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COMPARISON OF THE HAARM-3 FALLOUT MODEL WITH
NUCLEAR SAFETY PILOT PLANT (NSPP) DATA*

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## SUMMARY

Sodium-oxide aerosols have been generated in the Nuclear Safety Pilot Plant (NSPP) experiment[1] under vessel conditions appropriate for the LMFBR secondary containment following an HCDA. The primary goal of the NSPP program is to provide experimental validation for the HAARM-3 aerosol behavioral code.[2] Validation can be determined by direct comparison of code predictions and integral test results using the same initial and boundary conditions.[3] In addition,[4] separate physical models within the code (e.g., for agglomeration, plate-out, and gravitational fallout) may be validated by a comparison of predicted values with measured instantaneous values. This paper presents a comparison of the gravitational fallout rate which is considered to be the primary depletion mechanism under prototypic secondary containment conditions.

The NSPP vessel is a stainless-steel cylinder with a diameter of 3.05m (10 ft.), an average height of 5.24m (17.2 ft.), and a volume of $38.3 m^3$ ($1350 ft.^3$). Sodium-oxide aerosol mass concentrations were measured by seven filter-type samplers at various vessel locations. Aerosol size distributions were obtained using Andersen impactors.[1] Fallout rates were measured by a sampler located near the vessel floor.

The fallout model used in the HAARM-3 code assumes a well-mixed aerosol system (all system variables are independent of location and are dependent on time only) and spherical particles for sodium-oxide aerosols. The particle settling velocity,[1,5,6] determined by balancing the particle weight with the drag force using Stokes' law and neglecting the air buoyancy, is given by

$$V = \frac{D^2 \rho C_1 g}{\mu} \qquad (1)$$

where V = particle settling velocity, D = particle diameter, $\rho$ = particle density, $C_1$ = Cunningham slip correction factor ($\sim$ 1 for NSPP sodium-oxide aerosols), g = gravitational acceleration, and $\mu$ = air viscosity.

The fallout rate per unit floor area, F, is estimated by

$$F = VC \qquad (2)$$

where C = aerosol mass concentration.

Figure 1 shows the aerosol size distributions in terms of the aerodynamic diameter[5] ($D_1 = D\rho^{1/2}$) measured in NSPP Run 103 and Run 104 at two instants of time. Substituting these values along with the air viscosity at room temperature into Eq. (1) (with $C_1 \sim 1$) yields the average particle settling velocity, V. A sample calculation is presented in Table 1.

Substituting the average settling velocity, V, and the aerosol mass concentration measured in the NSPP experiment at the same instant of time into Eq. (2) yields the corresponding fallout rate. A comparison of the fallout rates, both those calculated by the model used in the HAARM-3 code and NSPP data, is presented in Table 2. The agreement is within a factor of two and improves as time increases. This study provides a partial verification of the HAARM-3 code; further study will be continued.

## References


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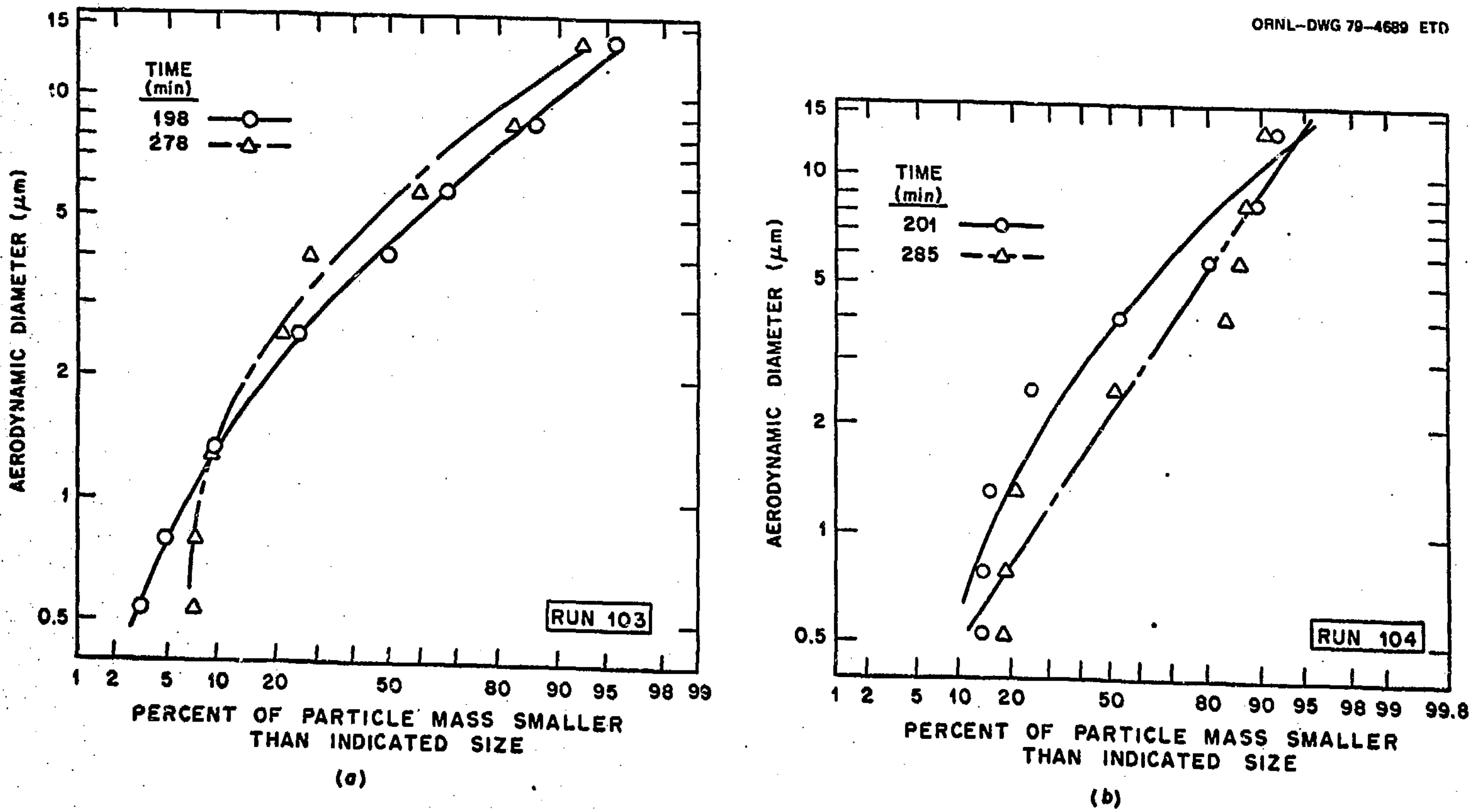


Fig. 1. Particle size distributions for sodium-oxide aerosols in the NSPP experiment: (a) Run 103, and (b) Run 104.

Table 1. Particle diameter and estimated settling velocity of sodium-oxide aerosols in NSPP Run 103 at t = 198 minutes

| Mass percentage in the range of | Mid-point | Aerodynamic diameter $D_1$ (μm) | Actual diameter D (μm) | Settling velocity $V_i$ (cm/s) | Average velocity $V=\sum_i^n V_i/n$ (cm/s) |
|---|---|---|---|---|---|
| 80 - 100% | 90% | 10 | $10/(\rho)^{1/2}$ | 0.298 | 0.0978 |
| 60 - 80% | 70% | 6.0 | $6.0/(\rho)^{1/2}$ | 0.107 | |
| 40 - 60% | 50% | 4.3 | $4.3/(\rho)^{1/2}$ | 0.0550 | |
| 20 - 40% | 30% | 2.8 | $2.8/(\rho)^{1/2}$ | 0.0233 | |
| 0 - 20% | 10% | 1.4 | $1.4/(\rho)^{1/2}$ | 0.00583 | |

Table 2. A Comparison of the Fallcut Rates Calculated by the Model and NSPP Data

| Run | Time t (min) | Av. Settling velocity V (cm/s) | Aerosol mass concentration C (μg/cc) | Fallout rate per unit floor area $F_{model}$ (μg/s-cm$^2$) | $F_{exp}$ (μg/s-cm$^2$) | $F_{model}/F_{exp}$ |
|---|---|---|---|---|---|---|
| 103 | 198 | 0.0978 | 0.16 | 0.0156 | 0.028 | 0.56 |
| 103 | 278 | 0.155 | 0.10 | 0.1155 | 0.0146 | 1.06 |
| 104 | 201 | 0.0984 | 0.59 | 0.0581 | 0.0346 | 1.68 |
| 104 | 285 | 0.0613 | 0.25 | 0.0153 | 0.0119 | 1.29 |