Department of Energy
Office of Worker Safety and Health Policy
Issue Paper on Potential Effects of a Decrease in the Limit for Equivalent Dose to the Lens of the Eye

Issue

On April 21, 2011, the International Commission on Radiological Protection (ICRP) issued a statement (ICRP reference 4825-3093-1464) that recommended lowering the limit on the equivalent dose to the lens of the eye (EqD-Eye) from 15 rems/year to 10 rems in 5 years with the dose in any single year limited to 5 rems. The ICRP based this recommendation on a review of information they interpreted as indicating that the threshold for radiation-induced effects in the lens of the eye was significantly lower than previously expected.

In response to ICRP's recommendation on EqD-Eye:

- The Nuclear Regulatory Commission (NRC) decided to include this recommendation as part of the material undergoing evaluation for a potential revision of NRC's radiation protection requirements in title 10, Code of Federation Regulations (C.F.R.), part 20.
    - In response to NRC's decision, the Health Physics Society sent a letter to NRC recommending that NRC collect information on cataract removal rates in current and retired workers and evaluate the practical impact of lowering the EqD-Eye limit before proposing any changes to the EqD-Eye limit.
    - In response to NRC's request for public comments published in the Federal Register (Docket ID NRC-2009-0279), Department of Energy (DOE) submitted responses to 10 questions contained in this Federal Register publication related to the impact of decreasing the EqD-Eye limit.
- The International Atomic Energy Agency (IAEA) incorporated this recommendation in its latest version of its basic safety series [General Safety Requirements Part 3 (Interim)]. Note that the laws of some countries require that they adopt IAEA or ICRP recommendations.

Because of the potential that some countries may change the EqD-Eye limit, DOE believes it is useful at this time to review the current requirements, guidance, and basic considerations pertinent to controlling and monitoring EqD-Eye and to discuss potential effects of a decrease in the EqD-Eye limit.

Currently Applicable Requirements and Guidance

Currently applicable requirements of EqD-Eye are contained in 10 C.F.R. 835, *Occupational Radiation Protection*, sections 2(b), 202(a)(3), and 402(a)(1)(iii). Currently applicable guidance is contained in DOE Guide (G) 441.1-1C Change (Chg) 1, *Radiation Protection Programs Guide for use with Title 10, Code of Federal Regulations, Part 835, Occupational Radiation Protection*, section 6.4.1.1. Appendices A and B below contain the full text of the sections cited above.

Discussion

Controlling and monitoring of lens of the eye dose

A review of the Radiation Exposure Monitoring System's (REMS) database reveals that DOE organizations reported measurable dose to the lens of the eye for approximately 80 percent of DOE workers currently issued dosimeters of any kind. Although the most accurate method to monitor EqD-Eye is to use a dosimeter element with a 300 mg/cm^2 shield, in almost all cases either the whole-body dose monitoring result or the skin dose monitoring result, or both, were used as a surrogate for monitoring the lens of the eye dose. There are limitations associated with using measurements of skin and whole-body dose as a surrogate for lens of the eye dose for various exposure situations because skin and whole-body dose are assessed at 7 mg/cm^2 and 1000 mg/cm^2, respectively, while the lens of the eye dose is assessed at 300 mg/cm^2. Table 1, below, summarizes key considerations in using skin or whole-body dose to monitor for EqD-Eye.

Table 1: Methods to Assess Eye Dose (EqD-Eye)
Using Dosimeter Elements with Filter Thicknesses Other than 300 mg/cm^2

Dosimeter element filter thickness[a] / **Exposure type**	**1000 mg/cm^2 (Whole body[b])**	**7 mg/cm^2 (Skin)**
Uniform photon (gamma, x ray) fields	• Provides unbiased assessment, independent of dosimeter location, except for photon radiation fields where the 300 mg/cm^2 dose exceeds the 1000 mg/cm^2 dose (fields with a significant dose component due to photons with energies less than 40 keV)	• Provides unbiased assessment, independent of dosimeter location • May overestimate dose from low energy photon fields
Nonuniform photon fields (Maximum dose to the lens of eye and head area)	• Provides unbiased assessment if dosimeter worn near the eyes, except for photon radiation fields where the 300 mg/cm^2 dose exceeds the 1000 mg/cm^2 dose; e.g., fields with a significant dose component due to photons with energies less than 40 keV • May under estimate eye dose if assessing whole-body dose using multiple dosimeters and compartmental method	• Provides unbiased assessment if dosimeter worn near the eyes • May overestimate dose from low energy photon fields
Nonuniform photon fields (Maximum dose not to the lens of eye and head area)	• Provides unbiased assessment if dosimeter worn near the eyes, except for photon radiation fields where the 300 mg/cm^2 dose exceeds the 1000 mg/cm^2 dose; e.g., fields with a significant dose component due to photons with energies less than 40 keV	• Provides unbiased assessment if dosimeter worn near the eyes • May overestimate dose from low energy photon fields

Dosimeter element filter thickness[a] / Exposure type	1000 mg/cm^2 (Whole body[b])	7 mg/cm^2 (Skin)
	• May over estimate eye dose if assessing whole-body dose using the dosimeter element that has the highest reading	
Beta radiation (radiation field located in the lens of eye and head area): Maximum energy less than 800 keV[c]	• Provides unbiased assessment (the dose to whole body and eye will be zero)	• May overestimate eye dose from this beta energy field (the overestimate increases as the beta energy increases)
Beta radiation (radiation field located in the lens of eye and head area): Maximum energy greater than 800 keV	• May underestimate beta eye dose - need to evaluate beta radiation fields and dosimeter response if using this approach • May provide unbiased assessment for fields with a significant beta dose component due to betas with energies greater than 2500 keV [d]	• May overestimate eye dose from this beta energy field (the overestimate decreases as the beta energy increases) • For beta energy less than 3500 keV compliance, the 10 C.F.R. 835 skin dose limit and monitoring threshold will ensure compliance with the 10 C.F.R. 835 lens of the eye dose limit and monitoring threshold

[a] Assessing eye dose using a dosimeter element with a 300 mg/cm^2 density thickness filter or using multi-element dosimeters and a data reduction algorithm to estimate dose to the lens of the eye at the 300 mg/cm^2 density thickness should provide unbiased estimates of EqD-Eye in most exposure situations.

[b] This element also may be used with use of protective eyewear with at least 700 mg/cm^2 density thickness so the density thickness of the lens of the eye is the same as the whole-body dosimeter element. If the dosimeter used to determine EqD-Eye is located behind face shields and respirators, consider accounting for the density thickness of such items.

[c] *Radiological Health Handbook.*

[d] "Calculation of Absorbed Dose at 0.07, 3.0, and 10.0 mm Depths in a Slab Phantom for Monoenergetic Electrons," Radiation Protection Dosimetry, Vol. 52 (1-4) 129-133 (1994).

For mixed fields; i.e., mixtures of beta radiation and either neutron and/or photon, use appropriate combinations of the exposure types listed in the table above.

Because neutron dosimeter response is very sensitive to neutron energy, as well as depth in, and location on, the body, this issue paper does not address evaluation of EqD-Eye using whole-body neutron dose.

Based on the above table, skin dose or whole-body dose provide unbiased estimates of EqD-Eye for exposures to uniform photon radiation fields having energies above 40 KeV. For radiological activities involving exposures from nonuniform x ray or gamma radiation fields or beta radiation, it may be prudent to consider monitoring EqD-Eye using a dosimeter, located near the eye, with an element filter thickness appropriate for the radiation monitored.

Protective eyewear can reduce the dose to the lens of the eye. Plastic or acrylic lenses will reduce the dose from beta radiation while lenses containing lead will reduce the doses from gamma and x-ray radiation. Protective eyewear using 1/10-inch (0.254 cm) of acrylic plastic will completely attenuate beta particles with maximum energies < 800 keV. This thickness provides protection from most beta-emitting isotopes with the exception of such isotopes as P-32, Y-90, and Pa-234.

Potential impacts of lowering EqD-Eye limit

Based on information obtained from the Department's REMS database, overall it appears that a decrease in the limit for lens of the eye dose will not have a major impact on monitoring for lens of the eye dose. Currently, the low average dose to DOE workers and the absence of very many DOE operations with the potential for significant external exposure make it unlikely that any DOE workers receive doses approaching the current 15 rems EqD-Eye limit. Review of the REMS database confirms that very few DOE workers, if any, exceeded a whole-body dose of 10 rems in 5 years, the ICRP recommended EqD-Eye limit resulting from normal DOE operations.

A review of the REMS database also reveals that DOE organizations reported measurable dose to the lens of the eye for approximately 80 percent of DOE workers currently issued dosimeters. However, in almost all cases, either the whole-body dose or the skin dose, or both, were used as a surrogate for lens of the eye dose. This suggests that for most DOE operations, the lens of the eye dose results are based on exposure to a relatively uniform radiation field of a type and energy not measurably attenuated by density thicknesses up to 1000 mg/cm^2.

Although lowering the EqD-Eye limit should not have a major impact on DOE operations, the following relatively minor impacts are anticipated for those exposure situations where the prospective EqD-Eye limit is approached.

- *Need to evaluate DOE operations more carefully with regard to the significance of eye dose:* Because lowering the EqD-Eye limit brings it closer to current DOE exposures to the lens of the eye, it will be necessary to evaluate DOE operations more carefully with regard to the significance of doses to the lens of the eye. Of particular interest will be nonuniform x ray and beta exposures to the head. Thus, there may be more situations where placing a dosimeter on the head is considered prudent.

- *Reduction in the energy level below which compliance with the 10 C.F.R. 835 skin dose limit and monitoring threshold will ensure compliance with the 10 C.F.R. 835 lens of the eye dose limit and monitoring threshold:* If the EqD-Eye limit is reduced to an average of 2 rem per

year, the energy level below which compliance with the 10 C.F.R. 835 skin dose limit and monitoring threshold will ensure compliance with the 10 C.F.R. 835 lens of the eye dose limit and monitoring threshold would decrease[1] on average from about 3.5 MeV to about 1.7 MeV.

- *Effective dose to the whole body may be limited by EqD-Eye under certain conditions:* If the EqD-Eye is reduced below 5 rems per year, then the effective dose to the whole body resulting from a uniform external exposure to the whole body will be limited by the dose to the lens of the eye. The reason is that for uniform external exposures by penetrating gamma radiation, all tissues and organs receive approximately the same equivalent dose – regardless of the depth in tissue. Under such radiation exposure conditions, the equivalent dose to the lens of the eye and the whole body (as well as skin) will be the same. If the EqD-Eye limit is reduced below the limit for total effective dose to the whole body, compliance with the EqD-Eye limit can only be achieved if the effective dose to the whole body is controlled to within the EqD-Eye limit.

  For individuals monitored for EqD-Eye using a method that results in an over estimate of EqD-Eye, the limitation on whole-body dose may be more severe than just described.

  The overall impact of lowering the EqD-Eye limit to a level equal to, or below, the regulatory limit for the equivalent dose to the whole body is to establish a *de facto* limit for effective dose to the whole body that is equal to, or less than, the EqD-Eye limit. Possible ways of addressing this impact would be to either lower the limit for total effective dose or establish a rigorous program of administrative controls or dose constraints at levels equal to, or below, the EqD-Eye.

---

[1] From table B.3 of International Commission on Radiation Protection and Measurements (ICRU) Report No. 43, for electrons of 3.5 MeV, the ratio of the dose equivalent at 7 mg/cm2 to the dose equivalent at 300 mg/cm2 is 3.8. For electrons of energies about 3.5 MeV and less, the dose to the lens of the eye will be at least a factor of 1/3.8 less than the dose to the skin.
Per 10 C.F.R. 835, the ratio of the limit for equivalent dose to lens of the eye to the limit for equivalent dose to the skin is 15 rems/50 rems or 1/3.3. Thus, controlling equivalent dose to the skin within DOE limits will control the EqD-Eye within DOE limits for beta energies less than 3.5 Mev. If the limit for equivalent dose to the lens of the eye is reduced to 2 rems, the ratio of the limit for EqD-Eye to the limit for equivalent dose to the skin becomes 2 rems/50 rems or 1/25. Per ICRU Report No. 43, for electrons of energies about 1.7 MeV or less, the dose to the lens of the eye will be less than a factor of 1/25 of the dose to the skin. Thus, controlling skin dose within DOE limits will only control the EqD-Eye within DOE limits for energies less than 1.7 MeV.

- *Monitoring issues resulting from differences in EqD-Eye limits in various countries:* A difference in the EqD-Eye limits between DOE and foreign countries may increase the need for vigilance in monitoring foreign workers performing DOE radiological activities. For example, in the future, if there are DOE workers from a foreign country having a lower EqD-Eye limit than DOE's EqD-Eye limit, it may be prudent to control these workers' EqD-Eye dose within their country's EqD-Eye limit. Particularly, if these workers plan to perform radiological work in their country of origin again during the dosimetry year or if these countries, as does DOE[2] and NRC[3], assess the dose from all exposures against their dose limits.

- *More real-time monitoring for EqD-Eye:* For radiological activities where beta radiation is a dominant source of exposure, EqD-Eye could be a problem to administratively control if the radiological control program relies on timely results from a passive dosimeter (e.g., thermoluminescence dosimeter). The use of electronic dosimeters may need to be evaluated for these types of situations.

- *Increased level and complexity of recordkeeping for EqD-Eye:* As pointed out above, DOE currently reports EqD-Eye for 80 percent of its workers issued dosimeters. Accordingly, a decrease in EqD-Eye limit could increase the fraction of workers monitored for EqD-Eye by, at the most, up to 20 percent. However, adopting the ICRP-recommended form of the EqD-Eye limit (10 rems in 5 years with no single year exceeding 5 rems) will require tracking EqD-Eye over a rolling 5-year period. Keeping track of doses over a rolling 5-year period will be much more cumbersome than the current annual tracking of doses.

Summary and Conclusion

- ICRP recommended lowering the limit for the equivalent dose to the lens of the eye (EqD-Eye) to an average of 2 rems per year. IAEA incorporated this recommendation in an interim version of the International Basic Safety Series on Radiation Protection and Safety of Radiation Sources.
- NRC is evaluating ICRP's recommendation for inclusion in a potential proposal to amend 10 C.F.R. 20.
- Minimal impacts of a decrease in the limit for EqD-Eye on DOE operations are expected.
- Potential impacts that may result are:

---

[2] Per 10 C.F.R. 835.202(b), all occupational doses received by a DOE worker are considered when determining compliance with the dose - even if the dose is received when the worker is performing radiological activities that are not covered by 10 C.F.R. 835. This provision would apply to a foreign individual who comes to DOE to work or to DOE workers who are U.S. citizens who also work in another country.

[3] Per 10 C.F.R. 20.1201(f) "The licensee shall reduce the dose that an individual may be allowed to receive in the current year by the amount of occupational dose received while employed by any other person (see § 20.2104(e))."

- Need to evaluate DOE operations more carefully with regard to the significance of EqD-Eye;
- Reduction in the energy below which compliance with the 10 C.F.R. 835 skin dose limit and monitoring threshold will ensure compliance with the 10 C.F.R. 835 lens of the eye dose limit and monitoring threshold;
- Effective dose to the whole body may be limited by EqD-Eye limit under certain conditions if the EqD-Eye limit is lowered to a level equal to less than the limit total effective dose;
- Monitoring issues resulting from differences in EqD-Eye limits in various countries;
- More real-time monitoring for EqD-Eye; and
- Increased level and complexity of recordkeeping for EqD-Eye.

- The Office of Worker Safety and Health Policy will continue to monitor the activities of ICRP, IAEA, NRC, and other scientific and regulatory bodies as they apply to limitations on EqD-Eye.

Appendix A: Currently Applicable Requirements

From: 10 C.F.R. 835, *Occupational Radiation Protection*

§ 835.2 Definitions.
(a) As used in this part:
******
(b) As used in this part to describe various aspects of radiation dose:

***Equivalent dose* (HT) means the product of average absorbed dose (DT, R) in rad (or gray) in a tissue or organ (T) and a radiation (R) weighting factor (wR).** For external dose, the equivalent dose to the whole body is assessed at a depth of 1 cm in tissue; **the equivalent dose to the lens of the eye is assessed at a depth of 0.3 cm in tissue**, and the equivalent dose to the extremity and skin is assessed at a depth of 0.007 cm in tissue. Equivalent dose is expressed in units of rem (or Sv).

§ 835.202 Occupational dose limits for general employees.

(a) Except for planned special exposures conducted consistent with § 835.204 and emergency exposures authorized in accordance with § 835.1302, the occupational dose received by general employees shall be controlled such that the following limits are not exceeded in a year:

(1) A total effective dose of 5 rems (0.05 Sv);
(2) The sum of the equivalent dose to the whole body for external exposures and the committed equivalent dose to any organ or tissue other than the skin or the lens of the eye of 50 rems (0.5Sv); and
(3) An equivalent dose to the lens of the eye of 15 rems (0.15 Sv).

§ 835.402 Individual monitoring.

(a) For the purpose of monitoring individual exposures to external radiation, personnel dosimeters shall be provided to and used by:

(1) Radiological workers who, under typical conditions, are likely to receive one or more of the following:

(i) An effective dose of 0.1 rem (0.001 Sv) or more in a year;
(ii) An equivalent dose to the skin or to any extremity of 5 rems (0.05 Sv) or more in a year;
(iii) An equivalent dose to the lens of the eye of 1.5 rems (0.015 Sv) or more in a year;

Appendix B: Currently Applicable Guidance:

From: DOE G 441.1-1C Chg 1, *Radiation Protection Programs Guide for use with Title 10, Code of Federal Regulations, Part 835, Occupational Radiation Protection*

6.4.1.1 Lens of the Eye Monitoring

The equivalent dose to the lens of the eye is assessed at a depth of 0.3 cm in tissue (300 mg/cm^2) [10 C.F.R. 835.2(b), Equivalent dose].

For uniform exposures, a measurement taken in the torso region is sufficient. For nonuniform exposures that would result in an individual receiving a significantly higher dose to the lens of the eye than to the whole body, such as access to, or near, reactor beams, x-ray machines, sources of beta radiation, and shield penetrations, the dose should be measured near the eye, such as with a dosimeter worn on the side of the head or forehead.

For beta particles with maximum energies less than about 3.5 MeV, the dose limit to the skin is more restrictive than that for the lens of the eye. At higher energies, the lens of the eye dose limit dominates. Therefore, at beta energies below 3.5 MeV, if it can be shown that skin monitoring is not required, it follows that lens of the eye monitoring is also not required (see ICRU Report No. 43, *Determination of Dose Equivalents from External Sources - Part 2*). Protective eyewear using 1/10-inch (0.254 cm) of acrylic plastic will completely attenuate beta particles with maximum energies < 800 KeV. This covers most beta-emitting isotopes with the exception of P-32, Y-90, and Pa-234. See the *Radiological Health Handbook* (1970 version).