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A Study on Assumption of Accident Scenarios during Decommissioning of Nuclear Power Plant

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1. Introduction

The type of accident scenario for a Nuclear Power Plant (NPP) after a permanent shutdown will be different from that of the operation phase. Serious accidents or incidents, postulated during the phase in which the plant was in operation, may be excluded during the decommissioning. The absence or reduction of physical-chemical mechanisms (pressure, temperature, production rate of radionuclides, etc.) that could initiate or increase the extension of accidental discharges to the environment considerably reduce hazard for the NPP. However, given that there is radioactivity that can be emitted off-site if the existing confinement barriers are damaged by an accident or any malfunctions, it is necessary to analyze and adopt a set of accident situation for the nuclear decommissioning.

In this study, to identify potential accidents, the lists of major accidents included in Appendix I of NUREG-0586 were reviewed [1]. Based on the accident lists included in NUREG-0586, we have classified the accident types that potentially effect on public dose. In evaluating postulated accidents during operation phase, the definition of source term is assumed based on the fuel damage rate. However, during the decommissioning phase, since the spent fuel is transferred to the intermediate areas such as independent spent fuel storage installation or centralized spent fuel storage facilities, the assumption approach for defining the source term needs to be different from that in operation.

Therefore, the purpose of this study is to establish the methodology for how to calculate radiation source term taking into accounts the each major accident scenarios during dismantling works. In addition, the accident outline for each accident is assumed and the parameters to be applied for the accident assessment is discussed. We hope that the approach to applying methodology to calculate source term, proposed in this paper, will give a valuable insight to other related researcher who need to analysis the potential radiological accidents, especially for the nuclear decommissioning.

2. Accident types

The type of accidents that can have a radiological impact on the public could be majorly categorized into drop, fire/explosion, loss of confinement, and liquid spills.

2.1. Drop

A drop event can be initiated by a malfunction of the tools for the handling of load or human errors. The consequences of these drops may lead to the dispersion of radioactive aerosols from the surface contamination.

2.2. Fire / Explosion

A fire event could affect several plant systems, structures, and components simultaneously. Combustible materials can be ignited by either external ignition sources (e.g. oxyacetylene torches) or internal sources (e.g. spontaneous combustion). Radioactive contaminants from HEPA filters or radioactive waste may be released into the atmosphere due to the fire.

Explosions can occur from the ion exchange resin off-gases, explosives, inflammable gas (e.g. acetylene, LPG) storage bottles. Due to the aforementioned explosion in the dismantling work area, radioactive materials are released into the atmosphere resulting in spreads out of the site through the ventilation system installed in the containment building.

2.3. Loss of confinement

The cutting works will cause radioactive material release into the atmosphere. Preventative measures like the confinement system will be selected to prevent airborne contaminations into the air. However, loss of confinement may occur due to human error, loss of power, failure of mechanism, etc.

2.4. Liquid spill

Internal decontamination methods typically use liquids to remove radioactive contaminations from the surface of the objects (e.g. chemical decontamination, high pressure water washing). Liquid radioactive waste or decontamination waste can have a radiological effect on the public due to damage or leakage of storage tank.

3. Assumptions for source term

The approach is described based on the representative accident scenarios as following.

3.1. Drop accident

It is assumed that the accident would occur during the transport of the steam generator to the radioactive waste treatment facility where it will be segmented. During transport, the steam generator will drop from a high position, due to failure of the lifting mechanism or any kind of cause.

The accident causes the detachment of a fraction of 10^{-3} [2], from the activity deposited on the primary generator inside, and its subsequent release into the atmosphere in the containment as an aerosol form.

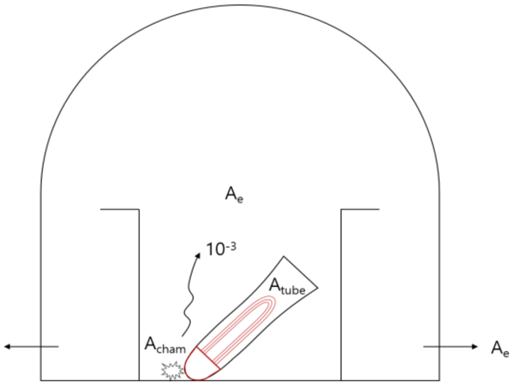

Fig. 1. Dropping the steam generator during its transportation.

To calculate the radioactivity released, once the accident has occurred, the following equation (1) is used and its concept is simply expressed in Fig. 1.

$$A_e = (A_{tube} \cdot S_{tube} + A_{cham} \cdot S_{cham}) \cdot F_r \quad \cdots\cdots\cdots \quad (1)$$

A_e: Activity released to environment (source term SG)
A_{tube}: Superficial contamination of SG bundle tubes (Bq/cm^2)
S_{tube}: Surface of SG bundle tubes (cm^2)
A_{cham}: Superficial contamination of SG coolant chamber (Bq/cm^2)
S_{cham}: Surface of SG coolant chamber (cm^2)
F_r: fraction released $=10^{-3}$ [2]

For the radioactivity of surface contamination (A_{tube}, A_{cham}), the initial characterization data of the primary system can be used. And it is assumed, conservatively, that radioactive contamination in the total surface area of the tube and the chamber is released.

3.2. Fire / Explosion accident

This accident postulates the explosion of several bottles of acetylene used as fuel for the thermal segmentation of the Reactor Pressure Vessel. It is assumed that the radioactive aerosol generated by cutting fully fills the cutting area. The assumption also considered that the explosion causes the re-suspension, and the materials deposited on the interior surface of cutting area. Finally, the explosion causes the destruction of HEPA filters in the ventilation systems.

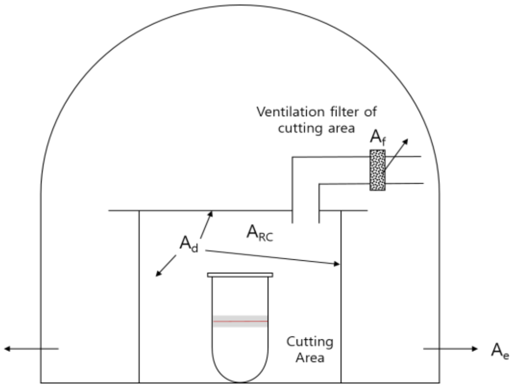

Fig. 2. Explosion during the segmentation of the Reactor Pressure Vessel.

To calculate the radioactivity released, once the accident has occurred, the following equation (2) is used and its concept is simply expressed in Fig. 2.

$$A_c = (A_f + A_{RC} + A_d) \quad \cdots\cdots\cdots \quad (2)$$

A_c: total activity released in containment (Bq)
A_f: activity in filters (Bq)
A_{RC}: Airborne contamination in the cutting area from cutting activities (Bq)
A_d: deposited contamination on the walls (Bq)
A_e: activity released into the environment (Bq), that is equal to A_c (no filtration or deposition)

In the atmosphere of cutting area, the radioactive aerosol is filled with dust form generated by cutting at a rate of 100 mg/m^3 [3]. And radioactivity in the filter can be calculated by applying a value that the total activity airborne when the most active part of the Reactor Vessel Internal (RVI) is cut.

3.3. Loss of confinement accident

Among the works related to the thermal cutting of contaminated components, it is assumed that cutting the reactor coolant pump can be considered on behalf of other contaminated equipment as an enveloping scenario. This accident postulates the performance of a complete circumferential cut of the pump's housing, assuming that, due to unexpected causes such as human error, failure of confinement system, etc. Finally, contaminations will be released through the exhaust stack of the containment ventilation system, whose filters are not taken into account in a conservative manner.

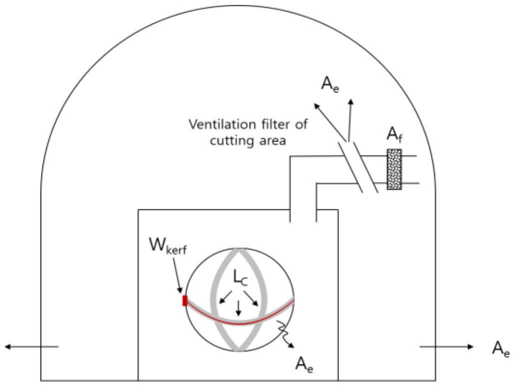

Fig. 3. Loss of confinement during a circumferential cut of the Coolant Pump

To calculate the radioactivity released, once the accident has occurred, the following equation (3) is used and it is simply expressed Fig. 3.

$$A_e = A_{sur} \cdot L_C \cdot W_{kerf} \quad \cdots\cdots\cdots \quad (3)$$

A_{sur}: Superficial contamination of RCP (Bq/cm^2)
L_{CT}: total length of RCP cutting (cm)
W_{kerf}: width of cutting depending on the technique (cm)

3.4. Liquid spill accident

During the dismantling process of RVI, it will be cut under water and this water will be collected in a tank. It is assumed that the water tank located outdoors and damaged due to unexpected causes such as corrosion, human error, disaster, etc. Even though the refueling tank is not filled with water, it is assumed for a conservative approach.

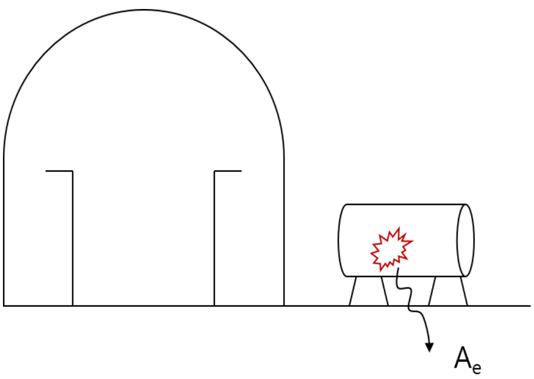

Fig. 4. Leak of liquid waste in the refueling tank

To calculate the activity released into the ocean, a total water volume should be considered. And the water purification system will be installed under water, inside the Spent Fuel Pool. The total amount of liquid radioactivity can be calculated by using both the limit activity (Bq/m^3) in the water and the volume (m^3).

4. Public dose assessment

4.1. Assessment methodology

In this study, accident scenarios were conservatively assumed that all radioactivity released will extend to the off site without functioning any filters. The main exposure pathways are (1) external exposure by radioactive clouds from gamma and beta radiation, and (2) internal exposure by suction of contaminated air [4]. In addition, the pathways for evaluating the impact of public due to radiological accident is the same as in operation phase.

The atmospheric diffusion factor (X/Q) was applied at the Exclusion Area Boundary (EAB) for 2 hours, and conservatively, the emission type can be applied to the ground release.

5. Conclusion

In case of accident from the NUREG reference, the most radiological effect on public is identified as the loss of confinement. It was found that the effect of the released effluent was much lower than the public dose criteria. The radiological impact of the public for the accidents in decommissioning phase may be insignificant

In this paper, the methodology for defining the source term for each accident type was analyzed. Because it is important that the radiation source term should be firstly calculated to assess the radiological impact on public.

Basically, during the transition period for decommissioning, initial characterization needs to be carried out to identify contamination type and extent (key radionuclides, inventory, etc.). If the actual radionuclide data is available from the initial characterization, a reliable radiological assessment for the each accident can be performed. Even if the actual data cannot be applied, applying the data of the same system would be a reasonable approach. For the sake of evaluating the accidents in a reliable manner, reasonable assumptions as well as obtaining the data to be applied are very important to assess the radiological impact on the public.

REFERENCES

[1] U.S NRC, Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities, NUREG-0586.
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[4] U.S.NRC, Atmospheric Dispersion Models for Potential Accident Consequence Assessment at Nuclear Power Plant, Regulatory Guide 1.145.