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DRAFT REGULATORY GUIDE AND VALUE/IMPACT STATEMENT

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Division 8
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PROPOSED REVISION 2 TO REGULATORY GUIDE 8.14
PERSONNEL NEUTRON DOSIMETERS

A. INTRODUCTION

Section 20.202, "Personnel Monitoring," of 10 CFR Part 20, "Standards for Protection Against Radiation," requires that licensees supply personnel monitoring equipment and require its use by specified individuals. This guide provides guidance acceptable to the NRC staff on the use of personnel neutron dosimeters where exposure to neutrons occurs.

B. DISCUSSION

The American National Standards Institute has approved a standard entitled "Personnel Neutron Dosimeters (Neutron Energies Less than 20 MeV)" and designated ANSI N319-1976.[1] This standard gives performance criteria, use factors, and dosimetry system calibration criteria for neutron dosimetry systems. Accuracy criteria are not included among the performance criteria, however.

This guide supplements the standard by adding an accuracy requirement. The guide also provides substitutes for certain of the standard's performance requirements because data from tests performed by both Battelle Pacific Northwest Laboratory and Rensselaer Polytechnic Institute at light-water nuclear power reactors showed that the requirements of the standard could not be met by NTA film in some circumstances. *

[1] Copies may be obtained from the American National Standards Institute, Inc., 1430 Broadway, New York, New York 10018.

* Lines indicate substantive changes from Revision 1 to this guide.

One problem in neutron dosimetry is that some neutron dosimeters, with the exception of albedo dosimeters, are less sensitive than most gamma dosimeters. Section 20.202 of the NRC regulations requires personnel monitoring if a worker is likely to receive a whole body dose of more than about 300 mrems in a quarter year. Some neutron dosimeters have difficulty measuring neutron doses of this magnitude, depending on the neutron spectral distribution. The difficulty becomes even more severe in a mixed radiation field where neutrons contribute only a portion of the 300 mrems. Thus, the licensees may require personnel monitoring when the neutron dose is less than 300 mrems in a quarter, but the standard requires the dosimeters to be able to detect only 300 millirems per quarter or 300 mrems divided by the number of dosimetry periods per quarter (paragraph 4.1 of the standard). This problem is discussed in Regulatory Position C.1.

C. REGULATORY POSITION

ANSI N319-1976, "Personnel Neutron Dosimeters (Neutron Energies Less than 20 MeV),"[1] provides guidance acceptable to the NRC staff on the use of personnel neutron dosimeters, as supplemented and modified below.

1. PERSONNEL NEUTRON DOSIMETRY TECHNIQUES

Neutron dosimeters should be worn whenever the neutron dose equivalent is likely to exceed 300 mrems in a quarter (the minimum sensitivity required of a neutron dosimeter in paragraph 4.1 of Section 4, "Dosimetry System Performance," of the standard). If personnel monitoring is required by § 20.202 because of the total radiation exposure likely to occur but the neutron dose equivalent is not likely to exceed 300 mrems in a quarter, the following alternatives are acceptable with regard to personnel neutron dosimetry:

a. Using more sensitive dosimeters. The licensee may use a dosimeter with a demonstrated sensitivity greater than that required in the standard. Albedo neutron dosimeters are generally believed to be more sensitive than required by the standard for most neutron exposure circumstances. NTA film is sometimes used as a neutron dosimeter; however, it is not an acceptable neutron dosimeter for use at power reactors since it has been demonstrated that the major portion of neutron dose equivalent from nuclear power reactor neutrons is from neutrons whose energies are less than the threshold energy of NTA film (about 0.7 MeV). NTA film may be used as a dosimeter for other activities involving neutrons if (1) humidity can be controlled, (2) it can be shown that the energy distribution would provide a significant fraction of the dose from neutrons with energies greater than 0.7 MeV, and (3) tracks are counted on a large area of film.

b. Calculated neutron dose equivalent to supplement neutron dosimeter. A licensee may use a personnel neutron dosimeter but may substitute a calculated neutron dose equivalent for the measured dose equivalent if the measured dose equivalent cannot be reliably determined because of the lack of sensitivity of the dosimeter. Calculated dose equivalents may be based on neutron dose equivalent rates as measured by rem meter survey instruments (using either the Andersson-Braun or Hankins design) and known personnel occupancy times. Another alternative to calculated dose equivalents is the use of the neutron/gamma ratio. The neutron/gamma ratio is acceptable only if it has been established by prior use of rem meter survey instruments that the neutron/gamma ratio is virtually constant (e.g., ± 50%) throughout each area that personnel may occupy. More information on determining neutron dose equivalents by neutron/gamma ratio is given in Regulatory Guide 8.4, "Direct-Reading and Indirect-Reading Pocket Dosimeters."

c. Calculated neutron dose equivalent in place of neutron dosimeter. If an individual is not likely to receive a neutron dose equivalent in excess of 100 mrems in a quarter but would still be required to be provided personnel monitoring under § 20.202 (e.g., when gamma exposure is estimated to be in excess of 300 millirems per quarter), a personnel neutron dosimeter may be omitted. The neutron dose equivalent should then be estimated by the methods in Regulatory Position C.1.b. This procedure is discussed in more detail in Regulatory Position C.3 of Regulatory Guide 8.4.

d. Neutron dose equivalent much smaller than gamma dose equivalent. If the whole body neutron dose equivalent is not likely to exceed 10% of the gamma plus x-ray dose equivalent, neutron dosimeters may be omitted and the neutron dose equivalent may be assumed equal to zero.

e. Negligible neutron dose equivalent. If the neutron dose equivalent is not likely to exceed 30 millirems per quarter, or 10 millirems per quarter for individuals under 18 years of age, neutron dosimeters may be omitted and the neutron dose equivalent assumed equal to zero. The determination that an individual is not likely to receive a neutron dose equivalent of 30 millirems per quarter should not be based on previous NTA film badge readings since NTA film is not sufficiently sensitive to detect this dose equivalent rate.

2. PERFORMANCE REQUIREMENTS

Section 4, "Dosimetry System Performance," of the standard on performance requirements for the dosimetry system should be modified and supplemented by the following:

a. Instead of paragraph 4.1 of the standard on lower limit of detection, the following should be used:

"The lower limit of detection of the dosimetry system shall not exceed 300 millirems per quarter. The quarterly lower limit of detection (LLD) in millirems at the 95% confidence level is defined as

$$LLD = 4.66S\sqrt{N}$$

where N is the number of dosimetry exchange periods in a quarter and S is the standard deviation of the normal background on the control dosimeter in millirems."

(This definition of LLD was chosen to be consistent with the NRC position previously stated in Tables 1 and 3 of Regulatory Guide 4.8, "Environmental Technical Specifications for Nuclear Power Plants." The basis for the definition is given in USERDA report HASL-300, p. D-08-01.[2])

b. Instead of the 10% limit on the standard deviation in paragraph 4.4 of the standard on precision, a limit of 30% should be used.

[2] Harley, John H., Editor, HASL Procedures Manual, HASL-300, USERDA, revised annually.

c. The following accuracy requirement should be added:

"When exposed to an unmoderated californium-252 source, the average accuracy of a set of 10 dosimeters exposed in the range from 100 mrems to 3 rems should be ±50%."

d. The tests necessary to verify that the dosimetry system meets the requirements in the standard may be performed by the licensee or by someone selected by the licensee. These tests need be performed on a system just once but should be repeated any time changes are made in the dosimetry system (e.g., processing the dosimeters differently). In the case of NTA film, each different type of packaging should be considered a different system to be tested separately. A licensee following the recommendations of this guide should maintain records to show that his neutron dosimeters have been tested and meet the performance requirements of Section 4 of the standard.

3. MEETING THE FADING REQUIREMENTS OF THE STANDARD

To meet the fading requirements in paragraphs 5.3 and 5.4 of Section 5, "Use Factors," of the standard, the licensee should irradiate four dosimeters with a neutron dose equivalent of at least 0.5 rem. The dosimeters should then be stored for an entire dosimeter exchange period at a humidity similar to that expected in normal use. The dosimeters should then be read to verify that, on the average, they meet the fading criterion (paragraph 5.3 of the standard). If humidity is a significant cause of fading, the test should be performed during a period of high humidity.

4. DOSIMETRY SYSTEM CALIBRATION

Section 6, "Dosimetry System Calibration," of the standard gives suggestions on dosimetry system calibration. The calibration may be performed by the licensee or by someone selected by the licensee, but records describing the dosimeter calibration should be maintained by the licensee. The calibration should be repeated any time the licensee has reason to believe the neutron spectrum has changed and the previous calibration might not be valid.

Calibration of dosimeter response may be performed by exposing the dosimeter and a reference monitoring instrument in the actual locations where significant neutron exposure occurs. The spherical Hankins or the Andersson-Braun design rem meters or similar instruments may be used as reference monitoring instruments. These monitoring instruments should be calibrated by sources whose calibration is traceable to the National Bureau of Standards.

Calibrations of dosimeter response may also be performed by the dosimeter processor. The processor should use a calibration factor applicable to the dose spectrum delivered to the individuals wearing the dosimeters.

5. MAINTAINING BODY CONTACT

Albedo neutron systems usually require close body contact at all times during usage. Sizable errors can occur if close body contact is not maintained. Albedo neutron dosimeters should have a means of maintaining this necessary close contact with the body.

D. IMPLEMENTATION

This proposed Revision 2 of the guide has been released to encourage public participation in its development. Except in those cases in which an applicant has proposed an acceptable alternative method for complying with specified portions of the Commission's regulations, the methods described in the currently active guide (Revision 1, August 1977) will continue to be used in the evaluation of license applications that were docketed after November 1, 1977. The methods to be described in the active Revision 2 reflecting public comments will be used in the evaluation of all license applications docketed after the implementation date to be specified. The implementation date will in no case be earlier than June 1, 1980.

DRAFT VALUE/IMPACT STATEMENT

1. THE PROPOSED ACTION

1.1 Description of the Proposed Action

Section 20.202 "Personnel Monitoring," of 10 CFR Part 20, "Standards for Protection Against Radiation," requires that licensees supply personnel monitoring equipment and require its use by specified individuals. Some workers at NRC-licensed facilities may occupy restricted areas where the potential for exposure to neutrons would require the use of personnel neutron dosimeters. The proposed action will update earlier guidance on acceptable personnel dosimetry methods for use in assessing occupational exposure to neutrons.

1.2 Need for the Proposed Action

In August 1977, the NRC published Regulatory Guide 8.14, "Personnel Neutron Dosimeters," which indicated when personnel neutron dosimeters were required by 10 CFR Part 20 to be worn and what alternative dosimetry methodologies were acceptable in establishing the neutron dose of a worker.

Recent data obtained in conjunction with two research contracts* funded by the NRC show that (1) NTA film is not a reliable dosimeter for use in assessing neutron doses when a large proportion of the neutron dose is from neutrons with energies less than 0.7 MeV, which is considered the threshold energy of film and (2) the use of a neutron/gamma ratio does not always enable accurate estimation of the neutron dose unless it can be established by routine and periodic surveys that the ratio remains constant. The scope of these research contracts was to measure and characterize the neutron spectra in the containment of pressurized water reactors (PWRs) to test the response of NTA film to the neutron spectra in numerous reactor containment structures while at power and to evaluate the response of numerous other personnel dosimeters and survey instruments where appropriate.

Owing to many causal factors such as humidity, fading, lack of sensitivity, and the general inability of NTA film to respond to neutrons with energies less than 0.7 MeV, NTA film has been demonstrated to be a very poor dosimeter for use at power reactors. Data compiled in the above research programs showed

*Rensselaer Polytechnic Institute Research Project No. 5-24675 and Department of Energy Contract EY-76-C-06-1830 with Battelle Pacific Northwest Laboratory.

that NTA film did not respond at all or measured only a very small fraction of the neutron dose. Also, an assessment of the neutron/gamma ratio throughout a power reactor containment by one researcher (Rensselaer Polytechnic Institute) showed that the ratio may vary significantly depending on the location in the reactor containment structure and the energy response function of the type of neutron survey instrument used.

Active Regulatory Guide 8.14 (Revision 1, August 1977), although it cautions the licensee of the limitations of NTA film, does not advise the licensee that NTA film is not acceptable for neutron personnel dosimetry at power reactors. The data compiled in the two NRC research programs on this subject show that technical advances in albedo dosimeters make them a better alternative to NTA film as a neutron personnel dosimeter for use at nuclear power reactors. Also, the current guide allows the use of neutron/gamma ratios as an acceptable method of calculating the neutron dose in those cases in which a dosimeter has demonstrated lack of sensitivity or the neutron dose is not expected to exceed 300 millirems per quarter but personnel dosimetry is required by § 20.202 for other forms of radiation. However, the neutron gamma/ratio varies widely throughout the containment structure of a nuclear power plant and in order to obtain accurate estimation of a neutron dose received, evidence that the ratio remains constant should be established by routine and periodic surveys of areas for which this ratio is to be applied. The NRC staff believes it is therefore appropriate to revise Regulatory Guide 8.14 to reflect this recently acquired information on neutron dosimetry.

1.3 Value/Impact of the Proposed Action

1.3.1 NRC Operations

The value in revising Regulatory Guide 8.14 is that it would provide the licensee and the NRC inspector with "state of the technology" neutron dosimetry, which has changed somewhat since the development of the existing guide. The actual development of the revised Regulatory Guide 8.14 will require few additional resources of either man-hours or funding. Two NRC contracts on analysis of neutron spectra and various dosimeter responses to moderated fission neutrons in power reactors have already been funded, and final reports will likely be completed this year. The data thus far compiled from these contracts provide the bases for the proposed changes in Regulatory Guide 8.14.

1.3.2 Other Government Agencies

Not applicable.

1.3.3 Industry

There should be little impact on industry. The revision of Regulatory Guide 8.14 will require few additional expenditures of time or resources since the revised guide is intended to reflect the current "state of technology" in personnel neutron dosimetry. The only significant economic impact that could result would be the loss of revenue by a few dosimetry processors that now provide NTA film badge service to nuclear power reactor licensees since the major purpose of revising Regulatory Guide 8.14 is to advise power reactor licensees that NTA film should not be used for neutron dosimetry.

Power reactor licensees who calculate the neutron dose by the neutron/gamma ratio method will now be required to demonstrate that the neutron/gamma ratio is constant within ± 50% in those areas of the reactor containment where it is intended to use the ratio to calculate the neutron dose. A change to the stay-time method may require the purchase of additional neutron survey instruments. However, the proposed guide states that the use of the neutron/gamma ratio method may still be justified for use as long as the licensee can demonstrate that the ratio is virtually constant throughout areas normally occupied by workers.

A recent survey of some NRC licensees by the NRC Office of Inspection and Enforcement provides data indicating that only one out of fifteen PWRs surveyed used NTA film to assess neutron dose. Also, only one PWR used the neutron/gamma ratio method instead of the stay-time method to assess neutron dose for containment entry while at power.

1.3.4 Workers

There would be no expected detrimental impact to workers. The value would be that a worker would know that "state-of-the-technology" dosimetry techniques are being examined to ensure that the best methods are being used to assess his or her exposure to neutrons. By ensuring that the best dosimetry techniques are used, the integrated risk to a worker from exposure to radiation can be better evaluated. Particular problems with NTA film include limited sensitivity, fading due to humidity, and energy dependence; these factors are often interpreted to mean a zero dose even though use of portable survey instruments has established that neutrons exist in the working area. Similarly, the improper use of the neutron/gamma ratio method may result in a poor evaluation of the worker's neutron dose equivalent.

If the worker's neutron exposure is determined using more sensitive and accurate dosimetry techniques, it may result in the limitation (i.e., reduction) of the exposure to other forms of radiation. To this extent, the risk to an individual worker could possibly be reduced. However, by using dosimeters that are more sensitive than NTA film, one might also witness an apparent increase in the individual or collective dose because neutron exposure that had previously been assumed to be zero could now be assessed. However the potential impact on the collective dose would not be great since neutron exposures at nuclear power reactors constitute a small fraction of the total collective dose. Also, only a limited number of workers who may be required to enter containment during power operation are exposed to neutrons.

The importance of very accurately assessing any exposure to intermediate or fast neutrons is highlighted by the recent controversy over the need to adjust the quality factor used to determine the neutron dose equivalent. Dr. Harold Rossi has proposed on the basis of a dual-action theory (dose squared response of low LET radiation) that the quality factor for neutrons needs to be increased an order of magnitude. If Rossi's contentions are proven correct, low levels of neutron exposure to the limited number of workers who routinely enter the containment structure of PWRs while they are at power may become the limiting exposure circumstances for these workers.

1.3.5 Public

Not applicable.

1.4 Decision on the Proposed Action

It is recommended that a revision of Regulatory Guide 8.14 be undertaken in order to ensure that nuclear power plant licensees use personnel neutron dosimetry methods that are both accurate and of appropriate sensitivity to evaluate neutron exposures experienced in working areas.

2. TECHNICAL APPROACH

Since the intent is to revise an existing regulatory guide in order to incorporate updated technical information on acceptable personnel neutron dosimeters and acceptable methods for calculating neutron doses when the use of a personnel dosimeter is not warranted, no alternative technical approaches have been identified.

3. PROCEDURAL APPROACH

The only procedural approach considered is the revision of Regulatory Guide 8.14, "Personnel Neutron Dosimeters."

4. STATUTORY CONSIDERATIONS

4.1 NRC Authority

The regulatory guide does not have the force of law, however, it is intended as an aid and describes methods that are acceptable to the NRC staff and that a licensee may adopt in order to be in compliance with a regulation that has the force of law.

4.2 Need for NEPA Statement

The revision of Regulatory Guide 8.14 has no environmental impact; therefore no NEPA statement is required.

5. RELATIONSHIP TO OTHER EXISTING OR PROPOSED REGULATIONS OR POLICIES

No known conflict with any existing regulation or other government policy exists.

6. SUMMARY AND CONCLUSIONS

Some data obtained from the two NRC research contracts have shown that the energy and concomitant dose distribution of fission neutrons within PWR containments is such that NTA film is of little value as a personnel dosimeter. There is little neutron exposure associated with most boiling water reactors compared with PWRs because of their design differences and because there is no entry to the drywell area during power operation of BWRs inerted with nitrogen. It is known that NTA film does not respond to neutrons with energies less than about 0.7 MeV and further that most of the neutron fluence in a typical PWR containment during power operation is less than 0.7 MeV. It is also known that NTA film is relatively insensitive to doses of less than 30 millirems per exposure and is quite susceptible to fading caused by humidity unless properly packaged. In this regard, one often finds that temperature and humidity are normally quite high in the containment of PWRs and that most containment entries to make routine inspections result in neutron doses of less than 30 mrems. Only personnel dosimeters with proven sensitivity to low- and intermediate-energy neutrons (i.e., albedo dosimeters) should be used at nuclear power plants. For low dose situations, alternative methods of calculating neutron dose may be acceptable in lieu of a personnel dosimeter. Acceptable methods include the neutron/gamma dose ratio and stay-time. However, since the neutron/gamma ratio has been shown to vary widely in work areas of PWR containments, it should be used with discretion.

In order to ensure that workers are provided with appropriate personnel neutron dosimetry, the staff has determined that Regulatory Guide 8.14 should be revised to reflect the following: (1) NTA film is not an acceptable personnel neutron dosimeter for use at nuclear power plants and (2) the use of the neutron/gamma ratio as an alternative method to calculate neutron dose is acceptable, especially for nuclear power plants, only when it is demonstrated that the ratio remains virtually constant in all occupied work areas.

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