

photons incident on the phantoms from various locations. Empirical algorithms were developed to relate the  $EDE_{ex}$  resulting from the full range of exposure situations to the indicated doses that could be measured at the surface of the body. Two algorithms were developed to estimate  $EDE_{ex}$  from just two dosimeters worn on the trunk of the whole body (front and back, respectively). The first algorithm is a simple, non-weighted averaging of the front and back dosimeter readings. The second algorithm weights the higher of the two dosimeter readings.

### 5.0 Technical Evaluation

The staff reviewed the technical descriptions of the EPRI method for estimating  $EDE_{ex}$ ; the resulting data and conclusions contained in Technical Report TR-101909, Volumes 1 and 2; Implementation Guide TR-109446 and the supporting technical papers published by the principal EPRI investigators. The staff also performed independent calculations to verify a sampling of the results tabulated in these documents.

The EPRI work indicates that a single dosimeter (calibrated to read DDE), worn on the chest, provides a reasonably accurate estimate of  $EDE_{ex}$  when the individual is exposed to a number of randomly distributed radiation sources during the monitoring period. This is consistent with current allowable dosimetry practices and requires no special approval. The alternate definition of TEDE requested, would allow the licensee the option to monitor worker dose with a single DDE measurement as currently required, or to control TEDE using  $EDE_{ex}$  (as determined by the EPRI two badge method) in situations where monitoring the highest DDE would require moving, or supplementing, the single badge.

The data presented in the EPRI reports indicate that the weighted two-dosimeter algorithm provides a reasonably conservative estimate of  $EDE_{ex}$ . However, the non-weighted algorithm does not always give a conservative result. The licensee has stated that it will only use the weighted two-dosimeter algorithm such that:  $EDE_{ex} = \frac{1}{2} (MAX + \frac{1}{2} (R_{front} + R_{back}))$  where  $R_{front}$  is the reading of the dosimeter on the front of the body,  $R_{back}$  is the reading of the dosimeter on the back of the body, and MAX is the higher of the front or back dosimeter readings.

Additional issues and limitations noted in the staff's review are included in the following paragraphs.

Partial-body irradiations, that preferentially shield the dosimeter,

could bias the EPRI method results in the non-conservative direction. The licensee has stated that they will ensure that the dosimeters are worn so that at least one of the two badges "sees" the source(s) of radiation. In other words, the radiological work will be conducted, and the dosimeters worn in such a way, so that no shielding material is present, between the radioactive source(s) and the whole body, that would cast a shadow on the dosimeter(s) not cast over other portions of the whole body.

Isotropic dosimeters (e.g., dosimeters that respond independently of the angle of the incident radiation) are impractical and not widely available commercially. Therefore, the licensee must implement the EPRI method using dosimeters that will have an angular dependent response. If the dosimeter reading decreases more rapidly than  $EDE_{ex}$ , with increasing exposure angle, the resulting  $EDE_{ex}$  estimate will be biased in the non-conservative direction. The EPRI principle investigators have addressed this issue of angular dependence in their published technical paper entitled "A Study of the Angular Dependence Problem In Effective Dose Equivalent Assessment" (*Health Physics* Volume 68, No. 2, February 1995, pp. 214-224). The licensee has stated that the dosimeters used to estimate  $EDE_{ex}$  will have demonstrated angular response characteristics at least as good as that specified in this technical paper. In addition, the dosimeters will be calibrated to indicate DDE at the monitored location, to ensure their readings reflect electronic equilibrium conditions.

The EPRI method for estimating  $EDE_{ex}$  from two dosimeter readings is not applicable to exposure situations where the sources of radiation are nearer than 12 inches (30 cm) from the surface of the body. Tables 5 thru 7 in EPRI TR-101909, Volume 2, provide calculated  $EDE_{ex}$  values resulting from exposure to point sources in contact with the torso of the body. However, the staff review determined that the information provided in these tables does not bound all of the pertinent point source exposure situations. The licensee has stated that the use of  $EDE_{ex}$ , to determine compliance with the TEDE limit, resulting from point sources (i.e., hot particles) on, or near the surface of the body, is outside the scope of this request.

Table 8 in TR-101909, Volume 2, provides a summary of the  $EDE_{ex}$ , and dosimeter (front and back) readings calculated for parallel beams and point sources used to develop the EPRI algorithms. However, the magnitude of the units for the parallel beam dose

factors listed are low by five orders of magnitude (e.g., "E-15 rad-cm squared per photon" instead of the correct "E-10 rad-cm squared per photon"). This error does not effect the conclusions drawn from the data. However, the specific dose factors listed in Table 8 should not be used to calculate  $EDE_{ex}$ .

When EDE is used to calculate TEDE under the revised definition, the requirement in 10 CFR part 20.1201(c), that DDE be determined for the part of the body receiving the highest exposure, is not applicable. However, when TEDE is calculated using the DDE (i.e., from a single dosimeter reading), 10 CFR 20.1201(c) does apply.

The exemption applies only to the definition (and methods for calculating) TEDE. It does not modify the dose limits for any individual organ or tissue, or the methods for complying, specified in 10 CFR part 20 (i.e., 10 CFR 20.1201(a)(1)(ii), (a)(2) and 10 CFR 20.1208). The licensee is still required to provide surveys and monitoring necessary to demonstrate compliance with these requirements.

### 6.0 Evaluation Summary

The staff concludes that calculating TEDE using  $EDE_{ex}$  as proposed by the licensee in place of DDE provides a more accurate estimate of the risk associated with the radiation exposures experienced by radiation workers at a nuclear power plant. Additionally, the staff finds that the proposal to limit TEDE such that

$$EDE_{ex} + CEDE \leq 5 \text{ rem}$$

is consistent with the basis for the limits in 10 CFR part 20. Therefore, subject to the limitations noted above and agreed to by the licensee, defining TEDE to mean the sum of  $EDE_{ex}$  or DDE (for external exposures) and CEDE (for internal exposures), in lieu of the current 10 CFR 20.1003 definition, is acceptable.

Additionally, the staff concludes that the methods for estimating  $EDE_{ex}$  described in EPRI Technical Report TR-101909, Volumes 1 and 2, and Implementation Guide TR-109446 are based on sound technical principles. The proposed EPRI weighted, two-dosimeter algorithm provides an acceptably conservative estimate of  $EDE_{ex}$  with a degree of certainty that is comparable to that inherent in the methods allowed by 10 CFR part 20 for estimating CEDE. Therefore, subject to the limitations noted above, using the EPRI weighted, two-dosimeter algorithm so that

$$EDE_{ex} = \frac{1}{2} (MAX + \frac{1}{2} R_{front} + R_{back}))$$