Introduction

- **Definition of an inadvertent boron dilution accident**
  - It may be caused by improper operator action or by a failure in the boronic acid makeup flow path, which reduces the flow of borated water to the charging pump suction.
  - Either cause can produce a boron concentration of the charging flow, which is below the concentration of the reactor coolant.
  - This event is classified as an Anticipated Operational Occurrence.

- **Analysis method**
  - The boron dilution accident is performed through deterministic safety analysis method.
  - So the result is very limited.
  - Most limited boron dilution flow rate is assumed.
  - The boron dilution accident was performed using probabilistic analysis method.
  - It can eliminate unnecessary conservatism.
  - A more realistic analysis of boron dilution accident was performed.

Methods and Assumption

- **Basic assumptions for probabilistic analysis of boron dilution accident**
  - Plant: WH type domestic 2-loop nuclear power plant.
  - Operating mode: shutdown mode 5 (cold shutdown).
  - Using Failure Modes Effects Analysis (FMEA).
  - FMEA is performed to determine equipment failures and operator errors that could lead to an inadvertent boron dilution of the RCS.
  - Passive components (heat exchangers, tanks, pipes, and manual valves) were not included in this analysis.
  - Operator errors to open or close manual valves that could lead to an inadvertent boron dilution initiating event are considered in this analysis.
  - An event tree is constructed to assess mitigation of the boron dilution initiating events.
  - The dilution flows to the RCS for each inadvertent boron dilution initiating events.
  - Corresponding available time that the operator has after the neutron flux multiplication alarm.

Analysis Results

- **FMEA results**
  - The potential initiators identified in the FMEA is 9 cases.
  - CVCS Mixed-Bed Demineralizer Flushing Operation
  - CVCS Cation-Demineralizer Flushing Operation
  - CVCS Anion-Demineralizer Flushing Operation
  - BTRS(Boron Thermal Regeneration System) Boron Flushing Operation
  - BTRS(Boron Thermal Regeneration System) Regen Flushing Operation
  - Radiation Monitor Flushing Operation
  - BCMS(Boron Concentration Measurement System) Flushing Operation
  - Chemical Mixing Tank Flushing Operation
  - RMS(Reactor Makeup System)
  - Emergency Boration Line Flushing Operation

  - Final case of initiating an inadvertent boron dilution event are three cases.

- **Chemical addition**
  - A boron dilution event could be initiated either during or after chemical addition, if both the inlet and outlet valves to the chemical mixing tank are not closed.
  - The initiating event frequency of a dilution event occurring during chemical addition is 4.0E-04 per reactor years and these values were calculated by quoting the values in NUREG/CR-1278.

- **CVCS mixed bed demineralizer flush**
  - CVCS mixed bed demineralizer flush is divided to 2 cases.
  - Boron dilution event during the CVCS mixed bed demineralizer flushing operation.
  - Boron dilution event after the CVCS mixed bed demineralizer flushing operation.
  - Boron dilution initiating event frequency.

- **Reactor makeup system**
  - Event tree is constructed to determine the total initiating event frequency contribution from the reactor makeup system (Figure 1, Table 1 & Table 2).
  - According to Table 2, the dilution flow rate is divided into three category. Table 3 lists the initiating event probabilities and frequencies (per reactor year) for an inadvertent boron dilution event during reactor makeup operation.

Conclusions

- **Probabilistic boron dilution accident analysis was performed and through this analysis potential flow paths between the unborated water supply and RCS were identified.**
- **Loss of shutdown margin frequency for total potential initiators (Chemical Addition, CVCS Mixed Bed Demineralizer Flush, Reactor Makeup System) frequency is more conservative than the occurrence frequency of AOO.**
- It is too conservative to assume maximum dilution flow rate in deterministic safety analysis.
- It is reasonable to assume average dilution flow rate in deterministic safety analysis boron dilution accident analysis.