Item B-65: Iodine Spiking (Rev. 2)

DESCRIPTION

Historical Background

This NUREG-0471[1] task is to develop and confirm a model for the iodine spiking phenomenon, in which the iodine concentration in the reactor coolant rises to many times its equilibrium concentration level (peak concentration) followed by a decay back to a level below the peak concentration. Procurement of data from operating plants and the development of a fuel release model for predicting the magnitude of the spikes will provide an understanding of this phenomenon which is not presently available. Improved knowledge of this topic would establish a better basis for accident calculations and could be used as a basis for establishing new reactor coolant activity limits.

Safety Significance

The calculated radiological consequences for some postulated design basis accidents are highly dependent upon the magnitude of the iodine spike assumed in the dose calculation model. These calculations are made with conservative assumptions, incorporating an iodine spiking factor which is based on a limited sample of plant data, and are in turn used to establish allowable coolant activity limits in the TS governing plant operations. However, the iodine spiking is a significant effect in only non-core melt accident consequences, which are not major contributors to nuclear plant risk.

PRIORITY DETERMINATION

A technical analysis of the proposed resolution of this issue was performed by PNL.[2] The resolution of this issue would apply to all operating and planned LWRs.

Frequency/Consequence Estimate

For converting thyroid exposure to equivalent whole body exposure, PNL derived a PWR expected public risk of 0.0143 man-rem/RY for a non-core melt SGTR and a coincident iodine spike using: (a) the PWR SGTR Task Force estimates for the probability of non-core melt SGTR events (1.3 x 10^{-3}/RY) and the amount of radioiodine (I-131) released (53,600 Ci/event); (b) the Prairie Island 1 conversion factor for translating curies of I-131 released to thyroid exposure; and (c) the conversion factor derived in the prioritization of Item III.A.1.3, "Maintain Supplies of Thyroid Blocking Agent." Using the ratioing technique described in NUREG/CR-2800[3] and a BWR small break LOCA frequency of 1.4 x 10^{-3} /RY, a BWR expected public risk due to a small break LOCA with a coincident iodine spike of 0.0185 man-rem/RY was derived.

Peak iodine concentration levels were estimated by AEB based on the average measured PWR and BWR coolant activity levels and an average peaking factor of 500, which was derived from the small population of data available on the iodine spiking phenomena. The peak primary coolant activity levels derived in this manner were estimated to be 60 µCi/gm and 4 µCi/gm for PWRs and BWRs, respectively,

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[1] NUREG-0471, "Generic Task Problem Descriptions (Categories B, C, and D)," U.S. Nuclear Regulatory Commission, June 1978.
[2] NUREG/CR-2800, "Guidelines for Nuclear Power Plant Safety Issue Prioritization Information Development," U.S. Nuclear Regulatory Commission, February 1983, (Supplement 1) May 1983, (Supplement 2) December 1983, (Supplement 3) September 1985, (Supplement 4) July 1986, (Supplement 5) July 1996.
[3] NUREG/CR-2800, "Guidelines for Nuclear Power Plant Safety Issue Prioritization Information Development," U.S. Nuclear Regulatory Commission, February 1983, (Supplement 1) May 1983, (Supplement 2) December 1983, (Supplement 3) September 1985, (Supplement 4) July 1986, (Supplement 5) July 1996.

and represent the base case average peak iodine concentrations before resolution of this issue.

Dose calculations used by the STGR Task Force were performed using an assumed coolant iodine activity level increase by a factor of 20 and a maximum allowed primary coolant iodine concentration of 1.0 μCi/gm for PWRs and 0.2 μCi/gm for BWRs, or an allowable primary coolant peak iodine concentration of 20 μCi/gm and 4 μCi/gm for PWRs and BWRs, respectively. It was assumed that new coolant activity limits established after the iodine spiking phenomena was better understood and would not permit allowable peak iodine concentrations greater than those derived above. Thus, the above values are assumed to represent the adjusted case peak allowable coolant activity concentrations after resolution of this issue.

The thyroid dose was converted into a risk-equivalent whole-body dose using the assumptions that: (1) health effects from thyroid dose are 95% curable with no long-term effects, and (2) whole-body dose is given five times the weighting of thyroid dose (consistent with NRC protective action guides).

The post-implementation or adjusted public risk was determined by multiplying the pre-implementation or base case public risk by the ratio of the post-implementation reactor primary peak iodine concentration level to the preimplementation average primary peak iodine concentration. As a result, the adjusted case public risk of 0.00477 man-rem/RY and 0.0185 man-rem/RY was calculated for PWRs and BWRs, respectively.

The change in public risk which might be realized by completion of this issue was determined by subtracting adjusted public risk from the base case public risk. The change in public risk was thus calculated to be 0.00953 man-rem/RY and 0 man-rem/RY by multiplying the above changes in public risk by the respective number of reactors and their average remaining lifetime (i.e., PWRs -90 reactors and 28.8 years; BWRs - 44 reactors and 27.4 years) and adding the products. Total public risk reduction was estimated to be 25 man-rem for completion of this issue.

Since this iodine spiking issue does not significantly affect core-melt accident consequences, resolution of the issue would not result in a core-melt frequency change.

Cost Estimate

From the currently available data, it was judged that the 4-hour sampling interval following a transient, which is currently proposed in LCOs, would probably miss some spiking peaks. A change to a 2-hour interval was thus assumed to provide adequate information for peak activity determination. The total sampling period following a major power transient was estimated to be 33 hours. At a sampling interval of 2 hours, rather than 4 hours, it was estimated that 8 additional samples would be required following each major transient. A survey of the available iodine spiking data resulted in an estimated frequency of iodine spiking events of 0.52/RY and 0.14/RY for PWRs and BWRs, respectively.

Industry Cost: It was assumed that the costs to industry are due to the increased frequency of iodine sampling after each transient. No new equipment for sampling and analysis was assumed to be required. However, some minor modification of the sampling systems was assumed to be required at operating plants to accommodate the increased sampling frequency.

At the 71 operating plants, 4 man-weeks of labor were assumed to upgrade the sampling and analysis capability to accommodate the shorter sampling interval. At a cost of $2,270/man-week, a total industry implementation cost of $645,000 was calculated.

Increased industry operating costs were estimated using the 8 estimated additional samples per major transient, the above estimated iodine spike frequencies for PWRs and BWRs, the respective number of reactors and their average remaining life, and an estimated 2 man-hours to obtain and analyze a reactor coolant sample. A total industry operating cost of $1.38M was calculated. Therefore, the total industry cost associated with this issue was estimated to be $2M.

NRC Cost: Efforts required by the NRC to develop and confirm a model for the iodine-spiking phenomenon could be significant because little is known about the physics associated with the phenomenon. Two staff-years of NRC effort were estimated for the development of new requirements. Contractor support of the development of new requirements was estimated to be $300,000. At a cost of $100,000/man-year for NRC personnel, a total NRC cost of $0.5M for resolution of the issue and development of new requirements was estimated.

It was assumed that NRC staff time would be expended in the review of increased sampling requirements and the resulting information during the lifetime of the plants. It was estimated that 0.1 man-week/RY would be required to monitor the new sampling requirements and plant results at a total NRC cost of $860,000. Thus, the total NRC cost is estimated to be about $1.4M.

Value/Impact Assessment

Based on a public risk reduction of 25 man-rem, the value/impact score is given by:

$$S = \frac{25\,\text{man} - \text{rem}}{\$(2 + 1.4)\text{M}}$$

$$= 7.4\,\text{man} - \text{rem} / \$\text{M}$$

Uncertainties

Uncertainty in cost was found to be small, about ±50%. Uncertainty in the public risk reduction estimate ranged from about plus 2 orders of magnitude on the upper bound to about minus 1 order of magnitude on the lower bound.

Other Considerations

It was assumed that all the labor associated with obtaining and analyzing additional record coolant samples would, of necessity, be expended in moderate radiation fields. In addition, one-fourth of the labor estimated for modification of the sampling systems at operating plants was assumed to occur in a moderate radiation field. Assuming a field of 25 millirem/hr a total increased ORE of 370 man-rem was estimated.

CONCLUSION

The total public risk reduction calculated for this issue is insignificant. Furthermore, the value/impact ratio is poor. The estimated increase in ORE due to the assumed resolution of the iodine spiking issue is large in comparison to the estimated public risk reduction, which would also be an incentive for a drop priority assignment. Uncertainty, although high for the public risk reduction estimate, would only support a remote possibility that the issue could warrant as high as a medium-priority assignment. Therefore, based upon the above considerations, we recommend that this issue be assigned a DROP priority.