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REGULATORY GUIDE

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OCCUPATIONAL RADIATION DOSE ASSESSMENT IN LIGHT-WATER REACTOR POWER PLANTS DESIGN STAGE MAN-REM ESTIMATES

A. INTRODUCTION

Section 50.34, "Contents of Applications; Technical Information," of 10 CFR Part 50, "Licensing of Production and Utilization Facilities," requires that each applicant for a permit to construct a nuclear power reactor provide a preliminary safety analysis report (PSAR) and that each applicant for a license to operate such a facility provide a final safety analysis report (FSAR). Section 50.34 specifies in general terms the information to be supplied in these reports.

A more detailed description of the information needed by the NRC staff in its evaluation of applications is given in Regulatory Guide 1.70, "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants." Section 12.4, "Dose Assessment," of Regulatory Guide 1.70 states that the safety analysis report should provide the estimated annual radiation exposure to personnel at the proposed plant during normal operations. The purpose of the man-rem estimate requirement is to ensure that adequate detailed attention is given during the preliminary design stage (as described in the PSAR), as well as during construction after completion of design (as described in the FSAR), to dose-causing activities to ensure that personnel exposures will be as low as reasonably achievable (ALARA). The safety analysis report provides an opportunity for the applicant to demonstrate the adequacy of that attention and to describe whatever design and procedural changes have resulted from the dose assessment process.

The objective of this guide is to describe a method acceptable to the NRC staff for performing an assessment of collective occupational radiation dose as part of the process of designing a light-water-cooled power reactor (LWR).

B. DISCUSSION

The dose assessment process requires a good working knowledge of (1) the principal factors contributing to occupational radiation exposures that occur at a nuclear reactor power plant and (2) methods and techniques for ensuring that the occupational radiation exposure will be ALARA. In assessing the collective occupational dose at a plant, the applicant evaluates each potentially significant dose-causing activity at that plant, specifically examining such things as design, shielding, plant layout, traffic patterns, expected maintenance, and radioactivity sources, with a view to reducing unnecessary exposures and considering the cost-effectiveness of each dose-reducing method and technique. This evaluation process and the dose reductions that may be expected to result are the principal objectives of the dose assessment.

The principal benefits arising from this evaluation process occur during the period of preliminary design since many of the ALARA practices are part of the design process. On the other hand, additional benefits can also accrue during advanced design stages and even during early construction stages, as better evaluation of dose-causing operations are available and further design refinements can be identified. In addition, operations that will need special planning and careful dose control can be identified at the preoperational stage when the applicant can take advantage of all design options for reducing dose.

C. REGULATORY POSITION

This guide describes the format and content for assessments of the total annual occupational (man-rem) dose at an LWR—principally during the design stage. The dose assessment at this stage should include estimated annual personnel exposures during normal operation and during anticipated operational occurrences. It should include estimates of the frequency of occurrence, the existing or resulting radiation levels, the manpower requirements, and the duration of such activities. These estimates can be based on operating experience at similar plants, although to the extent possible estimates should include consideration of the design of the proposed plant, including radiation field intensities calculated on the basis of the plant-specific shielding design.

The dose assessment process and the concomitant dose reduction analysis should involve individuals trained in plant system design, shield design, plant operation, and health physics, respectively. Knowledge from all these disciplines should be applied to the dose assessment in determining cost-effective dose reductions.

Plant experience provides useful information on the numbers of people needed for jobs, the duration of different jobs, and the frequency of the jobs, as well as on actual occupational radiation exposure experience. The applicant should utilize personnel exposure data for specific kinds of work and job functions available from similar operating LWRs. (See Regulatory Guide 1.16, "Reporting of Operating Information—Appendix A Technical Specifications," for examples of work and job functions.) Useful reports on these data have been published by the Atomic Industrial Forum, Inc., and the Electric Power Research Institute, and a summary report on occupational radiation exposures at nuclear power plants is distributed annually by the Nuclear Regulatory Commission.

The occupational dose assessment should include projected doses during normal operations, anticipated operational occurrences, and shutdowns. Some of the exposure-causing activities that should be considered in this dose assessment include steam generator tube plugging and maintenance, repairs, inservice inspection, and replacement of pumps, valves, and gaskets. Doses from nonroutine activities that are anticipated operational occurrences should be included in the applicant's ALARA dose analysis. Radiation sources and personnel activities that contribute significantly to occupational radiation exposures should be clearly identified and analyzed with respect to similar exposures that have occurred under similar conditions at other operating facilities. In this manner, corrective measures can be incorporated in the design at an early stage.

Tables 1 through 8 are examples of worksheets for tabulation of data in the dose assessment process to indicate the factors considered. The actual numbers appearing in the dose columns will depend on plant-specific information developed in the course of the dose assessment review.

An objective of the dose assessment process should be to develop:

(1) A completed summary table of occupational radiation exposure estimates (such as Table 1).

(2) Sufficient illustrative detail (such as that shown in Tables 2 through 8) to explain how the radiation exposure assessment process was performed, and

(3) A description of any design changes that were made as a result of the dose assessment process.

During the final design stage, dose assessment can be substantially refined, since at this time details of the design will be known. In particular, completed shielding design and layout of equipment should permit better estimates of radiation field intensities in locations where work will be performed.

As a result of the dose assessment process, it is to be expected that various dose-reducing design changes and innovations will be incorporated into the design.

D. IMPLEMENTATION

The purpose of this section is to provide information to applicants regarding the NRC staff's plans for using this regulatory guide.

This guide reflects current NRC staff practice. Therefore, except in those cases in which the applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the method described herein is being and will continue to be used in the evaluation of submittals in connection with applications for construction permits or operating licenses until this guide is revised as a result of suggestions from the public or additional staff review. For construction permit, the review will focus principally on design considerations; for operating license, the review will focus principally on administrative and procedural considerations.

TABLE 1

TOTAL OCCUPATIONAL RADIATION EXPOSURE ESTIMATES

Activity	*Dose (man-rems/year)*
Reactor operations and surveillance (see Tables 2 & 3)	*
Routine maintenance (see Table 4)	–
Waste processing (see Table 5)	–
Refueling (see Table 6)	–
Inservice inspection (see Table 7)	–
Special maintenance (see Table 8)	–
Total man-rems/year	–

*Occupational exposures from Tables 2 through 8 are entered in Table 1 and added to obtain the facility's estimated total yearly occupational dose.

Values shown in Tables 2 through 8 are typical examples (for BWRs and PWRs) for illustrative purposes only. Actual values can vary, depending on the facility type (BWR or PWR), design, and size.

TABLE 2

OCCUPATIONAL DOSE ESTIMATES DURING ROUTINE OPERATIONS AND SURVEILLANCE*

Activity	*Average dose rate (mrem/hr)*	*Exposure time (hr)*	*Number of workers*	*Frequency*	*Dose (man-rems/year)*
Walking	0.2	0.5	2	1/shift	0.22
Checking:					
Containment cooling system	1	1	1	1/day	0.36
Accumulators	1.5	1	1	1/day	0.54
Pressurizer valves	10	0.2	1	1/day	0.73
Boron acid (BA) makeup system	5	0.2	1	1/day	0.36
Fuel pool system	1	0.25	1	1/day	0.09
Control rod drive (CRD) system:					
Modules	1	1	1	1/day	0.36
Controls	0.5	0.5	1	1/shift	0.27
Filters	0.5	0.5	1	1/day	0.09
Pumps:					
CRD	0.5	0.2	1	1/day	0.04
Residual heat removal	1	0.2	1	1/day	0.07
:	:	:	:	:	:
Total					

*The data shown are for illustrative purposes only and would be expected to vary significantly from plant to plant.

TABLE 3

OCCUPATIONAL DOSE ESTIMATES DURING NONROUTINE OPERATION AND SURVEILLANCE*

Activity	*Average dose rate (mrem/hr)*	*Exposure time (hr)*	*Number of workers*	*Frequency*	*Dose (man-rems/year)*
Operation of equipment:					
Traversing in-core probe system	2	2	2	3/year	0.02
Safety injection system	5	1	1	1/month	0.06
Feedwater pumps & turbine	1	1	1	1/week	0.05
Instrument calibration	2	1	1	1/day	0.73
Collection of radioactive samples:					
Liquid system	10	0.5	1	1/day	1.83
Gas system	5	0.5	1	1/month	0.03
Solid system	10	0.5	1	4/year	0.02
Radiochemistry	1	1	2	1/day	0.73
Radwaste operation	3	8	3	1/week	3.75
Health physics	1	2	2	1/day	1.46
:	:	:	:	:	:
Total					

*The data shown are for illustrative purposes only and would be expected to vary significantly from plant to plant.

TABLE 4
OCCUPATIONAL DOSE ESTIMATES DURING ROUTINE MAINTENANCE*

Activity	*Average dose rate (mrem/hr)*	*Exposure time (hr)*	*Number of workers*	*Frequency*	*Dose (man-rems/year)*
Mechanical:					
Changing filters:					
Waste filter	100	0.5	1	6/year	0.3
Laundry filter	100	0.5	1	10/year	0.5
Boron acid filter	100	0.5	1	2/year	0.1
Pressure valves	10	0.5	1	1/week	0.26
BA makeup pump	10	0.3	1	1/week	0.16
BA holding pump	10	0.3	1	1/week	0.16
Instrumentation and controls:					
Transmitter inside containment	5	0.5	2	2/week	0.52
Transmitter outside containment	1	2	1	1/week	0.1
Standby gas treatment system	2	2	2	2/year	0.02
Radwaste processing system	10	20	2	4/year	1.6
:	:	:	:	:	:
Total					

*The data shown are for illustrative purposes only and would be expected to vary significantly from plant to plant.

TABLE 5
OCCUPATIONAL DOSE ESTIMATES DURING WASTE PROCESSING*

Activity	*Average dose rate (mrem/hr)*	*Exposure time (hr)*	*Number of workers*	*Frequency*	*Dose (man-rems/year)*
Control room	0.1	3000	1	1/year	0.3
Sampling and filter changing	10	4	1	1/week	2.1
Panel operation, inspection, and testing	1	2	1	1/day	0.73
Operation of waste processing and packaging equipment	2	12	2	1/week	2.5
:	:	:	:	:	:
Total					

*The data shown are for illustrative purposes only and would be expected to vary significantly from plant to plant.

TABLE 6
OCCUPATIONAL DOSE ESTIMATES DURING REFUELING*

Activity	Average dose rate (mrem/hr)	Exposure time (hr)	Number of workers	Frequency	Dose (man-rems/year)
Reactor pressure vessel head and internals—removal and installation	30	60	6	1/year	10.8
Fuel preparation	10	24	2	1/year	0.48
Fuel handling	2.5	100	4	1/year	1.0
Fuel shipping	15	15	2	1/year	0.45
:	:	:	:	:	:
Total					

*The data shown are for illustrative purposes only and would be expected to vary significantly from plant to plant.

Most work functions performed during refueling, and the associated occupational dose received, will vary depending on facility design (BWR or PWR), reactor pressure vessel size, and number of fuel assemblies in the reactor core. For a detailed description of pre-planned activities, time, and manpower schedule, refer to the "critical path for refueling tasks," which should be available from the Nuclear Steam Supply System (NSSS) supplier.

TABLE 7
OCCUPATIONAL DOSE ESTIMATES DURING INSERVICE INSPECTION*

Activity	Average dose rate (mrem/hr)	Exposure time (hr)	Number of workers	Frequency	Dose (man-rems/year)
Providing access: installation of platforms, ladders, etc., removal of thermal insulation	40	30	4	1/year	4.8
Inspection of welds	40	100	3	1/year	12.0
Follow up: installation of thermal insulation platform removal and cleanup	40	40	4	1/year	6.4
:	:	:	:	:	:
Total					

*The data shown are for illustrative purposes only and would be expected to vary significantly from plant to plant.

Estimates should be based on average yearly values over a 10-year period. Variations are expected as a consequence of reactor size, design, number of welds to be inspected yearly, and the degree of equipment automation available for remote examination of welds.

TABLE 8
OCCUPATIONAL DOSE ESTIMATES DURING SPECIAL MAINTENANCE*

Activity	*Average dose rate (mrem/hr)*	*Exposure time (hr)*	*Number of workers*	*Frequency*	*Dose (man-rems/year)*
Servicing of control rod drives	50	12	3	1/year	1.8
Servicing of in-core detectors	15	10	2	1/year	0.3
Replacement of control blades	15	10	2	1/year	0.3
Dechanneling of spent and channeling of new fuel assemblies	10	60	2	1/year	1.2
Steam generator repairs	1000	4	6	1/year	24.0
:	:	:	:	:	:
Total					

*The data shown are for illustrative purposes only and would be expected to vary significantly from plant to plant.

Most preplanned (or routine) maintenance activities during outage are described in the "critical path for refueling tasks," which should be available from the NSSS supplier, and are performed in parallel with the critical path refueling tasks to shorten reactor outage time

Actual dose will depend on facility design as well as size and thermal output and number of fuel assemblies in the reactor core.