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VIRGINIA ELECTRIC AND POWER COMPANY

BETA DOSIMETRY REPORT

(Number 2)

BY:

CORPORATE HEALTH PHYSICS

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TABLE OF CONTENTS

INTRODUCTION

On April 11, 1983, Virginia Electric and Power Company (Vepco) received a Confirmation of Action Letter (CAL-280/83-01 and CAL-281/83-01) from the Nuclear Regulatory Commission (NRC) pertaining to the Surry Power Station. Item Number 3 stated, "By July 5, 1983, complete an evaluation to resolve the discrepancy between beta radiation dose measurements made with portable survey instruments and measurements made with thermoluminescent dosimeters. Until this evaluation is completed, retain detailed survey records to provide sufficient information to adjust thermoluminescent dosimetry results, should such adjustment become necessary. Also, until the above evaluation is completed, control personnel exposure to beta radiation based on dose rate measurements made with portable survey instruments".

In order to resolve this item, Vepco developed the following action plan:

1. Empirically identify the beta spectral components;

2. Determine the response of the beta survey instrumentation (Eberline Model RO2A) to the identified spectra and determine a correction factor for this instrumentation;

3. Assess the beta dose to the lens of the eye as it relates to whole body dose;

4. Determine if a beta source similar to the identified station beta spectra is available;

5. Review the thermoluminescent dosimetry (TLD) beta dose algorithms with respect to the identified station spectra in order to determine if a correction factor is required;

6. Expose TLD's to a beta slab source at known distances and dose rates to determine a TLD correction factor;

7. Compare the TLD dose algorithm for Strontium/Yttrium-90 to the correction factor determined using the beta slab source.

On August 12, 1983, Corporate Health Physics issued a report that addressed Items 1-3 above. A subsequent request to the NRC for a 90 day extension from the July 5, 1983, deadline to facilitate completion of Vepco's action plan was granted. This report addresses Items 4-7.

In the first report, Vepco empirically identified the beta spectral components as being, primarily, isotopes of cobalt and cesium. From analysis of the collected data a beta spectral distribution with a maximum beta energy of 0.631 MeV was determined to be representative of Surry's spectra.

Vepco retained the services of the University of Lowell for the performance of TLD irradiations and to perform beta spectral measurements to confirm that the maximum beta energy incident on the TLD's was approximately 0.631 MeV. TLD badges were supplied for the irradiations by both North Anna and Surry. Also, TLD "control" badges were used to detect any systematic bias in the readouts.

A thallium-204 point source rather than a slab source, as stated in Item 7, was used for both the TLD irradiations and the RO2/RO2A correction factor determination. This change was made based on point source beta spectral data published by Idaho National Engineering Laboratory (INEL) and Eberline Instrument Corporation, Figures 4 and 5 respectively, referenced in the August 12, 1983, Beta Dosimetry Report.

TLD BADGE DESIGN & DOSE ALGORITHM

The TLD badges are Teledyne model PB-3 badges containing a $CaSo_4$:Dy phosphor impregnated teflon ribbon (see Figure 1). The badge has four filtered areas: Area 1, 7 mg/cm^2 mylar window; Area 2, 1000 mg/cm^2 of teflon; Areas 3-4, 0.136 inches of copper and aluminum. Area 1 filters out only those radiations normally filtered out by the epidermis; photons less than 7 keV, betas less than 70 keV, and all alphas. Area 2 filters out all the betas of energies less than 2.2 MeV and most photons less than 15 keV. Areas 3 and 4 are used solely to monitor photons between 30 keV and 3 MeV to within $\pm$20%.

The beta dose algorithm developed by Teledyne, which follows, is based on strontium/yttrium-90 betas in accordance with the beta standard chosen in ANSI N13.11, Criteria for Testing Personnel Dosimetry Performance.

TELEDYNE ISOTOPES BETA DOSE ALGORITHM

Beta dose equivalent (β)

(1) $\beta = 0.90\ [A1 - A2(1.12 - 0.05R + 0.02R^2)]$
for A2 and A4 $\geq$ 10 mrem and R $<$ 4

(2) $\beta = A1 - A2\ (1.2 + 0.04R^2)$
for A4 $\geq$ 10 mrem and R $\geq$ 4

(3) $\beta = 0.90\ (A1 - A2)$
for A2 or A4 $<$ 10 mrem

A1 = net open window value
A2 = net teflon beta filter value
A3, A4 = net slotted copper filter + aluminum filter value

Net Value = TLD reading - control

R-value - An indication of the incident photon energy.
If the value of R is less than 4, the high photon energies predominate.
If the value of R is greater than 4, the low photon energies predominate.

R = A2/A4

Note that R is indeterminate for A4 = 0.

For the beta dose calculation, if R is less than 1.0 set it equal to 1.0 and perform the calculation.

Equations 1 and 2 are used to calculate the beta dose in the presence of a high or low energy photon field respectively, while Equation 3 is used to calculate the beta dose when the photon contribution to the dose is negligible. Calculations in this report were based on Equation 3 since the badges were irradiated by only betas. It should be noted that the stations generally use Equation 1 and that Equations 1 and 2 are variations of Equation 3 with an extra term used to correct for any photon over-response in area 2.

IRRADIATION

Vepco contracted the University of Lowell to perform the necessary thallium-204 beta irradiations of the Teledyne PB-3 badges. Beta spectral measurements were also performed to confirm that the air attenuated beta spectral maximum approximates the 631 keV endpoint energy which was determined to be characteristic of Surry's beta field. The actual beta endpoint energy of the beta spectra used in the irradiations was 628 keV as measured with an NE-102 plastic scintillator. Fourteen badges were irradiated in two groups of seven on a lucite phantom. The absorbed dose rate was 44 mrad/hr as measured at a 7 mg/cm^2 depth and the total delivered dose to the badges was approximately 1954 mrad.

RESULTS

TLD readings, using a Teledyne Model 8300 and 9150 reader at Surry and North Anna respectively, are shown in Tables 1 and 2. Examination of this data indicates that:

1. The TLD response is independent of the TLD reader used.

2. The TLD beta dose algorithm under-responds by a factor of 2.24 and 2.27 at Surry and North Anna respectively.

3. The Teledyne algorithm should be modified to correct for the under-response.

The station results were analyzed as a single group of readings, since each set of data was within 2 sigma of each other and indicates an under-response factor of $2.25 \pm 7.9\%$.

Correction of the Teledyne algorithm is accomplished by multiplying each equation by the correction factor of 2.25. The modified equations are listed below.

MODIFIED TELEDYNE ISOTOPES BETA DOSE ALGORITHM

Beta dose equivalent (β)

(1) $\beta = 2.03\ [A1 - A2(1.12 - 0.05R + 0.02R^2)]$
for A2 and A4 $\geq$ 10 mrem and R $<$ 4

(2) $\beta = 2.25\ [A1 - A2(1.2 + 0.04R^2)]$
for A4 $\geq$ 10 mrem and R $\geq$ 4

(3) $\beta = 2.03\ (A1 - A2)$
for A2 or A4 $<$ 10 mrem

RECOMMENDATIONS AND CONCLUSIONS

The result of the TLD badge irradiations to the thallium-204 beta source indicates that the beta response of the Teledyne PB-3 badge is not independent of energy and the Teledyne beta dose algorithms should be modified to reflect the beta spectra found at Surry Power Station. Therefore, it is recommended that Surry adopt the modified Teledyne Isotopes beta dose algorithm for in plant personnel dosimetry applications. These results and recommendations should resolve the concern about the beta response of the Teledyne PB-3 badges.

It is recommended that the modified beta dose algorithm be adopted for use by Surry for its personnel dosimetry program. However, it would still be appropriate to use the strontium/yttrium-90 based equations for confirmatory measurements and National Voluntary Laboratory Accreditation Program (NVLAP) certification tests.

Figure 1 Teledyne Isotopes Whole-Body Dosimeter

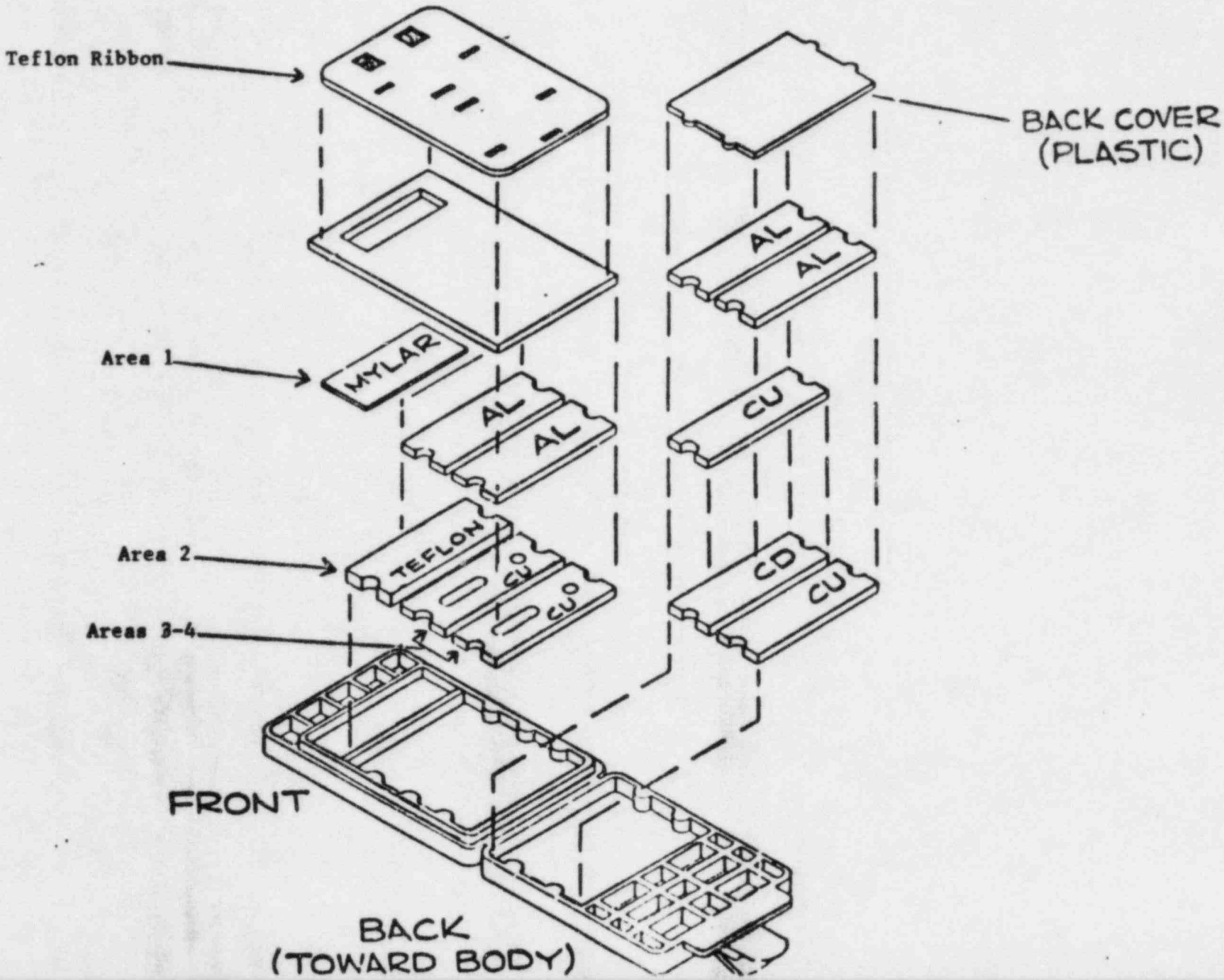

TABLE 1

Surry TLD Results

TLD	Delivered Dose (mrad)	Reported Dose (mrad)	Correction Factor
1	1954.0	927.0	2.11
2	1954.0	854.1	2.29
3	1954.0	950.4	2.06
4	1954.0	870.3	2.25
5	1954.0	749.7	2.61
6	1954.0	892.8	2.19
7	1954.0	891.9	2.19

$\overline{X}$ = 2.24

σ = 0.179

TABLE 2

North Anna TLD Results

TLD	Delivered Dose (mrad)	Reported Dose (mrad)	Correction Factor
1	1954.0	770.86	2.53
2	1954.0	781.66	2.50
3	1954.0	861.76	2.27
4	1954.0	896.86	2.18
5	1954.0	979.66	1.99
6	1954.0	902.26	2.17
7	1954.0	879.76	2.22

$\overline{X}$ = 2.27

σ = 0.191