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The Assessment of Radio-nuclide Release and of Dosage in a Postulated Single SGTR Event in the Wolsong NPP with Defect Fuel

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1. Introduction

As a part of the Ministry of Knowledge Economy (MKE) Nuclear Power Technology Development Project, KNF and KOPEC have been studying the effects of defect fuel on the nuclear power plant(NPP) operation.

In the postulated event of steam generator tube rupture(SGTR) of a nuclear power plant, the assessments have been traditionally based on the over-conservative assumptions. The regulatory criteria on the dosage have been revised to be more specific and tight[1,2]. These changes in regulatory environments require the utilities to streamline the methodologies and assumptions of dosage assessments to be more reasonably conservative as well.

The assumptions of new approach to evaluating the existing iodine concentration in primary heat transport system(PHTS) and secondary coolant system have been made to be more rigorous. The iodine concentration in the PHTS increases sharply, if there is any defect fuel in the fuel channel, after the reactor shut-down rather than during the normal steady operating condition. This fact has been accounted for in the assessments of radio-nuclide releases[3,4].

Another change in approach being tested is the assessment of dosage applying more reasonable assumptions to the ADDAM code replacing the PEAR code for Wolsong NPP.

2. Methods and Results

In this section the models and assumptions for dosage assessments for a single steam generator tube rupture are described.

2.1 Thermohydraulics

Since the discharge flow of a single steam generator tube rupture is within the capacity of the D_2O feed system, it is assumed that the operator actions are credited for reactor trip, controlled cooldown and engaging shutdown cooling system.

Operator is credited to confirm SGTR and to shutdown the reactor 15 minutes after the second alarm, which is the D_2O in H_2O high concentration alarm (at about 10 minutes into the event).

Following reactor shutdown, it is assumed that operator takes the procedures of normal cooldown mode using PHT pumps and condenser steam discharge valves and/or atmospheric steam discharge valves (CSDV's/ASDV's). This assumption is for conservatism in terms of radio-nuclide release. For the normal cooldown mode, the expected steam discharge path is through the CSDV's. However, in order to bound the release calculation, the steam is assumed to be discharged through the ASDV's.

When the PHTS coolant temperature falls to the shutdown cooling(SDC) entry temperature, the operator would close CSDV's/ASDV's, and valve in the shutdown cooling system(SDCS). This would terminate the leakage from the steam and feedwater system to the atmosphere.

2.2 Radio-nuclide Release to the Environment

The following radio-nuclides are considered for release.

- iodine mixture (that is, mixture of isotopes of iodine),
- noble gas mixture (that is, mixture of isotopes of krypton and xenon), and
- tritium.

The time period of steam flow through the ASDV's to the atmosphere is from the time of reactor shutdown at 25 minutes to the time of engaging the SDCS at 65 minutes (PHTS coolant temperature is at SDC entry condition). The steam flow rate through the ASDV's is determined by energy balance of the steam generator. Integrating the flow rate over the time period of discharge, the integrated steam discharge can be obtained as follows:

$$M_s = Q_c / (\bar{h}_g - \bar{h}_{fw}) \qquad (1)$$

Where:

M_s = integrated steam discharge
Q_c = total energy input to the SG coolant
$\bar{h}_g$, $\bar{h}_{fw}$ = average enthalpy of steam and feedwater, respectively.

2.3 Analytical Model of Radio-nuclide Release

The radionuclide releases to the environment are calculated using a simple analytical model. The model simulates the transient mass and radionuclide concentrations in the four steam generators(SG) and the feedtrain.

The concentration of radioactive species in the secondary system is determined by solving the governing equations about the radionuclides.

Fig. 1 shows a schematic illustration of the model components and the important parameters governing the radionuclide concentration in the secondary system.

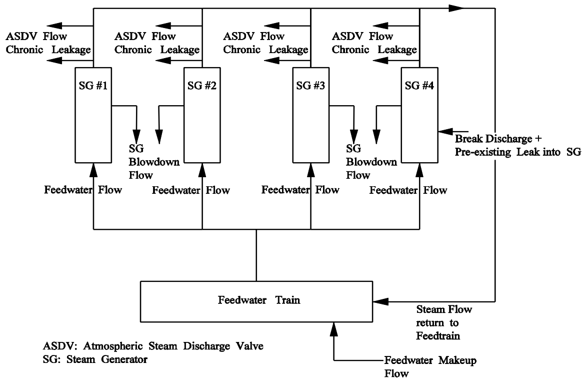

Fig. 1 Illustration of secondary system model used to determine radionuclide distribution and release to the atmosphere

The governing equations which simulate the physical processes shown in Fig. 1 can be obtained from the following relationships for each radionuclide:

The change in the radionuclide in SG i =
the incoming radionuclide to SG i from feedtrain
\+ the incoming radionuclide to SG i from primary coolant system
\- the radionuclide leaving SG i via blowdown
\- the radionuclide leaving SG i via steam flow out of boiler (i = 1 ~ 4);

The change in the radionuclide in feedtrain =
the incoming radionuclide to feedtrain via net returning steam flow from all SG's
\- the radionuclide leaving feedtrain via feed water flow to all SG's
\- the radionuclide leaving feedtrain due to chronic leakage.

Attenuation of radionuclide leaving steam generators must be properly considered.

The relationships of mass balance or continuity of flow can be applied to the above relationships.

The above relationships are appropriate for all dissolved radionuclides. All noble gases, such as krypton and xenon, are assumed to degas from the liquid phase as they enter the steam generator and exit the steam generator immediately with the steam as non-condensable gases. Consequentially, there is never any holdup of noble gases in the secondary system. Thus, the above relationships do not apply to noble gases.

2.4 Numerical Model of Radio-nuclide Release

The numerical model to calculate time-dependant radionuclide concentrations and mass inventories for feedtrain and each steam generator for dissolved elements and noble gasses can be obtained from the governing equations. The numerical solution to the differential equations is obtained using the Euler method, which is a first order approximation to the solution.

Integrated discharge of radionuclides can be obtained by the numerical integration over the time period of discharge rate multiplied by the concentration of the species.

2.5 Radiological Dose

New approach to assess the radiological dose has been being tested. The new approach includes employing new computer analysis codes and more reasonable assumptions. A typical test case has shown that the dosage obtained this way is approximately an order of magnitude less than the result from the typical old methodology.

2.6 Results

The radio-nuclide release assessed by applying the new assumptions for radio-nuclide concentrations in the coolant together with the new approach to the assessment of radiological dose results in a much reasonably conservative value which satisfies the dose criteria with more relaxed target operating limit value of radio-nuclide concentration in primary coolant.

3. Conclusions

The radio-nuclide release assessed by the new approach has been proved to be more reasonably conservative rather than to be too much over-conservative. Together with the new streamlined approach in the dosage assessment being tested, it shows the possibility that the operating limit value can be relaxed to be more reasonably conservative than that of the present Wolsong 2,3,4 NPP's[5].

REFERENCES

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