UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

AUG 3 1978

MEMORANDUM FOR: Edson G. Case, Acting Director
Office of Nuclear Reactor Regulation

FROM: Saul Levine, Director
Office of Nuclear Regulatory Research

SUBJECT: RESEARCH INFORMATION LETTER #32
IMPROVEMENTS IN THE AEROSOL BEHAVIOR CODE FOR RADIOLOGICAL ASSESSMENTS OF LMFBRS

REFERENCE: J. A. Gieseke, et. al., "Characteristics of Agglomerates of Sodium Oxide Aerosol Particles," BMI-NUREG-1977, (August 1977)

32

Introduction

This memorandum transmits the results of completed research on the measurement of sodium oxide aerosol properties. Sodium oxide is the key aerosol constituent in postulated severe LMFBR accidents. This work was completed as part of the Aerosol Measurements and Modeling program at Battelle Columbus Laboratories under the direction and sponsorship of the Advanced Reactor Safety Research, Office of RES. The work consisted primarily of the experimental measurement of the effective density of sodium-oxide aerosols as a function of agglomerate size. The effective density is an important parameter in predicting how an aerosol population will behave in an enclosed containment in terms of natural removal processes. For the most severe postulated LMFBR accident scenarios (HCDA and core melt), sodium-oxide aerosol represents the highest airborne mass concentrations in the containment vessel and is expected to dominate and govern the behavior of the fuel and fission product aerosol. Therefore, as a first step in improving the aerosol behavior code, HAARM-2, separate effects work was carried out on sodium-oxide aerosol.

The results of these separate effects measurements have been incorporated into the models of the aerosol behavior code HAARM-2, and together with some additional improvements used to generate a new version called HAARM-3. The improved models in HAARM-3 provide a more realistic description of particle characteristics and thereby allow improved estimates of sodium-oxide aerosol behavior during a postulated HCDA. The HAARM code is used by NRR for LMFBR site radiological consequence assessment. Enclosed is a copy of the HAARM-3 users manual for operation of the code. The code has recently been placed on the Brookhaven computer and Dr. John Long of your staff is familiar with its operation. Release of the code was expedited to be available for NRR review of the FFTF-FSAR. The results of the research used in improving the code have been reviewed at Research Review Group meetings with participation by NRR staff.

Discussion

An important aspect in performing LMFBR accident analyses for siting evaluations is the postulated release from the containment of radioactivity in the form of aerosol particles. The prediction of aerosol behavior in containment depends on the microscopic characteristics of the individual particles. Aerosol behavior processes of most interest to LMFBR accident analysis are agglomeration and growth of particles and settling.

Particle shapes and densities have a pronounced effect on the settling velocities of the individual aerosols. Also, certain mechanisms for agglomeration are known to depend on the cross sectional areas of the individual particles, a parameter which is directly related to particle shape and density. Because of the complexity of the processes controlling aerosol behavior, it is nearly impossible to derive information on these aerosol characteristics from integral experiments. Therefore, separate effects experiments were performed to determine the physical characteristics of sodium-oxide aerosols.

A Milliken-cell apparatus was chosen for performing measurements because thermal forces as well as agglomerate physical properties could be determined. In addition to the Milliken-thermal cell, agglomerate properties were further characterized through electron microscopy. The primary objective of the measurements was the determination of the sodium-oxide agglomerate effective density. The density of the agglomerate differs from that of the actual material in that as the agglomerate grows there are voids or holes between the particles and the density is less than that of the solid material. These measurements allow determination of the real radius, which in turn affects the collision area, an important parameter in some of the agglomeration processes. As a part of the determination of the effective density, the aerosol primary particle size distribution was determined and the value for the mass median particle radius (0.5 μm) used in the HAARM-3 code was verified. Also another parameter, the first order slip correction factor, was determined (a value of 1.37) and this value was incorporated into the code.

The primary particle size distribution of the sodium oxide was determined by electron microscopic techniques. The aerosol was generated by burning sodium in air. The results indicated that the primary particle size distribution may be modeled by a log normal distribution with a geometric mean diameter of 0.45 μm and a geometric standard deviation of 1.47. Knowing the primary size distribution one may relate the equivalent mass diameter of particles comprising an agglomerate. The equivalent mass diameter is the diameter of a sphere having a mass equal to that of the agglomerate. Using the equation for a log normal distribution and the equation relating equivalent mass diameter to the primary particle size distribution parameters (Ref. 1), one can derive an expression for

α (the density correction factor). This equation permits a direct comparison of α measured values and the theory of Kop et al. (Ref. 1). The measurements indicated a reasonable agreement to the theory for an average primary particle density of 2.27 g/cm^3.

Evaluation and Application

The characteristics of sodium oxide agglomerates, available from the measurements, have been incorporated into the computer code. Also, provisions were made to the code to account for the effect of nonspherical shapes of agglomerates on the mobility and on the collision cross section. Calculation of the values of α allow the determination of a new radius instead of using a radius based upon the theoretical density. The increased radius has the effect of enhancing the collision area for gravitational agglomeration and increasing the settling velocity. Comparison calculations were made showing the differences between HAARM-2 and HAARM-3 predictions of airborne mass concentrations and leaked mass for various assumed initial aerosol releases in a typical LMFBR containment. The results of these comparisons are attached in Table 1 and Figures 1 and 2. Using the HAARM-3 code with the improved models there is a reduction in the amount of leaked mass as a function of time (Figure 2). Also included, Figure 3 is a comparison of predictions of suspended aerosol mass concentration vs. time for each of the two codes with an integral aerosol test. This test, the first of a series being performed at the Containment Systems Test Facility (CSTF) at HEDL for DOE, represents the largest known aerosol test performed to date. The CSTF vessel is about a 1/2 scale model of reactor containment, with respect to vessel height, the key geometry parameter in the agglomeration and settling of aerosols. As can be seen in Figure 3, the HAARM-3 code provides much better agreement with the experimental results.

Future Work

Currently work in this area is being directed towards the characterization of fuel (UO_2) aerosols which includes the determination of the aerodynamic properties of the particles. With the completion of this work, program emphasis will be placed on the interaction of mixed aerosols (sodium-oxide and fuel) primarily in large integral tests. The goal of this research is the verification of the HAARM-3 code. A code verification plan is currently being developed to implement the accomplishment of that goal.

Recommendations

The HAARM-3 code will allow NRR to perform improved estimates of the depletion of sodium and fuel aerosol in the reactor building and other containment spaces for use in radiological assessments of postulated LMFBR accidents. It is recommended that NRR use the HAARM-3 code as opposed to earlier versions in performing aerosol calculations in view of the information presented in this RIL. For further information on the application and use of HAARM-3 contact Dr. John Larkins in RES.

Saul Levine

Saul Levine, Director
Office of Nuclear Regulatory Research

Enclosure:
HAARM-3 Users Manual

TABLE 1 LEAKED MASS PREDICTED BY HAARM-2 AND HAARM-3 CODES

Initial Concentration, $\mu g/cm^3$	Time	Mass Leaked, g (Accumulated) HAARM-2	Mass Leaked, g (Accumulated) HAARM-3
2	2 hrs	15	15
	1 day	68	58
	30 days	76	65
10	2 hrs	72	65
	1 day	255	110
	30 days	269	113
100	2 hrs	480	158
	1 day	865	160
	30 days	870	161

Pertinent Input Data:

Leak Rate - 0.1 percent per day

Initial R_{50} = 0.5 μm

Initial σ_R = 2.0

Gas Temperature - 310 K.

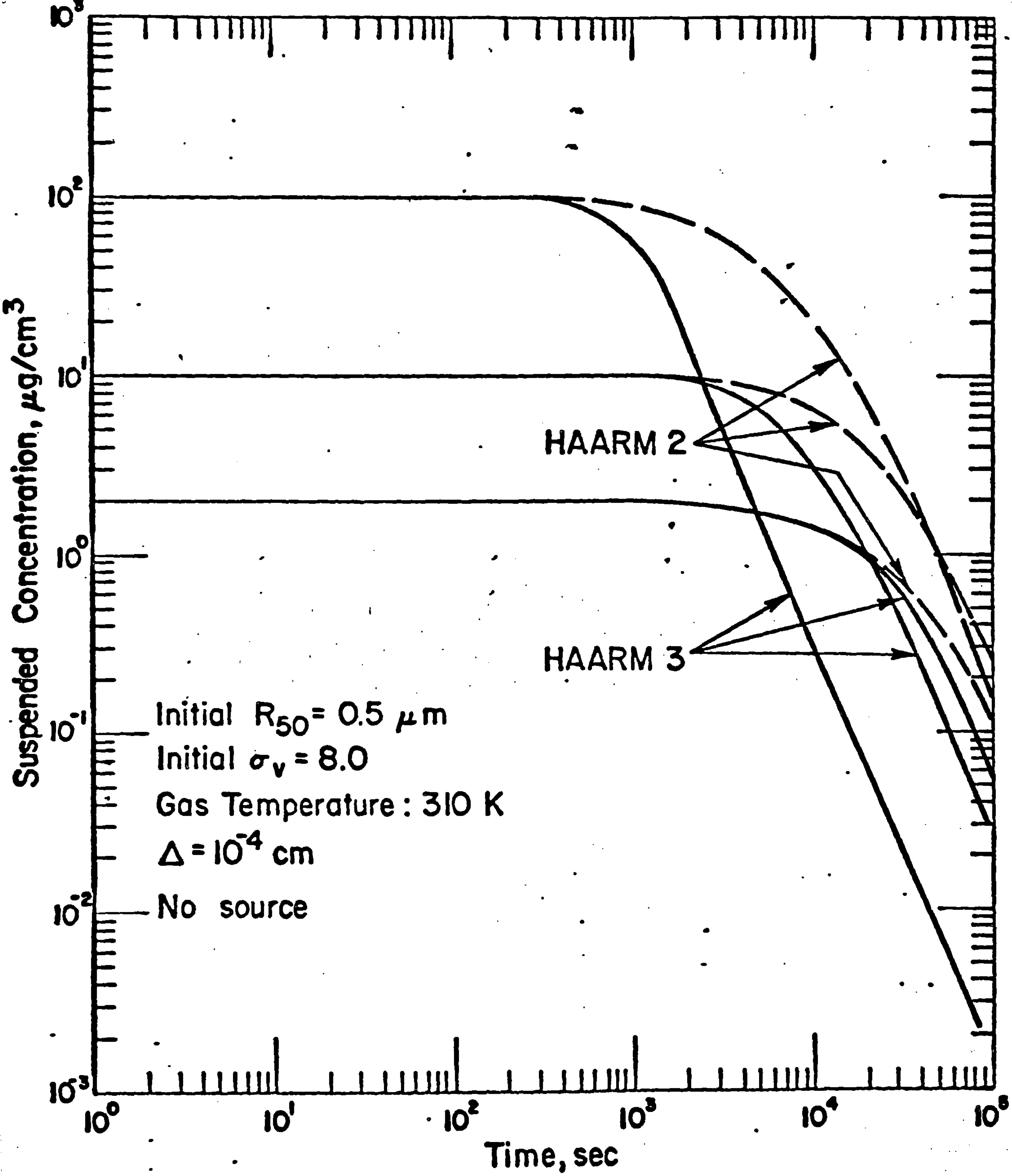

FIGURE 1 SUSPENDED AEROSOL MASS CONCENTRATION WITH TIME FOR THE CRBR CONTAINMENT GEOMETRY AT THREE INITIAL CONCENTRATION LEVELS

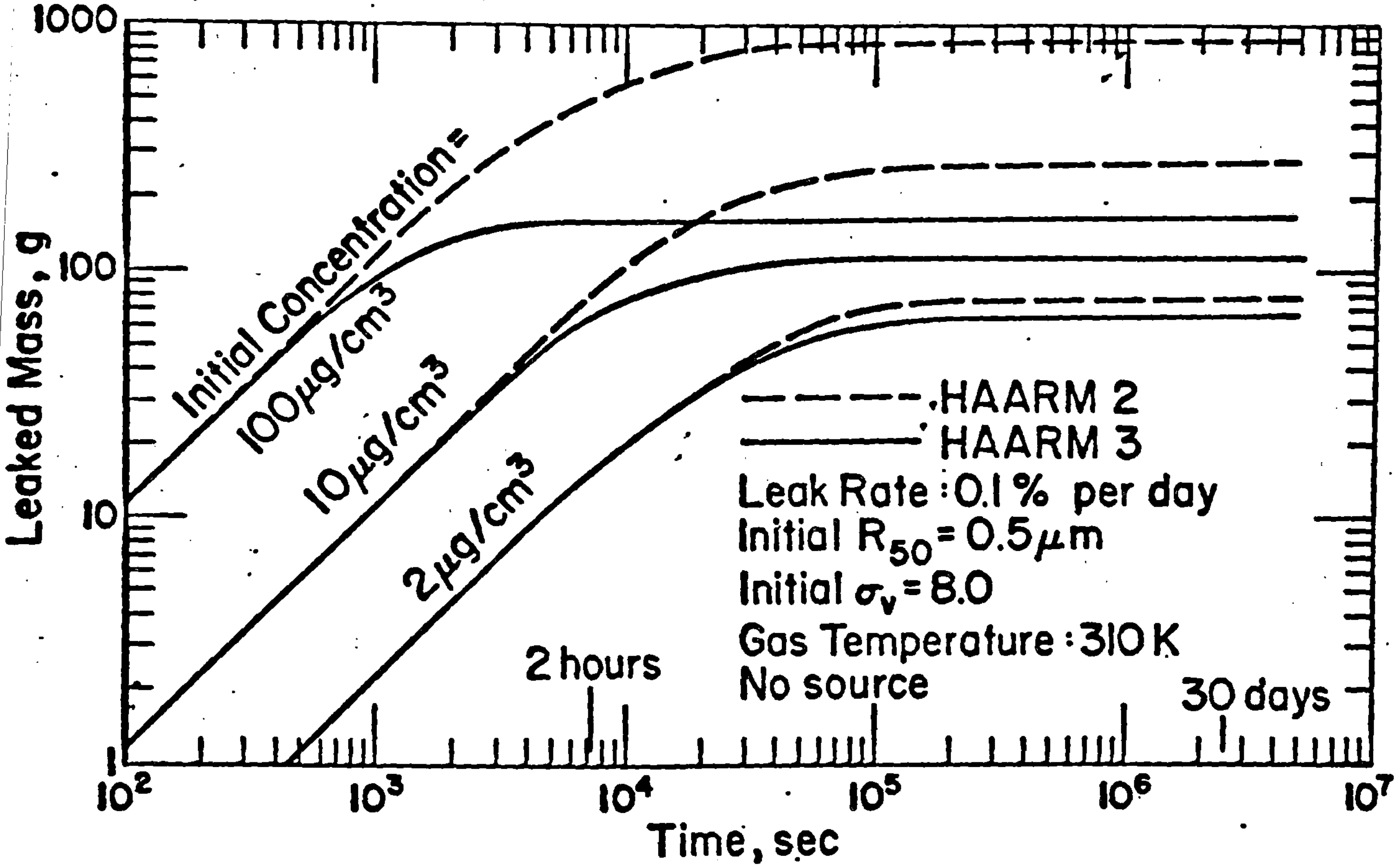

FIGURE 2 LEAKED MASS WITH TIME FOR THE CRBR CONTAINMENT GEOMETRY AT THREE INITIAL CONCENTRATION LEVELS

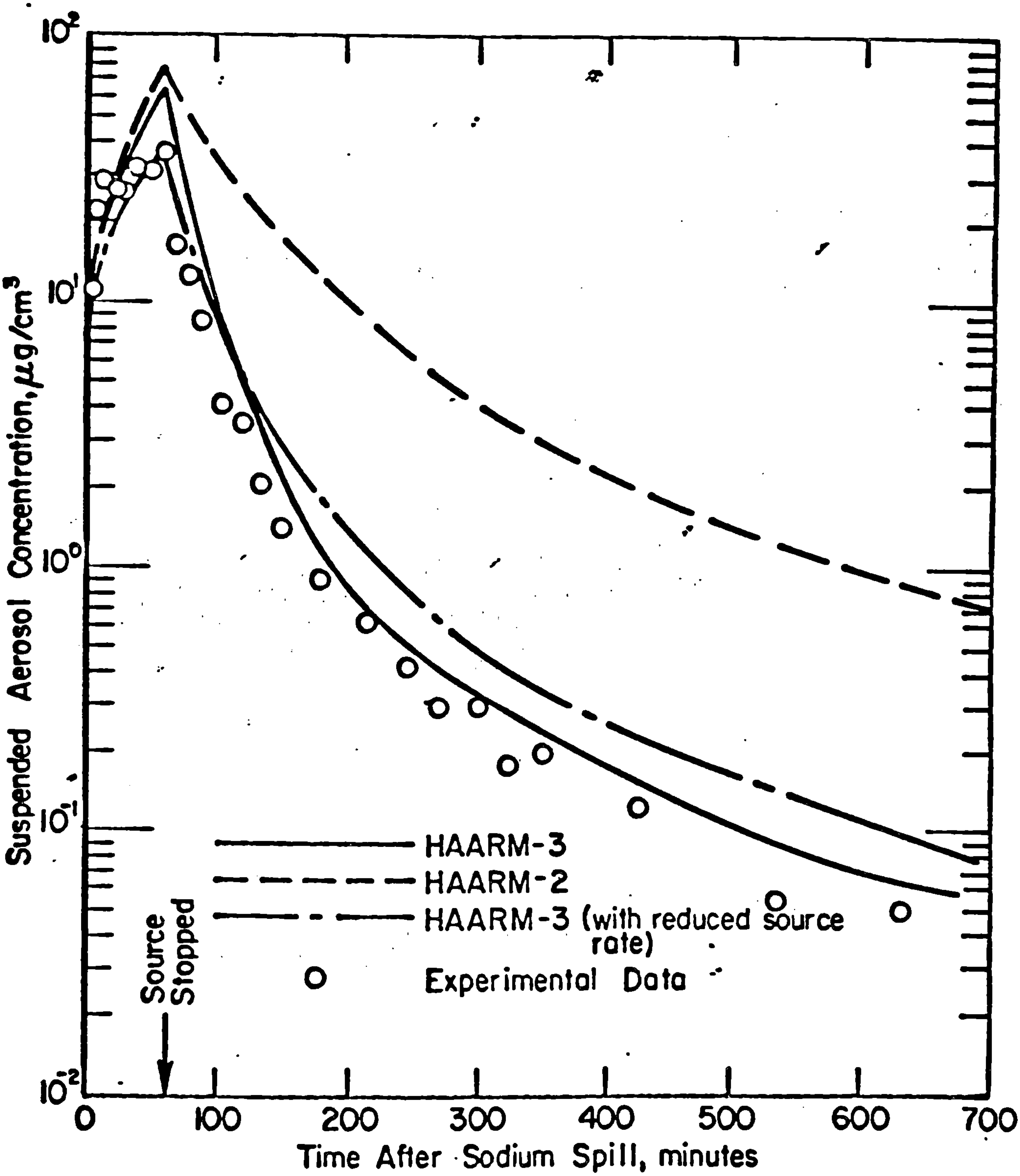

FIGURE 3 COMPARISON OF PREDICTIONS AND EXPERIMENTAL RESULTS; AIRBORNE CONCENTRATIONS, CSTF TEST AB-1