論文 / 著書情報
Article / Book Information

Title	Energy Release in Criticality Accidents Involving Two Fuel Solution Tanks
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Citation	Transactions of the American Nuclear Society, Vol. 109, , pp. 888-889
Issue date	2013, 11
URL	http://www.ans.org/pubs/transactions/
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Energy Release in Criticality Accidents Involving Two Fuel Solution Tanks

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INDRODUCTION

In criticality accidents of fuel solutions, if there are several solution tanks located near the tank that becomes super-critical, the total released energy can be larger than that involving just one tank, because of the neutron interaction between the tanks. Thus, it is important to perform transient analysis in such cases by taking into account the neutron interaction between the tanks. The conventional point kinetic analysis method cannot be applied to such analysis. In previous studies, a kinetic analysis code based on an integral kinetic model[1][2][3][4] was proposed and applied to the kinetic analysis of criticality accidents in a weakly coupled system[5]. If it is possible to know the total energy release in a compound accident compared to an accident in a single solution tank, this would be useful for the protection against radiation in such accidents. The purpose of this study was to show the possibility of predicting the total energy released in criticality accidents involving several fuel solution tanks from the knowledge of how much energy is released in a single solution tank using the integral kinetic model.

ANALYSIS METHOD

The integral kinetic model is a methodology to calculate the time-dependent fission density change of each region based on the following equation:

$$N_i(t) \approx \sum_{j=1}^{n} \int_{-\infty}^{t} \alpha_{ij}(t-t')N_j(t')dt',$$

where $N_i(t)$ is the total fission density in region i at time t, and $\alpha_{ij}(\tau)$ is the probability density function for secondary prompt fission in region i resulting from the first fission in source region j with time difference τ.

By obtaining $\alpha_{ij}(\tau)$ in advance by Monte Carlo calculations, we can calculate the change of power in each region $N_i(t)$. A modified version of MVP2.0[6] was used for the calculation of $\alpha_{ij}(\tau)$. In the model, delayed neutrons were not treated.

CALCULATION CONDITIONS

Fig. 1 shows the calculation geometries in the case of a single tank case and two tanks. We assumed a uranyl nitrate solution with 10% enrichment and a uranium concentration of 280 gU/L. The inner diameter of the fuel

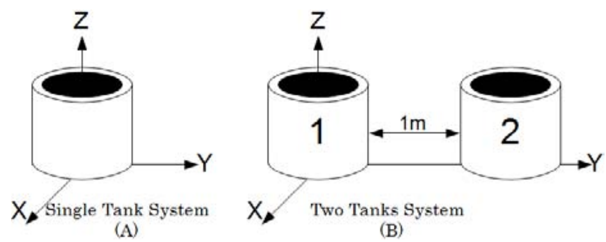

Fig.1 Calculation geometry in Single tank (A) and two tanks (B)

solution tanks was 1 m. The height of the fuel solution in the initial condition was 21.3 cm. The systems were critical with low power (1 W) at the initial condition. Two types of feedback models were used for the analysis. One is a temperature feedback model, which includes the increase of fuel solution temperature and volume expansion by the temperature increase. The other includes not only the temperature feedback, but also the radiolytic gas void effect. In the latter model, the combined effect of the increase of volume and the uniform reduction of solution nuclide density is examined. The amount of radiolytic gas production was estimated by the equation obtained by TRACY experiments[7]. The reactivity was inserted by the increase of fuel solution height in a tank.

ANALYSIS RESULTS

Table 1 shows the analysis results when the inserted reactivity was 0.0020 Δk/k. The total energies released in the case of a single tank case and two tanks are shown in the figure. The results in the case of the temperature feedback model and the temperature feedback and void effect model are shown, respectively. It is shown that estimates for the total energy released can differ greatly depending on the feedback model. If the void effect is included in the feedback model, the total released energy can be very small compared to the feedback effect with void effect only. But the relations of the energy in the two-tank case to that of the single-tank case were very close regardless of the feedback model. The analysis of

Table 1 Total released energy in single tank and two tanks (unit: MJ)

Feedback	Temperature feedback only		Temperature feedback and void effect	
Geometry	Single tank	Two tanks (Relative energy to single tank)	Single tank	Two tanks (Relative energy to single tank)
Tank 1	9.1	9.2 (101%)	2.3	2.3 (100%)
Tank 2	-	0.8 (9%)	-	0.2 (9%)
Total	9.1	10.0 (110%)	2.3	2.6 (109%)

the two-tank situation produced a total energy relative to the single-tank situation of 110% in the temperature feedback model and 109% in the temperature and void feedback model.

These results suggest that the relative energy of the two scenarios may not depend greatly on the feedback model. It also suggests that if we know the total energy released in the single-tank case, it may be possible to predict the total energy released in the two-tank case. For more detailed discussion, further analysis under various different conditions is needed.

CONCLUSIONS

To estimate the total energy released in criticality accidents by several fuel solution tanks, preliminary analysis was performed based on the integral kinetic model. The results showed that it may be possible to estimate the total energy released by an accident involving several fuel solution tanks from the knowledge of the amount of energy released in the case of a single-tank accident. For more detailed discussion, further analysis at various conditions is required.

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