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Lead Factor Improvement of Surveillance Capsule Assembly in Reactor Vessel

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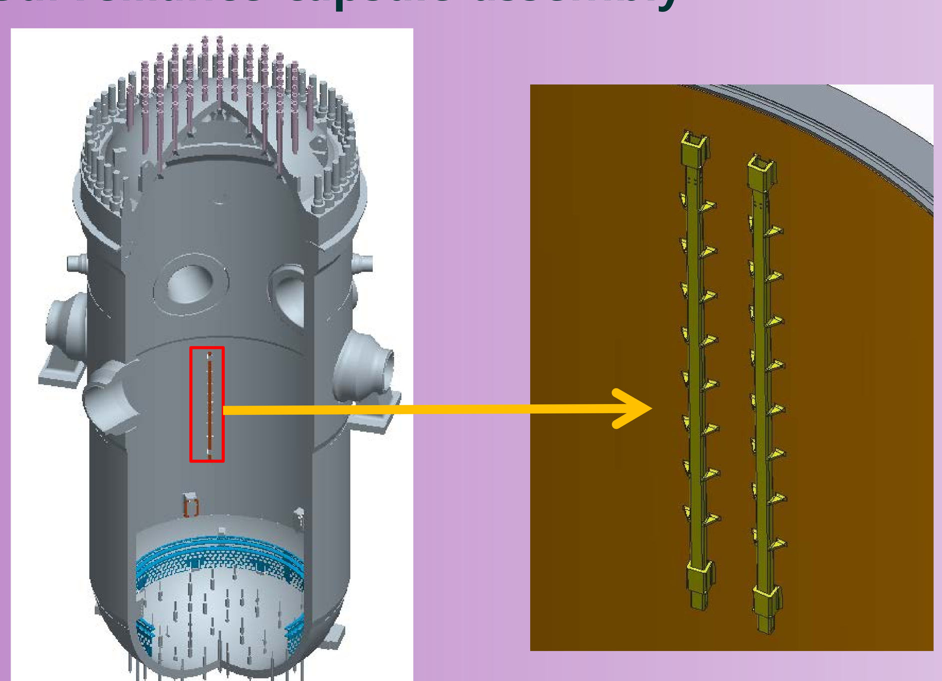
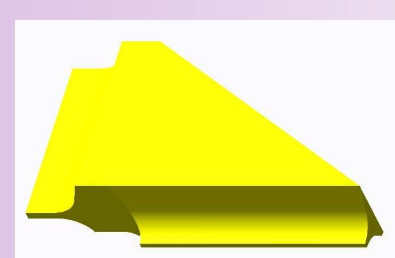
Introduction

The reactor vessel surveillance capsule assembly (SCA) is a structure installed on the inner wall of the reactor vessel to surveil the change in the material properties of the reactor vessel due to neutron irradiation during its lifetime. Surveillance specimens made of reactor vessel material are inserted in the SCA. The SCA installed in the reactor vessel is periodically pulled out, and changes in mechanical properties of the specimen due to neutron irradiation during the life of the reactor are surveilled. The SCA is installed close to the core so that it receives a greater dose of neutron irradiation than the inner wall of the reactor vessel. By allowing the surveillance specimen to receive more neutrons than the reactor vessel, it is possible to know in advance the material properties of the reactor vessel that will change in the future. As such, a lead factor is used as a parameter indicating the difference of the neutron irradiation dose between the reactor vessel and the surveillance specimen. The lead factor is expressed as the ratio of the neutron irradiation dose irradiated on the surveillance to that on the inner wall of the reactor vessel. Therefore, as the lead factor is greater than 1, it is possible to predict the change in the material properties of the reactor vessel in the future farther from the surveillance specimen. In addition, the closer to 1, the closer the material property data to the point at which the surveillance specimen is withdrawn. In the case of the OPR1000 and APR1400, which are operating nuclear power plants in Korea, the lead factor is close to 1 because the SCA is installed relatively close to the inner wall of the reactor vessel. Therefore, it is difficult to predict changes in the material properties of the reactor vessel during long-term use. In this paper, we intend to improve the lead factor to predict the changes in the material properties of reactor vessels of the large nuclear power plant in the far future. For this purpose, the necessary lead factor has been calculated and the optimum location of the SCA has been set.

Surveillance Capsule Assembly & Lead Factor

- **Surveillance capsule assembly**





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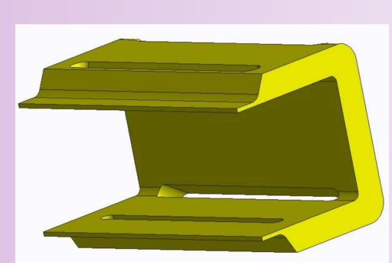


<Bracket>

<Location & shape of surveillance capsule assembly >

- **Lead Factor**

  - Lead Factor = $\dfrac{\text{Neutron fluence of surveillance capsule}}{\text{Neutron fluence of reactor vessel}}$
  - ASTM E185-82
    - Specimen irradiation history duplicates as closely as possible
    - Recommended lead factor : 1.0 ~ 3.0
  - Lead factors of operation plants
    - WH type & Pramatome plant : 2.5 ~ 3.5
    - OPR1000 : 1.35 ~ 1.45
    - APR1400 : 1.35 ~ 1.40

Lead Factor Calculation

- **Target Lead Factor : 1.5~3.0**
  - In order to calculate the target lead factor, ASTM E185, which is presented as a standard in the relevant domestic notice (Nuclear Reactor Pressure Vessel Surveillance Test Standard) and the Unites States federal regulations (10CFR50 Appendix H) is reviewed.
    - Domestic requirement : 1.5 ~ 3.0
    - ASTM E185 (2010 Ver.) requirement : 1.5 ~ 5.0

  ☞ Therefore, the range of the target lead factor that satisfies both the notice and the revisions of the technical standard was determined to be between 1.5 and 3.0.

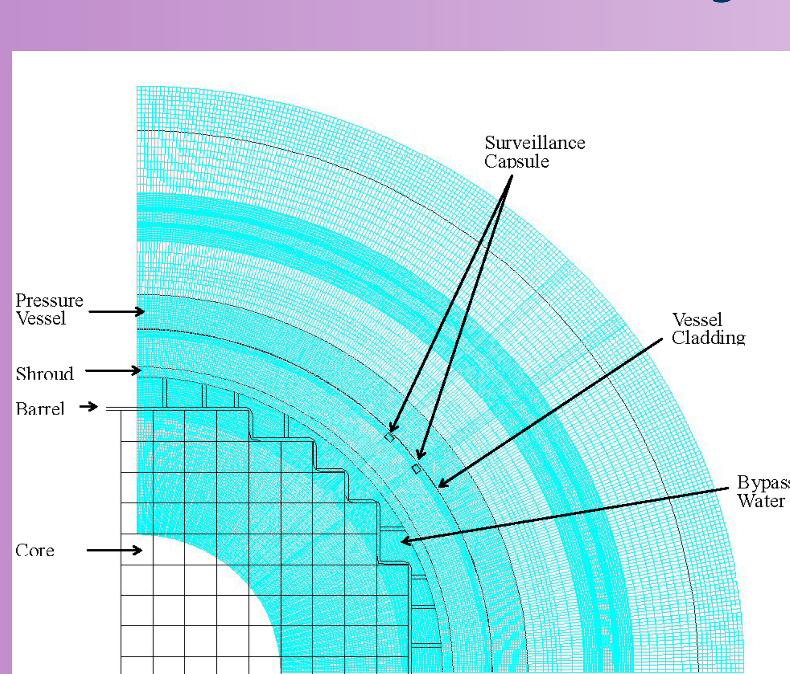
- **Necessary Lead Factor : 1.91**
  - Final lead factor is 1.91, which is the value obtained by adding 0.4 of each margin to the target lead factor of 1.51.
  - Final necessary lead factor of 1.91 is reasonable because it exists in the range of 1.5 to 3.0, which is the target lead factor

< Contributing causes to lead factor error >

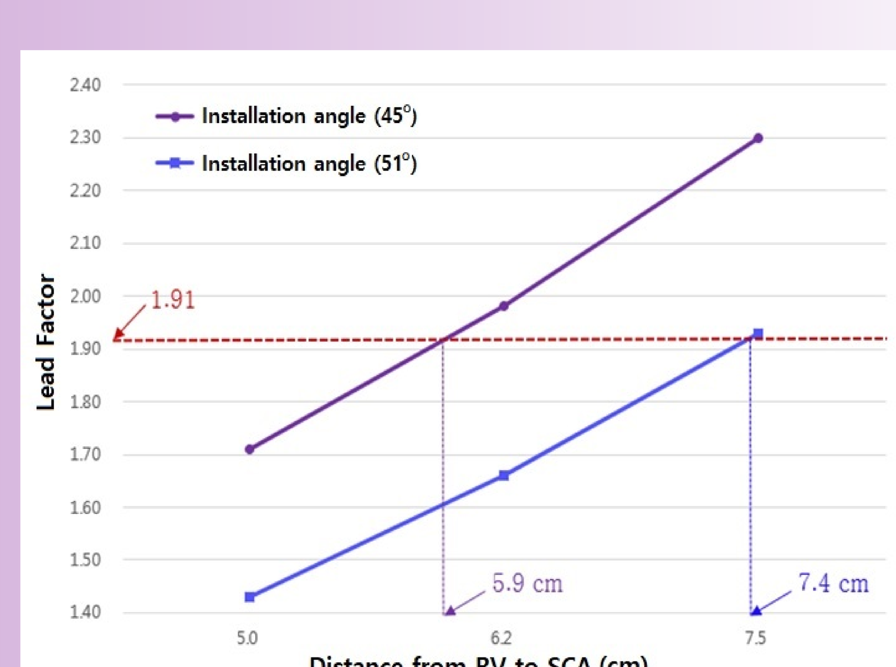
Contributing causes to LF error	Error bound
Calculation method	0.12
Core power distribution	0.05
Gap between RV and SCA	0.19
Bias of measured values	0.04
Sum. of factors	0.40

Location of Surveillance Capsule Assembly

- **Circumferential Installation angle of SCAs**

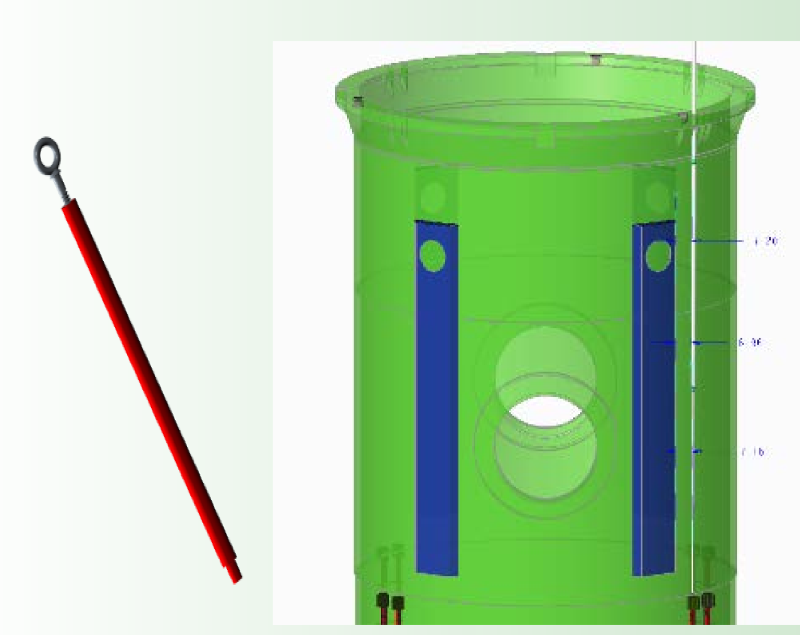


< Neutron transport calculation model >

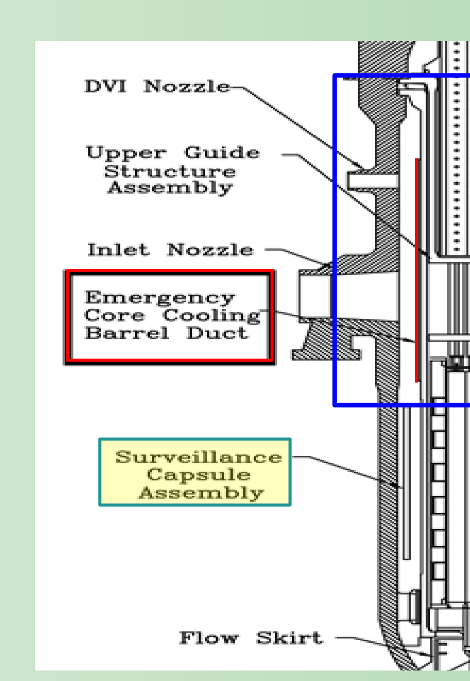


< Cyclic hardening of Heat A >

- **Interference Check**



< IG/OG check of SCAs>



< Interference check with RVIs >

Conclusions

In order to increase the utilization of large-scale nuclear power plant SCAs and to operate a stable surveillance program, the position of the SCA was positioned closer to the reactor core to increase the lead factor. As the SCA's lead factor increases, it is possible to reliably secure and utilize the material property change data of the nuclear reactor vessel due to neutron irradiation during the life time of the reactor vessel of large-scale nuclear power plants. And this improvement in the lead factor of large-scale nuclear power plants will not only increase the reliability of domestic operating plants but also contribute to strengthen the expert competitiveness of nuclear power plants in the future.