CHARACTERISTICS OF GENERATED AEROSOLS AND ESTIMATION OF AIR CONTAMINATION IN DECOMMISSIONING OF THE JAPAN POWER DEMONSTRATION REACTOR

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INTRODUCTION

A decommissioning program of the Japan Power Demonstration Reactor(JPDR) started in order to establish technical bases for future dismantlement of commercial nuclear power plants. Some techniques of reactor dismantling were developed. Various cutting methods were tested during the dismantling of the JPDR, which had variety of structures, materials and contamination level. JAERI developed an underwater plasma-arc cutting system which is capable of effective cutting highly activated reactor components and consequently reducing radiation exposure of workers. The extent of air contamination generated from underwater cutting had been unknown because of insufficient experiences of application of this technique. Methods for estimating the level of air contamination which results from the underwater cutting are necessary to evaluate radiation exposure of workers. A mathematical model of estimating air contamination level was proposed for aerosol generation during in-air and underwater cutting processes. The model was examined and some characteristics of the generated aerosols were investigated.

MATHEMATICAL MODEL FOR ESTIMATING AIR CONTAMINATION LEVEL

The air contamination is caused by the aerosols due to the cutting. An air contamination estimating model for the reactor dismantling is shown in Fig. 1. Formulas to calculate the total radioactivity of material generated during cutting operations were given by Smith et al.(1). The evaluation method of airborne activity resulting from radioactive surface contamination was developed by Shapiro(2). Both methods were applied to our model. The dispersion rate for in-air cutting was defined as activity ratio of material generated during the cutting to dispersed aerosols, and was given by:

$$\lambda a = Ca(Vs \cdot S + F)T/A \qquad \text{(i)}$$

where: λa = dispersion rate for in-air cutting

- Ca = airborne concentration for in-air cutting (Bq/cm^3)
- Vs = settling velocity of aerosols (cm/min)
- S = area of floor (cm^2)
- F = ventilation rate (cm^3/min)
- T = working time in cutting operation(min)
- A = total radioactivity of material generated during cutting operation

The dispersion rate for underwater cutting was defined as radioactivity ratio of material generated during underwater cutting to dispersed aerosols from the water into the air, and was given by:

$$\lambda w(d) = Cw\ (Vs \cdot S + F)T/A \qquad \text{(ii)}$$

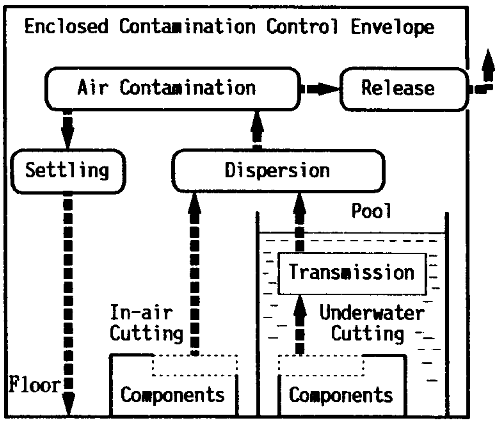

Fig. 1 Air contamination estimating model for the reactor dismantling

where: $\lambda w(d)$ = dispersion rate for underwater cutting

Cw = airborne concentration for underwater cutting (Bq/cm^3)

d = water depth at cutting operation (m)

Aerosol transmission factor (P (d)) was defined as:

$$P(d) = \lambda w(d) / \lambda a \qquad \text{(iii)}$$

MEASUREMENTS OF AEROSOLS

The radioactivity air concentration and size distribution of aerosols were measured to investigate characteristics of dispersed aerosols in a thermal cutting process. The reactor internals and pipes connected to reactor pressure vessel(RPV) were cut in the air with oxyacetylene and plasma-arc torches. The highly activated internals were cut contourly at water depths between 1 m and 8 m in the RPV and spent fuel storage pool with underwater plasma-arc cutting systems(Fig. 2). Typical surface or specific radioactivity of contaminated components are listed in Table 1.

Radioactive aerosols generated by the cutting were collected on glass fiber filters with a low pressure cascade impactor and a dust sampler. The aerosols were sampled at an exit of an enclosed contamination control envelope. Radioactivity on the filters were measured with a GM counter and a high purity Ge γ -ray spectrometer.

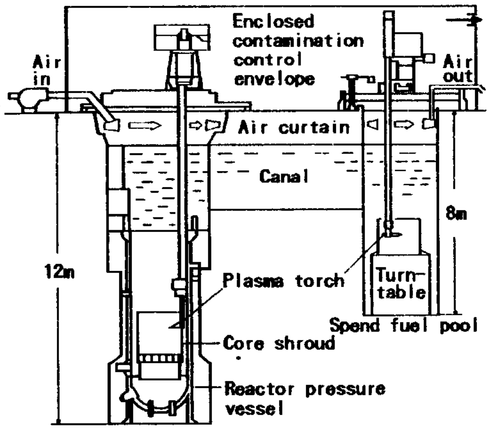

Fig. 2 Schematic view of cutting of reactor components in the water

Table 1 Radioactivity levels in major contaminated reactor components

Code	Component	Radioactivity
a	Pipes connected to RPV	2.9×10^2 Bq/cm^2
b	Channel box	2.0×10^4 Bq/cm^3
c	Core shroud	2.9×10^7 Bq/cm^3
d	Bottom grid	3.0×10^5 Bq/cm^3
e	Core support	1.5×10^5 Bq/cm^3
f	Control rod	3.0×10^7 Bq/cm^3
g	In-core monitor tube	2.0×10^{10} Bq/cm^3

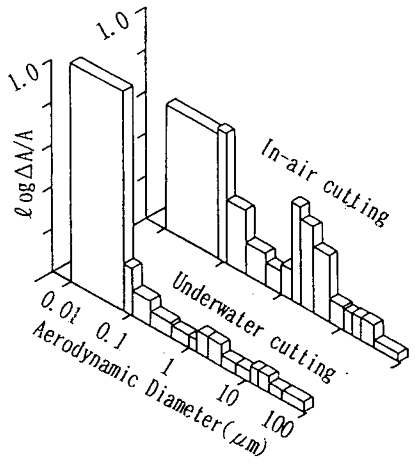

Fig. 3 Size distribution of aerosol generated by thermal cutting in the air and in the water

RESULTS AND DISCUSSION

1) Aerosol size and size distribution

Figure 3 shows size distribution of aerosol generated by thermal cutting in the air and in the water. In the case of in-air cutting, bimodal distribution was observed, which has peaks at 0.05 μ m and 3 μ m of aerosol size. On the other hand, in the case of underwater cutting, only a single peak was observed at 0.05 μ m. This property may be explained by the fact that the big-size aerosols in bubbles were easily captured by the water.

2) Dispersion rate during in-air and underwater cutting

Dispersion rates for in-air cutting were calculated by Equation (i) using data measured in the pipe cutting. The results are plotted at 0 m of water depth in Fig. 4. The dispersion rate ranges from 3×10^{-4} to 3×10^{-2}. The geometric mean of the rate is 3×10^{-3}. Dispersion rates for underwater cutting were calculated also by Equation (ii) using data measured in the cutting of internals. The dispersion rate decreases exponentially with the water depth as shown in Fig. 4. The geometric means are 6×10^{-5} and 3×10^{-7} at 2 m and 8 m water depth, respectively.

3) Aerosol transmission factor

The typical transmission factors as given by Equation (iii) are 2×10^{-2} at 2 m, 1×10^{-3} at 4.5 m and 1×10^{-4} at 8 m depths in the water. These results show that the dispersion volume of aerosols depends on the water depth of cutting operation.

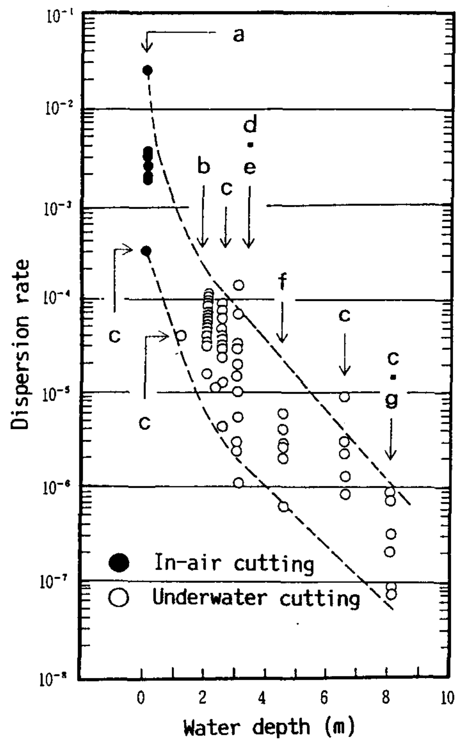

Fig. 4 Dispersion rates for in-air and underwater cutting (a-g: components in Table 1)

CONCLUSION

The characteristics of the aerosols generated from some structure-cutting operations were studied through the dismantling works of the JPDR. A model was proposed to estimate air contamination level due to aerosol generation. The transmission factors of aerosols in the water were obtained and found to decrease drastically with the water depth. The model and accumulated data will be helpful for accurate estimation of occupational radiation exposure and planning of reasonable dismantling methods in future decommissioning of commercial nuclear power plants.

REFERENCES

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