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SKIN DOSE FROM DISTRIBUTED RADIOACTIVE SOURCES AND HOT PARTICLES - REGULATIONS AND RECOMMENDATIONS.

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ABSTRACT

The issues concerning Beta Dosimetry, Hot Particle Dosimetry, and associated dose to skin have been highlighted since the 1979 TMI-2 accident report of the Presidential Commission. The conclusions drawn from the DOE/EML International Beta Dosimetry Symposium of 1983 are still valid. The questions of location(s) of the radiosensitive layer of human skin, the most valid method of skin dose measurement, and interpretation of associated radiobiological data are still lingering. The need for improving beta calculation standards and procedures are more evident now than in 1983. This paper will discuss the newest ICRP and NCRP recommendations, as well as the regulations and guidelines from the NRC. I would expect that the draft recommendations published in this paper will be considerably changed by the time of the January, 1991 presentation of this paper.

INTRODUCTION

Beta dosimetry issues have been in current focus since Three Mile Island Unit 2 accident dosimetry highlighted the basic problems. The 1979 Report to the President's Commission on the Accident at Three Mile Island[1] discussed beta dosimetry problems in the health physics sections. Both the Nuclear Regulatory Commission's Rogovin Report on TMI[2] as well as the Health Physics "Blue Ribbon" Committee Report[3] discussed beta dosimetry problems in general terms.

Participants in a DOE-EML Beta Dosimetry Workshop (12/81) recommended an international Beta Dosimetry Symposium which was held in February, 1983, chaired by Thomas Gesell, and sponsored by Department of Energy, Nuclear Regulatory Commission and the Health Physics Society (Reference 4). The Conclusions drawn from this 1983 Symposium are as equally valid today as they were then:

1. It is apparent that the 7 mg/cm^2 (or 5-10 mg/cm^2) depth at which the sensitive layer of the skin is defined is seriously in question when compared with empirical biological data. The overwhelming consensus of the symposium participants was that a representative(s) of the organizers communicate a formal request to the NCRP and the several Federal agencies to re-evaluate the scientific bases for the current standard and formulate a more realistic one. A finite sensitive skin layer, say from 10 to 40 mg/cm^2 would be more realistic biologically and would coincidentally simplify the measurement process.

2. It was emphasized that low energy photons are also "non-penetrating" and should be reported as "skin" dose also. Tissue equivalent detectors are essential in order to provide a system in which the calibration factor converting response of the detector to dose is the same for both radiation types.

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3. It was generally conceded that though the measured personnel doses in mixed fields have been inaccurate, they have been over-reported in most cases. Though this results in a conservative approach to personnel protection, it is a poor policy since total plant exposures are generally higher through more frequent personnel changes, and thus any subsequent epidemiological studies of radiation effects would be biased.

4. There was a recurring expression of need for consistent guidance in the area of 1) definition of skin areas of concern (1 cm^2 or 100 cm^2 and 2) what constitutes an extremity (finger tip or hand). Standard-making organizations should be requested to study the needs in this area and formulate practical guidelines.

5. Since personnel dosimeters are small and the dose rate and spectrum can change dramatically over the surface area of the body in low penetrating radiation environments, additional guidance is also needed to assist in 1) dosimeter placement, and 2) wearing location(s) (under clothing or not).

6. The need for improved portable survey instruments was recognized, including:

   a. Tissue-equivalent response independent of energy and radiation type.

   b. Ability to measure dose rates at "shallow" and/or "deep" depths.

   c. Micro-Electronic processing of data for ease and speed of data reduction in the field.

7. It was recognized that when evaluating a "new" hazard, frequently data collected are more extensive than required after the hazard has been adequately defined. Beta (nonpenetrating) dosimetry is at the point in its development where a large amount of data is required. Some parts of the nuclear industry are believed not to have significant beta problems (mining, perhaps uranium mills, etc.) but will require more analyses with improved instruments in order to adequately establish this as a fact. However, it is becoming increasingly clear that though the beta dose may not be limiting, there is increased need to accurately document the actual dose received.

8. It is apparent that beta calibration standards and procedures are inadequate. There was a call for the establishment of secondary standards calibration labs and intercalibration programs.

9. There are new information and calculation/analytical techniques currently becoming available. However, the need for improved dose calculational techniques was noted. It was recommended that facilities and persons with recognized abilities in this area produce the improved techniques on a high priority basis and make them available in the literature and through the distribution list of those attending this symposium.

The guidance requested above is still urgently needed.

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NEW HOT PARTICLE GUIDANCE

1. The NCRP Report 106[15] completely sidesteps the issue of the location of the target depth in skin for performing beta dosimetry. The location of the cells at highest risk, which is the depth at which we should be averaging dose, is known to be different for stochastic and non stochastic effects (Ref. 19). This Report also does not address the issue of what skin area should be averaged for reporting dose. As you can see from Table 1, the earlier recommendations for averaging dose to skin vary from one to 100 cm^2 areas. The NCRP Report 106 states that a specific area for averaging hot particle dose is "inappropriate".

2. This Report 106 on Hot Particles, is highly specialized, and does not apply to:

   a. distributed (general) skin contamination
   b. skin exposure from distant sources
   c. inhalation of hot particles (I know of only one case)
   d. ingestion of hot particles
   e. hot particles in eyes
   f. hot particles in eardrum
   g. hot particles on male gonad

3. Although the limit of 75 pCi hr. per exposure incident appears reasonable, the NRC, in its enforcement policy has the option of citing the licensee (when below 75 pCi hr. exposure) for poor practice in cases where the NRC feels the exposure was reasonably avoidable.

NEW CRITERIA FOR GENERAL SKIN EXPOSURE

An earlier draft (1988) of the proposed New 10CFR20 had 100 cm^2 as the area of skin to be averaged. This dose averaging area was changed back to 1 cm^2, but there seems to be no good technical answer for why only one cm^2. Thus we have the situation where the NRC had the opportunity to average over a more reasonable (100 cm^2) area of skin, but has chosen not to do so. Refer to Table 1.

The newest ICRP draft (Recommendations of the Commission February, 1990) recommends an area of 100 cm^2 for averaging skin dose in the case of surface contamination, and an area of the highest 1 cm^2 in the case of accidental irradiation.

ICRP26 (Ref. 14) in 1977 recommended a skin dose limit of 0.5 Sv/yr (50 rem/yr). Initially, I believed that this was a very conservative dose limit that was chosen so as to be the same as several other organs. Further investigation revealed that this 0.5 Sv/yr skin dose limit is not so conservative, because of the synergistic effect of utraviolet radiation (UVA) and ionizing radiation, as well as the lack of information concerning how radiation effects the immune functions associated with the cells of the epidermis (Langerhans cells).

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SKIN DOSE AND CONTAMINATION INCIDENTS

HISTORY OF HIGH DOSES TO HANDS AT NUCLEAR POWER STATIONS (Fig. 1)

Peach Bottom (October 1981)

A maintenance worker received an unplanned exposure to the hand while visually inspecting the inservice fuel inspection platform at the Unit 2 spent fuel pool (SFP). This exposure occurred when the worker picked up fuel channel clips from the fuel elevator with his hand. The area radiation monitors alarmed. A nearby radiation control technician immediately instructed the maintenance worker to put down the fuel channel clips. The clips were then placed into a bucket in the spent fuel pool. Subsequent radiological survey of the fuel channel clips indicated a gamma dose rate of 3.2 R/hr at 1.8 inches. Exposure to the worker's hand was estimated at 527 mrem.

Sequoyah (August 1982)

Two flow tests of reactor systems performed in August 1982, using Na-24 as a tracer, resulted in an extremity exposure to one worker of 10 rem. Because this exposure was higher than those incurred during past flow tests, the licensee initiated an investigation to determine the cause of the high exposure. The licensee concluded that because of the high contact dose-rate (1.5 R/sec) of the Na-24 source vial, its cap should not be removed by hand as was the case in previous tests; instead remote handling tools should be used. The licensee also concluded that, because Na-24 is not commonly used at nuclear power plants, health physics management should provide better training and pre-job planning to both radiological control technicians (RCTs) and radiation workers with regard to the handling of radionuclides, such as Na-24, used in flow testing. Based on this event, the licensee determined that prior to 1982, extremity dose evaluation for flow testing had underestimated the actual doses, and that the extremity monitoring program for the plant should be upgraded.

Rancho Seco (July 1984)

After the completion of a tube plugging job, a worker entered the steam generator to vacuum loose debris. The worker picked up an object that was too large to be vacuumed and tossed it out of the steam generator. The object had been earlier identified as part of a high pressure injection nozzle thermal sleeve. The radiation level of the object read 28 R/hr at six inches. A licensee radiation protection investigation concluded that no overexposure had occurred.

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Point Beach (April 1989)

An inservice inspection (ISI) engineer received a dose to the hand of 4.7 rem during a closeout inspection of the Unit B steam generator. The exposure occurred when the engineer picked up an object and passed it outside the steam generator without knowing that the radiation level of the object read 200 R/hr at near contact.

TMI-2 (September 1989)

Two workers handled a piece of material believed to be fuel debris. The RCT monitoring the work was unaware that the workers had handled the object. After the RCT surveyed the object, it was returned to the reactor vessel because of its high dose rate. The licensee initiated an inquiry when the first worker, on the following day, asked another RCT about the health implications of handling fuel debris. The calculated skin dose to the left hand of one of the workers was 55 rem.

SUMMARY OF FITZPATRICK INCIDENT OF 1990

On March 8, 1990 Worker P inadvertently contaminated his right glove and cross contaminated a 4 cm^2 area of the skin (pad) of the left hand with ^{24}Na.

The most accurate dose assessment for Worker P is 16.335 rads β and .728 rads γ (total of 17.06 rads per cm^2) to the live tissue of the skin of the left thumb. This is the highest square centimeter dose to an area just under 64 mg/cm^2 of stratum corneum (dead skin). A special series of computer runs were performed to determine the gamma portion of the dose. The beta dose was calculated by both the Cross (Reference 17) and the VARSKIN (Reference 18) methods and indicated agreement to within a few percent.

The NRC on site inspection team (O'Connell and Chawaga) requested that the dose be calculated at a depth of 0.007 cm ($7mg/cm^2$). This dose is 48.2 rads β + 0.57 rads γ to yield a total of 48.8 rads per cm^2. For this contamination incident, it is biologically and anatomically inappropriate to calculate the dose to an area below only 7 mg/cm^2 of stratum corneum.

This dose to the skin of the left thumb is well below the threshold for any observable skin effects. Medical personnel verified this by observing no first or second wave erythema (reddening of the skin) on Worker P.

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RECOMMENDATIONS FROM FITZPATRICK INCIDENT (AND SIMILAR INCIDENTS)

Review lessons learned from this incident with all operational and appropriate support personnel. (This includes a review of what should have been covered in the ALARA Pre-Plan Meeting for the ^{24}Na Feedwater Flow Test.)

All Health Physics and Chemistry Professionals and Senior Technicians should attend a Professional Enrichment Course concerning β hazards and associated β assay and dosimetry.

The Skin Decontamination Procedure should be revised to include the requirements to obtain medical permission to utilize agents other than soap, water and surgical scrubs (i.e. Potassium Permanganate/ Sodium Bisulfate or stronger solutions). The "Medical Assistance" section should encourage the person having difficulty tin decontaminating to obtain medical assistance.

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FIGURE 1

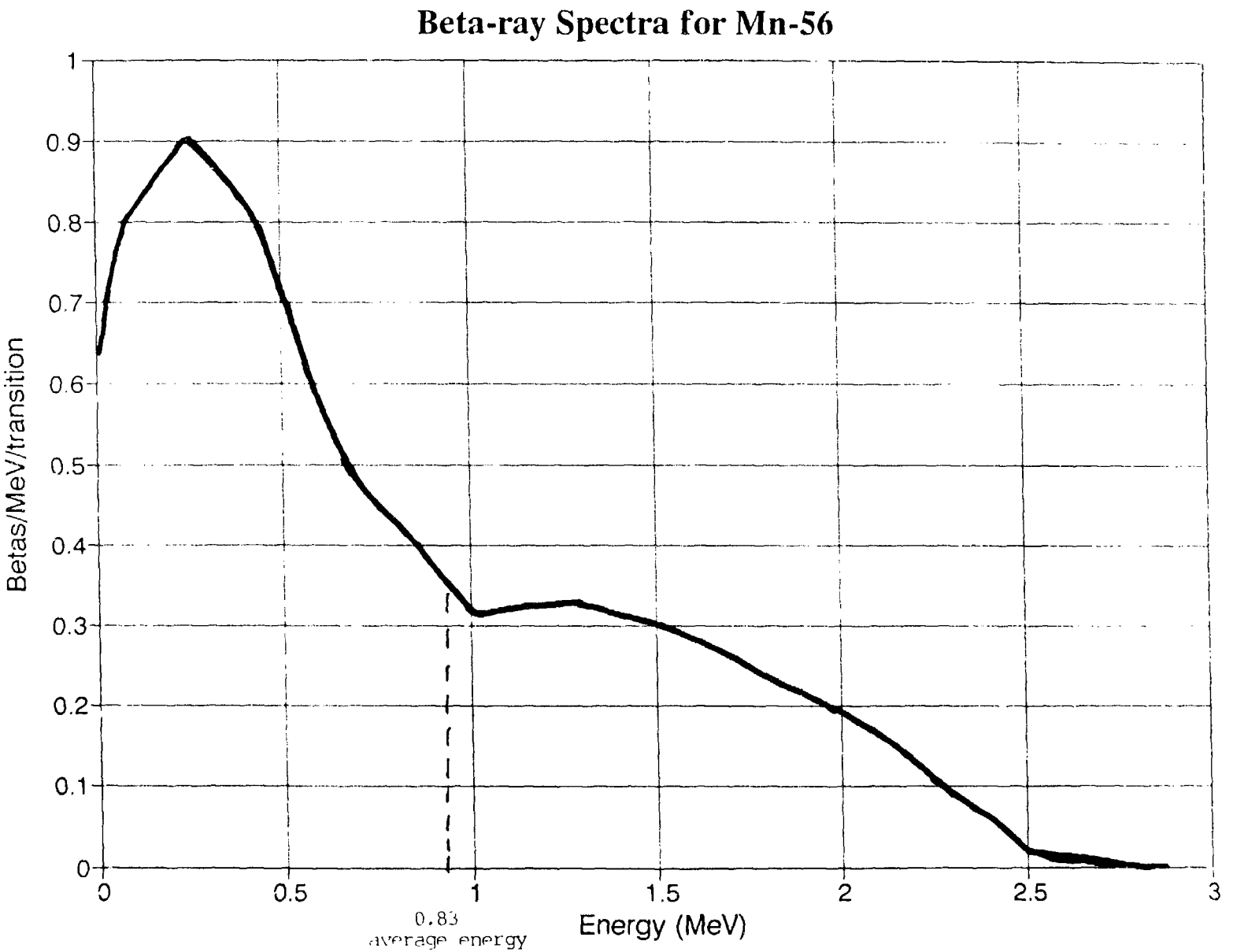
Beta-ray Spectra for Mn-56
Betas/MeV/transition
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.5
1
1.5
2
2.5
3
0.83
average energy
Energy (MeV)

TABLE 1 (cont.)

Recommendations Concerning Dose to the Skin

Year Organization	Dose/Year	Dose/Quarter	Area to average over	Depth for Measurement	Extemity Dose
1989 ICRP DRAFT on Hot Particle	300 rads/cm^2 (may not be limited to cm^2 area)		"No biological bases for 1 cm^2 average"	10-15 mg/cm^2	Not Addressed
1990 NCRP Committee 89-1 (Report No. 106) Limit for Exposures to Hot Particles on the Skin	Maximum of 75 HCi-hr exposure for hot particles in in contact with skin		NA (particle $\leq\approx$ 1 mm diameter	NA (Can calculate activity to skin surface)	NA Note: exposures > 75 µCi-hr. require medical evaluation
May, 1989 NRC Staff Recommendation to ACRS on Hot Particle (INTERIM)	50 rads/cm^2 per hot particle. No notice of violation for single exposure below 50 rads.	1 hot particle per quarter	1 cm^2 (no limit on size of hot particle)	7 mg/cm^2	NA
PRESENT REGULATION Code of Federal Regulations 10 CFR 20.101 (Since early 1960s)	30 rem/yr.	7.5 rem/qtr.	1 cm^2	7 mg/cm^2	75 rem/yr. 18.75 rem/qtr.
NRC Info. Notice 90-48 Aug 2, 1990 Enforcement Policy for Hot Particle Exposures	75 µCi-hr exposure for Hot Particles in contact with skin	qtr. limit dropped	NA	NA	Note: exposures >75 µCi/hr require medical evaluation
New 10CFR20 as of Jan. 1992	50 rem/yr	Qtr. limit dropped	1 cm^2	7 mg/cm^2	50 rem/yr qtr. limit dropped