Internal Exposure Management
NRC Roles and Responsibilities and Recent Licensee Performance

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Abstract

The U.S. Nuclear Regulatory Commission (NRC) is an independent agency of the United States of America. Its mission is to regulate the Nations's civilian use of byproduct, source, and special nuclear materials, to ensure adequate protection of public health and safety, to promote the common defense and security, and to protect the environment. This paper discusses the roles and responsibilities of the NRC in the area of internal exposure management, discusses the NRC's regulations controlling occupational radiation exposure, and discusses supporting guidance issued by the NRC in the area of ALARA for internal exposure control. In addition, this paper discusses recent performance of selected licensee types in the area of internal exposure management, and briefly discusses NRC inspection methodology and NRC response to an internal exposure case.

A. Role and responsibility of the NRC

The NRC's scope of responsibilities includes regulation of commercial nuclear power plants; research, test, and training reactors; fuel cycle facilities; medical, academic, and industrial uses of nuclear materials; and the transport, storage, and disposal of nuclear materials and waste.

The NRC fulfills its responsibilities through a system of licensing and regulatory activities that includes among others: licensing the siting, design, construction, operation, and decommissioning of applicable facilities; licensing possession and use of materials; conducting confirmatory research; developing and implementing rules and regulations that govern licensed nuclear activities; and conducting inspection and enforcement activities. The NRC implements its inspection responsibilities, in part, by conducting onsite inspections at locations of licensed activities using defined inspection procedures.

The NRC and its licensees share a common responsibility to protect public heath and safety. Federal regulations and the NRC regulatory program are important elements in the protection of the public. NRC licensees, however, have the primary responsibility for the safe use of nuclear materials.

B. Regulations controlling occupational radiation exposure

The primary NRC regulations controlling occupational and public radiation exposure are contained in Title 10, Code of Federal Regulations, Part 20 (10 CFR 20), „Standards for Protection Against Radiation.„10 CFR 20 establishes standards for protection against ionizing radiation resulting from activities conducted under NRC licenses. These activities include licenses to possess; use; transfer; or dispose of byproduct, source, or special nuclear material or to operate production or utilization facilities under regulations contained in 10 CFR Parts 30 through 36, 39, 40, 50, 60, 61, 70 or 72.

10 CFR 20 Subpart C, „Occupational Dose Limits,„incorporates recommendations of the International Commission on Radiological Protection (ICRP) (1977) and provides the basic occupational exposure limits (20.1201) for adults. These are annual limits (whichever is more limiting) of:

- 0.05 Sievert (Sv) (5 rems) total effective dose equivalent,
- 0.5 Sv (50 rems) for the sum of the deep dose equivalent and the committed dose equivalent to any individual organ or tissue other than the lens of the eye, and
- 0.15 Sv (15 rems) eye dose equivalent, and
- 0.50 Sv (50 rems) shallow dose equivalent to the skin or to any extremity.

10 CFR 20 also provides requirements for exposure monitoring and assessment including summation of external and internal doses (20.1202), determination of external doses from airborne radioactive materials (20.1203), and determination of internal exposures (20.1204). Other subparts provide conditions requiring individual monitoring of external and internal occupational doses, requirements for records and reporting of exposures, and requirements to

conduct surveys that may be necessary and reasonable to comply with the regulations in Part 20. Appendix B to 10 CFR 20, provides a listing of annual limits of intake (ALIs) and derived air concentrations (DACs) of radionuclides to allow licensees to monitor, assess, and control internal exposure.

For purposes of maintaining internal exposure as low as is reasonably achievable (ALARA), 10 CFR 20 establishes specific requirements for development of a radiation protection program and requires that the licensee use, to the extent practicable, procedures and engineering controls, based on sound radiation protection principles, to achieve occupational doses and doses to the public that are ALARA. 10 CFR 20 also provides specific requirements to ensure doses, due to intakes of radioactive material, are ALARA. For example, 10 CFR 20 provides requirements for use of respiratory protection equipment and other controls to limit internal exposure in restricted areas. An important aspect of these regulations is that, if it is impractical to apply process or other engineering controls to reduce concentrations of radioactive material in air to values below those that define an airborne radioactivity area, the licensee is required, consistent with maintaining the total effective dose ALARA, to increase monitoring and limit intakes by, among other controls: control of access, limitation of exposure times, or use of respiratory protection equipment. The NRC has recently revised its requirements for use of respiratory protective equipment to recognize new respiratory protection devices and procedures that have proven effective, adopt new national consensus standards, and conform NRC requirements to new requirements of other U.S. worker protection agencies. The revised requirements allow licensees to consider safety factors, other than radiological factors, in its ALARA analysis to determine whether or not respiratory protective equipment should be used.

In addition to the exposure control regulations established by the NRC discussed above, the NRC has also established regulations for training of radiation workers to allow them to understand health protection problems associated with radiation and radioactive materials. These regulations require that workers be instructed in precautions and procedures to minimize exposure and be instructed in the purpose and function of protective devices employed. These regulations are outlined in 10 CFR Part 19, „ Notices, Instructions and Reports to Workers: Inspection and Investigation.“ The instructions provide workers information to allow them to take some individual responsibility to minimize their exposure to radiation and radioactive material.

C. Supporting guidance documents

Because of the wide variety of licensees under its regulatory purview, and the need to provide standardized guidance to its licensees on acceptable practices and methods for exposure monitoring, measurement and reporting, the NRC has established various documents which provide guidance to licensees on such matters as surveys, personnel monitoring, exposure assessment, and reporting. Foremost among these documents are NRC Regulatory Guides(RGs). RGs are issued to describe, and make available to licensees and the public, methods acceptable to the NRC staff of implementing specific parts of the NRC's regulations. The guides, which receive public and industry comment, delineate techniques used by the NRC staff in evaluating specific problems, postulated accidents, or to provide guidance to applicants. The RGs reference consensus standards (e.g., American National Standards). The guides are not substitutes for regulations, and compliance with them is not required unless a licensee has specifically committed to a particular RG's use. Methods and solutions different from those set out in RGs will be acceptable if they provide a basis for findings requisite to the issuance or continuance of a permit or license by the NRC. In some instances, RGs have been incorporated by reference into licenses.

Various RGs deal specifically with airborne radioactivity surveys and internal exposure monitoring, assessment, and recording. RGs also provide guidance on acceptable concepts, models, equations, and assumptions for a bioassay program; guidance on air sampling in the work place and applications of bioassays for fission and activation products; guidance on health physics surveys in uranium mills; guidance on monitoring criteria and methods to calculate occupational radiation doses; instructions for recording and reporting occupational radiation exposure data; and use of respiratory protection equipment. In addition, RGs also provide detailed information on programs and practices to maintain internal and external exposure ALARA. For example, RGs provide basic principles and practices for ALARA programs for facilities such as power reactors, uranium mining and milling, and medical institutions. An example of such a RG is RG 8.10, „Operating Philosophy for Maintaining Occupational Radiation Exposures As Low As Is Reasonably Achievable.“

The NRC also publishes other documents which provide useful information for conducting surveys, monitoring, and internal exposure assessment. For example, the NRC issues documents called NUREGs, and like RGs these are available to licensees and the public and cover a wide range of topics. The NUREGs differ from RGs in that they provide very detailed information on a variety of topics including research topics. For example NUREG/CR-4884, „Interpretation of Bioassay Measurements„ is a comprehensive manual (about 800 pages) that describes how to compute intakes of radioactive material from both in-vivo and in-vitro bioassay measurements. Another NUREG (0713),

discussed later, is issued annually and provides a summary of internal and external occupational exposure at commercial Nuclear Power Reactors and other NRC licensed facilities.

The NRC also provides information to its licensees and the public that may be of importance to operations at a particular type of facility. The types of generic correspondence most frequently issued are Information Notices (INs). These notices typically cover an important issue or event and are designed to provide timely information to specific licensees coupled with a brief NRC assessment. Licensees are not required to take action on INs. INs have been issued to provide information on such matters as unplanned intakes of radioactive material, unplanned external exposure events, and changes to regulations.

The NRC has other means to provide information to licensees; however, the above-described methods are typically used for matters involving surveys, monitoring, and assessment of personnel exposure to airborne radioactivity. The information and guidance provided by the NRC helps licensees to establish programs to maintain occupational and public exposure ALARA.

Finally, the NRC does maintain its own web page (www.nrc.gov). This tool is readily accessible to the public. It provides information on a wide variety of topics, including newly released documents as discussed above. NRC regulations, Regulatory Guides, NUREGs, and Information Notices are available on the web. I invite you to visit www.nrc.gov.

D. Inspections

NRC inspections provide direct oversight of important activities at facilities including the adequacy and effectiveness of the licensee's ALARA program. The inspections are conducted at its licensed facilities in accordance with formally approved inspection guidance including guidance on ALARA Programs. These guidance documents describe the type of inspection to be performed, the program attributes to be reviewed, and the inspection frequency. The inspections are scheduled and tracked via computers, which better allows the NRC to effectively manage its resources and provide oversight of its licensees commensurate with the safety significance of licensed activities. The inspections review safety activities and verify compliance with applicable regulatory requirements. In the event of non-conformance or safety deficiencies, the NRC first checks to see if the licensee has or will place the finding into its corrective action program. Enforcement action may be taken for uncorrected matters or significant problems after conduct of appropriate meetings with licensee personnel and review of facts. Enforcement actions are guided by NRC enforcement manuals and guidance readily available on the web.

Recently, the NRC has revised its inspection approach and implemented a pilot Regulatory Oversight Process. The process provides for risk-informed reviews of the licensee's activities in strategic performance areas. For example, in the area of Nuclear Power Plants, performance is evaluated in several strategic areas (Reactor Safety, Radiation Safety, and Safeguards) through a combination of NRC inspections and the nuclear power plant licensee's use of performance indicators. The process provides for inspections in risk significant sub-areas called „Cornerstones.„ The Cornerstones are initiating events, mitigation systems, barrier integrity, emergency preparedness, public exposure control, occupational exposure control, and physical protection. Inspections are conducted in discrete „inspectable areas„ within each cornerstone. Findings from the inspections and outputs from performance indicators are input into a Significance Determination Process which assesses the significance of the finding and prompts further NRC action consistent with an „Action Matrix.„ The new inspection process is expected to be fully implemented at all U.S. Nuclear power plants in 2000 and will provide for inspection and oversight of ALARA Programs.

E. Occupational exposures at NRC licensed facilities

NRC licensees are required to assess and report instances of intakes of airborne radioactive materials consistent with the requirements of 10 CFR 20. The NRC has, since 1969, been compiling occupational radiation exposure data. The data has been published in publically available NUREGs. In 1994, consistent with a major revision to 10 CFR 20, the reporting of whole body exposure changed to reporting of Total Effective Dose Equivalent (TEDE). Consequently, reports since 1994 provide internal exposure data in Committed Effective Dose equivalents (CEDE). Maximum Committed Dose Equivalents (CDE) and Total Organ Dose Equivalents (TODEs) are also compiled. The data is published annually in NUREG-0713, „Occupational Radiation Exposure at Commercial Nuclear Power Reactors and Other Facilities.„ Currently, data through 1997 has been published and the report containing 1998 draft data was under review at the time of this workshop.

NUREG-0713 is a compilation of external and internal radiation exposure data maintained in the NRC's Radiation

Exposure Information Reporting System (REIRS). The data is compiled from reports from licensees subject to the reporting requirements of 10 CFR 20.2206. The NUREG allows for review of collective exposure for different types of licensees and permits, among other uses, the evaluation of the effectiveness of the overall NRC/licensee radiation protection and ALARA efforts, the identification of unfavorable trends, the monitoring of transient workers who may affect dose distribution statistics through multiple counting, the evaluation of radiological risks, and the comparative evaluation of radiation protection performance. The compilation includes information on exposures at nuclear power reactors; industrial radiographers; fuel processors (including uranium enrichment), fabricators; manufacturers and distributors of byproduct material; independent spent fuel storage installations; and facilities for land disposal of low level waste.

Tables 1, 2 and 3, provide data excerpted from NUREG-0713 Vol.19 (1997) and draft Vol. 20(1998). The tables provide, respectively, a summary of collective and average CEDE based on the type of NRC licensee for 1997 and 1998, a summary of maximum occupational internal exposures by exposure category for 1997 and 1998, and a summary of collective CEDE for each year for the period 1994-1998. The tables together provide an informative summary of the magnitude of collective and average internal exposures sustained at NRC licensed facilities in the U.S..

Table 1. Collective and Average Committed Effective Dose Equivalent (CEDE) by Licensee Type

Year >>	1997			1998		
Licensee Type	**Num. of people with measured CEDE**	**Collective CEDE (person-rem, person-cSv)**	**Avg. Meas. CEDE (rem, cSv)**	**Num. of people with measured CEDE**	**Collective CEDE (person-rem, person-cSv)**	**Avg. Meas. CEDE (rem, cSv)**
Nuclear Pharmacies	**22**	**0.276**	**0.013**	**26**	**0.314**	**0.012**
Manufact/ Distribution	**8**	**0.146**	**0.018**	**8**	**0.164**	**0.021**
Uranium Enrichment	**36**	**0.314**	**0.009**	**58**	**0.242**	**0.004**
Fuel Fabrication	**2,639**	**800.16**	**0.303**	**2,462**	**741.8**	**0.301**
Reactors	**1,034**	**10.99**	**0.011**	**943**	**18.89**	**0.020**

Source: NUREG 0713 (1997 Final, 1998 draft)

Fuel facilities exhibited the highest percentage of internal dose and the highest average CEDE per individual.

Table 2. Maximum Occupational Exposures by Exposure Category

Year >>	1997		1998	
Exposure category	**Number of People with meas. Dose**	**Maximum Exposure Reported (rem, cSv)**	**Number of People with meas. Dose**	**Maximum Exposure Reported (rem, cSv)**
CEDE (Committed Effective Dose Equivalent)	**4,105**	**2.88**	**3,907**	**3.40**
CDE (Committed Dose Equivalent)	**3,376**	**29.65**	**2,898**	**28.35**
TODE (Total Organ Dose Equivalent)	**62,984**	**29.65**	**56,310**	**28.57**
TEDE (Total Effective Dose Equivalent)	**77,094**	**4.48**	**67,221**	**12.92**

Source: NUREG 0713(1997 Final, 1998 draft)

Table 3. Internal Dose - Committed Effective Dose Equivalent - CEDE (1994-1998)

Year	Total number of people with measured CEDE	Collective CEDE (person-rem, person-cSv)	Average measured CEDE for licensees required to report under 10 CFR 20.2206 (rem, cSv)
1994	**3,244**	**1,024.85**	**0.316**
1995	**2,948**	**709.01**	**0.241**
1996	**3,042**	**722.16**	**0.237**
1997	**3,739**	**811.89**	**0.217**
1998	**3,513**	**766.06**	**0.218**

Source: NUREG 0713(1997 Final, 1998 draft)

There were no exposures in excess of applicable NRC limits in the period 1994 - 1998 solely attributable to intakes of radioactive material for those licensees who provide reports of individual monitoring in accordance with 10 CFR 20.2206 (i.e., nuclear power reactors; industrial radiographers; fuel processors (including uranium enrichment), fabricators; manufacturers and distributors of byproduct material; independent spent fuel storage installations; and facilities for land disposal of low level waste). There were two exposures in excess of the applicable extremity limit in 1997, and four exposures in excess of the TEDE limit in 1998 due to deep dose equivalent attributable to radiography activities. The maximum CDE exposures occurred at fuel fabrication facilities.

F. Case Example

Unplanned intake of radioactive material at a reactor facility and NRC response

In November 1996, through information provided by its onsite resident inspector, the NRC became aware of elevated airborne radioactivity within the reactor cavity at a pressurized water reactor nuclear power station undergoing refueling. The NRC staff reviewed airborne radioactivity sample analyses, associated with a licensee inspection activity, and concluded that the licensee may not have properly monitored or assessed internal exposure of workers who had worked in the reactor cavity during the activity. This review prompted a subsequent onsite inspection which reviewed the adequacy and effectiveness of the licensee's radiological controls, including internal exposure controls, for the specific work activities. The inspection confirmed that the licensee had not properly monitored airborne radioactivity or assessed exposure to airborne transuranic radioactive material. The licensee had conducted air sampling using fixed air sampling (FAS) but had not provided personnel air samplers (PAS) for the workers. In addition, because of the delay in identifying the extent of potential internal exposure, the licensee had not initiatedin-vitro sample analyses. The licensee had, however, conducted exposure assessment for activation products. Subsequent analyses by the NRC and the licensee indicated the potential existed to exceed applicable organ dose limits due to the transuranic radioactivity. The licensee subsequently initiated a comprehensive review of the event and concluded that internal exposure was limited due to the relatively rapid clearance of material from the body and no applicable limit had been exceeded. The NRC performed follow-up assessment and used available internal dosimetry codes to assess the intake. The assessment reviewed radionuclide compositions, potential impacts of particle sizes, and individual excretion rates. Although no exposure in excess of applicable limits was identified, the reviews did identify areas for improvement including work control and oversight by radiation protection personnel, failures to follow radiation work permits, inadequate airborne radioactivity sampling and analysis, and weaknesses in dose assessment.

The NRC inspection prompted significant action by the licensee to identify root causes and implement program improvements. To alert the industry to the event, the NRC issued Information Notice 97-36, „Unplanned Intakes By Workers of Transuranic Airborne Radioactive Materials and External Exposure Due to Inadequate Control of Work.„

The NRC conducted follow-up inspections at the facility to confirm implementation of licensee program enhancements and performed direct oversight of the resumption of potential airborne radioactivity producing activities. The referenced Information Notice provides a summary of the event and the airborne radioactivity monitoring and exposure assessment matters identified by the licensee as well as a summary of licensee corrective actions. The Information Notice is available at the previously discussed NRC web site.

Conclusion

The U.S. Nuclear Regulatory Commission regulates the civilian use of byproduct, source, and special nuclear materials and has roles and responsibilities in the area of internal exposure management. The agency has established regulatory requirements for its licensees to ensure occupational radiation exposure is maintained as low as is reasonably achievable. The NRC has published various documents to inform its licensees of practical methods to maintain occupational exposure ALARA. The NRC tracks and evaluates exposure data across licensee types to allow for review and evaluation of the effectiveness of the overall NRC/licensee radiation protection and ALARA efforts and the identification of unfavorable trends. In the period 1994-1998, there was a 30 % reduction in average measured CEDE for those licensee types required to provide individual monitoring reports in accordance with 10 CFR 20.2206. In addition, and during the same period, no individual in these same licensee types exceeded an NRC occupational exposure limit due to intake of radioactive material.