RADIATION PROTECTION AND DOSE EVALUATIONS

Radiation Protection Policy

Radiation protection, as practiced internationally and within the United States, is based on three fundamental principles, as described in International Commission on Radiological Protection (ICRP) Publication 103, "The 2007 Recommendations of the International Commission on Radiological Protection" (*Annals of the ICRP*, Volume 37, Nos. 2–4). These principles are (1) justification of the exposure; (2) optimization of protection; and (3) limitation of individual dose. The U.S. Nuclear Regulatory Commission standards for protection against ionizing radiation (Title 10 of the *Code of Federal Regulations* (10 CFR) Part 20, "Standards for Protection against Radiation") and other U. S. Nuclear Regulatory Commission (NRC) regulatory requirements embody these principles, particularly those related to optimization of protection and limitation of individual dose.

The first principle, justification, states that "any decision that alters the radiation exposure situation should do more good than harm" (ICRP Publication 103). Thus, the principle of justification would apply to the proposal and planning for changes to insulation or sump areas within a facility and would indicate that the benefits of the action should outweigh the detriments. Decisions associated with justification do not simply take radiation doses into account, but rather should encompass all of the possible benefits and detriments of the proposal. Thus, a decision may be justified by conclusions that the benefits of improved safety outweigh the detriment of occupational exposure and other detriments associated with taking the action. Rarely, in fact, does the radiation dose associated with the activity serve as the only decision criterion.

The second principle, optimization, states that "the likelihood of incurring exposure, the number of people exposed, and the magnitude of their individual doses should be kept as low as reasonably achievable, taking into account economic and societal factors" (ICRP Publication 103). Thus, once a particular exposure situation has been determined to be justified, it is also necessary to take actions to reduce exposures to as low as is reasonably achievable (ALARA). The NRC regulations at 10 CFR 20.1101(b) contain the ALARA requirement, which is amplified in several regulatory guides, such as Regulatory Guide 8.8, "Information Relevant to Ensuring that Occupational Radiation Exposures at Nuclear Power Stations Will Be as Low as Is Reasonably Achievable." It should be noted that maintaining radiation exposures ALARA is not necessarily the same as minimization of exposure.

The third principle, limitation, states that "the total dose to any individual from regulated sources in planned exposure situations other than medical exposure of patients should not exceed the appropriate limits" (ICRP Publication 103). Limits for occupational exposure are contained in 10 CFR 20.1201, "Occupational Dose Limits for Adults"; 10 CFR 20.1206, "Planned Special Exposures"; 10 CFR 20.1207, "Occupational Dose Limits for Minors"; and 10 CFR 20.1208, "Dose Equivalent to an Embryo/Fetus." Exceeding an occupational exposure limit is a significant violation and subject to enforcement.

Application of these three principles first requires that the activity is justified in terms of the net benefit. Radiation dose can be, but may not always be, considered in this justification decision.

Some practices are deemed so frivolous that no amount of radiation exposure can be justified. Once the activity is justified, it must be conducted in a way that the resulting radiation exposures are maintained within the dose limits and are ALARA.

Consistent with the justification principle, the NRC's backfit policy requires the staff, in certain instances, to complete a regulatory analysis that includes a cost/benefit analysis to ensure that the costs associated with a proposed change in regulatory position are justified by the resulting benefit. This regulatory analysis is not required for backfits involving adequate protection, compliance with Commission regulations or orders, or a redefinition of the level of protection considered adequate for public health and safety or the common defense and security. However, when a regulatory analysis is required, both occupational and public dose incurred or averted are factors included in this analysis. NUREG/BR-0184, "Regulatory Analysis Technical Evaluation Handbook—Final Report," issued January 1997, provides guidance on how the monetary value of these doses are determined and factored into the analysis. In accordance with this guidance, dose is considered as a cost at the rate of $2,000 per rem.

The Commission does not have a separate "ALARA Policy" as a policy statement. However, provisions to keep planned exposures ALARA have been a formal regulatory requirement (i.e., a "shall" statement) in 10 CFR Part 20 since its revision in 1991. The Statements of Consideration published with the 1991 revised rule (Volume 56, page 23367, of the *Federal Register*) clarify that licensees are required to have a "radiation protection program that includes provisions for keeping radiation doses ALARA," and that there is no established standard as to how much collective dose is, or is not, warranted in any specific operational situation. Historically, the NRC has typically not accepted requests by reactor licensees to delete or defer safety-related activities, such as surveillance tests (required by the plant's technical specifications), based solely on ALARA (e.g., deferring a safety-related activity that would incur some amount of additional occupational dose). Licensees are required to perform those activities that ensure adequate protection of public health and safety in a manner that is ALARA.

The discussions of radiation protection policy in this enclosure and the SECY paper were coordinated with the Office of Federal and State Materials and Environmental Management Programs.

Typical Operational Doses at U.S. Pressurized-Water Reactors

Based on a review of NUREG-0713, Volume 30, "Occupational Radiation Exposure at Commercial Nuclear Power Reactors and Other Facilities," issued in 2008, the following information was obtained regarding typical operational doses incurred by industry. The 3-year average collective dose per reactor is one of the metrics that the NRC uses in the Reactor Oversight Program to evaluate the effectiveness of the licensee's ALARA program.

Based on the 207 reactor-years of operation accumulated over a 3-year period (ending December 31, 2008) at 69 pressurized-water reactors (PWRs), the average 3-year collective total effective dose equivalent (TEDE) per reactor was found to be 75 person-rem. Based on the 105 reactor-years of operation accumulated over the same period by 35 boiling-water reactors, the average 3-year collective TEDE per reactor was found to be 142 person-rem.

Analysis of Potential Doses from Insulation Replacements

Industry Estimates

A Nuclear Energy Institute letter dated April 7, 2010 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML101050354), stated that current NRC options for addressing remaining issues would require wholesale replacement of insulation systems and additional plant-specific testing. These changes will result in significant worker exposure in high-radiation areas of PWR containments, with some estimates ranging from 100 person-rem to 600 person-rem. In the April 15, 2010, Commission meeting, the industry stated that the average dose impact per plant would be 200 person-rem.

Actual Total Doses from Insulation Replacements including Hazardous Materials

The staff informally requested information from licensees that had actually performed insulation replacements in response to Generic Safety Issue (GSI)-191, "Assessment of Debris Accumulation on Pressurized-Water Reactor Sump Performance," to determine the likely dose impact of additional modifications at the remaining high-fiber plants. The average occupational dose, based on responses received, was 18.7 person-rem per plant. The actual dose incurred at each of the plants from replacing insulation, including the scope of changes, is presented below:

- Case 1: A plant received 6 person-rem during replacement of 411 linear feet of insulation as follows:
    - 76 linear feet of Min-K insulation on large reactor coolant system piping
    - 39 linear feet of Cal-Sil insulation on 14-inch steam generator/feedwater piping in containment
    - 296 linear feet of Cal-Sil on small steam generator blowdown piping
- Case 2: A plant received 8.9 person-rem during replacement of 2,319 linear feet of Cal-Sil and Microtherm insulation located near the steam generators in the loop rooms.
- Case 3: A plant received 35.9 person-rem during replacement/jacketing repairs of 5,799 feet of Cal-Sil and Microtherm insulation. Replacements were performed at locations near the steam generators in the loop rooms. Jacketing was added or repaired in basement and annulus areas on emergency core cooling system lines, residual heat removal lines, and service water lines.
- Case 4: A plant received 4.4 person-rem during replacement of 20 linear feet of Cal-Sil insulation on a regenerative heat exchanger. Five percent of this Cal-Sil contained asbestos.

- Case 5: A plant received 21 person-rem including scaffolding for replacement of mineral wool and NUKON® with reflective metal insulation (RMI) over two outages. The scope of replacements included the following:

  - Replaced mineral wool with RMI on steam generators.
  - Replaced NUKON® with RMI on pressurizer head and spray line.
  - Replaced NUKON® from valves on pressurizer.
  - Replaced NUKON® with RMI on steam generator drains.
  - Removed mineral wool from blowdown lines.

- Case 6: A plant received a total of 4.7 person-rem during the following replacements:

  - Removed 14.3 cubic feet of fibrous insulation areas, such as a safety injection check valve enclosure and gaps in various lines at joints and hangers.

  - Removed or replaced 40–50 cubic feet of Cal-Sil. Removed Cal-Sil from inactive piping sections and replaced Cal-Sil with RMI on a section of safety injection piping in the steam generator cavities on safety injection.

  - Added banding to several hundred linear feet of Cal-Sil on over 40 small-bore piping lines, including chemical and volume control system letdown and regenerative lines, reactor coolant pump seal return lines, pressurizer spray and sample lines, primary sample lines, primary drainlines, steam generator sample lines, and safety injection lines.

- Case 7: A plant received 19.6 person-rem during replacement of 400 linear feet of piping insulation and replacement of steam generator insulation on all three steam generators from the tubesheet to the transition area.

- Case 8: A plant received 43.9 person-rem for replacement of 1,300 linear feet of piping insulation and replacement of steam generator insulation on all three steam generators from the tubesheet to the transition area.

- Case 9: A plant received 23.6 person-rem for the replacement of 975 cubic feet of Cal-Sil and 691 cubic feet of Temp Mat. Replacements were performed on the steam generators, pressurizer, and reactor vessel head. Some of this material was replaced with RMI. Asbestos insulation was present in the steam generator bays and the entire area was treated as an asbestos work area, which required tenting and other precautions.

Remaining Plants That Have Hazardous Materials

The NRC staff reviewed plant submittals to determine, and NEI anecdotally confirmed that approximately 18 of the 69 PWR units have some amount of asbestos insulation within a zone of influence (ZOI) for GSI-191. Almost all of the asbestos insulation reported was Cal-Sil insulation. The NRC staff notes that 11 of those 18 units have already resolved GSI-191, with the exception of in-vessel effects. Of the seven remaining units, five also reported the assumed

ZOIs used in analysis. None of these five plants credited a reduced ZOI for asbestos material. The remaining two plants did not report a ZOI assumed for the asbestos insulation. Based on the information obtained, the NRC staff notes that licensees typically assume staff-accepted, or larger, ZOIs for insulation containing asbestos. As such, these materials are less likely to be replaced. Additionally, while the presence of hazardous materials would be expected to increase doses because of the need for extra precautions, Case 9 above shows that the effects are not significantly out of line with doses received during replacement of insulation that does not contain hazardous materials. Furthermore, expected doses from insulation replacements are likely to be more sensitive to replacements in high-dose locations, as suggested by the relatively large dose for replacement of 20 linear feet of insulation on a regenerative heat exchanger in Case 4 above.

Dose Conclusions

No established standard exists for how much collective dose is, or is not, warranted in any specific operational situation. Once an activity is determined to be justified, licensees are required to conduct those activities in a manner that is ALARA. Ensuring that exposures are ALARA includes work planning and dose assessments to evaluate the need for, or effectiveness of, alternate dose mitigation strategies (i.e., additional shielding, source term reduction, use of respiratory protection); tracking and trending of the actual doses received in the execution of the work plan; and taking additional protective actions as necessary to achieve doses that are ALARA.

The staff expects that the remaining high-fiber plants would prefer to take advantage of reduced ZOIs for NUKON® using sure-hold bands rather than large insulation replacement campaigns using RMI. This would reduce expected doses as compared to actual insulation replacements. The highest reported dose incurred during actual insulation replacements, as noted above, was 44 person-rem. This collective dose equates to a cost of $88,000 in a regulatory analysis. The staff recognizes that this may not be a bounding value, since the scope of modifications needed at some plants to fully address GSI-191 could be larger than that for the limited sample of plants the staff obtained. Even if this number is not bounding, the dose cost is clearly not out of line with the expected doses from larger scope outage work performed occasionally by licensees (e.g., steam generator replacement).

Industry dose estimates range up to 600 person-rem ($1.2 million) with an average of 200 person-rem ($400,000). These values seem excessively conservative compared to the actual industry experience reported above. One reason for the apparent discrepancy could be that licensees are required to maintain doses ALARA in accordance with current regulations. This means that, after determining that insulation replacements are necessary, a licensee would be required by ALARA regulations to perform the replacements in an optimized manner to minimize incurred dose. This may mean electing to replace one insulation configuration over another within the same ZOI to minimize dose. This may also mean electing to replace insulation within the ZOI that does not contain hazardous materials (e.g., asbestos). However, it is unclear to what extent additional ALARA work planning or alternate means of GSI-191 resolution would reduce these estimated costs.

However, even if the estimates based on actual insulation replacements are too low for some plants, given the existence of hazardous materials (e.g., asbestos) that require additional

protective measures, such as use of respiratory protective devices that may result in increased dose, the staff notes that justification in terms of dose is only performed for backfits in which adequate protection, compliance with agency regulations, or redefining adequate protection are not involved. The staff has not performed a regulatory analysis in this case. However, the staff believes that the data show that the cost in terms of dose for insulation replacement is within the range of large-scope work that licensees have performed in the past (e.g., steam generator replacements). Furthermore, the staff does not believe that the dose likely to be received in support of issue resolution is excessive given the safety issues discussed in the paper.