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RESULTS AND CODE PREDICTIONS FOR ABCOVE AEROSOL CODE VALIDATION WITH LOW CONCENTRATION NaOH AND NaI AEROSOL -- CSTF TEST AB7

HEDL-TME--85-1

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Date Published: October 1985

HANFORD ENGINEERING DEVELOPMENT LABORATORY — Operated by Westinghouse Hanford Company, P.O. Box 1970, Richland, WA, a Subsidiary of Westinghouse Electric Corporation. Prepared for the USDOE, Assistant Secretary for Nuclear Energy, Deputy Assistant Secretary for Reactor Systems, Development and Technology, Office of Technology Support Programs, under Contract No. DE-AC06-76FF02170, B&R No. AF-15-40-20-5.

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ABSTRACT

A program for aerosol behavior code validation and evaluation (ABCOVE) has been developed in accordance with the LMFBR Safety Program Plan. The ABCOVE program is a cooperative effort between the USDOE, the USNRC, and their contractor organizations currently involved in aerosol code development, testing or application. The third large-scale test in the ABCOVE program, AB7, was performed in the 850-m^3 CSTF vessel with a two-species test aerosol. The test conditions involved the release of a simulated fission product aerosol, NaI, into the containment atmosphere after the end of a small sodium pool fire. Four organizations made pretest predictions of aerosol behavior using five computer codes. Two of the codes (QUICKM and CONTAIN) were discrete, multiple species codes, while three (HAA-3, HAA-4, and HAARM-3) were log-normal codes which assume uniform coagglomeration of different aerosol species. Detailed test results are presented and compared with the code predictions for eight key aerosol behavior parameters.

ACKNOWLEDGMENTS

The work covered by this report represents the cooperative efforts of many people in a number of organizations. Computer code predictions were made by U.S. Department of Energy contractor organizations (Hanford Engineering Development Laboratory and Rockwell International) and by Nuclear Regulatory Commission contractors (Battelle Columbus Laboratories, and Sandia National Laboratories). Valuable advice on planning the experiment was provided by the multi-laboratory participants and by L. Petrosky, Westinghouse Electric Corporation. The test was performed and reported by the Safety Systems Development group at HEDL, L. D. Muhlestein, Manager. Test performance was sponsored by the U.S. Department of Energy, Office of Reactor Research and Technology, Safety and Physics Division, under the coordination of the Fast Reactor Safety Technical Management Center at Argonne National Laboratory.

The successful completion of the planning, pretest code predictions, test performance and analyses and post-test code predictions on a timely schedule was possible because of the excellent cooperation and adherance to schedules exhibited by all the program participants. The authors wish to express particular appreciation to the following individuals.

H. Alter	U.S. Department of Energy
L. Baker	Fast Reactor Safety/Technical Management Center
R. Curtis	U.S. Nuclear Regulatory Commission
H. Jordan	Battelle Columbus Laboratories
K. Murata	Sandia National Laboratories
J. Otter	Rockwell International, Rocketdyne Division
E. Selle	Hanford Engineering Development Laboratory

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1.0 INTRODUCTION

A program for aerosol behavior code validation and evaluation (ABCOVE) has been developed in accordance with the LMFBR Safety Program Plan. The ABCOVE program is a cooperative effort between the U.S. Department of Energy, the U.S. Nuclear Regulatory Commission, and their contractors currently involved in nuclear aerosol code development, testing or application. The purpose of the ABCOVE program is to provide a basis for judging the adequacy of existing aerosol behavior computer codes to describe inherent aerosol attenuation in containment buildings during postulated accidents. The program involves both analytical calculations by code developers and users and large-scale confirmatory tests in the 850-m^3 containment vessel of the Containment Systems Test Facility (CSTF). A key element of the ABCOVE program is that all code calculations are made without knowledge of the experimental results and thus give a true measure of the code capabilities without benefit of post-test fitting.

Each ABCOVE test is carried out in four stages: plannning and pretest computer code predictions, test performance and analysis, blind post-test computer code calculations based on actual test conditions and comparison of code predictions with the experimental measurements. During the planning stage, the test conditions (containment geometry, thermal conditions, and aerosol source information) are specified as completely as possible to eliminate as many sources of discrepancies in the code calculations as possible. However, code input parameters regarding aerosol behavior are not specified, and each participant is free to excercise his own judgement as to the proper values for such parameters as shape factors, collision efficiency, and boundary layer thickness for diffusional deposition. Most participants selected values for these parameters which gave good agreement with available test data.

Three ABCOVE tests have been performed in the CSTF to date. The first test, AB5, was performed in September, 1982 and the results were reported.[1] A single-species aerosol was used in Test AB5, with the aerosol being generated by spraying sodium at a high rate into an air atmosphere. The conditions for test AB5 were conducive to high agglomeration and settling rates, a condition applicable for severe LMFBR accidents. The results of test AB5 and the associated computer code calculations were encouraging in that important aspects of aerosol behavior, such as total leaked mass and suspended concentration during the aerosol source period were predicted reasonably well. However, there were significant discrepancies among the codes for some of the aerosol parameters, notably suspended concentration after source cutoff and plated mass on vertical surfaces.

The second test in the ABCOVE series, AB6, was performed July 19, 1983[2]. The primary purpose of test AB6 was to demonstrate coagglomeration behavior of two different aerosol species with overlapping source periods, and to determine the capabilities of existing aerosol behavior codes to predict the behavior of each species. The experimental conditions simulated an accident environment in which a fission product, NaI, was released in the presence of a sodium spray fire. Test AB6 provided useful information and insight into NaI behavior during a severe sodium fire accident condition, but conclusions regarding the codes' capabilities to predict the NaI behavior were clouded by the possible presence of unmodeled phenomena such as resuspension of deposited aerosol and decomposition of NaI.

The present report describes the third and final test in the ABCOVE series, test AB7, and compares the computer code predictions with experimental results. The primary purpose of test AB7 was similar to that of test AB6, but the thermal conditions were much milder, thereby reducing resuspension and decomposition processes to negligible effects.

2.0 SUMMARY AND CONCLUSIONS

The third test in the ABCOVE series, AB7, was performed on September 25, 1984, in the 850-m^3 Containment Systems Test Facility (CSTF) vessel. The test conditions involved the release of a simulated fission product aerosol, sodium iodide (NaI), into the containment vessel atmosphere after the end of a small sodium pool fire. The quantity of sodium oxide released during the sodium pool fire was so low that all of it was reacted to sodium hydroxide, NaOH, aerosol by moisture in the containment atmosphere. The maximum suspended mass concentration of NaOH was 3 g/m^3, approximately 10% of that attained in test AB6 and only approximately 2% of the maximum reached in test AB5. Thus, the agglomeration rate was much lower in test AB7 than in previous ABCOVE tests. Approximately the same quantity of NaI was released in test AB7 as was released in test AB6, giving a maximum concentration of 0.42 g/m^3 in the present test.

The timing of the NaI release was critically different in the two tests. In test AB6, the NaI was released during the sodium fire and the sodium fire was continued well past the end of the NaI source. In the present test, the NaI source period began at the end of the NaOH source period. Coagglomeration behavior was significantly different in the two tests due to the relative timing of the NaI source periods. In the present test, the NaOH aerosol source period was from 0 to 600 s, while the NaI source began at 600 s and ended at 2400 s.

The thermal conditions in the containment vessel were quite mild, with a maximum atmosphere temperature of 34°C and absolute pressure of 122 kPa. Natural convection was probably minimal during this test; nevertheless, mixing was good and uniform aerosol concentration was quickly attained throughout the atmosphere. Resuspension effects were believed to have been negligible due to the low convection velocities and the sticky nature of the aerosol deposit compared to that of test AB6.

The NaI aerosol was generated ex-containment by a volatilization-condensation processs and injected into the containment atmosphere with a nitrogen carrier gas. The aerodynamic mass median diameter (AMMD) of the NaI source was 0.80 μm, with a geometric standard deviation, σ_g of 1.60, while the NaOH aerosol AMMD was 2.05 μm with a σ_g of 1.63.

Pretest computer code calculations were made by all participants, based on the initially intended test conditions. Due to equipment malfunction, the conditions under which test AB7 was actually performed varied considerably from the test plan specifications. For this reason, the pretest code predictions are not reported in this document. The actual test conditions were provided to the ABCOVE participants and four of them performed "blind" post-test calculations. The blind post-test predictions were made without knowledge (except for the HEDL participant) of the test measurements of aerosol behavior. No effort was made to improve the agreement of code and test results by post-test adjustment of input parameters, such as particle shape factors and source particle size.

Five codes were used in the blind post-test calculations. They were HAA-3[(3)], HAA-4[(4)], HAARM-3[(5)], CONTAIN[(6)] and QUICKM[(7)]. Each of the codes has unique differences in its modeling of physical processes, approach used for solution of the integro-differential aerosol agglomeration equation, capability of accounting for multiple aerosol species, and stage of development. Each code has its advantages and limitations. The first three listed above are "log-normal" codes, so called because they assume the aerosol size distribution to be log-normal at all times. The last two of the codes listed above are "discrete," i.e., the aerosol size distribution is divided into a number of discrete size groups. Treatment of multiple aerosol species is handled differently by each of the two classes of codes. The log-normal codes assume that particle composition is independent of size, i.e., that the aerosol is uniformly coagglomerated. The discrete codes assume that the particles within each discrete size group have uniform chemical composition, but allow the composition to vary between size groups.

Each code user reported the predicted magnitude of eight output parameters that describe aerosol behavior. The reported parameters include: suspended mass concentration, aerodynamic mass median diameter of suspended aerosol, geometric standard deviation of particle size distribution, aerodynamic settling mean diameter, leaked mass, settled mass, plated mass, and instantaneous combined removal rate. Most of these parameters were reported for both aerosol species. All code results were reported in digital format at 12 specified times to facilitate comparisions.

Specific conclusions and summary statements supported by the reported work are as follows:

(1) The test measurements show that the aerosol was not uniformly coagglomerated, as evidenced by the varying chemical composition of aerosol deposit on cascade impactor stages and the different rates of fallout for the two aerosol species. The impactor stages which collected small particles were significantly richer in NaI than were the stages which collected large particles at all times. This observation is compatible with the fact that the rate of NaI removal from the atmosphere was always less than that of NaOH, since sedimentation was shown to dominate the removal process for both aerosol species.

(2) Significant differences in the predictions of NaI behavior is noted between the two classes of codes (discrete, sectionally uniform codes and log-normal, uniform coagglomeration codes).

(3) The discrete, sectionally uniform codes (CONTAIN and QUICKM) agreed well with one another and were in excellent agreement with most experimental measurements for both NaOH and NaI for all times to $2x10^5$ s. Furthermore, they correctly predicted the slower removal for NaI than for NaOH in the present test, as they had also correctly predicted the faster removal of NaI than NaO_x in test AB6[2].

(4) The log-normal, uniform coagglomeration codes (HAA-3, HAA-4 and HAARM-3) showed significant variability within their class, with HAA-4 generally giving better agreement with experiment. These codes predicted the fallout behavior of the dominant mass aerosol species (NaOH) fairly well at early times (less than 2400 s), but greatly underpredicted at long times, as they had done in previous ABCOVE tests. They greatly overpredicted the suspended concentration of the minor mass species (NaI) after the end of the NaI source.

(5) Leaked mass was predicted more accurately than was suspended mass concentration at discrete times. The discrete codes predicted the total leaked mass of NaOH within 7%; the leaked mass of NaI within 20%. The log-normal codes underpredicted the leaked mass of NaOH by a factor of two; the leaked mass of NaI by a factor of approximately 5.

(6) Sedimentation was by far the dominant aerosol depletion process for both NaOH and NaI species. Settled mass was 11 times greater than plated mass for NaOH; 45 times greater for NaI, even though plating area was 8.5 times greater than the upward facing horizontal surface area. All of the codes predicted that sedimentation was dominant, but significant variations between code predictions of plated mass were noted.

(7) Both aerosol species were deposited on interior vertical surfaces (no heat sink) to essentially the same or greater extent as on the outer vessel vertical walls (heat sink). This is a similar finding to that obtained in previous ABCOVE tests, and shows that thermophoresis was not the dominant process for deposition onto vertical surfaces. The experimental results suggest that impaction and interception may be the important mechanisms for wall deposition. These processes are not modeled in any of the codes involved in the ABCOVE program.

(8) The measured particle size distribution of suspended aerosol was predicted more accurately by the discrete codes than by the log-normal codes for both species. All five of the codes correctly predicted the increase in median size and in geometric standard deviation after the end of the source periods, but the predicted magnitudes varied greatly.

(9) The containment atmosphere was fairly well mixed by the weak convection currents. At times after the end of the aerosol sources, the suspended concentration was reasonably uniform, as measured by 10 samplers located at various elevations and radii in the vessel.

(10) No code was used by more than one participant in the present exercise, so no new information was obtained on the effect of user-selected input on code performance.

(11) The data obtained from the AB7 experiment and code effort suggest that only codes which properly account for the variation in agglomerate composition as a function of agglomerate size can correctly predict the behavior of the minor mass constituents in multiple species aerosol situations where the individual species have different source periods. Further assessment is needed before this conclusion can be extended to other conditions.

(12) No attempt has been made to prepare a summary report covering all three ABCOVE tests and the attendant code calculations. Further, no attempt has been made to evaluate or rate individual codes. The documentation provided earlier[1, 2] and the present document can serve as a good basis for such a summary and evaluation if such an effort is made in the future.

3.0 EXPERIMENTAL FACILITY AND PROCEDURE

3.1 FACILITY DESCRIPTION

The test was performed in the Containment Systems Test Facility (CSTF). The chief feature of the CSTF is the model containment vessel which is located within a ventilated concrete building. Other features include a sodium supply system, instrumentation systems, control room and data acquisition system, data reduction and analysis systems, chemical laboratory rooms, utility services, maintenance shop and offices.

3.1.1 Containment Vessel

The CSTF containment vessel (CV) is a 850-m^3 (30,000-ft^3) carbon steel vessel with a design pressure of 0.517 MPa gauge (75 psig). It is installed in a concrete pit with the top half extending above the elevation of the main building work area, as shown by the schematic elevation view in Figure 3-1 . All interior surfaces are coated with a modified phenolic paint, and exterior surfaces are covered with a 25.4-mm layer of fiberglass insulation with an outer aluminum vapor barrier. Additional details of the containment vessel are provided in Table 3-1.

3.1.2 Sodium System

Commercial grade sodium, procured in 400-lb solid pack drums, was melted in a portable clam shell heater and charged into the sodium supply tank. The supply tank was suspended from a load cell so that the combined weight of tank and sodium could be measured as a function of time. Approximately 33 m of Schedule 40 1/2-inch pipe connected the tank to the spray nozzle, as shown in Figure 3-1. Two valves and a magnetic flowmeter were located in the sodium line.

A single sodium spray nozzle* was installed at the -6.1 m elevation (2.38 m above the catch pan). The nozzle was oriented to spray upward at the vessel centerline.

*Spraying Systems Co., Wheaton, IL 60187, Model 1/4 BA2.

3.1.3 Sodium Iodide Aerosol Generator

NaI aerosol was generated by vaporizing NaI salt in a nitrogen carrier gas stream and then creating aerosol by a nucleation and condensation process. The latter was induced by rapidly mixing the hot NaI vapor with cold nitrogen in a nucleator vessel. A sketch of the generation equipment is shown in Figure 3-2.

The vaporizer was fabricated of 304 SS 10-in. Schedule 40 pipe and had a height of 530 mm. It had a flat bottom and a dished top head. Its design pressure was 82.7 kPa at 870°C (12 psig at 1600°F). It had a gas sparge ring with 188 4.8-mm diameter holes located near the bottom.

The nucleator was fabricated of 304 SS 12-in. Schedule 40 pipe with two dished heads and an overall height of 1.73 m. Its design pressure was 82.7 kPa at 430°C (12 psig at 800°F). Its volume was 0.125 m^3.

The procedure for generating NaI aerosol was to charge 19 kg of NaI crystals into the vaporizer and to heat the vaporizer to 875°C in an oven. At this temperature NaI is a liquid with a vapor pressure of approximately 18 mm Hg.[8] Nitrogen gas heated to 840°C was metered and injected to the sparge ring, which was immersed approximately 120 mm below the surface of the NaI pool. The hot nitrogen gas, carrying some NaI vapor, exited from the top through a 38-mm diameter pipe to the inlet of the nucleator. The gas was kept superheated by an electric heater. Immediately upon entering the nucleator it was mixed with cold nitrogen to give a 220°C mixture temperature. The gas-aerosol stream was sent to a bypass filter during the heatup stage, and was valved to the containment vessel (CV) at the desired time. The pipe leading to the containment vessel was 38-mm ID and it projected horizontally 400 mm past the CV wall at a CV elevation of -4.57 m and an azimuth of 8°. (See Appendix A for a description of the CV coordinate system). At the end of the NaI injection period, the NaI aerosol stream was valved back to the bypass filter and the heaters were shut off.

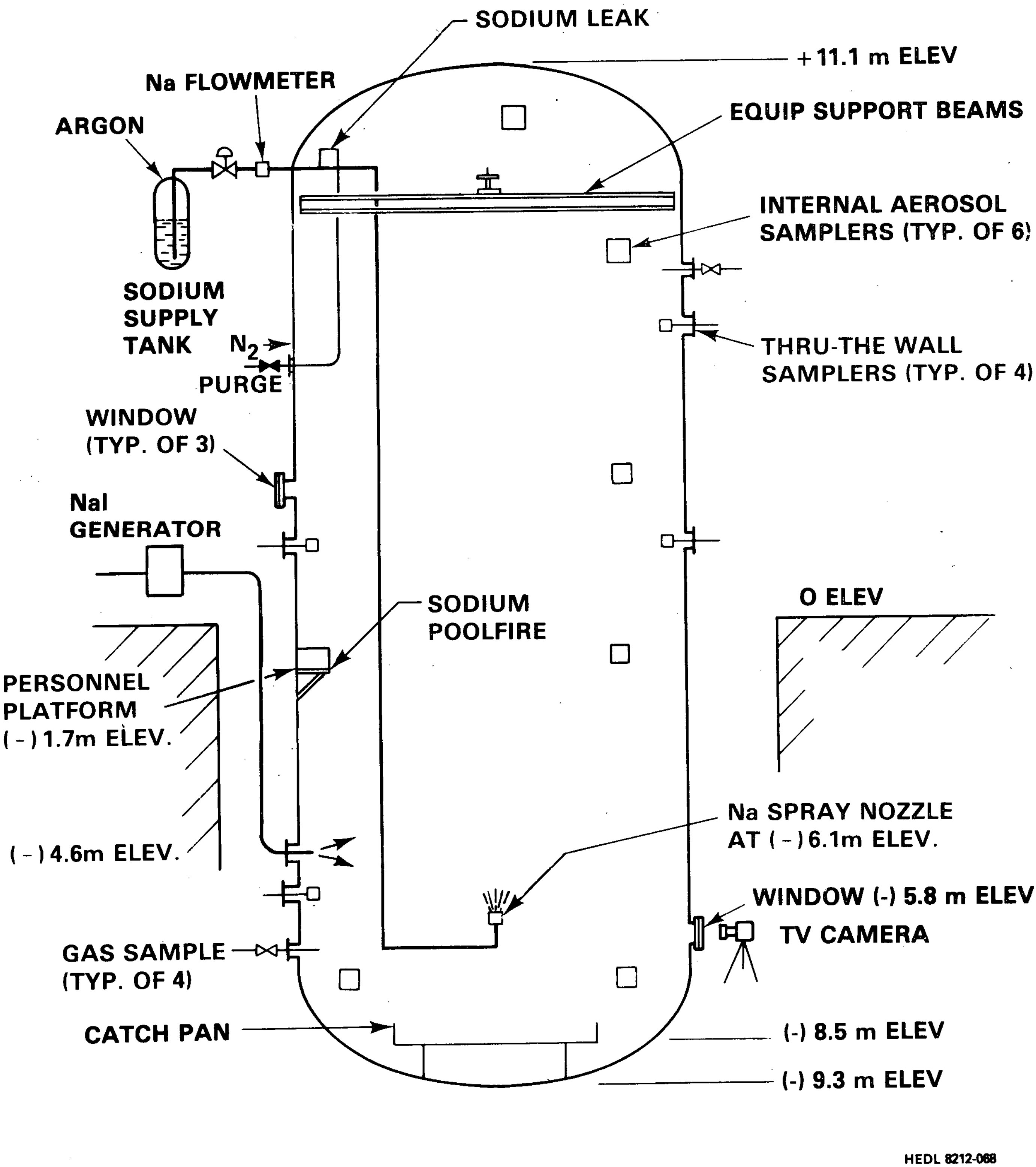

FIGURE 3-1. Schematic Diagram of Experimental Arrangement for Test AB7.

TABLE 3-1

CSTF CONTAINMENT VESSEL PROPERTIES

General	
Code	ASME Section VIII, 1962
Material	Carbon Steel, SA 212-B
Interior paint (phenolic)	0.51 mm (0.020 in.)
Exterior thermal insulation	Fiberglass, 25 mm thick, k = 0.0467 W/m°C at 100°C; sp heat = 753 J/kgK; ρ = 96 kg/m^3
Design pressure	0.517 MPa at 160°C (75 psig at 320°F)
Nominal leak rate	1.0% per day at 69 kPa overpressure
Normal total emissivity of paint	0.9

Dimensions		
Diameter (ID)	7.62 m	(25.0 ft)
Overall height	20.3 m	(66.7 ft)
Cylinder height	16.5 m	(54.0 ft)
Enclosed volume	852 m3	(30,086 ft3)
Weight, kg (lb)		
Top head	9,345	(20,600)
Bottom head	9,345	(20,600)
Cylinder	51,320	(113,100)
Penetrations and doubler plates	7,125	(15,700)
Catch pan	500	(1,000)
Internal components	13,840	(30,450)
Total weight	91,475	(201,450)
Surface Areas for Heat Transfer, m2 (ft^2)		
Top head	63.0	(678)
Bottom head	63.0	(678)
Cylinder	394	(4,242)
Total area for heat transfer to environs	520	(5,598)
Internal components	221	(2,380)
Surface Areas for Aerosol Settling, m2 (ft^2)		
Bottom head (unshaded area)	36.7	(395)
Catch pan	11.1	(120)
Personnel deck	4.2	(45)
Internal components	36.2	(390)
Total	88.2	(950)

TABLE 3-1 (CONT.)

CSTF CONTAINMENT VESSEL PROPERTIES

Surface Areas for Aerosol Plating, m2 (ft^2)		
Vessel shell	520	(5,598)
Internal components	232	(2,500)
Total	752	(8,098)
Thickness for Heat Transfer, mm (in.)		
(Average lumped values)*		
Top head	19.3	(0.760)
Bottom head	19.3	(0.760)
Cylinder	16.9	(0.667)
Internal components	8.4	(0.330)

*Average Thickness = $\left(\frac{\text{Weight}}{\text{(area) density of steel}}\right)$

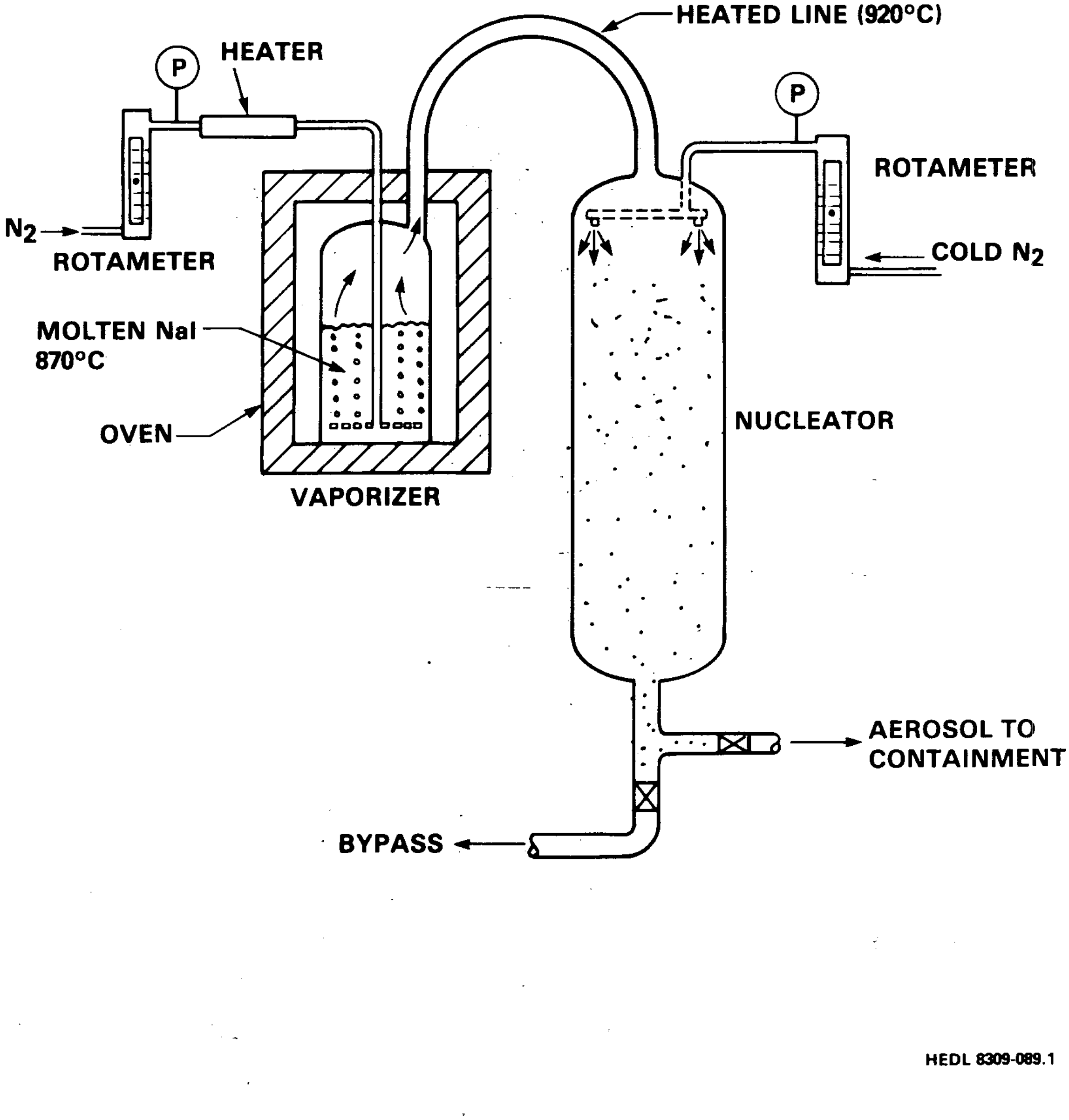

FIGURE 3-2. Schematic Diagram of NaI Aerosol Generation System.

3.2 EXPERIMENTAL MEASUREMENTS

The methods and instrumentation for the experimental measurements used in this work have been described previously.[9] The measurements are summarized in Table 3-2 and discussed briefly in the following paragraphs.

3.2.1 Aerosol Characterization

The careful characterization of the test aerosol was an important part of the present work. The suspended mass concentration, the particle size distribution, and the chemical composition were measured periodically by direct sampling at various times and locations throughout the tests.

The mass concentration of suspended particles was measured as a function of time by periodically passing a measured quantity of gas through small filters located directly in the containment atmosphere and subsequently analyzing the material collected on the filter for NaI and Na. Two types of sampling techniques were used: in-vessel filter clusters located at different elevations and radii, and through-the-wall (TTW) samplers inserted and retrieved through air locks on the vessel wall. The locations of the six in-vessel clusters and the four TTW sampling stations are given in Table 3-3.

The aerodynamic size distribution was determined by sampling with cascade impactors inserted through the wall. Two types of cascade impactors were used: Andersen Mark III 8-stage* and Sierra model 225 6-stage**. Previous tests have shown that these instruments give good agreement when proper sample sizes are taken and proper calibration data are supplied. Glass fiber collection surfaces provided by the manufacturers were used.

The instantaneous deposition rate of particles was measured by exposing

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*Andersen Samplers, Inc., Atlanta, Ga.
**Sierra Instruments Co., Inc., Carmel Valley, CA.

TABLE 3-2

EXPERIMENTAL MEASUREMENTS AND ACCURACY

Measurement(b)	No. of Locations	No. of Times	Standard Error	Method
Suspended aerosol mass concentration	6	1	± 25%	In-vessel filter clusters
Suspended aerosol mass concentration	4	24	± 15%	Through-the-wall samplers
Aerosol particle size and σ_g	1	12	± 20%	Cascade impactor
Aerosol instantaneous deposition rate	2	4	± 20%	Through-the-wall coupons
Integral settled mass/unit area	23	1	± 10%	Fall-out pans
Integral plated mass on vessel walls per unit area	8	1	± 20	Vessel wall smears
Aerosol mass deposited in catch pan	1	1	± 10%	Wash and analyze for Na
Total settled aerosol mass	1	1	± 10%	Wash vessel floor
Total aerosol wall plateout	1	1	± 30%	Wash vessel walls
Temperature of containment atmosphere	28	(a)	± 2%	Thermocouples
Temperature of vessel surface	18	(a)	± 2%	Thermocouples
Temperature of Na sprayed	2	(a)	± 2%	Thermocouples
Containment pressure	1	(a)	± 1%	Pressure transducer
Containment O_2 concentration	2	(a)	± 2%	On-line O_2 analyzer
Containment H_2 concentration	1	(a)	± 20%	On-line H_2 analyzer
Containment moisture concentration	2	(a)	± 30%	On-line humidity analyzer
Sodium spray mass flow rate	1	(a)	± 10%	Magnetic flowmeter and load cell
Overall Na and NaI mass balances	N/A	1	± 10%	Weighing, washing, volume chem. analysis, calculation

(a) Continuous
(b) For Na and NaI, as appropriate

TABLE 3-3

AEROSOL SAMPLE LOCATIONS

Station No.	CV Nozzle No.	Elevation (m)	Azimuth[a] (degrees)	Radius (m)
Through-the-wall				
T1	N2A	+ 6.1	225	3.73
T2	N3A	+ 1.5	290	3.73
T3	N33	+ 1.37	135	3.73
T4	N17A	- 5.8	85	3.73
In-vessel clusters				
C1	---	+ 9.45	240	1.43
C2	---	+ 6.70	270	2.74
C3	---	+ 3.66	270	2.74
C4	---	+ 0.30	180	2.74
C5	---	- 6.70	180	2.74
C6	---	- 6.70	0	2.74

(a) Clockwise looking down, zero degrees at center of 2.44-m equipment hatch. (See Appendix A).

coupons in a horizontal orientation for brief periods at a through-the-wall station. The top surface of the coupon was washed and the rinse water analyzed for sodium. The deposition rate was calculated as a total mass flux of particles. No information was obtained on settling as a function of particle size by this technique. The "deposition velocity" was calculated by dividing the flux by the airborne concentration.

Additional information regarding the CSTF aerosol characterization methods is provided in Reference (9).

3.2.2 Temperature Measurements

All temperatures were measured by calibrated Chromel-Alumel® thermocouples with stainless steel sheaths. Readout was in parallel on strip chart recorders, magnetic tape, and paper tape. The location of the thermocouples are listed in Appendix A.

3.2.3 Pressure Measurements

The absolute and gauge pressure in the containment vessel was measured by a pressure transducer and a Heise gauge. In addition, the differential pressure across the sodium spray nozzle was measured by a differential pressure transducer.

3.2.4 Gas Analysis System

The composition of the containment gas was measured continuously at two locations (+6.1 and -6.7 m elevation) by pulling samples through tubing to on-line analyzers located ex-vessel. Filters were provided at the tube inlet to prevent aerosol from entering the analyzers.

®Chromel-Alumel is a registered trademark of the Richmond Machine Products Corp, Staten Island, NY

3.2.5 Data Acquisition System

Many of the key experimental measurements were made manually and periodically, e.g., filter samples, cascade impactor samples, electron microscope samples, and samples for chemical analyses. The data associated with these manual samples were logged by technicians onto data sheets or recorded in notebooks.

The on-line instrumentation included thermocouples, pressure transducers, sodium flowrate meter, sodium supply tank load cell, and gas analyzers for O_2 H_2 and water vapor. The output of these sensors was recorded in parallel on strip chart recorders and on a 140-channel digital data acquisition system (DAS)*. For test AB7, 118 channels were recorded on magnetic tape every 50 seconds initially, with decreasing frequency at later times. Information on identification of data recorded on each DAS channel is provided in Appendix A. Digital output for all channels for the initial 60 minutes is presented in Appendix B. For times greater than 60 minutes the measured parameters changed more slowly, and summary tables of average temperature and pressure data extending to 20 hours are presented in Appendix C.

3.3 CHEMICAL ANALYSES

Filter papers from cascade impactors, through-the-wall aerosol concentration samplers, and in-vessel filter clusters were analyzed for sodium by either acid titration or emission spectrometry. Analyses for iodide was by ion specific electrode. Appropriate blank corrections were made to account for background sodium and iodine in the filter paper and demineralized water.

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*John Fluke Manufacturing Co., Inc. Mountlake Terrace, WA 98043
Datalogger Model 2240.

3.4 EXPERIMENTAL PROCEDURE

The following key activities were performed during test AB7:

- Preparation of a Test Plan describing the intended test conditions.
- Pretest computer code predictions.
- Preparation of detailed Test Operating Procedures.
- Installation of sodium spray and NaI generation systems.
- Installation and calibration of instruments.
- Pretest photography.
- Drying of the CV to constant, normal humidity air.
- Sealing the vessel so that it was essentially leak-tight.
- Inject air to establish desired pretest pressure (118.3 kPa absolute).
- Charge sodium to sodium supply tank and preheat to test temperature (590°C).
- At time zero (t_0), open sodium valve to start sodium flow. (The TV monitor showed that sodium drops fall from high in the containment vessel immediately after the valve was opened. Post-test inspection showed that the sodium accumulated and burned as a pool at the -1.7 m elevation.)
- At 20 seconds after t_0, close sodium valve, stopping sodium flow. (Sodium continued to burn as a pool fire for 10 minutes.)
- Make test measurements according to Section 3.2.
- At 10 minutes after t_0, start NaI aerosol injection to containment atmosphere.
- At 40 minutes after t_0, terminate NaI aerosol injection by closing valve to containment and opening valve to bypass filter.
- Continue to make test measurements for 1650 minutes.
- At 44 hours after t_0, start air purge of containment vessel.
- At 45 hours after t_0, open personnel door, take pictures and samples.
- Clean up containment vessel and NaI equipment and make mass balances.
- Perform chemical analyses.
- Issue report of actual test conditions.

- Blind post-test computer code calculations performed.
- Data reduction and engineering analyses performed.
- Comparisons made of code predictions with experimental results.

3.5 TEST CONDITIONS

The test conditions for test AB7 are summarized in Table 3-4.

TABLE 3-4

SUMMARY OF TEST CONDITIONS FOR TEST AB7

Test Condition	Value
Initial Containment Atmosphere	
Temperature, mean (°C)	23.9
Pressure, absolute (kPa)	118.4
Oxygen concentration (vol %)	20.95
Dew point (°C)	1.5
Nominal leak rate (% per day)	1.0
Sodium Spill	
Sodium flow rate (g/s)	322
Sodium flow duration (s)	20
Sodium fall distance (m)	10.0
Sodium mass delivered (kg)	6.434
Initial sodium temperature (°C)	590
Pool fire burning area (m^2)	0.93
Pool fire burn duration (s)	600
Containment Conditions During Test (See Appendices A and B for time-dependent data)	
Maximum average temperature of atmosphere (°C)	33.7
Maximum average temperature of steel vessel (°C)	25.2
Maximum pressure, absolute (kPa)	122.6
Final oxygen concentration (vol %)	20.25
Final dewpoint (°C)	1.3
Hydrogen concentration (vol %)	<0.1

TABLE 3-4 Cont'd

NaOH Aerosol Source

Chemical form	NaOH
Material density (g/cm^3)	2.13
Mass ratio, NaOH to Na	1.74
Initial concentration	0
Start time for aerosol release (s)	0
Stop time (s)	600
Release rate (g NaOH/s)	5.03
Total NaOH release (g)	3018
Source 50% diameter (μm)	0.5
Source geometric standard deviation	2.0

NaI Aerosol Source

Chemical form	NaI
Material density (g/cm^3)	3.67
Initial concentration	0
Start time for aerosol release (s)	600
Stop time (s)	2400
Release rate (g NaI/s)	0.197
Total NaI aerosol released (g)	354.6
Source 50% diameter (μm)	0.54
Source geometric standard deviation	1.55

4.0 EXPERIMENTAL RESULTS

4.1 GENERAL OBSERVATIONS

Zero time (t_0) for test AB7 is defined as the instant that sodium started to flow to the containment vessel. It occurred at 12:00:00 noon on September 25, 1984. The television monitor showed a bright light and large, glowing drops coming from a high elevation in the containment atmosphere immediately after the sodium valve was opened. The valve was closed at 12:00:20. Post-test inspection revealed that a tube fitting that connected a nitrogen purge line to the sodium line at the +8.23-m elevation had loosened and allowed sodium to flow from the full 11-mm diameter opening. The horizontal sodium stream impinged the vertical web of a 14-inch I-beam located approximately 0.5 m from the tube fitting and fell to a small horizontal ledge at the -1.68 m elevation, where it accumulated and burned as a pool fire. Some burning may have occurred as the drops fell to the ledge. Figure 4-1 is a photograph of the personnel platform where the pool fire occurred.

The visibility in the containment atmosphere decreased to approximately 0.5 m within a few minutes after the spill and remained at that value for 40 minutes before it began to increase. Periodically during the first seven minutes a flickering, diffuse orange flow was observed through the lower windows. No change in the visual appearance of the aerosol was noticed during the period that NaI aerosol was being injected.

The containment vessel was kept sealed until 2640 minutes after the spill, when a fresh air purge was begun. At 2700 minutes, the vessel was entered, photographs were made, and samples were taken. The aerosol deposit was much lighter than in previous CSTF tests. Figure 4-2 shows that there was a thin white layer on upwared facing horizontal surfaces, but no visual evidence of aerosol on vertical surfaces.

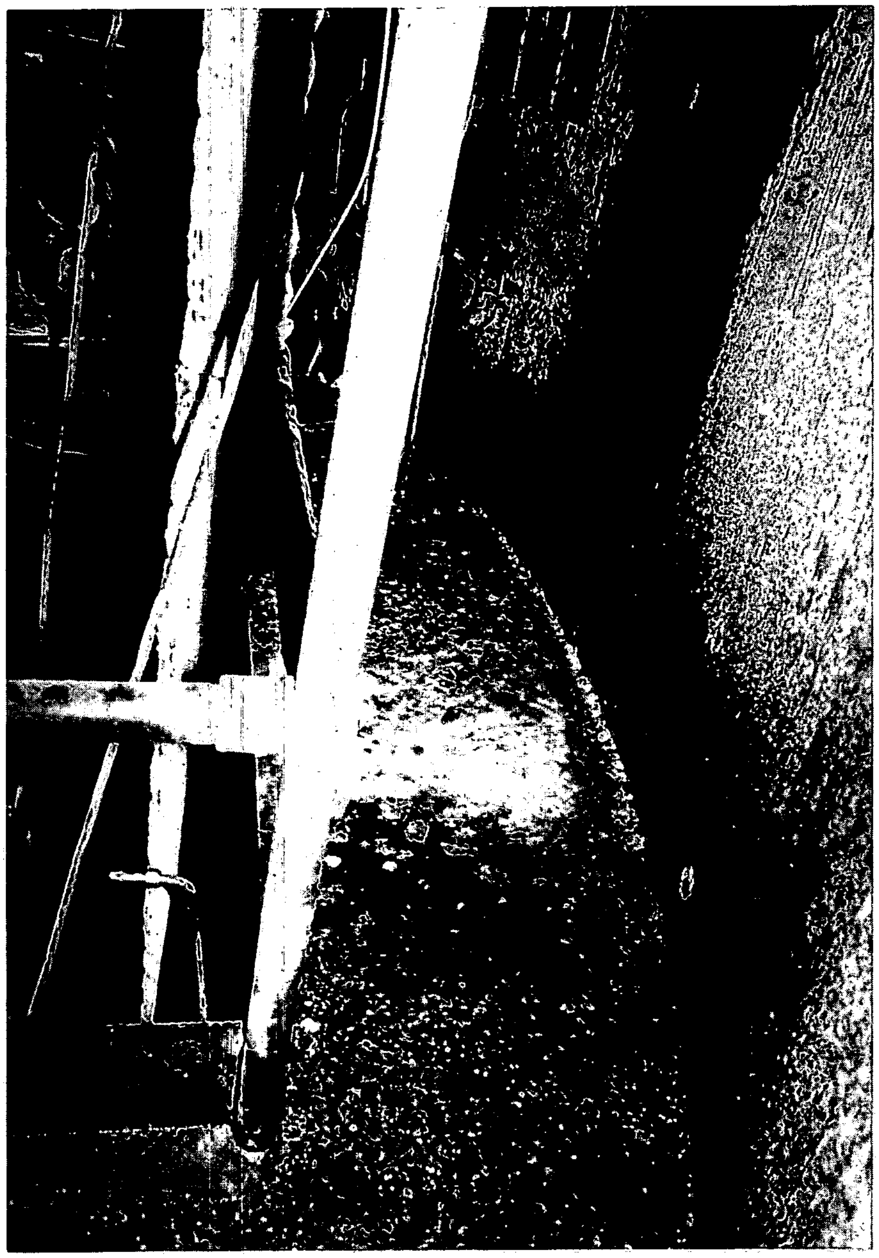

FIGURE 4-1. Post-Test Photograph of the Pool Fire Region. Neg 8406565-10cn

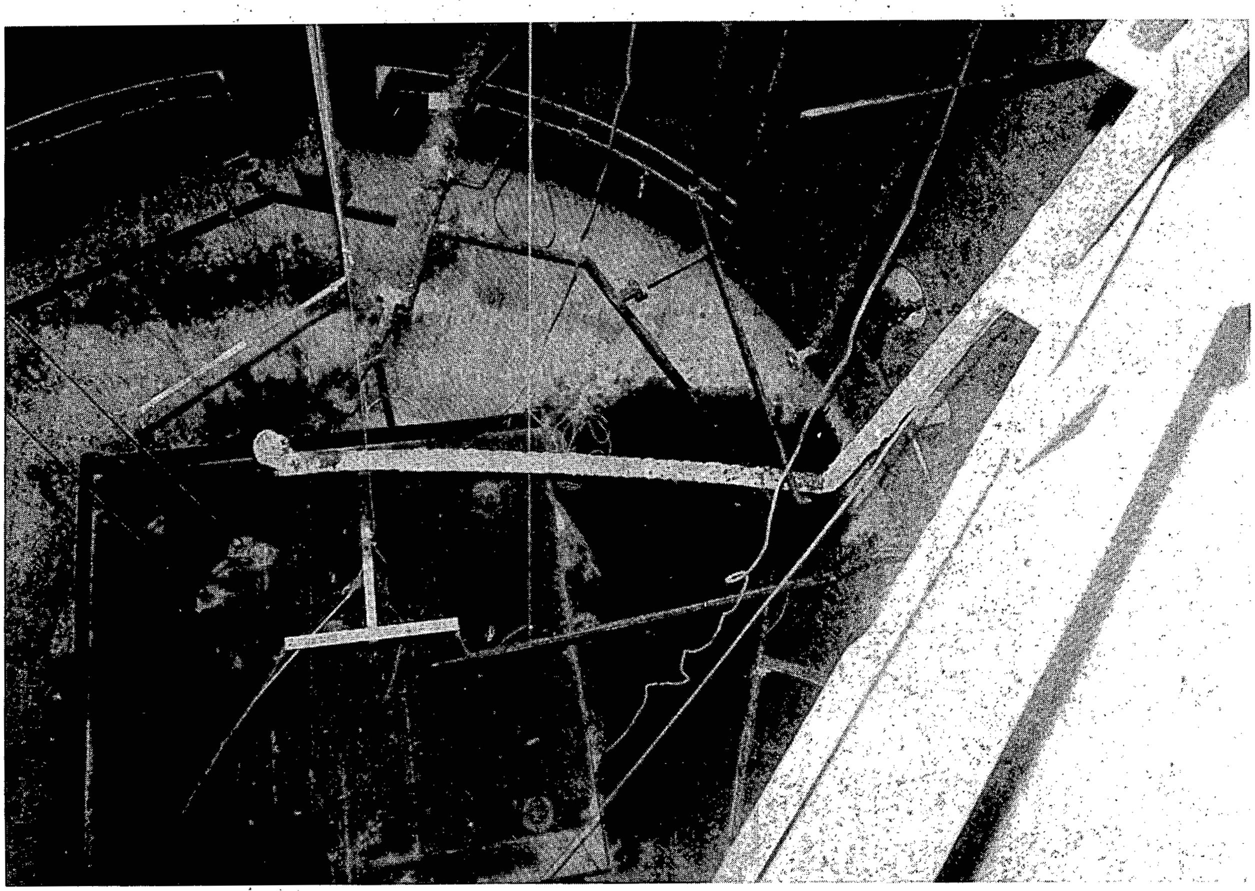

FIGURE 4-2. Post-Test View of the Aerosol Deposit on the Containment Vessel Bottom Head. Neg 8406565-6cn

The data logger output for the first 60 minutes is listed in Appendix B in digital form. Data for longer time periods are given in Appendix C and the text.

4.2 NaOH AEROSOL GENERATION

A loose tubing fitting on a tee in the 1/2-inch sodium line failed immediately after the sodium flow began. The failure was such that sodium leaked from the full 11-mm diameter opening and fell to the personnel deck at the -1.68 m elevation (7.6 m^2 above the bottom of the containment vessel), where it formed a pool of approximately 1 m area and burned as a pool fire. The flow of sodium was stopped at 20 seconds by closing a valve in the delivery line. The duration of the pool fire is believed to have been approximately 10 minutes. The sodium oxide aerosol that was released from the burning sodium was quickly coverted to NaOH aerosol by moisture in the containment atmosphere.

4.3 NaI AEROSOL GENERATION

The NaI aerosol generation system is described in Section 3.1.3. During startup, the aerosol was sent to a bypass filter until steady-state conditions were attained. At 10 minutes after time zero, it was valved to the containment vessel (CV) and the generation rate maintained constant until the end of the NaI source period thirty minutes later, when it was valved back to the bypass filter during generator cool-down.

The temperature of the molten NaI pool in the vaporizer averaged 871 $\pm$ 4.5°C, as measured by a thermocouple in a submerged thermowell. The volumetric flow rates of nitrogen streams to the vaporizer and nucleator vessels were kept constant by a technician assigned to the flow control system. Since the vapor pressure of NaI varies by less than 2% for the measured temperature variation, the volatilization rate can be considered constant. For constant deposition rate in the nucleator and lines, the release to the containment vessel was constant.

4.4 CONTAINMENT RESPONSE

4.4.1 Containment Temperature and Pressure

Very little heat was released by the burning sodium, compared with previous CSTF tests. Gas temperatures and pressures remained fairly constant at 27.0 ± 3.0°C and 120 ± 1.5 kPa, respectively. More detailed temperature and pressure information is provided in Appendices B and C.

4.4.2 Containment Atmosphere Composition

The gaseous composition of the containment atmosphere was determined continuously by monitoring flowing gas streams extracted from the vessel at two different locations. The gas streams were analyzed for oxygen,* hydrogen,** and water vapor dew point.*** The on-line measured concentrations are reported in volume percent for oxygen and hydrogen and the dew point in °C for water vapor in Appendix B.

The initial containment atmosphere was air with 20.95 vol % oxygen and 1.5°C dew point. The final oxygen concentration was 20.25 vol % and the final dew point was 1.3°C. A leak from a water pipe is thought to have added a small quantity of water to the atmosphere. The hydrogen concentration was undetectable.

4.4.3 Conversion Factors for Standard to Actual Containment Conditions

The volume occupied by a given molar quantity of gas in the containment atmosphere varied throughout the test as the gas temperature and pressure varied. Aerosol sampling was performed with rotameters calibrated for standard conditions (1 atm, 0°C). The ratio of standard to actual volumes in the containment atmosphere are listed in Table C-1, Appendix C.

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*Beckman Instruments, Inc., Fullertone, CA, Model 7003.
**Teledyne Analytical Instruments, San Gabriel, CA, Model 102.
***General Eastern Instrument Corp., Watertown, MA, Model 1100A.

4.5 AEROSOL SOURCE TERM

4.5.1 NaOH Aerosol Source

The chemical form of the sodium fire aerosol was NaOH. Although some hydration may have occurred, all calculations in this report are based on anhydrous NaOH.

4.5.1.1 NaOH Aerosol Release Timing

The NaOH aerosol release began at time zero (t_0) and continued until the end of the pool fire ten minutes later (t= 600 s).

4.5.1.2 Sodium Mass Balance

The sodium supply tank was supported by a load cell which sensed the weight of tank plus sodium. The load cell reading decreased by 5.86 kg during the spill. A total of 6.43 kg (as Na) was accounted for in the washes of the containment vessel and in the samples. The mass determined by containment washing is believed to be more accurate because of uncertainty of sodium holdup in the piping and hysteresis error in the load cell system. A sodium mass blance is given in Table 4-1.

TABLE 4-1

SODIUM MASS BALANCE

	kg
Sodium tank weight loss	5.86
Mass Na recovered by washing vessel and in samples	6.43
Difference	+ 0.57 (+9.7%)

4.5.1.3 NaOH Aerosol Release Rate

Based on the post-test washing of the containment vessel, 6.43 kg of sodium were released to containment during the 20-second spill. On the basis of previous pool fire tests in the CSTF, it is assumed that 27% of the sodium was aerosolized, or 1737 g. Thus, 3020 g of NaOH aerosol was released. Assuming that the release occurred at a constant rate over the 10-minute period, the NaOH aerosol release rate was 5.03 g/s.

4.5.1.4 NaOH Source Particle Size

Cascade impactor samples taken shortly after the end of the release period showed that significant agglomeration had occurred, probably in the high concentration region near the burning sodium. No information was obtained on the size of the primary particles, so the recommendation is made that the same size distribution assumed for test AB6[2] be used as code input. This is a mass median diameter of 0.5 μm and a geometric standard deviation, σ_g, of 2.0. The density of the primary particles is assumed to be that of NaOH, 2.13 g/m^3.

4.5.2 Sodium Iodide Aerosol Source

4.5.2.1 NaI Source Timing

Release of NaI aerosol to the containment atmosphere began at 600 seconds after t_0 and ended at 2400 seconds.

4.5.2.2 NaI Source Release Rate

A total of 355 g NaI was accounted for in the containment vessel washes. Substantiation of this value by other means was not possible due to operating difficulties. However, this value is believed to be accurate to ± 10%. Assuming that the release was constant over the 1800-s release period, the average NaI release rate to the containment atmosphere was 0.197 g/s. The NaI generation method is described in Section 3.1.3.

4.5.2.3 NaI Source Particle Size

Cascade impactor samples taken shortly after the start of NaI aerosol release showed that the source size distribution for NaI was essentially the same as used as code input for test AB6[2]. The mass median diameter (d_{50}) was 0.54 μm and the geometric standard deviation (σ_g) was 1.55.

4.6 AEROSOL SUSPENDED MASS CONCENTRATION

The containment atmosphere was reasonably well mixed at all times during test AB7. The uniformity of suspended mass concentration can be seen in Tables 4-2 and 4-3 for NaOH and NaI, respectively. In Tables 4-2 and 4-3 the elevation of through-the-wall (TTW) sample station T1 was +6.1 m, stations T2 and T3 were +1.5 m, and station T4 was at -5.8 m. The NaOH concentration was more uniform than that of the NaI aerosol at times during NaI injection. Near the end of the NaI injection period and afterwards, the NaI concentration was also quite uniform.

In addition to the TTW samples, six filter clusters were installed within the containment atmosphere at elevations ranging from +9.45 m to -6.7 m (see Table 3-3). The average values for the suspended concentration of NaOH and NaI measured by the filter clusters are listed in Tables 4-4 and 4-5. The average values measured at the same times by the TTW samples are also listed in Tables 4-4 and 4-5. Good agreement between the two sampling methods is indicated in the tables for NaI aerosol, with less favorable agreement for NaOH. The filter cluster method averaged 25% lower than the average value for the TTW sample for NaOH aerosol. For NaI, the filter clusters averaged 4% lower than the TTW samples, except for the first sample time, when the NaI was not well mixed. It is concluded that the average value for all ten sampling stations gives the most accurate value for average suspended concentration in the entire vessel.

TABLE 4-2

SUSPENDED NaOH CONCENTRATIONS AT INDIVIDUAL TTW SAMPLE LOCATIONS

Time (s)	Suspended concentration (g NaOH/m^3 at Containment Cond.)					
	T1[a]	T2	T3	T4	Average	σ
5.40(2)[b]	2.30	2.87	---	3.74	2.98	0.592
7.80(2)	2.90	5.23	---	3.15	3.76	1.28
1.02(3)	----	4.19	3.70	3.32	3.74	0.436
1.26(3)	2.99	2.85	---	3.58	3.14	0.387
1.50(3)	3.44	2.90	---	4.14	3.49	0.622
1.74(3)	---	3.23	---	3.98	3.60	0.530
1.98(3)	---	3.22	3.48	3.70	3.47	0.240
2.22(3)	---	2.80	---	3.25	3.02	0.318
2.46(3)	---	2.70	---	2.70	2.70	0.000
2.70(3)	---	---	2.56	2.94	2.75	0.269
3.00(3)	---	2.78	---	2.35	2.57	0.304
3.30(3)	---	1.90	2.57	2.40	2.30	0.352
3.60(3)	2.80	2.12	---	2.28	2.40	0.356
3.84(3)	1.98	2.07	---	2.30	2.12	0.165
4.14(3)	1.84	---	2.12	2.24	2.07	0.205
4.44(3)	2.92	1.98	---	2.00	2.30	0.537
4.74(3)	2.96	1.88	2.01	2.03	2.22	0.498
5.10(3)	---	2.02	---	1.90	1.96	0.085
5.46(3)	1.16	---	1.54	1.79	1.50	0.317
6.06(3)	1.84	1.73	---	1.57	1.71	0.136
6.66(3)	---	1.57	---	---	1.57	---
7.08(3)	1.52	1.47	1.35	1.52	1.47	0.080
9.78(3)	1.06	1.09	1.01	1.06	1.06	0.033

TABLE 4-2 (Cont'd)

Time (s)	Suspended concentration (g NaOH/m^3 at Containment Cond.) T1[a]	T2	T3	T4	Average	σ
1.14(4)[b]	0.720	---	0.777	0.833	0.777	0.057
7.35(4)	1.09(-2)	1.46(-2)	---	1.16(-2)	1.24(-2)	1.97(-3)
8.10(4)	1.04(-2)	1.26(-2)	8.94(-3)	8.77(-3)	1.02(-2)	1.77(-3)
8.79(4)	6.85(-3)	8.90(-3)	7.03(-3)	7.29(-3)	7.52(-3)	9.39(-4)
9.90(4)	4.70(-3)	5.63(-3)	---	5.32(-3)	5.22(-3)	4.74(-4)

(a) Refer to Table 3-3 for coordinates of TTW sample stations.
(b) Numbers in parenthesis are exponents of ten.

TABLE 4-3

SUSPENDED NaI CONCENTRATIONS AT INDIVIDUAL TTW SAMPLE LOCATIONS

Time (s)	Suspended concentration g NaI/m^3 at Containment Cond. T1[a]	T2	T3	T4	Average	σ
7.80(2)[b]	1.72(-2)	---	---	7.44(-2)	4.58(-2)	4.04(-2)
1.02(3)	---	2.60(-2)	1.01(-1)	6.88(-2)	6.40(-2)	3.94(-2)
1.26(3)	3.20(-1)	5.10(-2)	---	1.39(-1)	1.70(-1)	1.37(-1)
1.50(3)	4.53(-1)	5.00(-2)	---	2.76(-1)	2.60(-1)	2.02(-1)
1.74(3)	---	1.66(-1)	---	3.43(-1)	2.55(-1)	1.25(-1)
1.98(3)	---	2.37(-1)	5.35(-1)	3.93(-1)	3.88(-1)	1.49(-1)
2.22(3)	---	3.16(-1)	---	3.82(-1)	3.49(-1)	4.67(-2)
2.46(3)	---	3.76(-1)	---	4.99(-1)	4.38(-1)	8.70(-2)
2.70(3)	---	---	4.74(-1)	4.83(-1)	4.79(-1)	6.40(-3)
3.00(3)	---	4.28(-1)	---	4.30(-1)	4.29(-1)	1.41(-3)
3.30(3)	---	3.22(-1)	4.90(-1)	4.68(-1)	4.27(-1)	9.10(-2)
3.60(3)	5.18(-1)	3.95(-1)	---	4.10(-1)	4.41(-1)	6.70(-2)
3.84(3)	3.84(-1)	4.15(-1)	---	4.26(-1)	4.08(-1)	2.20(-2)
4.14(3)	3.73(-1)	---	4.39(-1)	3.69(-1)	3.94(-1)	3.90(-2)
4.44(3)	5.84(-1)	4.04(-1)	---	4.24(-1)	7.71(-1)	1.00(-1)
4.74(3)	---	3.82(-1)	4.29(-1)	4.32(-1)	4.14(-1)	2.80(-2)
5.10(3)	---	4.07(-1)	---	4.01(-1)	4.04(-1)	4.00(-3)
5.46(3)	2.59(-1)	---	3.24(-1)	3.96(-1)	3.26(-1)	6.90(-2)
6.06(3)	3.72(-1)	3.20(-1)	---	3.63(-1)	3.52(-1)	2.80(-2)
6.66(3)	---	3.40(-1)	---	---	3.40(-1)	---
7.08(3)	3.31(-1)	3.18(-1)	2.98(-1)	3.41(-1)	3.22(-1)	1.90(-2)
9.78(3)	2.46(-1)	2.54(-1)	2.26(-1)	2.56(-1)	2.46(-1)	1.40(-2)

TABLE 4-3 (Cont'd)

Time (s)	Suspended concentration g NaI/m^3 at Containment Cond. T1[a]	T2	T3	T4	Average	σ
1.14(4)	1.46(-1)	---	1.92(-1)	2.13(-1)	1.84(-1)	3.40(-2)
7.35(4)	4.68(-3)	4.39(-3)	---	4.57(-3)	4.55(-3)	1.46(-4)
8.10(4)	4.11(-3)	4.02(-3)	3.45(-3)	3.73(-3)	3.82(-3)	3.00(-4)
8.79(4)	3.12(-3)	3.14(-3)	2.97(-3)	3.14(-3)	3.09(-3)	8.22(-5)
9.90(4)	2.30(-3)	2.15(-3)	---	2.46(-3)	2.30(-3)	1.55(-4)

(a) Refer to Table 3-3 for coordinates of TTW sample stations.
(b) Numbers in parenthesis are exponents of ten.

TABLE 4-4

COMPARISON OF SUSPENDED NaOH CONCENTRATIONS MEASURED BY FILTER CLUSTERS AND TTW SAMPLES

	Average Suspended Concentration ± 1 σ (g NaOH/m^3 at CV Conditions)			
Time (s)	Cluster Samples[b]	TTW Samples[c]	All Samples	Ratio, Cluster To TTW
5.40(2)[a]	1.89(0) ± 4.95(-1)	2.98(0) ± 5.92(-1)	2.25(0) ± 7.58(-1)	0.840
1.05(3)	1.99(0) ± 2.71(-1)	3.74(0) ± 4.36(-1)	2.57(0) ± 9.26(-1)	0.532
2.01(3)	1.93(0) ± 2.29(-1)	3.47(0) ± 2.40(-1)	2.44(0) ± 8.01(-1)	0.556
2.73(3)	1.91(0) ± 2.69(-1)	2.75(0) ± 2.69(-1)	2.12(0) ± 4.61(-1)	0.695
3.81(3)	1.71(0) ± 3.79(-1)	2.12(0) ± 1.65(-1)	1.85(0) ± 3.08(-1)	0.807
5.43(3)	1.36(0) ± 4.77(-1)	1.50(0) ± 3.17(-1)	1.41(0) ± 4.18(-1)	0.907
6.96(3)	1.04(0) ± 3.88(-1)	1.47(0) ± 8.02(-2)	1.21(0) ± 2.65(-1)	0.719
1.12(4)	6.02(-1) ± 2.22(-1)	7.77(-1) ± 5.65(-2)	6.60(-1) ± 1.67(-1)	0.775
7.35(4)	1.03(-2) ± 2.84(-3)	1.24(-2) ± 1.97(-3)	1.10(-2) ± 2.54(-3)	0.831
9.75(4)	5.05(-3) ± 9.03(-4)	5.22(-3) ± 4.74(-4)	5.11(-3) ± 7.60(-4)	0.967
				0.764 Avg

(a) Numbers in parenthesis are exponents of ten.
(b) Average of 6 locations listed in Table 3-3.
(c) From Table 4-2.

TABLE 4-5

COMPARISON OF SUSPENDED NaI CONCENTRATIONS MEASURED BY FILTER CLUSTERS AND TTW SAMPLES

Time (s)	Cluster Samples[b]	TTW Samples[c]	All Samples	Ratio, Cluster To TTW
	Average Suspended Concentration ± 1 σ (g NaOH/m^3 at CV Conditions)			
5.40(2)[a]	0	0	0	--
1.05(3)	6.20(-3) ± 8.67(-3)	6.41(-2) ± 3.94(-2)	2.60(-2) ± 3.56(-2)	0.097
2.01(3)	3.52(-1) ± 1.90(-1)	3.88(-1) ± 1.49(-1)	3.63(-1) ± 1.69(-1)	0.905
2.73(3)	4.59(-1) ± 9.7(-2)	4.79(-1) ± 6.4(-3)	4.65(-1) ± 8.23(-2)	0.958
3.81(3)	4.48(-1) ± 7.19(-2)	4.08(-1) ± 2.2(-2)	4.35(-1) ± 5.53(-2)	1.10
5.43(3)	3.44(-1) ± 1.64(-1)	3.26(-1) ± 6.9(-2)	3.36(-1) ± 1.37(-1)	1.06
6.96(3)	2.98(-1) ± 1.37(-1)	3.22(-1) ± 1.9(-2)	3.08(-1) ±) 9.77(-2)	0.925
1.12(4)	2.11(-1) ± 1.05(-1)	1.84(-1) ± 3.4(-2)	2.02(-1) ±) 8.13(-2)	1.15
7.35(4)	5.33(-3) ± 2.14(-3)	4.55(-3) ± 1.5(-4)	5.07(-3) ±) 1.48(-3)	1.17
9.75(4)	2.97(-3) ± 8.00(-4)	2.30(-3) + 1.6(-4)	2.79(-3) ±) 8.34(-4)	1.29
				0.962 Avg

(a) Numbers in parenthesis are exponents of ten.
(b) Average of 6 locations listed in Table 3-3.
(c) From Table 4-2.

The suspended concentration is plotted as a function of time in Figure 4-3, using the average values of all samples where available and the TTW average values at other times. Figure 4-3 shows that the NaOH concentration increased to a maximum of 3.0 g/m^3 at the end of the NaOH source period, remained constant for the next 1400 seconds, then decreased slowly with time.

The NaI concentration increased to a maximum of 0.42 g/m^3 at the end of the NaI source period, remained constant for 1400 seconds, then decreased slowly with time.

It is apparent from the slopes of the two curves in Figure 4.3 that the fractional removal rate of NaI was less than that of NaOH. At the end of the NaI source period, the NaOH concentration was a factor of 6.7 greater than that of the NaI concentration, while at 10^5 seconds, it exceeded the NaI concentration by only a factor of 1.9. The lower removal rate of NaI is displayed more clearly in Figure 4-4, where the dimensionless concentrations are plotted as a function of time on semi-logarithmic paper.

4.7 AEROSOL PARTICLE SIZE

4.7.1 Cascade Impactor Data

The chief particle size measurement technique used in test AB7 employed cascade impactors. The impactors were inserted directly into the containment atmosphere in a horizontal position. Two types of multijet impactors were used, an Andersen Mark III* circular jet sampler and a Sierra Model 226** rectangular slit sampler. Precut glass fiber paper furnished by the manufacturers was used as the stage collection surface. A description of the technique and discussion of errors has been provided.[9] The standard error ($\pm$ 1σ) is believed to be $\pm$ 20%. All cascade samples were taken at the T3 through-the-wall station at + 1.37 m elevation.

*Manufactured by Andersen 2000, Inc., Atlanta, GA.
**Manufactured by Sierra Instrument Co., Carmel Valley, CA.

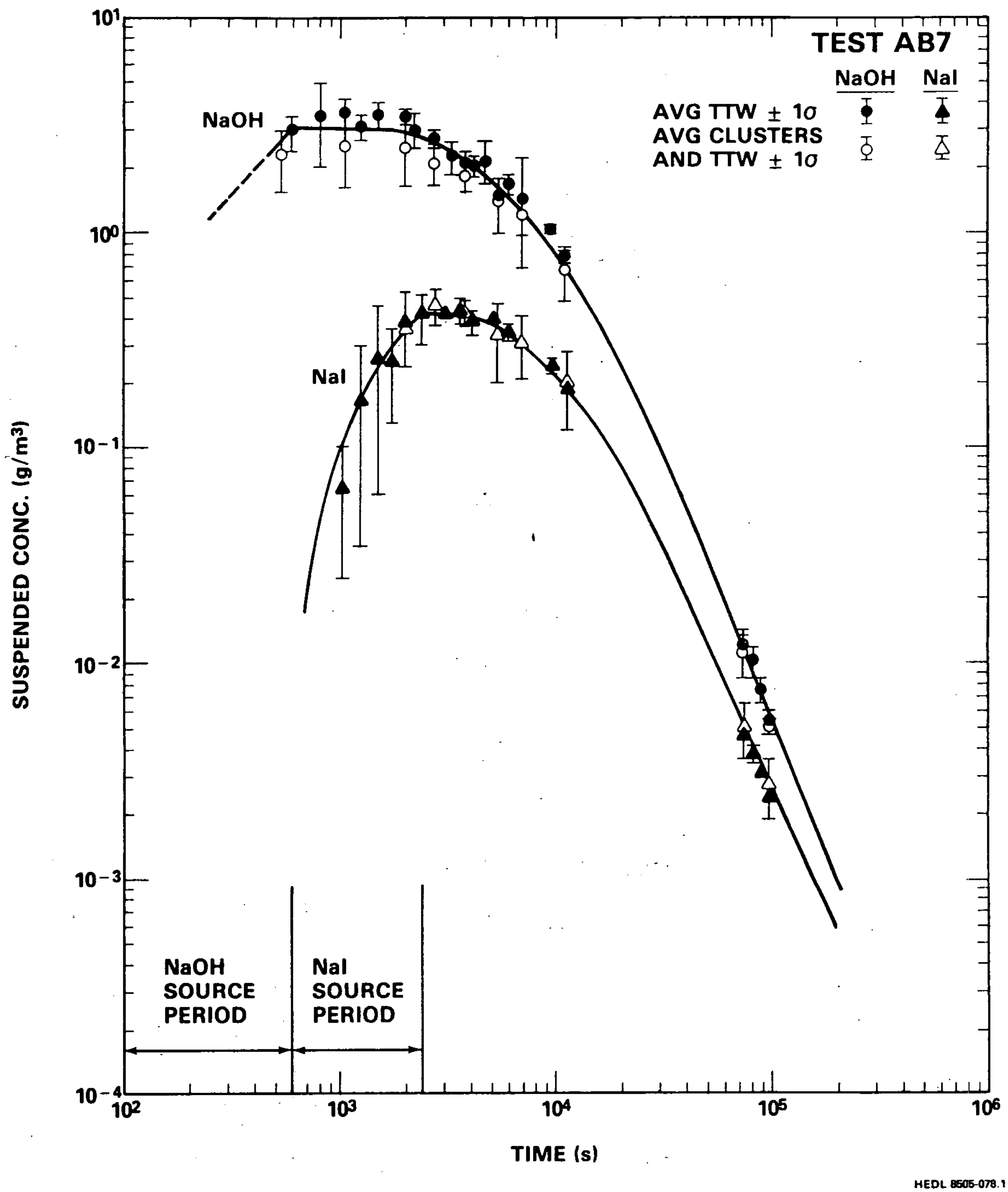

FIGURE 4-3. Suspended Mass Concentrations of NaOH and NaI as a Function of Time.

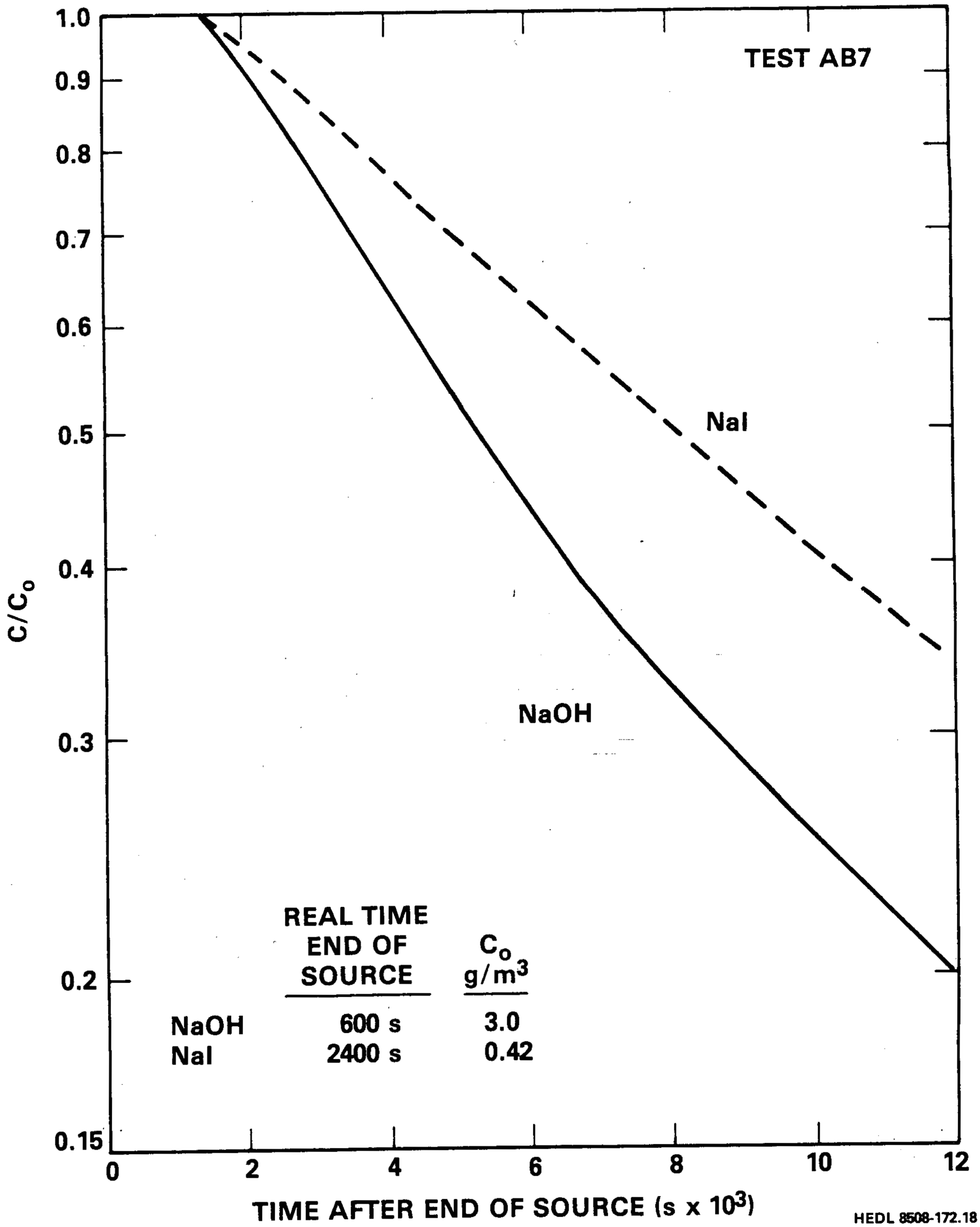

FIGURE 4-4. Comparison of NaOH and NaI Concentration Decay Rates After Source Cutoffs.

The cascade impactors showed that the aerosol generally had a log-normal distribution. One data set that typifies the cascade impactor results is shown in Figure 4-5. The aerodynamic mass median diameter (AMMD) and geometric standard deviation, σ_g, obtained from plots similar to Figure 4-5 are listed in Table 4-6. Also listed in Table 4-6 are the aerodynamic settling mean diameters, d_{sa}, calculated from Equation (1).

$$d_{sa} = (\text{AMMD}) \quad \exp \left(\ell n \ \sigma_g\right)^2 \qquad (1)$$

Plots of the AMMDs for NaOH and NaI taken from Table 4-6 are shown in Figure 4-6. Figure 4-6 shows that, during the source release periods, the AMMD for NaOH was 2.0 μm and for NaI was 0.8 μm. The AMMDs increased to maximum values of 5.4 and 4.4 for NaOH and NaI, repsectively, and then slowly decreased with time. The AMMD for NaI was always less than the AMMD for NaOH.

The geometric standard deviations, σ_g, for NaOH and NaI are plotted in Figure 4-7. The values of σ_g were the same for both types of aerosol, within experimental error.

The aerodynamic settling mean diameters, d_{sa}, are plotted in Figure 4-8 as a function of time. The d_{sa} for NaOH was 2.5 μm at the end of the NaOH source period. It slowly increased until approximately 4000 s, when the rate of increase accelerated and a maximum value of 8.7 μm was reached at 4500 s, after which it slowly decreased with time, reaching a value of 2.6 at 10^5 s. The d_{sa} for NaI began at 1.0 μm at the start of the NaI release period and then exhibited the same trends as NaOH, always remaining at values less than that of NaOH. Since the removal rate from the atmosphere is strongly dependent on the mean settling diameter, the conclusion can be made, on the basis of Figure 4-8, that the rate of NaI removal should always be less than that for NaOH in test AB7. This was the case, as discussed in Section 4.6.

The raw cascade impactor data are presented in tables and figures in Appendix D.

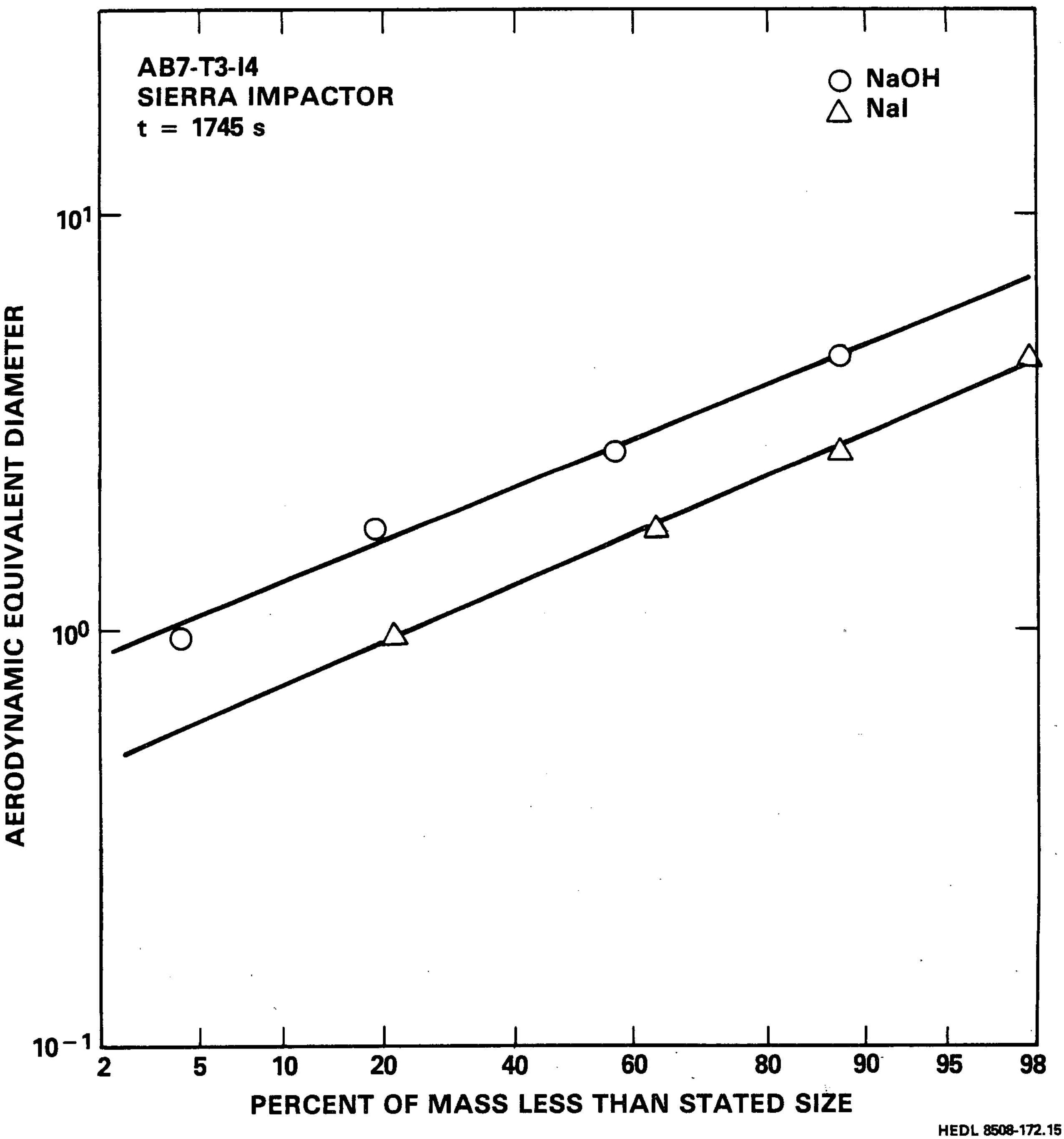

FIGURE 4-5. Typical Cascade Impactor Data Plotted on Log-Probability Paper.

TABLE 4-6

CASCADE IMPACTOR DATA

Time (s)	NaOH AMMD (mm)	NaOH σ_g	NaOH d_{sa}(b) (μm)	NaI AMMD (μm)	NaI σ_g	NaI d_{sa}(b) (μm)
7.80(2)(a)	2.05	1.63	2.60	0.80	1.60	1.00
1.27(3)	2.18	1.63	2.77	0.76	2.10	1.32
1.75(3)	2.47	1.64	3.15	1.46	1.72	1.96
2.24(3)	2.68	1.62	3.38	2.00	1.70	2.65
3.04(3)	2.78	1.81	3.95	2.10	1.79	2.95
3.84(3)	3.37	1.78	4.70	2.58	1.80	3.64
4.39(3)	5.40	2.00	8.73	4.25	2.00	6.87
6.18(3)	4.75	1.74	6.46	4.20	1.67	5.46
1.02(4)	4.20	1.74	5.71	3.80	1.79	5.33
7.29(4)	2.52	1.44	2.88	2.20	1.45	2.53
9.75(4)	2.32	1.50	2.73	1.98	1.50	2.33

(a) Numbers in parenthesis are exponents of ten.
(b) Calculated by Equation (1).

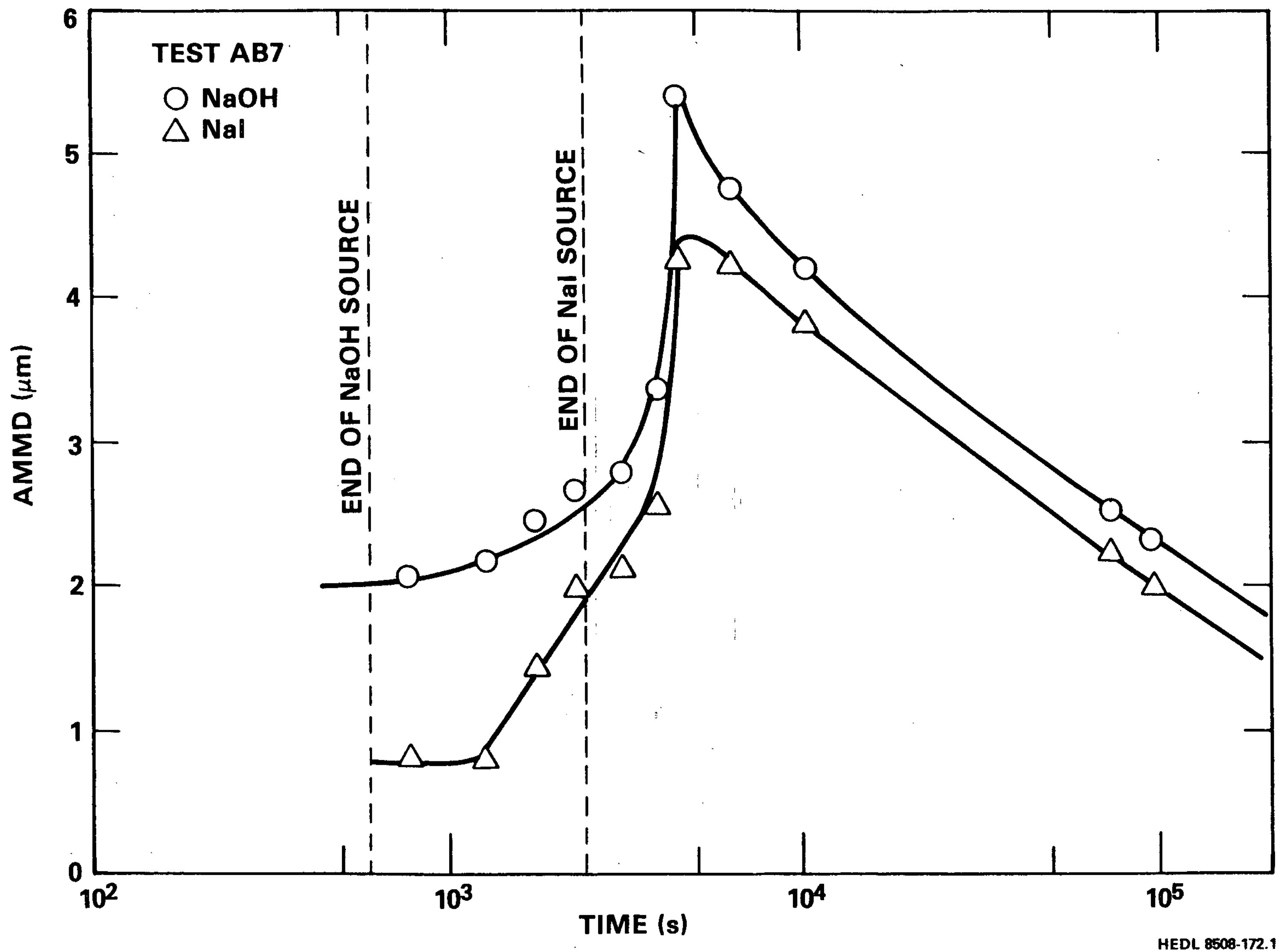

FIGURE 4-6. Plot of AMMD as a Function of Time.

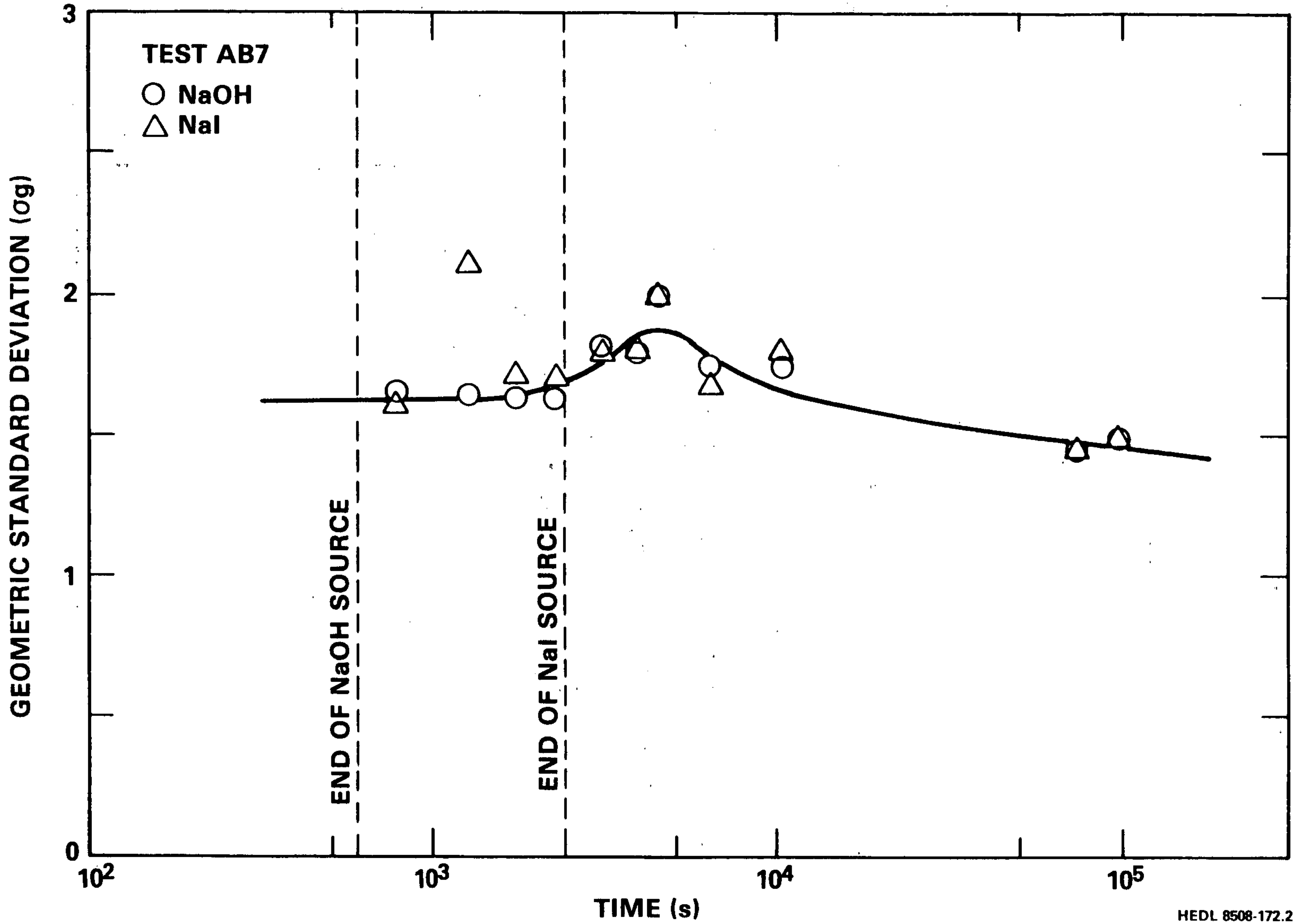

FIGURE 4-7. Plot of Geometric Standard Deviation as a Function of Time.

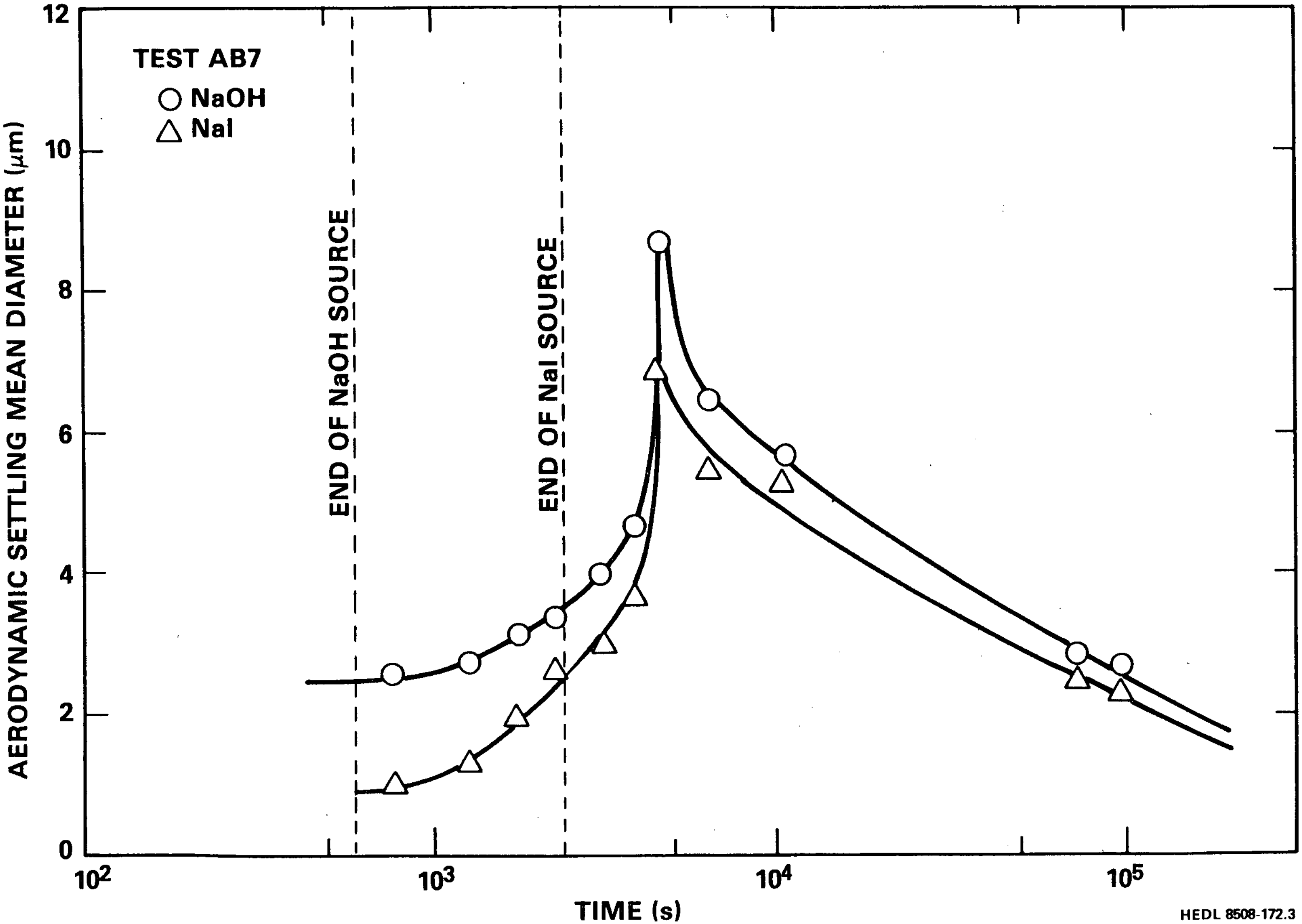

FIGURE 4-8. Plot of Aerodynamic Settling Mean Diameter as a Function of Time.

4.7.2 Size Calculated from Mass Balance on Containment Atmosphere

A mass balance on the containment atmosphere during a constant source release period in a well-mixed containment gives:

$$\lambda_t = \frac{I - V \frac{dc}{dt}}{VC} \qquad (2)$$

where:

λ_t = overall removal rate constant at time t, s^{-1}
I = aerosol release rate, g/s
V = containment volume, m^3
C = suspended aerosol concentration, g/m^3
t = time, s

For short time steps, Equation (2) can be approximated by:

$$\lambda_t = \frac{1}{C_{avg}} \left(\frac{I}{V} - \frac{\Delta C}{\Delta t} \right) \qquad (3)$$

where:

C_{avg} = average value for conc. during time step Δt
ΔC = change in conc. during time step Δt

After the aerosol source cutoff, Equation (3) simplifies to:

$$\lambda_t = \frac{\Delta C}{C_{avg} \, \Delta t} \qquad (4)$$

The overall removal rate constant, λ_t, is equal to the sum of the removal rate constants for the three removal processes of importance:

$$\lambda_t = \lambda_s + \lambda_p + \lambda_\ell \tag{5}$$

where:

λ_s = rate constant due to gravity settling
λ_p = rate constant due to plating
λ_ℓ = rate constant due to leakage

For test AB7, it can be shown that for t > 2000 s,

$$\lambda_s >> \lambda_p >> \lambda_\ell \tag{6}$$

so that λ_s is approximately equal to the overall rate constant for times > 2000 s.

The gravitational rate constant due to settling is related to the deposition velocity, u_t, by Equation (7):

$$u_t = \frac{\lambda_s V}{A_s} \tag{7}$$

where:

A_s = surface area available for settling.

Finally, the settling mean diameter, d_s, can be computed from Stokes' law (Equation 8) when u_t is known.

$$d_s = \left(\frac{18\mu_f \; u_t}{g \quad \rho_p}\right)^{0.5} \tag{8}$$

where:

d_s = settling mean diameter (cm)
μ_f = fluid viscosity (g/cm s)
g = acceleration due to gravity (cm/s^2)
ρ_p = effective particle density (g/cm^3)

In order to compare the data with the aerodynamic data obtained with the cascade impactors, the particle density was assigned a value of unity.

The removal rate constants and the aerodynamic settling mean diameters were calculated by use of Equations (2) through (8) and by numerically differentiating the curves in Figure 4-3 for suspended concentration. These data are presented in Table 4-7 for NaOH and NaI.

4.7.3 Comparison of Cascade Impactor Data with Size Calculated from Mass Balance

The aerodynamic settling mean diameters calculated from cascade impactor data, and from a mass balance on the containment atmosphere are listed in Table 4-8. The data of Table 4-8 show that the settling mean diameters calculated from cascade impactor measurements were significantly lower than those calculated from a mass balance on the containment atmosphere at times earlier than 4000 seconds. One reason for the difference in the two methods is that the aerosol size distribution was not log normal at early times. Examination of the cascade impactor data in Appendix D shows that, at early times, the use of AMMD and σ_g listed in Table 4-6 understates the mass fraction of the largest particles. Thus, the settling mean diameters calculated from Equation (1) are too small at early times. Fair agreement is noted at times greater than 4000 seconds, when the size distribution is nearly log-normal.

TABLE 4-7

REMOVAL RATE CONSTANT AND AERODYNAMIC SETTLING MEAN DIAMETER
COMPUTED FROM MASS BALANCE ON CONTAINMENT ATMOSPHERE

	NaOH		NaI	
Time (s)	λ_{t_1} (s^{-1})	d_{sa} (μm)	λ_{t_1} (s^{-1})	d_{sa} (μm)
2.10(3)[a]	1.18(-4)	6.20	---	---
2.30(3)	1.21(-4)	6.28	---	---
2.50(3)	1.24(-4)	6.35	---	---
2.70(3)	1.46(-4)	6.89	---	---
2.90(3)	1.69(-4)	7.42	---	---
3.20(3)	1.90(-4)	7.86	---	---
3.60(3)	2.00(-4)	8.07	---	---
4.00(3)	2.05(-4)	8.17	6.74(-5)	4.68
4.25(3)	2.05(-4)	8.17	7.45(-5)	4.92
4.50(3)	2.04(-4)	8.15	7.60(-5)	4.95
4.75(3)	2.01(-4)	7.93	7.74(-5)	5.02
5.00(3)	1.92(-4)	7.81	8.97(-5)	5.40
5.25(3)	1.88(-4)	7.75	1.02(-4)	5.76
5.50(3)	1.82(-4)	7.70	1.05(-4)	5.84
5.75(3)	1.77(-4)	7.50	1.07(-4)	5.90
6.00(3)	1.72(-4)	7.41	1.08(-4)	5.93
6.50(3)	1.65(-4)	7.33	1.09(-4)	5.98
7.00(3)	1.56(-4)	7.15	1.12(-4)	6.04
7.50(3)	1.49(-4)	6.96	1.14(-4)	6.09
8.50(3)	1.36(-4)	6.65	1.11(-4)	5.95
9.50(3)	1.27(-4)	6.36	1.06(-4)	5.87

TABLE 4-7 (Cont'd)

Time (s)	NaOH λ_{t1} (s^{-1})	NaOH d_{sa} (μm)	NaI λ_{t1} (s^{-1})	NaI d_{sa} (μm)
1.10(4)	1.23(-4)	6.32	1.05(-4)	5.85
1.30(4)	1.18(-4)	6.20	9.88(-5)	5.67
1.50(4)	1.10(-4)	5.98	9.60(-5)	5.59
1.70(4)	1.05(-4)	5.85	9.50(-5)	5.56
1.90(4)	9.24(-5)	5.48	8.70(-5)	5.32
2.25(4)	9.09(-5)	5.44	7.66(-5)	4.99
2.75(4)	8.23(-5)	5.18	7.01(-5)	4.78
3.50(4)	6.51(-5)	4.60	5.90(-5)	4.40
4.50(4)	5.61(-5)	4.27	4.79(-5)	3.95
5.50(4)	4.38(-5)	3.78	3.79(-5)	3.51
6.50(4)	3.91(-5)	3.57	3.53(-5)	3.39
7.5(4)	3.69(-5)	3.47	2.91(-5)	3.08
8.5(4)	3.03(-5)	3.14	2.78(-5)	3.01
9.5(4)	2.58(-5)	2.90	2.46(-5)	2.83
1.10(5)	2.50(-5)	2.85	2.29(-5)	2.73

(a) Numbers in parenthesis are exponents of ten.

TABLE 4-8

COMPARISON OF AEROSOL SIZE IN CONTAINMENT ATMOSPHERE MEASURED BY CASCADE IMPACTOR AND CALCULATED FROM MASS BALANCE

Time (s)	d_{sa} for NaOH (mm)		d_{sa} for NaI (mm)	
	Cascade Impactor[a]	Mass Balance[b]	Cascade Impactor[a]	Mass Balance[b]
7.80(2)[c]	2.60	(d)	1.00	(d)
1.26(3)	2.77	(d)	1.32	(d)
1.75(3)	3.15	(d)	1.96	(d)
2.24(3)	3.38	6.25	2.65	(d)
3.04(3)	3.95	7.65	2.95	(d)
3.84(3)	4.70	8.10	3.64	4.60
4.39(3)	8.73	8.16	6.87	4.93
6.18(3)	6.46	7.40	5.46	5.95
1.02(4)	5.72	6.34	5.33	5.86
7.29(4)	2.88	3.50	2.53	3.15
9.75(4)	2.73	2.88	2.33	2.78

(a) From Table 4-6.
(b) Interpolated from data of Table 4-7.
(c) Numbers in parenthesis are exponents of ten.
(d) Concentration decay rate too small for accurate calculation.

Both types of measurement show that the particle size increased with time to a maximum value and then decreased thereafter. For NaOH, the maximum occurred at approximately 4400 s and for NaI it occurred at approximately 5000 s. Both methods showed that the NaOH settling mean diameter was larger than that of NaI at all times.

4.8 AEROSOL DEPOSITION ON HORIZONTAL SURFACES

The distribution of settled mass within the containment vessel was determined from analyses of settling trays located at 22 different locations and exposed to the containment atmosphere throughout the test. Each tray had 266 cm^2 of upward facing surface. After the test, the trays were retrieved and the deposited material analyzed for NaOH and NaI. The results are presented in Table 4-9. The individual samples listed in Table 4-9 are arranged into four groups according to their general location within the containment environment. The average surface concentration of each group is then multiplied by the upward facing surface area of that portion of the containment vessel. By this method, a total of 2684 g of NaOH were found to have settled on horizontal surfaces. Dividing this mass by the total settling area of 88.2 m^2 gives a weighted mean surface concentration of 30.4 g NaOH/m^2. The NaOH settled surface concentration was fairly uniform throughout the containment vessel, ranging from 26.7 g/m^2 for internal components to 33.9 g/m^2 for the bottom head.

In a similar manner, Table 4-9 shows that 414 g of NaI were found on horizontal surfaces. Dividing by 88.2 m^2 total settling area gives an average surface concentration of 4.69 g/m^2 for settled NaI. The NaI settled surface concentration was also fairly uniform throughout the containment vessel, ranging from 4.13 g/m^2 on the personnel platform to 5.41 on the catch pan.

TABLE 4-9

INTEGRAL SETTLED MASS BY DEPOSITION TRAYS

Sample No	Location	Area Represented (m^2)	NaOH Surface Conc. (g NaOH/m^2)	NaOH (g NaOH)	NaI Surface Conc. (g NaI/m^2)	NaI (g NaI)
D50	Personnel Platform at -1.7 m		29.3		4.02	
D51	Personnel Platform at -1.7 m		25.1		4.10	
D52	Personnel Platform at -1.7 m		24.2		4.20	
D53	Personnel Platform at -1.7 m		47.8		4.21	
			----		----	
	Avg Personnel Platform	4.2	31.6	133	4.13	17.4
D54	Bottom Head		28.2		4.97	
D55	Bottom Head		29.8		4.95	
D56	Bottom Head		29.9		4.40	
D57	Bottom Head		41.5		4.97	
D64	Bottom Head		26.5		4.99	
D65	Bottom Head		26.1		4.54	
D66	Bottom Head		27.5		4.84	
D67	Bottom Head		61.3		5.58	
			----		----	
	Avg Bottom Head	36.7	33.9	1243	4.90	179 .8
D59	Catch Pan at -8.66m		30.4		5.26	
D60	Catch Pan at -8.66m		29.1		5.03	
D61	Catch Pan at -8.66m		32.3		5.26	
D62	Catch Pan at -8.66m		31.7		6.11	
D63	Catch Pan at -8.66m		29.8		5.41	
			----		----	
	Avg Catch Pan	11.1	30.7	340	5.41	60.1
D68	Internal Components		25.3		4.60	
D69	Internal Components		33.0		4.95	
D70	Internal Components		31.0		5.01	
D71	Internal Components		24.6		3.60	
D72	Internal Components		19.8		3.51	
			----		----	
	Avg Internal Components	36.2	26.7	968	4.33	156.9
		----		----		---
	Overall Total	88.2		2684		414.2

4.9 AEROSOL DEPOSITION ON VERTICAL SURFACES AND CEILING

4.9.1 Deposition on Vessel Walls and Ceiling

Aerosol deposition on the containment vessel walls and ceiling was measured post-test by wiping a measured area of the painted wall with a series of damp cloths and analyzing for Na and NaI. The results of sampling in this manner at eight different locations are listed in Table 4-10 for NaOH and NaI.

The data of Table 4-10 show a general trend of increasing surface concentration with decreasing elevation for both NaOH and NaI. Although one of the ceiling samples gave a high NaOH concentration, the ceiling concentration was generally lower than that of the vertical walls.

4.9.2 Deposition on Vertical Panels

Seven 305 x 305-mm panels were installed in a vertical position in the containment atmosphere as a means of measuring aerosol plating with negligible thermophoretic effect. The panels were fabricated of polished stainless steel, 0.79 mm thick, and were hung by wires at various distances from the vessel wall at the vessel mid-elevation. Six of the panels were oriented with the surface parallel to the containment wall, while one panel was oriented normal to the wall. The panels were exposed to the containment conditions for the entire test period.

The panels were retrieved during the post-test entry and sampling period, and each side of each panel was washed separately and analyzed for NaOH and NaI. The results are listed in Table 4-11. In Table 4-11, the columns labeled "inward surface" give the data for the sides of the panels that faced toward the center of the containment vessel, and the columns headed by "outward surface" are for the sides facing the wall.

TABLE 4-10

WALL AND CEILING POST-TEST SURFACE CONCENTRATION

Sample(a) No.	Wall Elevation (m)	NaOH Mass Sampled (g NaOH)	NaOH Surface Conc. ($gNaOH/m^2$)	NaI Mass Sampled (g NaI)	NaI Surface Conc. ($g NaI/m^2$)
W1	Ceiling, center	0.0362	0.389	0.00234	0.02520
W2	Ceiling, edge	0.0166	0.178	0.00068	0.00731
W3	+9.1	0.0265	0.285	0.00106	0.01140
W4	+4.3	0.0259	0.278	0.00128	0.01376
W5	+1.8	0.0233	0.251	0.00174	0.01871
W6	-0.9	0.0325	0.349	0.00052	0.00559
W7	-3.7	0.0279	0.300	0.00040	0.00430
W8	-6.4	0.0432	0.464	0.00080	0.00860
Average all samples			0.312		0.0119
Standard deviation (1σ)			0.088		0.0071
Average ceiling			0.284		0.0163
Average wall			0.321		0.0104
Standard deviation (1σ)			0.077		0.0054

(a) Wash and wipe 0.093 m^2 of painted wall surface.

The data of Table 4-11 show that the outward facing surfaces collected significantly more of each aerosol species than the inward facing surfaces did. This behavior is similar to that observed during test AB6[2], in which the same vertical panels were installed in identical locations. The vertical panels also collected significantly more aerosol mass per unit area than was deposited on the main containment walls (see Table 4-10). This behavior was also observed during test AB6.

4.9.3 Comparison of Deposition on Vertical and Horizontal Surfaces

A comparison of aerosol deposition on vertical walls of the containment vessel with settled mass on horizontal surfaces is given in Table 4-12. Table 4-12 shows that approximately 90% of the NaOH settled on horizontal surfaces, while only 10% was deposited on vertical wall and ceiling surfaces. The relative proportions of NaOH settling and plating in the current test are similar to those in previous tests in the CSTF[1, 2].

Table 4-12 shows that 98% of the NaI settled onto horizontal surfaces, while only 2% plated on walls and ceiling. This is a significantly lower proportion of NaI plated than in a previous test[2], where 11.6% was found on wall and ceiling. This can be explained by the different time periods that NaI aerosol was released in the two tests. In the previous test (AB6) the NaI release to containment occurred at the same time that that NaO_x aerosol was being generated by a sodium spray fire, while in the present test, the NaI release occurred after the NaOH release had terminated. It is likely that co-agglomeration with NaOH particles resulted in the NaI being associated with larger particles in the present test. Also, thermophoretic and turbulent deposition forces were weaker in the present, low temperature case.

TABLE 4-11

AEROSOL DEPOSITION ON VERTICAL PANELS[a]

Sample No.	Orientation[b]	Distance From Wall (mm)	NaOH Conc. (g NaOH/m^2) Inward Surface[c]	NaOH Conc. (g NaOH/m^2) Outward Surface	NaOH Ratio Out/In	NaI Conc. (g NaI/m^2) Inward Surface[c]	NaI Conc. (g NaI/m^2) Outward Surface	NaI Ratio Out/In
VP-1	P	64	2.68	4.93	1.84	0.0096	0.0290	3.02
VP-2	P	64	1.20	4.43	3.69	0.0040	0.0374	9.35
VP-3	P	64	0.703	1.28	1.82	0.0264	0.0210	0.80
VP-4	P	460	4.56	6.40	1.40	0.0116	0.0661	5.70
VP-5	P	610	7.43	13.3	1.79	0.0416	0.0162	0.39
VP-6	P	1500	0.151	0.419	2.77	0.0071	0.0099	1.39
VP-7	N	900	5.80[d]	0.365[d]	---	0.0486[d]	0.0039[d]	---
Average			2.79	5.13	2.22	0.0167	0.0299	3.44

(a) Smooth stainless steel, 0.093 m^2 each side, 0.79 mm thick.
(b) P = parallel to wall, N = normal to wall.
(c) Inward means facing center of vessel; outward means facing wall of vessel.
(d) Panel was normal to wall, no inward or outward surface. Not included in average.

TABLE 4-12

COMPARISON OF AEROSOL DEPOSITION ON HORIZONTAL AND VERTICAL SURFACES[a]

	NaOH		NaI	
	Vertical And Ceiling	Upward Facing Horizontal	Vertical And Ceiling	Upward Facing Horizontal
Surface Area (m^2)	752	88.3	752	88.3
Avg Surface Conc (g/m^2)	0.312[b]	30.4	0.012[b]	4.69
Mass Deposited (g)	235	2684[c]	8.95	414[c]
Mass Fraction Deposited[d]	0.102	0.898	0.021	0.979

(a) Based on post-test sampling.
(b) From Table 4-10.
(c) From Table 4-9.
(d) Neglecting leakage from the containment vessel.

4.10 CO-AGGLOMERATION BEHAVIOR

4.10.1 NaI Fraction in Aerosol on Cascade Impactor Stages

The glass fiber stage papers from the cascade impactors were analyzed for NaI and NaOH. The results are tabulated in Appendix D, where the mass of each species and the NaI mass fraction is listed for each stage. Since each stage corresponds to a known cut diameter, the data show how the NaI fraction varied as a function of particle size. The data of Appendix D are plotted in Figures 4-9 and 4-10 for the time period during the NaI injection and after the end of NaI injection, respectively.

Figure 4-9 shows that during the period when NaI was being generated (but after the end of NaOH aerosol generation) the extremities of the aerosol size spectra were rich in NaI compared to median sized particles. This trend became less pronounced as time passed and the concentration of NaI increased. After the end of the NaI source period(2400 s), the minima in

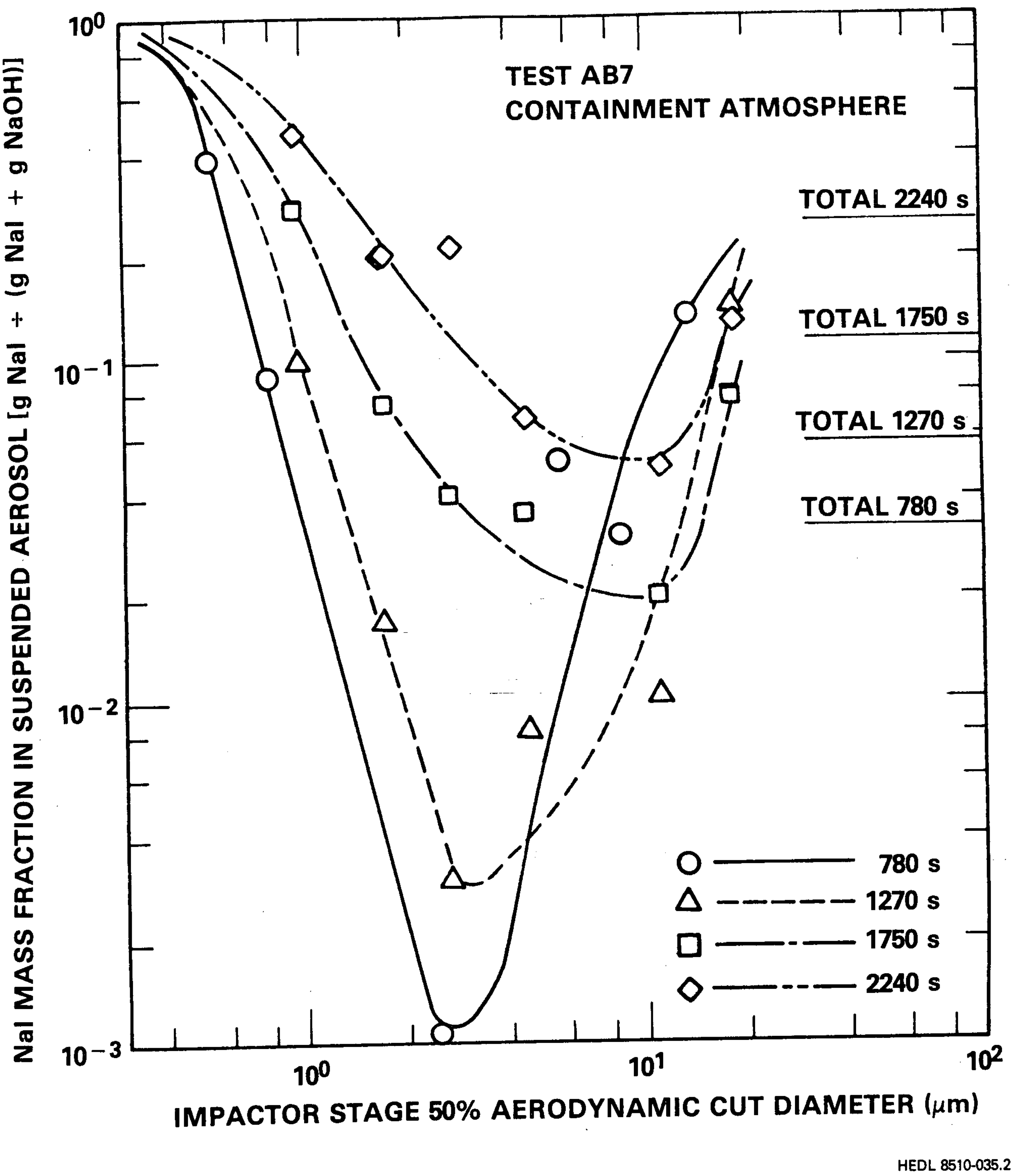

FIGURE 4-9. NaI Mass Fraction in Aerosol on Cascade Impactor Stages During NaI Aerosol Injection Period.

the curves vanished and fairly straight lines were obtained, with the smallest particles being very rich in NaI and the largest particles rich in NaOH (Figure 4-10). This trend persisted for the duration of the experiment.

4.10.2 NaI Mass Fraction in Suspended Aerosol Determined by Filter Sampling

The mass fraction of NaI in the suspended aerosol increased continuously with time, as shown by Figure 4-11. Beginning at zero at times prior to the start of the NaI source, the NaI mass fraction increased rapidly after the start of NaI source and reached a value of 0.14 by the end of the NaI source period. Due to the fact that the particles were nonuniform in NaI/NaOH ratio as a function of size and the larger particles were richest in NaOH (see Figure 4-10), the NaOH suspended concentration decreased more rapidly than did the NaI, because settling was the dominant removal mechanism at late times. Thus, the mass ratio of NaI in the remaining suspended aerosol continued to increase after the end of the NaI source period, as shown by Figure 4-11. Figures 4-10 and 4-11 thus confirm and explain the faster removal of NaOH shown in the plot of suspended concentration versus time in Figure 4-3.

4.10.3 NaI Mass Fraction of Settled Aerosol

The NaI mass fraction in the aerosol deposited on horizontal surfaces was determined by analyzing samples deposited in fallout trays location at 22 different locations throughout the containment vessel. The results are listed in Table 4-13, which gives the mass of NaI, mass of NaOH, and the NaI mass fraction, assuming that only NaI and NaOH were present. Table 4-13 shows that all 22 samples gave fairly uniform NaI mass fraction, even though the samples were taken at elevations ranging from -8.48 m to +8.7 m. The arithmetic mean value was 0.137 and the standard deviation was 0.022 (16%).

The fallout tray data of Table 4-13 are for integral samples collected over the entire test period. Comparison of Table 4-13 with Figure 4-11, which gives the NaI mass fraction in the suspended aerosol as a function of time,

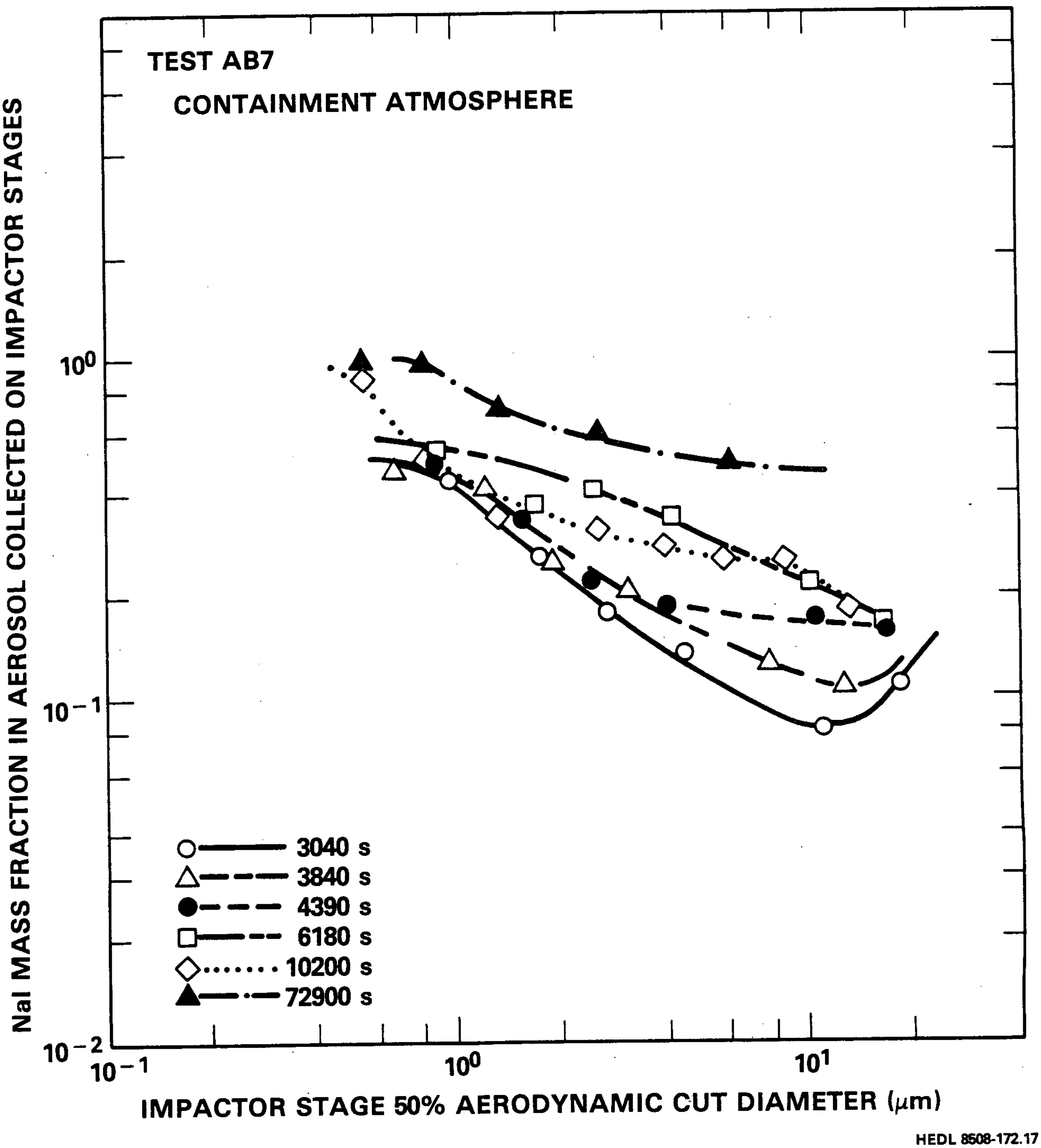

FIGURE 4-10. NaI Mass Fraction in Aerosol on Cascade Impactor Stages After End of NaI Injection Period.

TABLE 4-13

NAI MASS FRACTION IN AEROSOL SETTLED ON HORIZONTAL SURFACES

Sample No.	Sample Elevation (m)(a)	Mass Deposited (g)(b) NaI	NaOH	NaI Mass Fraction
D50	0	0.105	0.768	0.121
D51	-1.7	0.107	0.658	0.140
D52	-1.7	0.110	0.634	0.148
D53	-1.7	0.110	1.252	0.081
D54	-8.48	0.130	0.739	0.150
D55	-8.48	0.130	0.781	0.143
D56	-8.48	0.115	0.783	0.128
D57	-8.48	0.130	1.087	0.107
D58	-8.48	---	---	---
D59	-8.48	0.138	0.796	0.148
D60	-8.48	0.132	0.762	0.148
D61	-8.48	0.138	0.846	0.140
D62	-8.48	0.160	0.830	0.162
D63	-8.48	0.142	0.781	0.154
D64	-8.48	0.131	0.694	0.159
D65	-8.48	0.119	0.684	0.148
D66	-8.48	0.127	0.721	0.150
D67	-8.48	0.146	1.606	0.083
D68	-4.27	0.121	0.623	0.163
D69	+3.05	0.130	0.865	0.131
D70	+6.1	0.131	0.812	0.139
D71	+8.7	0.095	0.645	0.128
D72	+8.7	0.092	0.519	0.150
Average				0.137
σ				0.022

(a) Lowest point of bottom head is at -9.3 m. Sample collectors were at various radii and azimuth.
(b) Integral sample exposed throughout test.

shows that the higher NaI mass fractions attained in the suspended aerosol at long times (up to 0.3) had little effect on the total integral settled mass. The average NaI mass fraction in the fallout trays (0.137) corresponds with the NaI mass fraction in suspended aerosol at the time that the NaI source was terminated, as shown in Figure 4-11.

4.10.4 NaI Mass Fraction of Plated Aerosol

The NaI mass fraction in the aerosol deposited on vertical walls and ceiling surfaces was determined by removing the deposit from selected regions of known area (0.093 m^2) and analyzing for the two aerosol species. The surface deposit was removed by wiping with a series of damp cloths until no more aerosol could be removed, then leaching the cloths with water. The results are given in Table 4-14.

TABLE 4-14

NAI MASS FRACTION IN AEROSOL DEPOSITED ON VESSEL VERTICAL WALL AND CEILING

Sample No.	Sample Elevation (m)(a)	Mass Deposited (mg/m2) NaI	Mass Deposited (mg/m2) NaOH	NaI Mass Fraction
W1	Ceiling, center	25.2	389	0.061
W2	Ceiling, edge	7.3	178	0.039
W3	Wall, +9.1	11.4	285	0.038
W4	Wall, +4.3	13.8	278	0.047
W5	Wall, +1.8	18.7	251	0.069
W6	Wall, -0.9	5.6	349	0.016
W7	Wall, -3.7	4.3	300	0.014
W8	Wall, -6.4	8.6	464	0.018
Average				0.0378
σ				0.0208

(a) NaI was released at -4.6 m elevation.

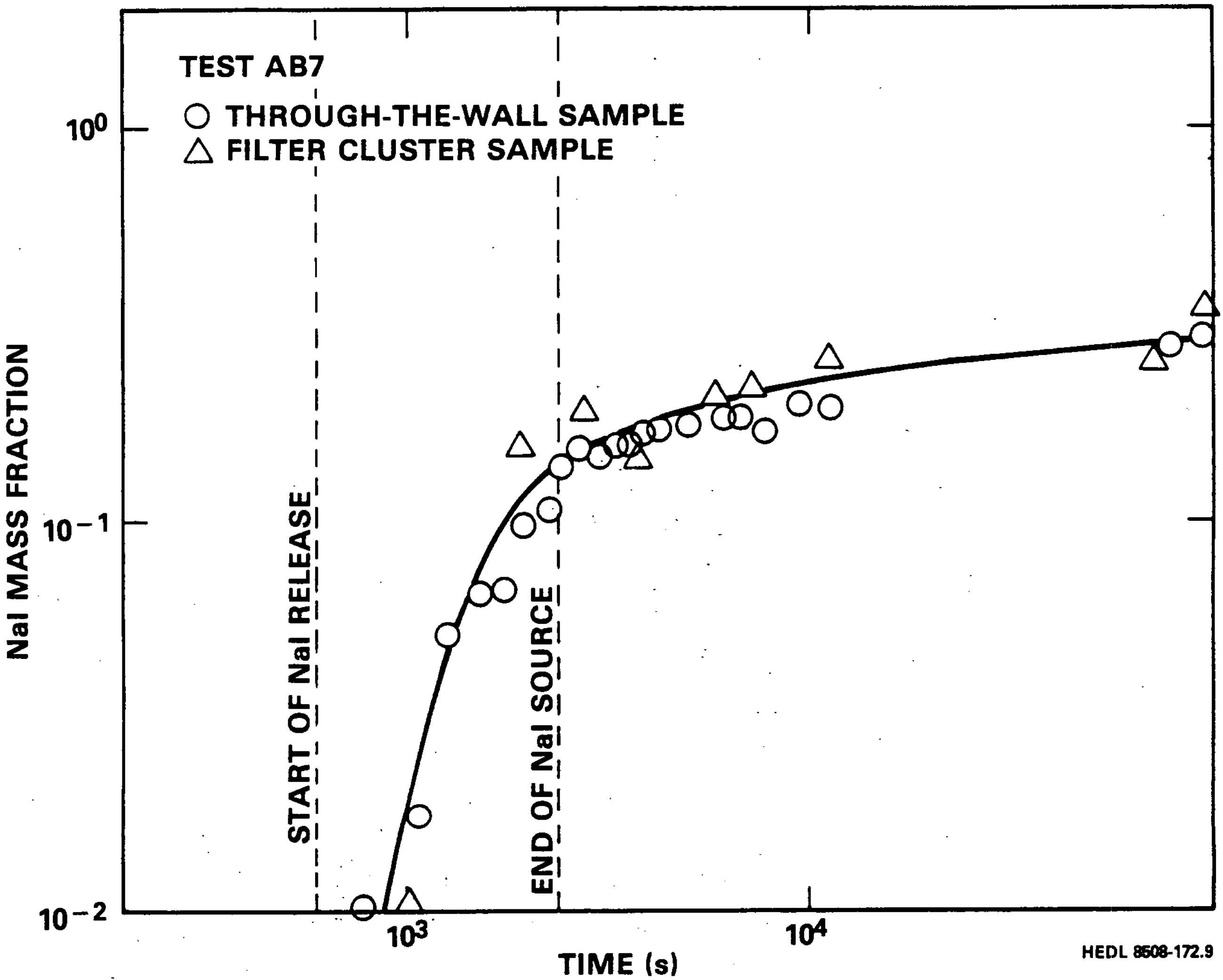

FIGURE 4-11. NaI Mass Fraction in Suspended Aerosol Determined by Filter Sampling.

The data presented in Table 4-14 show considerable differences in NaI to NaOH ratio in the plated aerosol as a function of elevation within the containment vessel. Samples taken from high in the vessel were significantly richer in NaI than samples taken at lower elevations. This is surprising in view of the fact that both NaI and NaOH suspended aerosol concentration were quite uniform throughout the containment atmosphere (see Tables 4-2 and 4-3).

The average value of the NaI mass fraction in the wall and ceiling deposits (0.0388) was significantly lower than that of the aerosol that was collected in the horizontal fallout trays (0.137). One explanation is that the aerosol particle size increased significantly during the NaI source period and for 40 minutes afterward, as shown in Figures 4-6 and 4-8. During early time, when the particle size was small and wall plating processes were maximum, the NaI mass fraction was low (see Figure 4-11).

4.11 AEROSOL DENSITY

The mass of aerosol released into the containment vessel during test AB7 was too small to permit measurement of settled density, as was done in previous tests in the CSTF[1,2]. On the basis of previous experience, the bulk density of the AB7 aerosol is estimated to be approximately 1 g/cm^3.

4.12 LEAKED MASS

The actual quantity of aerosol leaked from the containment vessel was not measured directly. For the purpose of comparing leaked mass with code predictions, a calculation was made using the same assumption used in the computer code cases--that aerosol leaked at a constant 1% of the suspended mass per day. The data of Table 4-15 were computed by Equation(9), using concentration data taken from Figure 4-3.

$$M_\ell = \sum_{0}^{n} L\ V\ C_{avg} \Delta t \qquad (9)$$

where:

M_ℓ = mass of aerosol leaked, g
L = leak rate, s^{-1}
V = containment volume, m^3
C_{avg} = average suspended conc. during time step, g/m^3
Δt = duration of time step, s

The data of Table 4-15 are plotted in Figure 4-12. Table 4-15 and Figure 4-12 show that only 15% of the total computed NaI leakage had occurred by the end of the NaI source period. In test AB6, 95% of the computed NaI leakage had occurred by the end of the NaI source period. The less rapid leakage in the present test is attributed to the fact that the NaI concentration was much lower than in test AB7, resulting in much less washout. Also, in test AB7, the NaOH source continued after the end of the NaI source.

It should be reemphasized that the data of Table 4-15 and Figure 4-12 are not based on actual measurement, but on calculations based on experimentally measured suspended concentration and the assumption of a constant 1%/day leakage rate.

4.13 SETTLED MASS

The integral settled mass was determined from fallout tray data, as discussed in Sections 4.8 and 4.9.3. Table 4-12 shows that a total of 2684 g of NaOH and 414 g of NaI settled onto horizontal surfaces during test AB7.

TABLE 4-15

LEAKED MASS COMPUTED FROM SUSPENDED CONCNTRATION
AND ASSUMED 1% PER DAY LEAKAGE

Time (s)	Leaked Mass (g)		Time (s)	Leaked Mass (g)	
	NaOH	NaI		NaOH	NaI
100	2.91(-3)(a)	0	8,500	1.67(0)	2.43(-1)
300	2.62(-2)	0	10,000	1.81(0)	2.78(-1)
600	1.02(-1)	0	12,000	1.95(0)	3.17(-1)
900	1.91(-1)	1.01(-3)	15,000	2.10(0)	4.04(-1)
1300	3.09(-1)	5.67(-3)	20,000	2.28(0)	4.51(-1)
1800	4.57(-1)	1.66(-2)	30,000	2.45(0)	5.12(-1)
2000	5.16(-1)	2.26(-2)	40,000	2.54(0)	5.43(-1)
2400	6.32(-1)	2.96(-2)	50,000	2.58(0)	5.61(-1)
2700	7.15(-1)	4.22(-2)	60,000	2.61(0)	5.72(-1)
3000	7.93(-1)	5.47(-2)	70,000	2.62(0)	5.80(-1)
3600	9.38(-1)	7.97(-2)	80,000	2.63(0)	5.85(-1)
4200	1.07(0)	1.04(-1)	90,000	2.64(0)	5.89(-1)
5000	1.22(0)	1.35(-1)	100,000	2.65(0)	5.92(-1)
6500	1.45(0)	1.86(-1)	150,000	2.67(0)	6.01(-1)
7200	1.53(0)	2.08(-1)	200,000	2.67(0)	6.04(-1)

(a) Numbers in parenthesis are exponents of 10.

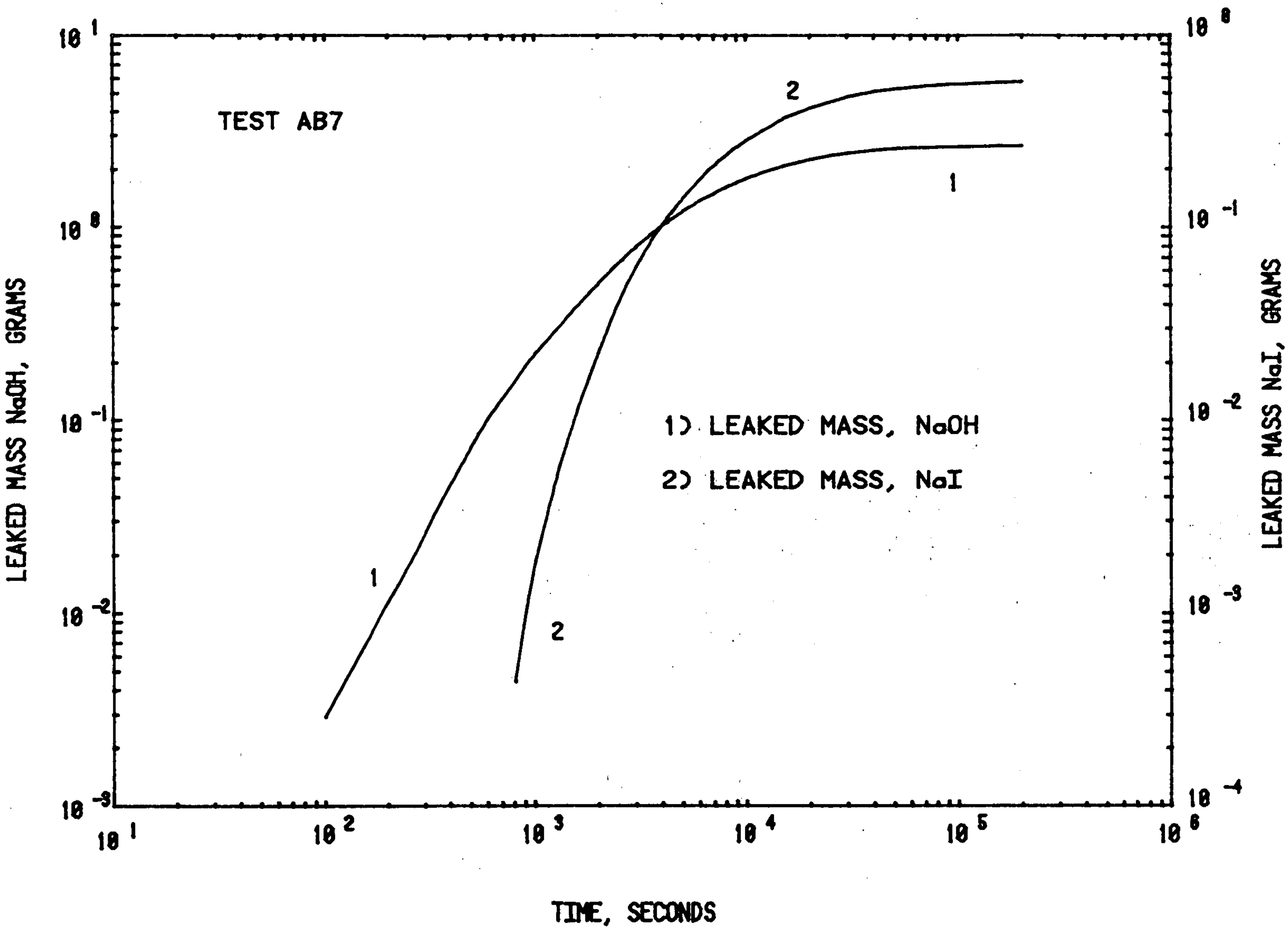

FIGURE 4-12. Leaked Aerosol Mass Computed with Assumption of Constant 1% per day Leakage Rate.

4.14 PLATED MASS

The integral plated mass on vertical and ceiling surfaces was determined by post-test wall wipe measurements, as discussed in Section 4.9. Table 4-12 shows that a total of 235 g of NaOH and 8.95 g of NaI plated onto vertical and ceiling surfaces during test AB7.

4.15 INSTANTANEOUS COMBINED REMOVAL RATE

The instantaneous combined removal rate constant, λ_t was calculated by differentiating the suspended mass concentration curve of Figure 4-13, as discussed in Section 4.7.2. The computed values of λ_t are listed in Table 4-7 and plotted in Figure 4-13 as a function of time.

Figure 4-13 shows that, for both types of aerosol species, λ_t increased at early times, reached a maximum value and then slowly decreased for the duration of the test. Figure 4-13 also shows that the removal rate for NaOH was always greater than for NaI, although their magnitudes approached each other at long times.

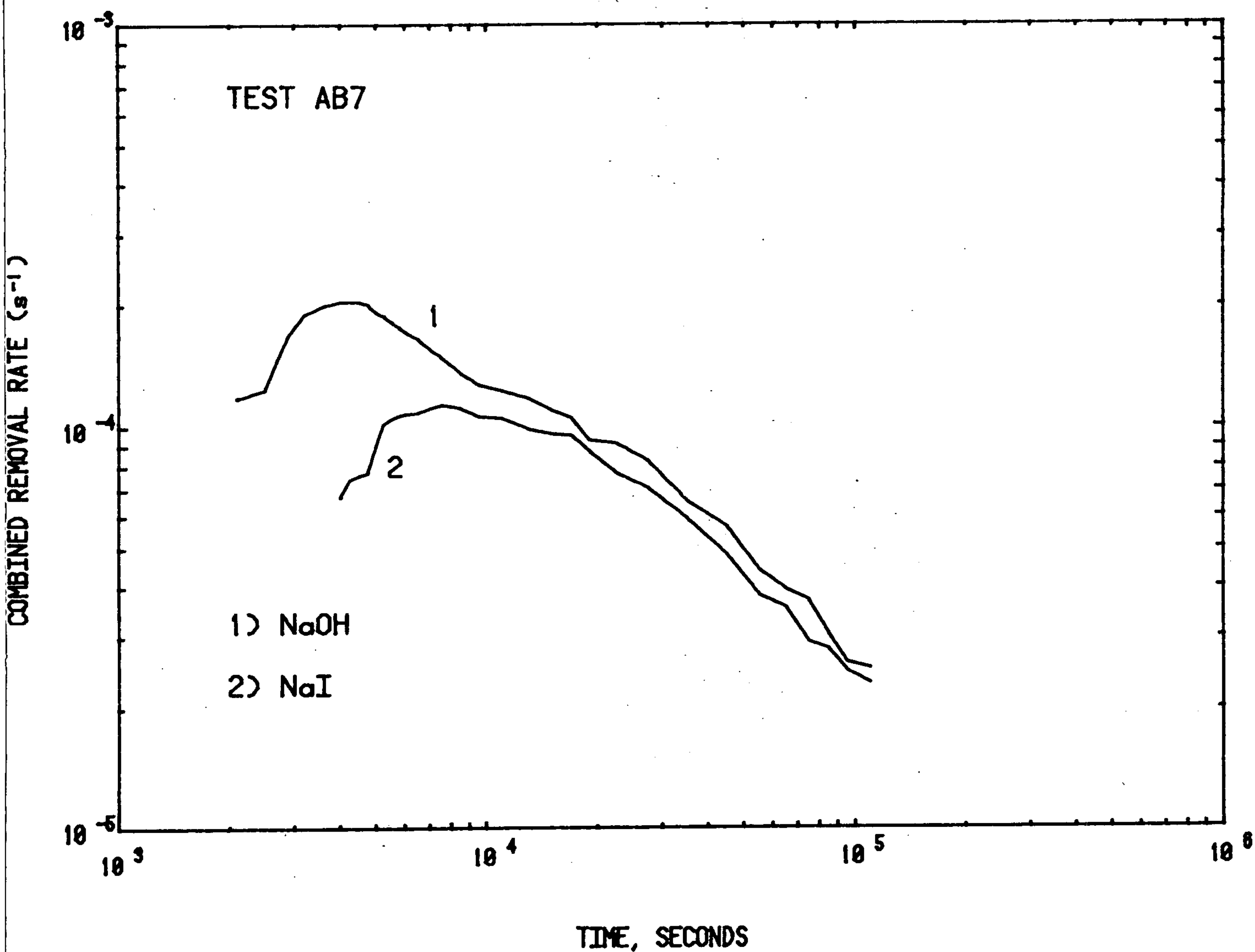

FIGURE 4-13. Plot of Instantaneous Combined Removal Rate for NaOH and NaI Aerosols.

5.0 COMPARISON OF EXPERIMENTAL RESULTS WITH COMPUTER CODE PREDICTIONS

5.1 IDENTIFICATION OF CODES AND USERS

Four individuals participated in making computer code predictions of test AB7. These people, their affiliations, and mailing addresses are listed in Table 5-1.

TABLE 5-1

LIST OF PARTICIPANTS FOR ABCOVE TEST AB7

Participant	Affiliation	Address
R. K. Hilliard	Hanford Engineering Development Laboratory	P.O. Box 1970 Richland, WA 99352
Hans Jordan	Battelle Columbus Laboratories	505 King Avenue Columbus, OH 43201
K. K. Murata	Sandia National Laboratories	P.O. Box 5800 Albuquerque, NM 87115
J. M. Otter	Rockwell International Rocketdyne Division	6633 Canoga Avenue Canoga Park, CA 91304

The aerosol codes used to predict aerosol behavior, along with the corresponding participants, are identified in Table 5-2. Each code was exercised by only one participant, so no information was obtained on variation between users of the same code, as was done for test AB5.(1) The code cases are assigned identification numbers, as shown in Table 5-2, to facilitate discussions and comparisons with data in subsequent sections of this report.

Three of the codes (HAA-3,(3) HAA-4,(4), and HAARM-3,(5) are termed "log-normal" because they use the assumption that the suspended aerosol always has a log-normal size distribution. Two of the codes (CONTAIN(6) and

QUICKM[7]) are termed "discrete" because they divide the suspended aerosol size spectrum into a finite number of groups, normally 20 to 40 groups, with user-specified size range for each group. QUICKM was previously designated as MSPEC[7].

TABLE 5-2

CODE CASES FOR ABCOVE TEST AB7

Code Case No.	Code	User	Log-Normal or Discrete	Co-agglomeration Assumption
1	HAA-3C	HEDL/SSD	Log-Normal	Uniform
2	HAA-4	Rockwell	Log-Normal	Uniform
3	HAARM-3	HEDL/SSD	Log-Normal	Uniform
4	CONTAIN-1B, Mod 415	SNL	Discrete	Sectionally Uniform
5	QUICKM	BCL	Discrete	Sectionally Uniform

Different methods of handling multiple species aerosol are also used by various codes. It has been common in the past to use the assumption that a multiple species aerosol is uniformly co-agglomerated; i.e., that each particle has the same composition regardless of size. All of the log-normal codes used in the present study use this assumption. Recently, several multiple species codes have been developed which treat a mixture of species mechanistically by assuming that all particles within a given size can be characterized by the same average composition. The QUICKM and CONTAIN codes used in the present study are of this class. Not all "discrete" codes are multispecies codes. For instance, the QUICK[10] and NAUA[11] codes are discrete but use the uniform co-agglomeration assumption.

Pretest code calculations are not reported for test AB7 because the conditions under which the test was performed were changed significantly from the test plan, as discussed in Section 4.1. However, "blind" post-test calculations were made using the five codes listed in Table 5-2. Although the HEDL participant had general knowledge of the test results before he made the post-test calculations with HAA-3 and HAARM-3, detailed test data were not available and no attempt was made to fit the code to the experiment. Calculations by the other three participants were truly blind, in that no experimental data on aerosol behavior per se were made available; only information on thermal conditions and aerosol mass generation was made available to reflect the actual conditions.

5.2 CODE INPUTS

After the test was completed, test data related to aerosol generation and thermal conditions were transmitted to the participants. Key test parameters for use in post-test calculations are summarized in Table 5-3. Thermal conditions in the CSTF vessel were supplied in tabular digital form as described in Section 4.4 and Appendix C.

Numerical values of code input parameters that were used in the five code cases were submitted by each participant and are listed in Tables 5-4 through 5-6. In some instances, the input parameters listed in Tables 5-4 through 5-6 are equivalent ones derived from the actual ones to provide a common format.

Input parameters related to the aerosol source are listed in Table 5-4. Code input values are listed for material density, source size, geometric standard deviation, and particle source rate. Inspection of the listed inputs indicate that all five code cases used identical or nearly identical numerical values for parameters related to the aerosol source.

Code input parameters that are related to the behavior of agglomerated particles are listed in Table 5-5. Because of differences in modeling, the same input parameters for different codes may not infer the same calculations. The parameters listed in Table 5-6 are defined as follows.

TABLE 5-3

TEST CONDITIONS TRANSMITTED TO CODE USERS
FOR USE IN MAKING BLIND POST-TEST CALCULATIONS
FOR TEST AB7

Parameter	Measured Or Estimated Value
NaOH Aerosol Source	
Chemical form	NaOH
Material density (g/cm^3)	2.13
Mass ratio, NaOH to Na	1.74
Initial concentration	0
Start time for aerosol release (s)	0
Stop time (s)	600
Release rate (g NaOH/s)	5.03
Total NaOH release (g)	3018
Source 50% diameter (μm)	0.5
Source geometric standard deviation	2.0
NaI Aerosol Source	
Chemical form	NaI
Material density (g/cm^3)	3.67
Initial concentration	0
Start time for aerosol release (s)	600
Stop time (s)	240
Release rate (g NaI/s)	0.197
Total NaI aerosol released (g)	354.6
Source 50% diameter (um)	0.54
Source geometric standard deviation	1.55
General	
Leakage rate (%/day, constant)	1.0
Settling area (cm^2)	8.82×10^5
Plating area (cm^2)	7.52×10^6
Volume (cm^3)	8.52×10^8
Initial temperature (°C)	27.0
Initial pressure (kPa absolute)	120
Initial dewpoint (°C)	1.5
Temperature of containment atmosphere (°C)	27.0
Temperature of containment vessel (°C)	24.0

TABLE 5-4

CODE INPUT PARAMETERS RELATED TO THE AEROSOL SOURCE

Code Case No.	Code	Material Density (g/cm^3)		Source d_{50} (μm)		Source σ_g		Source Rate (No./s cm^3)		Source Rate ($g/s\ m^3$)	
		NaOH	NaI	NaOH	NaI	NaOH	NaI	NaOH	NaI	NaOH	NaI
1	HAA-3C	2.13	2.13	0.5	0.5	2.0	2.0	3.68(5)[a]	1.81(3)	--	--
2	HAA-4	2.13	3.67	0.5	0.54	2.0	1.55	---	---	5.90(-3)	2.31(-4)
3	HAARM-3	2.13	2.13	0.5	0.5	2.0	2.0	3.68(5)	1.82(3)	---	---
4	CONTAIN	2.13	2.13	0.5	0.54	2.0	1.55	---	---	5.90(-3)	2.31(-4)
5	QUICKM	2.13	3.67	0.5	0.544	2.0	1.55	---	---	5.9(-3)	2.31(-4)

(a) Numbers in parenthesis are exponents of 10.

TABLE 5-5

CODE INPUT PARAMETERS RELATED TO AGGLOMERATE BEHAVIOR

Code Case No.	Code	Chi	Gamma	Alpha	Epsilon	Non-Stoksien Correction
1	HAA-3C	--	--	0.2	10.0	Klyachko
2	HAA-4	1.2	5.0	--	0.06[(a)]	Klyachko
3	HAARM-3	1.3	3.0	--	10.0	Klyachko
4	CONTAIN	1.5	2.25	--	(b)	None
5	QUICK	1.3	2.5	--	(b)	(c)

(a) Collision efficiency for inertial agglomeration.
(b) Internally coded Fuchs approximation, $1.5\ [r_j/(r_j + r_i)]^2$.
(c) Empirical friction factor correlation.

TABLE 5-6

CODE INPUT PARAMETERS RELATED TO ATMOSPHERE TEMPERATURES AND WALL DEPOSITION

Code Case No.	Code	Atm Temp Variable or Constant	Diffusion Delta (m)	Wall Gradient (°K/m)	Gas/Particle Conductivity Ratio	Turbulent Dissipation Constant (m^2/s^3)
1	HAA-3C	Variable	2.5(-7)[a]	--	--	--
2	HAA-4	Variable	1.5(-4)	Variable[b]	5.0(-2)	0
3	HAARM-3	Variable	2.5(-7)	Variable	1.0(-1)	0
4	CONTAIN	Variable	1.0(-5)	5.0(2)[c]	5.0(-2)	1.0(-3)
5	QUICKM	Constant	1.0(-4)	0	0	0

(a) Numbers in parenthesis are exponents of 10.
(b) Atmosphere temperature 1 cm from wall minus surface temperature divided by constant 0.003 m thermophoretic plating boundary layer.
(c) During sodium pool fire only.

CHI

CHI is a dynamic shape factor that allows the particle drag to be related to Stokes' law for spheres. CHI is a denominator factor in Stokes' law, and because non-spherical agglomerates settle more slowly than spherical agglomerates, CHI is equal to or larger than unity.

GAMMA

GAMMA is a factor which relates the effective collision radius of a particle to the actual particle radius. Because non-spherical agglomerates are able to collide more effectively, GAMMA is equal to or larger than unity.

ALPHA

ALPHA is a density modification factor used to account for the reduced settling velocity of agglomerates compared to solid spheres. Generally, it is a numerator factor in Stokes' law and its value is less than or equal to unity.

EPSILON

EPSILON is a gravitational collision efficiency used in the HAA codes. It relates to the fraction of particles in a swept volume that is captured by a falling particle. A value of 10 was inadvertently used in the HAA-3 and HAARM-3 codes, rather than a value of 1.0 as was done in previous ABCOVE tests. Post-test calculations using a value of 1.0 gave essentially the same results for the AB7 conditions, so the original "blind" calculation is reported and discussed in this document.

KLYACHKO

The KLYACHKO parameter allows deviations from Stokes' drag that occur at high Reynolds numbers to be taken into account. This factor becomes important for particles larger than approximately 100 μm.

The numerical values for aerosol parameters listed in Table 5-5 were not specified by the test performer. They were selected by the code user, based on the user's experience. Most users selected the parameters on the basis of code fits with earlier large-scale sodium fire aerosol tests in the CSTF.

Code input parameters related to atmosphere temperatures, diffusional deposition, and thermophoretic plating are summarized in Table 5-6. Inspection of the data of Table 5-6 shows that the variables selected by the users covered a significant numerical range. Diffusional plating boundary layer thickness was assigned values from 2.5×10^{-7} m to 1.5×10^{-4} m. The small value for delta used in the HAA-3 code results from the assumption that all plateout is caused by diffusion, and delta is assigned an empirical value to match previous experiments. The wall temperature gradient values ranged from zero to 500°K/m. Some of the codes used variable gradients. The assigned values of the ratio of gas to particle thermal conductivity varied from 0.005 to 0.1, a factor of 20.

5.3 BLIND POST-TEST CODE PREDICTIONS

Blind post-test predictions submitted by each participant are tabulated in Appendix E. These predictions were made with the benefit of test data on thermal conditions and aerosol mass generation rate. No information or aerosol behavior per se was made available, hence the predictions were "blind" to aerosol behavior data.

5.4 COMPARISON OF CODE PREDICTIONS WITH EACH OTHER AND WITH TEST MEASUREMENTS

Code predictions of key aerosol behavior parameters are compared with each other and with experimental measurements in the following sections by listing numerical values of parameters at 12 discrete times. Tables of code predictions and experimental results are provided in Appendices F through M.

As tools for evaluating the accuracy of individual code case predictions, two indices are listed in the tables in Appendices F through M for each code case. The first is the ratio of the individual code prediction to the average of all codes. This index has only marginal value in assessing a code, but does show how it relates to the other code cases. The second (and more important) index is the ratio of the individual code prediction to the experimental value. It should be noted that experimental measurements were not always made at the precise times reported by the code users. In these instances, the experimental values listed in the tables were obtained by plotting the experimental data, drawing a smooth curve through the data points and interpolating. This index is useful for comparing the code prediction with the experimental measurement. Comparisons are made separately for NaOH and NaI.

An effort is made to quantify the overall performance of each code case by tabulating the number of times the code predicted the experimental value within specified limits.

5.4.1 Suspended Mass Concentration

5.4.1.1 Suspended NaOH Concentration

The suspended mass concentration of NaOH aerosol predicted by the five code cases are plotted in Figure 5-1 for the full time period of the experiment. The experimental measurements are also plotted for comparison with the code predictions. Several observations are apparent from Figure 5-1. First, all five of the codes were in good agreement with experimental results during the NaOH source release period and for approximately 1200 s afterwards. This fact is shown more clearly in Figure 5-2, where the concentrations during the source release period are plotted on an expanded scale for easier visualization. The codes ranged from 3% low to 30% higher than the experimental value during this period.

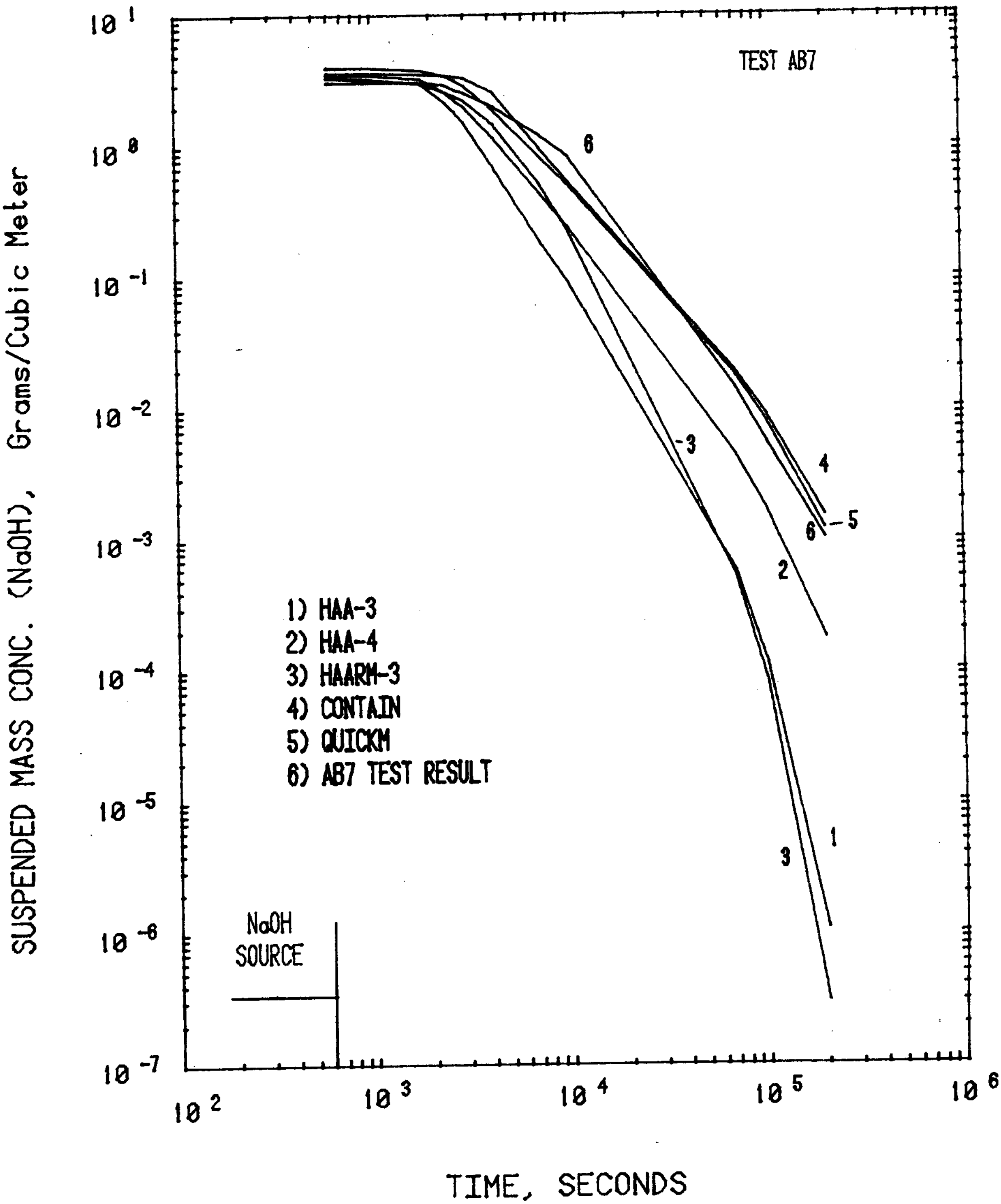

FIGURE 5-1. Plot of Code Predictions and Test Results for NaOH Suspended Mass Concentration.

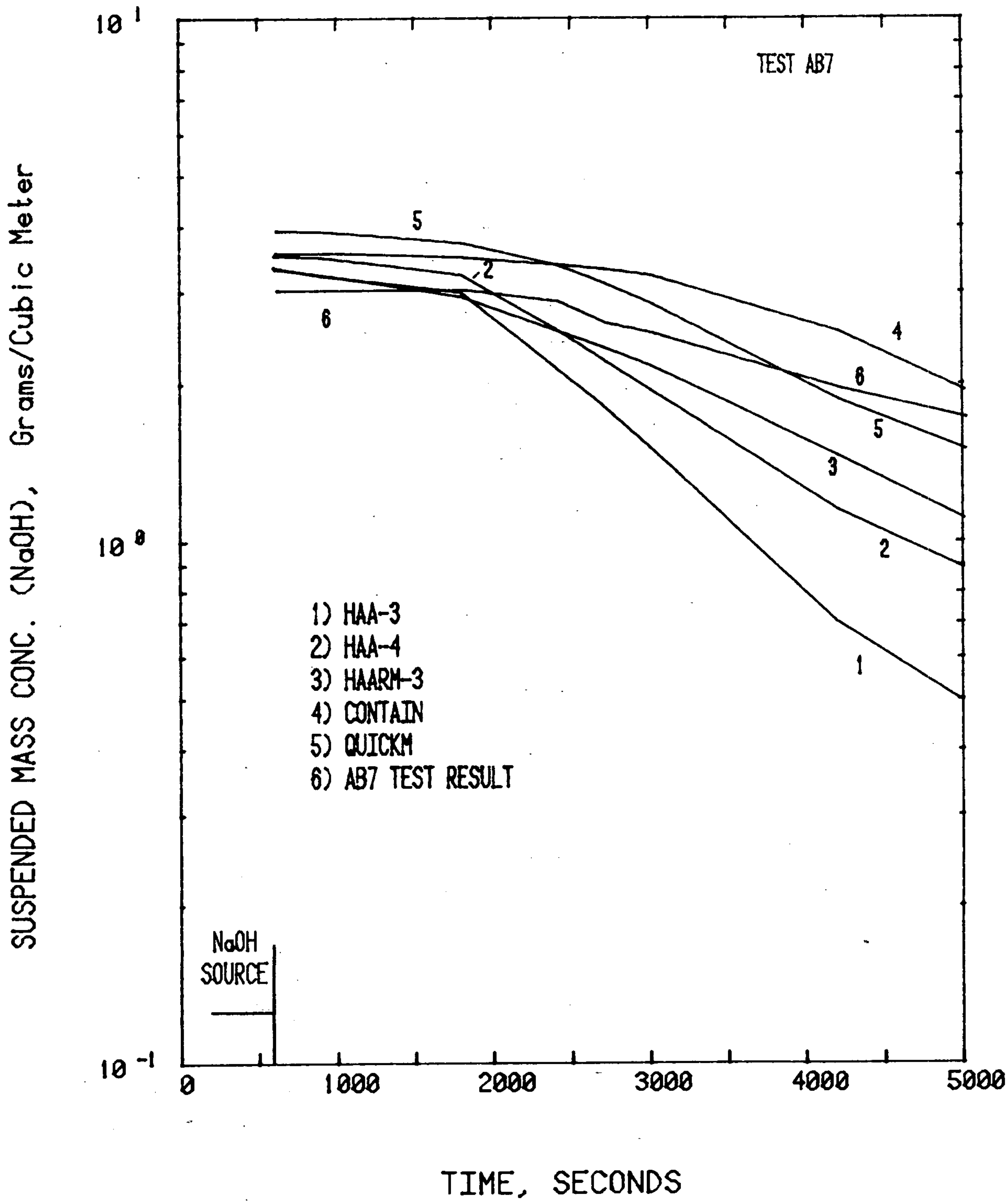

FIGURE 5-2. Plot of Code Predictions of Suspended NaOH Concentration at Early Times.

Secondly, after 1800 s (1200 s after end of source) the curves for the various codes begin to diverge. The three log-normal codes underpredicted the test result by ever-increasing margins. HAA-3 and HAARM-3 were low by a factor of approximately 50 at 10^5 s, while HAA-4 was considerably better, but was still low by a factor of 3 at 10^5 s.

A third observation shown by Figure 5-1 is that the two discrete codes predicted the experimental result quite closely throughout the entire test period. QUICKM and CONTAIN gave very similar results, being within 10% of each other at all times, and never more than 50% different than the experimental measurement. This is excellent agreement for blind calculations. Detailed digital information on the suspended NaOH mass concentration predicted for the seven code cases is given in Appendix F. Each table in Appendix F relates to one of the 12 specified code reporting times. The arithmetic average values for the code predictions are shown in the tables. Experimental measurements for suspended mass concentration were extracted from the data presented in Section 4.6 and listed as a footnote in the Appendix F tables. The ratios of the individual code predictions to the experimental result are given in the last column of the Appendix F tables.

The number of times that each code case predicted the experimental value within a factor of two is tabulated in Table 5-7. The factor of two would not be inferred as a universally accepted criterion for adequate validation, but is believed to provide a reasonable basis for the present study. It is also consistent with the similar comparisons made in earlier ABCOVE test reports[1, 2].

5.4.1.2 Suspended NaI Concentration

The suspended mass concentration of NaI aerosol predicted by the 5 code cases are plotted in Figure 5-3 for the full time period of the experiment. The experimental measurements are also plotted for comparison. Figure 5-3 shows that good agreement with experimental measurements was obtained by all the codes during the NaI source release period, ranging from 30% low (HAA-3) to 5% high (QUICKM) at the end of the source period. The data for early times are plotted in Figure 5-4 on an expanded time scale.

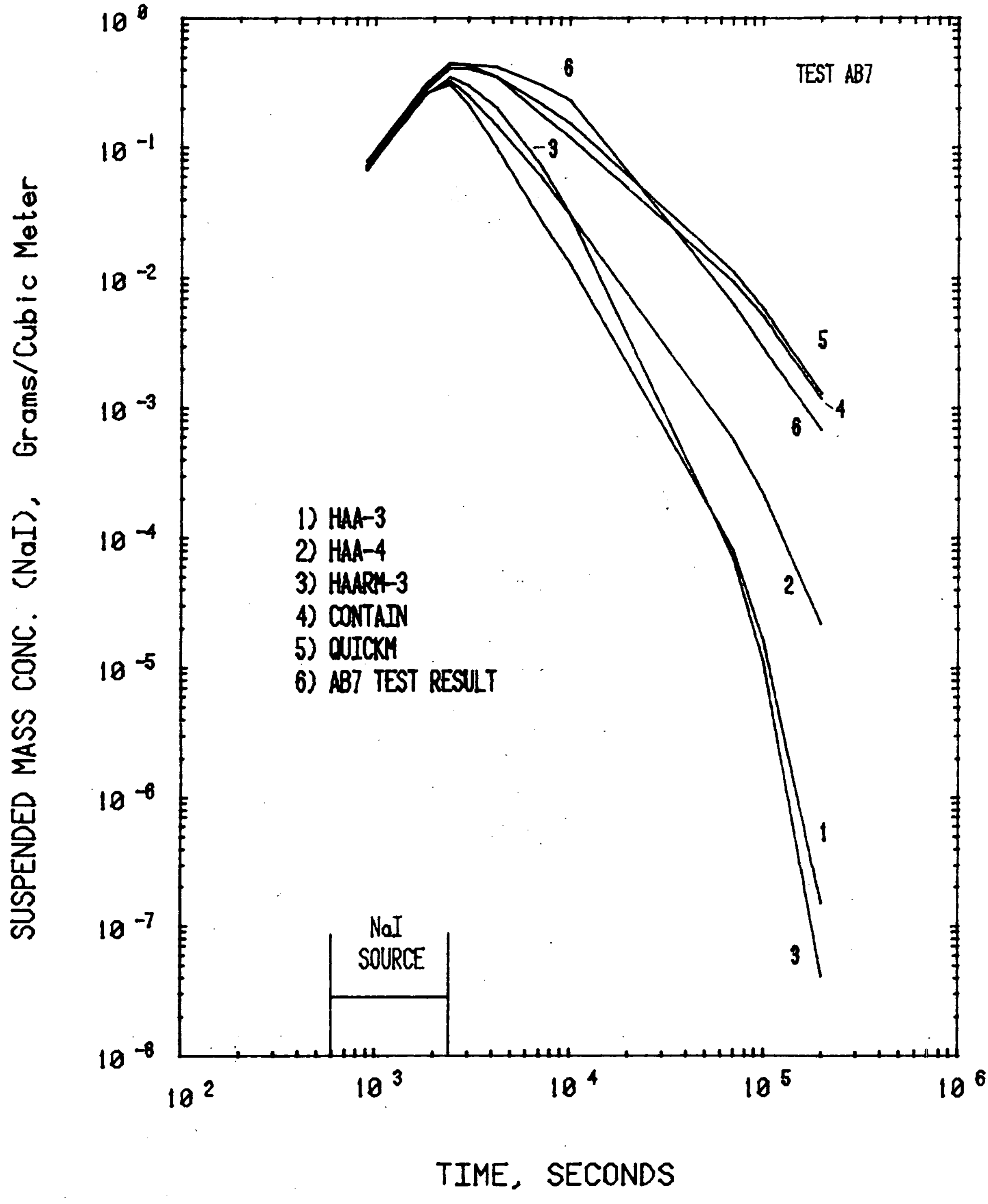

FIGURE 5-3. Plot of Code Predictions and Test Results for NaI Suspended Mass Concentration.

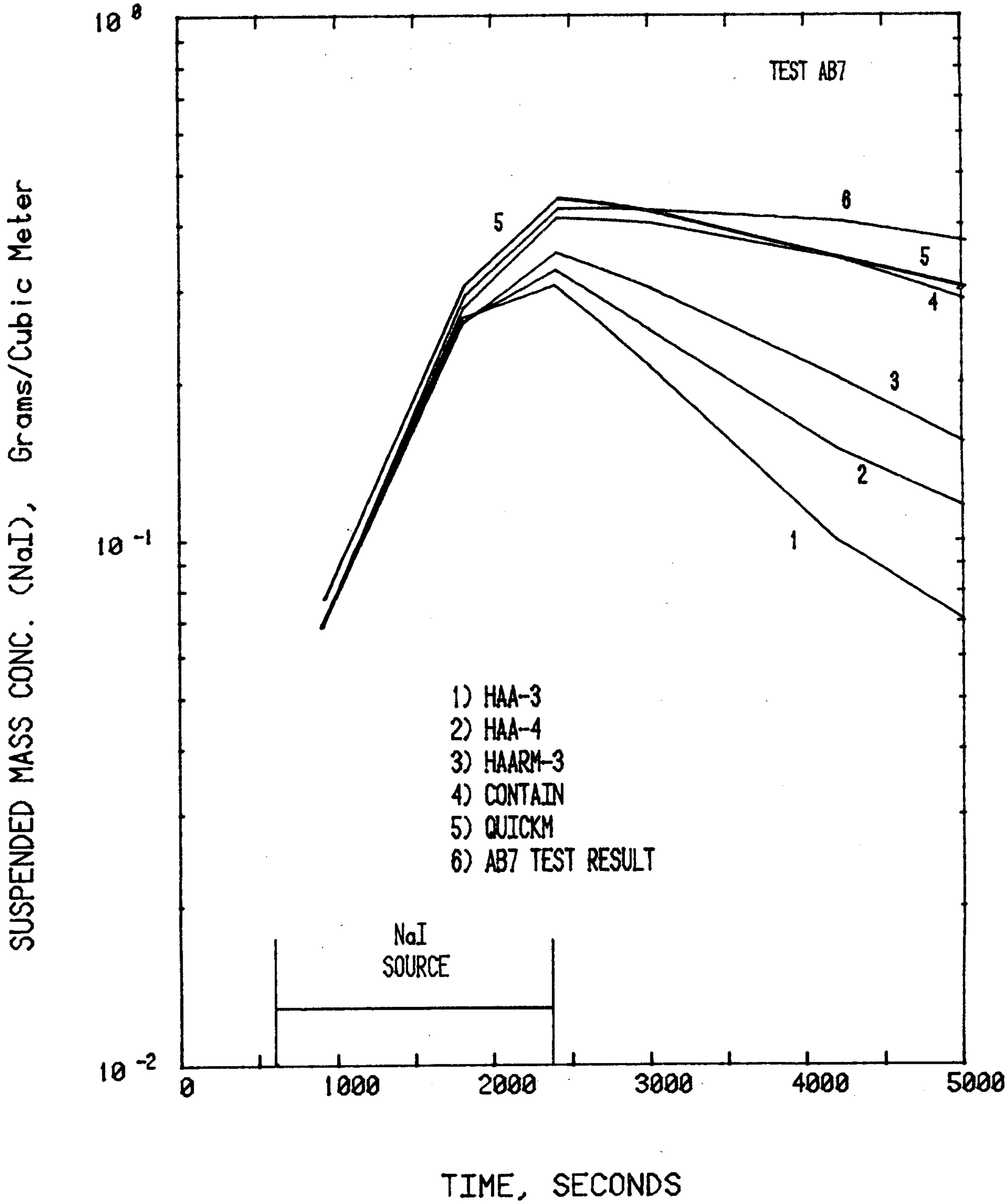

FIGURE 5-4. Plot of Code Predictions of Suspended NaI Concentration at Early Times.

After the end of the NaI source period, the codes diverged, with the discrete code following the test measurement curve quite well, and the log-normal codes underpredicting at ever increasing margins with time. As was the case for NaOH, the QUICKM and CONTAIN codes gave nearly identical results for NaI concentration. They were within 5% at end of source, 40% low at 10^5 s, and 100% high at 10^5 s. These are excellent results for blind calculations.

The log-normal codes underpredicted the test result by only 25% at the end of the NaI source (2400 s) but were approximately a factor of 10 low at 10^4 s. At 10^5 s, the HAA-4 code underpredicted the test value by a factor of 12, while the HAA-3 and HAARM-3 codes underpredicted by a factor of 200.

Detailed digital information on the suspended NaI concentration predicted for the seven code cases is given in Appendix F.

The number of times that each code case predicted the experimental value within a factor of two is tabulated in Table 5-7.

5.4.2 Aerodynamic Mass Median Diameter

5.4.2.1 AMMD of NaOH Aerosol

The aerodynamic mass median diameters (AMMD), based on NaOH analysis, predicted by the codes are plotted in Figure 5-5. All of the codes underpredicted the test measurement during the source release period. For 1500 s to 4200 s, all of the codes overpredicted the test measurement, and all codes except QUICKM continued to overpredict for several hours. At long times, all codes were in good or fair agreement with the test results.

Comparisons of NaOH size distributions predicted by the codes with cascade impactor measurements are provided as log-probability plots in Figures 5-6 and 5-7 for 1800 s and 4200 s, respectively. To enable a direct comparison of codes with test data, the code data are plotted as aerodynamic diameter. Cascade impactor samples were not taken at the exact time that the codes

TABLE 5-7

CODE CASES WITH CORRECT PREDICTIONS FOR SUSPENDED CONCENTRATION

Time (s)	NaOH[a]					NaI[a]				
	1[b]	2	3	4	5	1	2	3	4	5
6.0(2)[c]	Y	Y	Y	Y	Y					
9.0(2)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
1.8(3)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
2.4(3)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
2.7(3)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
3.0(3)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
4.2(3)	N	Y	Y	Y	Y	N	N	Y	Y	Y
7.2(3)	N	N	N	Y	Y	N	N	N	Y	Y
1.0(4)	N	N	N	Y	Y	N	N	N	Y	Y
7.0(4)	N	N	N	Y	Y	N	N	N	Y	Y
1.0(5)	N	N	N	Y	Y	N	N	N	Y	Y
2.0(5)	N	N	N	Y	Y	N	N	N	Y	Y
Total Correct	6	7	7	12	12	5	5	6	12	12

(a) Y indicates code predicted test measurement within a factor of two; N indicates code predicted greater than factor of two from measured value.
(b) Code case: Refer to Table 5-2 for identification.
(c) Number in parenthesis are exponents of ten.

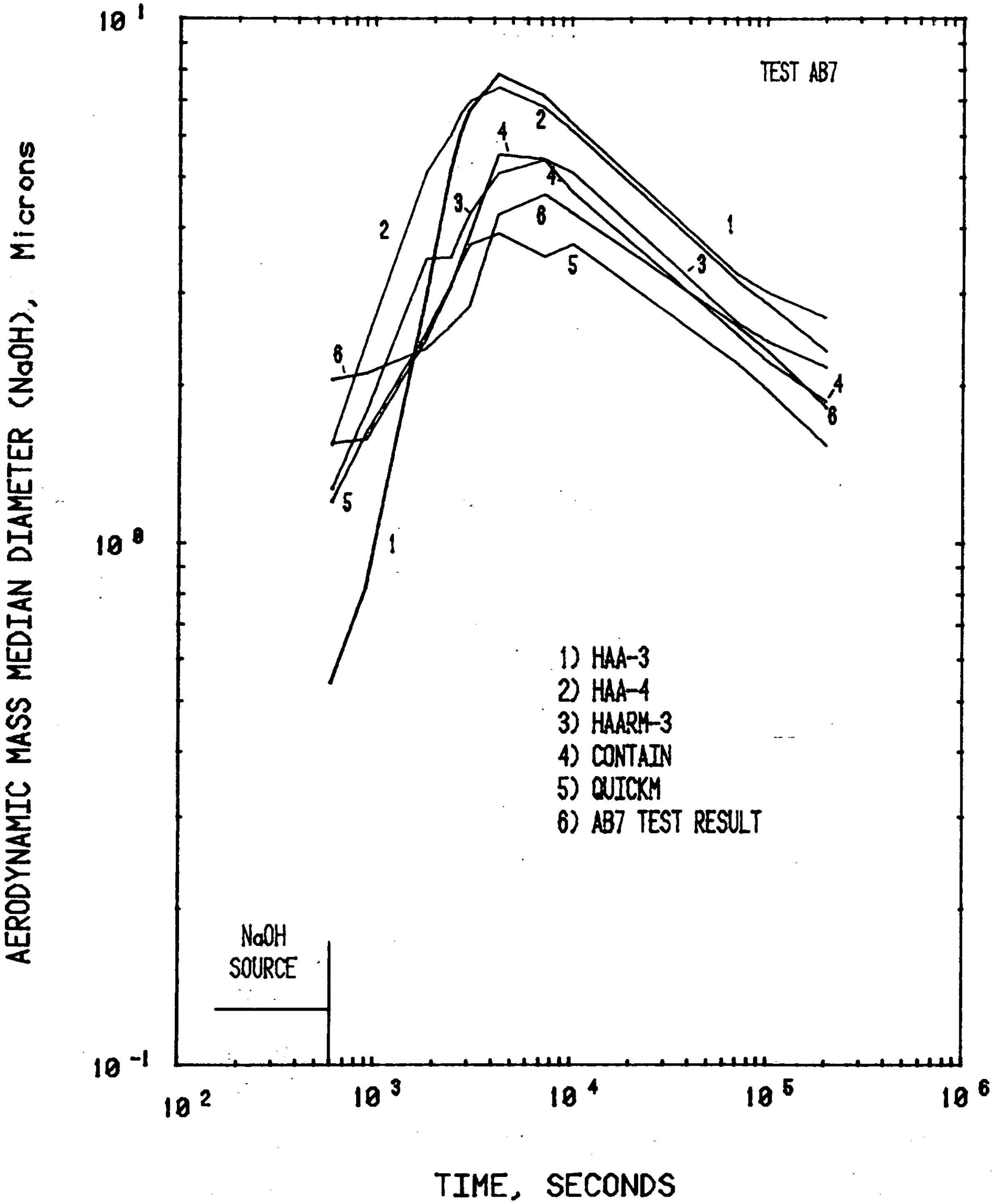

FIGURE 5-5. Plot of Code Predictions and Test Results of AMMD for NaOH.

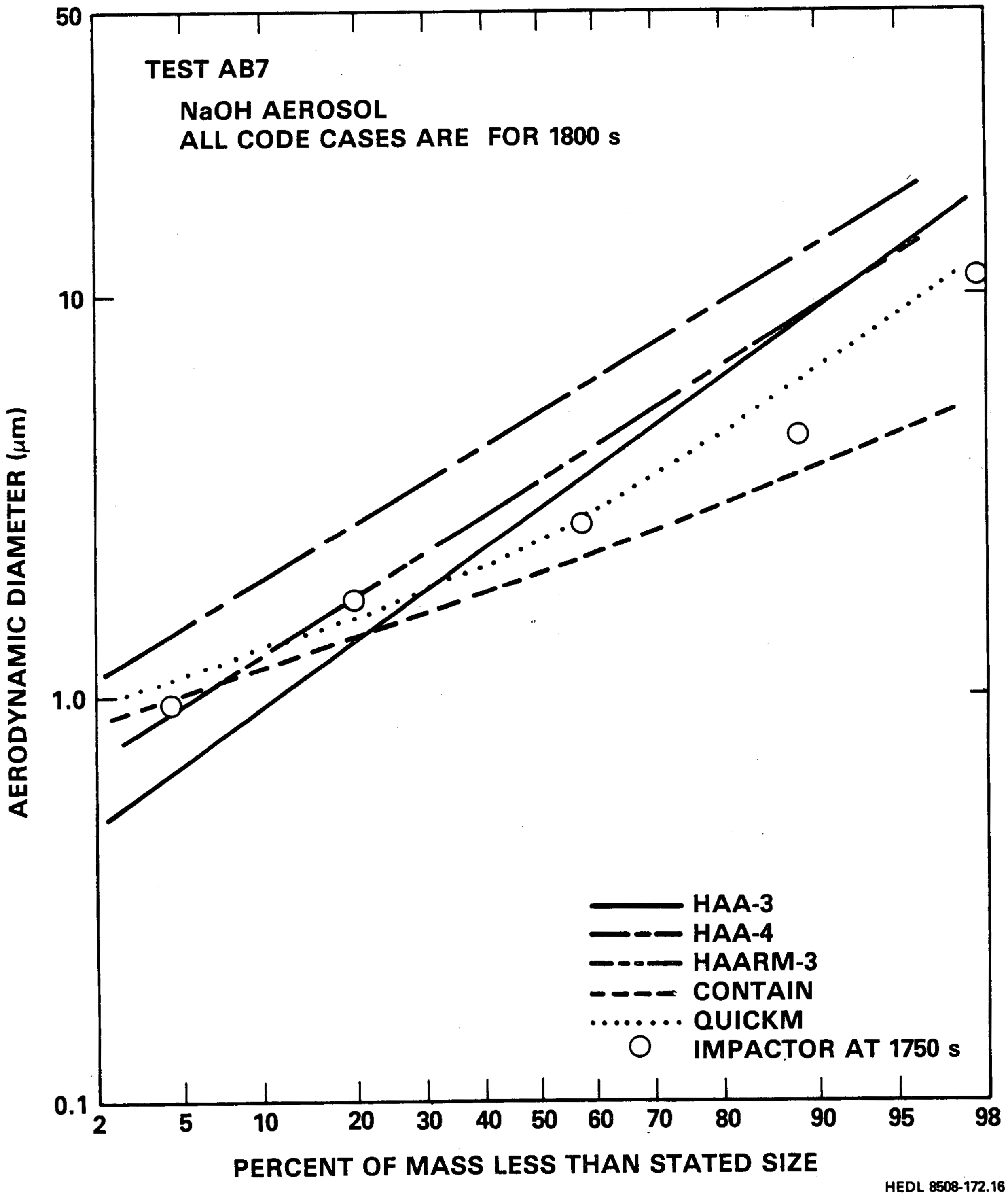

FIGURE 5-6. Log-Probability Plot of NaOH Aerosol Size Distribution at 1800 s.

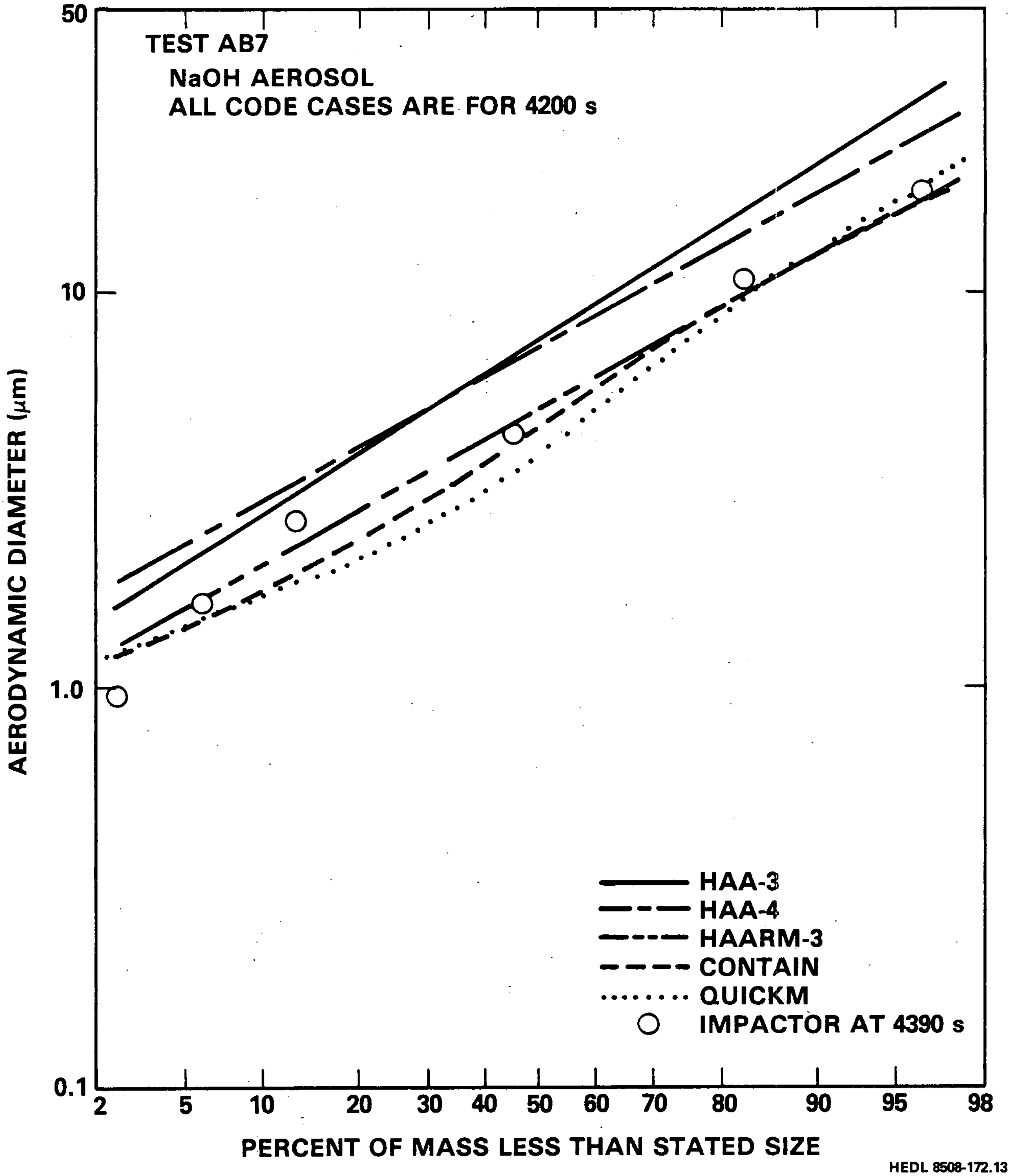

FIGURE 5-7. Log-Probability Plot of NaOH Aerosol Size Disbribution at 4200 s.

reported, so the impactor sample taken nearest to the code reporting time was used. Figures 5-6 and 5-7 show that the discrete codes (CONTAIN and QUICKM) agreed well with the cascade impactor data. The log-normal codes generally overpredicted, but were better at 4200 s than at the earlier time.

All of the codes predicted an increase in the AMMD, reaching a maximum at approximately one hour after the end of the NaOH source release period, after which the AMMD decreased slowly with time. The test measurements exhibited a similar trend.

Detailed digital information on the NaOH AMMD predicted by each code case is presented in Appendix G for the 12 specified reporting times. The AMMD for individual aerosol species was not reported by the CONTAIN and QUICKM codes. The values for CONTAIN and QUICKM were calculated by the test performer by plotting the reported size distribution on log-probability paper. The mass median diameter (MMD) obtained from this plot was converted to AMMD by the use of Equation (10).

$$\text{AMMD} = \text{MMD}\left(\frac{\rho}{\chi}\right)^{0.5} \tag{10}$$

where:

ρ = material density of aerosol particle

χ = dynamic shape factor

The experimental values listed as footnotes in Appendix G tables were obtained from cascade impactor measurements reported in Section 4.7.1. Since the impactor measurements were not made precisely at the times reported by the computer codes, the measured values were extracted from Figure 4-6, which is a plot of experimental AMMD as a function of time.

The number of times that individual code cases predicted the experimental value within a factor of 1.5 are shown in Table 5-8. Note that a factor of 1.5 is used for evaluating particle size parameters, rather than a factor of two as is done for other parameters. Particle sizes and standard deviations do not vary over as wide a range as other parameters and, for this reason, the error band was assigned a value of 1.5, rather than 2.0.

5.4.2.2 AMMD of NaI Aerosol

The AMMD based on NaI predicted by the codes are plotted in Figure 5-8. The figure clearly shows that the log-normal codes greatly overpredicted the AMMD as a group, while the discrete codes were in reasonably good agreement with the test measurement.

Comparison of NaI size distributions predicted by the codes with cascade impactor measurements are provided as log-probability plots in Figures 5-9 and 5-10 for 1800 s and 4200 s, respectively. The data of Figure 5-9 is for a time during the NaI source release period. It shows that the discrete codes gave good agreement with the cascade impactor measurements, while the log-normal, uniform co-agglomeration codes greatly overpredicted the NaI AMMD. This is strong evidence that the aerosol was not uniformly co-agglomerated during the source release period. The data shown in Figure 5-10 are for a time well after the end of the NaI source, and thus should show the extent of co-agglomeration after 1800 s without a source of small particles. The figure shows that the discrete codes predicted the experimental measurement very well at the large end of the size spectrum, but only fair agreement is noted for small particles. The log-normal code HAA-4 was in reasonably good agreement, though slightly high, over the entire spectrum. HAA-3 and HAARM-3 overpredicted significantly over the entire spectrum.

TABLE 5-8

CODE CASES WITH CORRECT PREDICTIONS FOR AMMD

Time (s)	NaOH[a]					NaI[a]				
	1[b]	2	3	4	5	1	2	3	4	5
6.0(2)	N	Y	Y	Y	N	-	-	-	-	-
9.0(2)	N	Y	Y	Y	Y	Y	N	N	Y	Y
1.8(3)	Y	N	Y	Y	Y	N	N	N	Y	Y
2.4(3)	N	N	Y	Y	Y	N	N	N	Y	Y
2.7(3)	N	N	Y	Y	Y	N	N	N	Y	Y
3.0(3)	N	N	Y	Y	Y	N	N	N	Y	Y
4.2(3)	N	N	Y	Y	Y	N	N	Y	Y	Y
7.2(3)	Y	Y	Y	Y	Y	N	N	Y	Y	Y
1.0(4)	Y	Y	Y	Y	Y	N	N	Y	Y	Y
7.0(4)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
1.0(5)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
2.0(5)	Y	Y	Y	Y	Y	N	N	Y	Y	Y
Total Correct	6	7	12	12	11	3	2	6	11	11

(a) Y indicates code predicted within a factor OF 1.5, N indicates code predicted greater than factor of 1.5 from measured value.
A dash indicates that no predictions were made for that time.
(b) Code case: Refer to Table 5-2 for identification.

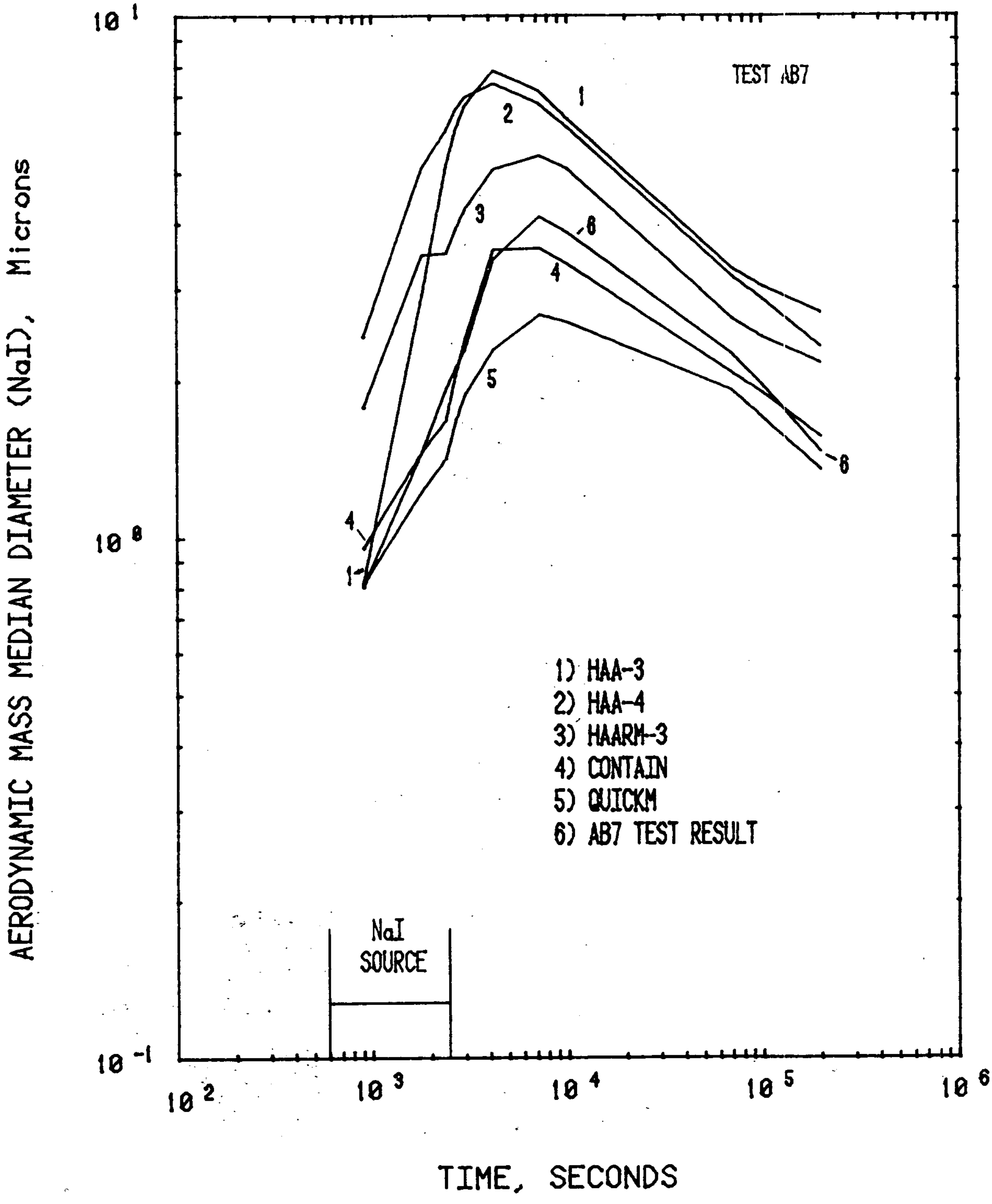

FIGURE 5-8. Plot of Code Predictions of AMMD for NaI.

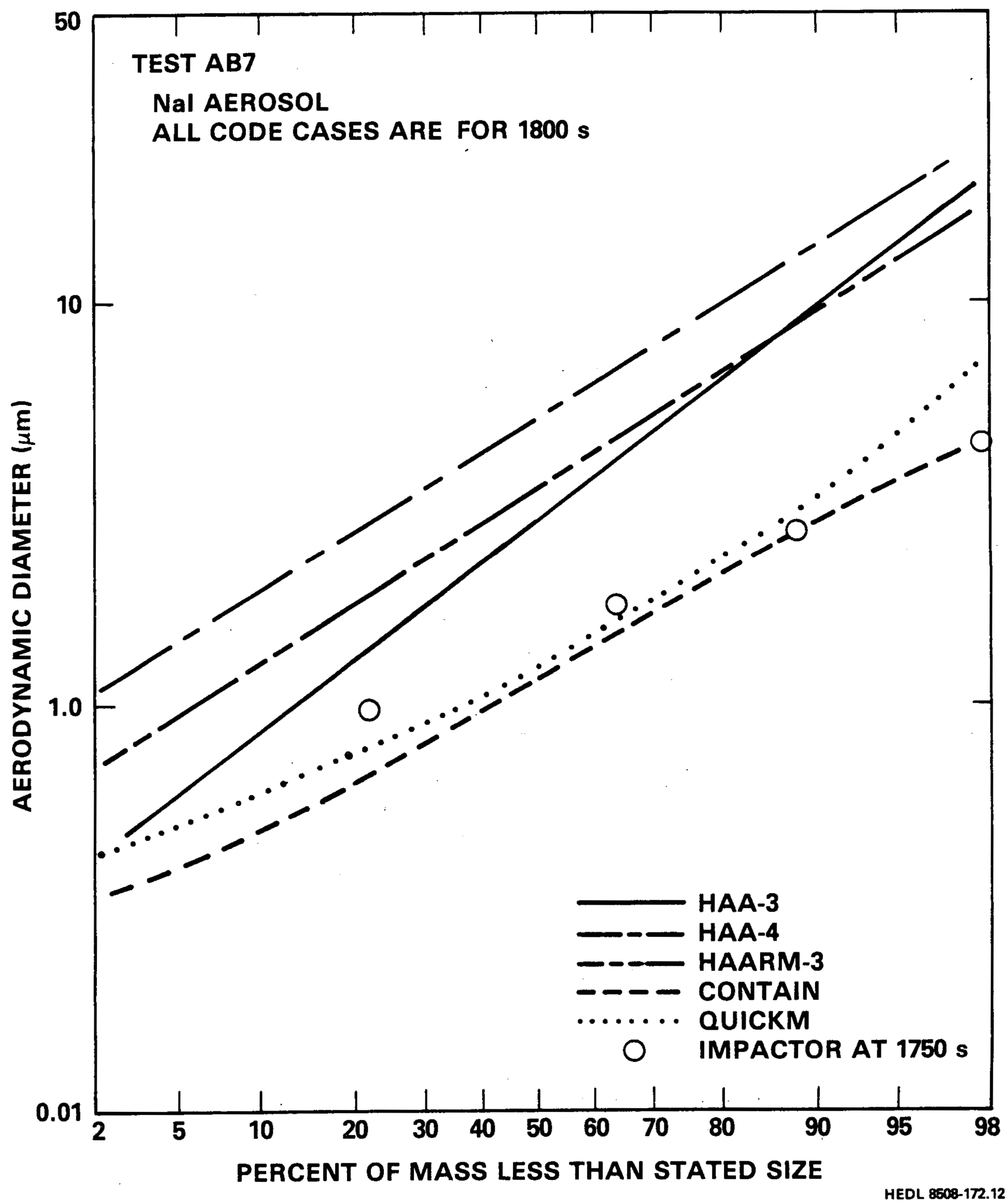

FIGURE 5-9. Log-Probability Plot of NaI Aerosol Size Distribution at 1800 s.

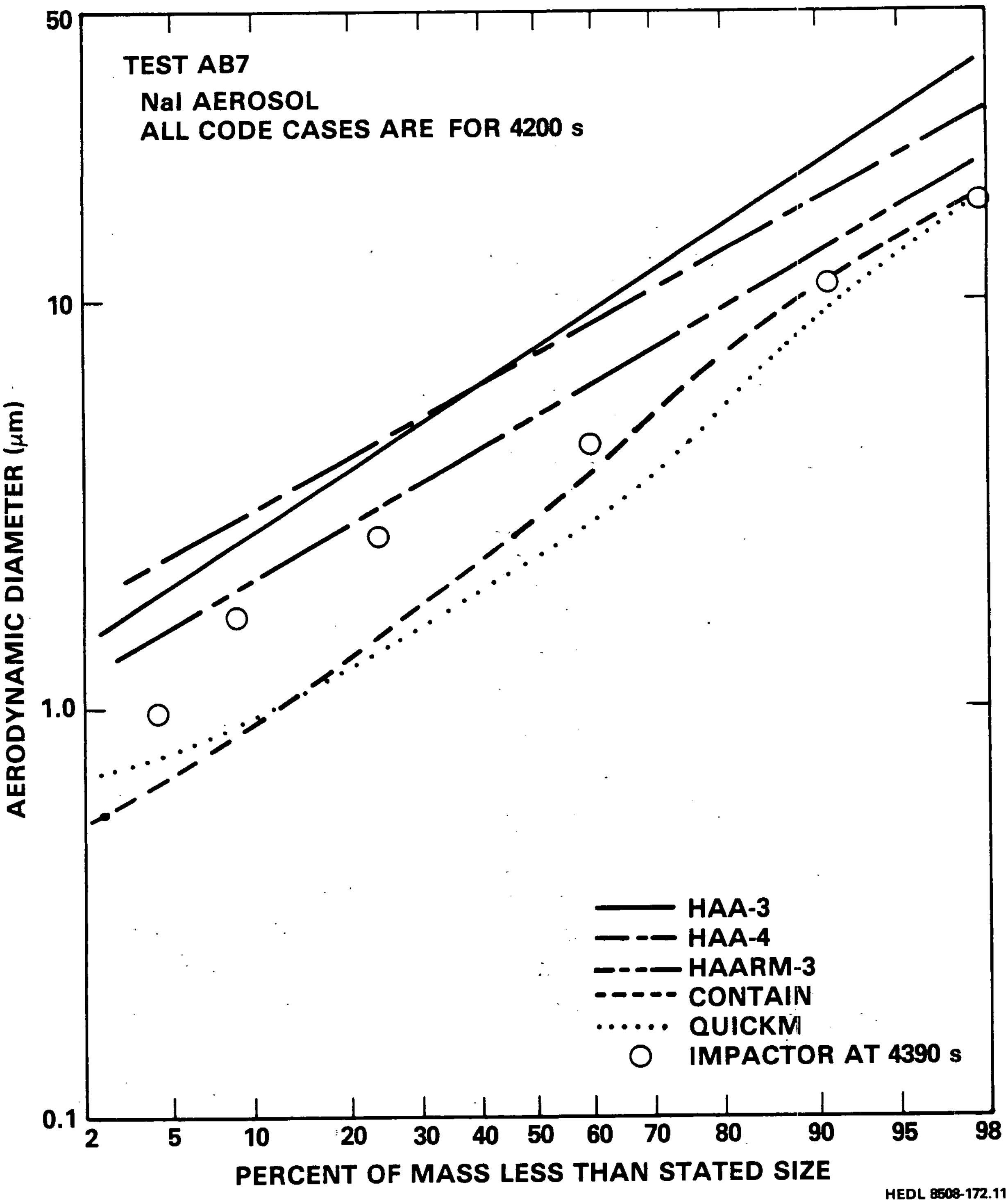

FIGURE 5-10. Log-Probability Plot of NaI Aerosol Size Distribution at 4200 s.

The data on AMMD and size distribution lead to the conclusion that mixed species aerosols are not uniformly co-agglomerated and that the discrete, uniform bin codes are capable of faithfully following the co-agglomeration process.

Detailed digital information on the NaI AMMD predicted by the codes is presented in Appendix G.

The number of times that each code case predicted the experimental value of NaI AMMD within a factor of 1.5 is tabulated in Table 5-8.

5.4.3 Geometric Standard Deviation

5.4.3.1 Geometric Standard Deviation for NaOH Aerosol

The code predictions for geometric standard deviation of the NaOH aerosol, σ_g, are plotted in Figure 5-11. All of the codes except CONTAIN over-predicted σ_g during the source release period, compared to cascade impactor test measurements. All codes predicted an increase in σ_g after the end of the NaOH source period, reaching maxima at approximately the end of the NaI source period. The NaI aerosol probably did not affect the NaOH size distribution significantly, because the NaI maximum suspended concentration was only 10% of the NaOH concentration at that time.

Neither the CONTAIN or QUICKM code reported the value of σ_g for the individual aerosol species. Therefore, the test performer calculated the individual σ_g by plotting the reported size distribution for each species on log-probability paper and using the relationship defined by Equation (11) to determine an approximate value for σ_g.

$$\sigma_g = \frac{84.1\% \text{ size}}{50\% \text{ size}} \qquad (11)$$

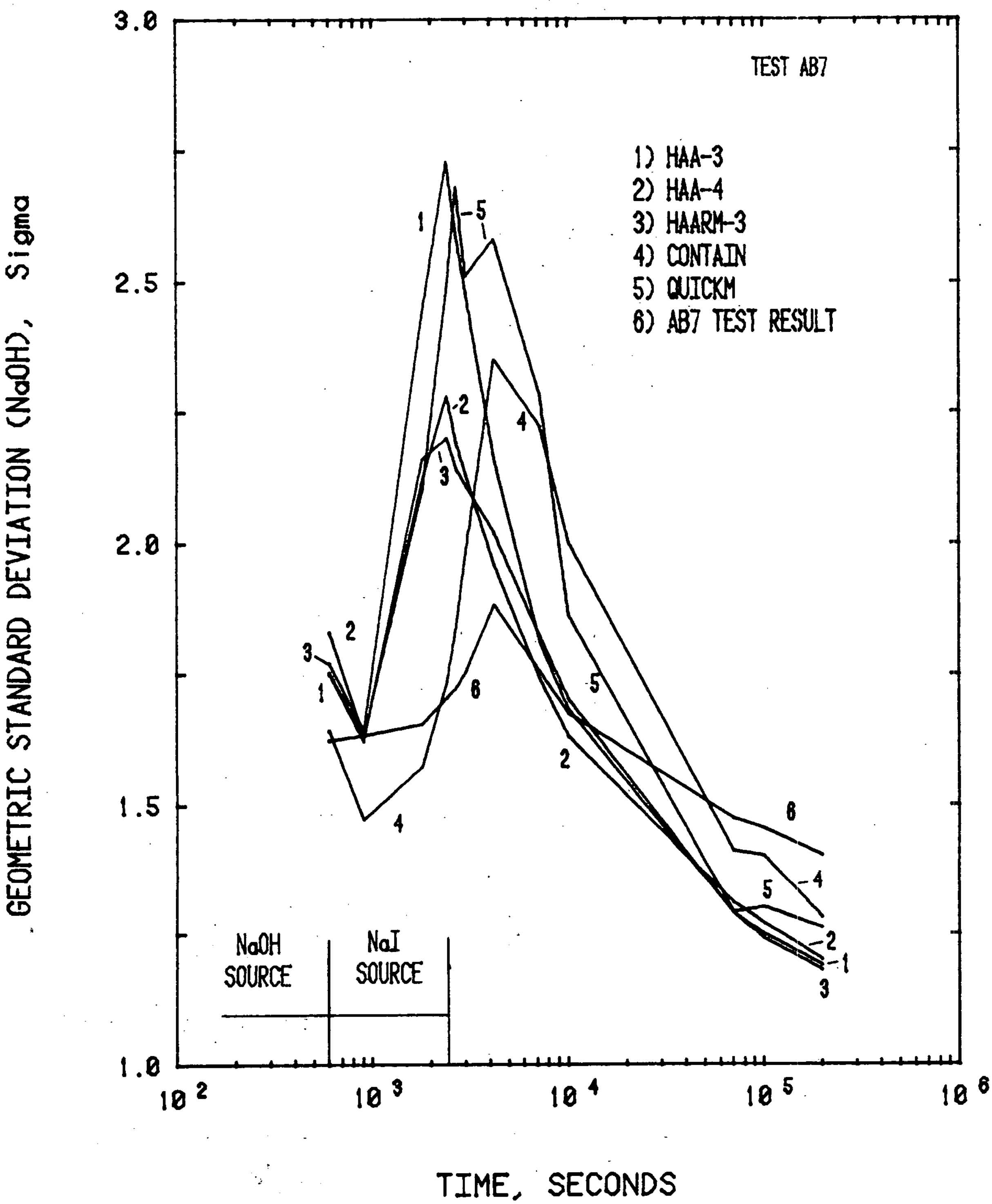

FIGURE 5-11. Plot of Code Predictions of Geometric Standard Deviation for NaOH.

Figure 5-11 shows that after the maxima, the code-predicted values quickly decreased to the experimental values and all codes underpredicted the experimental measurement at times greater than 50000 s.

Detailed digital information on σ_g predicted by each code case is presented in Appendix H for the 12 reporting times. The experimental values listed in the tables were obtained from cascade impactor measurements, as reported in Section 4.7.1. Since the experimental measurements were not made at precisely the times reported for the computer codes, the measured values for σ_g were plotted as a function of time in Figure 4-7 and the experimental values were picked from this curve for the desired times.

The number of times that individual code cases predicted the experimental value within a factor of 1.5 is shown in Table 5-9. All five of the codes predicted σ_g within a factor of 1.5 at all times except HAA-3, which predicted 11 times out of 12 within the 1.5 accuracy factor.

5.4.3.2 Geometric Standard Deviation for NaI Aerosol

The code predictions for geometric standard deviation of the aerosol based on NaI content are plotted as a function of time in Figure 5-12, along with the experimental results based on cascade impactor measurements. The figure shows that all the codes overpredicted the value of σ_g during the NaI source release period, but were within a factor of 1.5 of the experimental measurement. This fact is also shown in Figure 5-9, where the distributions are presented in a log-probability plot. After the end of the NaI source, the log-normal code predictions decreased to that of the experimental measurement at 10^4s, then underpredicted for the duration of the test. The two discrete codes overpredicted the test measurement until approximately 10^5 s.

Detailed digital information on σ_g predicted by each code is presented in Appendix H. The number of times that each code predicted the experimental result within a factor of 1.5 is shown in Table 5-9.

TABLE 5-9

CODE CASES WITH CORRECT PREDICTIONS OF GEOMETRIC STANDARD DEVIATION

Time (s)	NaOH[a]					NaI[a]				
	1[b]	2	3	4	5	1	2	3	4	5
6.0(2)	Y	Y	Y	Y	Y	-	-	-	-	-
9.0(2)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
1.8(3)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
2.4(3)	N	Y	Y	Y	Y	N	Y	Y	Y	Y
2.7(3)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
3.0(3)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
4.2(3)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
7.2(3)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
1.0(4)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
7.0(4)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
1.0(5)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
2.0(5)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Total Correct	11	12	12	12	12	10	11	11	11	11

(a) Y indicates code predicted within a factor of 1.5 for the indicated time. N indicates code predicted greater than a factor of 1.5 from measured value.
A dash indicates that no predictions were made for that time.

(b) Code case: Refer to Table 5-2 for identification.

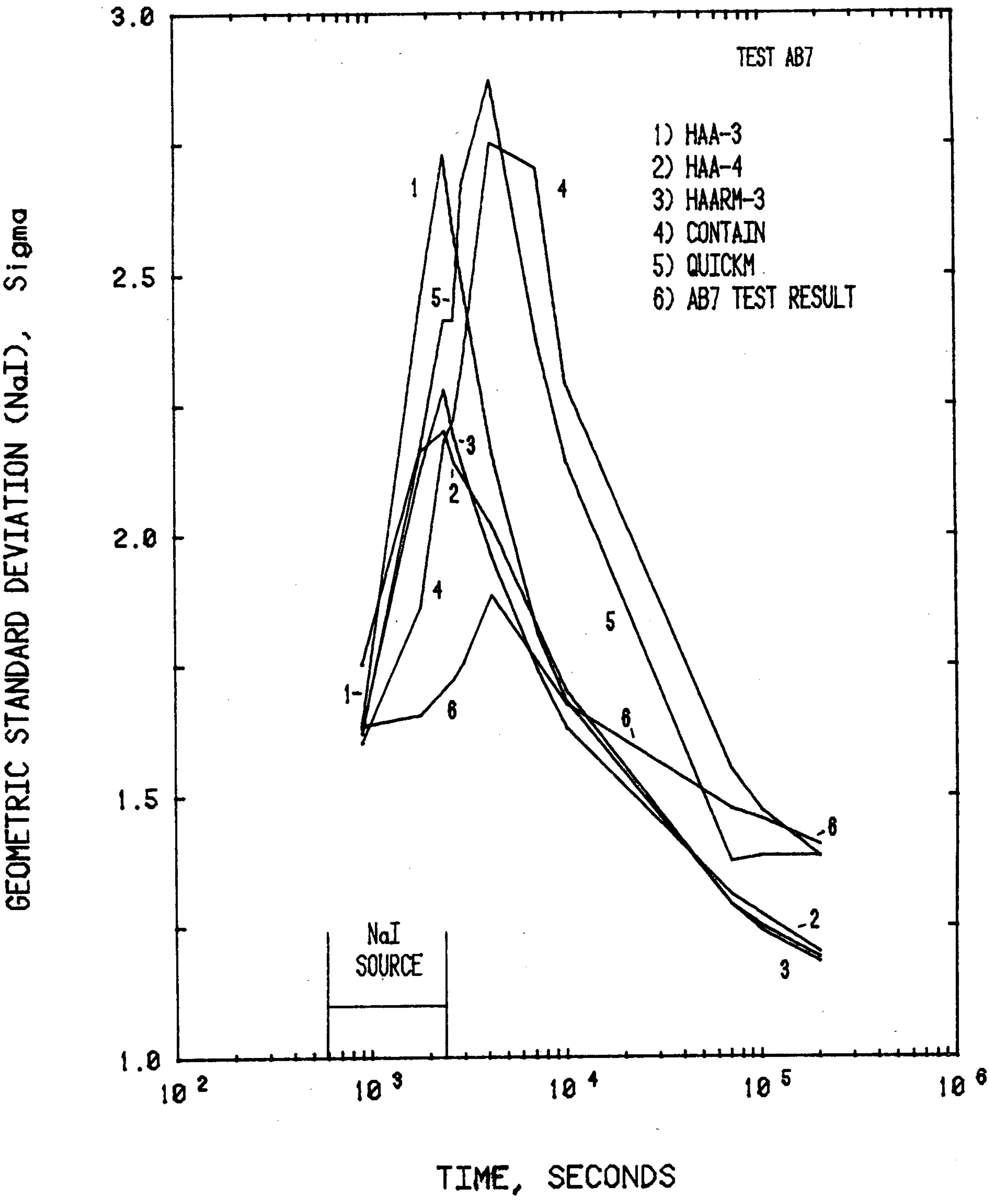

FIGURE 5-12. Plot of Code Predictions of Geometric Standard Deviation of NaI.

5.4.4 Aerodynamic Settling Mean Diameter

5.4.4.1 Aerodynamic Settling Mean Diameter for NaOH

The aerodynamic settling mean diameter, d_{sa}, is defined as the diameter of a particle which has a settling velocity equal to the sedimentation velocity for the whole aerosol. The term "aerodynamic" refers to unit density spherical particles.

The code predictions for d_{sa}, based on NaOH content, are plotted in Figure 5-13. The experimental data in Figure 5-13 were calculated from the rate of change of suspended mass concentration and the use of Stokes' law for settling of unit density spheres, as discussed in Section 4.7.2. The assumption was made that wall plating was insignificant compared with sedimentation, an assumption shown to be valid in Section 4.9.3.

Figure 5-13 shows that all of the codes predicted the value of d_{sa} fairly well immediately after the end of the NaOH source, but all of the codes overpredicted significantly until approximately 10^4 s, after which good agreement with experimental measurement was again attained. No clear trend between log-normal and discrete codes can be seen.

Detailed information on the predicted values of d_{sa} are presented in Appendix I for the 12 specified code reporting times.

The number of times that individual codes cases predicted the experimental value within a factor of 1.5 is shown in Table 5-10.

5.4.4.2 Aerodynamic Settling Mean Diameter for NaI

The code predictions for d_{sa}, based on NaI content, are presented in Figure 5-14. Inspection of Figures 5-13 and 5-14 shows very similar trends for d_{sa} for the two aerosol species. HAA-4, CONTAIN and QUICKM predicted the test measurement better than HAA-3 and HAARM-3 did.

The number of times that individual code cases predicted the experimental value within a factor of 1.5 is shown in Table 5-10.

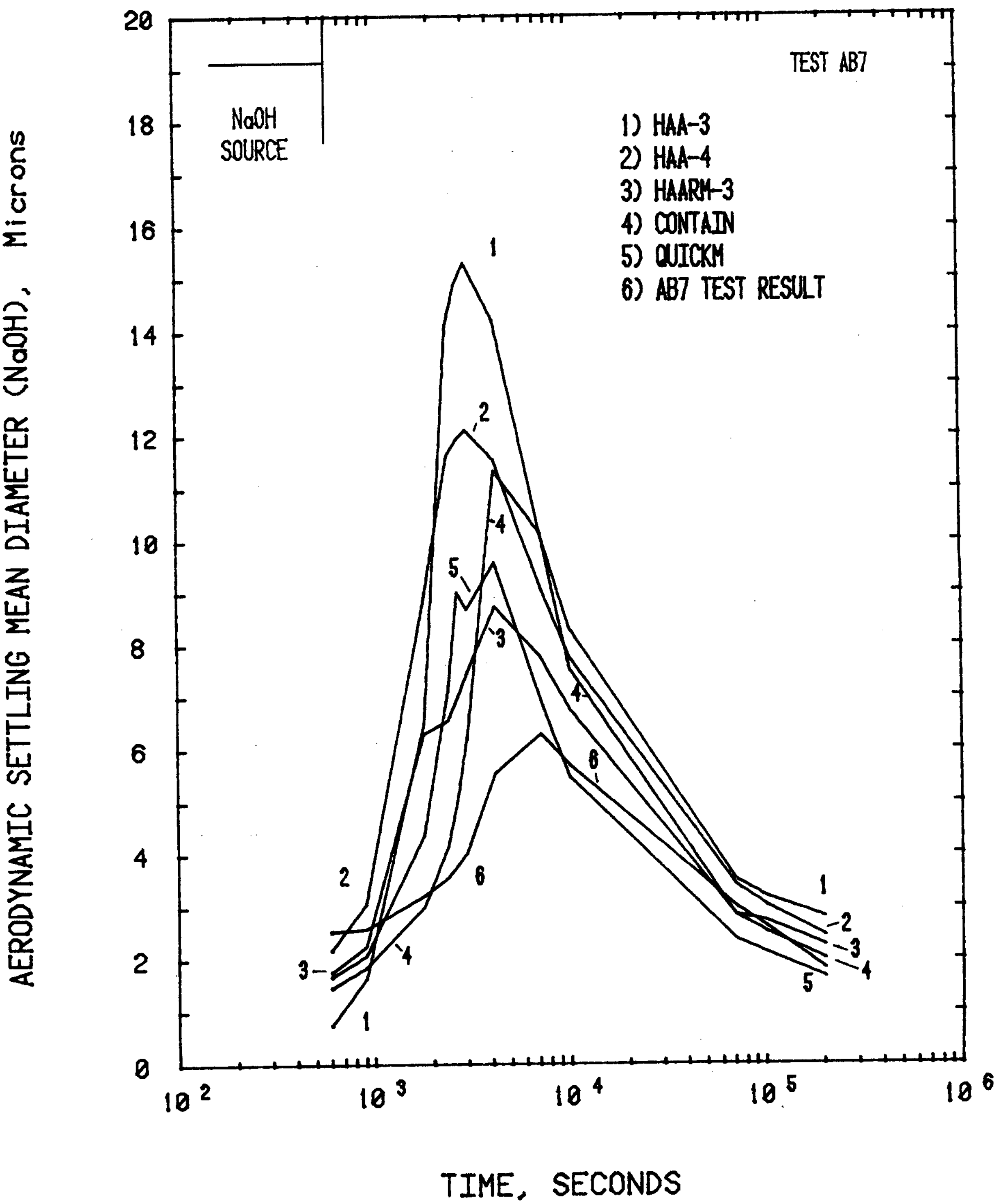

FIGURE 5-13. Plot of Code Predictions of Aerodynamic Settling Mean Diameter for NaOH.

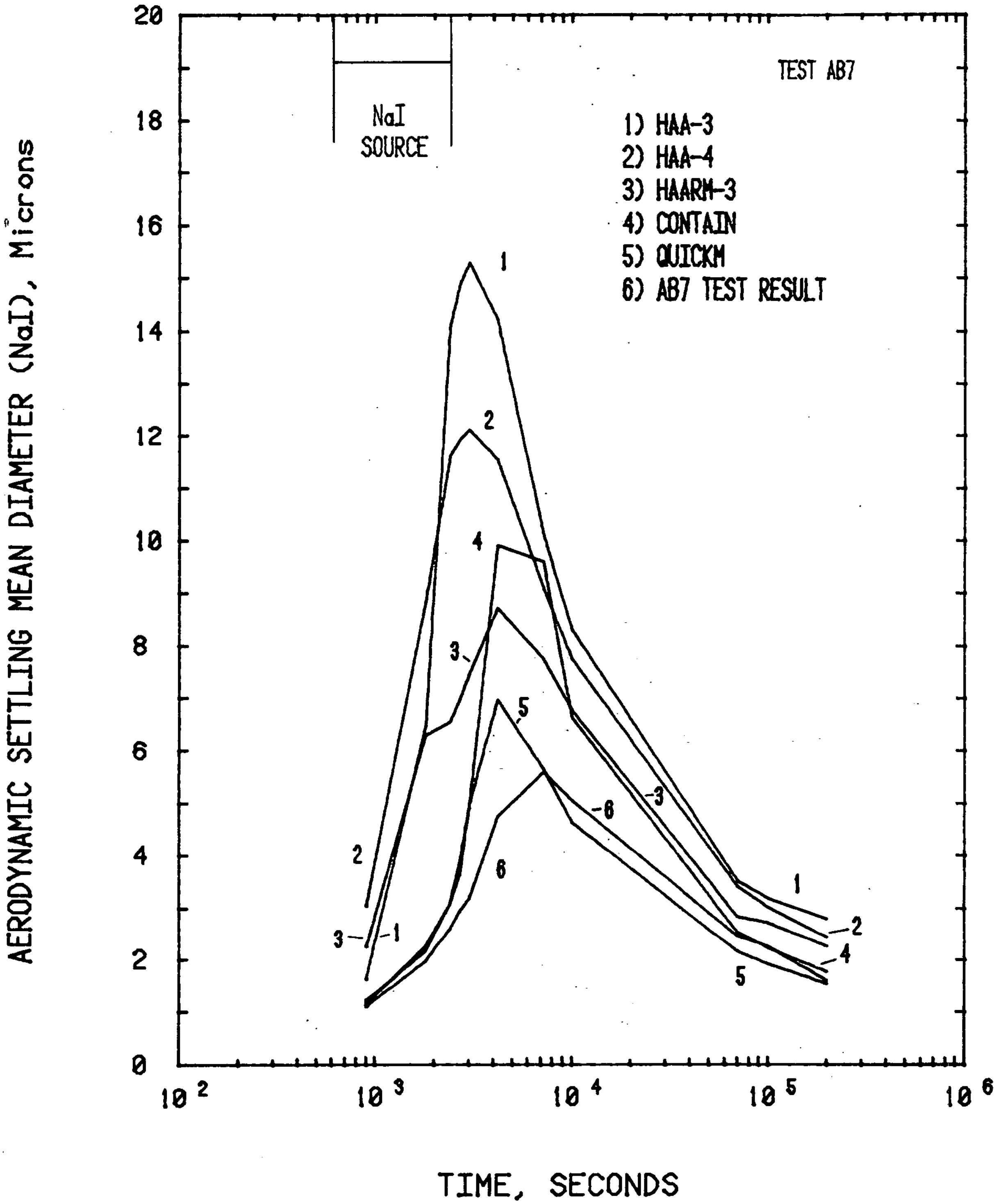

FIGURE 5-14. Plot of Code Predictions of Aerodynamic Settling Mean Diameter for NaI.

TABLE 5-10

CODE CASES WITH CORRECT PREDICTIONS OF AERODYNAMIC SETTLING MEAN DIAMETER

Time (s)	NaOH[a]					NaI[a]				
	1[b]	2	3	4	5	1	2	3	4	5
6.0(2)	N	Y	Y	N	Y	-	-	-	-	-
9.0(2)	Y	Y	Y	Y	Y	Y	N	N	Y	Y
1.8(3)	N	N	N	Y	Y	N	N	N	Y	Y
2.4(3)	N	N	N	Y	N	N	N	N	Y	Y
2.7(3)	N	N	N	Y	N	N	N	N	Y	Y
3.0(3)	N	N	N	N	N	N	N	N	Y	Y
4.2(3)	N	N	N	N	N	N	N	N	N	Y
7.2(3)	N	Y	Y	N	Y	N	N	Y	N	Y
1.0(4)	Y	Y	Y	Y	Y	N	Y	Y	Y	Y
7.0(4)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
1.0(5)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
2.0(5)	Y	Y	Y	Y	Y	N	Y	Y	Y	Y
Total Correct	5	7	7	8	8	3	4	5	9	11

(a) Y indicates code predicted within a factor of 1.5, N indicates code predicted outside a factor of 1.5 from the measured value.
(b) Code case: Refer to Table 5-2 for identification.

5.4.5 Leaked Mass

5.4.5.1 Leaked NaOH Mass

The code predictions for the mass of NaOH aerosol leaked from the containment vessel are plotted as a function of time in Figure 5-15. The experimental values from which curve 6 was drawn were calculated, using the same assumption as used in the code cases - that aerosol leaked at a constant 1% of the suspended mass per day. A discussion of the experimental results for leaked mass is provided in Section 4.12.

Detailed digital information on the mass of NaOH aerosol predicted to have leaked from the containment vessel at the twelve specified times is listed in Appendix J.

Figure 5-15 shows that CONTAIN and QUICKM, the two discrete codes, predicted the measured leaked NaOH mass very closely at all times. The three log-normal codes underpredicted the experimental value at times greater than 3000 s, being low by a factor of approximately 5 at long times.

The number of times that individual code cases predicted within a factor of two the experimental value is shown in Table 5-11. It is of interest to note that the log-normal codes were generally more accurate in predicting leaked mass than they are in predicting suspended mass concentration at discrete times. The discrete codes predicted within a factor of two at all times for both suspended concentration and leaked mass.

5.4.5.2 Leaked NaI Mass

The code predictions for the mass of NaI leaked from the containment vessel are plotted as a function of time in Figure 5-16. The codes performed very similarly for NaI as they did for NaOH leaked mass, with the log-normal codes significantly underpredicting the measured value and the discrete codes being in good agreement at all times.

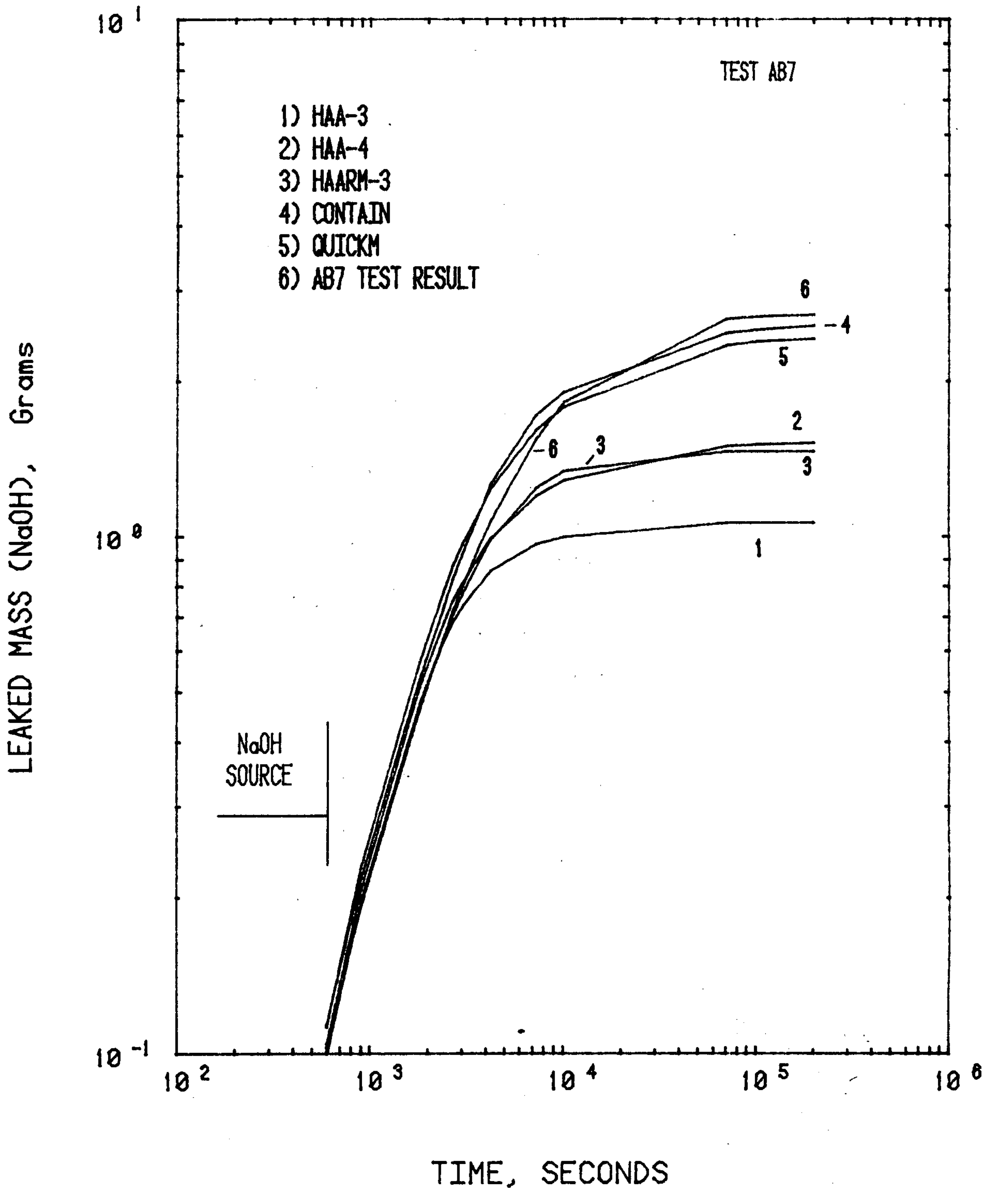

FIGURE 5-15. Plot of Code Predictions and Test Results of Leaked NaOH Mass.

TABLE 5-11

CODE CASES WITH CORRECT PREDICTIONS OF LEAKED MASS

Time	NaOH[a]					NaI[a]				
(s)	1[b]	2	3	4	5	1	2	3	4	5
6.0(2)	Y	Y	Y	Y	Y	-	-	-	-	-
9.0(2)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
1.8(3)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
2.4(3)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
2.7(3)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
3.0(3)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
4.2(3)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
7.2(3)	Y	Y	Y	Y	Y	N	Y	Y	Y	Y
1.0(4)	Y	Y	Y	Y	Y	N	N	Y	Y	Y
7.0(4)	N	Y	Y	Y	Y	N	N	N	Y	Y
1.0(5)	N	Y	Y	Y	Y	N	N	N	Y	Y
2.0(5)	N	Y	Y	Y	Y	N	N	N	Y	Y
Total Correct	9	12	12	12	12	6	7	8	11	11

(a) Y indicates code predicted within a factor of 2, N indicates code predicted outside a factor of 2 from the measured value.
(b) Code case: Refer to Table 5-2 for identification.

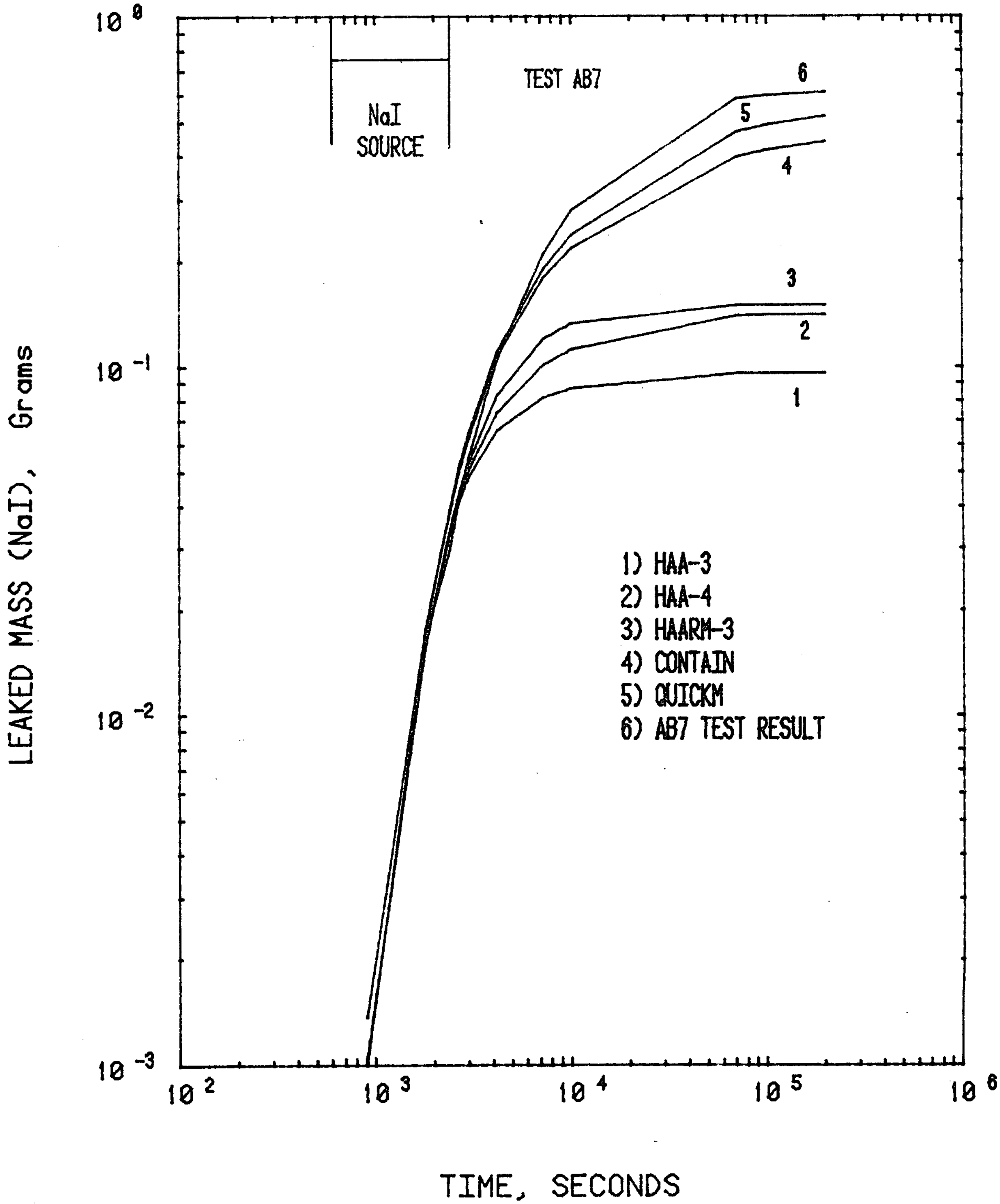

FIGURE 5-16. Plot of Code Predictions and Test Results of Leaked NaI Mass.

Detailed digital information on the mass of NaI aerosol predicted to have leaked from the containment vessel at the twelve specified times is listed in Appendix J. The number of times the individual codes predicted the NaI leaked mass within a factor of two is shown in Table 5-11.

5.4.6 Settled Mass

5.4.6.1 Settled NaOH Mass

The code predictions for the mass of NaOH aerosol collected on horizontal surfaces by gravitational settling are plotted in Figure 5-17. This parameter was measured experimentally only at the end of the experiment. The method of determining settled mass is discussed in Section 4.13. Figure 5-17 shows that all of the codes predicted settled mass very well. Detailed digital information in Appendix K shows that all five code cases predicted the measured value of final settled NaOH mass within 24%.

The number of times that individual code cases predicted the experimental value within $\pm$15% is shown in Table 5-12.

5.4.6.2 Settled NaI Mass

The code predictions for the mass of NaI collected on horizontal surfaces by gravitational settling are plotted as a function of time in Figure 5-18. All five codes predicted the settled NaI mass very well, with predictions ranging from 20% low (HAARM-3) to 5% low (QUICKM).

5.4.7 Plated Mass

5.4.7.1 Plated NaOH Mass

The code predictions for plated NaOH mass are plotted in Figure 5-19. This parameter was measured only at the end of the test, as discussed in Section 4.14.

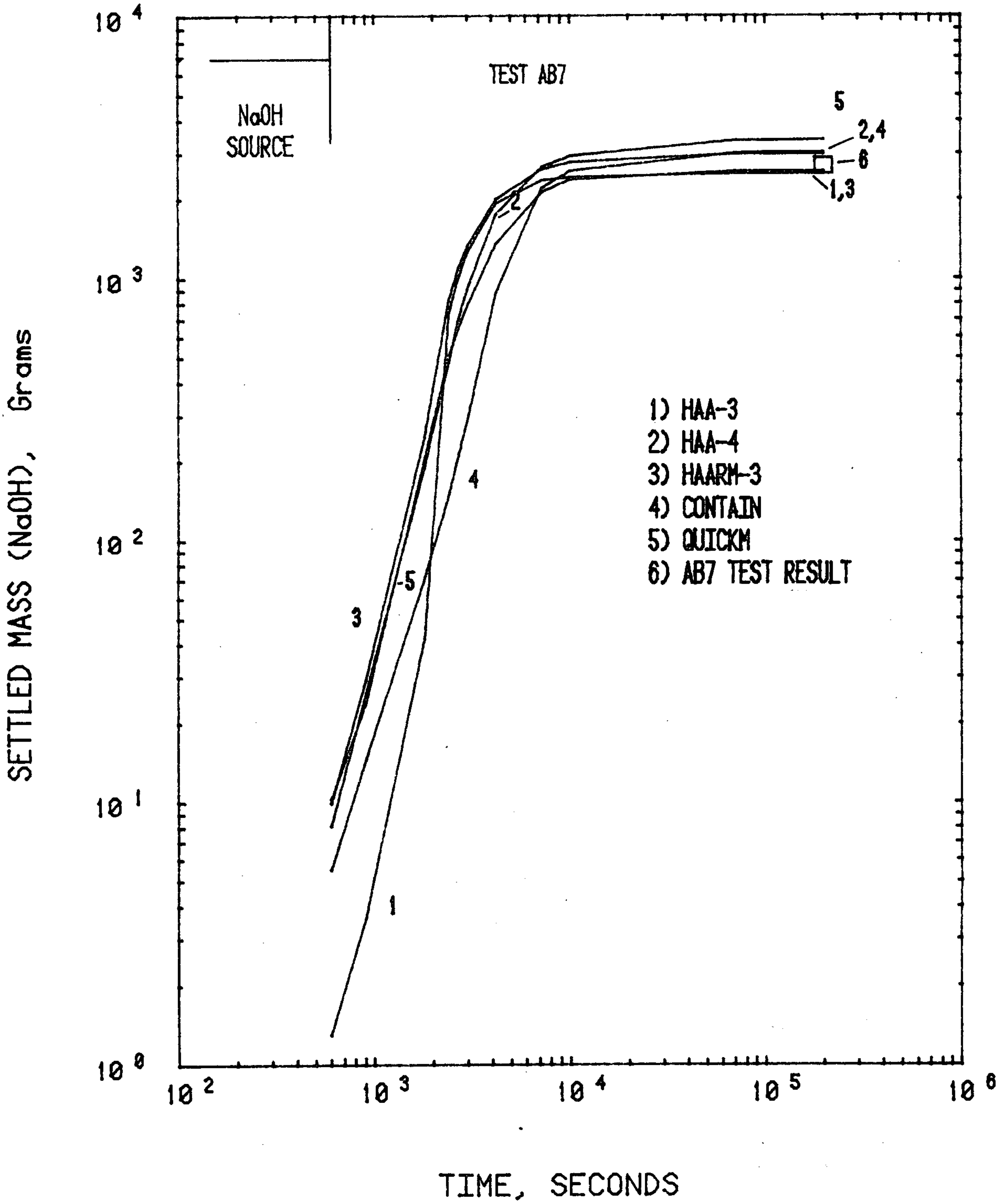

FIGURE 5-17. Plot of Code Predictions of Settled NaOH Mass.

TABLE 5-12

CODE CASES WITH CORRECT PREDICTIONS OF SETTLED MASS

Code Case(c)	Predicted Settled Mass(a)(b) Within +15% of Measurement	
	NaOH	NaI
1	Y	N
2	Y	Y
3	Y	N
4	Y	Y
5	N	Y

(a) At end of test.
(b) Y indicates yes; N indicates no.
(c) Refer to Table 5-2 for identification.

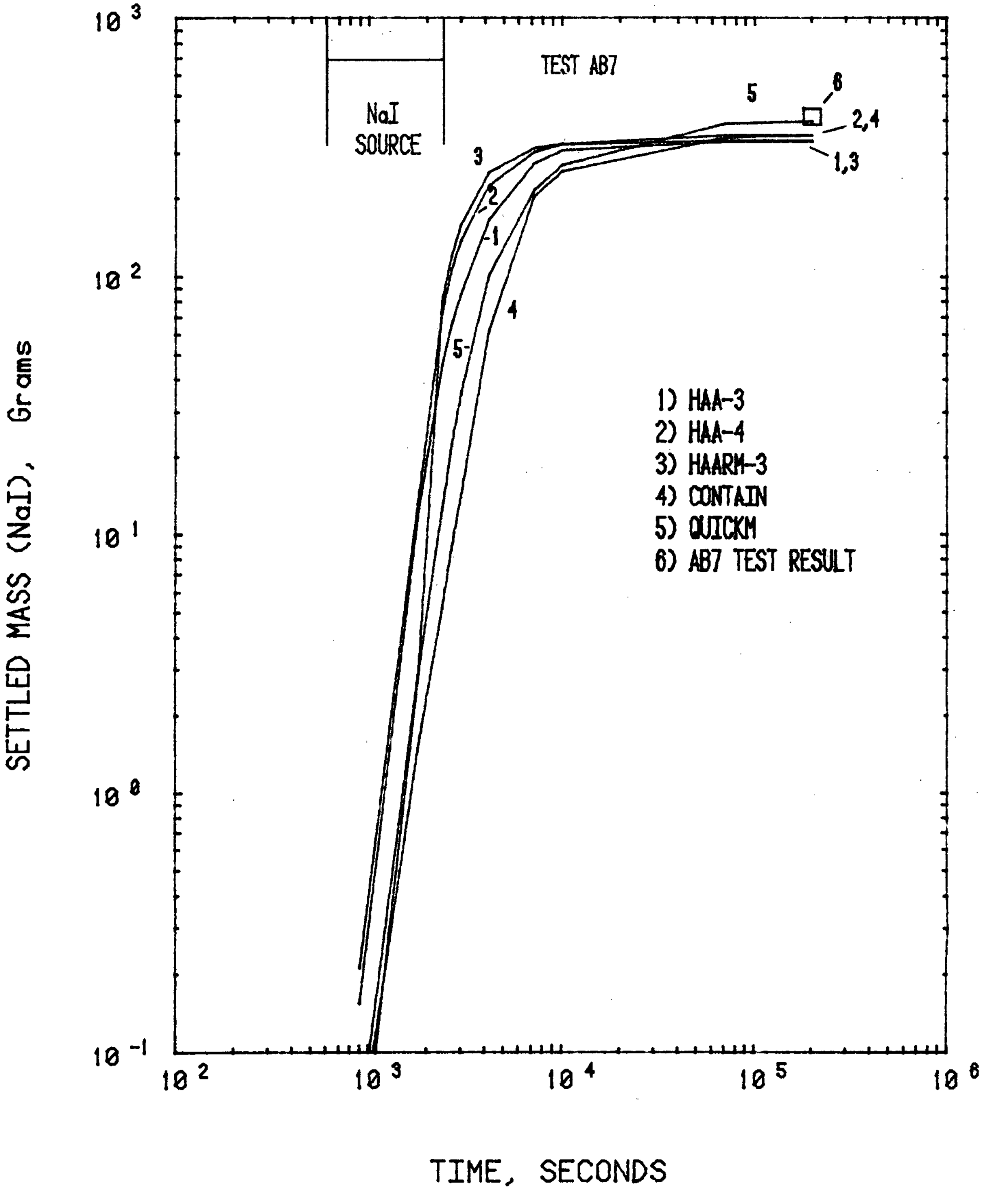

FIGURE 5-18. Plot of Code Predictions of Settled NaI Mass.

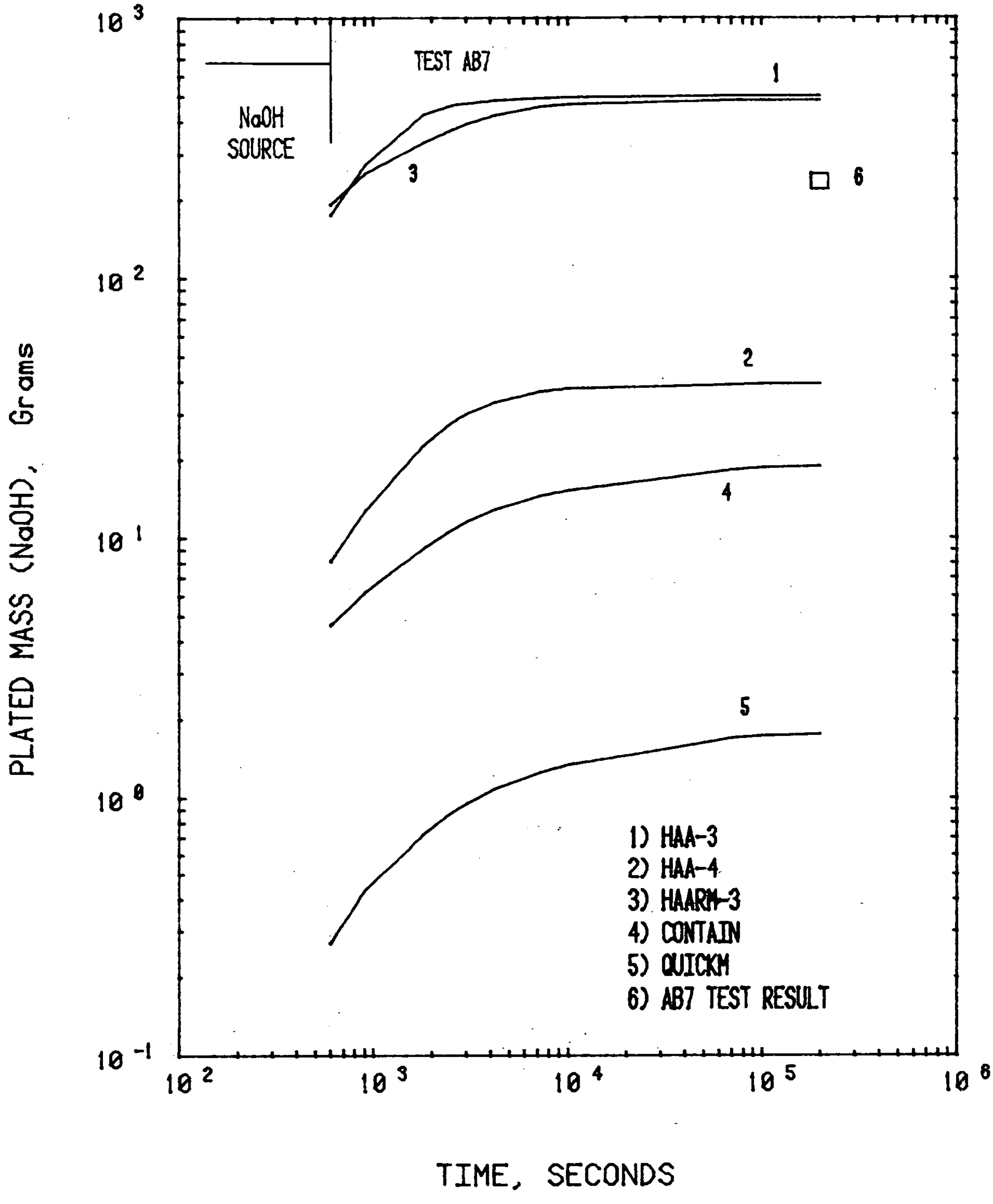

FIGURE 5-19. Plot of Code Predictions of Plated NaOH Mass.

As was the case in earlier ABCOVE tests[1,2], the code predictions were more scattered for plated mass than for any other parameter. The reason for the wide range of predictions is apparent from an inspection of Table 5-6, which lists the values of input parameters related to wall deposition which were used in the various codes. Values of the Brownian diffusion boundary layer thickness (delta) differed by a factor of 600 among the codes. Two of the codes (HAA-3 and QUICKM) did not account for thermophoresis, although QUICKM has the capability of doing so.

At the end of the test, HAA-3 and HAARM-3 overpredicted the measured plated NaOH mass by a factor of 2, HAA-4 underpredicted by a factor of 6, CONTAIN underpredicted by a factor of 12.5, and QUICKM underpredicted by a factor of 136.

Table 5-13 shows that only the HAA-3 code predicted the measured value within a factor of 2.

Detailed digital information on code predictions of plated NaOH mass is provided in Appendix L.

5.4.7.2 Plated NaI Mass

The code predictions for plated NaI mass are plotted as a function of time in Figure 5-20. The experimental measurement was made only at the end of the experiment, and this is plotted as the single point in Figure 5-20. Detailed digital information on code predictions is provided in Appendix L.

Figure 5-20 and Appendix L show that there was considerable scatter among the code predictions for plated NaI. Only HAA-3 predicted the measured value within a factor of two.

TABLE 5-13

CODE CASES WITH CORRECT PREDICTIONS FOR PLATED MASS

Code(c) Case	Predicted Plated Mass(a)(b) Within a Factor of 2 from Measurement	
	NaOH	NaI
1	Y	N
2	Y	Y
3	Y	N
4	Y	Y
5	N	Y

(a) At end of test.
(b) Y indicates yes; N indicates no.
(c) Refer to Table 5-2 for identification.@END(VERBATIM)

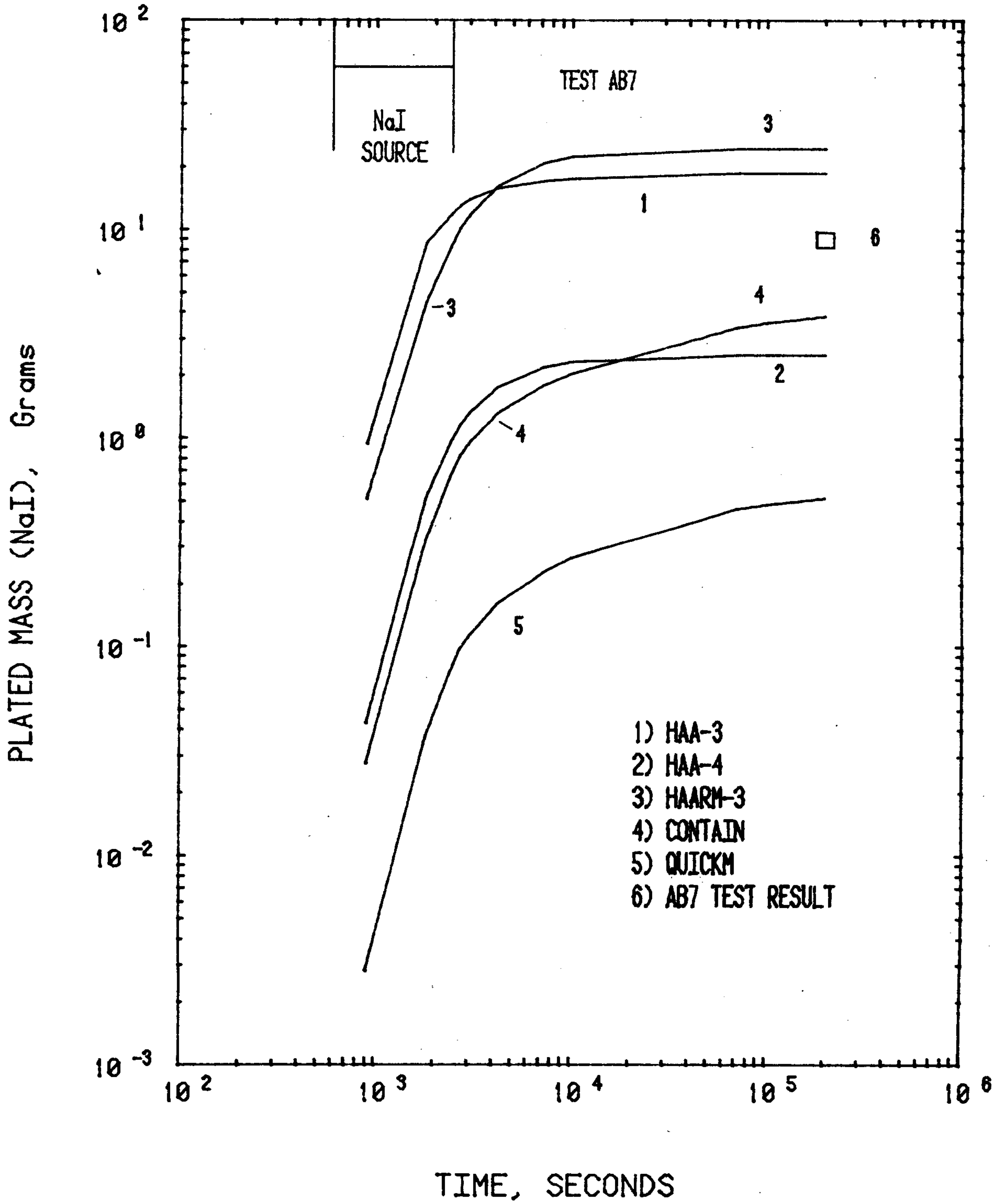

FIGURE 5-20. Plot of Code Predictions of Plated NaI Mass.

5.4.8 Instantaneous Combined Removal Rate

5.4.8.1 Removal Rate for NaOH Aerosol

The predicted values for the combined instantaneous removal rates of suspended NaOH aerosol are plotted in Figure 5-21. Detailed digital information is provided in Appendix M. The experimental values were calculated from the rate of change of suspended mass concentration and by the use of a mass balance on the containment atmosphere, as discussed in Section 4.15. The CONTAIN did not report the removal rate for the individual aerosol species.

For several of the code cases, the removal rate was reported in terms of mass rate rather than fractional rate. For these cases, the mass rate was converted to fraction removal by Equation (12).

$$\lambda_t = \frac{R}{VC} \tag{12}$$

where:

λ_t = removal rate, s^{-1}
R = mass removal rate, g/s
V = 852 m^3
C = suspended mass conc., g/m^3

Figure 5-21 shows that HAA-4 and QUICKM predicted the NaOH removal rate quite well at most times. The number of times that each code case predicted the experimental value within a factor of 2 is shown in Table 5-14.

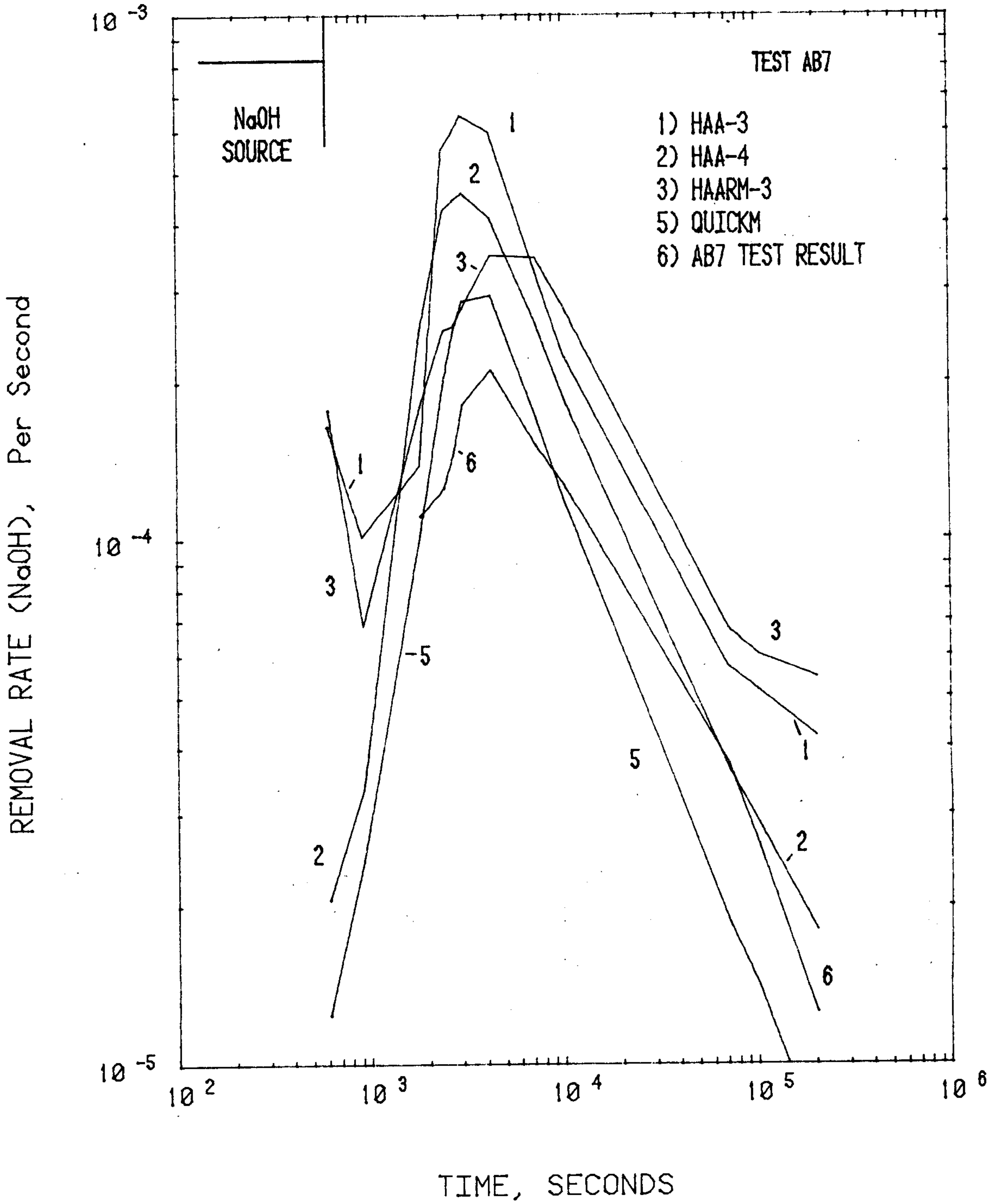

FIGURE 5-21. Plot of Instantaneous Combined Removal Rates for NaOH.

TABLE 5-14

CODE CASES WITH CORRECT PREDICTIONS FOR INSTANTANEOUS REMOVAL-RATE

Time (s)	NaOH[a] 1[b]	NaOH[a] 2	NaOH[a] 3	NaOH[a] 4	NaOH[a] 5	NaI[a] 1	NaI[a] 2	NaI[a] 3	NaI[a] 4	NaI[a] 5
6.0(2)	(c)	(c)	(c)	(c)	(c)	(c)	(c)	(c)	(c)	(c)
9.0(2)	(c)	(c)	(c)	(c)	(c)	(c)	(c)	(c)	(c)	(c)
1.8(3)	Y	N	Y	(d)	Y	(c)	(c)	(c)	(c)	(c)
2.4(3)	N	N	Y	(d)	Y	(c)	(c)	(c)	(c)	(c)
2.7(3)	N	N	Y	(d)	Y	(c)	(c)	(c)	(c)	(c)
3.0(3)	N	N	Y	(d)	Y	N	N	N	(d)	N
4.2(3)	N	Y	Y	(d)	Y	N	N	N	(d)	N
7.2(3)	N	Y	N	(d)	Y	N	N	N	(d)	N
1.0(4)	Y	Y	N	(d)	Y	N	Y	N	(d)	N
7.0(4)	Y	Y	Y	(d)	Y	Y	Y	Y	(d)	N
1.0(5)	Y	Y	N	(d)	Y	N	Y	N	(d)	N
2.0(5)	N	Y	N	(d)	Y	N	Y	N	(d)	Y
Total Correct	4	6	6	(d)	10	1	4	1	(d)	1

(a) Y indicates code predicted within a factor of 2, N indicates code predicted outside a factor of 2 from experimental measurement.
(b) Code case: Refer to Table 5-2 for identification.
(c) Experimental data not available at this time.
(d) Not reported.

5.4.8.2 Removal Rate for NaI Aerosol

The predicted values for the removal rate of suspended NaI aerosol are plotted as a function of time in Figure 5-22. Detailed digital information is provided in Appendix M.

Figure 5-22 shows that the three log-normal codes overpredicted the experimental measurement significantly at early times. HAA-4 gave good agreement for times later than 10^4 s. CONTAIN did not report the removal rate for NaI. QUICKM underpredicted the removal rate significantly at all times, which is surprising in view of the good agreement between QUICKM and experimental measurements for all other parameters. The removal rates reported by QUICKM are for sedimentation only. Since other removal processes (diffusion and leak) were insignificant compared to sedimentation at all times, this does not account for the inconsistency. It is concluded that there may be a reporting error in the QUICKM output.

5.5 DISCUSSION OF CODE PREDICTIONS

This discussion highlights some of the more significant aspects of code predictions for test AB7. No attempt is made to arrive at value judgments as to the accuracy of any of the codes. What is given here is intended to assist the reader in reviewing some of the results of the ABCOVE program for test AB7.

5.5.1 Comparison of Log-Normal and Discrete Code Results

The codes involved in the test AB7 exercise can be classified into two broad groups: the log-normal, uniform co-agglomeration codes (HAA-3, HAA-4, HAARM-3) and the discrete, sectionally uniform codes (CONTAIN, QUICKM). It is unfortunate that a discrete, uniform co-agglomeration code was not involved, since some of the differences observed between the discrete and log-normal codes is probably due more to the manner of handling multiple species than in the

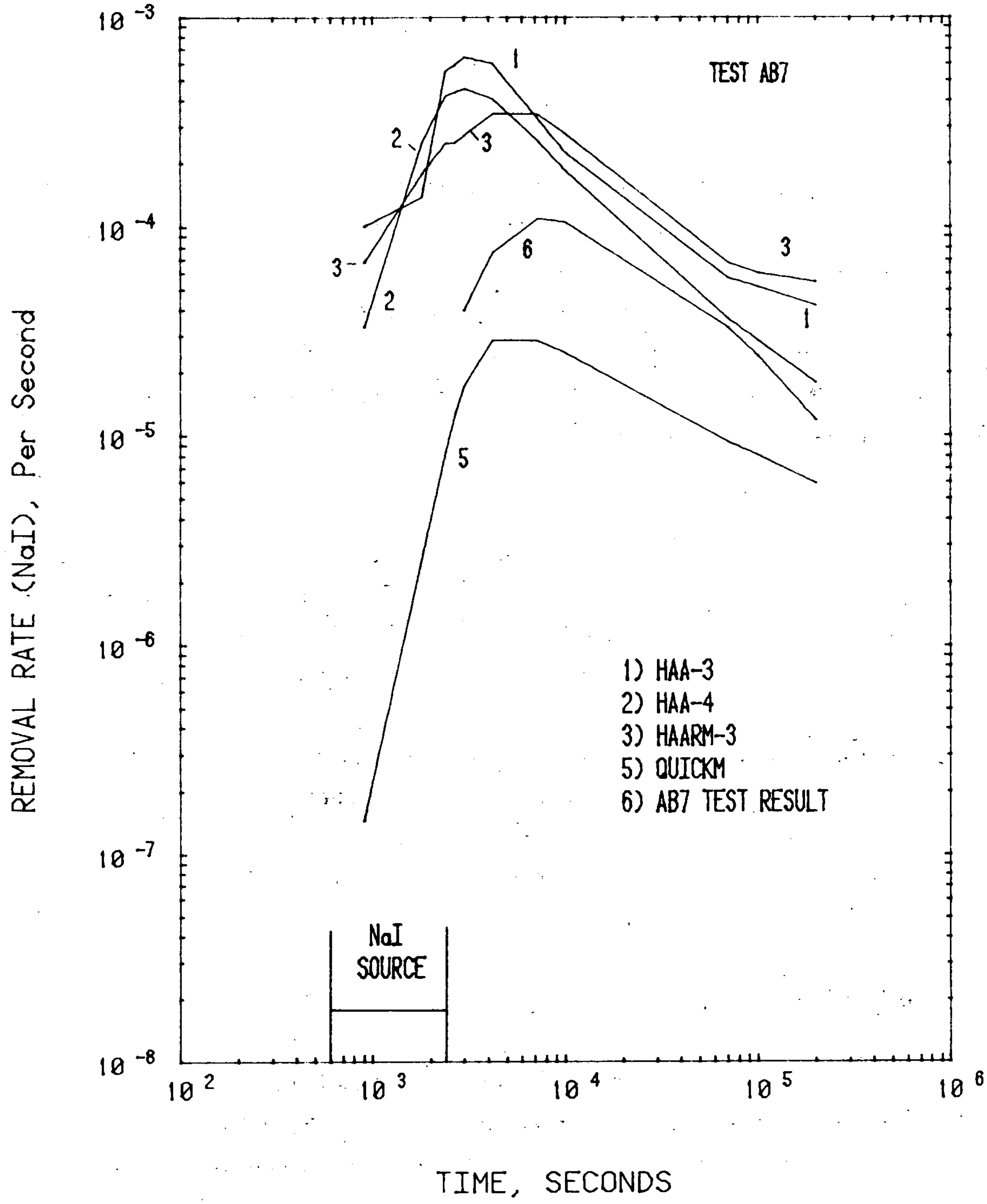

FIGURE 5-22. Plot of Instantaneous Combined Removal Rate for NaI.

analytical methods for defining the size spectrum. For the sake of brevity, the two classes are termed "discrete" and "log-normal" in the following discussion, but the differences in handling multiple species should be kept in mind by the reader.

5.5.1.1 Suspended Mass Concentration

The individual code predictions of suspended mass concentration are plotted in Figures 5-1 through 5-4. In Table 5-15 the data are presented as average values for the two types of codes. Also listed in Table 5-15 are the dimensionless concentrations, based on the concentration at the ends of the source for the two aerosol species. The data of Table 5-15 are plotted in Figure 5-23 for the NaOH Aerosol and in Figure 5-24 for NaI. The experimental data are also plotted in a similar fashion.

An examination of Figure 5-23 shows that the discrete codes were in good agreement with the experimental measurement for NaOH at all times, whereas the log-normal codes, as a group, underpredicted the experiment at all times after the end of the NaOH source. Figure 5-24 shows a similar behavior for the NaI aerosol species, with even greater underprediction by the log-normal codes.

The difference between the discrete and log-normal codes is shown somewhat differently in Figure 5-25, where the ratios of the code predictions to experimental measurement of suspended concentration are plotted as a function of time. Figure 5-25 clearly shows the superiority of the discrete code predictions for both NaOH and NaI.

5.5.1.2 Leaked Mass

For accident cases where containment integrity is maintained, offsite consequences would be governed mainly by leaked mass due to normal leakage. In the ABCOVE exercise, normal leakage was assumed to be constant at 1% per day for both the doe calculations and experimental result. Thus, the leaked mass is directly proportional to the time-integrated suspended mass.

TABLE 5-15

CODE PREDICTIONS OF DIMENSIONLESS SUSPENDED CONCENTRATION AFTER END OF SOURCE -- TEST AB7

Run Time (s)	Time After (s): End of NaOH Source	Time After (s): End of NaI Source	Log-Normal Code Average(a): NaOH C	Log-Normal Code Average(a): NaOH C/C_o	Log-Normal Code Average(a): NaI C	Log-Normal Code Average(a): NaI C/C_o	Discrete Code Average(b): NaOH C	Discrete Code Average(b): NaOH C/C_o	Discrete Code Average(b): NaI C	Discrete Code Average(b): NaI C/C_o
6.0(2)	0	-	3.39(0)	1.00(0)	-	-	3.72(0)	1.0	-	-
9.0(2)	3.0(2)	-	3.34(0)	9.86(-1)	-	-	3.71(0)	9.97(-1)	-	-
1.8(3)	1.2(3)	-	3.05(0)	8.99(-1)	-	-	3.57(0)	9.61(-1)	-	-
2.4(3)	1.8(3)	0	2.40(0)	7.09(-1)	3.29(-1)	1.00(0)	3.35(0)	9.00(-1)	4.28(-1)	1.00(0)
2.7(3)	2.1(3)	3.0(2)	2.13(0)	6.28(-1)	2.91(-1)	8.86(-1)	3.19(0)	8.58(-1)	4.20(-1)	9.81(-1)
3.0(3)	2.4(3)	6.0(2)	1.87(0)	5.53(-1)	2.56(-1)	7.78(-1)	3.01(0)	8.09(-1)	4.09(-1)	9.57(-1)
4.2(3)	3.6(3)	1.8(3)	1.10(0)	3.25(-1)	1.50(-1)	4.58(-1)	2.18(0)	5.85(-1)	3.42(-1)	8.00(-1)
7.2(3)	6.8(3)	4.8(3)	3.78(-1)	1.11(-1)	5.20(-2)	1.58(-1)	8.80(-1)	2.36(-1)	1.92(-1)	4.50(-1)
1.0(4)	9.4(3)	7.6(3)	1.82(-1)	5.37(-2)	2.46(-2)	7.49(-2)	5.09(-1)	1.37(-1)	1.32(-1)	3.10(-1)
7.0(4)	6.9(4)	6.8(4)	1.78(-3)	5.24(-4)	2.37(-4)	7.21(-4)	1.80(-2)	4.85(-3)	9.97(-3)	2.33(-2)
1.0(5)	1.0(5)	9.8(4)	6.20(-4)	1.83(-4)	8.09(-4)	2.46(-5)	8.23(-3)	2.21(-3)	5.28(-3)	1.23(-2)
2.0(5)	2.0(5)	1.98(5)	5.68(-5)	1.67(-5)	7.33(6)	2.22(-5)	1.32(-3)	3.56(-4)	1.21(-3)	2.83(-3)

(a) Average of HAA-3, HAA-4, and HARRM-3 code predictions.
(b) Average of CONTAIN and QUICKM code predictions.

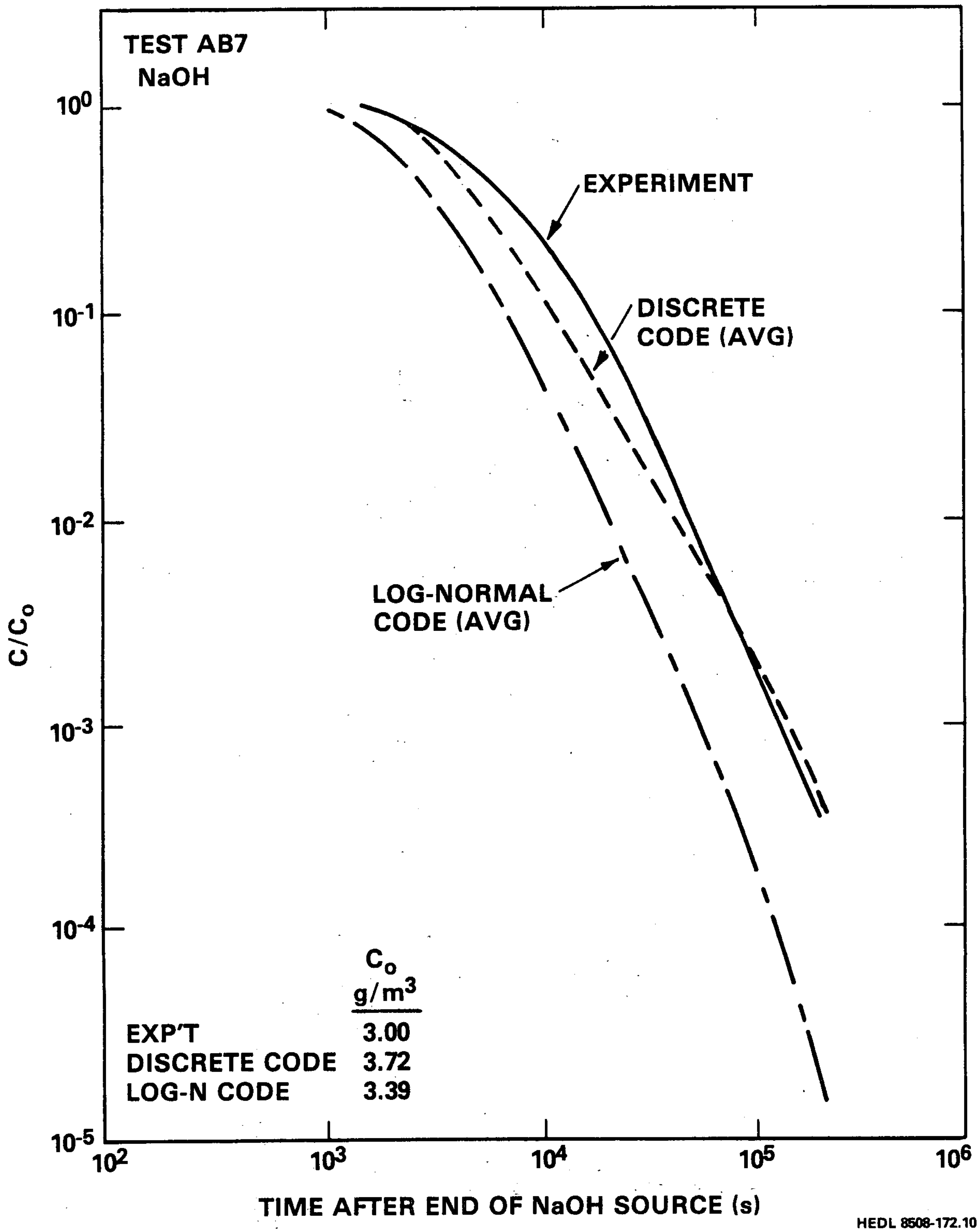

FIGURE 5-23. Comparison of Discrete and Log-Normal Code Predictions for NaOH Suspended Concentration After the End of Source.

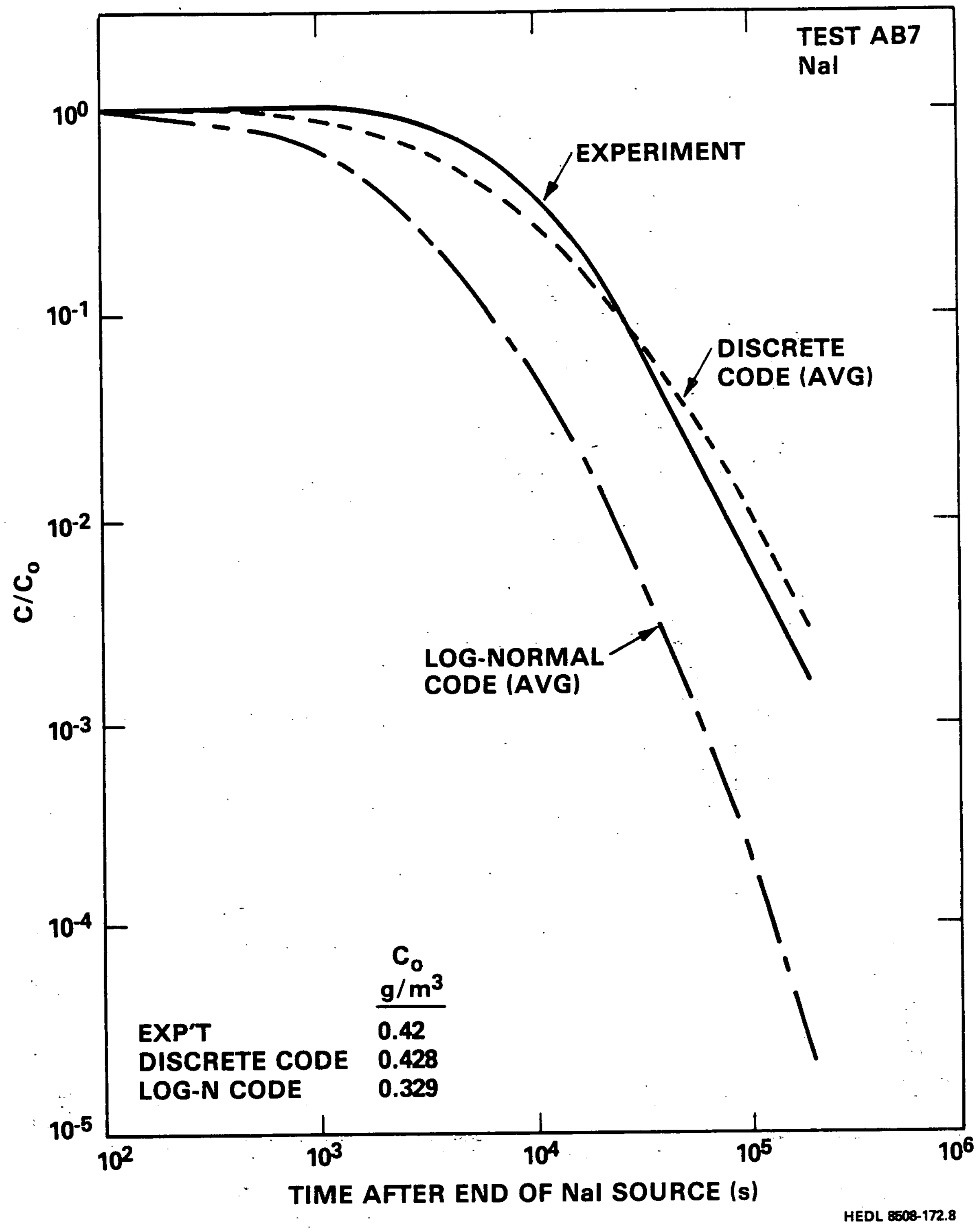

FIGURE 5-24. Comparison of Discrete and Log-Normal Code Predictions for NaI Suspended Concentration After the End of Source.

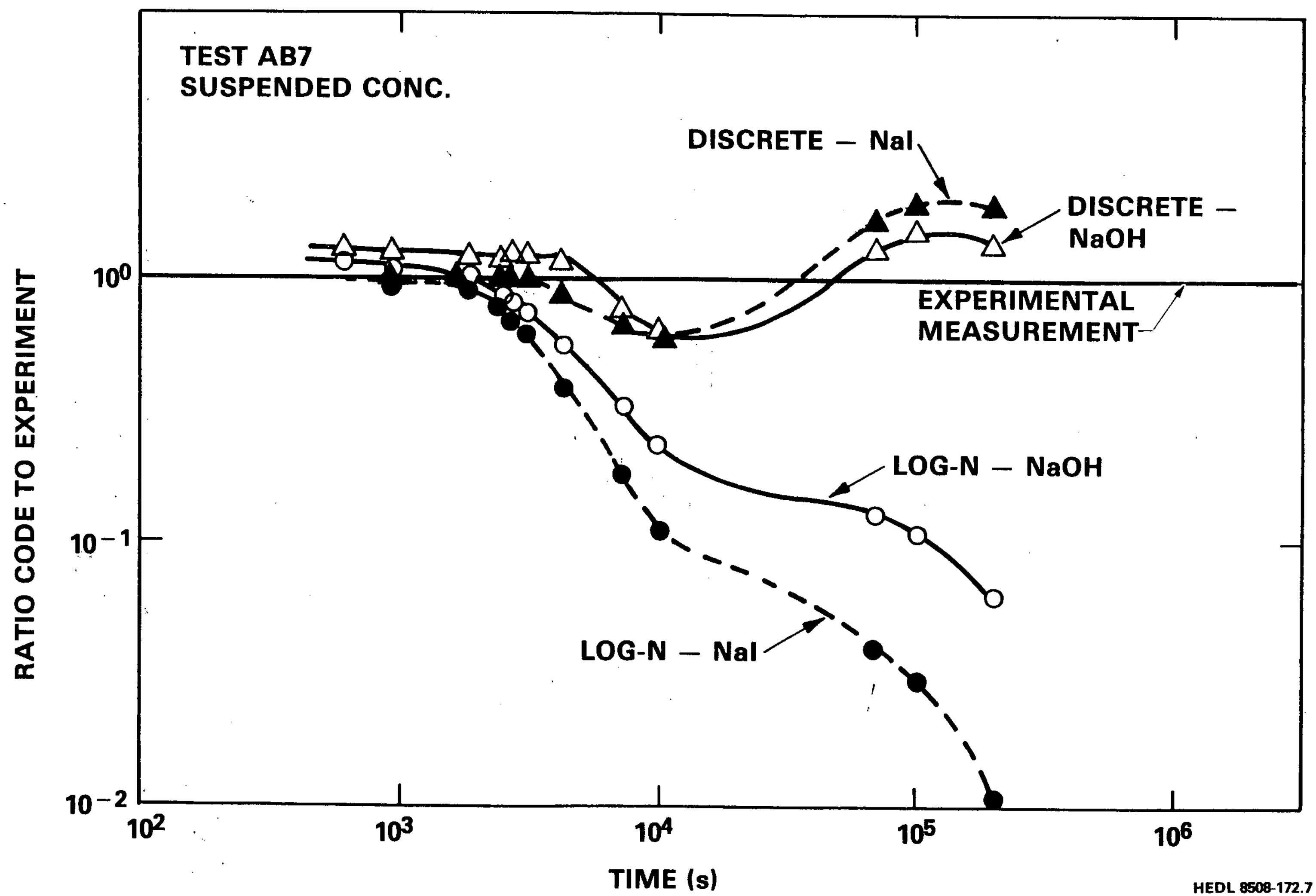

FIGURE 5-25. Ratios of Code Prediction of Suspended Concentration to Experiment for Discrete and Log-Normal Codes.

The ratio of code prediction to experiment for leaked mass is plotted as a function of time for both NaOH and NaI in Figure 5-26. The reader should note that the ordinate in Figure 5-26 is a linear scale rather than the log scale used in Figure 5-26. Figure 5-26 shows that the leaked mass was predicted better by the discrete codes for both types of aerosol species.

5.5.1.3 Particle Size

The settling mean diameter is a better measure of the aerosol particle size than the mass median diameter for conditions where gravitational settling dominates the removal processes (as in the present case) and for an aerosol that does not have a log-normal size distribution. The aerodynamic settling mean diameter (ASMD) is plotted in Figure 5-27 as the ratio of code to experiment for the two classes of codes. The discrete codes again gave better agreement with experiment than the log-normal codes did. The log-normal codes greatly overpredicted the ASMD (especially for NaI) at times near the end of the NaI source. This explains why the suspended concentration predicted by the log-normal codes decreased more rapidly than the experimental measurement.

Better agreement of the log-normal codes could undoubtedly be obtained by post-test calculations with different values of key input parameters, but this was not done. The discrete codes were in reasonable agreement with experiment for both aerosol species.

5.5.1.4 Plated Mass

The ratio of code prediction to experiment for wall plated mass is given in Table 5-16 for each of the five codes. Only the total plateout at the end of the test is given, since that is the only time experimental data are available. Table 5-16 shows that the log-normal codes were in better agreement

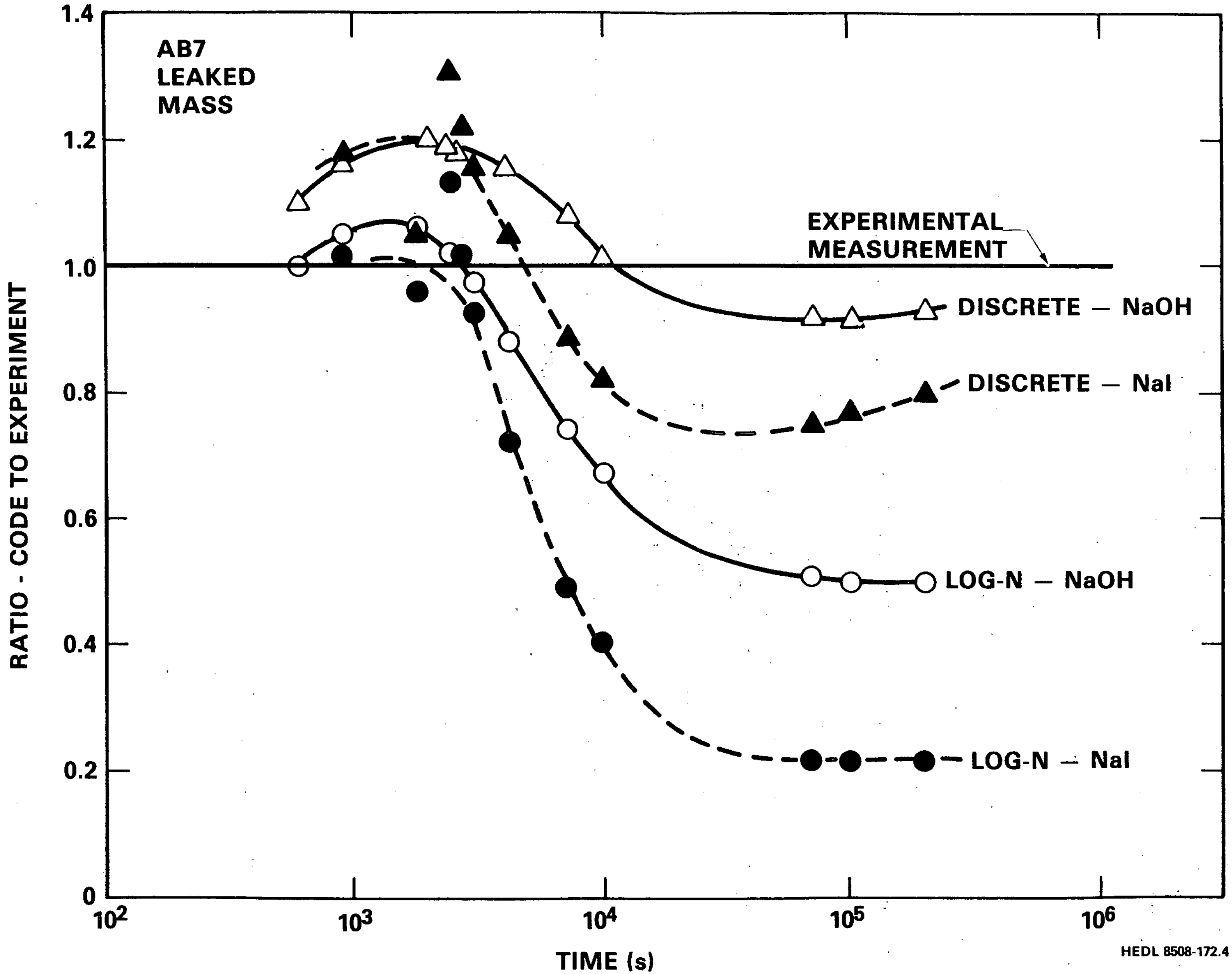

FIGURE 5-26. Ratios of Code Prediction of Leaked Mass to Experiment for Discrete and Log-Normal Codes.

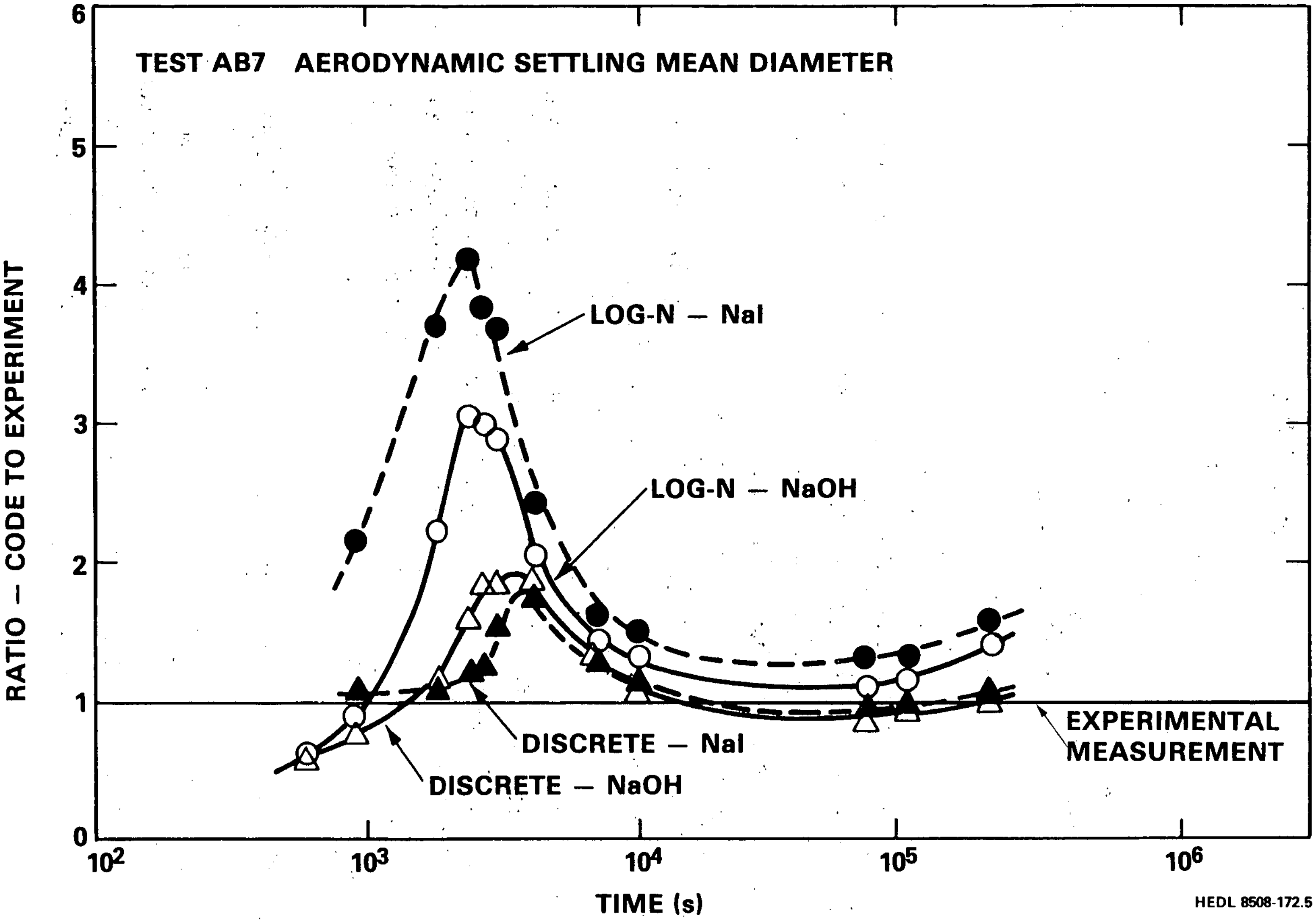

FIGURE 5-27. Ratios of Code Prediction of ASMD to Experiment for Discrete and Log-Normal Codes.

TABLE 5-16

COMPARISON OF PREDICTIONS OF PLATED MASS

Code	Ratio of Code to Test[a] NaOH	NaI
HAA-3	2.14	2.08
HAA-4	0.17	0.28
HAARM-3	2.03	2.74
CONTAIN	0.08	0.43
QUICKM	0.007	0.06
Log-Normal Average	1.45	1.70
Discrete Average	0.044	0.25

(a) At $2x10^5$s.

with experiment than the discrete codes. However, this is not due to the nature of the codes, but to the values used for input wall plating parameters. HAA-3 and HAARM-3 used an empirical value for the diffusion boundary layer thickness that had given good agreement with experimental measurement in previous CSTF tests. An examination of the diverse input values used by the various codes (refer to Table 5-6) explains why such a large variation in output was obtained for wall plateout.

Poor agreement of code predictions for wall plateout with experiment was also noted in previous ABCOVE tests[1,2]. Although wall plateout is usually a minor removal mechanism in large containment buildings (compared with settling), the amount of aerosol plated onto vertical surfaces can be important from a heat transfer aspect, and an effort to improve the capability of codes for predicting this parameter is warranted.

5.5.2 Comparison of Aerosol Behavior in Test AB7 With Test AB6 Results

A detailed comparison of test AB7 with previous ABCOVE tests is beyond the scope of the present document, but a brief discussion is presented on comparisons of test AB7 with test AB6. The discussion is limited to code performances in predicting the suspended mass concentration of NaO_x and NaI.

Tests AB6 and AB7 differed in two important aspects, which affected the behavior of the lesser mass species (NaI). First, mass release rate of the dominant mass species, NaO_x, was 15 times greater in test AB6 compared to test AB7. This resulted in the maximum suspended mass concentration of NaO_x being approximately 10 times greater in test AB6, which caused a higher rate of agglomeration, larger particles and more rapid fallout. The second important difference between the two tests was the relative timing of release for the two aerosol species. In test AB6, the NaI was released first and NaO_x release continued for 2400 s after the end of the NaI release period. In test AB7, the NaI source period occurred after the end of the NaOH release.

The effects of the two key experimental differences in the two tests can be seen in Figure 5-28, in which the dimensionless suspended mass concentrations are plotted as a function of time on semilogarithmic paper. First, the concentration decreased much more rapidly in test AB6 for both aerosol species. This was due to the higher absolute concentration of NaO_x in test AB6. Both log-normal and discrete codes predict this behavior due to concentration differences. The inflection in the NaI curve for test AB6 is believed to be due to resuspension(2).

Secondly, Figure 5-28 shows that the concentration of NaI decreased more rapidly than that of NaOH in test AB6, while the converse was true in test AB7. This interesting behavior was caused by the different timing of release of NaI and is predicted by the discrete, sectionally uniform codes. Since the log-normal codes use the assumption that all aerosol particles have the same composition, they predict the same fallout rates for NaI and NaO_x, which is not supported by the experimental results.

Several other differences in the two tests should be noted. The temperature of the containment atmosphere was very low in test AB7 (34°C maximum), and NaI was not exposed to oxidizing conditions at high temperature, as was the case in test AB6. Although the authors do not believe that significant I_2

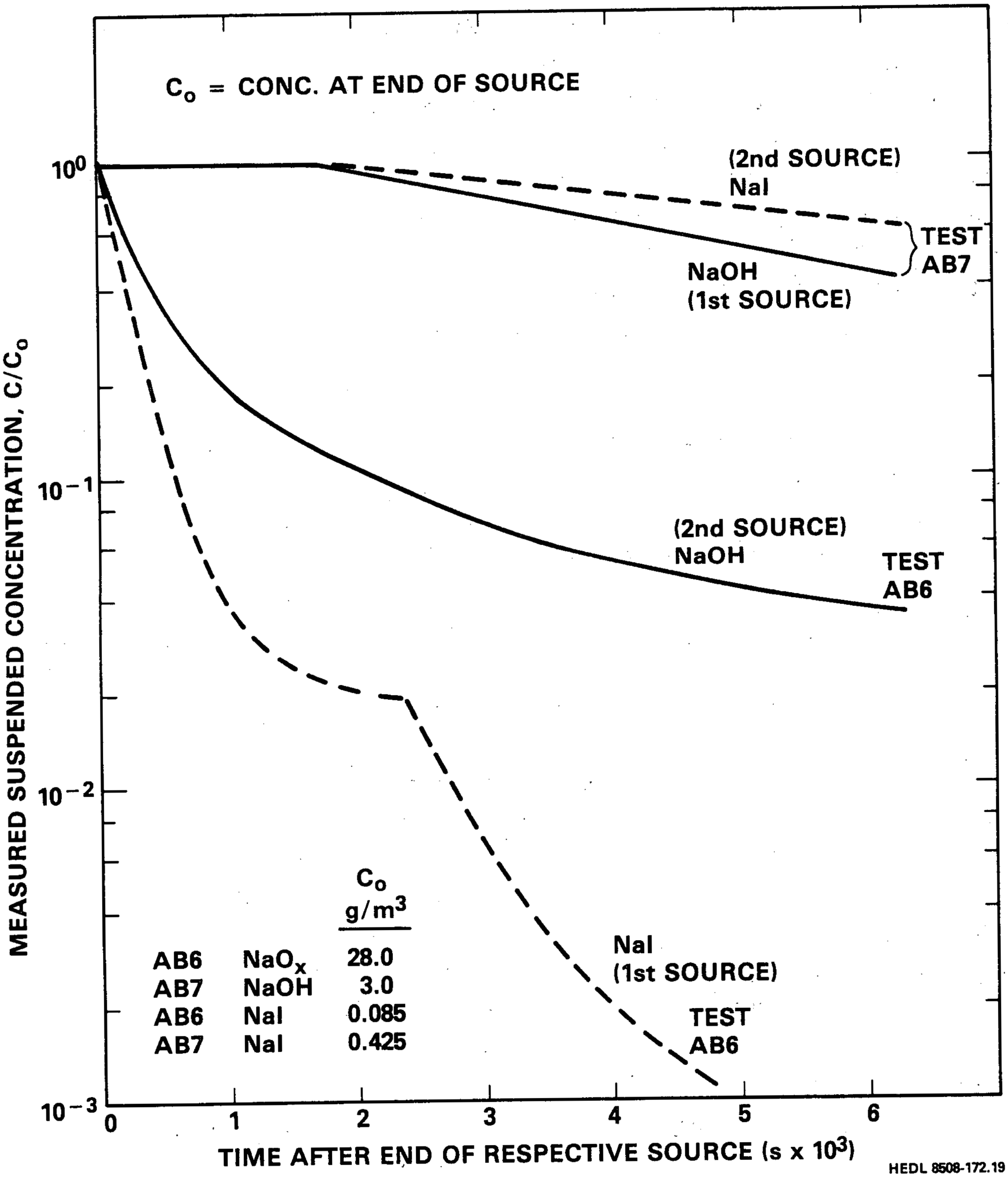

FIGURE 5-28. Comparison of Relative Rates of NaO_x and NaI Concentration Decay in Tests AB6 and AB7.

formation occurred in test AB6, there was a much lower probability of I_2 formation in test AB7. Another difference between the two tests was that in test AB7 the convection velocities were much lower, the aerosol deposit thickness was much thinner, and the deposit was wet and sticky, all of which tended to minimize resuspension in test AB7. Significant resuspension was suspected in test AB6[2]. Another difference in the two tests was that the ratio of NaI to NaO_x suspended mass was much higher for test AB7, enabling larger NaI samples to be taken, with better experimental accuracy for NaI.

The performance of codes in predicting the NaI suspended mass concentration in tests AB6 and AB7 is shown in Figure 5-29. In Figure 5-29 the dimensionless concentration, based on concentration at the end of the NaI source, is plotted on logarithmic paper as a function of time after the end of the NaI source. Interpretation of the test AB6 results is complicated because of the suspected resuspension of previously deposited aerosol, which may have caused the slowing of decay at times to 2400 s. The inflection in the AB6 experimental curve at 2400 s coincided with the end of the sodium spray fire and its attendant vigorous convection currents.

Figure 5-29 shows that the discrete codes agreed well with the AB6 experiment at times less than 1000 s and with test AB7 at all times. The log-normal codes overpredicted the AB6 experiment significantly at times less than 2400 s and underpredicted the AB7 experiment at all times. The HAA-4 code prediction is plotted separately from the other log-normal codes for test AB6 because it was in better agreement with experiment than the other log-normal codes. It predicted approximately the same as the other log-normal codes for test AB7.

The authors conclude that the discrete, sectionally uniform codes are capable of good accuracy in the prediction of the behavior of a multiple species aerosol with different source periods. The authors also conclude that the assumption of uniform coagglomeration used in all of the log-normal codes appears to be incorrect and can lead to significant error in predicting the minor mass species in a multiple species aerosol under some conditions.

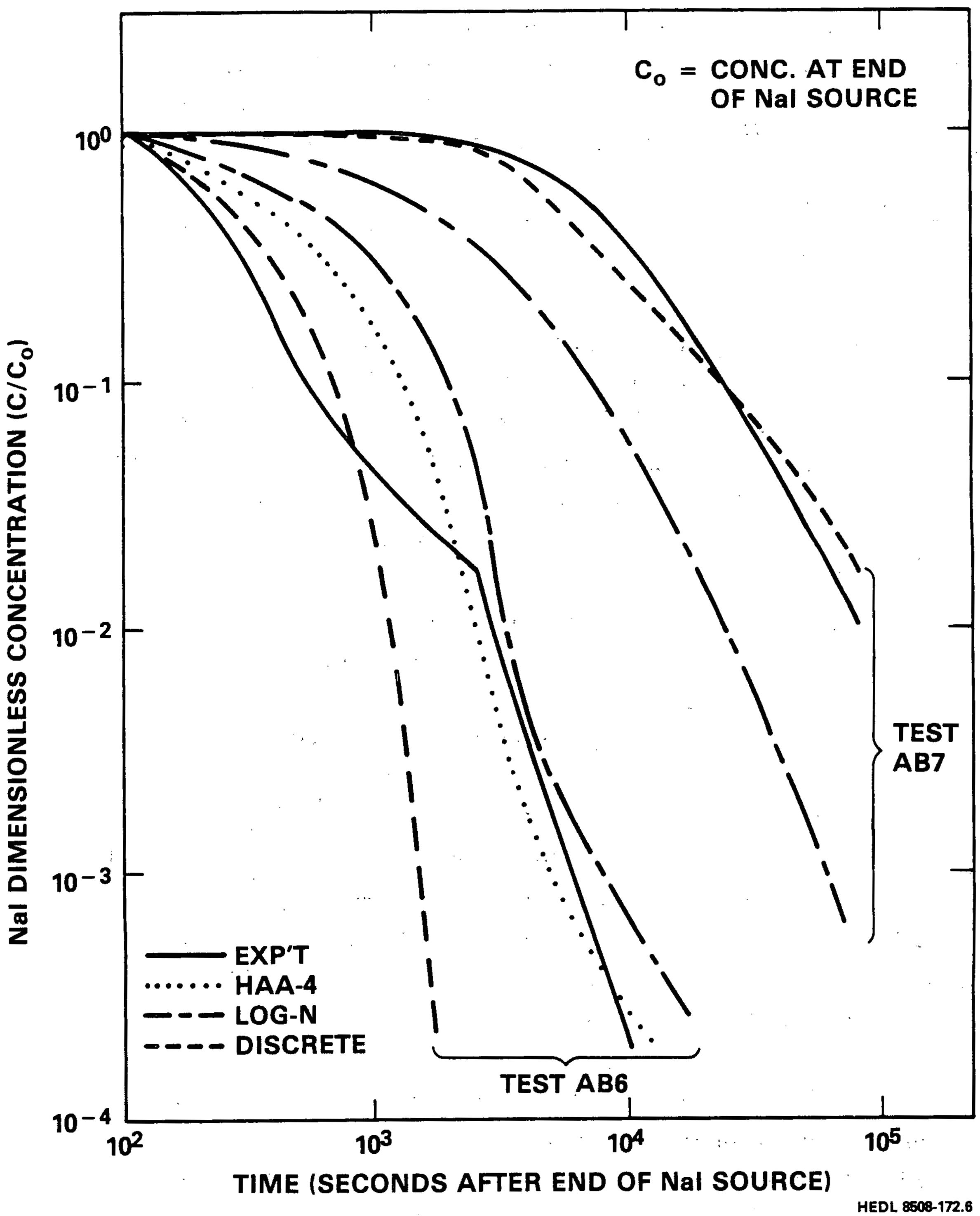

FIGURE 5-29. Comparison of Code Predictions of NaI Suspended Concentration for Tests AB6 and AB7.

6.0 REFERENCES

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APPENDIX A

DATA ACQUISITION SYSTEM CHANNEL IDENTIFICATION AND SENSOR LOCATION

APPENDIX A

DATA ACQUISITION SYSTEM CHANNEL IDENTIFICATION

The identification and location of each data acquisition system (DAS) channel is given in Table A-1. Coordinates used to define the thermocouple locations cited in Table A-1 are illustrated in Figure A-1.

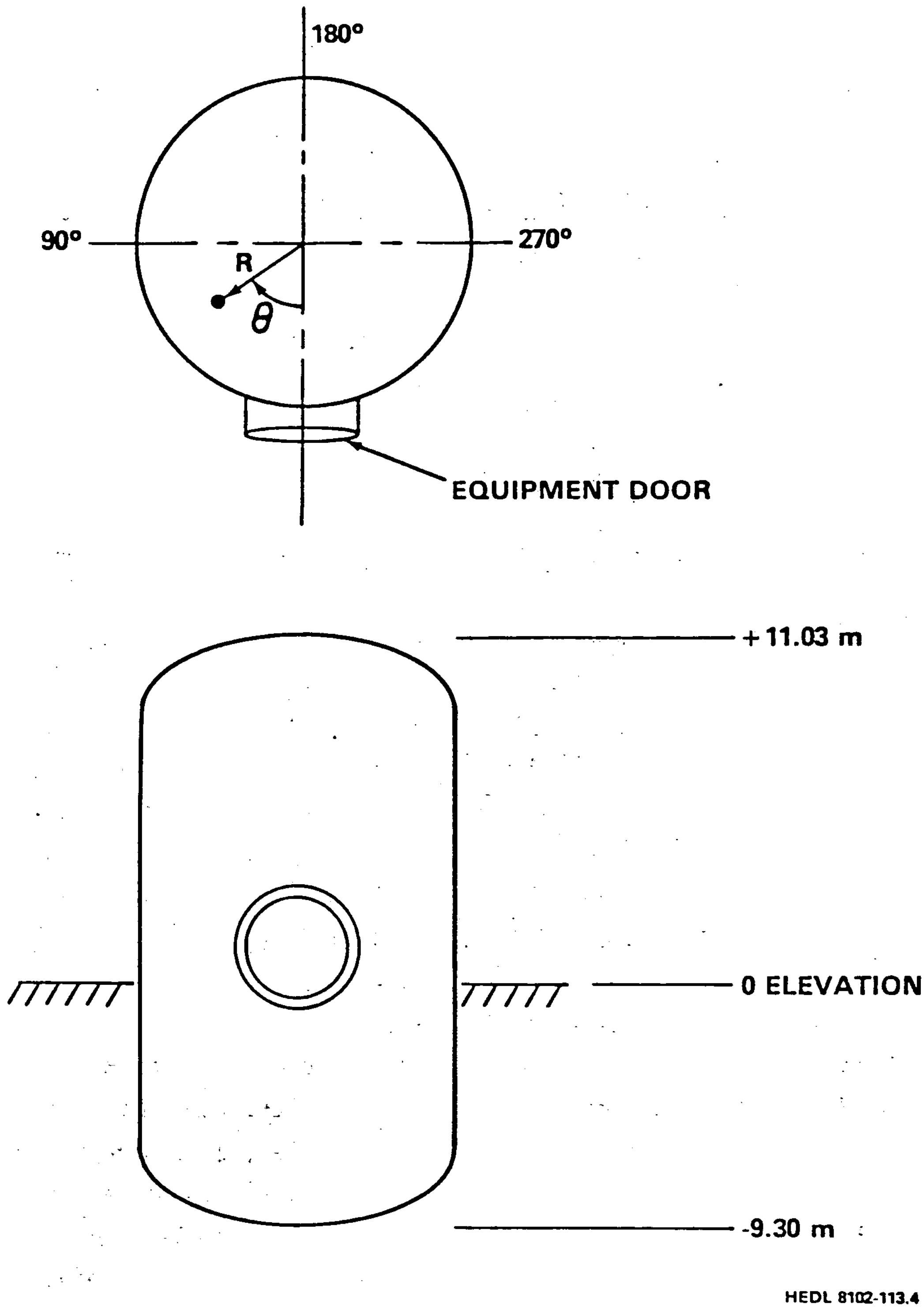

FIGURE A-1. Spatial Coordinates Used to Define Thermocouple Locations in Table A-1.

TABLE A-1

DATA ACQUISITION SYSTEM CHANNEL IDENTIFICATION - TEST AB7

No.	Recorder & Point	Measurement	Output	Description & Location
0	-	std temp	°F	Set at 100°
*1	3-1	CV atmos temp	°F	+9.15-m elev, 1.27-m radius, 150°
*2	3-2	CV atmos temp	°F	+5.79-m elev, 1.27-m radius, 175°
*3	3-3	CV atmos temp	°F	+2.44-m elev, 1.27-m radius, 175° 1/8" diam, 1/4" tube
*4	3-4	CV atmos temp	°F	-0.91-m elev, 1.27-m radius, 175° 1/8" diam, 1/4" tube
*5	3-5	CV atmos temp	°F	-3.96-m elev, 1.27-m radius, 175° 1/8" diam, 1/4" tube
*6	3-6	CV atmos temp	°F	-7.01-m elev, 1.27-m radius, 175° 1/8" diam, 1/4" tube
*7	3-7	CV atmos temp	°F	+9.15-m elev, 2.24-m radius, 160°
*8	3-8	CV atmos temp	°F	+5.79-m elev, 2.24-m radius, 175°
*9	3-9	CV atmos temp	°F	+2.44-m elev, 2.24-m radius, 175°
*10	3-10	CV atmos temp	°F	-0.91-m elev, 2.24-m radius, 175°
*11	3-11	CV atmos temp	°F	-3.96-m elev, 2.24-m radius, 175°
*13	3-13	CV atmos temp	°F	+9.15-m elev, 2.90-m radius, 170°
*14	3-14	CV atmos temp	°F	+5.79-m elev, 2.90-m radius, 175°
*15	3-15	CV atmos temp	°F	+2.44-m elev, 2.90-m radius, 175°
*16	3-16	CV atmos temp	°F	-0.91-m elev, 2.90-m radius, 175°
*17	3-17	CV atmos temp	°F	-3.96-m elev, 2.90-m radius, 175°
*18	3-18	CV atmos temp	°F	-7.01-m elev, 2.90-m radius, 175°
*19	3-19	CV atmos temp	°F	+9.15-m elev, 3.40-m radius, 170°
*20	3-20	CV atmos temp	°F	+5.61-m elev, 3.40-m radius, 175°
*21	3-21	CV atmos temp	°F	+2.44-m elev, 3.40-m radius, 175°
*22	3-22	CV atmos temp	°F	-0.73-m elev, 3.40-m radius, 175°
*23	3-23	CV atmos temp	°F	-4.27-m elev, 3.40-m radius, 175°
*24	3-24	CV atmos temp	°F	-7.01-m elev, 3.40-m radius, 175°

*Used in averaging to obtain mean atmospheric temperature.

TABLE A-1 (Cont'd)

No.	Recorder & Point	Measurement	Output	Description & Location
25**	6-1	CV steel temp	°F	Inside surface, +8.84-m elev, 180°
26**	6-2	CV steel temp	°F	Inside surface, +8.84-m elev, 0°
27	6-3	CV steel temp	°F	Inside surface, +4.57-m elev, 30°
28	6-4	CV steel temp	°F	Inside surface, +4.57-m elev, 210°
29	6-5	CV steel temp	°F	Inside surface, -0.91-m elev, 30°
30**	6-6	CV steel temp	°F	Inside surface, -0.91-m elev, 210°
32**	6-8	CV steel temp	°F	Inside surface, -3.66-m elev, 210°
33	6-9	CV 18-in I beam	°F	Surface, +8.5-m elev, 0" radius
34	6-10	CV atmos temp	°F	At T1 station, 0.15 m from wall
35	6-11	CV 18-in I beam	°F	Surface, +8.5-m elev, 2.44-m raduis
36	6-12	CV atmos temp	°F	At T2 station, 0.16 m from wall
37	6-13	CV 18-in I beam	°F	Surface, +8,5-m elev, 3.66-m, radius, 180°
38	6-14	CV steel temp	°F	Top dome surface, 0.31-m radius
39	6-15	CV atmos temp	°F	0.010 m from dome surface, 0.31-m radius
40	6-16	CV atmos temp	°F	0.019 m from dome surface, 0.31-m radius
41	6-17	CV atmos temp	°F	0.051 m from dome surface, 0.31-m radius
42	6-18	CV atmos temp	°F	0.305 m from dome surface, 0.31-m radius
43**	6-19	CV steel temp	°F	Inside surface -5.79-m elev, 225°
44	6-20	CV steel temp	°F	Inside surface -9.15-m elev, 300°
45	6-21	CV steel temp	°F	Inside surface -8.54-m elev, 180°
46	6-22	CV steel temp	°F	Inside surface -9.45-m elev, 300° bottom head
47	6-23	CV atmos temp	°F	-5.79-m elev, 1.22-m radius, 95°
48**	6-24	CV steel temp	°F	Inside surface +10.7-m elev, 1.22-m radius, 285°
49	11-1	CV steel temp	°F	Outside surface top dome center, +11.0-m elev
50**	11-2	CV steel temp	°F	Outside surface, +6.10-m elev, 180° azimuth
51**	11-3	CV steel temp	°F	Outside surface, +1.22-m elev, 180° azimuth
52**	11-4	CV steel temp	°F	Outside surface, -3.05-m elev, 180° azimuth

**Used in averaging to obtain mean temp. of CV steel.

TABLE A-1 (Cont'd)

No.	Recorder & Point	Measurement	Output	Description & Location
53**	11-5	CV steel temp	°F	Outside surface, -8.79-m elev, 135°
54	11-6	Outside air	°F	+9.15-m elev, 0.30-m from CV, 260°
55	11-7	Outside air	°F	+2.13-m elev, 0.30-m from CV, 180°
56	11-8	Outside air	°F	-6.10-m elev, 0.30-m from CV, 180°
57	11-9	Outside air	°F	Ex-CV room ventilation exhaust
58	11-10	18-in I beam	°F	-0.46-m radius, +8.5-m elev, embed, 180°
59	11-11	18-in I beam	°F	-3.36-m radius, +8.5-m elev, embed, 180°
61	11-13	CV atmos temp	°F	0.010 m from wall, +1.52 m elev, 100°
62	11-14	CV atmos temp	°F	0.020 m from wall, +1.52 m elev, 100°
63	11-15	CV atmos temp	°F	0.050 m from wall, +1.52 m elev, 100°
64	11-16	CV atmos temp	°F	0.305 m from wall, +1.52 m elev, 100°
65**	11-17	CV steel temp	°F	Inside surface +1.52 m elev, 100°
66**	11-18	CV steel temp	°F	Inside surface +4.27 m elev, 180°
67**	11-19	CV steel temp	°F	Inside surface +1.22 m elev, 345°
68**	11-20	CV steel temp	°F	Inside surface, -5.79 m elev, 30°
69	11-21	CV insulation	°F	Outer surface, -6.10 m elev, 108°
70	11-22	CV atmos temp	°F	At T3 station, -0.15 m from wall
71	11-23	CV insulation	°F	-3.96 m elev, outer surface 108°
77	5-5	CV atmos temp	°F	At T4 station, 0.15 m from wall
78		18-in I beam	°F	Surface, +8.5 m elev, 1.83 m radius, 180°
79		18-in I beam	°F	Surface, +8.5 elev, 3.05-m radius, 180°
80		CV atmos temp	°F	+6.71 m elev, 1.27 m radius, 175°
81		CV atmos temp	°F	+6.71 m elev, 2.90 m radius, 175°
82	5-10	CV steel temp	°F	Outside surface, +8.84-m elev, 270°
83	5-11	CV steel temp	°F	Outside surface, -0.92-m elev, 30°
84	5-12	CV steel temp	°F	Outside surface, -7.01-m elev, 90°
85		CV steel temp	°F	HM-3 Temp, outer wall, +0.46-m elev, 266°

**Used in averaging to obtain mean temp. of steel.

TABLE A-1 (Cont'd)

No.	Recorder & Point	Measurement	Output	Description & Location
86		CV steel temp	°F	HM-2 Temp, outer wall, +0.46-m elev, 254°
87		CV steel temp	°F	HM-4 Temp, inside wall, +8.54-m elev, 280°
88		CV steel temp	°F	HM-5 Temp, inside wall, +5.49-m elev, 327°
89		CV steel temp	°F	HM-6 Temp, inside wall, -6.10-m elev, 327°
90		CV atmos temp	°F	-0.91-m elev, 0.91-m radius
91		CV atmos temp	°F	-0.91-m elev, centerline
93		CV atmos temp	°F	-4.27-m elev, centerline
92		CV atmos temp	°F	-4.27-m elev, 0.91-m radius
97		Na line temp	°F	Na line 1.22-m from nozzle
98		Nozzle temp	°F	Na spray nozzle
102		CV steel	°F	Catch pan floor, -8.48-m elev, center
103		CV atmos	°F	0.30 m above catch pan
104		Temperature	°F	NaI Liquid Temp
105		Temperature	°F	Nucleator outlet temp
113	3-12	Sodium temp	°F	Sodium supply tank, TK-2
141	7-4	Percent O_2	mV	+6.10 m elev, 3.51 m radius, 255°
159	7-11	Percent O_2	mV	-6.70 m elev, 3-51 m radius, 70°
163	8-Red	CV Pressure	mV	CV Pressure 600MV = 60 PSIA = 413.7 kPa
164	10 Red	Diff Pressure	mV	Differential pressure between TK-2 and CV
166	9 Green	Diff Pressure	mV	CV and spray nozzle pressure diff
167		Heat Flux	mV	HM-1, 8.21 BTU/Ft^2-Hr-mV, +0.46 m elev, 254°, inside wall surface
168		Heat Flux	mV	HM-2, 8.27 BTU/Ft^2-Hr-mV, +0.46 m elev, 254°, outside wall surface
169		Heat Flux	mV	HM-3, 8.08 BTU/Ft^2-Hr-mV, +0.46 m elev, 260°, outside surface under insulation
170		Heat Flux	mV	HM-4, 9.05 BTU/Ft^2-Hr-mV, +8.54 m elev, 280°, inside wall surface

TABLE A-1 (Cont'd)

No.	Recorder & Point	Measurement	Output	Description & Location
171		Heat Flux	mV	HM-5, 9.23 BTU/Ft^2-Hr-mV, +5.49 m elev, 327°, inside wall surface
172		Heat Flux	mV	HM-6 11.25 BTU/Ft^2-Hr-mV, 6.40 m elev, 327°, inside wall surface
174	7-1	Dewpoint	mV	+6.10 m elev, 3.51 m radius, 255° 100mV = 37.8°C
175	7-2	Dewpoint	mV	-6.70 m elev, 3.51 m radius, 70° 100mV = 37.8°C
178	7-5	Percent H_2	mV	+6.10 m elev, 3.51 m radius, 255° 100mV = 37.8°C
179	7-6	Percent H_2	mV	-6.70 m elev, 3.51 m radius, 70° 100mV =
180	4-Red	Sodium flow	mV	Sodium spray rate, 10 mV = 630 g/s
181	8-Blue	Sodium mass, lb	mV	Load cell on TK-2, 600 mV=600 lb=272 kg
182	9-Red	Rad. Heat Flux	mV	Radiant heat flux meter, -1.93 m elev, 8[illegible] azimuth, 0.47 m from outer wall

APPENDIX B

DIGITAL TEST DATA OUTPUT FOR INITIAL 56 MINUTES FOR ALL CHANNELS

APPENDIX B

DIGITAL OUTPUT FOR INTIAL 56 MINUTES FOR ALL CHANNELS

All the digital data recorded on magnetic tape during the initial 56 minutes of test AB7 are listed in Tables B-1 through B-13. After 56 minutes, temperatures were fairly uniform throughout the vessel and the average values given in Appendix C can be used.

Identification of each data acquisition system (DAS) channel is provided in Appendix A.

The contents of Tables B-1 through B-13 are as follows:

Tables	Channels
B-1	DAS 1 through DAS 9
B-2	DAS 10 through DAS 19
B-3	DAS 20 through DAS 28
B-4	DAS 29 through DAS 38
B-5	DAS 39 through DAS 47
B-6	DAS 48 through DAS 56
B-7	DAS 57 through DAS 66
B-8	DAS 67 through DAS 80
B-9	DAS 81 through DAS 89
B-10	DAS 90 through DAS 101
B-11	DAS 102 through DAS 164
B-12	DAS 166 through DAS 179
B-13	DAS 181 through DAS 182

TABLE B-1

DIGITAL OUTPUT FOR CHANNELS 1 THROUGH 9 -- TEST AB7
(REFER TO TABLE A-1 FOR CHANNEL DESCRIPTIONS)

TIME SECONDS	DAS# 1 DEG C	DAS# 2 DEG C	DAS# 3 DEG C	DAS# 4 DEG C	DAS# 5 DEG C	DAS# 6 DEG C	DAS# 7 DEG C	DAS# 8 DEG C	DAS# 9 DEG C
-4.7	25.1	23.8	23.7	23.4	23.4	22.8	25.6	24.1	23.9
-3.9	25.1	23.8	23.7	23.5	23.4	22.8	25.6	24.1	23.9
-3.0	25.1	23.8	23.7	23.4	23.4	22.8	25.6	24.1	23.8
-2.2	25.1	23.8	23.7	23.4	23.4	22.8	25.6	24.1	23.8
-1.4	25.1	23.8	23.7	23.4	23.5	22.8	25.6	24.1	23.9
-0.5	25.1	23.9	23.7	23.4	23.5	22.8	25.6	24.1	23.9
0.3	32.9	23.9	23.8	23.7	23.6	23.0	29.2	25.2	25.0
1.1	55.3	29.0	25.4	24.8	24.5	23.4	53.6	41.8	30.4
2.0	47.7	32.1	26.7	25.1	24.7	23.6	48.1	39.2	30.6
2.8	44.1	33.3	27.4	25.2	24.7	23.6	44.6	36.7	30.7
3.6	42.1	33.6	27.8	25.3	24.8	23.6	42.4	34.7	30.0
4.5	40.2	33.4	27.9	25.4	24.8	23.6	40.3	33.0	29.6
5.3	38.5	33.0	28.1	25.4	24.8	23.6	38.8	31.9	29.3
6.1	37.3	32.4	28.1	25.5	24.8	23.6	37.7	30.7	28.7
7.0	35.1	31.8	28.1	25.7	25.0	23.7	36.4	30.3	28.6
7.8	33.3	31.3	28.1	25.8	25.1	23.7	34.2	29.9	28.5
8.6	33.9	30.8	28.1	25.9	25.2	23.8	34.1	29.3	28.4
9.5	33.8	30.4	28.0	25.9	25.2	23.8	34.1	29.1	27.4
10.3	33.7	30.0	27.8	25.9	25.2	23.8	34.0	28.7	27.4
11.1	33.3	29.5	27.6	26.0	25.2	23.9	33.7	27.7	27.1
12.0	33.0	29.0	27.4	26.1	25.3	24.0	33.3	27.4	27.1
12.8	32.7	28.6	27.3	26.2	25.4	24.1	33.0	27.3	27.2
13.6	32.4	28.2	27.3	26.2	25.5	24.3	32.8	27.4	27.3
14.5	32.1	27.9	27.4	26.3	25.6	24.4	32.6	27.6	27.4
15.3	31.7	27.8	27.4	26.4	25.7	24.5	32.1	27.6	27.4
16.1	31.4	27.7	27.4	26.5	25.8	24.6	31.9	27.7	27.6
21.1	29.4	27.6	27.7	26.8	26.3	25.3	29.5	27.9	27.8
26.1	29.3	27.9	28.0	27.1	26.7	25.8	29.5	28.4	28.2
31.1	29.5	28.3	28.3	27.5	27.1	26.3	29.5	28.8	28.6
36.1	28.9	28.3	28.4	27.7	27.3	26.3	29.1	28.4	28.3
41.1	29.2	27.9	28.0	27.5	27.0	25.9	29.6	27.8	27.8
46.1	29.1	27.3	27.4	27.0	26.4	25.4	29.6	27.1	27.1
51.1	28.9	26.9	26.9	26.6	25.9	25.0	29.4	26.8	26.6
56.1	28.8	26.8	26.6	26.3	25.6	24.7	29.4	26.8	26.3

TABLE B-2

DIGITAL OUTPUT FOR CHANNELS 10 THROUGH 19 -- TEST AB7
(REFER TO TABLE A-1 FOR CHANNEL DESCRIPTIONS)

TIME SECONDS	DAS# 10 DEG C	DAS# 11 DEG C	DAS# 13 DEG C	DAS# 14 DEG C	DAS# 15 DEG C	DAS# 16 DEG C	DAS# 17 DEG C	DAS# 18 DEG C	DAS# 19 DEG C
-4.7	23.7	23.6	25.2	21.4	23.9	23.7	23.8	22.9	25.3
-3.9	23.7	23.6	25.3	24.3	24.0	23.7	23.8	23.0	25.4
-3.0	23.7	23.6	25.3	24.3	24.0	23.7	23.7	23.0	25.4
-2.2	23.6	23.7	25.3	24.3	23.9	23.7	23.8	22.9	25.4
-1.4	23.7	23.6	25.3	24.3	24.0	23.7	23.8	23.0	25.4
-0.5	23.7	23.7	25.3	24.3	24.0	23.7	23.8	23.0	25.4
0.3	24.8	24.3	31.1	25.5	25.0	24.6	24.6	23.7	31.9
1.1	26.8	26.1	53.2	40.7	32.0	27.6	26.7	24.9	54.8
2.0	26.5	25.7	47.9	38.0	31.9	26.8	26.1	24.7	50.6
2.8	26.3	25.4	44.2	35.8	31.2	26.4	25.7	24.3	47.1
3.6	26.3	25.2	41.4	34.2	30.4	26.3	25.4	24.1	44.4
4.5	26.2	25.1	39.7	32.9	29.9	26.2	25.3	24.0	42.4
5.3	26.0	25.0	38.3	32.2	29.5	25.9	25.2	24.0	40.7
6.1	26.2	25.1	37.1	30.9	29.0	26.3	25.3	24.0	39.3
7.0	26.6	25.3	36.3	30.5	28.7	26.8	25.6	24.2	38.4
7.8	26.5	25.4	34.4	30.3	28.7	26.7	25.7	24.2	36.4
8.6	26.6	25.6	34.2	29.7	28.4	26.7	25.7	24.2	36.2
9.5	26.4	25.5	33.8	29.4	27.6	26.2	25.6	24.3	35.4
10.3	26.3	25.3	33.6	29.1	27.4	26.4	25.6	24.3	34.7
11.1	26.4	25.5	33.2	28.2	27.1	26.4	25.7	24.3	34.3
12.0	26.4	25.6	32.8	27.8	27.1	26.6	25.9	24.3	33.8
12.8	26.7	25.9	32.6	27.8	27.2	26.7	26.2	24.5	33.3
13.6	26.7	25.9	32.3	27.7	27.3	26.8	26.3	24.7	32.8
14.5	26.7	26.1	31.9	27.8	27.4	26.7	26.3	24.7	32.5
15.3	26.9	26.2	31.6	27.8	28.2	26.9	26.4	24.8	32.1
16.1	26.9	26.3	31.2	27.9	27.6	27.0	26.6	24.8	32.1
21.1	27.2	26.8	29.9	28.0	27.8	27.3	26.9	25.3	30.4
26.1	27.5	27.1	29.3	28.5	28.1	27.6	27.3	25.7	29.7
31.1	27.8	27.4	29.1	28.8	28.4	27.9	27.6	25.9	29.3
36.1	27.9	27.4	28.8	28.6	28.3	27.9	27.6	25.8	28.8
41.1	27.4	26.8	29.3	28.1	27.8	27.4	26.9	25.3	29.6
46.1	26.6	26.1	29.3	27.3	27.1	26.7	26.1	24.9	29.3
51.1	26.2	25.6	29.1	27.1	26.7	26.2	25.7	24.7	29.2
56.1	26.0	25.4	29.0	27.0	26.4	26.0	25.4	24.5	29.1

TABLE B-3

DIGITAL OUTPUT FOR CHANNELS 20 THROUGH 28 -- TEST AB7
(REFER TO TABLE A-1 FOR CHANNEL DESCRIPTIONS)

TIME SECONDS	DAS# 20 DEG C	DAS# 21 DEG C	DAS# 22 DEG C	DAS# 23 DEG C	DAS# 24 DEG C	DAS# 25 DEG C	DAS# 26 DEG C	DAS# 27 DEG C	DAS# 28 DEG C
-4.7	24.0	23.9	23.6	23.3	22.7	22.9	22.9	22.8	22.8
-3.9	24.1	23.9	23.6	23.4	22.7	23.0	22.9	22.8	22.8
-3.0	24.0	23.9	23.6	23.4	22.7	23.0	22.9	22.8	22.8
-2.2	24.0	23.9	23.6	23.4	22.7	23.0	22.9	22.8	22.8
-1.4	24.1	23.9	23.6	23.4	22.7	23.0	22.9	22.8	22.8
-0.5	24.1	23.9	23.7	23.4	22.7	23.1	23.0	22.8	22.8
0.3	25.2	25.0	24.5	24.1	23.4	23.9	23.3	22.8	22.8
1.1	43.9	32.2	27.6	25.7	25.0	24.9	23.7	23.3	23.0
2.0	39.5	31.8	26.8	25.4	24.5	24.7	23.7	23.8	23.1
2.8	36.5	31.9	26.6	25.2	24.2	24.6	23.7	24.1	23.4
3.6	34.2	31.1	26.4	25.1	24.1	24.6	23.8	24.2	23.5
4.5	32.7	30.4	26.7	25.1	24.1	24.6	23.8	24.2	23.7
5.3	31.2	29.7	26.2	25.0	24.1	24.6	23.9	24.2	23.8
6.1	30.6	28.9	27.0	25.2	24.1	24.6	24.0	24.2	23.8
7.0	30.1	28.7	27.3	25.4	24.2	24.5	24.0	24.1	23.9
7.8	29.9	28.8	26.8	25.6	24.3	24.4	24.1	24.1	23.9
8.6	29.3	28.3	26.9	25.6	24.2	24.6	24.1	24.1	23.9
9.5	28.8	27.8	26.8	25.5	24.2	24.6	24.2	24.1	24.0
10.3	28.4	27.6	26.6	25.5	24.1	24.6	24.2	24.1	24.0
11.1	28.1	27.2	26.7	25.5	24.2	24.6	24.2	24.1	24.0
12.0	27.5	26.9	26.6	25.6	24.2	24.6	24.2	24.0	24.0
12.8	27.3	26.9	26.6	25.7	24.3	24.7	24.3	24.0	24.0
13.6	27.2	26.9	26.6	25.8	24.4	24.6	24.3	24.0	24.0
14.5	27.2	27.0	26.7	25.9	24.6	24.7	24.4	24.0	24.1
15.3	27.2	27.1	26.8	26.0	24.7	24.7	24.4	24.0	24.1
16.1	27.3	27.2	26.8	26.1	24.7	24.6	24.4	24.0	24.1
21.1	27.4	27.4	27.0	26.4	25.1	24.7	24.6	24.1	24.1
26.1	27.9	27.7	27.3	26.7	25.5	24.8	24.7	24.2	24.2
31.1	28.2	27.9	27.6	27.0	25.7	24.9	24.8	24.3	24.4
36.1	28.1	27.9	27.6	27.0	25.5	25.1	24.9	24.5	24.6
41.1	27.5	27.4	27.2	26.4	25.1	25.1	25.1	24.4	24.7
46.1	27.0	26.8	26.5	25.7	24.6	25.2	25.2	24.6	24.7
51.1	26.8	26.4	26.1	25.3	24.3	25.3	25.2	24.6	24.7
56.1	26.7	26.2	25.9	25.1	24.1	25.3	25.3	24.6	24.7

TABLE B-4

DIGITAL OUTPUT FOR CHANNELS 29 THROUGH 38 -- TEST AB7
(REFER TO TABLE A-1 FOR CHANNEL DESCRIPTIONS)

TIME SECONDS	DAS# 29 DEG C	DAS# 30 DEG C	DAS# 32 DEG C	DAS# 33 DEG C	DAS# 34 DEG C	DAS# 35 DEG C	DAS# 36 DEG C	DAS# 37 DEG C	DAS# 38 DEG C
-4.7	22.8	22.7	23.0	23.3	23.9	23.6	23.9	23.1	24.1
-3.9	22.8	22.7	23.1	23.3	23.9	23.6	23.9	23.1	24.0
-3.0	22.8	22.6	23.1	23.3	23.9	23.6	23.9	23.1	24.0
-2.2	22.8	22.7	23.1	23.3	23.8	23.6	23.9	23.1	24.1
-1.4	22.8	22.7	23.1	23.3	23.8	23.6	23.8	23.1	24.1
-0.5	22.8	22.7	23.1	23.3	23.9	23.6	23.9	23.1	24.1
0.3	22.9	22.7	22.8	23.6	52.7	23.8	32.6	23.7	35.8
1.1	23.1	22.9	23.1	24.9	49.7	25.1	33.2	24.2	35.8
2.0	23.2	23.0	23.1	24.9	43.9	25.0	32.3	24.6	34.2
2.8	23.2	23.0	23.1	24.8	39.6	25.2	31.4	24.6	33.7
3.6	23.2	23.1	23.2	24.7	36.4	25.2	30.6	24.7	32.8
4.5	23.3	23.1	23.2	24.7	34.2	25.3	29.9	24.7	32.5
5.3	23.3	23.1	23.2	24.9	32.6	25.3	29.5	24.7	31.6
6.1	23.3	23.1	23.2	24.8	31.5	25.3	29.0	24.9	31.2
7.0	23.4	23.1	23.2	24.9	30.9	25.4	28.8	24.8	30.6
7.8	23.4	23.2	23.2	24.9	30.4	25.4	28.6	24.9	30.0
8.6	23.4	23.2	23.3	25.0	29.9	25.6	28.3	24.9	30.1
9.5	23.5	23.2	23.3	25.0	29.2	25.6	28.1	24.9	29.7
10.3	23.5	23.2	23.3	25.1	28.7	25.7	27.9	24.9	29.4
11.1	23.5	23.2	23.3	25.1	28.1	25.7	27.7	25.1	29.2
12.0	23.5	23.3	23.3	25.0	27.8	25.7	27.7	25.0	28.9
12.8	23.5	23.3	23.4	25.1	27.7	25.7	27.4	25.1	28.7
13.6	23.6	23.3	23.4	25.1	27.4	25.8	27.4	25.1	28.5
14.5	23.6	23.3	23.4	25.1	27.6	25.8	27.4	25.1	28.4
15.3	23.6	23.3	23.4	25.1	27.6	25.8	27.4	25.1	28.4
16.1	23.6	23.3	23.4	25.1	27.7	25.8	27.4	25.1	28.2
21.1	23.7	23.5	23.6	25.2	27.6	25.9	27.4	25.2	27.9
26.1	23.9	23.6	23.7	25.3	27.9	26.1	27.7	25.3	27.7
31.1	24.0	23.8	23.8	25.4	28.1	26.3	28.3	25.3	27.6
36.1	24.2	23.9	23.9	25.6	27.9	26.4	28.2	25.4	27.6
41.1	24.3	24.1	24.0	25.6	27.6	26.5	27.5	25.6	27.7
46.1	24.3	24.1	24.1	25.7	26.4	26.6	26.8	25.6	27.8
51.1	24.3	24.1	24.1	25.7	26.1	26.7	26.3	25.7	27.8
56.1	24.3	24.2	24.2	25.8	25.9	26.7	26.1	25.7	27.9

TABLE B-5

DIGITAL OUTPUT FOR CHANNELS 39 THROUGH 47 -- TEST AB7
(REFER TO TABLE A-1 FOR CHANNEL DESCRIPTIONS)

TIME SECONDS	DAS# 39 DEG C	DAS# 40 DEG C	DAS# 41 DEG C	DAS# 42 DEG C	DAS# 43 DEG C	DAS# 44 DEG C	DAS# 45 DEG C	DAS# 46 DEG C	DAS# 47 DEG C
-4.7	26.7	27.1	27.6	28.2	22.7	22.4	22.4	21.6	23.6
-3.9	26.7	27.2	27.7	28.2	22.7	22.4	22.4	21.6	23.7
-3.0	26.7	27.1	27.7	28.1	22.7	22.4	22.4	21.7	23.6
-2.2	26.6	27.1	27.6	28.2	22.7	22.4	22.4	21.6	23.6
-1.4	26.9	27.1	27.7	28.1	22.7	22.4	22.3	21.6	23.6
-0.5	26.9	27.3	27.8	28.2	22.7	22.4	22.4	21.5	23.7
0.3	53.5	59.7	62.0	66.5	22.7	22.4	22.6	21.5	24.5
1.1	56.0	58.2	61.2	62.9	22.9	22.6	22.8	21.7	26.4
2.0	51.7	54.1	56.8	58.8	23.1	22.6	22.8	21.8	26.3
2.8	50.4	52.7	55.2	56.4	23.1	22.7	22.7	21.8	25.8
3.6	48.2	50.4	52.8	54.2	23.2	22.7	22.7	21.9	25.4
4.5	46.6	48.7	50.8	51.8	23.2	22.7	22.5	21.9	25.2
5.3	44.4	46.3	48.4	49.6	23.2	22.7	22.6	21.8	25.2
6.1	43.4	45.3	47.2	48.0	23.2	22.7	22.6	21.7	25.2
7.0	41.2	42.9	44.8	45.4	23.3	22.7	22.7	21.6	25.4
7.8	39.9	41.6	43.1	43.4	23.3	22.7	22.7	21.5	25.8
8.6	39.4	40.8	42.2	42.3	23.3	22.7	22.7	21.7	25.8
9.5	38.2	39.6	41.1	41.8	23.3	22.7	22.7	21.6	25.7
10.3	37.3	38.3	39.7	40.3	23.3	22.6	22.6	21.7	25.8
11.1	36.3	37.7	39.0	39.4	23.3	22.7	22.7	21.6	25.9
12.0	35.7	36.8	38.1	38.5	23.3	22.6	22.7	21.6	26.0
12.8	34.7	35.7	36.9	37.5	23.3	22.6	22.7	21.5	26.2
13.6	34.3	35.2	36.4	36.8	23.4	22.7	22.7	21.4	26.1
14.5	33.9	34.7	35.7	36.2	23.4	22.7	22.7	21.4	26.2
15.3	33.8	34.6	35.6	36.1	23.4	22.7	22.7	21.4	26.3
16.1	33.2	34.0	35.0	35.6	23.5	22.7	22.7	21.4	26.4
21.1	31.9	32.4	33.2	33.6	23.7	22.7	22.8	21.5	26.7
26.1	30.9	31.3	32.0	32.4	23.8	22.7	22.9	21.6	26.9
31.1	30.6	31.0	31.5	31.7	23.9	22.8	23.0	21.9	27.3
36.1	30.4	30.7	31.2	31.3	24.1	22.8	23.0	21.8	27.2
41.1	30.7	30.8	31.3	31.5	24.1	22.8	23.0	22.1	26.8
46.1	30.8	31.2	31.7	31.7	24.0	22.8	22.9	22.1	25.8
51.1	30.6	30.9	31.4	31.7	23.9	22.8	22.9	21.9	25.3
56.1	30.7	31.1	31.5	31.8	23.9	22.8	22.9	21.4	25.1

TABLE B-6

DIGITAL OUTPUT FOR CHANNELS 48 THROUGH 56 -- TEST A87
(REFER TO TABLE A-1 FOR CHANNEL DESCRIPTIONS)

TIME SECONDS	DAS# 48 DEG C	DAS# 49 DEG C	DAS# 50 DEG C	DAS# 51 DEG C	DAS# 52 DEG C	DAS# 53 DEG C	DAS# 54 DEG C	DAS# 55 DEG C	DAS# 56 DEG C
-4.7	20.6	24.6	22.9	22.9	22.1	22.6	20.7	19.9	20.4
-3.9	20.7	24.6	22.9	22.9	22.1	22.7	20.8	19.9	20.3
-3.0	20.7	24.6	22.9	22.9	22.1	22.6	20.8	19.8	20.6
-2.2	20.7	24.6	22.9	22.9	22.1	22.7	20.7	19.8	20.7
-1.4	20.7	24.7	22.9	22.9	22.1	22.7	20.8	19.8	20.6
-0.5	20.6	24.7	23.0	22.9	22.1	22.7	20.8	19.9	20.7
0.3	20.7	24.7	23.0	23.2	22.1	22.7	20.8	20.0	20.7
1.1	20.7	25.0	23.2	23.0	22.1	22.7	20.7	20.1	20.4
2.0	20.7	25.3	23.3	23.1	22.1	22.7	20.8	19.9	20.3
2.8	20.7	25.6	23.4	23.1	22.1	22.7	20.9	19.9	20.6
3.6	20.7	25.8	23.4	23.1	22.1	22.7	20.9	19.9	20.3
4.5	20.7	26.1	23.6	23.2	22.1	22.7	20.9	20.0	20.4
5.3	20.8	26.3	23.6	23.2	22.1	22.7	20.9	19.9	20.8
6.1	20.8	26.6	23.6	23.3	22.1	22.7	20.9	20.0	20.8
7.0	20.8	26.7	23.7	23.3	22.1	22.7	20.8	19.9	20.9
7.8	20.7	26.9	23.7	23.3	22.1	22.7	20.8	19.9	20.8
8.6	20.7	27.0	23.7	23.3	22.1	22.7	20.9	20.1	20.8
9.5	20.8	27.2	23.8	23.4	22.1	22.7	20.8	19.9	20.6
10.3	20.8	27.3	23.8	23.4	22.1	22.7	20.8	19.9	20.7
11.1	20.7	27.4	23.8	23.4	22.1	22.7	20.9	20.0	20.4
12.0	20.8	27.5	23.8	23.4	22.1	22.7	20.8	20.1	20.6
12.8	20.6	27.6	23.9	23.4	22.2	22.8	20.8	19.9	20.7
13.6	20.8	27.6	23.9	23.5	22.1	22.8	20.8	19.9	20.4
14.5	20.9	27.7	23.9	23.5	22.1	22.7	20.9	19.9	20.8
15.3	20.8	27.7	23.9	23.5	22.1	22.8	21.1	19.9	20.8
16.1	20.8	27.8	24.0	23.6	22.1	22.8	20.9	20.0	20.2
21.1	20.9	28.1	24.1	23.7	22.2	22.8	20.9	20.0	20.6
26.1	20.9	28.2	24.3	23.8	22.2	22.8	21.1	20.0	20.7
31.1	20.9	28.3	24.4	23.9	22.2	22.8	21.2	20.1	20.7
36.1	20.9	28.4	24.6	24.1	22.3	22.9	21.3	20.1	20.9
41.1	21.0	28.6	24.7	24.2	22.3	22.9	21.1	20.1	20.5
46.1	21.1	28.7	24.8	24.3	22.3	22.9	21.1	20.1	20.6
51.1	20.8	28.7	24.8	24.3	22.3	22.9	21.3	20.0	20.6
56.1	20.9	28.8	24.9	24.3	22.4	22.9	21.1	20.1	20.8

TABLE B-7

DIGITAL OUTPUT FOR CHANNELS 57 THROUGH 66 -- TEST A87
(REFER TO TABLE A-1 FOR CHANNEL DESCRIPTIONS)

TIME SECONDS	DAS# 57 DEG C	DAS# 58 DEG C	DAS# 59 DEG C	DAS# 61 DEG C	DAS# 62 DEG C	DAS# 63 DEG C	DAS# 64 DEG C	DAS# 65 DEG C	DAS# 66 DEG C
-4.7	19.8	23.4	23.5	23.4	23.6	23.8	24.0	22.7	22.4
-3.9	19.9	23.4	23.5	23.3	23.5	23.7	24.0	22.7	22.4
-3.0	19.8	23.4	23.5	23.3	23.6	23.8	24.0	22.8	22.4
-2.2	19.9	23.4	23.6	23.4	23.6	23.8	24.0	22.7	22.4
-1.4	19.9	23.4	23.6	23.4	23.6	23.8	24.1	22.7	22.4
-0.5	19.9	23.5	23.6	23.4	23.6	23.8	24.0	22.7	22.4
0.3	19.9	23.5	23.6	24.7	25.1	25.3	25.6	22.9	22.6
1.1	20.1	23.6	24.2	28.7	29.1	29.3	29.0	23.3	22.8
2.0	19.9	23.7	24.3	30.2	30.8	31.4	30.9	23.4	23.0
2.8	19.9	23.8	24.3	30.1	30.7	31.3	31.4	23.5	23.1
3.6	19.9	23.8	24.4	28.9	29.4	29.9	30.6	23.4	23.2
4.5	19.9	23.9	24.4	27.7	28.1	28.7	29.4	23.4	23.2
5.3	19.9	24.0	24.5	26.9	27.3	27.8	28.6	23.4	23.2
6.1	20.0	24.1	24.6	26.9	27.3	27.7	28.4	23.4	23.2
7.0	19.9	24.2	24.7	27.0	27.6	28.1	28.4	23.4	23.2
7.8	19.9	24.2	24.8	27.0	27.4	27.9	28.5	23.4	23.2
8.6	20.0	24.3	24.8	26.6	27.1	27.5	28.3	23.4	23.2
9.5	20.1	24.3	24.9	26.8	27.0	27.4	27.9	23.4	23.2
10.3	20.0	24.4	25.0	26.1	26.6	26.9	27.6	23.4	23.2
11.1	20.1	24.5	25.1	26.2	26.5	26.9	27.4	23.4	23.2
12.0	19.9	24.6	25.1	26.2	26.6	26.9	27.3	23.5	23.2
12.8	19.9	24.6	25.2	26.0	26.4	26.8	27.3	23.5	23.2
13.6	19.9	24.6	25.2	26.1	26.6	27.0	27.4	23.5	23.2
14.5	19.9	24.7	25.2	26.0	26.4	26.8	27.3	23.5	23.2
15.3	20.1	24.7	25.3	26.1	26.4	26.9	27.4	23.6	23.2
16.1	20.0	24.8	25.3	26.1	26.5	26.9	27.4	23.6	23.3
21.1	20.0	25.1	25.6	26.2	26.7	27.2	27.7	23.7	23.4
26.1	19.9	25.2	25.8	26.7	27.1	27.4	27.9	23.8	23.6
31.1	20.1	25.4	25.9	26.8	27.3	27.7	28.2	23.9	23.7
36.1	20.1	25.7	26.1	26.9	27.4	27.7	28.1	24.1	23.8
41.1	20.2	25.8	26.2	26.4	26.8	27.2	27.6	24.2	23.9
46.1	20.1	25.9	26.3	25.7	26.0	26.3	26.6	24.2	23.9
51.1	20.1	26.1	26.4	25.5	25.8	26.0	26.4	24.2	23.9
56.1	20.1	26.2	26.4	25.4	25.7	25.9	26.2	24.2	23.9

TABLE B-8

DIGITAL OUTPUT FOR CHANNELS 67 THROUGH 80 -- TEST A07
(REFER TO TABLE A-1 FOR CHANNEL DESCRIPTIONS)

TIME SECONDS	DAS# 67 DEG C	DAS# 68 DEG C	DAS# 69 DEG C	DAS# 70 DEG C	DAS# 71 DEG C	DAS# 77 DEG C	DAS# 78 DEG C	DAS# 79 DEG C	DAS# 80 DEG C
-4.7	22.5	22.6	21.9	24.1	21.7	23.2	20.2	23.4	24.0
-3.9	22.5	22.6	21.9	24.1	21.7	23.2	20.3	23.4	24.1
-3.0	22.5	22.6	21.9	24.1	21.7	23.2	20.3	23.5	24.1
-2.2	22.5	22.6	21.9	24.2	21.7	23.2	20.3	23.5	24.0
-1.4	22.5	22.6	21.9	24.1	21.7	23.2	20.3	23.5	24.0
-0.5	22.5	22.6	21.9	24.2	21.7	23.2	20.3	23.5	24.0
0.3	22.5	22.6	21.9	25.7	21.7	23.6	20.3	24.1	28.7
1.1	22.7	22.7	21.9	30.2	21.7	24.9	20.3	24.8	45.6
2.0	22.9	22.8	21.9	30.9	21.7	25.1	20.3	25.0	41.2
2.8	23.2	22.8	21.9	31.6	21.7	25.0	20.4	25.1	36.7
3.6	23.2	22.8	21.9	31.1	21.7	24.8	20.3	25.1	33.9
4.5	23.3	22.9	21.9	30.0	21.7	24.8	20.3	25.2	32.2
5.3	23.2	22.9	21.9	29.2	21.7	24.8	20.4	25.2	31.1
6.1	23.2	22.9	22.0	28.7	21.7	24.8	20.3	25.3	29.4
7.0	23.2	22.9	22.0	28.6	21.7	24.8	20.4	25.3	30.1
7.8	23.2	22.9	22.0	28.4	21.7	24.9	20.4	25.4	29.4
8.6	23.2	23.0	22.0	28.2	21.7	25.0	20.4	25.4	29.2
9.5	23.2	23.0	22.0	27.6	21.7	25.0	20.4	25.5	28.9
10.3	23.1	23.0	22.0	27.3	21.7	25.1	20.4	25.5	28.6
11.1	23.1	23.0	22.0	27.1	21.7	25.2	20.4	25.6	28.1
12.0	23.1	23.0	22.0	27.0	21.7	25.3	20.4	25.6	27.5
12.8	23.1	23.0	22.0	27.0	21.7	25.4	20.5	25.6	27.2
13.6	23.1	23.1	22.0	27.1	21.7	25.5	20.4	25.7	27.3
14.5	23.1	23.1	22.1	27.2	21.7	25.6	20.4	25.7	27.2
15.3	23.1	23.1	22.1	27.2	21.8	25.7	20.4	25.7	27.3
16.1	23.1	23.1	22.1	27.3	21.8	25.8	20.4	25.7	27.4
21.1	23.3	23.2	22.1	27.4	21.8	26.2	20.5	25.8	27.7
26.1	23.3	23.3	22.1	27.7	21.9	26.4	20.5	25.9	28.2
31.1	23.4	23.4	22.2	28.2	21.9	26.7	20.4	26.1	28.6
36.1	23.6	23.5	22.2	28.1	21.9	26.7	20.6	26.3	28.2
41.1	23.6	23.5	22.2	27.6	21.9	26.2	20.6	26.3	27.6
46.1	23.6	23.4	22.3	26.9	21.9	25.4	20.7	26.4	26.8
51.1	23.7	23.4	22.3	26.5	21.9	24.9	20.7	26.4	26.8
56.1	23.7	23.4	22.3	26.3	21.9	24.6	20.7	26.5	26.8

TABLE B-9

DIGITAL OUTPUT FOR CHANNELS 81 THROUGH 89 -- TEST AB7
(REFER TO TABLE A-1 FOR CHANNEL DESCRIPTIONS)

TIME SECONDS	DAS# 81 DEG C	DAS# 82 DEG C	DAS# 83 DEG C	DAS# 84 DEG C	DAS# 85 DEG C	DAS# 86 DEG C	DAS# 87 DEG C	DAS# 88 DEG C	DAS# 89 DEG C
-4.7	24.2	23.0	22.3	21.8	23.2	21.9	23.7	22.7	22.6
-3.9	24.1	23.1	22.3	21.9	23.2	21.9	23.8	22.8	22.6
-3.0	24.1	23.0	22.4	21.9	23.2	22.0	23.8	22.8	22.6
-2.2	24.2	23.1	22.4	21.9	23.2	22.0	23.8	22.8	22.6
-1.4	24.2	23.0	22.3	21.9	23.2	22.0	23.8	22.8	22.6
-0.5	24.2	23.1	22.4	21.9	23.2	22.0	23.8	22.8	22.6
0.3	28.2	23.2	22.4	21.9	23.5	22.2	29.5	23.5	29.4
1.1	45.9	23.8	22.4	21.9	24.4	22.9	27.8	24.3	28.7
2.0	41.3	24.1	22.4	21.9	24.8	23.2	27.4	24.1	27.6
2.8	36.6	24.4	22.4	21.9	24.9	23.2	27.8	23.9	26.7
3.6	34.3	24.7	22.5	21.9	25.0	23.3	27.9	23.8	25.6
4.5	32.6	24.9	22.5	21.9	25.1	23.4	27.9	23.7	24.9
5.3	31.4	25.1	22.6	21.9	25.2	23.4	28.2	23.7	24.4
6.1	30.7	25.3	22.6	22.0	25.3	23.5	28.1	23.7	24.1
7.0	30.5	25.4	22.6	22.0	25.3	23.6	28.0	23.8	24.1
7.8	29.9	25.6	22.6	21.9	25.4	23.6	28.0	23.7	23.8
8.6	29.6	25.7	22.6	21.9	25.4	23.6	27.9	23.7	23.7
9.5	29.2	25.8	22.7	22.0	25.5	23.7	28.0	23.7	23.6
10.3	28.8	25.9	22.7	22.0	25.6	23.7	27.9	23.7	23.4
11.1	28.7	26.0	22.7	22.0	25.6	23.7	27.8	23.7	23.6
12.0	28.1	26.1	22.7	22.0	25.6	23.7	27.8	23.7	23.7
12.8	27.3	26.2	22.7	22.0	25.7	23.7	27.8	23.7	23.8
13.6	27.3	26.2	22.8	22.0	25.7	23.8	27.7	23.8	24.0
14.5	27.3	26.3	22.8	22.0	25.8	23.8	27.7	23.8	24.2
15.3	27.4	26.4	22.8	22.1	25.8	23.8	27.7	23.8	24.4
16.1	27.5	26.4	22.8	22.1	25.8	23.8	27.7	23.8	24.5
21.1	27.8	26.8	22.9	22.1	26.0	23.9	27.7	23.9	25.0
26.1	28.3	27.2	23.1	22.2	26.2	24.1	27.7	24.1	25.3
31.1	28.6	27.4	23.2	22.3	26.3	24.2	27.7	24.2	25.4
36.1	28.3	27.6	23.3	22.4	26.5	24.3	27.8	24.3	25.3
41.1	27.6	27.7	23.5	22.4	26.6	24.4	27.8	24.4	24.9
46.1	27.1	27.8	23.6	22.5	26.7	24.4	27.8	24.5	24.3
51.1	27.0	27.9	23.7	22.5	26.7	24.5	27.8	24.6	24.1
56.1	26.9	27.9	23.7	22.5	26.7	24.5	27.8	24.6	24.1

TABLE B-10

DIGITAL OUTPUT FOR CHANNELS 90 THROUGH 101 -- TEST A87
(REFER TO TABLE A-1 FOR CHANNEL DESCRIPTIONS)

TIME SECONDS	DAS# 90 DEG C	DAS# 91 DEG C	DAS# 92 DEG C	DAS# 93 DEG C	DAS# 97 DEG C	DAS# 98 DEG C	DAS# 99 DEG C	DAS# 100 DEG C	DAS# 101 DEG C
-4.7	23.6	23.7	23.7	23.8	527.8	241.0	24.2	22.8	23.7
-3.9	23.7	23.7	23.7	23.8	528.1	239.4	24.2	22.8	23.7
-3.0	23.7	23.7	23.7	23.8	528.3	241.7	24.2	22.8	23.7
-2.2	23.7	23.7	23.7	23.8	528.5	240.7	24.3	22.8	23.7
-1.4	23.7	23.7	23.7	23.8	528.7	239.4	24.2	22.8	23.7
-0.5	23.7	23.7	23.7	23.8	528.9	240.7	24.2	22.8	23.7
0.3	23.7	24.0	23.8	23.9	531.2	251.2	24.2	23.6	24.4
1.1	24.2	24.9	24.0	24.4	529.3	328.6	24.2	25.3	26.9
2.0	24.5	25.2	24.2	24.6	528.3	389.1	24.2	25.1	27.4
2.8	24.8	25.3	24.3	24.7	524.7	559.2	24.2	24.6	27.3
3.6	24.9	25.4	24.4	24.9	515.6	630.1	24.2	24.4	27.4
4.5	25.1	25.6	24.5	25.0	507.2	630.9	24.2	24.0	27.3
5.3	25.2	25.7	24.6	25.2	499.1	608.1	24.2	23.8	28.2
6.1	25.5	26.1	25.0	25.3	491.9	668.9	24.2	23.6	28.4
7.0	26.2	26.8	25.4	25.6	485.7	690.8	24.2	23.7	28.6
7.8	26.6	27.1	25.7	25.7	479.5	678.3	24.2	23.8	29.2
8.6	26.6	27.1	25.8	25.7	473.9	681.9	24.2	23.7	28.1
9.5	26.6	27.0	25.8	25.7	468.3	687.4	24.2	23.7	27.6
10.3	26.6	26.9	25.8	25.8	463.0	700.0	24.2	23.7	27.8
11.1	26.6	26.9	25.9	25.8	457.8	709.4	24.2	23.9	28.3
12.0	26.6	26.9	25.9	25.8	452.7	722.4	24.2	24.2	28.7
12.8	26.6	26.9	26.1	25.9	447.7	733.6	24.2	24.3	29.3
13.6	26.8	27.1	26.1	26.1	442.7	741.6	24.2	24.6	29.7
14.5	26.8	27.1	26.2	26.2	437.7	749.1	24.2	24.8	30.1
15.3	26.9	27.2	26.3	26.3	432.9	759.6	24.2	25.0	30.4
16.1	27.1	27.4	26.4	26.4	428.3	802.0	24.2	25.1	30.7
21.1	27.7	28.0	26.9	26.9	401.9	809.2	24.2	25.6	30.8
26.1	28.1	28.6	27.3	27.4	378.1	-5573.3	24.2	25.9	31.6
31.1	28.4	29.0	27.7	27.8	356.3	724.7	24.2	26.1	31.5
36.1	28.6	28.9	27.8	27.9	336.8	622.6	24.1	25.6	29.4
41.1	28.5	28.5	27.6	27.6	319.2	451.6	24.1	25.1	27.9
46.1	27.8	27.6	27.1	26.9	303.4	385.1	24.1	24.5	26.5
51.1	27.2	26.9	26.5	26.3	289.0	349.4	24.1	24.2	25.9
56.1	26.7	26.5	26.1	25.9	273.4	311.2	24.1	24.2	25.4

TABLE B-11

DIGITAL OUTPUT FOR CHANNELS 102 THROUGH 164 -- TEST AB7
(REFER TO TABLE A-1 FOR CHANNEL DESCRIPTIONS)

TIME SECONDS	DAS# 102 DEG C	DAS# 103 DEG C	DAS# 104 DEG C	DAS# 105 DEG C	DAS# 113 DEG C	DAS# 141 % O2	DAS# 159 % O2	DAS# 163 KPaG	DAS# 164 KPaD
-4.7	22.7	22.7	874.2	138.3	591.4	20.7	21.0	118.3	154.6
-3.9	22.7	22.7	873.9	138.4	591.2	20.7	21.0	118.3	154.8
-3.0	22.7	22.7	873.9	138.5	591.3	20.7	21.0	118.3	155.0
-2.2	22.7	22.7	873.9	139.6	591.1	20.7	21.0	118.4	155.2
-1.4	22.7	22.7	873.9	139.9	591.0	20.7	21.0	118.3	155.4
-0.5	22.7	22.7	873.8	139.2	591.1	20.7	21.0	118.4	155.5
0.3	22.9	23.3	873.8	138.9	591.2	20.7	21.0	122.6	149.2
1.1	22.9	25.1	873.8	139.3	591.1	20.7	21.0	122.1	150.7
2.0	23.0	24.7	873.7	139.3	590.9	20.6	21.0	121.2	117.2
2.8	23.0	24.2	873.8	139.2	591.2	20.6	21.0	120.6	110.9
3.6	23.1	23.7	873.6	139.3	591.3	20.6	21.0	120.1	109.2
4.5	23.1	23.5	873.7	139.2	591.1	20.6	21.0	119.8	107.8
5.3	23.3	23.3	873.7	139.6	590.9	20.6	21.0	119.7	106.1
6.1	23.5	23.5	873.7	139.6	590.5	20.6	21.0	119.6	104.5
7.0	24.2	23.6	873.3	142.3	590.8	20.6	21.0	119.6	102.4
7.8	25.2	23.5	873.0	141.9	590.6	20.6	21.0	119.6	100.1
8.6	24.7	23.4	872.9	141.9	590.3	20.6	21.0	119.4	98.5
9.5	24.7	23.4	872.7	141.3	590.0	21.5	18.0	117.7	96.6
10.3	24.7	23.4	872.2	153.5	589.7	20.6	21.0	119.3	95.2
11.1	24.8	23.6	871.1	156.0	589.3	20.5	20.3	117.4	93.6
12.0	24.9	23.7	870.2	155.4	589.2	20.6	20.9	119.4	91.9
12.8	25.0	23.8	869.1	155.3	588.9	20.6	20.9	119.5	90.3
13.6	25.0	23.9	868.1	156.2	588.7	20.6	20.9	119.5	88.6
14.5	25.0	24.1	867.9	156.2	588.4	20.6	20.9	119.6	87.0
15.3	25.1	24.2	867.9	156.5	588.4	20.5	20.9	119.7	85.3
16.1	25.2	24.2	867.8	156.2	587.4	20.5	20.9	119.8	83.7
21.1	25.4	24.4	866.3	155.1	586.4	20.4	20.8	120.3	74.1
26.1	25.7	24.8	867.4	153.5	584.9	20.3	20.8	120.8	65.9
31.1	25.9	24.9	871.9	153.9	583.5	20.2	20.7	121.3	58.6
36.1	25.9	24.8	874.2	153.6	582.1	20.2	20.6	121.7	52.3
41.1	25.8	24.4	877.9	133.6	580.6	20.0	20.5	121.8	46.7
46.1	25.6	24.1	882.4	112.4	579.2	20.1	20.5	121.6	42.2
51.1	25.4	23.9	877.0	101.4	577.8	20.1	20.5	121.5	37.8
56.1	25.2	23.9	868.1	94.2	576.2	20.1	20.4	121.4	33.6

TABLE B-12

DIGITAL OUTPUT FOR CHANNELS 166 THROUGH 179 -- TEST AB7
(REFER TO TABLE A-1 FOR CHANNEL DESCRIPTIONS)

TIME SECONDS	DAS# 166 KPaD	DAS# 167 W/SQ. M	DAS# 168 W/SQ. M	DAS# 171 W/SQ. M	DAS# 172 W/SQ. M	DAS# 174 DEG C	DAS# 175 DEG C	DAS# 178 H2 %	DAS# 1 H2 %
-4.7	-0.3	13.0	16.5	10.8	389.6	1.8	0.8	0.0	1.
-3.9	-0.3	14.1	15.8	8.8	388.9	1.8	0.8	0.0	0.
-3.0	-0.4	15.1	17.3	8.8	387.1	1.8	0.8	0.0	1.
-2.2	-0.3	13.3	8.4	7.9	391.0	1.8	0.8	0.0	0.
-1.4	-0.3	16.2	12.9	8.8	388.2	1.8	0.8	0.0	0.
-0.5	-0.4	13.8	17.6	8.8	389.6	1.8	0.8	0.0	-1
0.3	86.8	5103.0	22.8	126.0	384.3	1.8	0.8	0.0	0.
1.1	99.2	304.0	37.0	153.8	385.1	1.8	0.6	0.0	1.
2.0	103.7	182.9	33.0	94.6	385.8	1.9	0.5	0.1	-1.
2.8	103.3	145.4	26.7	79.5	385.6	2.0	0.5	0.1	-3.
3.6	102.6	111.6	31.4	63.4	386.0	2.1	0.5	0.3	-0.
4.5	97.6	89.7	35.1	47.3	386.8	2.1	0.5	0.2	0.
5.3	93.9	86.3	34.6	42.7	388.1	2.2	0.6	0.2	3.
6.1	87.0	73.8	25.9	43.2	388.0	2.3	0.6	0.2	0.
7.0	80.2	80.3	30.4	52.3	389.4	2.4	0.2	0.3	-0
7.8	69.9	70.2	33.0	39.2	388.9	2.5	0.5	0.2	1
8.6	64.0	67.8	27.2	35.9	387.9	2.5	0.6	0.2	-0
9.5	57.8	64.2	34.0	31.6	389.0	2.6	0.6	0.2	-0
10.3	52.5	48.6	25.1	31.3	388.7	2.6	0.6	0.2	1
11.1	47.2	44.2	34.3	29.5	389.0	2.5	-0.1	0.3	0
12.0	42.3	48.6	33.8	32.1	388.9	2.7	0.6	0.2	-0
12.8	37.7	45.2	34.3	25.1	388.9	2.7	0.6	0.2	0
13.6	33.1	40.5	23.0	28.9	388.7	2.8	0.6	0.2	4
14.5	30.0	62.1	25.7	25.7	387.5	2.8	0.6	0.2	0
15.3	27.2	55.4	27.2	29.8	388.5	2.8	0.6	0.2	3
16.1	24.2	60.8	41.1	26.0	387.7	2.9	0.6	0.2	1.
21.1	8.2	42.9	26.7	26.3	386.0	3.1	0.4	0.2	-2
26.1	2.6	42.6	29.8	26.3	385.8	3.2	0.4	0.2	1.
31.1	0.7	37.9	36.4	26.6	387.8	3.2	0.5	0.2	-0
36.1	0.3	33.8	38.7	25.1	387.9	3.2	0.3	0.2	0.
41.1	-0.3	29.3	33.0	22.2	387.8	3.2	0.2	0.2	1
46.1	-1.4	23.6	29.0	17.2	387.8	3.1	0.1	0.2	0
51.1	-2.5	24.1	28.5	15.8	387.3	3.1	0.1	0.2	0
56.1	-3.5	17.1	38.7	14.3	388.4	3.1	0.1	0.2	1

TABLE B-13

DIGITAL OUTPUT FOR CHANNELS 181 THROUGH 182 -- TEST AB7
(REFER TO TABLE A-1 FOR CHANNEL DESCRIPTIONS)

TIME SECONDS	DAS# 181 KG	DAS# 182 W/SQ. M
-4.7	41.1	0.1
-3.9	41.0	0.1
-3.0	40.8	0.1
-2.2	41.0	0.1
-1.4	41.8	0.1
-0.5	41.5	0.1
0.3	35.9	0.2
1.1	36.3	0.1
2.0	37.8	0.1
2.8	35.7	0.1
3.6	35.1	0.1
4.5	35.8	0.1
5.3	35.7	0.1
6.1	35.7	0.1
7.0	35.7	0.1
7.8	35.6	0.1
8.6	35.7	0.1
9.5	35.6	0.1
10.3	35.5	0.1
11.1	35.5	0.1
12.0	35.4	0.1
12.8	35.3	0.1
13.6	35.3	0.1
14.5	35.4	0.1
15.3	35.3	0.1
16.1	35.3	0.1
21.1	35.2	0.1
26.1	35.1	0.1
31.1	35.1	0.1
36.1	35.0	0.1
41.1	35.0	0.1
46.1	35.0	0.1
51.1	34.9	0.1
56.1	34.9	0.1

A P P E N D I X   C

TEMPERATURE AND PRESSURE DATA

APPENDIX C

TEMPERATURE AND PRESSURE DATA

Table C-1 presents the mean containment temperature, mean containment vessel steel temperature, containment pressure, factor for converting standard volume to volume at containment conditions, and the temperature gradients at the vertical wall and ceiling, all as a function of time from -5.52 minutes to 1170 minutes.

TABLE C-1

TEMPERATURE AND PRESSURE DATA FOR TEST AB7

TIME MIN.	CV ATMOS AVG TEMP DEG C	CV PRESS KPa	FACTOR STD. TO ACTUAL CU. M	AVG CV STEEL TEMP DEG C	GRADIENT DEG C / CM WALL	GRADIENT DEG C / CM CEILING
-5.52	23.9	118.4	1.074	22.8	0.6	1.7
-4.68	23.8	118.3	1.074	22.8	0.7	1.8
-3.85	23.9	118.3	1.074	22.8	0.6	1.8
-3.02	23.9	118.3	1.074	22.8	0.6	1.8
-2.18	23.9	118.4	1.074	22.8	0.7	1.7
-1.35	23.9	118.3	1.074	22.8	0.7	1.9
-0.52	23.9	118.4	1.074	22.8	0.7	1.9
0.32	25.6	122.6	1.106	23.5	1.7	11.8
1.15	33.7	122.1	1.072	23.7	5.4	13.5
1.98	32.3	121.2	1.069	23.7	6.8	11.7
2.82	31.4	120.6	1.067	23.8	6.6	11.1
3.65	30.6	120.1	1.066	23.8	5.4	10.2
4.48	29.9	119.8	1.066	23.8	4.3	9.4
5.32	29.4	119.7	1.066	23.8	3.6	8.5
6.15	29.0	119.6	1.066	23.8	3.5	8.1
6.98	28.8	119.6	1.068	23.8	3.6	7.1
7.82	28.4	119.6	1.069	23.8	3.6	6.6
8.65	28.3	119.4	1.067	23.8	3.1	6.3
9.48	28.0	117.7	1.053	23.8	3.4	5.7
10.32	27.9	119.3	1.068	23.8	2.7	5.3
11.15	27.7	117.4	1.052	23.9	2.7	4.8
11.98	27.6	119.4	1.070	23.9	2.7	4.5
12.82	27.6	119.5	1.071	23.9	2.5	4.0
13.65	27.5	119.5	1.072	23.9	2.6	3.9
14.48	27.5	119.6	1.072	23.9	2.5	3.6
15.32	27.5	119.7	1.073	23.9	2.5	3.6
16.15	27.5	119.8	1.074	23.9	2.6	3.3
16.98	27.6	119.8	1.074	23.9	2.7	3.1
17.82	27.5	119.9	1.075	24.0	2.8	3.0
18.65	27.5	120.0	1.076	24.0	2.6	3.0
19.48	27.4	118.2	1.061	24.0	2.7	2.7
20.32	27.5	120.2	1.078	24.0	2.7	2.7
21.15	27.5	120.3	1.078	24.1	2.6	2.7
21.98	27.5	120.4	1.079	24.1	2.7	2.6
22.82	27.6	119.5	1.071	24.1	2.8	2.4

TABLE C-1 (Cont'd)

TEMPERATURE AND PRESSURE DATA FOR TEST AB7

TIME MIN.	CV ATMOS AVG TEMP DEG C	CV PRESS KPa	FACTOR STD. TO ACTUAL CU. M	AVG CV STEEL TEMP DEG C	GRADIENT DEG C / CM WALL	GRADIENT DEG C / CM CEILING
23.65	27.5	120.5	1.080	24.1	2.6	2.3
24.48	27.5	120.6	1.081	24.1	2.9	2.3
25.32	27.5	120.7	1.082	24.1	2.8	2.0
26.15	27.7	120.8	1.082	24.2	2.8	2.2
26.98	27.7	120.9	1.083	24.2	2.8	2.0
27.82	27.8	121.0	1.084	24.2	2.8	2.1
28.65	27.8	121.1	1.084	24.2	2.8	2.0
29.48	27.9	121.2	1.085	24.2	3.0	2.1
30.32	27.9	121.2	1.086	24.2	2.8	1.9
31.15	27.9	121.3	1.086	24.3	2.9	2.0
31.98	27.9	121.4	1.087	24.3	2.9	1.9
32.82	27.9	121.5	1.088	24.3	2.7	1.8
33.65	27.9	121.6	1.088	24.3	2.7	1.9
34.48	27.9	121.6	1.089	24.3	2.9	1.7
35.32	27.9	121.7	1.089	24.3	2.7	1.7
36.15	27.8	121.7	1.090	24.4	2.8	1.9
36.98	27.8	121.8	1.091	24.4	2.5	1.7
37.82	27.7	121.8	1.091	24.4	2.5	1.8
38.65	27.7	121.9	1.092	24.4	2.4	2.0
39.48	27.7	121.9	1.093	24.4	2.4	2.0
40.32	27.7	121.9	1.093	24.4	2.3	2.0
41.15	27.5	121.8	1.092	24.4	2.2	2.0
41.98	27.4	121.8	1.092	24.4	2.1	2.1
42.82	27.3	121.7	1.092	24.5	1.8	2.1
43.65	27.2	121.7	1.092	24.5	1.7	2.1
44.48	27.1	121.6	1.092	24.5	1.6	2.1
45.32	27.0	121.6	1.092	24.5	1.6	2.0
46.15	27.0	121.6	1.092	24.5	1.5	2.0
46.98	26.9	121.6	1.092	24.5	1.4	2.0
47.82	26.8	121.5	1.092	24.5	1.4	2.0
48.65	26.8	121.5	1.092	24.5	1.4	2.0
49.48	26.7	121.5	1.092	24.5	1.4	2.0
50.32	26.7	121.5	1.092	24.5	1.4	2.0
51.15	26.6	121.5	1.092	24.5	1.3	1.9
51.98	26.6	121.4	1.092	24.5	1.3	1.9

TABLE C-1 (Cont'd)

TEMPERATURE AND PRESSURE DATA FOR TEST AB7

TIME MIN.	CV ATMOS AVG TEMP DEG C	CV PRESS KPa	FACTOR STD. TO ACTUAL CU. M	AVG CV STEEL TEMP DEG C	GRADIENT DEG C / CM WALL	GRADIENT DEG C / CM CEILING
52.82	26.6	121.5	1.092	24.5	1.2	2.0
53.65	26.5	121.4	1.092	24.5	1.3	2.0
54.48	26.5	121.4	1.092	24.5	1.3	1.9
55.32	26.5	121.4	1.092	24.5	1.2	2.0
56.15	26.4	121.4	1.092	24.5	1.2	1.9
56.98	26.4	121.4	1.092	24.6	1.1	1.9
57.82	26.4	121.4	1.092	24.6	1.2	1.8
58.65	26.4	121.4	1.092	24.6	1.2	1.9
59.48	26.3	121.4	1.092	24.6	1.1	1.9
60.32	26.3	121.4	1.092	24.6	1.1	1.8
70.00	26.1	121.3	1.092	24.7	0.9	1.9
81.00	26.0	121.2	1.092	24.7	0.8	1.9
91.00	25.9	121.2	1.092	24.7	0.7	2.0
101.00	25.9	121.2	1.092	24.8	0.9	2.0
111.00	25.8	121.2	1.092	24.8	0.7	1.7
121.00	25.8	121.1	1.092	24.8	0.7	2.0
131.00	25.8	121.1	1.092	24.9	0.7	2.1
141.00	25.8	121.2	1.092	24.9	0.6	1.9
151.00	25.8	121.2	1.092	24.9	0.6	2.1
161.00	25.8	121.2	1.093	24.9	0.6	2.0
171.00	25.8	121.1	1.092	24.9	0.6	1.7
181.00	25.8	121.1	1.092	24.9	0.6	2.2
191.00	25.7	121.0	1.091	25.0	0.6	2.1
201.00	25.7	121.0	1.091	25.0	0.6	2.0
209.98	25.8	121.0	1.091	25.0	0.4	2.0
239.98	25.8	121.0	1.091	25.0	0.5	2.3
269.98	25.8	121.1	1.091	25.1	0.5	2.3
299.98	25.8	121.1	1.092	25.1	0.4	2.3
329.98	25.8	121.2	1.092	25.1	0.4	2.1
359.98	25.9	121.2	1.092	25.1	0.4	2.0
389.98	25.9	121.2	1.093	25.1	0.4	2.0
419.98	25.9	121.3	1.093	25.2	0.4	2.0
479.98	25.9	121.4	1.094	25.2	0.3	2.0
539.98	26.0	121.5	1.094	25.2	0.4	2.2
599.98	26.0	121.6	1.096	25.2	0.4	2.1

TABLE C-1 (Cont'd)

TEMPERATURE AND PRESSURE DATA FOR TEST AB7

TIME MIN.	CV ATMOS AVG TEMP DEG C	CV PRESS KPa	FACTOR STD. TO ACTUAL CU. M	AVG CV STEEL TEMP DEG C	GRADIENT DEG C / CM WALL	GRADIENT DEG C / CM CEILING
659.98	26.0	121.6	1.096	25.2	0.4	2.3
719.98	26.0	121.7	1.096	25.2	0.4	2.3
779.98	26.0	121.7	1.097	25.2	0.4	2.1
839.98	26.0	121.7	1.096	25.2	0.3	2.1
899.98	26.0	121.7	1.096	25.2	0.3	2.0
959.98	26.0	121.7	1.096	25.2	0.4	2.3
1019.98	26.0	121.6	1.096	25.2	0.3	2.3
1079.98	26.0	121.5	1.095	25.2	0.3	2.2
1139.98	26.0	121.5	1.095	25.2	0.3	2.4
1169.98	26.0	121.5	1.095	25.2	0.3	2.3

APPENDIX D

CASCADE IMPACTOR DATA

APPENDIX D

CASCADE IMPACTOR DATA

Data for individual cascade impactor measurements and the calculational procedures used to extract size data from the stage deposits are presented in this appendix. The collection characteristics of each impactor stage were assumed to be controlled by the dimensionless impaction parameter:

$$\psi = \frac{\rho u d^2 C}{18 \mu D} \quad \text{(D-1)}$$

where:

- ψ - Impaction parameter (dimensionless)
- u = Gas velocity (cm/s)
- p = Particle density (g/cm^3)
- d = Particle diameter (cm)
- ξ = Gas viscosity (g/cm s)
- D = Impactor jet diameter (cm)
- C = Cunningham slip factor (dimensionless)

At the point of the impaction curve where 50% of the particles are collected, the impaction parameter ψ takes the value ψ_{50}. The 50% size is:

$$d_{50} = \left(\frac{18m \quad Dc_{50}}{uC} \right)^{0.5} \quad \text{(D-2)}$$

where:

d_{50} = Particle diameter at the 50% point on efficiency vs size curve

ψ_{50} = Impaction parameter for the jet at the 50% efficiency point

Equation D-2 was used to determine d_{50} values at flow conditions different from those to calibrate the impactor; it can also be used to relate the d_{50} to the value under calibration conditions. If C is assumed to be constant, then d_{50} can be expressed as:

$$d_{50} = (d_{50})_{ref} \left(\frac{\mu}{\mu_{ref}} \times \frac{Q_{ref}}{Q} \right)^{0.5} \qquad \text{(D-3)}$$

where:

d_{50} = Aerodynamic diameter at sampling conditions
μ = Viscosity of gas at sampling conditions
Q = Gas flow rate at sampling conditions
ref = Subscript indicating value of parameter under calibration or reference conditions

Cascade impactors of two designs (Andersen Mark III Circular jet impactor* and Sierra rectangular jet impactor**) were used for particle size analysis. Stage cut-size diameters used to interpret data obtained from the circular jet impactor are recommended by the manufacturer(D-1) and listed in Table D-1. These values are in good agreement with calibrations reported by Cushing et al.(D-2)

Stage cut-off diameters for the rectangular jet impactor are listed in Table D-2 and the data were obtained from the work of Cusing et al.(D-2) Cut diameters listed in Tables D-1 and D-2 were adjusted for sampling conditions using Equation D-3.

Particle size distributions were constructed from cascade impactor data using the cut-off diameter approach described by Mercer.(D-3) Table D-3 presents an example of the calculation method.

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*Manufactured by Andersen 2000, Inc., Atlanta, GA.
**Model 226, Stack Sampler, Manufactured by Sierra Instrument Co., Inc., Carmel Valley, CA.

TABLE D-1

STAGE CUT DIAMETERS FOR CIRCULAR JET IMPACTOR USED IN AIR CLEANING TESTS

Stage No.	d_{50}* (μm)
0	13.2
1	8.3
2	5.64
3	3.8
4	2.45
5	1.25
6	0.77
7	0.52

*Size of unit density spheres removed with 50% efficiency at 21°C, 1 atm pressure, and 0.50-ACFM flow rate.

TABLE D-2

STAGE CUT DIAMETERS FOR RECTANGULAR JET IMPACTOR USED IN AIR CLEANING TESTS

Stage No.	d_{50}* (μm)
1	18.0
2	11.0
3	4.4
4	2.65
5	1.70
6	0.95

*Size of unit density spheres removed with 50% efficiency at 28°C, 29.5 mm Hg pressure, and 0.25-ACFM flow rate.

TABLE D-3

EXAMPLE TREATMENT OF CASCADE IMPACTOR DATA

Stage No.[a]	NaI Mass (mg)[b]	Mass Fraction	Cumulative Fraction	Fraction[c] Less Than Cut Size	d_{50}[c] (μm)
1	0.0025	0.0036	0.0036	0.996	18.21
2	0.0018	0.0026	0.0062	0.994	11.13
3	0.0186	0.0269	0.0331	0.967	4.45
4	0.0709	0.1027	0.1358	0.864	2.68
5	0.1651	0.2392	0.3750	0.625	1.72
6	0.2870	0.4158	0.7908	0.209	0.96
BU Filter	0.1443	0.2091	1.000	---	---
Total	0.6902	1.000			

(a) Sample No. AB-7 T3-I4, taken at time 1745 s, with a Sierra 226 impactor, 0.123 actual liter/s.
(b) Net mass after correction for background on stage collection papers.
(c) These two columns are plotted in Figure 4-5.

The stage accumulations of sodium were obtained by washing each stage collection paper with water and analyzing the water by flame emmision spectrometry. Losses to the interstage impactor walls were ignored. The inlet walls were washed and analyzed for sodium, and the recovered sodium was assumed to be associated with aerosol particles larger than the first-stage cut-off diameter.

The particle size distribution was obtained by plotting the two right-hand columns in Table D-3 on log-probability paper as shown in Figure 4-5. The aerodynamic mass median diameter and geometric standard deviation can be obtained from the line drawn through the data points. The geometric standard deviation was obtained from:

$$\sigma_g = \frac{\text{Particle Diameter at 84.13\%}}{\text{Particle Diameter at 50\%}} \quad \text{(D-4)}$$

Mass distributions of sodium found on the cascade impactor stages are presented in Tables D-4 through D-31 for Test AB7.

REFERENCES FOR APPENDIX D

D-1 Operating Manual for Andersen 2000, Inc., Mark III and Mark III Particle Size Samplers, TR 76-900023, Andersen 2000 Inc., Atlanta, GA, January 1976.

D-2 K. M. Cushing et al., Particle Sizing Techniques for Control Device Evaluation: Cascade Impactor Calibrations, EPA-600/2-76-280, Southern Research Institute, Birmingham, AL, October 1876.

D-3 T. T. Mercer, "The Interpretation of Cascade Impactor Data," Industrial Hygiene Journal 26, pp. 236-241, 1965.

Table D-4
CASCADE IMPACTOR DATA - SAMPLE AB7-T3-I2

Type: Andersen III — Time: 13 Minutes
Stage paper background: 0.0056 mg Na, 0.0037 mg NaI
Filter paper background: 0.0120 mg Na, 0.0003 mg NaI

Stage No.	Aerodynamic Cut Diam. (μm)	Net Mass (mg) NaOH	Net Mass (mg) NaI	Ratio: NaI/(NaOH + NaI)	Fraction Less Than Cut Diam. NaOH	Fraction Less Than Cut Diam. NaI
Inlet	-----	0.0610	0.0022	0.035	----	----
1	13.5	0.0290	0.0046	0.137	0.985	0.967
2	8.48	0.0904	0.0029	0.031	0.971	0.954
3	5.76	0.0898	0.0048	0.051	0.957	0.931
4	3.88	0.4094	0.0000	0.0000	0.892	0.931
5	2.50	1.635	0.0015	0.001	0.633	0.924
6	1.28	2.973	0.0289	0.010	0.161	0.788
7	0.79	0.9197	0.0882	0.088	0.016	0.371
8	0.53	0.0777	0.0503	0.393	0.003	0.134
Filter	----	0.0203	0.0284	0.583	0.000	0.000
Total		6.305	0.2118	0.032		

Table D-5
CASCADE IMPACTOR DATA - SAMPLE AB7-T3-I3

Type: Sierra 226 — Time: 21.1 Minutes
Stage paper background: 0.0077 mg Na, 0.0024 mg NaI
Filter paper background: 0.286 mg Na, 0.0005 mg NaI

Stage No.	Aerodynamic Cut Diam. (μm)	Net Mass (mg) NaOH	Net Mass (mg) NaI	Ratio: NaI/(NaOH + NaI)	Fraction Less Than Cut Diam. NaOH	Fraction Less Than Cut Diam. NaI
Inlet	----	0.0000	0.0034	1.0000	----	----
1	18.1	0.0120	0.0020	0.143	0.998	0.982
2	11.1	0.0417	0.0004	0.010	0.989	0.981
3	4.43	0.3146	0.0024	0.008	0.927	0.973
4	2.67	1.1004	0.0034	0.003	0.707	0.962
5	1.71	2.4696	0.0420	0.017	0.220	0.824
6	0.956	0.8297	0.0908	0.099	0.055	0.525
Filter	----	0.2520	0.1596	0.388	0.000	0.000
Total		5.0200	0.3040	0.057		

Table D-6
CASCADE IMPACTOR DATA - SAMPLE AB7-T3-I4

Type: Sierra 226 — Time: 29 Minutes
Stage paper background: 0.0077 mg Na, 0.0024 mg NaI
Filter paper background: 0.286 mg Na, 0.0005 mg NaI

Stage No.	Aerodynamic Cut Diam. (μm)	Net Mass (mg) NaOH	Net Mass (mg) NaI	Ratio: NaI/ (NaOH + NaI)	Fraction Less Than Cut Diam. NaOH	Fraction Less Than Cut Diam. NaI
Inlet	-----	0.0000	0.0015	1.000	----	----
1	18.1	0.0123	0.0010	0.075	0.998	0.996
2	11.1	0.0860	0.0018	0.020	0.981	0.994
3	4.45	0.5443	0.0186	0.033	0.879	0.967
4	2.68	1.679	0.0709	0.040	0.563	0.864
5	1.72	2.058	0.1651	0.074	0.176	0.625
6	0.961	0.7435	0.2870	0.278	0.037	0.209
Filter	----	0.1941	0.1443	0.426	0.000	0.000
Total		5.3175	0.6902	0.115		

Table D-7
CASCADE IMPACTOR DATA - SAMPLE AB7-T3-I5

Type: Sierra 226 — Time: 37.4 Minutes
Stage paper background: 0.0077 mg Na, 0.0024 mg NaI
Filter paper background: 0.286 mg Na, 0.0005 mg NaI

Stage No.	Aerodynamic Cut Diam. (μm)	Net Mass (mg) NaOH	Net Mass (mg) NaI	Ratio: NaI/ (NaOH + NaI)	Fraction Less Than Cut Diam. NaOH	Fraction Less Than Cut Diam. NaI
Inlet	----	0.0000	0.0058	1.0000	----	----
1	18.3	0.0485	0.0071	0.128	0.996	0.997
2	11.2	0.3112	0.0156	0.048	0.972	0.993
3	4.46	1.494	0.1078	0.067	0.856	0.969
4	2.67	4.401	1.1953	0.214	0.513	0.696
5	1.72	5.003	1.2591	0.201	0.124	0.409
6	0.964	1.314	1.1348	0.463	0.021	0.151
Filter	----	0.2759	0.6622	0.706	0.000	0.000
Total		12.8475	4.3877	0.2546		

Table D-8
CASCADE IMPACTOR DATA - SAMPLE AB7-T3-I6

Type: Sierra 226 — Time: 50.6 Minutes
Stage paper background: 0.0077 mg Na, 0.0024 mg NaI
Filter paper background: 0.286 mg Na, 0.0005 mg NaI

Stage No.	Aerodynamic Cut Diam. (μm)	Net Mass (mg) NaOH	Net Mass (mg) NaI	Ratio: NaI/ (NaOH + NaI)	Fraction Less Than Cut Diam. NaOH	Fraction Less Than Cut Diam. NaI
Inlet	-----	0.0526	0.0177	0.252	----	----
1	18.1	0.4106	0.0494	0.107	0.976	0.989
2	11.1	0.4830	0.0422	0.080	0.951	0.982
3	4.45	3.442	0.5297	0.133	0.773	0.895
4	2.68	6.207	1.3286	0.177	0.452	0.677
5	1.72	6.063	2.1336	0.260	0.139	0.326
6	0.961	1.896	1.4988	0.442	0.041	0.079
Filter	----	0.792	0.4840	0.379	0.000	0.000
Total		19.3456	6.0840	0.239		

Table D-9
CASCADE IMPACTOR DATA - SAMPLE AB7-T3-I7

Type: Sierra 226 — Time: 64 Minutes
Stage paper background: 0.0077 mg Na, 0.0024 mg NaI
Filter paper background: 0.286 mg Na, 0.0005 mg NaI

Stage No.	Aerodynamic Cut Diam. (μm)	Net Mass (mg) NaOH	Net Mass (mg) NaI	Ratio: NaI/ (NaOH + NaI)	Fraction Less Than Cut Diam. NaOH	Fraction Less Than Cut Diam. NaI
Inlet	-----	0.0194	0.0848	0.814	----	----
1	12.6	0.4172	0.0503	0.108	0.983	0.984
2	7.71	1.6616	0.2364	0.125	0.920	0.956
3	3.09	10.945	2.7299	0.200	0.501	0.631
4	1.86	9.560	3.0902	0.244	0.136	0.262
5	1.19	2.2986	1.6036	0.411	0.048	0.071
6	0.666	0.587	0.4897	0.455	0.025	0.013
Filter	----	0.661	0.1092	0.142	0.000	0.000
Total		26.149	8.394	0.243		

Table D-10
CASCADE IMPACTOR DATA - SAMPLE AB7-T3-I8

Type: Sierra 226 — Time: 73 Minutes
Stage paper background: 0.0077 mg Na, 0.0024 mg NaI
Filter paper background: 0.286 mg Na, 0.0005 mg NaI

Stage No.	Aerodynamic Cut Diam. (μm)	Net Mass (mg) NaOH	Net Mass (mg) NaI	Ratio: NaI/ (NaOH + NaI)	Fraction Less Than Cut Diam. NaOH	Fraction Less Than Cut Diam. NaI
Inlet	-----	0.0816	0.0186	0.186	----	----
1	17.9	0.7254	0.0950	0.116	0.958	0.980
2	11.0	2.673	0.4455	0.143	0.820	0.901
3	4.39	7.658	1.734	0.185	0.423	0.593
4	2.64	5.954	2.026	0.254	0.115	0.233
5	1.69	1.403	0.829	0.371	0.042	0.085
6	0.947	0.4055	0.2511	0.382	0.022	0.041
Filter	----	0.4155	0.2309	0.357	0.000	0.000
Total		19.3158	5.6296	0.226		

Table D-11
CASCADE IMPACTOR DATA - SAMPLE AB7 - T3 - I9

Type: Sierra 226 — Time: 85.5 Minutes
Stage paper background: 0.0077 mg Na, 0.0024 mg NaI
Filter paper background: 0.286 mg Na, 0.0005 mg NaI

Stage No.	Aerodynamic Cut Diam. (μm)	Net Mass (mg) NaOH	Net Mass (mg) NaI	Ratio: NaI/ (NaOH + NaI)	Fraction Less Than Cut Diam. NaOH	Fraction Less Than Cut Diam. NaI
Inlet	-----	0.3118	0.0655	0.174	----	----
1	16.6	0.5108	0.0932	0.154	0.980	0.987
2	10.1	1.9438	0.4050	0.172	0.933	0.953
3	4.05	16.5677	3.650	0.180	0.531	0.646
4	2.44	16.3213	4.584	0.219	0.134	0.260
5	1.57	3.9136	1.870	0.323	0.039	0.103
6	0.875	0.9015	0.8290	0.479	0.017	0.033
Filter	----	0.6783	0.3953	0.368	0.000	0.000
Total		41.1488	11.8925	0.224		

Table D-12
CASCADE IMPACTOR DATA - SAMPLE AB7-T3-I10

Type: Sierra 226 Time: 103 Minutes
Stage paper background: 0.0077 mg Na, 0.0024 mg NaI
Filter paper background: 0.286 mg Na, 0.0005 mg NaI

Stage No.	Aerodynamic Cut Diam. (μm)	Net Mass (mg) NaOH	Net Mass (mg) NaI	Ratio: NaI/ (NaOH + NaI)	Fraction Less Than Cut Diam. NaOH	Fraction Less Than Cut Diam. NaI
=====	===========	======	======	============	=====	=====
Inlet	-----	0.6505	0.1310	0.168	----	----
1	16.6	1.2267	0.2483	0.168	0.968	0.988
2	10.1	3.1652	0.8611	0.214	0.914	0.962
3	4.05	30.1211	15.515	0.340	0.399	0.495
4	2.44	17.3530	12.4079	0.417	0.102	0.120
5	1.56	4.5616	2.5436	0.358	0.024	0.044
6	0.875	0.9483	1.1079	0.539	0.008	0.010
Filter	----	0.4865	0.3463	0.416	0.000	0.000
		=======	=======	=====		
Total		58.5129	33.1611	0.362		

Table D-13
CASCADE IMPACTOR DATA - SAMPLE AB7-T3-I11

Type: Andersen III Time: 170 Minutes
Stage paper background: 0.0056 mg Na, 0.0037 mg NaI
Filter paper background: 0.0120 mg Na, 0.0003 mg NaI

Stage No.	Aerodynamic Cut Diam. (μm)	Net Mass (mg) NaOH	Net Mass (mg) NaI	Ratio: NaI/ (NaOH + NaI)	Fraction Less Than Cut Diam. NaOH	Fraction Less Than Cut Diam. NaI
=====	===========	======	======	============	=====	=====
Inlet	-----	0.6975	0.1650	0.191	----	----
1	13.6	1.258	0.2765	0.180	0.970	0.983
2	8.56	4.942	1.6478	0.250	0.895	0.922
3	5.82	14.090	4.626	0.247	0.679	0.748
4	3.92	16.572	6.294	0.275	0.425	0.512
5	2.53	17.227	7.749	0.310	0.162	0.221
6	1.29	9.593	4.815	0.334	0.016	0.040
7	0.794	1.017	1.003	0.496	0.000	0.003
8	0.536	0.0093	0.0525	0.849	0.000	0.000
Filter	----	0.0000	0.0145	1.000	0.000	0.000
		======	======	=====		
Total		65.4056	26.6428	0.289		

Table D-14
CASCADE IMPACTOR DATA - SAMPLE AB7-T3-I16

Type: Andersen III — Time: 1215 Minutes
Stage paper background: 0.0056 mg Na, 0.0037 mg NaI
Filter paper background: 0.0120 mg Na, 0.0003 mg NaI

Stage No.	Aerodynamic Cut Diam. (μm)	Net Mass (mg) NaOH	NaI	Ratio: NaI/(NaOH + NaI)	Fraction Less Than Cut Diam. NaOH	NaI
Inlet	----	0.000	0.0151	1.000	----	----
1	13.6	0.000	0.0139	1.000	0	0.995
2	8.56	0.000	0.0140	1.000	0	0.993
3	5.82	0.0442	0.0391	0.470	0.984	0.986
4	3.92	0.2621	0.1154	0.306	0.892	0.966
5	2.53	1.331	2.0169	0.602	0.423	0.621
6	1.29	1.198	2.7755	0.699	0.000	0.147
7	0.794	0.000	0.7968	1.000	0.000	0.011
8	0.536	0.0000	0.0630	1.000	0.000	0.000
Filter	----	0.0000	0.0000	----	0.000	0.000
Total		2.8353	5.850	0.673		

Table D-15
CASCADE IMPACTOR DATA - SAMPLE AB7-T3-I17

Type: Andersen III — Time: 1638 Minutes
Stage paper background: 0.0056 mg Na, 0.0037 mg NaI
Filter paper background: 0.0120 mg Na, 0.0003 mg NaI

Stage No.	Aerodynamic Cut Diam. (μm)	Net Mass (mg) NaOH	NaI	Ratio: NaI/(NaOH + NaI)	Fraction Less Than Cut Diam. NaOH	NaI
Inlet	----	0.0000	0.0034	1.000	----	----
1	13.5	0.0000	0.0000	----	1.000	0.997
2	8.49	0.0105	0.0023	0.180	0.997	0.995
3	5.77	0.0442	0.0131	0.229	0.982	0.985
4	3.89	0.1995	0.0502	0.201	0.917	0.946
5	2.51	1.209	0.3341	0.216	0.523	0.679
6	1.28	1.335	0.5776	0.302	0.087	0.225
7	0.787	0.2639	0.2718	0.507	0.001	0.012
8	0.532	0.0025	0.0142	0.848	0.000	0.000
Filter	----	0.0000	0.0053	1.000	0.000	0.000
Total		3.0649	1.2770	0.293		

APPENDIX E

BLIND POST-TEST CODE PREDICTIONS SUBMITTED BY CODE USERS

APPENDIX E

BLIND POST-TEST CODE PREDICTIONS SUBMITTED BY CODE USERS

Blind post-test code predictions were sent to the test performer and to all the other ABCOVE program participants prior to release of test results of aerosol behavior. Copies of the tabular data submitted by each participant are presented in Table E-1 through E-5 as follows:

Table	Code Case	Code	User
E-1	1	HAA-3C	HEDL
E-2	2	HAA-4	RI/ESG
E-3	3	HAARM-3	HEDL
E-4	4	CONTAIN	SNL
E-5	5	QUICKM	BCL

TABLE E-1

POST-TEST PREDICITION OF ABCOVE TEST AB7 BY HEDL/SSD USING HAA-3C

Time (s)	Susp. Conc. (g/m^3) NaOH	Susp. Conc. (g/m^3) NaI	Particle Size Distribution[b] AMMD (μm)	Particle Size Distribution[b] σ_g	Leaked Mass (g) NaOH	Leaked Mass (g) NaI	Settled Mass (g) NaOH	Settled Mass (g) NaI	Plated Mass (g) NaOH	Plated Mass (g) NaI	Total Aerosol Removal Rate (s^{-1})
6.0(2)[a]	3.34	0.0	5.4 (-1)	1.77	1.0 (-1)	0.0	1.3	0.0	1.74(2)	0.0	1.64(-4)
9.0(2)	3.22	6.82(-2)	8.2 (-1)	1.64	1.97(-1)	1.02(-3)	3.59	2.65(-2)	2.72(2)	9.47(-1)	1.01(-4)
1.8(3)	2.99	2.65(-1)	2.92	2.44	4.72(-1)	1.59(-2)	4.22(1)	2.79(0)	4.28(2)	8.62	1.39(-4)
2.4(3)	2.15	3.07(-1)	5.15	2.73	6.25(-1)	3.3 (-2)	7.26(2)	8.12(1)	4.57(2)	1.18(1)	5.54(-4)
2.7(3)	1.82	2.59(-1)	6.03	2.59	6.84(-1)	4.14(-2)	1.0 (3)	1.21(2)	4.66(2)	1.31(1)	5.94(-4)
3.0(3)	1.51	2.15(-1)	6.72	2.48	7.33(-1)	4.84(-2)	1.26(3)	1.58(2)	4.72(2)	1.4 (1)	6.43(-4)
4.2(3)	7.02(-1)	1.0 (-1)	7.85	2.16	8.57(-1)	6.6 (-2)	1.94(3)	2.54(2)	4.85(2)	1.58(1)	5.96(-4)
7.2(3)	1.89(-1)	2.7 (-2)	7.15	1.81	9.65(-1)	8.15(-2)	2.36(3)	3.15(2)	4.94(2)	1.71(1)	3.27(-4)
1.0(4)	9.06(-2)	1.29(-2)	6.34	1.68	1.0	8.66(-2)	2.44(3)	3.26(2)	4.97(2)	1.75(1)	2.26(-4)
7.0(4)	5.59(-4)	7.96(-5)	3.28	1.29	1.07	9.59(-2)	2.51(3)	3.36(2)	5.04(2)	1.86(1)	5.7 (-5)
1.0(5)	1.12(-4)	1.59(-5)	3.03	1.25	1.07	9.6 (-2)	2.51(3)	3.36(2)	5.04(2)	1.86(1)	5.15(-5)
2.0(5)	1.05(-6)	1.49(-7)	2.7	1.19	1.07	9.6 (-2)	2.51(3)	3.36(2)	5.04(2)	1.86(1)	4.19(-5)

(a) Numbers in parenthesis are exponents of ten.

TABLE E-2

HAA-4 CODE AB7 BLIND POST-TEST PREDICTIONS

ABCOVE AB7 BLIND POST-TEST

	Time (Sec)	SUSPENDED MASS CONCENTRATION (KG/M++3) NaOH	NaI	LEAKED MASS (KG) NaOH	NaI	SETTLED MASS (KG) NaOH	NaI	PLATED MASS (KG) NaOH	NaI
1	6.0000E+02	3.52E-03	0.0	1.04E-04	0.0	9.89E-03	0.0	8.05E-03	0.0
2	9.0000E+02	3.49E-03	6.90E-05	2.08E-04	1.02E-06	2.93E-02	2.11E-04	1.26E-02	4.31E-05
3	1.8000E+03	3.23E-03	2.61E-04	5.10E-04	1.60E-05	2.48E-01	1.33E-02	2.26E-02	5.19E-04
4	2.4000E+03	2.54E-03	3.28E-04	6.81E-04	3.36E-05	8.26E-01	7.40E-02	2.68E-02	9.48E-04
5	2.7000E+03	2.23E-03	2.88E-04	7.52E-04	4.27E-05	1.09E+00	1.07E-01	2.84E-02	1.15E-03
6	3.0000E+03	1.95E-03	2.52E-04	8.13E-04	5.07E-05	1.33E+00	1.38E-01	2.97E-02	1.32E-03
7	4.2000E+03	1.15E-03	1.49E-04	9.92E-04	7.38E-05	2.00E+00	2.26E-01	3.31E-02	1.76E-03
8	7.2000E+03	4.35E-04	5.61E-05	1.20E-03	1.01E-04	2.61E+00	3.04E-01	3.64E-02	2.19E-03
9	1.0000E+04	2.37E-04	3.05E-05	1.29E-03	1.12E-04	2.78E+00	3.26E-01	3.74E-02	2.32E-03
10	7.0000E+04	4.37E-06	5.63E-07	1.50E-03	1.40E-04	2.97E+00	3.51E-01	3.88E-02	2.51E-03
11	1.0000E+05	1.67E-06	2.16E-07	1.51E-03	1.41E-04	2.98E+00	3.51E-01	3.89E-02	2.51E-03
12	2.0000E+05	1.69E-07	2.18E-08	1.52E-03	1.41E-04	2.98E+00	3.52E-01	3.89E-02	2.51E-03

SUSPENDED PARTICLE MATERIAL DENSITY AND SIZE DISTRIBUTION PARAMETERS

	Time (Sec)	Geometric Mass Median Radius (M++3)	Logarithmic Standard Deviation	Aerodynamic Equivalent Radius (M++3)	Count Mean Radius (M++3)	Average Material Density (KG/M++3)	Time (Sec)	Removal Rate (KG/Sec)	Aerodynamic Equivalent Radius (Micron)
1	6.0000E+02	5.45E-07	1.83E+00	7.71E-07	1.83E-07	2.13E+00	6.0000E+02	6.16E-5	1.08E+00
2	9.0000E+02	8.77E-07	1.63E+00	1.22E-06	4.31E-07	2.15E+03	9.0000E+-2	1.01E-4	1.52E+00
3	1.8000E+03	1.85E-06	2.12E+00	2.55E-06	3.39E-07	2.20E+03	1.8000E+03	7.42E-4	4.41E+00
4	2.4000E+03	2.18E-06	2.28E+00	3.02E-06	2.85E-07	2.24E+03	2.4000E+03	1.03E-3	5.81E+00
5	2.7000E+03	2.38E-06	2.19E+00	3.30E-06	3.77E-07	2.24E+03	2.7000E+03	9.49E-4	5.96E+00
6	3.0000E+03	2.52E-06	2.13E+00	3.49E-06	4.52E-07	2.24E+03	3.0000E+03	8.56E-4	6.06E+00
7	4.2000E+03	2.68E-06	1.96E+00	3.70E-06	6.89E-07	2.24E+03	4.2000E+03	4.52E-4	5.73E+00
8	7.2000E+03	2.44E-06	1.74E+00	3.38E-06	9.80E-07	2.24E+03	7.2000E+03	1.08E-4	4.54E+00
9	1.0000E+04	2.20E-06	1.63E+00	3.05E-06	1.07E-06	2.24E+03	1.0000E+04	4.22E-5	3.86E+00
10	7.0000E+04	1.13E-06	1.31E+00	1.58E-06	9.10E-07	2.24E+03	7.0000E+04	1.52E-7	1.69E+00
11	1.0000E+05	1.01E-06	1.27E+000	1.43E-06	8.50E-07	2.24E+03	1.0000E+05	4.60E-8	1.50E+00
12	2.0000E+05	8.18E-07	1.20E+000	1.16E-06	7.37E-07	2.24E+03	2.0000E+05	2.91E-9	1.20E+00

TABLE E-3

POST-TEST PREDICTION OF ABCOVE TEST AP7 BY HEDL/SSD USING HAARM-3

Time (s)	Susp. Conc. (g/m^3)		Particle Size Distribution[b]		Leaked Mass (g)		Settled Mass (g)		Plated Mass (g)		Total Aerosol Removal Rate
	NaOH	NaI	AMMD (μm)	σ_g	NaOH	NaI	NaOH	NaI	NaOH	NaI	(s^{-1})
6.0(2)[a]	3.31	0.0	1.26	1.75	9.95(-2)	0.0	1.03(1)	0.0	1.89(2)	0.0	1.76(-4)
9.0(2)	3.22	6.82(-2)	1.77	1.62	1.96(-1)	1.04(-3)	2.38(1)	1.54(-1)	2.49(2)	5.19(-1)	6.8 (-5)
1.8(3)	2.92	2.58(-1)	3.47	2.16	4.71(-1)	1.58(-2)	2.05(2)	1.2 (1)	3.28(2)	4.48	1.79(-4)
2.4(3)	2.52	3.52(-1)	3.5	2.2	6.32(-1)	3.4 (-2)	5.05(2)	4.61(1)	3.61(2)	8.21	2.5 (-4)
2.7(3)	2.34	3.27(-1)	3.89	2.14	7.04(-1)	4.4 (-2)	6.46(2)	6.57(1)	3.75(2)	1.02(1)	2.54(-4)
3.0(3)	2.16	3.01(-1)	4.25	2.11	7.7 (-1)	5.33(-2)	7.91(2)	8.6 (1)	3.87(2)	1.18(1)	2.75(-4)
4.2(3)	1.45	2.03(-1)	5.08	2.02	9.82(-1)	8.29(-2)	1.36(3)	1.66(2)	4.19(2)	1.63(1)	3.47(-4)
7.2(3)	5.09(-1)	7.11(-2)	5.39	1.82	1.24	1.2 (-1)	2.14(3)	2.74(2)	4.51(2)	2.08(1)	3.43(-4)
1.0(4)	2.19(-1)	3.05(-2)	5.08	1.7	1.34	1.33(-1)	2.38(3)	3.08(2)	4.62(2)	2.23(1)	2.76(-4)
7.0(4)	4.96(-4)	6.93(-5)	2.62	1.29	1.46	1.5 (-1)	2.55(3)	3.32(2)	4.78(2)	2.45(1)	6.71(-5)
1.0(5)	7.8 (-5)	1.09(-5)	2.41	1.24	1.46	1.5 (-1)	2.55(3)	3.32(2)	4.78(2)	2.45(1)	5.99(-5)
2.0(5)	2.91(-7)	4.07(-8)	2.15	1.18	1.46	1.5 (-1)	2.55(3)	3.32(2)	4.78(2)	2.45(1)	5.41(-5)

(a) Numbers in parenthesis are exponents of ten.

TABLE E-4

BLIND POST-TEST PREDICTIONS OF TEST AB7 BY SNL USING CONTAIN CODE

Time (s)	Susp. Conc. (g/m^3)		AMMD (μm)[a]		σ_g [a]		Aerodynamic Settling Mean Diam. (μm)		
	NaOH	NaI	NaOH	NaI	NaOH	NaI	NaOH[b]	NaI[b]	Combined
6.0(2)[c]	3.54(0)	0	1.15(0)	--	1.64(0)	--	1.43(0)	--	1.43(0)
9.0(2)	3.53(0)	6.95(-2)	1.56(0)	9.5(-1)	1.47(0)	1.60(0)	1.81(0)	1.18(0)	1.84(0)
1.8(3)	3.46(0)	2.76(-1)	2.43(0)	1.45(0)	1.57(0)	1.86(0)	2.98(0)	2.13(0)	3.03(0)
2.4(3)	3.36(0)	4.10(-1)	3.07(0)	1.67(0)	1.73(0)	2.18(0)	4.14(0)	3.07(0)	4.12(0)
2.7(3)	3.29(0)	4.06(-1)	3.45(0)	2.04(0)	1.84(0)	2.22(0)	5.00(0)	3.85(0)	4.85(0)
3.0(3)	3.20(0)	4.00(-1)	3.87(0)	2.38(0)	1.98(0)	2.33(0)	6.17(0)	4.87(0)	5.70(0)
4.2(3)	2.50(0)	3.43(-1)	5.48(04)	3.55(0)	2.35(0)	2.75(0)	1.13(1)	9.88(0)	9.38(0)
7.2(3)	9.44(-1)	1.76(-1)	5.36(0)	3.57(0)	2.22(0)	2.70(0)	1.01(1)	9.57(0)	8.72(0)
1.0(4)	5.26(-1)	1.17(-1)	4.64(0)	3.32(0)	2.00(0)	2.29(0)	7.50(0)	6.60(0)	6.97(0)
7.0(4)	1.86(-1)	9.14(-3)	2.48(0)	2.06(0)	1.41(0)	1.55(0)	2.80(0)	2.50(0)	2.75(0)
1.0(5)	8.70(-3)	4.95(-3)	2.20(0)	1.88(0)	1.40(0)	1.47(0)	2.46(0)	2.18(0)	2.39(0)
2.0(5)	1.48(-3)	1.16(-3)	1.85(0)	1.55(0)	1.28(0)	1.38(0)	1.96(0)	1.72(0)	1.84(0)

Time (s)	Leaked Mass (g)		Settled Mass (g)		Plated Mass (g)		Removal Rate NaOH + NaI (kg/s)	AMMD Combined Aerosol (μm)
	NaOH	NaI	NaOH	NaI	NaOH	NaI		
6.0(2)	1.13(-1)	0	5.45(0)	0	4.53(0)	0	3.56(-2)	1.15(0)
9.0(2)	2.17(-1)	1.37(-3)	1.44(1)	4.22(-2)	6.05(0)	2.77(-2)	4.15(-2)	1.53(0)
1.8(3)	5.26(-1)	1.77(-2)	7.10(1)	1.49(0)	8.93(0)	3.25(-1)	1.02(-1)	2.34(0)
2.4(3)	7.27(-1)	3.86(-2)	1.49(2)	5.18(0)	1.03(1)	6.54(-1)	1.85(-1)	2.93(0)
2.7(3)	8.25(-1)	5.06(-2)	2.09(2)	8.74(0)	1.08(1)	8.18(-1)	2.48(-1)	3.30(0)
3.0(3)	9.20(-1)	6.25(-2)	2.90(2)	1.40(1)	1.13(1)	9.50(-1)	3.30(-1)	3.70(0)
4.2(3)	1.26(0)	1.07(-1)	8.75(2)	6.13(1)	1.27(1)	1.32(0)	6.95(-1)	5.32(0)
7.2(3)	1.71(0)	1.79(-1)	2.20(3)	2.03(2)	1.43(1)	1.79(0)	2.37(-1)	5.04(0)
1.0(4)	1.90(0)	2.18(-1)	2.55(3)	2.53(2)	1.51(1)	2.05(0)	8.74(-2)	4.37(0)
7.0(4)	2.47(0)	3.97(-1)	2.98(3)	3.43(2)	1.81(1)	3.40(0)	6.36(-4)	2.33(0)
1.0(5)	2.52(0)	4.16(-1)	2.99(3)	3.46(2)	1.84(1)	3.59(0)	2.42(-4)	2.10(0)
2.0(5)	2.55(0)	5.19(-1)	3.00(3)	3.49(2)	1.87(1)	3.86(0)	2.99(-5)	1.66(0)

(a) Obtained from log-probability plot of reported discrete size data.
(b) Calculated from log-probability plot of reported size data; d_s = AMMD $\exp(\ln^2 \sigma_g)$.
(c) Numbers in parenthesis are exponents of 10.

TABLE E-5

BLIND POST-TEST PREDICTIONS OF TEST AB7 BY BCL USING QUICKM CODE

Time (s)	Susp. Conc. (g/m^3) NaOH	NaI	AMMD (μm) NaOH[a]	AMMD (μm) NaI[a]	AMMD (μm) Combined	σ_g NaOH[a]	σ_g NaI[a]	σ_g Combined	Aero. Settling Mean Diam. (μm) NaOH[b]	Aero. Settling Mean Diam. (μm) NaI[b]
6.0(2)[c]	3.91(0)	0	1.19	--	1.19	1.75	--	1.75	1.63	--
9.0(2)	3.89(0)	7.67(-2)	1.61	0.81	1.58	1.63	1.75	1.68	2.04	1.11
1.8(3)	3.69(0)	3.04(-1)	2.50	1.22	2.51	2.10	2.16	1.98	4.33	2.21
2.4(3)	3.34(0)	4.45(-1)	3.10	1.41	2.90	2.48	2.41	2.21	7.07	3.06
2.7(3)	3.09(0)	4.34(-1)	3.40	1.66	3.22	2.68	2.41	2.25	8.98	3.60
3.0(3)	2.82(0)	4.19(-1)	3.70	1.87	3.47	2.51	2.67	2.28	8.63	4.90
4.2(3)	1.85(0)	3.42(-1)	3.88	2.28	3.78	2.58	2.87	2.26	9.53	6.93
7.2(3)	8.15(-1)	2.09(-1)	3.50	2.66	3.47	2.28	2.37	2.05	6.90	5.60
1.0(4)	4.92(-1)	1.48(-1)	3.32	2.57	3.15	1.83	2.14	1.92	4.78	4.58
7.0(4)	1.75(-2)	1.08(-2)	2.18	1.90	2.12	1.29	1.37	1.46	2.33	2.10
1.0(5)	7.77(-3)	5.60(-3)	1.94	1.68	1.84	1.30	1.38	1.43	2.08	1.86
2.0(5)	1.17(-3)	1.26(-3)	1.52	1.34	1.48	1.26	1.38	1.37	1.60	1.49

Time (s)	Leaked Mass (g) NaOH	Leaked Mass (g) NaI	Settled Mass (g) NaOH	Settled Mass (g) NaI	Plated Mass (g) NaOH	Plated Mass (g) NaI	Removal Rate (s^{-1}) NaOH	Removal Rate (s^{-1}) NaI
6.0(2)	1.12(-1)	0	8.06(0)	0	2.68(-1)	0	1.24(-5)	--
9.0(2)	2.28(-1)	1.00(-3)	2.57(1)	4.80(-2)	4.24(-1)	2.82(-3)	2.43(-5)	1.45(-7)
1.8(3)	5.66(-1)	1.74(-2)	1.89(2)	2.84(0)	7.12(-1)	3.66(-2)	1.02(-4)	2.56(-6)
2.4(3)	7.76(-1)	3.91(-2)	4.78(2)	1.23(1)	8.39(-1)	7.52(-2)	2.00(-4)	8.27(-6)
2.7(3)	8.72(-1)	5.22(-2)	6.87(2)	2.19(1)	8.90(-1)	9.53(-2)	2.49(-4)	1.27(-5)
3.0(3)	9.59(-1)	6.48(-2)	9.18(2)	3.47(1)	9.34(-1)	1.12(-1)	2.84(-4)	1.73(-5)
4.2(3)	1.23(0)	1.10(-1)	1.75(3)	9.98(1)	1.06(0)	1.59(-1)	2.91(-4)	2.87(-5)
7.2(3)	1.60(0)	1.89(-1)	2.64(3)	2.14(2)	1.23(0)	2.27(-1)	1.70(-4)	2.86(-5)
1.0(4)	1.77(0)	2.38(-1)	2.92(3)	2.66(2)	1.32(0)	2.66(-1)	1.18(-4)	2.49(-5)
7.0(4)	2.33(0)	4.68(-1)	3.33(3)	3.84(2)	1.67(0)	4.63(-1)	1.87(-5)	9.43(-6)
1.0(5)	2.37(0)	4.91(-1)	3.33(3)	3.88(2)	1.70(0)	4.89(-1)	1.41(-5)	8.09(-6)
2.0(5)	2.40(0)	5.19(-1)	3.34(3)	3.92(2)	1.73(0)	5.24(-1)	7.03(-6)	5.90(-6)

(a) Obtained from log-probability plot of reported size data.
(b) Calculated from log-probability plot; d_s = AMMD exp ($\ln^2 \sigma_g$).
(c) Numbers in parenthesis are exponents of 10.

APPENDIX F

CODE COMPARISONS OF SUSPENDED MASS CONCENTRATION

Table F1
SUSPENDED MASS CONCENTRATION AT 600 SECONDS

CODE	USER	NaOH Blind Post-Test Code (g/m^3)	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code (g/m^3)	NaI Ratio Code to Average	NaI Ratio Code to Test (b)
HAA-3	HEDL	3.34 (c)	0.948	1.113			
HAA-4	RI/ESG	3.52	0.999	1.173			
HAARM-3	HEDL	3.31	0.939	1.103			
CONTAIN	SNL	3.54	1.005	1.180			
QUICKM	BCL	3.91	1.110	1.303			
AVERAGE		3.524		1.175			

(a) Test AB7 result for NaOH = 3.0(0) ± 5.0(-1)
(b) Test AB7 result for NaI = 0.0
(c) Numbers in parenthesis are exponents of 10.

Table F2
SUSPENDED MASS CONCENTRATION AT 900 SECONDS

CODE	USER	NaOH Blind Post-Test Code (g/m^3)	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code (g/m^3)	NaI Ratio Code to Average	NaI Ratio Code to Test (b)
HAA-3	HEDL	3.22 (c)	0.928	1.073	6.82(-2)	0.970	0.974
HAA-4	RI/ESG	3.49	1.006	1.163	6.9(-2)	0.981	0.986
HAARM-3	HEDL	3.22	0.928	1.073	6.82(-2)	0.970	0.974
CONTAIN	SNL	3.53	1.017	1.177	6.95(-2)	0.988	0.993
QUICKM	BCL	3.89	1.121	1.297	7.67(-2)	1.091	1.096
AVERAGE		3.47		1.157	7.032(-2)		1.005

(a) Test AB7 result for NaOH = 3.0(0) ± 5.0(-1)
(b) Test AB7 result for NaI = 7.0(-2) ± 3.0(-3)
(c) Numbers in parenthesis are exponents of 10.

Table F3
SUSPENDED MASS CONCENTRATION AT 1800 SECONDS

CODE	USER	NaOH Blind Post-Test Code (g/m^3)	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code (g/m^3)	NaI Ratio Code to Average	NaI Ratio Code to Test (b)
HAA-3	HEDL	2.99 (c)	0.918	0.997	2.65(-1)	0.971	0.914
HAA-4	RI/ESG	3.23	0.991	1.077	2.61(-1)	0.957	0.900
HAARM-3	HEDL	2.92	0.896	0.973	2.58(-1)	0.946	0.890
CONTAIN	SNL	3.46	1.062	1.153	2.76(-1)	1.012	0.952
QUICKM	BCL	3.69	1.133	1.230	3.04(-1)	1.114	1.048
AVERAGE		3.26		1.086	2.73(-1)		0.941

(a) Test AB7 results for NaOH = 3.0(0) ± 5.0(-1)
(b) Test AB7 results for NaI = 2.9(-1) ± 4.0(-2)
(c) Numbers in parenthesis are exponents of 10.

Table F4
SUSPENDED MASS CONCENTRATION AT 2400 SECONDS

CODE	USER	NaOH Blind Post-Test Code (g/m^3)	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code (g/m^3)	NaI Ratio Code to Average	NaI Ratio Code to Test (b)
HAA-3	HEDL	2.15 (c)	0.773	0.754	3.07(-1)	0.833	0.722
HAA-4	RI/ESG	2.54	0.913	0.891	3.28(-1)	0.890	0.772
HAARM-3	HEDL	2.52	0.906	0.884	3.52(-1)	0.955	0.828
CONTAIN	SNL	3.36	1.208	1.179	4.1(-1)	1.113	0.965
QUICKM	BCL	3.34	1.201	1.172	4.45(-1)	1.208	1.047
AVERAGE		2.782		0.976	3.684(-1)		0.867

(a) Test AB7 results for NaOH = 2.85(0) ± 5.0(-1)
(b) Test AB7 results for NaI = 4.25(-1) ± 3.0(-2)
(c) Numbers in parenthesis are exponents of 10.

Table F5
SUSPENDED MASS CONCENTRATION AT 2700 SECONDS

CODE	USER	NaOH Blind Post-Test Code (g/m^3)	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code (g/m^3)	NaI Ratio Code to Average	NaI Ratio Code to Test (b)
HAA-3	HEDL	1.82 (c)	0.713	0.700	2.59(-1)	0.756	0.609
HAA-4	RI/ESG	2.23	0.873	0.858	2.88(-1)	0.840	0.678
HAARM-3	HEDL	2.34	0.916	0.900	3.27(-1)	0.954	0.769
CONTAIN	SNL	3.29	1.288	1.265	4.06(-1)	1.184	0.955
QUICKM	BCL	3.09	1.210	1.188	4.34(-1)	1.266	1.021
AVERAGE		2.554		0.982	3.43(-1)		0.807

(a) Test AB7 result for NaOH = 2.60(0) ± 4.0(-1)
(b) Test AB7 result for NaI = 4.25(-1) ± 3.0(-2)
(c) Numbers in parenthesis are exponents of 10.

Table F6
SUSPENDED MASS CONCENTRATION AT 3000 SECONDS

CODE	USER	NaOH Blind Post-Test Code (g/m^3)	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code (g/m^3)	NaI Ratio Code to Average	NaI Ratio Code to Test (b)
HAA-3	HEDL	1.51 (c)	0.649	0.609	2.15(-1)	0.677	0.512
HAA-4	RI/ESG	1.95	0.838	0.786	2.52(-1)	0.794	0.600
HAARM-3	HEDL	2.16	0.928	0.871	3.01(-1)	0.948	0.717
CONTAIN	SNL	3.2	1.375	1.290	4(-1)	1.260	0.952
QUICKM	BCL	2.82	1.211	1.137	4.19(-1)	1.320	0.998
AVERAGE		2.33		0.939	3.174(-1)		0.756

(a) Test AB7 result for NaOH = 2.48(0) ± 4.0(-1)
(b) Test AB7 result for NaI = 4.20(-1) ± 3.0(-2)
(c) Numbers in parenthesis are exponents of 10.

Table F7
SUSPENDED MASS CONCENTRATION AT 4200 SECONDS

		NaOH			NaI		
		Blind Post-Test Code	Ratio		Blind Post-Test Code	Ratio	
CODE	USER	(g/m^3)	Code to Average	Code to Test (a)	(g/m^3)	Code to Average	Code to Test (b)
HAA-3	HEDL	7.02(-1) (c)	0.459	0.360	1(-1)	0.440	0.250
HAA-4	RI/ESG	1.15	0.751	0.590	1.49(-1)	0.655	0.373
HAARM-3	HEDL	1.45	0.947	0.744	2.03(-1)	0.893	0.508
CONTAIN	SNL	2.5	1.634	1.282	3.43(-1)	1.508	0.858
QUICKM	BCL	1.85	1.209	0.949	3.42(-1)	1.504	0.855
AVERAGE		1.531		0.785	2.274(-1)		0.569

(a) Test AB7 result for NaOH = 1.95(0) ± 2.5(-1)
(b) Test AB7 result for NaI = 4.00(-1) ± 2.5(-2)
(c) Numbers in parenthesis are exponents of 10.

Table F8
SUSPENDED MASS CONCENTRATION AT 7200 SECONDS

		NaOH			NaI		
		Blind Post-Test Code	Ratio		Blind Post-Test Code	Ratio	
CODE	USER	(g/m^3)	Code to Average	Code to Test (a)	(g/m^3)	Code to Average	Code to Test (b)
HAA-3	HEDL	1.89(-1) (c)	0.327	0.160	2.7(-2)	0.249	0.093
HAA-4	RI/ESG	4.35(-1)	0.752	0.369	5.81(-2)	0.537	0.200
HAARM-3	HEDL	5.09(-1)	0.880	0.431	7.11(-2)	0.657	0.245
CONTAIN	SNL	9.44(-1)	1.632	0.800	1.76(-1)	1.626	0.607
QUICKM	BCL	8.15(-1)	1.409	0.691	2.09(-1)	1.931	0.721
AVERAGE		5.784(-1)		0.490	1.083(-1)		0.373

(a) Test AB7 result for NaOH = 1.18(0) ± 1.2(-1)
(b) Test AB7 result for NaI = 2.9(-1) ± 2.5(-2)
(c) Numbers in parenthesis are exponents of 10.

Table F9
SUSPENDED MASS CONCENTRATION AT 10000 SECONDS

CODE	USER	NaOH: Blind Post-Test Code (g/m³)	NaOH: Ratio Code to Average	NaOH: Ratio Code to Test (a)	NaI: Blind Post-Test Code (g/m³)	NaI: Ratio Code to Average	NaI: Ratio Code to Test (b)
HAA-3	HEDL	9.06(-2) (c)	0.290	0.110	1.29(-2)	0.190	0.059
HAA-4	RI/ESG	2.37(-1)	0.757	0.289	3.05(-2)	0.450	0.139
HAARM-3	HEDL	2.19(-1)	0.700	0.267	3.05(-2)	0.450	0.139
CONTAIN	SNL	5.26(-1)	1.681	0.641	1.17(-1)	1.726	0.532
QUICKM	BCL	4.92(-1)	1.572	0.600	1.48(-1)	2.184	0.673
AVERAGE		3.13(-1)		0.382	6.78(-2)		0.308

(a) Test AB7 result for NaOH = 8.2(-1) ± 3.0(-2)
(b) Test AB7 result for NaI = 2.2(-1) ± 2.0(-2)
(c) Numbers in parenthesis are exponents of 10.

Table F10
SUSPENDED MASS CONCENTRATION AT 70000 SECONDS

CODE	USER	NaOH: Blind Post-Test Code (g/m³)	NaOH: Ratio Code to Average	NaOH: Ratio Code to Test (a)	NaI: Blind Post-Test Code (g/m³)	NaI: Ratio Code to Average	NaI: Ratio Code to Test (b)
HAA-3	HEDL	5.59(-4) (c)	0.067	0.040	7.96(-5)	0.019	0.013
HAA-4	RI/ESG	4.37(-3)	0.526	0.312	5.63(-4)	0.136	0.094
HAARM-3	HEDL	4.96(-4)	0.060	0.035	6.93(-5)	0.017	0.012
CONTAIN	SNL	1.86(-2)	2.240	1.329	9.14(-3)	2.213	1.523
QUICKM	BCL	1.75(-2)	2.107	1.250	1.08(-2)	2.615	1.800
AVERAGE		8.31(-3)		0.593	4.131(-3)		0.688

(a) Test AB7 result for NaOH = 1.40(-2) ± 5.0(-3)
(b) Test AB7 result for NaI = 6.00(-3) ± 2.5(-4)
(c) Numbers in parenthesis are exponents of 10.

Table F11
SUSPENDED MASS CONCENTRATION AT 100000 SECONDS

CODE	USER	NaOH Blind Post-Test Code (g/m^3)	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code (g/m^3)	NaI Ratio Code to Average	NaI Ratio Code to Test (b)
HAA-3	HEDL	1.12(-4) (c)	0.031	0.021	1.59(-5)	0.007	0.006
HAA-4	RI/ESG	1.67(-3)	0.456	0.309	2.16(-4)	0.100	0.079
HAARM-3	HEDL	7.8(-5)	0.021	0.014	1.09(-5)	0.005	0.004
CONTAIN	SNL	8.7(-3)	2.373	1.611	4.95(-3)	2.293	1.800
QUICKM	BCL	7.77(-3)	2.119	1.439	5.6(-3)	2.594	2.036
AVERAGE		3.67(-3)		0.679	2.16(-3)		0.785

(a) Test AB7 result for NaOH = 5.4(-3) ± 5.5(-4)
(b) Test AB7 result for NaI = 2.75(-3) ± 4.0(-4)
(c) Numbers in parenthesis are exponents of 10.

Table F12
SUSPENDED MASS CONCENTRATION AT 200000 SECONDS

CODE	USER	NaOH Blind Post-Test Code (g/m^3)	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code (g/m^3)	NaI Ratio Code to Average	NaI Ratio Code to Test (b)
HAA-3	HEDL	1.05(-6) (c)	0.002	0.001	1.49(-7)	0.000	0.000
HAA-4	RI/ESG	1.69(-4)	0.300	0.172	2.18(-5)	0.045	0.034
HAARM-3	HEDL	2.91(-7)	0.001	0.000	4.07(-8)	0.000	0.000
CONTAIN	SNL	1.48(-3)	2.624	1.510	1.16(-3)	2.375	1.785
QUICKM	BCL	1.17(-3)	2.074	1.194	1.26(-3)	2.580	1.938
AVERAGE		5.641(-4)		0.576	4.884(-4)		0.751

(a) Test AB7 result for NaOH = 9.8(-4) ± 3.0(-4)
(b) Test AB7 result for NaI = 6.5(-4) ± 2.5(-4)
(c) Numbers in parenthesis are exponents of 10.

APPENDIX G

CODE COMPARISONS OF AERODYNAMIC MASS MEDIAN DIAMETER

Table G1
AERODYNAMIC MASS MEDIAN DIAMETER AT 600 SECONDS

CODE	USER	NaOH			NaI		
		Blind Post-Test Code AMMD (Micron)	Ratio		Blind Post-Test Code AMMD (Micron)	Ratio	
			Code to Average	Code to Test (a)		Code to Average	Code to Test (b)
HAA-3	HEDL	5.4(-1) (c)	0.446	0.267			
HAA-4	RI/ESG	1.54	1.271	0.762			
HAARM-3	HEDL	1.26	1.040	0.624			
CONTAIN	SNL	1.53	1.262	0.757			
QUICKM	BCL	1.19	0.982	0.589			
AVERAGE		1.212		0.600			

(a) Test AB7 result for NaOH = 2.02(0) ± 4.0(-1)
(b) Test AB7 result for NaI = 0
(c) Numbers in parenthesis are exponents of 10.

Table G2
AERODYNAMIC MASS MEDIAN DIAMETER AT 900 SECONDS

CODE	USER	NaOH			NaI		
		Blind Post-Test Code AMMD (Micron)	Ratio		Blind Post-Test Code AMMD (Micron)	Ratio	
			Code to Average	Code to Test (a)		Code to Average	Code to Test (b)
HAA-3	HEDL	8.2(-1) (c)	0.500	0.394	8.2(-1)	0.604	1.025
HAA-4	RI/ESG	2.44	1.488	1.173	2.44	1.797	3.050
HAARM-3	HEDL	1.77	1.079	0.851	1.77	1.303	2.213
CONTAIN	SNL	1.56	0.951	0.750	9.5(-1)	0.700	1.188
QUICKM	BCL	1.61	0.982	0.774	8.1(-1)	0.596	1.013
AVERAGE		1.64		0.788	1.36		1.698

(a) Test AB7 result for NaOH = 2.08(0) ± 4.0(-1)
(b) Test AB7 result for NaI = 8.0(-1) ± 8.0(-2)
(c) Numbers in parenthesis are exponents of 10.

Table G3
AERODYNAMIC MASS MEDIAN DIAMETER AT 1800 SECONDS

CODE	USER	NaOH Blind Post-Test Code AMMD (Micron)	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code AMMD (Micron)	NaI Ratio Code to Average	NaI Ratio Code to Test (b)
HAA-3	HEDL	2.92 (c)	0.889	1.259	2.92	1.031	2.014
HAA-4	RI/ESG	5.1	1.553	2.198	5.1	1.801	3.517
HAARM-3	HEDL	3.47	1.057	1.496	3.47	1.225	2.393
CONTAIN	SNL	2.43	0.740	1.047	1.45	0.512	1.000
QUICKM	BCL	2.5	0.761	1.078	1.22	0.431	0.841
AVERAGE		3.284		1.416	2.832		1.953

(a) Test AB7 result for NaOH = 2.32(0) ± 4.0(-1)
(b) Test AB7 result for NaI = 1.45(0) ± 2.5(-1)
(c) Numbers in parenthesis are exponents of 10.

Table G4
AERODYNAMIC MASS MEDIAN DIAMETER AT 2400 SECONDS

CODE	USER	NaOH Blind Post-Test Code AMMD (Micron)	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code AMMD (Micron)	NaI Ratio Code to Average	NaI Ratio Code to Test (b)
HAA-3	HEDL	5.15 (c)	1.234	2.004	5.15	1.449	2.682
HAA-4	RI/ESG	6.04	1.448	2.350	6.04	1.699	3.146
HAARM-3	HEDL	3.5	0.839	1.362	3.5	0.985	1.823
CONTAIN	SNL	3.07	0.736	1.195	1.67	0.470	0.870
QUICKM	BCL	3.1	0.743	1.206	1.41	0.397	0.734
AVERAGE		4.172		1.623	3.554		1.851

(a) Test AB7 result for NaOH = 2.57(0) ± 5.0(-1)
(b) Test AB7 result for NaI = 1.92(0) ± 3.5(-1)
(c) Numbers in parenthesis are exponents of 10.

Table G5

AERODYNAMIC MASS MEDIAN DIAMETER AT 2700 SECONDS

CODE	USER	NaOH Blind Post-Test Code AMMD (Micron)	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code AMMD (Micron)	NaI Ratio Code to Average	NaI Ratio Code to Test (b)
HAA-3	HEDL	6.03 (c)	1.290	2.250	6.03	1.491	2.871
HAA-4	RI/ESG	6.6	1.412	2.463	6.6	1.632	3.143
HAARM-3	HEDL	3.89	0.832	1.451	3.89	0.962	1.852
CONTAIN	SNL	3.45	0.738	1.287	2.04	0.504	0.971
QUICKM	BCL	3.4	0.727	1.269	1.66	0.410	0.790
AVERAGE		4.674		1.744	4.044		1.926

(a) Test AB7 result for NaOH = 2.68(0) ± 5.0(-1)

(b) Test AB7 result for NaI = 2.10(0) ± 4.0(-1)

(c) Numbers in parenthesis are exponents of 10.

Table G6

AERODYNAMIC MASS MEDIAN DIAMETER AT 3000 SECONDS

CODE	USER	NaOH Blind Post-Test Code AMMD (Micron)	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code AMMD (Micron)	NaI Ratio Code to Average	NaI Ratio Code to Test (b)
HAA-3	HEDL	6.72 (c)	1.317	2.400	6.72	1.514	2.947
HAA-4	RI/ESG	6.98	1.368	2.493	6.98	1.572	3.061
HAARM-3	HEDL	4.25	0.833	1.518	4.25	0.957	1.864
CONTAIN	SNL	3.87	0.758	1.382	2.38	0.536	1.044
QUICKM	BCL	3.7	0.725	1.321	1.87	0.421	0.820
AVERAGE		5.104		1.823	4.44		1.947

(a) Test AB7 result for NaOH = 2.80(0) ± 5.0(-1)

(b) Test AB7 result for NaI = 2.28(0) ± 4.0(-1)

(c) Number in parenthesis are exponents of 10.

Table 67
AERODYNAMIC MASS MEDIAN DIAMETER AT 4200 SECONDS

CODE	USER	NaOH Blind Post-Test Code AMMD (Micron)	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code AMMD (Micron)	NaI Ratio Code to Average	NaI Ratio Code to Test (b)
HAA-3	HEDL	7.85 (c)	1.322	1.869	7.85	1.500	2.309
HAA-4	RI/ESG	7.4	1.246	1.762	7.4	1.414	2.176
HAARM-3	HEDL	5.08	0.856	1.210	5.08	0.971	1.494
CONTAIN	SNL	5.48	0.923	1.305	3.55	0.679	1.044
QUICKM	BCL	3.88	0.653	0.924	2.28	0.436	0.671
AVERAGE		5.94		1.414	5.232		1.539

(a) Test AB7 result for NaOH = 4.20(0) ± 1.0(0)
(b) Test AB7 result for NaI = 3.40(0) ± 8.0(-1)
(c) Numbers in parenthesis are exponents of 10.

Table 68
AERODYNAMIC MASS MEDIAN DIAMETER AT 7200 SECONDS

CODE	USER	NaOH Blind Post-Test Code AMMD (Micron)	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code AMMD (Micron)	NaI Ratio Code to Average	NaI Ratio Code to Test (b)
HAA-3	HEDL	7.15 (c)	1.270	1.561	7.15	1.400	1.744
HAA-4	RI/ESG	6.76	1.200	1.476	6.76	1.324	1.649
HAARM-3	HEDL	5.39	0.957	1.177	5.39	1.056	1.315
CONTAIN	SNL	5.36	0.952	1.170	3.57	0.699	0.871
QUICKM	BCL	3.5	0.621	0.764	2.66	0.521	0.649
AVERAGE		5.632		1.230	5.11		1.245

(a) Test AB7 result for NaOH = 4.58(0) ± 9.0(-1)
(b) Test AB7 result for NaI = 4.10(0) ± 8.0(-1)
(c) Numbers in parenthesis are exponents of 10.

Table G9
AERODYNAMIC MASS MEDIAN DIAMETER AT 10000 SECONDS

CODE	USER	NaOH			NaI		
		Blind Post-Test Code AMMD (Micron)	Ratio		Blind Post-Test Code AMMD (Micron)	Ratio	
			Code to Average	Code to Test (a)		Code to Average	Code to Test (b)
HAA-3	HEDL	6.34 (c)	1.226	1.502	6.34	1.354	1.664
HAA-4	RI/ESG	6.1	1.179	1.445	6.1	1.303	1.601
HAARM-3	HEDL	5.08	0.982	1.204	5.08	1.085	1.333
CONTAIN	SNL	4.64	0.897	1.100	3.32	0.709	0.871
QUICKM	BCL	3.7	0.715	0.877	2.57	0.549	0.675
AVERAGE		5.172		1.226	4.682		1.229

(a) Test AB7 result for NaOH = 4.22(0) ± 8.0(-1)
(b) Test AB7 result for NaI = 3.81(0) ± 7.5(-1)
(c) Numbers in parenthesis are exponents of 10.

Table G10
AERODYNAMIC MASS MEDIAN DIAMETER AT 70000 SECONDS

CODE	USER	NaOH			NaI		
		Blind Post-Test Code AMMD (Micron)	Ratio		Blind Post-Test Code AMMD (Micron)	Ratio	
			Code to Average	Code to Test (a)		Code to Average	Code to Test (b)
HAA-3	HEDL	3.28 (c)	1.195	1.276	3.28	1.260	1.464
HAA-4	RI/ESG	3.16	1.152	1.230	3.16	1.214	1.411
HAARM-3	HEDL	2.62	0.955	1.019	2.62	1.006	1.170
CONTAIN	SNL	2.48	0.904	0.965	2.06	0.791	0.920
QUICKM	BCL	2.18	0.794	0.848	1.9	0.730	0.848
AVERAGE		2.744		1.068	2.604		1.163

(a) Test AB7 result for NaOH = 2.57(0) ± 5.0(-1)
(b) Test AB7 result for NaI = 2.24(0) ± 4.4(-1)
(c) Numbers in parenthesis are exponents of 10.

Table G11
AERODYNAMIC MASS MEDIAN DIAMETER AT 100000 SECONDS

CODE	USER	NaOH Blind Post-Test Code AMMD (Micron)	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code AMMD (Micron)	NaI Ratio Code to Average	NaI Ratio Code to Test (b)
HAA-3	HEDL	3.03 (c)	1.218	1.317	3.03	1.277	1.554
HAA-4	RI/ESG	2.86	1.150	1.243	2.86	1.206	1.467
HAARM-3	HEDL	2.41	0.969	1.048	2.41	1.016	1.236
CONTAIN	SNL	2.2	0.884	0.957	1.88	0.793	0.964
QUICKM	BCL	1.94	0.780	0.843	1.68	0.708	0.862
AVERAGE		2.49		1.082	2.372		1.216

(a) Test AB7 result for NaOH = 2.30(0) ± 4.6(-1)
(b) Test AB7 result for NaI = 1.95(0) ± 3.9(-1)
(c) Numbers in parenthesis are exponents of 10.

Table G12
AERODYNAMIC MASS MEDIAN DIAMETER AT 200000 SECONDS

CODE	USER	NaOH Blind Post-Test Code AMMD (Micron)	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code AMMD (Micron)	NaI Ratio Code to Average	NaI Ratio Code to Test (b)
HAA-3	HEDL	2.7 (c)	1.281	1.500	2.7	1.342	1.862
HAA-4	RI/ESG	2.32	1.101	1.289	2.32	1.153	1.600
HAARM-3	HEDL	2.15	1.020	1.194	2.15	1.069	1.483
CONTAIN	SNL	1.85	0.878	1.028	1.55	0.770	1.069
QUICKM	BCL	1.52	0.721	0.844	1.34	0.666	0.924
AVERAGE		2.11		1.171	2.012		1.388

(a) Test AB7 result for NaOH = 1.8(0) ± 3.6(-1)
(b) Test AB7 result for NaI = 1.45(0) ± 3.0(-1)
(c) Numbers in parenthesis are exponents of 10.

APPENDIX H

CODE COMPARISONS OF GEOMETRIC STANDARD DEVIATION

Table H1
GEOMETRIC STANDARD DEVIATION AT 600 SECONDS

CODE	USER	NaOH			NaI		
		Blind Post-Test Code Sigma	Ratio		Blind Post-Test Code Sigma	Ratio	
			Code to Average	Code to Test		Code to Average	Code to Test
HAA-3	HEDL	1.77	1.013	1.093			
HAA-4	RI/ESG	1.83	1.047	1.130			
HAARM-3	HEDL	1.75	1.001	1.080			
CONTAIN	SNL	1.64	0.938	1.012			
QUICKM	BCL	1.75	1.001	1.080			
AVERAGE		1.75		1.079			

(a) Test AB7 result for NaOH = 1.62 ± 0.15

Table H2
GEOMETRIC STANDARD DEVIATION AT 900 SECONDS

CODE	USER	NaOH			NaI		
		Blind Post-Test Code Sigma	Ratio		Blind Post-Test Code Sigma	Ratio	
			Code to Average	Code to Test (a)		Code to Average	Code to Test (b)
HAA-3	HEDL	1.64	1.026	1.006	1.64	0.995	1.006
HAA-4	RI/ESG	1.63	1.020	1.000	1.63	0.989	1.000
HAARM-3	HEDL	1.62	1.014	0.994	1.62	0.983	0.994
CONTAIN	SNL	1.47	0.920	0.902	1.6	0.971	0.982
QUICKM	BCL	1.63	1.020	1.000	1.75	1.062	1.074
AVERAGE		1.6		0.980	1.65		1.011

(a) Test AB7 result for NaOH = 1.63 ± 0.15
(b) Test AB7 result for NaI = 1.63 ± 0.15

Table H3
GEOMETRIC STANDARD DEVIATION AT 1800 SECONDS

CODE	USER	NaOH			NaI		
		Blind Post-Test Code Sigma	Ratio		Blind Post-Test Code Sigma	Ratio	
			Code to Average	Code to Test (a)		Code to Average	Code to Test (b)
HAA-3	HEDL	2.44	1.174	1.479	2.44	1.136	1.479
HAA-4	RI/ESG	2.12	1.020	1.285	2.12	0.987	1.285
HAARM-3	HEDL	2.16	1.039	1.309	2.16	1.006	1.309
CONTAIN	SNL	1.57	0.756	0.952	1.86	0.866	1.127
QUICKM	BCL	2.1	1.011	1.273	2.16	1.006	1.309
AVERAGE		2.08		1.259	2.15		1.302

(a) Test AB7 result for NaOH = 1.65 ± 0.15
(b) Test AB7 result for NaI = 1.65 ± 0.15

Table H4
GEOMETRIC STANDARD DEVIATION AT 2400 SECONDS

CODE	USER	NaOH			NaI		
		Blind Post-Test Code Sigma	Ratio		Blind Post-Test Code Sigma	Ratio	
			Code to Average	Code to Test (a)		Code to Average	Code to Test (b)
HAA-3	HEDL	2.73	1.195	1.606	2.73	1.157	1.606
HAA-4	RI/ESG	2.28	0.998	1.341	2.28	0.966	1.341
HAARM-3	HEDL	2.2	0.963	1.294	2.2	0.932	1.294
CONTAIN	SNL	1.73	0.757	1.018	2.18	0.924	1.282
QUICKM	BCL	2.48	1.086	1.459	2.41	1.021	1.418
AVERAGE		2.284		1.344	2.36		1.388

(a) Test AB7 result for NaOH = 1.70 ± 0.15
(b) Test AB7 result for NaI = 1.70 ± 0.15

Table H5
GEOMETRIC STANDARD DEVIATION AT 2700 SECONDS

CODE	USER	NaOH Blind Post-Test Code Sigma	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code Sigma	NaI Ratio Code to Average	NaI Ratio Code to Test (b)
HAA-3	HEDL	2.59	1.132	1.506	2.59	1.121	1.506
HAA-4	RI/ESG	2.19	0.957	1.273	2.19	0.948	1.273
HAARM-3	HEDL	2.14	0.935	1.244	2.14	0.926	1.244
CONTAIN	SNL	1.84	0.804	1.070	2.22	0.961	1.291
QUICKM	BCL	2.68	1.171	1.558	2.41	1.043	1.401
AVERAGE		2.29		1.330	2.31		1.343

(a) Test AB7 result for NaOH = 1.72 ± 0.15
(b) Test AB7 result for NaI = 1.72 ± 0.15

Table H6
GEOMETRIC STANDARD DEVIATION AT 3000 SECONDS

CODE	USER	NaOH Blind Post-Test Code Sigma	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code Sigma	NaI Ratio Code to Average	NaI Ratio Code to Test (b)
HAA-3	HEDL	2.48	1.106	1.417	2.48	1.058	1.417
HAA-4	RI/ESG	2.13	0.950	1.217	2.13	0.909	1.217
HAARM-3	HEDL	2.11	0.941	1.206	2.11	0.900	1.206
CONTAIN	SNL	1.98	0.883	1.131	2.33	0.994	1.331
QUICKM	BCL	2.51	1.120	1.434	2.67	1.139	1.526
AVERAGE		2.242		1.281	2.344		1.339

(a) Test AB7 result for NaOH = 1.75 ± 0.15
(b) Test AB7 result for NaI = 1.75 ± 0.15

Table H7
GEOMETRIC STANDARD DEVIATION AT 4200 SECONDS

CODE	USER	NaOH Blind Post-Test Code Sigma	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code Sigma	NaI Ratio Code to Average	NaI Ratio Code to Test (b)
HAA-3	HEDL	2.16	0.976	1.149	2.16	0.918	1.149
HAA-4	RI/ESG	1.96	0.885	1.043	1.96	0.833	1.043
HAARM-3	HEDL	2.02	0.912	1.074	2.02	0.859	1.074
CONTAIN	SNL	2.35	1.061	1.250	2.75	1.169	1.463
QUICKM	BCL	2.58	1.165	1.372	2.87	1.220	1.527
AVERAGE		2.214		1.178	2.352		1.251

(a) Test AB7 result for NaOH = 1.88 ± 0.20
(b) Test AB7 result for NaI = 1.88 ± 0.20

Table H8
GEOMETRIC STANDARD DEVIATION AT 7200 SECONDS

CODE	USER	NaOH Blind Post-Test Code Sigma	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code Sigma	NaI Ratio Code to Average	NaI Ratio Code to Test (b)
HAA-3	HEDL	1.81	0.917	1.034	1.81	0.867	1.034
HAA-4	RI/ESG	1.74	0.881	0.994	1.74	0.833	0.994
HAARM-3	HEDL	1.82	0.922	1.040	1.82	0.872	1.040
CONTAIN	SNL	2.22	1.125	1.269	2.7	1.293	1.543
QUICKM	BCL	2.28	1.155	1.303	2.37	1.135	1.354
AVERAGE		1.974		1.128	2.09		1.193

(a) Test AB7 result for NaOH = 1.75 ± 0.18
(b) Test AB7 result for NaI = 1.75 ± 0.18

Table H9
GEOMETRIC STANDARD DEVIATION AT 10000 SECONDS

CODE	USER	NaOH Blind Post-Test Code Sigma	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code Sigma	NaI Ratio Code to Average	NaI Ratio Code to Test (b)
HAA-3	HEDL	1.68	0.947	1.006	1.68	0.890	1.006
HAA-4	RI/ESG	1.63	0.919	0.976	1.63	0.863	0.976
HAARM-3	HEDL	1.7	0.958	1.018	1.7	0.900	1.018
CONTAIN	SNL	2	1.127	1.198	2.29	1.213	1.371
QUICKM	BCL	1.86	1.048	1.114	2.14	1.133	1.281
AVERAGE		1.774		1.062	1.89		1.131

(a) Test AB7 result for NaOH = 1.67 ± 0.20
(b) Test AB7 result for NaI = 1.67 ± 0.20

Table H10
GEOMETRIC STANDARD DEVIATION AT 70000 SECONDS

CODE	USER	NaOH Blind Post-Test Code Sigma	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code Sigma	NaI Ratio Code to Average	NaI Ratio Code to Test (b)
HAA-3	HEDL	1.29	0.979	0.878	1.29	0.947	0.878
HAA-4	RI/ESG	1.31	0.994	0.891	1.31	0.962	0.891
HAARM-3	HEDL	1.29	0.979	0.878	1.29	0.947	0.878
CONTAIN	SNL	1.41	1.070	0.959	1.55	1.138	1.054
QUICKM	BCL	1.29	0.979	0.878	1.37	1.006	0.932
AVERAGE		1.32		0.897	1.362		0.927

(a) Test AB7 result for NaOH = 1.47 ± 0.15
(b) Test AB7 result for NaI = 1.47 ± 0.15

Table H11
GEOMETRIC STANDARD DEVIATION AT 100000 SECONDS

CODE	USER	NaOH Blind Post-Test Code Sigma	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code Sigma	NaI Ratio Code to Average	NaI Ratio Code to Test (b)
HAA-3	HEDL	1.25	0.967	0.862	1.25	0.946	0.862
HAA-4	RI/ESG	1.27	0.983	0.876	1.27	0.961	0.876
HAARM-3	HEDL	1.24	0.960	0.855	1.24	0.938	0.855
CONTAIN	SNL	1.4	1.084	0.966	1.47	1.112	1.014
QUICKM	BCL	1.3	1.006	0.897	1.38	1.044	0.952
AVERAGE		1.292		0.891	1.322		0.912

(a) Test AB7 result for NaOH = 1.45 ± 0.15
(b) Test AB7 result for NaI = 1.45 ± 0.15

Table H12
GEOMETRIC STANDARD DEVIATION AT 200000 SECONDS

CODE	USER	NaOH Blind Post-Test Code Sigma	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code Sigma	NaI Ratio Code to Average	NaI Ratio Code to Test (b)
HAA-3	HEDL	1.19	0.974	0.850	1.19	0.940	0.850
HAA-4	RI/ESG	1.2	0.982	0.857	1.2	0.948	0.857
HAARM-3	HEDL	1.18	0.966	0.843	1.18	0.932	0.843
CONTAIN	SNL	1.28	1.047	0.914	1.38	1.090	0.986
QUICKM	BCL	1.26	1.031	0.900	1.38	1.090	0.986
AVERAGE		1.222		0.873	1.27		0.904

(a) Test AB7 result for NaOH = 1.40 ± 0.15
(b) Test AB7 result for NaI = 1.40 ± 0.15

A P P E N D I X I

CODE COMPARISONS OF AERODYNAMIC SETTLING MEAN DIAMETER

Table I1
AERODYNAMIC SETTLING MEAN DIAMETER AT 600 SECONDS

CODE	USER	NaOH			NaI		
		Blind Post-Test Code (Micron)	Ratio		Blind Post-Test Code (Micron)	Ratio	
			Code to Average	Code to Test (a)		Code to Average	Code to Test (b)
HAA-3	HEDL	7.5(-1) (c)	0.488	0.302			
HAA-4	RI/ESG	2.16	1.406	0.871			
HAARM-3	HEDL	1.72	1.120	0.694			
CONTAIN	SNL	1.42	0.924	0.573			
QUICKM	BCL	1.63	1.061	0.657			
AVERAGE		1.54		0.619			

(a) Test AB7 result for NaOH = 2.48 ± 0.50
(b) Test AB7 result for NaI = 0
(c) Numbers in parenthesis are exponents of 10.

Table I2
AERODYNAMIC SETTLING MEAN DIAMETER AT 900 SECONDS

CODE	USER	NaOH			NaI		
		Blind Post-Test Code (Micron)	Ratio		Blind Post-Test Code (Micron)	Ratio	
			Code to Average	Code to Test (a)		Code to Average	Code to Test (b)
HAA-3	HEDL	1.64	0.762	0.651	1.64	0.891	1.547
HAA-4	RI/ESG	3.04	1.413	1.206	3.04	1.652	2.868
HAARM-3	HEDL	2.23	1.036	0.885	2.23	1.212	2.104
CONTAIN	SNL	1.81	0.841	0.718	1.18	0.641	1.113
QUICKM	BCL	2.04	0.948	0.810	1.11	0.603	1.047
AVERAGE		2.152		0.854	1.84		1.736

(a) Test AB7 result for NaOH = 2.52 ± 0.5
(b) Test AB7 result for NaI = 1.06 ± 0.2

Table I3
AERODYNAMIC SETTLING MEAN DIAMETER AT 1800 SECONDS

CODE	USER	NaOH Blind Post-Test Code (Micron)	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code (Micron)	NaI Ratio Code to Average	NaI Ratio Code to Test (b)
HAA-3	HEDL	6.47	1.121	2.041	6.47	1.240	3.370
HAA-4	RI/ESG	8.82	1.528	2.782	8.82	1.703	4.594
HAARM-3	HEDL	6.27	1.086	1.978	6.27	1.210	3.266
CONTAIN	SNL	2.98	0.516	0.940	2.13	0.411	1.109
QUICKM	BCL	4.33	0.750	1.366	2.21	0.427	1.151
AVERAGE		5.774		1.821	5.18		2.698

(a) Test AB7 result for NaOH = 3.17 ± 0.6
(b) Test AB7 result for NaI = 1.92 ± 0.38

Table I4
AERODYNAMIC SETTLING MEAN DIAMETER AT 2400 SECONDS

CODE	USER	NaOH Blind Post-Test Code (Micron)	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code (Micron)	NaI Ratio Code to Average	NaI Ratio Code to Test (b)
HAA-3	HEDL	1.41(1) (c)	1.623	4.006	1.41(1)	1.838	5.529
HAA-4	RI/ESG	1.16(1)	1.335	3.295	1.16(1)	1.512	4.549
HAARM-3	HEDL	6.52	0.751	1.852	6.52	0.850	2.557
CONTAIN	SNL	4.14	0.477	1.176	3.07	0.400	1.204
QUICKM	BCL	7.07	0.814	2.009	3.06	0.399	1.200
AVERAGE		8.69		2.468	7.67		3.008

(a) Test AB7 result for NaOH = 3.52 ± 0.7
(b) Test AB7 result for NaI = 2.55 ± 0.5
(c) Numbers in parenthesis are exponents of 10.

Table I5

AERODYNAMIC SETTLING MEAN DIAMETER AT 2700 SECONDS

CODE	USER	NaOH			NaI		
		Blind Post-Test Code (Micron)	Ratio		Blind Post-Test Code (Micron)	Ratio	
			Code to Average	Code to Test (a)		Code to Average	Code to Test (b)
HAA-3	HEDL	1.49(1) (c)	1.561	3.973	1.49(1)	1.800	5.138
HAA-4	RI/ESG	1.19(1)	1.247	3.173	1.19(1)	1.445	4.103
HAARM-3	HEDL	6.94	0.727	1.851	6.94	0.842	2.393
CONTAIN	SNL	5	0.524	1.333	3.85	0.467	1.328
QUICKM	BCL	8.98	0.941	2.395	3.6	0.437	1.241
AVERAGE		9.544		2.545	8.24		2.841

(a) Test AB7 result for NaOH = 3.75 ± 0.7
(b) Test AB7 result for NaI = 2.90 ± 0.6
(c) Numbers in parenthesis are exponents of 10.

Table I6

AERODYNAMIC SETTLING MEAN DIAMTER AT 3000 SECONDS

CODE	USER	NaOH			NaI		
		Blind Post-Test Code (Micron)	Ratio		Blind Post-Test Code (Micron)	Ratio	
			Code to Average	Code to Test (a)		Code to Average	Code to Test (b)
HAA-3	HEDL	1.53(1) (c)	1.542	3.844	1.53(1)	1.716	4.857
HAA-4	RI/ESG	1.21(1)	1.219	3.040	1.21(1)	1.357	3.841
HAARM-3	HEDL	7.42	0.748	1.864	7.42	0.832	2.356
CONTAIN	SNL	6.17	0.622	1.550	4.87	0.546	1.546
QUICKM	BCL	8.63	0.870	2.168	4.9	0.549	1.556
AVERAGE		9.924		2.493	8.92		2.831

(a) Test AB7 result for NaOH = 3.98 ± 0.80
(b) Test AB7 result for NaI = 3.15 ± 0.63
(c) Numbers in parenthesis are exponents of 10.

Table I7
AERODYNAMIC SETTLING MEAN DIAMETER AT 4200 SECONDS

CODE	USER	NaOH Blind Post-Test Code (Micron)	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code (Micron)	NaI Ratio Code to Average	NaI Ratio Code to Test (b)
HAA-3	HEDL	1.42(1) (c)	1.286	2.582	1.42(1)	1.387	3.021
HAA-4	RI/ESG	1.15(1)	1.041	2.091	1.15(1)	1.123	2.447
HAARM-3	HEDL	8.69	0.787	1.580	8.69	0.849	1.849
CONTAIN	SNL	1.13(1)	1.023	2.055	9.88	0.965	2.102
QUICKM	BCL	9.53	0.863	1.733	6.93	0.677	1.474
AVERAGE		1.105(1)		2.008	1.024(1)		2.179

(a) Test AB7 result for NaOH = 5.50 ± 1.0
(b) Test AB7 result for NaI = 4.70 ± 1.0
(c) Numbers in parenthesis are exponents of 10.

Table I8
AERODYNAMIC SETTLING MEAN DIAMETER AT 7200 SECONDS

CODE	USER	NaOH Blind Post-Test Code (Micron)	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code (Micron)	NaI Ratio Code to Average	NaI Ratio Code to Test (b)
HAA-3	HEDL	1.01(1) (c)	1.151	1.616	1.01(1)	1.201	1.820
HAA-4	RI/ESG	9.08	1.034	1.453	9.08	1.079	1.636
HAARM-3	HEDL	7.71	0.878	1.234	7.71	0.917	1.389
CONTAIN	SNL	1.01(1)	1.151	1.616	9.57	1.138	1.724
QUICKM	BCL	6.9	0.786	1.104	5.6	0.666	1.009
AVERAGE		8.78		1.404	8.412		1.516

(a) Test AB7 result for NaOH = 6.25 ± 1.3
(b) Test AB7 result for NaI = 5.55 ± 1.1
(c) Numbers in parenthesis are exponents of 10.

Table I9
AERODYNAMIC SETTLING MEAN DIAMETER AT 10000 SECONDS

		NaOH			NaI		
		Blind Post-Test Code	Ratio		Blind Post-Test Code	Ratio	
CODE	USER	(Micron)	Code to Average	Code to Test (a)	(Micron)	Code to Average	Code to Test
HAA-3	HEDL	8.3	1.185	1.469	8.3	1.223	1.660
HAA-4	RI/ESG	7.72	1.102	1.366	7.72	1.138	1.544
HAARM-3	HEDL	6.73	0.961	1.191	6.73	0.992	1.346
CONTAIN	SNL	7.5	1.071	1.327	6.6	0.973	1.320
QUICKM	BCL	4.78	0.682	0.846	4.58	0.675	0.916
AVERAGE		7.01		1.240	6.78		1.357

(a) Test AB7 result for NaOH = 5.65 ± 1.2
(b) Test AB7 result for NaI = 5.00 ± 1.0

Table I10
AERODYNAMIC SETTLING MEAN DIAMETER AT 70000 SECONDS

		NaOH			NaI		
		Blind Post-Test Code	Ratio		Blind Post-Test Code	Ratio	
CODE	USER	(Micron)	Code to Average	Code to Test (a)	(Micron)	Code to Average	Code to Test (b)
HAA-3	HEDL	3.5	1.182	1.186	3.5	1.225	1.458
HAA-4	RI/ESG	3.38	1.141	1.146	3.38	1.183	1.408
HAARM-3	HEDL	2.8	0.945	0.949	2.8	0.980	1.167
CONTAIN	SNL	2.8	0.945	0.949	2.5	0.875	1.042
QUICKM	BCL	2.33	0.787	0.790	2.1	0.735	0.875
AVERAGE		2.962		1.004	2.86		1.190

(a) Test AB7 result for NaOH = 2.95 ± 0.5
(b) Test AB7 result for NaI = 2.40 ± 0.4

Table I11

AERODYNAMIC SETTLING MEAN DIAMETER AT 100000 SECONDS

CODE	USER	NaOH Blind Post-Test Code (Micron)	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code (Micron)	NaI Ratio Code to Average	NaI Ratio Code to Test (b)
HAA-3	HEDL	3.18	1.187	1.247	3.18	1.233	1.445
HAA-4	RI/ESG	3	1.119	1.176	3	1.163	1.364
HAARM-3	HEDL	2.68	1.000	1.051	2.68	1.039	1.218
CONTAIN	SNL	2.46	0.918	0.965	2.18	0.845	0.991
QUICKM	BCL	2.08	0.776	0.816	1.86	0.721	0.845
AVERAGE		2.68		1.051	2.58		1.173

(a) Test AB7 result for NaOH = 2.55 ± 0.4

(b) Test AB7 result for NaI = 2.20 ± 0.4

Table I12

AERODYNAMIC SETTLING MEAN DIAMETER AT 200000 SECONDS

CODE	USER	NaOH Blind Post-Test Code (Micron)	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code (Micron)	NaI Ratio Code to Average	NaI Ratio Code to Test (b)
HAA-3	HEDL	2.78	1.269	1.589	2.78	1.311	1.794
HAA-4	RI/ESG	2.4	1.096	1.371	2.4	1.132	1.548
HAARM-3	HEDL	2.21	1.009	1.263	2.21	1.042	1.426
CONTAIN	SNL	1.96	0.895	1.120	1.72	0.811	1.110
QUICKM	BCL	1.6	0.731	0.914	1.49	0.703	0.961
AVERAGE		2.19		1.251	2.12		1.368

(a) Test AB7 result for NaOH = 1.75 ± 0.35

(b) Test AB7 result for NaI = 1.55 ± 0.30

APPENDIX J

CODE COMPARISONS OF LEAKED MASS

Table J1
LEAKED MASS AT 600 SECONDS

CODE	USER	NaOH Blind Post-Test Code (g)	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code (g)	NaI Ratio Code to Average	NaI Ratio Code to Test (b)
HAA-3	HEDL	1(-1) (c)	0.946	0.980			
HAA-4	RI/ESG	1.04(-1)	0.984	1.020			
HAARM-3	HEDL	9.95(-2)	0.941	0.975			
CONTAIN	SNL	1.13(-1)	1.069	1.108			
QUICKM	BCL	1.12(-1)	1.060	1.098			
AVERAGE		1.06(-1)		1.036			

(a) Test AB7 result for NaOH = 1.02(-1) ± 1.0(-2)
(b) Test AB7 result for NaI = 0
(c) Numbers in parenthesis are exponents of 10.

Table J2
LEAKED MASS AT 900 SECONDS

CODE	USER	NaOH Blind Post-Test Code (g)	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code (g)	NaI Ratio Code to Average	NaI Ratio Code to Test (b)
HAA-3	HEDL	1.97(-1) (c)	0.942	1.031	1.02(-3)	0.936	1.010
HAA-4	RI/ESG	2.08(-1)	0.994	1.089	1.02(-3)	0.936	1.010
HAARM-3	HEDL	1.96(-1)	0.937	1.026	1.04(-3)	0.954	1.030
CONTAIN	SNL	2.17(-1)	1.037	1.136	1.37(-3)	1.257	1.356
QUICKM	BCL	2.28(-1)	1.090	1.194	1(-3)	0.917	0.990
AVERAGE		2.092(-1)		1.095	1.09(-3)		1.079

(a) Test AB7 result for NaOH = 1.91(-1) ± 2.0(-2)
(b) Test AB7 result for NaI = 1.01(-3) ± 1.0(-4)
(c) Numbers in parenthesis are exponents of 10.

Table J3
LEAKED MASS AT 1800 SECONDS

CODE	USER	NaOH Blind Post-Test Code (g)	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code (g)	NaI Ratio Code to Average	NaI Ratio Code to Test (b)
HAA-3	HEDL	4.72(-1) (c)	0.927	1.033	1.59(-2)	0.960	0.958
HAA-4	RI/ESG	5.1(-1)	1.002	1.116	1.6(-2)	0.966	0.964
HAARM-3	HEDL	4.71(-1)	0.925	1.031	1.58(-2)	0.954	0.952
CONTAIN	SNL	5.26(-1)	1.033	1.151	1.77(-2)	1.069	1.066
QUICKM	BCL	5.66(-1)	1.112	1.239	1.74(-2)	1.051	1.048
AVERAGE		5.09(-1)		1.114	1.66(-2)		0.998

(a) Test AB7 result for NaOH = 4.57(-1) ± 5.0(-2)
(b) Test AB7 result for NaI = 1.66(-2) ± 1.7(-3)
(c) Numbers in parenthesis are exponents of 10.

Table J4
LEAKED MASS AT 2400 SECONDS

CODE	USER	NaOH Blind Post-Test Code (g)	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code (g)	NaI Ratio Code to Average	NaI Ratio Code to Test (b)
HAA-3	HEDL	6.25(-1) (c)	0.908	0.989	3.3(-2)	0.925	1.115
HAA-4	RI/ESG	6.81(-1)	0.990	1.078	3.36(-2)	0.942	1.135
HAARM-3	HEDL	6.32(-1)	0.918	1.000	3.4(-2)	0.953	1.149
CONTAIN	SNL	7.27(-1)	1.056	1.150	3.86(-2)	1.082	1.304
QUICKM	BCL	7.76(-1)	1.128	1.228	3.91(-2)	1.096	1.321
AVERAGE		6.882(-1)		1.089	3.57(-2)		1.205

(a) Test AB7 result for NaOH = 6.32(-1) ± 6.3(-2)
(b) Test AB7 result for NaI = 2.96(-2) ± 3.0(-3)
(c) Numbers in parenthesis are exponents of 10.

Table J5
LEAKED MASS AT 2700 SECONDS

CODE	USER	NaOH Blind Post-Test Code (g)	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code (g)	NaI Ratio Code to Average	NaI Ratio Code to Test (b)
HAA-3	HEDL	6.84(-1) (c)	0.891	0.957	4.14(-2)	0.896	0.981
HAA-4	RI/ESG	7.52(-1)	0.980	1.052	4.27(-2)	0.925	1.012
HAARM-3	HEDL	7.04(-1)	0.917	0.985	4.4(-2)	0.953	1.043
CONTAIN	SNL	8.25(-1)	1.075	1.154	5.06(-2)	1.096	1.199
QUICKM	BCL	8.72(-1)	1.136	1.220	5.22(-2)	1.130	1.237
AVERAGE		7.674(-1)		1.073	4.62(-2)		1.094

(a) Test AB7 result for NaOH = 7.15(-1) ± 7.2(-2)
(b) Test AB7 result for NaI = 4.22(-2) ± 4.2(-3)
(c) Numbers in parenthesis are exponents of 10.

Table J6
LEAKED MASS AT 3000 SECONDS

CODE	USER	NaOH Blind Post-Test Code (g)	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code (g)	NaI Ratio Code to Average	NaI Ratio Code to Test (b)
HAA-3	HEDL	7.33(-1) (c)	0.874	0.924	4.84(-2)	0.865	0.885
HAA-4	RI/ESG	8.13(-1)	0.969	1.025	5.07(-2)	0.906	0.927
HAARM-3	HEDL	7.7(-1)	0.918	0.971	5.33(-2)	0.953	0.974
CONTAIN	SNL	9.2(-1)	1.097	1.160	6.25(-2)	1.117	1.143
QUICKM	BCL	9.59(-1)	1.143	1.209	6.48(-2)	1.158	1.185
AVERAGE		8.39(-1)		1.058	5.594(-2)		1.023

(a) Test AB7 result for NaOH = 7.93(-1) ± 8.0(-2)
(b) Test AB7 result for NaI = 5.47(-2) ± 5.5(-3)
(c) Numbers in parenthesis are exponents of 10.

Table J7
LEAKED MASS AT 4200 SECONDS

CODE	USER	NaOH Blind Post-Test Code (g)	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code (g)	NaI Ratio Code to Average	NaI Ratio Code to Test (b)
HAA-3	HEDL	8.57(-1) (c)	0.805	0.801	6.6(-2)	0.751	0.635
HAA-4	RI/ESG	9.92(-1)	0.932	0.927	7.38(-2)	0.839	0.710
HAARM-3	HEDL	9.82(-1)	0.923	0.918	8.29(-2)	0.943	0.797
CONTAIN	SNL	1.26	1.184	1.178	1.07(-1)	1.217	1.029
QUICKM	BCL	1.23	1.156	1.150	1.1(-1)	1.251	1.058
AVERAGE		1.065		0.995	8.794(-2)		0.846

(a) Test AB7 result for NaOH = 1.07(0) ± 1.1(-1)
(b) Test AB7 result for NaI = 1.04(-1) ± 1.0(-2)
(c) Numbers in parenthesis are exponents of 10.

Table J8
LEAKED MASS AT 7200 SECONDS

CODE	USER	NaOH Blind Post-Test Code (g)	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code (g)	NaI Ratio Code to Average	NaI Ratio Code to Test (b)
HAA-3	HEDL	9.65(-1) (c)	0.719	0.631	8.15(-2)	0.608	0.392
HAA-4	RI/ESG	1.2	0.894	0.784	1.01(-1)	0.753	0.486
HAARM-3	HEDL	1.24	0.923	0.810	1.2(-1)	0.895	0.577
CONTAIN	SNL	1.71	1.273	1.118	1.79(-1)	1.335	0.861
QUICKM	BCL	1.6	1.191	1.046	1.89(-1)	1.409	0.909
AVERAGE		1.343		0.878	1.341(-1)		0.645

(a) Test AB7 result for NaOH = 1.53(0) ± 1.5(-1)
(b) Test AB7 result for NaI = 2.08(-1) ± 2.1(-2)
(c) Numbers in parenthesis are exponents of 10.

Table J9
LEAKED MASS AT 10000 SECONDS

CODE	USER	NaOH Blind Post-Test Code (g)	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code (g)	NaI Ratio Code to Average	NaI Ratio Code to Test (b)
HAA-3	HEDL	1 (c)	0.685	0.552	8.66(-2)	0.550	0.312
HAA-4	RI/ESG	1.29	0.884	0.713	1.12(-1)	0.711	0.403
HAARM-3	HEDL	1.34	0.918	0.740	1.33(-1)	0.844	0.478
CONTAIN	SNL	1.9	1.301	1.050	2.18(-1)	1.384	0.784
QUICKM	BCL	1.77	1.212	0.978	2.38(-1)	1.511	0.856
AVERAGE		1.46		0.807	1.58(-1)		0.567

(a) Test AB7 result for NaOH = 1.81(0) ± 1.8(-1)
(b) Test AB7 result for NaI = 2.78(-1) ± 2.8(-2)
(c) Numbers in parenthesis are exponents of 10.

Table J10
LEAKED MASS AT 70000 SECONDS

CODE	USER	NaOH Blind Post-Test Code (g)	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code (g)	NaI Ratio Code to Average	NaI Ratio Code to Test (b)
HAA-3	HEDL	1.07 (c)	0.606	0.408	9.59(-2)	0.383	0.165
HAA-4	RI/ESG	1.5	0.849	0.573	1.4(-1)	0.560	0.241
HAARM-3	HEDL	1.46	0.827	0.557	1.5(-1)	0.600	0.259
CONTAIN	SNL	2.47	1.399	0.943	3.97(-1)	1.587	0.684
QUICKM	BCL	2.33	1.319	0.889	4.68(-1)	1.871	0.807
AVERAGE		1.77		0.674	2.502(-1)		0.431

(a) Test AB7 result for NaOH = 2.62(0) ± 2.6(-1)
(b) Test AB7 result for NaI = 5.80(-1) ± 5.8(-2)
(c) Numbers in parenthesis are exponents of 10.

Table J11
LEAKED MASS AT 100000 SECONDS

CODE	USER	NaOH Blind Post-Test Code (g)	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code (g)	NaI Ratio Code to Average	NaI Ratio Code to Test (b)
HAA-3	HEDL	1.07 (c)	0.600	0.404	9.6(-2)	0.371	0.162
HAA-4	RI/ESG	1.51	0.846	0.570	1.41(-1)	0.545	0.238
HAARM-3	HEDL	1.46	0.818	0.551	1.5(-1)	0.580	0.253
CONTAIN	SNL	2.51	1.407	0.947	4.16(-1)	1.607	0.703
QUICKM	BCL	2.37	1.328	0.894	4.91(-1)	1.897	0.829
AVERAGE		1.784		0.673	2.59(-1)		0.437

(a) Test AB7 result for NaOH = 2.65(0) ± 2.7(-1)
(b) Test AB7 result for NaI = 5.92(-1) ± 6.0(-2)
(c) Numbers in parenthesis are exponents of 10.

Table J12
LEAKED MASS AT 200000 SECONDS

CODE	USER	NaOH Blind Post-Test Code (g)	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code (g)	NaI Ratio Code to Average	NaI Ratio Code to Test (b)
HAA-3	HEDL	1.07 (c)	0.594	0.401	9.6(-2)	0.356	0.159
HAA-4	RI/ESG	1.52	0.844	0.569	1.41(-1)	0.523	0.233
HAARM-3	HEDL	1.46	0.811	0.547	1.5(-1)	0.557	0.248
CONTAIN	SNL	2.55	1.417	0.955	4.41(-1)	1.637	0.730
QUICKM	BCL	2.4	1.333	0.899	5.19(-1)	1.927	0.859
AVERAGE		1.8		0.674	2.694(-1)		0.446

(a) Test AB7 result for NaOH = 2.67(0) ± 2.7(-1)
(b) Test AB7 result for NaI = 6.04(-1) ± 6.0(-2)
(c) Numbers in parenthesis are exponents of 10.

APPENDIX K

CODE COMPARISONS OF SETTLED MASS

Table K1
SETTLED MASS AT 600 SECONDS

CODE	USER	NaOH Blind Post-Test Code (g)	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code (g)	NaI Ratio Code to Average	NaI Ratio Code to Test (a)
HAA-3	HEDL	1.3 (b)	0.186				
HAA-4	RI/ESG	9.89	1.413				
HAARM-3	HEDL	1.03(1)	1.471				
CONTAIN	SNL	5.45	0.779				
QUICKM	BCL	8.06	1.151				
AVERAGE		7					

(a) Test AB7 result not measured at this time.
(b) Numbers in parenthesis are exponents of 10.

Table K2
SETTLED MASS AT 900 SECONDS

CODE	USER	NaOH Blind Post-Test Code (g)	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code (g)	NaI Ratio Code to Average	NaI Ratio Code to Test (a)
HAA-3	HEDL	3.59 (b)	0.185		2.65(-2)	0.275	
HAA-4	RI/ESG	2.93(1)	1.514		2.11(-1)	2.190	
HAARM-3	HEDL	2.38(1)	1.229		1.54(-1)	1.599	
CONTAIN	SNL	1.44(1)	0.744		4.22(-2)	0.438	
QUICKM	BCL	2.57(1)	1.328		4.8(-2)	0.498	
AVERAGE		1.94(1)			9.634(-2)		

(a) Test AB7 result not measured at this time.
(b) Numbers in parenthesis are exponents of 10.

Table K3
SETTLED MASS AT 1800 SECONDS

CODE	USER	NaOH Blind Post-Test Code (g)	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code (g)	NaI Ratio Code to Average	NaI Ratio Code to Test (a)
HAA-3	HEDL	4.22(1) (b)	0.279		2.79	0.430	
HAA-4	RI/ESG	2.48(2)	1.642		1.33(1)	2.051	
HAARM-3	HEDL	2.05(2)	1.357		1.2(1)	1.851	
CONTAIN	SNL	7.1(1)	0.470		1.49	0.230	
QUICKM	BCL	1.89(2)	1.251		2.84	0.438	
AVERAGE		1.511(2)			6.484		

(a) Test AB7 result not measured at this time.
(b) Numbers in parenthesis are exponents of 10.

Table K4
SETTLED MASS AT 2400 SECONDS

CODE	USER	NaOH Blind Post-Test Code (g)	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code (g)	NaI Ratio Code to Average	NaI Ratio Code to Test (a)
HAA-3	HEDL	7.26(2) (b)	1.352		8.12(1)	1.856	
HAA-4	RI/ESG	8.26(2)	1.539		7.4(1)	1.691	
HAARM-3	HEDL	5.05(2)	0.941		4.61(1)	1.054	
CONTAIN	SNL	1.49(2)	0.278		5.18	0.118	
QUICKM	BCL	4.78(2)	0.890		1.23(1)	0.281	
AVERAGE		5.37(2)			4.38(1)		

(a) Test AB7 result not measured at this time.
(b) Numbers in parenthesis are exponents of 10.

Table K5
SETTLED MASS AT 2700 SECONDS

CODE	USER	NaOH			NaI		
		Blind Post-Test Code (g)	Ratio		Blind Post-Test Code (g)	Ratio	
			Code to Average	Code to Test (a)		Code to Average	Code to Test (a)
HAA-3	HEDL	1(3) (b)	1.377		1.21(2)	1.865	
HAA-4	RI/ESG	1.09(3)	1.501		1.07(2)	1.650	
HAARM-3	HEDL	6.46(2)	0.889		6.57(1)	1.013	
CONTAIN	SNL	2.09(2)	0.288		8.74	0.135	
QUICKM	BCL	6.87(2)	0.946		2.19(1)	0.338	
AVERAGE		7.264(2)			6.49(1)		

(a) Test AB7 result not measured at this time.
(b) Numbers in parenthesis are exponents of 10.

Table K6
SETTLED MASS AT 3000 SECONDS

CODE	USER	NaOH			NaI		
		Blind Post-Test Code (g)	Ratio		Blind Post-Test Code (g)	Ratio	
			Code to Average	Code to Test (a)		Code to Average	Code to Test (a)
HAA-3	HEDL	1.26(3) (b)	1.373		1.58(2)	1.834	
HAA-4	RI/ESG	1.33(3)	1.449		1.38(2)	1.602	
HAARM-3	HEDL	7.91(2)	0.862		8.6(1)	0.998	
CONTAIN	SNL	2.9(2)	0.316		1.4(1)	0.163	
QUICKM	BCL	9.18(2)	1.000		3.47(1)	0.403	
AVERAGE		9.18(2)			8.614(1)		

(a) Test AB7 result not measured at this time.
(b) Numbers in parenthesis are exponents of 10.

Table K7
SETTLED MASS AT 4200 SECONDS

CODE	USER	NaOH Blind Post-Test Code (g)	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code (g)	NaI Ratio Code to Average	NaI Ratio Code to Test (a)
HAA-3	HEDL	1.94(3) (b)	1.224		2.54(2)	1.574	
HAA-4	RI/ESG	2(3)	1.262		2.26(2)	1.400	
HAARM-3	HEDL	1.36(3)	0.858		1.66(2)	1.028	
CONTAIN	SNL	8.75(2)	0.552		6.13(1)	0.380	
QUICKM	BCL	1.75(3)	1.104		9.98(1)	0.618	
AVERAGE		1.59(3)			1.615(2)		

(a) Test AB7 result not measured at this time.
(b) Numbers in parenthesis are exponents of 10.

Table K8
SETTLED MASS AT 7200 SECONDS

CODE	USER	NaOH Blind Post-Test Code (g)	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code (g)	NaI Ratio Code to Average	NaI Ratio Code to Test (a)
HAA-3	HEDL	2.36(3) (b)	0.987		3.15(2)	1.202	
HAA-4	RI/ESG	2.61(3)	1.092		3.04(2)	1.160	
HAARM-3	HEDL	2.14(3)	0.895		2.74(2)	1.046	
CONTAIN	SNL	2.2(3)	0.921		2.03(2)	0.775	
QUICKM	BCL	2.64(3)	1.105		2.14(2)	0.817	
AVERAGE		2.39(3)			2.62(2)		

(a) Test AB7 result not measured at this time.
(b) Numbers in parenthesis are exponents of 10.

Table K9
SETTLED MASS AT 10000 SECONDS

CODE	USER	NaOH Blind Post-Test Code (g)	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code (g)	NaI Ratio Code to Average	NaI Ratio Code to Test (a)
HAA-3	HEDL	2.44(3) (b)	0.933		3.26(2)	1.102	
HAA-4	RI/ESG	2.78(3)	1.064		3.26(2)	1.102	
HAARM-3	HEDL	2.38(3)	0.910		3.08(2)	1.041	
CONTAIN	SNL	2.55(3)	0.976		2.53(2)	0.855	
QUICKM	BCL	2.92(3)	1.117		2.66(2)	0.899	
AVERAGE		2.614(3)			2.96(2)		

(a) Test AB7 result not measured at this time.
(b) Numbers in parenthesis are exponents of 10.

Table K10
SETTLED MASS AT 70000 SECONDS

CODE	USER	NaOH Blind Post-Test Code (g)	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code (g)	NaI Ratio Code to Average	NaI Ratio Code to Test (a)
HAA-3	HEDL	2.51(3) (b)	0.875		3.36(2)	0.962	
HAA-4	RI/ESG	2.97(3)	1.036		3.51(2)	1.005	
HAARM-3	HEDL	2.55(3)	0.889		3.32(2)	0.951	
CONTAIN	SNL	2.98(3)	1.039		3.43(2)	0.982	
QUICKM	BCL	3.33(3)	1.161		3.84(2)	1.100	
AVERAGE		2.87(3)			3.492(2)		

(a) Test AB7 result not measured at this time.
(b) Numbers in parenthesis are exponents of 10.

Table K11
SETTLED MASS AT 100000 SECONDS

CODE	USER	NaOH Blind Post-Test Code (g)	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code (g)	NaI Ratio Code to Average	NaI Ratio Code to Test (a)
HAA-3	HEDL	2.51(3) (b)	0.874		3.36(2)	0.958	
HAA-4	RI/ESG	2.98(3)	1.038		3.51(2)	1.001	
HAARM-3	HEDL	2.55(3)	0.888		3.32(2)	0.947	
CONTAIN	SNL	2.99(3)	1.041		3.46(2)	0.987	
QUICKM	BCL	3.33(3)	1.159		3.88(2)	1.107	
AVERAGE		2.872(3)			3.51(2)		

(a) Test AB7 result not measured at this time.
(b) Numbers in parenthesis are exponents of 10.

Table K12
SETTLED MASS AT 200000 SECONDS

CODE	USER	NaOH Blind Post-Test Code (g)	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code (g)	NaI Ratio Code to Average	NaI Ratio Code to Test (b)
HAA-3	HEDL	2.51(3) (c)	0.873	0.935	3.36(2)	0.954	0.812
HAA-4	RI/ESG	2.98(3)	1.036	1.110	3.52(2)	0.999	0.850
HAARM-3	HEDL	2.55(3)	0.887	0.950	3.32(2)	0.943	0.802
CONTAIN	SNL	3(3)	1.043	1.118	3.49(2)	0.991	0.843
QUICKM	BCL	3.34(3)	1.161	1.244	3.92(2)	1.113	0.947
AVERAGE		2.88(3)		1.072	3.522(2)		0.851

(a) Test AB7 result for NaOH = 2.684(3) ± 2.7(2)
(b) Test AB7 result for NaI = 4.14(2) ± 4.1(1)
(c) Numbers in parenthesis are exponents of 10.

A P P E N D I X   L

CODE COMPARISONS OF PLATED MASS

Table L1
PLATED MASS AT 600 SECONDS

CODE	USER	NaOH Blind Post-Test Code (g)	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code (g)	NaI Ratio Code to Average	NaI Ratio Code to Test (a)
HAA-3	HEDL	1.74(2) (b)	2.315				
HAA-4	RI/ESG	8.05	0.107				
HAARM-3	HEDL	1.89(2)	2.514				
CONTAIN	SNL	4.53	0.060				
QUICKM	BCL	2.68(-1)	0.004				
AVERAGE		7.52(1)					

(a) Test AB7 result not measured at this time.
(b) Numbers in parenthesis are exponents of 10.

Table L2
PLATED MASS AT 900 SECONDS

CODE	USER	NaOH Blind Post-Test Code (g)	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code (g)	NaI Ratio Code to Average	NaI Ratio Code to Test (a)
HAA-3	HEDL	2.72(2) (b)	2.518		9.47(-1)	3.075	
HAA-4	RI/ESG	1.26(1)	0.117		4.31(-2)	0.140	
HAARM-3	HEDL	2.49(2)	2.305		5.19(-1)	1.685	
CONTAIN	SNL	6.05	0.056		2.77(-2)	0.090	
QUICKM	BCL	4.24(-1)	0.004		2.82(-3)	0.009	
AVERAGE		1.081(2)			3.08(-1)		

(a) Test AB7 result not measured at this time.
(b) Numbers in parenthesis are exponents of 10.

Table L3
PLATED MASS AT 1800 SECONDS

CODE	USER	NaOH Blind Post-Test Code (g)	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code (g)	NaI Ratio Code to Average	NaI Ratio Code to Test (a)
HAA-3	HEDL	4.28(2) (b)	2.715		8.62	3.083	
HAA-4	RI/ESG	2.26(1)	0.143		5.19(-1)	0.186	
HAARM-3	HEDL	3.28(2)	2.081		4.48	1.602	
CONTAIN	SNL	8.93	0.057		3.25(-1)	0.116	
QUICKM	BCL	7.12(-1)	0.005		3.66(-2)	0.013	
AVERAGE		1.58(2)			2.8		

(a) Test AB7 result not measured at this time.
(b) Numbers in parenthesis are exponents of 10.

Table L4
PLATED MASS AT 2400 SECONDS

CODE	USER	NaOH Blind Post-Test Code (g)	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code (g)	NaI Ratio Code to Average	NaI Ratio Code to Test (a)
HAA-3	HEDL	4.57(2) (b)	2.670		1.18(1)	2.720	
HAA-4	RI/ESG	2.68(1)	0.157		9.48(-1)	0.219	
HAARM-3	HEDL	3.61(2)	2.109		8.21	1.893	
CONTAIN	SNL	1.03(1)	0.060		6.54(-1)	0.151	
QUICKM	BCL	8.39(-1)	0.005		7.52(-2)	0.017	
AVERAGE		1.712(2)			4.34		

(a) Test AB7 result not measured at this time.
(b) Numbers in parenthesis are exponents of 10.

Table L5
PLATED MASS AT 2700 SECONDS

CODE	USER	NaOH: Blind Post-Test Code (g)	NaOH: Ratio: Code to Average	NaOH: Ratio: Code to Test (a)	NaI: Blind Post-Test Code (g)	NaI: Ratio: Code to Average	NaI: Ratio: Code to Test (a)
HAA-3	HEDL	4.66(2) (b)	2.644		1.31(1)	2.582	
HAA-4	RI/ESG	2.84(1)	0.161		1.15	0.227	
HAARM-3	HEDL	3.75(2)	2.128		1.02(1)	2.011	
CONTAIN	SNL	1.08(1)	0.061		8.18(-1)	0.161	
QUICKM	BCL	8.9(-1)	0.005		9.53(-2)	0.019	
AVERAGE		1.763(2)			5.073		

(a) Test AB7 result not measured at this time.
(b) Numbers in parenthesis are exponents of 10.

Table L6
PLATED MASS AT 3000 SECONDS

CODE	USER	NaOH: Blind Post-Test Code (g)	NaOH: Ratio: Code to Average	NaOH: Ratio: Code to Test (a)	NaI: Blind Post-Test Code (g)	NaI: Ratio: Code to Average	NaI: Ratio: Code to Test (a)
HAA-3	HEDL	4.72(2) (b)	2.620		1.4(1)	2.484	
HAA-4	RI/ESG	2.97(1)	0.165		1.32	0.234	
HAARM-3	HEDL	3.87(2)	2.148		1.18(1)	2.094	
CONTAIN	SNL	1.13(1)	0.063		9.5(-1)	0.169	
QUICKM	BCL	9.34(-1)	0.005		1.12(-1)	0.020	
AVERAGE		1.802(2)			5.64		

(a) Test AB7 result not measured at this time.
(b) Numbers in parenthesis are exponents of 10.

Table L7
PLATED MASS AT 4200 SECONDS

CODE	USER	NaOH Blind Post-Test Code (g)	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code (g)	NaI Ratio Code to Average	NaI Ratio Code to Test (a)
HAA-3	HEDL	4.85(2) (b)	2.550		1.58(1)	2.235	
HAA-4	RI/ESG	3.31(1)	0.174		1.76	0.249	
HAARM-3	HEDL	4.19(2)	2.203		1.63(1)	2.306	
CONTAIN	SNL	1.27(1)	0.067		1.32	0.187	
QUICKM	BCL	1.06	0.006		1.59(-1)	0.022	
AVERAGE		1.902(2)			7.07		

(a) Test AB7 result not measured at this time.
(b) Numbers in parenthesis are exponents of 10.

Table L8
PLATED MASS AT 7200 SECONDS

CODE	USER	NaOH Blind Post-Test Code (g)	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code (g)	NaI Ratio Code to Average	NaI Ratio Code to Test (a)
HAA-3	HEDL	4.94(2) (b)	2.478		1.71(1)	2.031	
HAA-4	RI/ESG	3.64(1)	0.183		2.19	0.260	
HAARM-3	HEDL	4.51(2)	2.262		2.08(1)	2.470	
CONTAIN	SNL	1.43(1)	0.072		1.79	0.213	
QUICKM	BCL	1.23	0.006		2.27(-1)	0.027	
AVERAGE		1.994(2)			8.422		

(a) Test AB7 result not measured at this time.
(b) Numbers in parenthesis are exponents of 10.

Table L9
PLATED MASS AT 10000 SECONDS

CODE	USER	NaOH Blind Post-Test Code (g)	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code (g)	NaI Ratio Code to Average	NaI Ratio Code to Test (a)
HAA-3	HEDL	4.97(2) (b)	2.454		1.75(1)	1.969	
HAA-4	RI/ESG	3.74(1)	0.185		2.32	0.261	
HAARM-3	HEDL	4.62(2)	2.281		2.23(1)	2.509	
CONTAIN	SNL	1.51(1)	0.075		2.05	0.231	
QUICKM	BCL	1.32	0.007		2.66(-1)	0.030	
AVERAGE		2.03(2)			8.89		

(a) Test AB7 result not measured at this time.
(b) Numbers in parenthesis are exponents of 10.

Table L10
PLATED MASS AT 70000 SECONDS

CODE	USER	NaOH Blind Post-Test Code (g)	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code (g)	NaI Ratio Code to Average	NaI Ratio Code to Test (a)
HAA-3	HEDL	5.04(2) (b)	2.422		1.86(1)	1.880	
HAA-4	RI/ESG	3.88(1)	0.186		2.51	0.254	
HAARM-3	HEDL	4.78(2)	2.297		2.45(1)	2.476	
CONTAIN	SNL	1.81(1)	0.087		3.4	0.344	
QUICKM	BCL	1.67	0.008		4.63(-1)	0.047	
AVERAGE		2.082(2)			9.895		

(a) Test AB7 result not measured at this time.
(b) Numbers in parenthesis are exponents of 10.

Table L11
PLATED MASS AT 100000 SECONDS

CODE	USER	NaOH Blind Post-Test Code (g)	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code (g)	NaI Ratio Code to Average	NaI Ratio Code to Test (a)
HAA-3	HEDL	5.04(2) (b)	2.421		1.86(1)	1.872	
HAA-4	RI/ESG	3.89(1)	0.187		2.51	0.253	
HAARM-3	HEDL	4.78(2)	2.296		2.45(1)	2.465	
CONTAIN	SNL	1.84(1)	0.088		3.59	0.361	
QUICKM	BCL	1.7	0.008		4.89(-1)	0.049	
AVERAGE		2.082(2)			9.94		

(a) Test AB7 result not measured at this time.
(b) Numbers in parenthesis are exponents of 10.

Table L12
PLATED MASS AT 200000 SECONDS

CODE	USER	NaOH Blind Post-Test Code (g)	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code (g)	NaI Ratio Code to Average	NaI Ratio Code to Test (b)
HAA-3	HEDL	5.04(2) (c)	2.420	2.145	1.86(1)	1.860	2.078
HAA-4	RI/ESG	3.89(1)	0.187	0.166	2.51	0.251	0.280
HAARM-3	HEDL	4.78(2)	2.295	2.034	2.45(1)	2.450	2.737
CONTAIN	SNL	1.87(1)	0.090	0.080	3.86	0.386	0.431
QUICKM	BCL	1.73	0.008	0.007	5.24(-1)	0.052	0.059
AVERAGE		2.083(2)		0.886	10		1.117

(a) Test AB7 result for NaOH = 2.35(2) ± 6.0(1)
(b) Test AB7 result for NaI = 8.95(0) ± 2.7(-1)
(c) Numbers in parenthesis are exponents of 10.

APPENDIX M

CODE COMPARISONS OF INSTANTANEOUS REMOVAL RATE

Table M1
REMOVAL RATE AT 600 SECONDS

CODE	USER	NaOH Blind Post-Test Code (s^{-1})	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code (s^{-1})	NaI Ratio Code to Average	NaI Ratio Code to Test (a)
HAA-3	HEDL	1.64(-4) (b)	2.131				
HAA-4	RI/ESG	2.05(-5)	0.266				
HAARM-3	HEDL	1.76(-4)	2.287				
CONTAIN	SNL	1.19(-5)	0.155				
QUICKM	BCL	1.24(-5)	0.161				
AVERAGE		7.7(-5)					

(a) Test AB7 results not measured at this time.
(b) Numbers in parenthesis are exponents of 10.

Table M2
REMOVAL RATE AT 900 SECONDS

CODE	USER	NaOH Blind Post-Test Code (s^{-1})	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code (s^{-1})	NaI Ratio Code to Average	NaI Ratio Code to Test (a)
HAA-3	HEDL	1.01(-4) (b)	1.783		1.01(-4)	1.996	
HAA-4	RI/ESG	3.33(-5)	0.588		3.33(-5)	0.658	
HAARM-3	HEDL	6.8(-5)	1.200		6.8(-5)	1.344	
CONTAIN	SNL						
QUICKM	BCL	2.43(-5)	0.429		1.45(-7)	0.003	
AVERAGE		5.67(-5)			5.062(-5)		

(a) Test AB7 result not measured at this time.
(b) Numbers in parenthesis are exponents of 10.

Table M3
REMOVAL RATE AT 1800 SECONDS

CODE	USER	NaOH: Blind Post-Test Code (s^{-1})	NaOH: Ratio Code to Average	NaOH: Ratio Code to Test (a)	NaI: Blind Post-Test Code (s^{-1})	NaI: Ratio Code to Average	NaI: Ratio Code to Test (b)
HAA-3	HEDL	1.39(-4) (c)	0.830	1.264	1.39(-4)	0.974	
HAA-4	RI/ESG	2.5(-4)	1.493	2.273	2.5(-4)	1.753	
HAARM-3	HEDL	1.79(-4)	1.069	1.627	1.79(-4)	1.255	
CONTAIN	SNL						
QUICKM	BCL	1.02(-4)	0.609	0.927	2.56(-6)	0.018	
AVERAGE		1.68(-4)		1.523	1.43(-4)		

(a) Test AB7 result for NaOH = 1.1(-4) ± 2.2(-5)
(b) Test AB7 result for NaI not measured at this time.
(c) Numbers in parenthesis are exponents of 10.

Table M4
REMOVAL RATE AT 2400 SECONDS

CODE	USER	NaOH: Blind Post-Test Code (s^{-1})	NaOH: Ratio Code to Average	NaOH: Ratio Code to Test (a)	NaI: Blind Post-Test Code (s^{-1})	NaI: Ratio Code to Average	NaI: Ratio Code to Test (b)
HAA-3	HEDL	5.54(-4) (c)	1.554	4.432	5.54(-4)	1.795	
HAA-4	RI/ESG	4.22(-4)	1.184	3.376	4.22(-4)	1.368	
HAARM-3	HEDL	2.5(-4)	0.701	2.000	2.5(-4)	0.810	
CONTAIN	SNL						
QUICKM	BCL	2(-4)	0.561	1.600	8.27(-6)	0.027	
AVERAGE		3.57(-4)		2.852	3.09(-4)		

(a) Test AB7 result for NaOH = 1.25(-4) ± 2.5(-5)
(b) Test AB7 result for NaI not measured at this time.
(c) Numbers in parenthesis are exponents of 10.

Table M5
REMOVAL RATE AT 2700 SECONDS

CODE	USER	NaOH Blind Post-Test Code (s^{-1})	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code (s^{-1})	NaI Ratio Code to Average	NaI Ratio Code to Test (b)
HAA-3	HEDL	5.94(-4) (c)	1.544	4.097	5.94(-4)	1.824	
HAA-4	RI/ESG	4.42(-4)	1.140	3.048	4.42(-4)	1.357	
HAARM-3	HEDL	2.54(-4)	0.660	1.752	2.54(-4)	0.780	
CONTAIN	SNL						
QUICKM	BCL	2.49(-4)	0.647	1.717	1.27(-5)	0.039	
AVERAGE		3.85(-4)		2.653	3.26(-4)		

(a) Test AB7 result for NaOH = 1.45(-4) ± 2.9(-5)
(b) Test AB7 result for NaI not measured at this time.
(c) Numbers in parenthesis are exponents of 10.

Table M6
REMOVAL RATE AT 3000 SECONDS

CODE	USER	NaOH Blind Post-Test Code (s^{-1})	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code (s^{-1})	NaI Ratio Code to Average	NaI Ratio Code to Test
HAA-3	HEDL	6.43(-4)	1.551	3.572	6.43(-4)	1.840	16.075
HAA-4	RI/ESG	4.56(-4)	1.100	2.533	4.56(-4)	1.311	11.400
HAARM-3	HEDL	2.75(-4)	0.663	1.528	2.75(-4)	0.791	6.875
CONTAIN	SNL						
QUICKM	BCL	2.84(-4)	0.685	1.578	1.73(-5)	0.050	0.433
AVERAGE		4.15(-4)		2.303	3.48(-4)		8.696

(a) Test AB7 result for NaOH = 1.80(-4) ± 1.8(-5)
(b) Test AB7 result for NaI = 4.0(-5) ± 1.5(-6)
(c) Numbers in parenthesis are exponents of 10.

Table M7
REMOVAL RATE AT 4200 SECONDS

CODE	USER	NaOH Blind Post-Test Code (s^{-1})	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code (s^{-1})	NaI Ratio Code to Average	NaI Ratio Code to Test (b)
HAA-3	HEDL	5.96(-4) (c)	1.452	2.838	5.96(-4)	1.728	7.842
HAA-4	RI/ESG	4.08(-4)	0.994	1.943	4.08(-4)	1.183	5.368
HAARM-3	HEDL	3.47(-4)	0.845	1.652	3.47(-4)	1.006	4.566
CONTAIN	SNL						
QUICKM	BCL	2.91(-4)	0.709	1.386	2.87(-5)	0.083	0.378
AVERAGE		4.11(-4)		1.955	3.45(-4)		4.538

(a) Test AB7 result for NaOH = 2.1(-4) ± 4.2(-5)
(b) Test AB7 result for NaI = 7.6(-5) ± 1.5(-5)
(c) Numbers in parenthesis are exponents of 10.

Table M8
REMOVAL RATE AT 7200 SECONDS

CODE	USER	NaOH Blind Post-Test Code (s^{-1})	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code (s^{-1})	NaI Ratio Code to Average	NaI Ratio Code to Test (b)
HAA-3	HEDL	3.27(-4)	1.192	2.180	3.27(-4)	1.369	2.973
HAA-4	RI/ESG	2.57(-4)	0.937	1.713	2.57(-4)	1.076	2.336
HAARM-3	HEDL	3.43(-4)	1.251	2.287	3.43(-4)	1.436	3.118
CONTAIN	SNL						
QUICKM	BCL	1.7(-4)	0.620	1.133	2.86(-5)	0.120	0.260
AVERAGE		2.743(-4)		1.828	2.39(-4)		2.172

(a) Test AB7 result for NaOH = 1.50(-4) ± 2.0(-5)
(b) Test AB7 result for NaI = 1.10(-4) ± 2.2(-5)
(c) Numbers in parenthesis are exponents of 10.

Table M9
REMOVAL RATE AT 10000 SECONDS

CODE	USER	NaOH Blind Post-Test Code (s^{-1})	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code (s^{-1})	NaI Ratio Code to Average	NaI Ratio Code to Test (b)
HAA-3	HEDL	2.26(-4) (c)	1.123	1.780	2.26(-4)	1.270	2.152
HAA-4	RI/ESG	1.85(-4)	0.919	1.457	1.85(-4)	1.039	1.762
HAARM-3	HEDL	2.76(-4)	1.371	2.173	2.76(-4)	1.551	2.629
CONTAIN	SNL						
QUICKM	BCL	1.18(-4)	0.586	0.929	2.49(-5)	0.140	0.237
AVERAGE		2.013(-4)		1.585	1.78(-4)		1.695

(a) Test AB7 result for NaOH = 1.27(-4) ± 2.5(-5)
(b) Test AB7 result for NaI = 1.05(-4) ± 2.1(-5)
(c) Numbers in parenthesis are exponents of 10.

Table M10
REMOVAL RATE AT 70000 SECONDS

CODE	USER	NaOH Blind Post-Test Code (s^{-1})	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code (s^{-1})	NaI Ratio Code to Average	NaI Ratio Code to Test (b)
HAA-3	HEDL	5.7(-5) (c)	1.274	1.541	5.7(-5)	1.344	1.727
HAA-4	RI/ESG	3.62(-5)	0.809	0.978	3.62(-5)	0.854	1.097
HAARM-3	HEDL	6.71(-5)	1.499	1.814	6.71(-5)	1.582	2.033
CONTAIN	SNL						
QUICKM	BCL	1.87(-5)	0.418	0.505	9.34(-6)	0.220	0.283
AVERAGE		4.48(-5)		1.209	4.241(-5)		1.285

(a) Test AB7 result for NaOH = 3.7(-5) ± 7.5(-6)
(b) Test AB7 result for NaI = 3.3(-5) ± 6.6(-6)
(c) Numbers in parenthesis are exponents of 10.

Table M11
REMOVAL RATE AT 100000 SECONDS

CODE	USER	NaOH Blind Post-Test Code (s^{-1})	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code (s^{-1})	NaI Ratio Code to Average	NaI Ratio Code to Test (b)
HAA-3	HEDL	5.15(-5) (c)	1.337	1.981	5.15(-5)	1.391	2.146
HAA-4	RI/ESG	2.86(-5)	0.742	1.100	2.86(-5)	0.773	1.192
HAARM-3	HEDL	5.99(-5)	1.555	2.304	5.99(-5)	1.618	2.496
CONTAIN	SNL						
QUICKM	BCL	1.41(-5)	0.366	0.542	8.09(-6)	0.219	0.337
AVERAGE		3.853(-5)		1.482	3.703(-5)		1.543

(a) Test AB7 result for NaOH = 2.6(-5) ± 5.2(-6)
(b) Test AB7 result for NaI = 2.4(-5) ± 4.8(-6)
(c) Numbers in parenthesis are exponents of 10.

Table M12
REMOVAL RATE AT 200000 SECONDS

CODE	USER	NaOH Blind Post-Test Code (s^{-1})	NaOH Ratio Code to Average	NaOH Ratio Code to Test (a)	NaI Blind Post-Test Code (s^{-1})	NaI Ratio Code to Average	NaI Ratio Code to Test (b)
HAA-3	HEDL	4.19(-5) (c)	1.386	3.352	4.19(-5)	1.399	3.551
HAA-4	RI/ESG	1.79(-5)	0.592	1.432	1.79(-5)	0.598	1.517
HAARM-3	HEDL	5.41(-5)	1.789	4.328	5.41(-5)	1.806	4.585
CONTAIN	SNL						
QUICKM	BCL	7.03(-6)	0.233	0.562	5.9(-6)	0.197	0.500
AVERAGE		3.024(-5)		2.419	3(-5)		2.538

(a) Test AB7 result for NaOH = 1.25(-5) ± 3.7(-6)
(b) Test AB7 result for NaI = 1.18(-5) ± 3.5(-6)
(c) Numbers in parenthesis are exponents of 10.

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