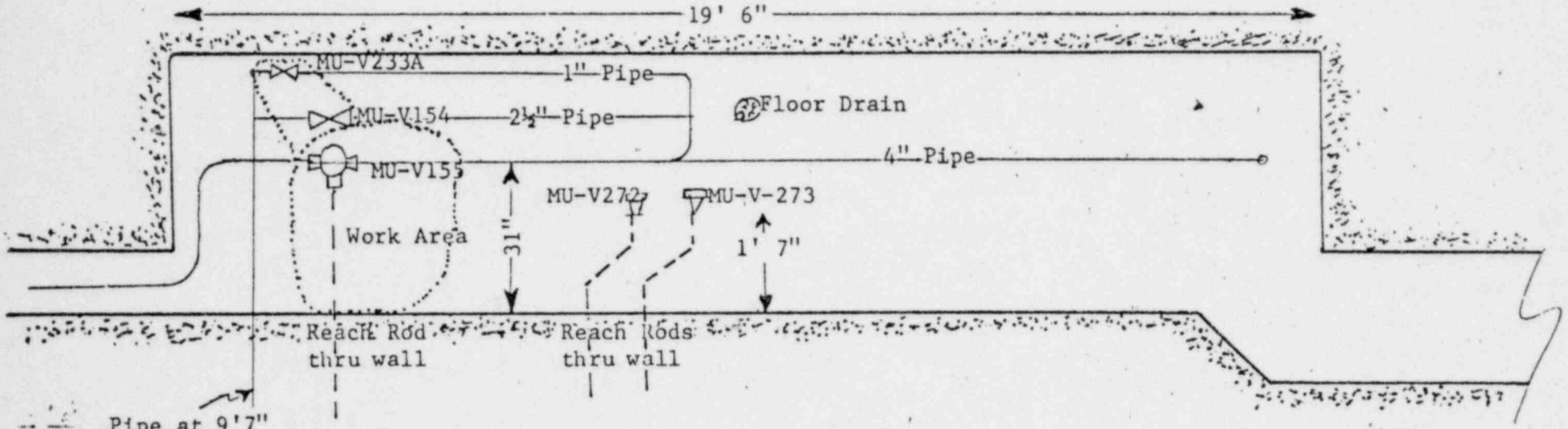
DOSE ASSESSMENT FROM THE AUGUST 28, 1979 ENTRY INTO THE TMI UNIT II

FUEL HANDLING BUILDING NORTH MAKE-UP VALVE ROOM

APPENDIX II

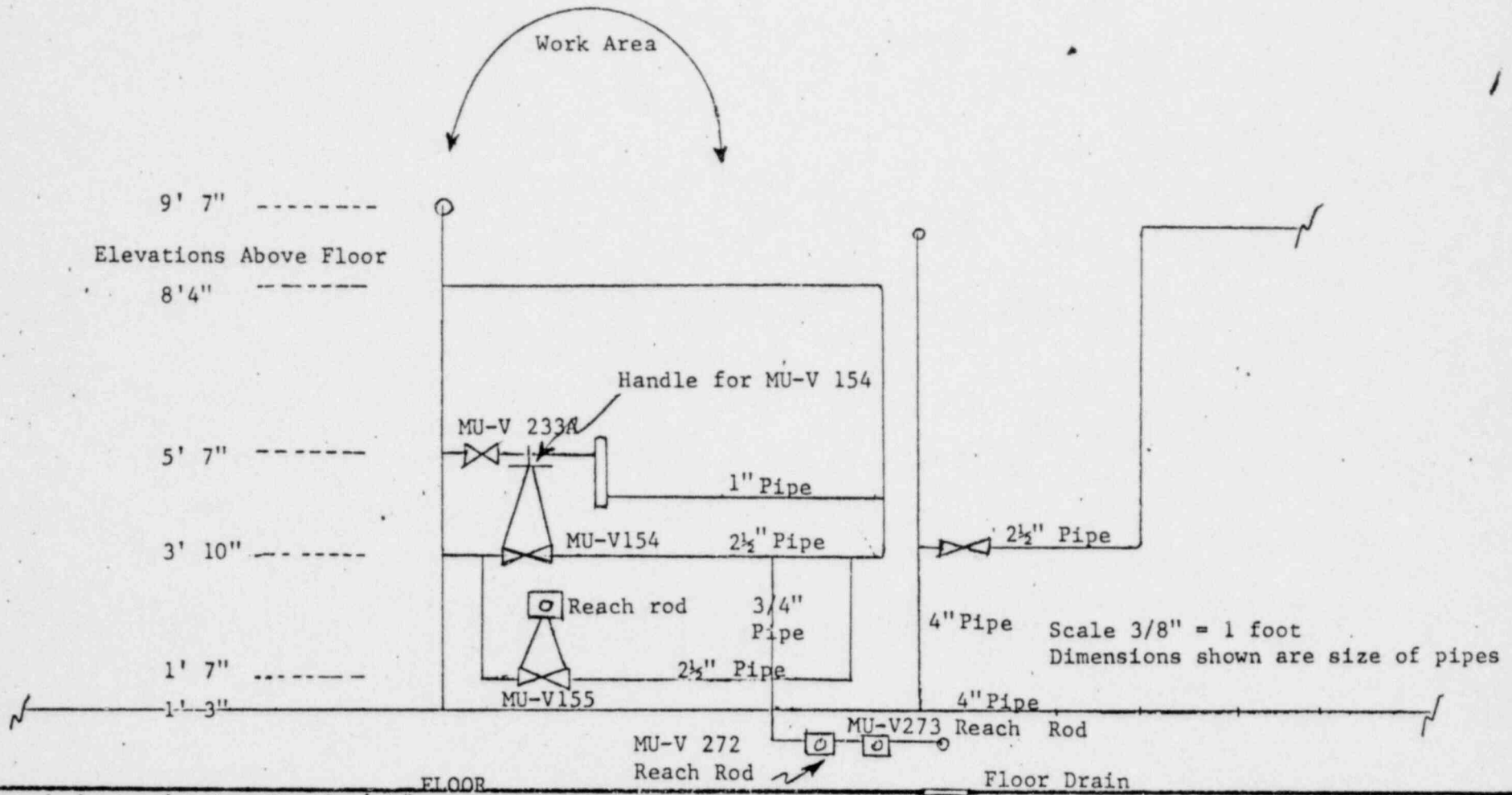
Sketches Showing Dimensions And Pipe Layout In The MU Valve Room

TMI UNIT II FUEL HANDLING BUILDING NORTH MAKE-UP VALVE ROOM Floor Plan



Work area indicated by dotted lines. The larger dotted area indicates position of body. Smaller dotted area indicates position entered only by hands and arms.

TMI UNIT II FUEL HANDLING BUILDING NORTH MAKE-UP VALVE ROOM Elevation/Section



DOSE ASSESSMENT FROM THE AUGUST 28, 1979 ENTRY INTO THE TMI UNIT II

FUEL HANDLING BUILDING NORTH MAKE-UP VALVE ROOM

APPENDIX III

Calibration Certificates For The Survey

Instrument "Teletector" Used To Survey

The Gamma Field In The Make-Up Valve Room

Prior To Entry For Repair Work

Porter-Gertz Consultants, Inc.
76 RITTENHOUSE PLACE
ARDMORE, PA. 19003
215-896-5353

November 30, 1979

The calibration of the Teletector utilized on September 28, 1979 was current as per the enclosed July 22, 1979 certificate. An operational check was made in a known field of 80 mR/hr. with this Teletector survey meter just prior to initial entry into the Make-Up Valve Room on August 28, 1979.

The calibration certificate dated September 11, 1979 was compiled after the valve room entry on August 28, 1979. The certificate indicates that the instrument was not operational on the date of calibration and therefore, no calibration data is available for it after the entry date.

Further checking revealed that the instrument was inoperative because it had been dismantled during the decontamination procedure that followed use of the instrument during the valve room survey. The high range GM tube in the instrument was also changed before re-assembly and recalibration.

FORM RS-
FD 3/1/

RAD Services Inc.

CALIBRATION CERTIFICATE

"This Certificate will be accompanied by Calibration Charts or Readings where applicable

CUSTOMER INFORMATION	INSTRUMENT INFORMATION
Customer Name: THREE MILE ISLAND	Instrument Manufacturer TELETECTOR
Customer Address:	Model 6112 B Serial Number 833
	External Probe(s) Serial #
Customer P.O. #	Calibration Method CS137 SN 107
Service W.O. #	CO60 SN 012

INSTRUMENT CALIBRATION INFORMATION

	Instrument Range	Calibration Standard Value	Instrument Response Before Calib.	Instrument Response After Calib.	Comment
1	2 MR/HR	0.5 mr/hr	0	0.5 mr/hr	
2		1.0		1.0	
3		1.5		1.5	
4					
5	50 MR/HR	10		10	
6		25		25	
7		50		50	
8					
9	2 R/HR	0.5 R/HR		0.5 R/HR	
10		1.0		1.0	
11		1.5		1.5	
12					
13	50 R/HR	5		5	
14		25		25	
15		49		49	
16					
17	1000 R/HR	9.9		10	
18		141		150	
19		737	↓	750	
20					

ADDITIONAL TESTS

Type of Test	Results		Test Date	Next Test Due Date
C & H	1 MR/HR	1 MR/HR		
	493 R/HR	500 R/HR		

STATEMENT OF CERTIFICATION

We Certify that the instrument listed above was calibrated and inspected prior to shipment and that it met all of the Manufacturers published operating specifications. We further certify that our Calibration Measurements are traceable to the National Bureau of Standards (We are not responsible for damage incurred during shipment or use of this instrument).

Instrument Calibrated by: A Thompson (Signed)

Calibration Date: 7/22/79

I certify that the above information is correct:

Authorized Agent

Title Date

DOSE ASSESSMENT FROM THE AUGUST 28, 1979 ENTRY INTO THE TMI UNIT II

FUEL HANDLING BUILDING NORTH MAKE-UP VALVE ROOM

APPENDIX IV

Photographs Of The Mock-Ups Performed

To Re-enact The Entry Into The Make-Up

Room And The Work Done On The Valves

NORTH MAKE-UP VALVE ROOM MOCK-UP

(28-AUG-79)

TIGHTENING PACKING ON MU-V-233A, STANDING ON 2½ INCH RC PIPE STRADDLING REACH ROD TO MU-V-155

OPERATORS C and E

FIGURE 1

NORTH MAKE-UP VALVE ROOM MOCK-UP

(28-AUG-79)

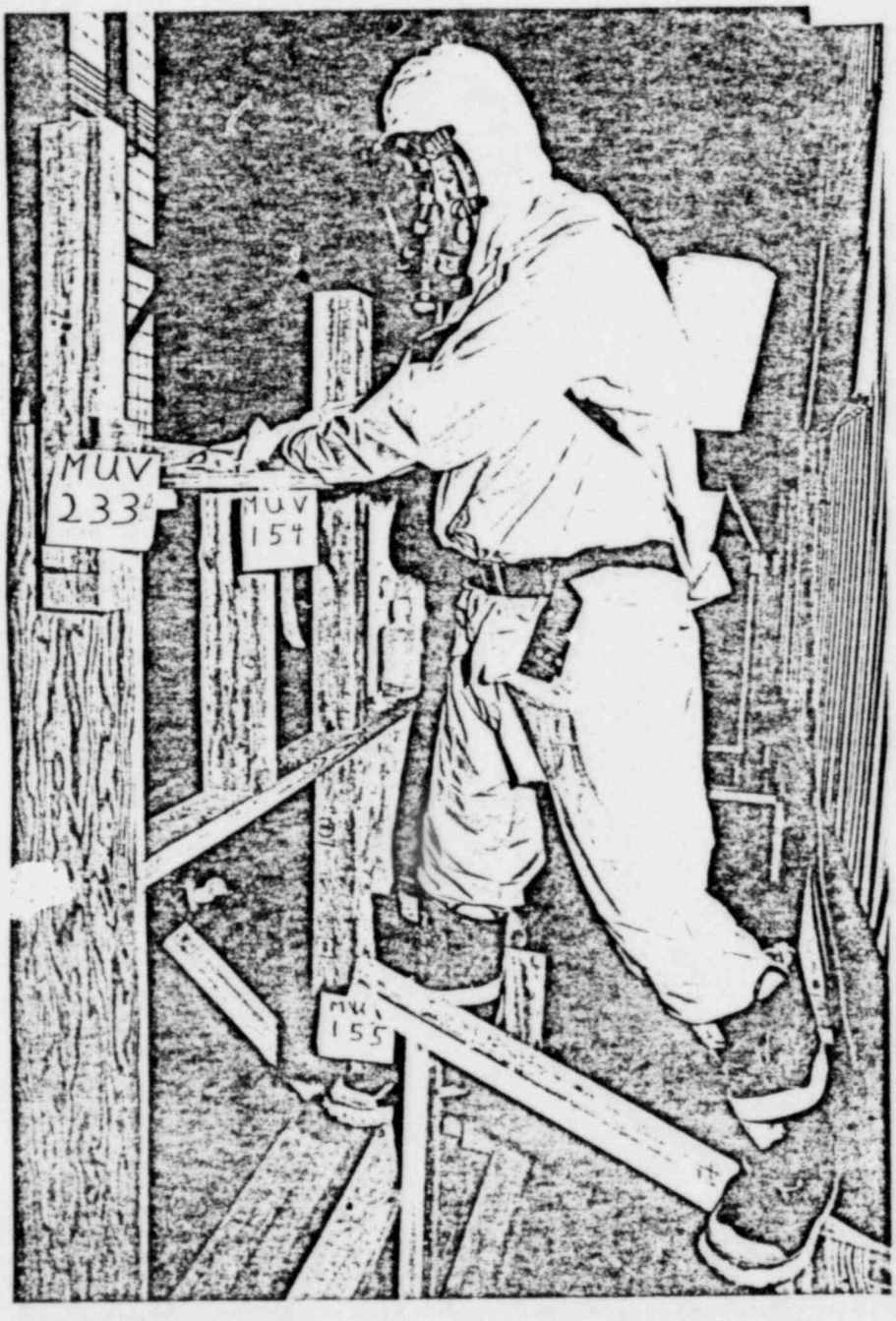
TIGHTENING PACKING ON MU-V-233A STANDING ON 2½ INCH RC PIPE

OPERATORS C and E

FIGURE 2

NORTH MAKE-UP VALVE ROOM MOCK-UP

(28-AUG-79)



TIGHTENING HAND WHEEL TO CLOSE MU-V-254 STANDING ON MU-V-155 REACH ROD

OPERATORS C and E

FIGURE 3

NORTH MAKE-UP VALVE ROOM MOCK-UP

(28-AUG-79)

WORKING ON MU-V-154 WHILE STANDING ON FLOOR

OPERATOR D

FIGURE 4

NORTH MAKE-UP VALVE ROOM MOCK-UP

(28-AUG-79)

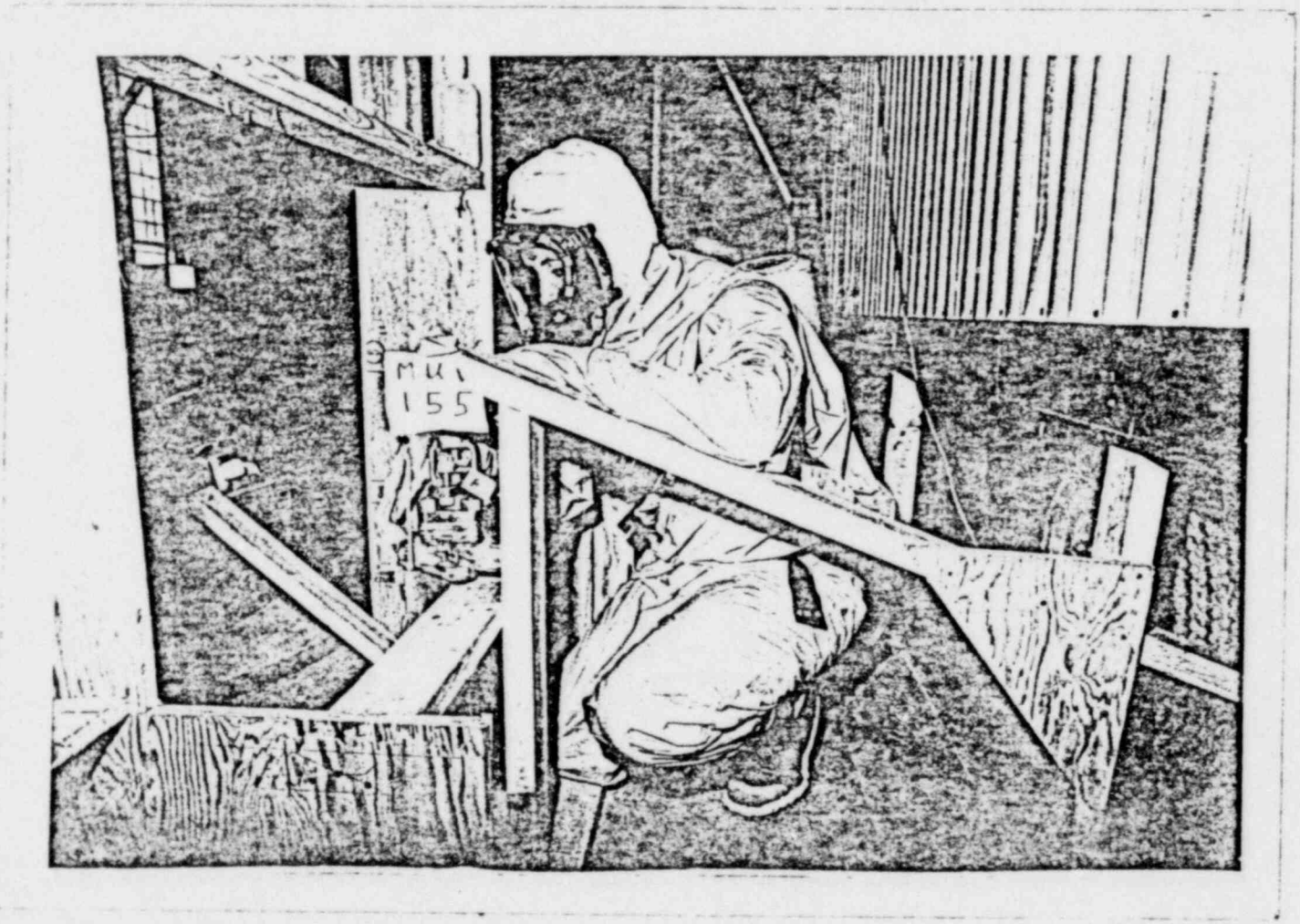
TURNING HAND WHEEL TO CLOSE MU-V-154

OPERATORS C and D

FIGURE 5

NORTH MAKE-UP VALVE ROOM MOCK-UP

(28-AUG-79)



TIGHTENING PACKING ON MU-V-155

OPERATORS I and J

FIGURE 6

NORTH MAKE-UP VALVE ROOM MOCK-UP

(28-AUG-79)

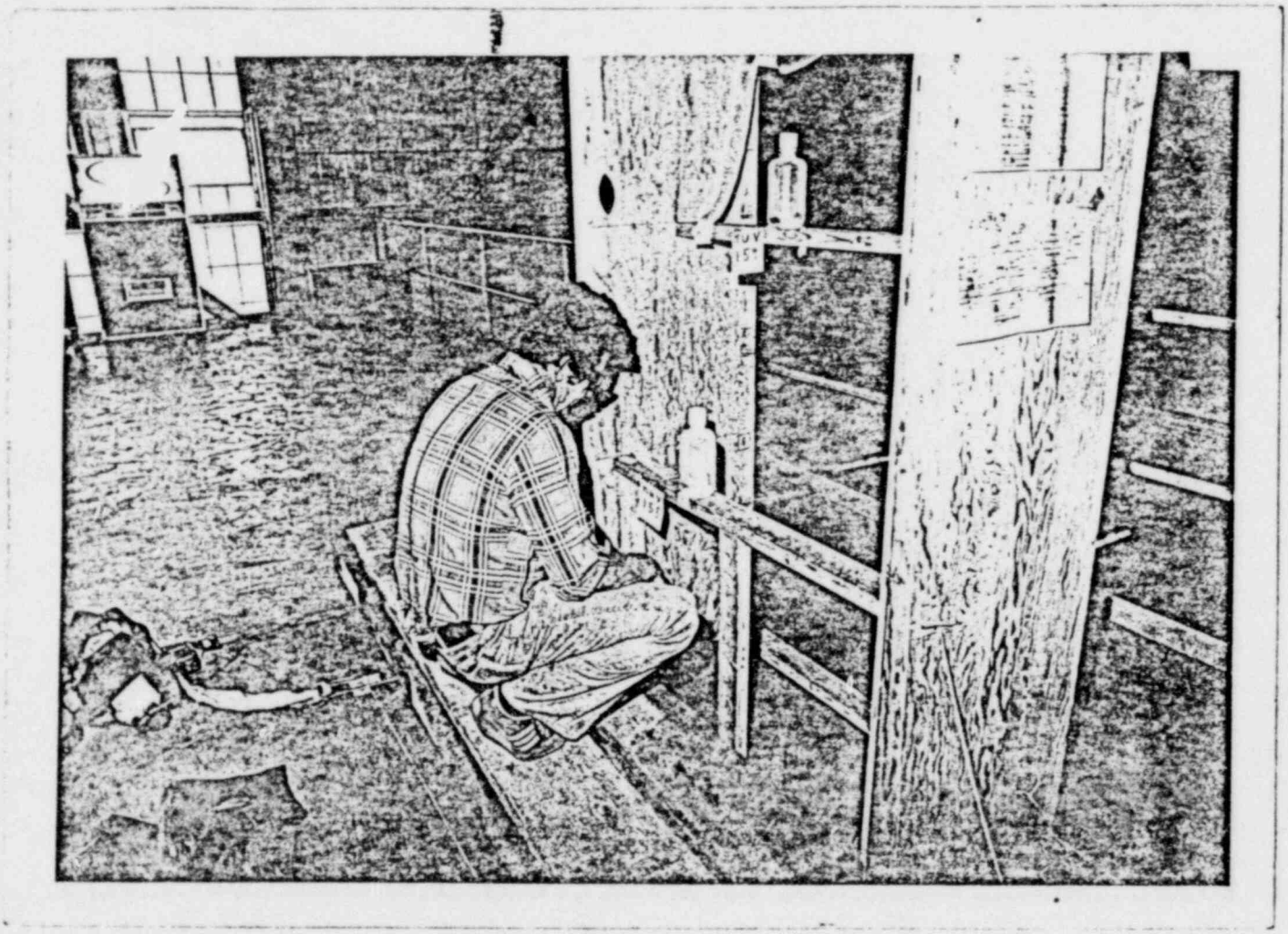
TIGHTENING PACKING ON MU-V-155

OPERATOR J

FIGURE 7

NORTH MAKE-UP VALVE ROOM MOCK-UP

(28-AUG-79)



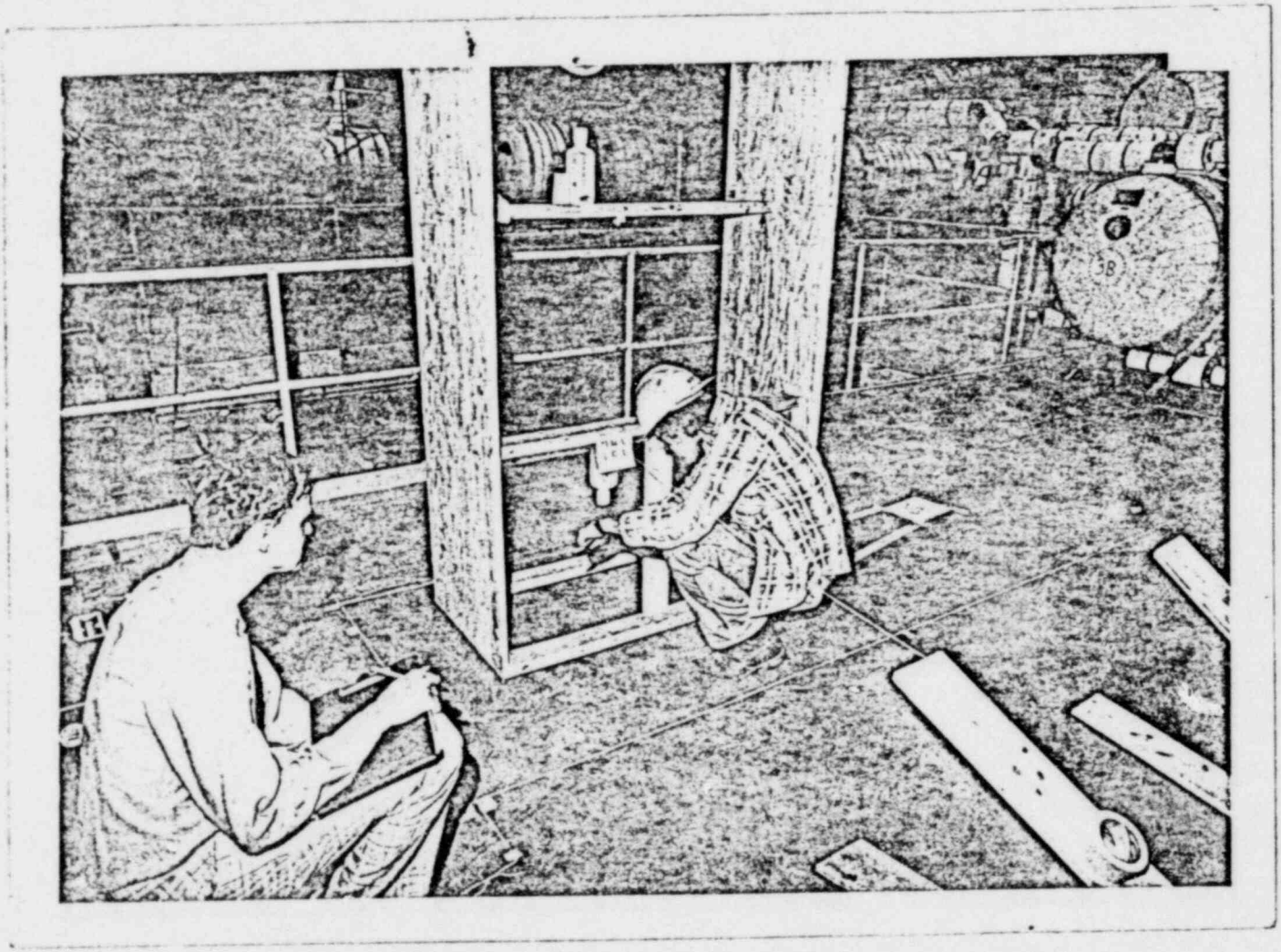
INSPECTING LEAKAGE FROM MU-V-155

H.P. FOREMAN A

FIGURE 8

NORTH MAKE-UP VALVE ROOM MOCK-UP

(28-AUG-79)



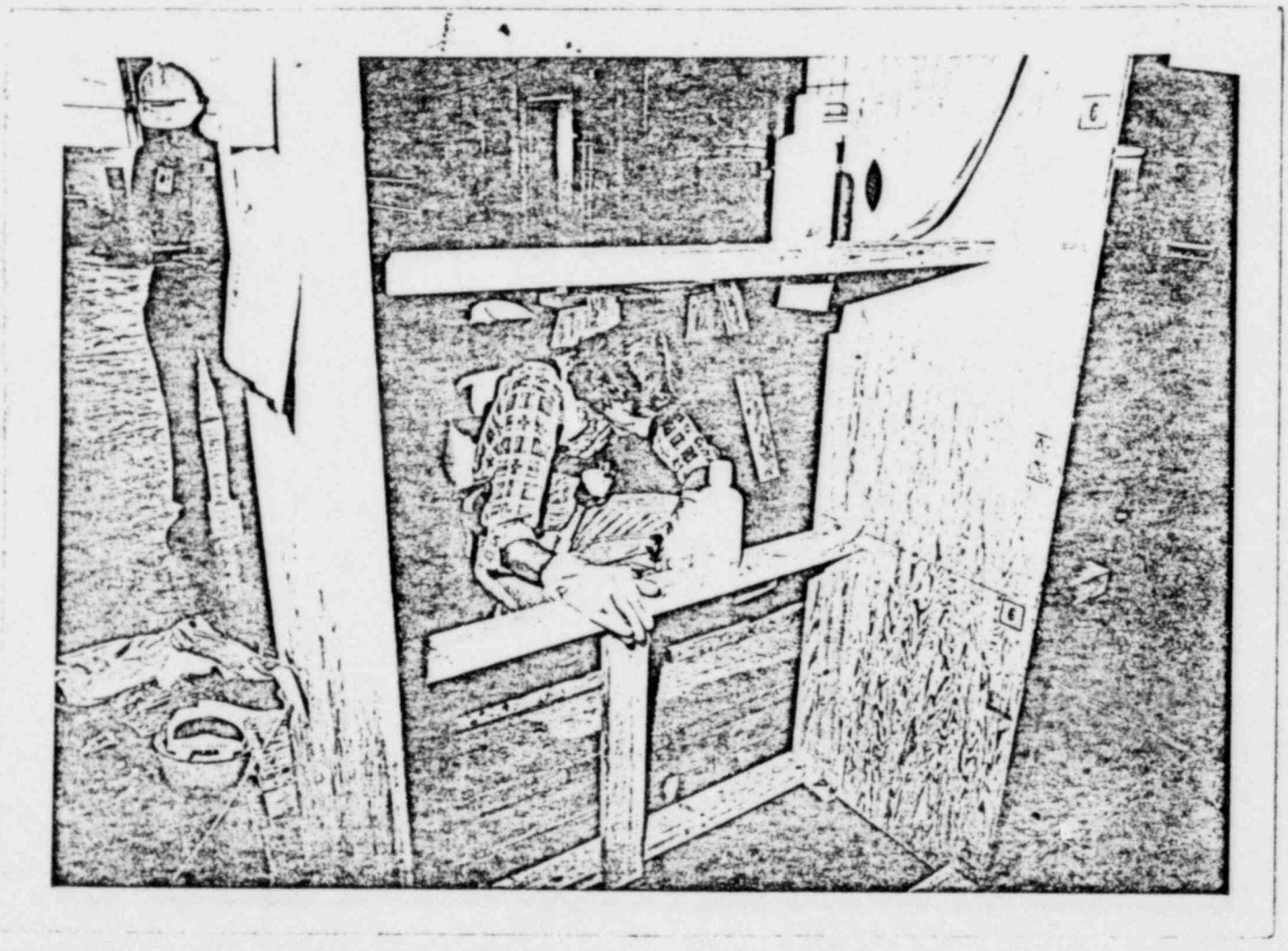
INSPECTING MU-V-155 FOR LEAKS AFTER TIGHTENING PACKING

OPERATOR I

FIGURE 9

NORTH MAKE-UP VALVE ROOM MOCK-UP

(28-AUG-79)



INSPECTING MU-V-155 FOR LEAKS AFTER TIGHTENING PACKING

OPERATOR J

FIGURE 10

NORTH MAKE-UP VALVE ROOM MOCK-UP

(28-AUG-79)

CLOSE-UP OF SCBA REGULATOR COVERING DOSIMETERS

FIGURE 11

NORTH MAKE-UP VALVE ROOM MOCK-UP

(28-AUG-79)

CLOSE-UP OF SCBA REGULATOR NOT COVERING DOSIMETERS

FIGURE 12

DOSE ASSESSMENT FROM THE AUGUST 28, 1979 ENTRY INTO THE TMI UNIT II FUEL HANDLING BUILDING NORTH MAKE-UP VALVE ROOM

APPENDIX V

Medical Evaluations Of The Overexposures By The Met-Ed Medical Consultant. Medical Evaluation Of The Inherent Shielding Of The Gonad.

REMS CORPORATION

3004 La Mancha St. NW
Albuquerque, New Mexico 87104
(505) 243-0236

Fred A. Mettler Jr., M.D., M.P.H., President

November 14, 1979

Porter-Gertz Associates
76 Rittenhouse Place
Ardmore, Pa.

Dear Sid;

Thanks for your call today regarding TMI. I have done a bit of research regarding the strontium dosimetry problem that you have.

In any measurements of tissue one has to be careful that the calculations are made on living people, preferably in the position of interest. Most measurements derived from anatomy books are derived from cadavers and are suspect.

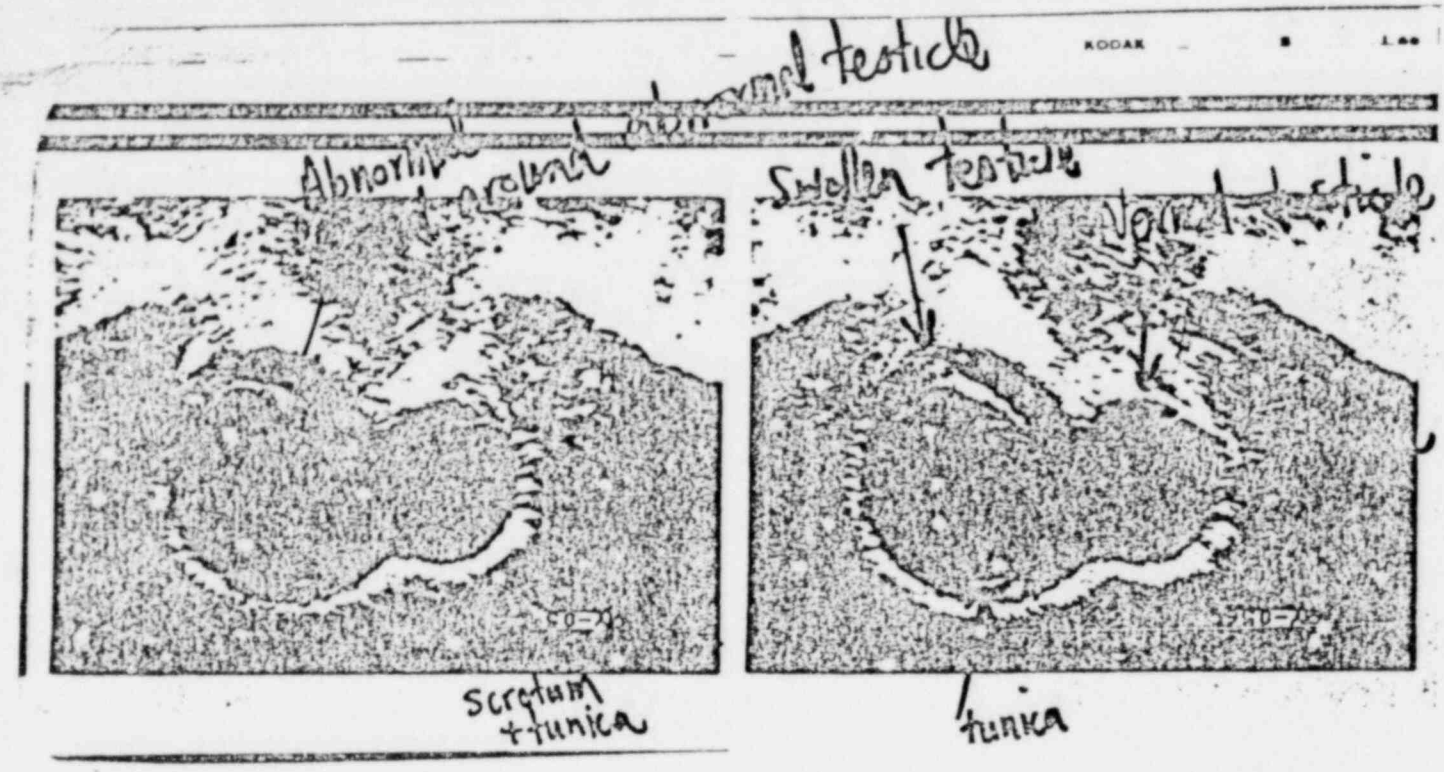
I have therefore reviewed ultrasound scans of the testicle made on young males. These were made using 5 MHz sound waves. The subjects are in a standing position with the scrotum immersed in a water bath. The results indicate that the thickness of tissue from the outside of the scrotum to the seminiferous tubules in the dependent portion averages 3mm. This includes the tunica.

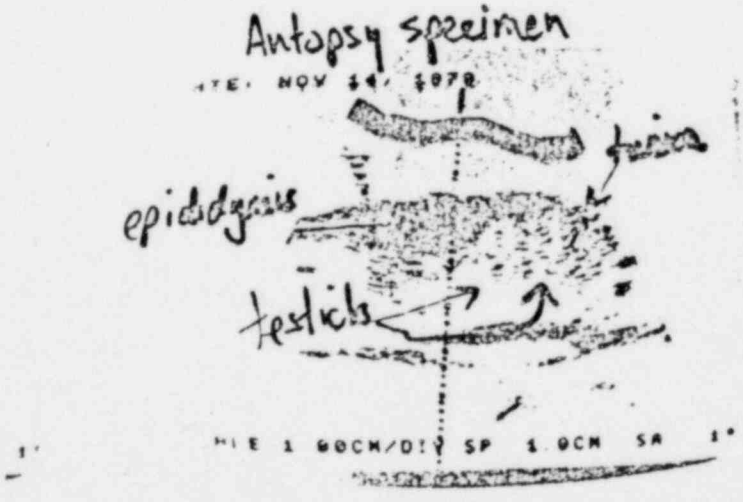
For your interest I have included a scan on a patient with a normal testicle on theright and a swollen testicle on the left. The left testicle also has an abnormal fluid collection around it which permits separation of the tunica and the scrotum so that both are visualized. In addition today I did a scan on a cadaver specimen which indicated as we suspected that the tunica is almost 1mm in thickness.

The average testicular size in normals was 3X3X5 cm. The density of tissue can be assumed to be approximately 1 gram per cubic centimeter. I hope that this information is of some use to you and to Metropolitan Edison. If I can be of more help please do not hesitate to call. Under separate cover I will be sending you some information concerning medical treatment of patients with internal contamination due to strontium.

Sincerely;

Fred A. Mettler Jr. M.D.


KODAK
Abnormal testicle
Swollen testicle
scrotum + tunica
tunica


Autopsy specimen
tunica
epididymis
testicle

rmc

PRESIDENT

radiation management corporation

UNIVERSITY CITY SCIENCE CENTER

3508 MARKET STREET
PHILADELPHIA, PA 19104
(215) 243-2950

November 21, 1979

Mr. R.W. Heward
Manager, Radiological Controls for
TMI #2 Recovery
METROPOLITAN EDISON COMPANY
P.O. Box 480
Middletown, PA 17057

Dear Mr. Heward:

This is in response to your letter (telecopied November 21, 1979, with attachment to this letter, "Summary of Doses to TMI-II Workers in the Make-up Valve Alley of the Fuel Handling Building on August 28, 1979" by Porter-Gertz Consultants, Inc.) The document is unsigned. You have asked me to give you a medical opinion regarding these exposures.

I am unable to identify which of the eleven workers I saw on August 30, 1979.

Assuming the dose calculations are correct as stated, I find that in all cases the skin doses have exceeded the quarterly limits as per 10CFR Part 20. I would not have expected these doses at the time they were received to have caused any overt clinical signs or symptoms. I would not expect these doses to result in any clinically detectable radiation damage, e.g., cancer, in the future.

The gonadal doses are within the limits specified in 10CFR Part 20. In my opinion these doses also should not result in any detectable damage now or in the future.

Reference the letter addressed to Mr. Elwin E. Clements dated November 21, 1979 (draft): In paragraph 4 delete "physically examined", as I do not recall physically examining this man specifically.

According to the dose estimates given in paragraph 2, you may include a statement in paragraph 5....

> "According to the dose estimates in paragraph 2 above, the exposure to the skin has exceeded the Federal quarterly limits. The exposures to the skin are medically insignificant, and I do not expect any clinically detectable damage from this radiation exposure now or in the future."

rmc

You may insert this paragraph in the appropriate letters to the employees and send them to me for signature.

For your information, I received a telephone call from Mr. Porter on October 23, 1979 stating I would have these dose estimates by October 29, 1979.

I hope this is satisfactory.

Sincerely,

Roger E. Linnemann, M.D.

REL:sk

rmc
radiation management corporation

PRESIDENT

UNIVERSITY CITY SCIENCE CENTER

3508 MARKET STREET
PHILADELPHIA, PA 19104
(215) 243-2950

November 21, 1979

Mr. R.W. Heward
Manager, Radiological Controls for
TMI #2 Recovery
METROPOLITAN EDISON COMPANY
P.O. Box 480
Middletown, PA 17057

RE: Visit to Three Mile Island on August 30, 1979

Dear Mr. Heward:

According to the records in my files, on August 30, 1979 I was asked to visit Three Mile Island to examine five employees who were overexposed to radiation. I was at TMI from 3:30 to 6:00 p.m. The examinations were at the request of Dick Dubiel.

History: While repairing a leaky valve in the primary collant circuit, five employees were exposed to radiation. They were wearing anti-C clothing and self-contained respirators. They had TLD dosimeters on various parts of the body, including the anterior portion of the tibia and the chest and ankles. The clothing was in tact; and the skin was not directly contaminated with primary coolant that leaked from the valve.

The emersion gamma dose was 15 R/hour. They were allowed to stay in there approximately 4 minutes. An overexposure was first detected on examination of the TLDs, which showed an increased beta dose. The highest dose to the legs was reported to be on the right lower leg of one employee, 148 rem; and the highest dose on the body was to the anterior chest of another employee, 30 rem. Gamma dosimeters recorded approximately 650 to 750 millirem.

The whole body counting was unremarkable. None of the five employees had any signs or symptoms of overexposure to radiation. Their main concern was anxiety about the dose by themselves, their families and the press. On examination of the skin they reported no evidence of reddening of the skin on any part of their body. Examination of the skin of the legs of the two employees with highest reported doses on this date was negative.

continued....

rmc

My impressions at this time were:

1) Possible skin overexposure to beta radiation according to the badge readings.

2) No evidence of significant gamma exposure according to badge readings.

3) Exposure to the skin, if correct according to badge readings, is not medically significant now or in the future.

My recommendations were:

1) 3 days of urine and fecal bioassay.

2) Analysis of the source of radiation to explain the high energy betas necessary to penetrate 3 layers of clothing and tape over the badge.

3) Plant should send me final dose assessments as soon as they are available.

4) No further bioassay testing pending final dose assessments.

Comment: I spent approximately two hours with the five employees discussing the biological effects of radiation, particularly as it pertains to the skin. I emphasized the large doses (approximately 600-800 R) required to develop a temporary erythema, and that cancer of the skin due to radiation exposure has not been documented, unless a previous chronic radiodermatitis had developed. This latter does not occur with the doses received.

I hope this is satisfactory.

Sincerely,

Roger E. Linnemann, M.D.