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# PRETEST AEROSOL CODE COMPARISONS FOR LWR AEROSOL CONTAINMENT TESTS LA1 AND LA2*

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KEY WORDS: REACTOR SAFETY, MODELING

## Introduction

The Light-Water-Reactor (LWR) Aerosol Containment Experiments (LACE) are being performed in Richland, Washington, at the Hanford Engineering Development Laboratory (HEDL) under the leadership of an international project board and the Electric Power Research Institute. These tests have two objectives: (1) to investigate, at large scale, the inherent aerosol retention behavior in LWR containments under simulated severe accident conditions, and (2) to provide an experimental data base for validating aerosol behavior and thermal-hydraulic computer codes.

Aerosol computer-code comparison activities are being coordinated at the Oak Ridge National Laboratory. For each of the six LACE tests, "pretest" calculations (for code-to-code comparisons) and "posttest" calculations (for code-to-test data comparisons) are being performed. The overall goals of the comparison effort are (1) to provide code users with experience in applying their codes to LWR accident-sequence conditions and (2) to evaluate and improve the code models.

## Description of LACE LA1 and LA2

The LACE experiments use the 852-$m^3$-volume Containment Systems Test Facility (CSTF) vessel at HEDL. A two-component aerosol source, consisting of a roughly 2/1 mass ratio of MnO and CsOH aerosols, was generated in tests LA1 and LA2.

Test LA1 was designed to simulate LWR "containment bypass" accident sequence conditions. In this test, aerosols were injected into a 0.63-m-diam, approximately 30-m-long test pipe (the pipe had six 90° bends). The flow velocity of the pipe inlet gas was about 100 m/s, while the outlet velocity was about 200 m/s. Aerosols transported through the pipe were then made airborne in the CSTF vessel.

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Test LA2 was designed to simulate LWR "failure to isolate containment" accident sequence conditions. In LA2, aerosols were injected directly into the CSTF vessel under condensing steam conditions. Conditions were such that a high aerosol leakage rate (comparable to expected aerosol deposition rates) was maintained.

## Code Input Definitions for Pretest Calculations

For pretest calculations, code users were given specific values of code input parameters, such as system geometry, aerosol source rates and sizes, pipe and vessel temperatures, and vessel gas leakage rates. We also specified both the code output parameters (total aerosol deposited in the test pipe, airborne aerosol concentration in the vessel, etc.) and the times for code outputs.

## Summary of LA1 and LA2 Pretest Results

Details of results from LA1 and LA2 pretest calculations have been summarized in two LACE letter reports (Wright and Arwood, 1986; Wilson and Arwood, 1986). For LA1, separate calculations were performed for aerosol behavior in the pipe and that in the CSTF vessel. Table 1 lists the codes that were used and the countries where the calculations were performed.

Table 1. Codes used for LA1, LA2 pretest calculations

| Test LA1 | | Test LA2 |
|---|---|---|
| Pipe calculations: code, country | Vessel calculations: code, country | Vessel calculations: code, country |
| AEROSIM, United Kingdom | AEROSIM, United Kingdom | AEROSIM-M, United Kingdom |
| MCT, United States | CONTAIN, United Kingdom | CONTAIN, United Kingdom |
| RETAIN-2C, Finland | CONTAIN, United States | HAA-4, United States |
| RETAIN-S, Sweden | MCT, United States | MAAP-3, Sweden |
| TRAP-MELT2, United Kingdom | NAUA-5, Finland | MCT-2, United States |
| | REMOVAL, Japan | NAUA-4, United States |
| | RETAIN-2C, Finland | NAUA-5, Finland |
| | RETAIN-S, Sweden | REMOVAL, Japan |

The following comments can be made relative to the LA1 and LA2 pretest results:

1. In terms of aerosol behavior in the pipe for LA1, four codes - AEROSIM, MCT, RETAIN-2C, and TRAP-MELT2 - predicted that

roughly 90% of the aerosol injected into the pipe was deposited in it. The other code used - RETAIN-S - predicted that only 10% of the aerosol injected was deposited; we do not know why these results differed. Although four codes produced similar results, three of these codes used incorrect aerosol source-size values. The calculated pipe deposition occurred due to turbulence; this mechanism, as modeled in the codes, is not sensitive to particle size for high turbulence levels.

2. Figure 1 illustrates the results for airborne aerosol concentration vs time in the CSTF vessel for LA1. Four of the codes calculated similar aerosol concentration results. However, five of the calculations for LA1 were performed with incorrect values for the aerosol-source particle size, thus causing many of the differences shown in the figure.

3. The LA1 pretest comparisons resulted in the identification of three code modeling errors: (1) a turbulent deposition-velocity error in TRAP-MELT2, (2) a thermophoretic deposition-velocity error in REMOVAL, and (3) a mass-balance error in MCT. All of these errors have been corrected. In addition, it was discovered that CONTAIN code users must be careful about the value of the "system time step" used in calculations. Variations in this input time step caused much of the observed variation in the CONTAIN results, as shown in Fig. 1.

4. Figure 2 illustrates calculated aerosol concentration vs. time data for LA2. Note that there is much better agreement in calculated aerosol concentrations for LA2 than for LA1; this is partially due to the fact that no aerosol-size input errors were made for the LA2 calculations.

The LACE pretest code-comparison exercises for LA1 and LA2 have already provided useful information for the project participants. More information will be obtained from future pretest and posttest LACE code comparisons.

## References

Wright, A. L. and P. C. Arwood, Summary of Pretest Aerosol Code Results for LWR Aerosol Containment Experiment (LACE) LA1, LACE Letter Report, NRC Technical Letter Report ORNL/NRC/LTR-86/4, proprietary, to be published.

Wilson, J. H. and P. C. Arwood, Summary of Pretest Aerosol Code Results for LWR Aerosol Containment Experiment (LACE) LA2, Lace Letter Report, proprietary, to be published.

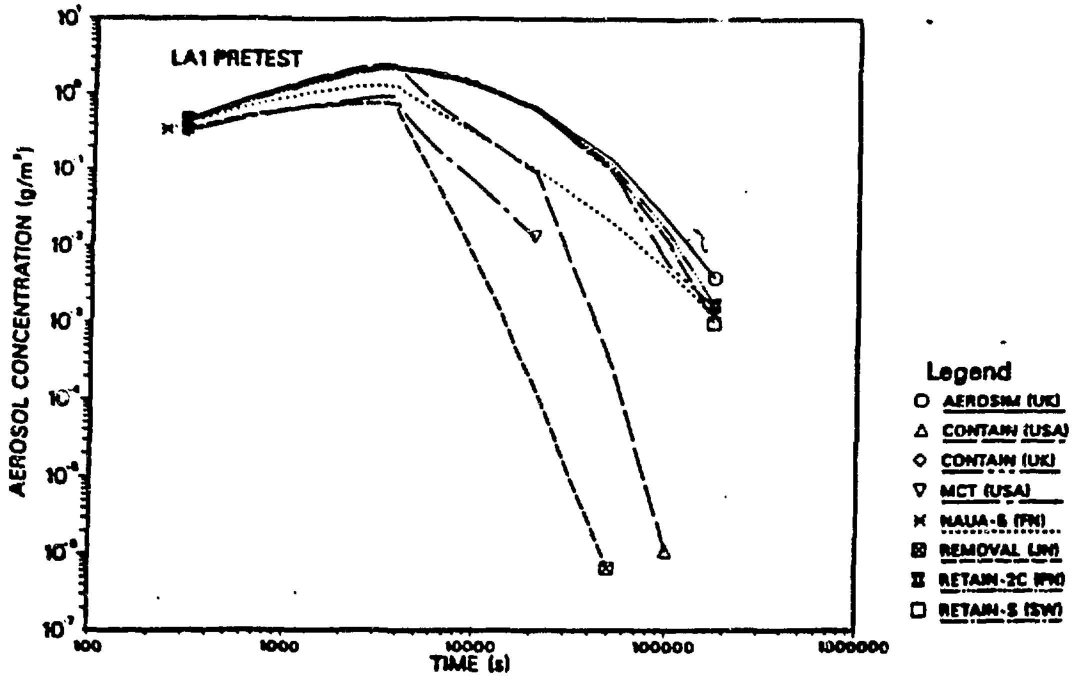



Fig. 1. LA1 pretest vessel results: airborne aerosol concentration vs time.

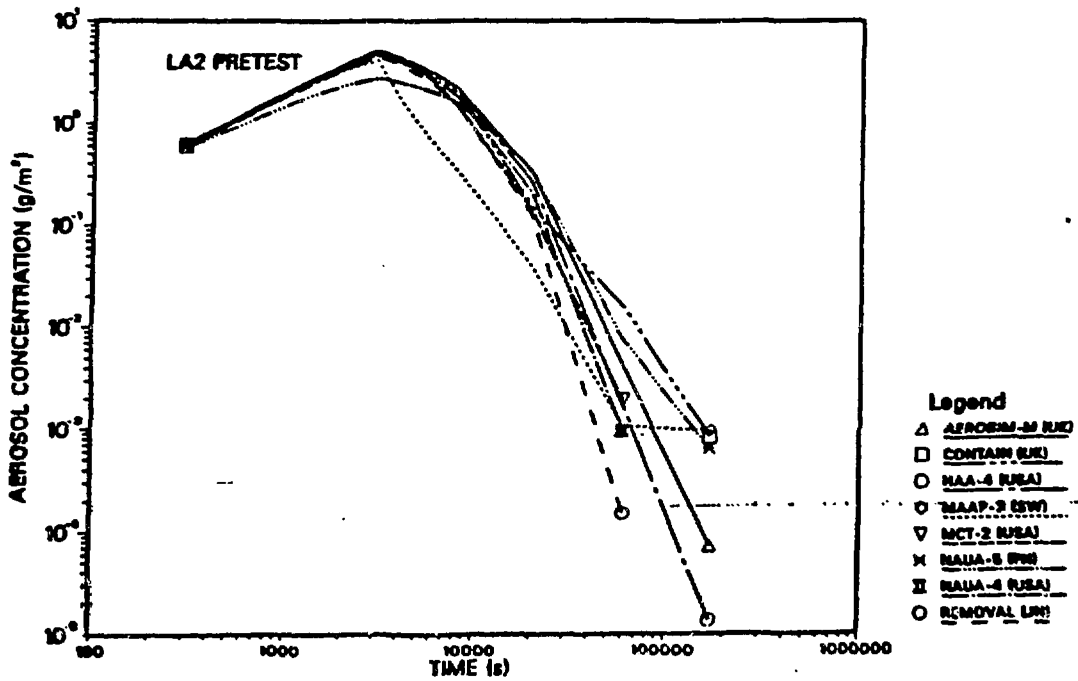



Fig. 2. LA2 pretest vessel results: airborne aerosol concentration vs time.

# LWR AEROSOL CONTAINMENT EXPERIMENTS (LACE): AEROSOL CODE COMPARISONS

- LACE TESTS: HANFORD ENGINEERING DEVELOPMENT LABORATORY (HEDL)
  - INVESTIGATE CONTAINMENT AEROSOL RETENTION BEHAVIOR FOR LWR ACCIDENT CONDITIONS
  - VALIDATE AEROSOL, THERMAL-HYDRAULIC CODES

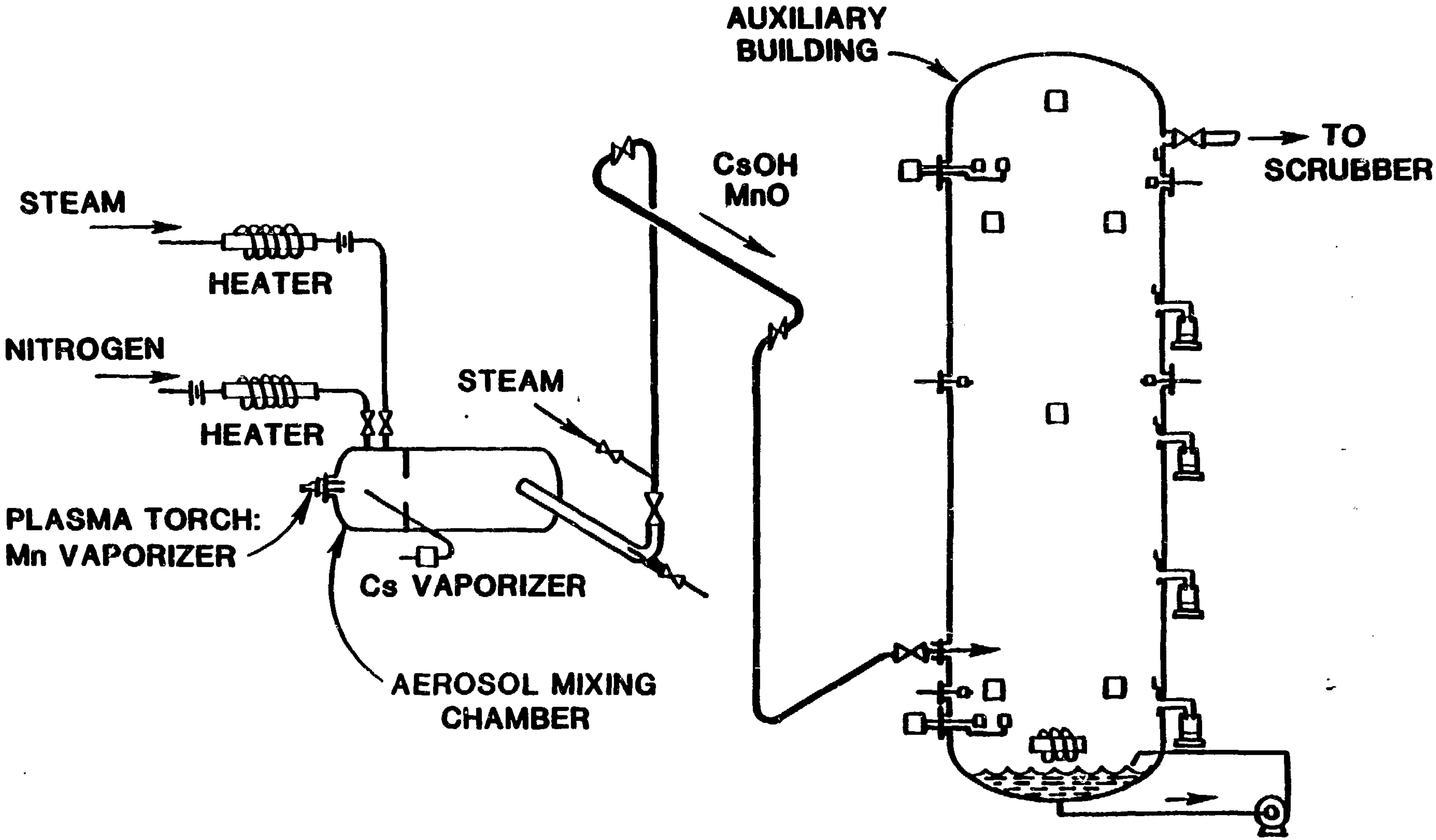
- ORNL AEROSOL CODE-COMPARISON ACTIVITIES:
  - PRETEST: CODE-CODE COMPARISONS
  - POSTTEST: CODE-DATA COMPARISONS

ORNL WS 47489

# LA1 TEST CONDITIONS

- "CONTAINMENT BYPASS" SEQUENCE SIMULATION
- AEROSOL FLOW THROUGH 30-m PIPE, 100 TO 200 m/s FLOW VELOCITY
- AEROSOL BEHAVIOR IN 850-$m^3$ VESSEL

ORNL DWG 86-676R



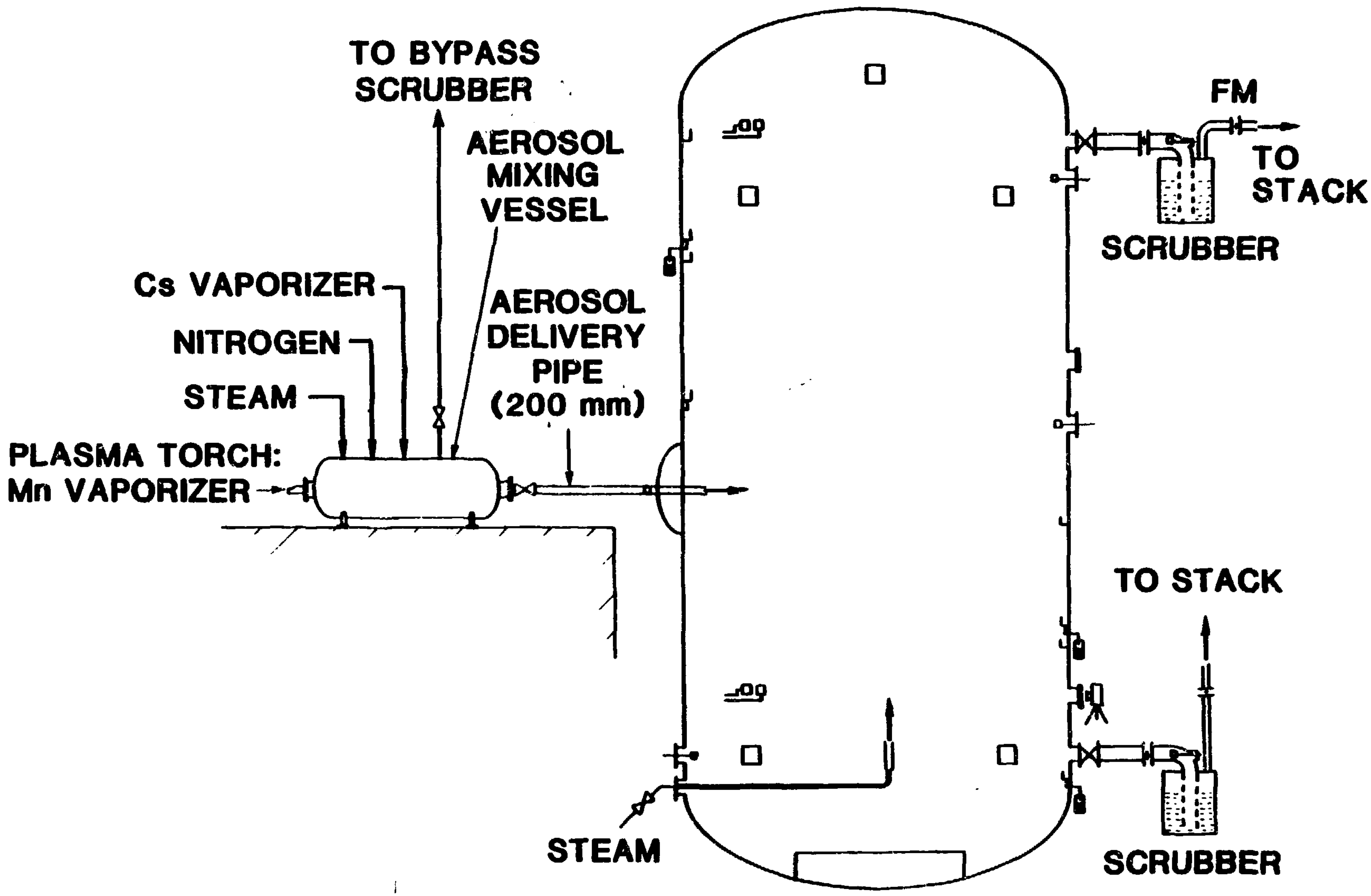

LA1 EXPERIMENTAL ARRANGEMENT

ORNL WS 47490

# LA2 TEST CONDITIONS

- "FAILURE TO ISOLATE" SEQUENCE SIMULATION
- AEROSOL BEHAVIOR IN 850-$m^3$ VESSEL, CONDENSING STEAM CONDITIONS
- HIGH GAS LEAKAGE RATE FROM VESSEL

ORNL DWG 86-674R




LA2 EXPERIMENTAL ARRANGEMENT

ORNL WS 47496

## AEROSOL TRANSPORT CODES USED FOR LACE CALCULATIONS

- AEROSIM-M (UNITED KINGDOM)
- MAAP-3 (SWEDEN)
- MCT-2 (UNITED STATES)
- NAUA (ITALY, FINLAND, UNITED STATES)
- REMOVAL (JAPAN)
- RETAIN (FINLAND, SWEDEN)
- TRAP-MELT2 (ITALY, JAPAN, UNITED KINGDOM, UNITED STATES)

ORNL WS 47497

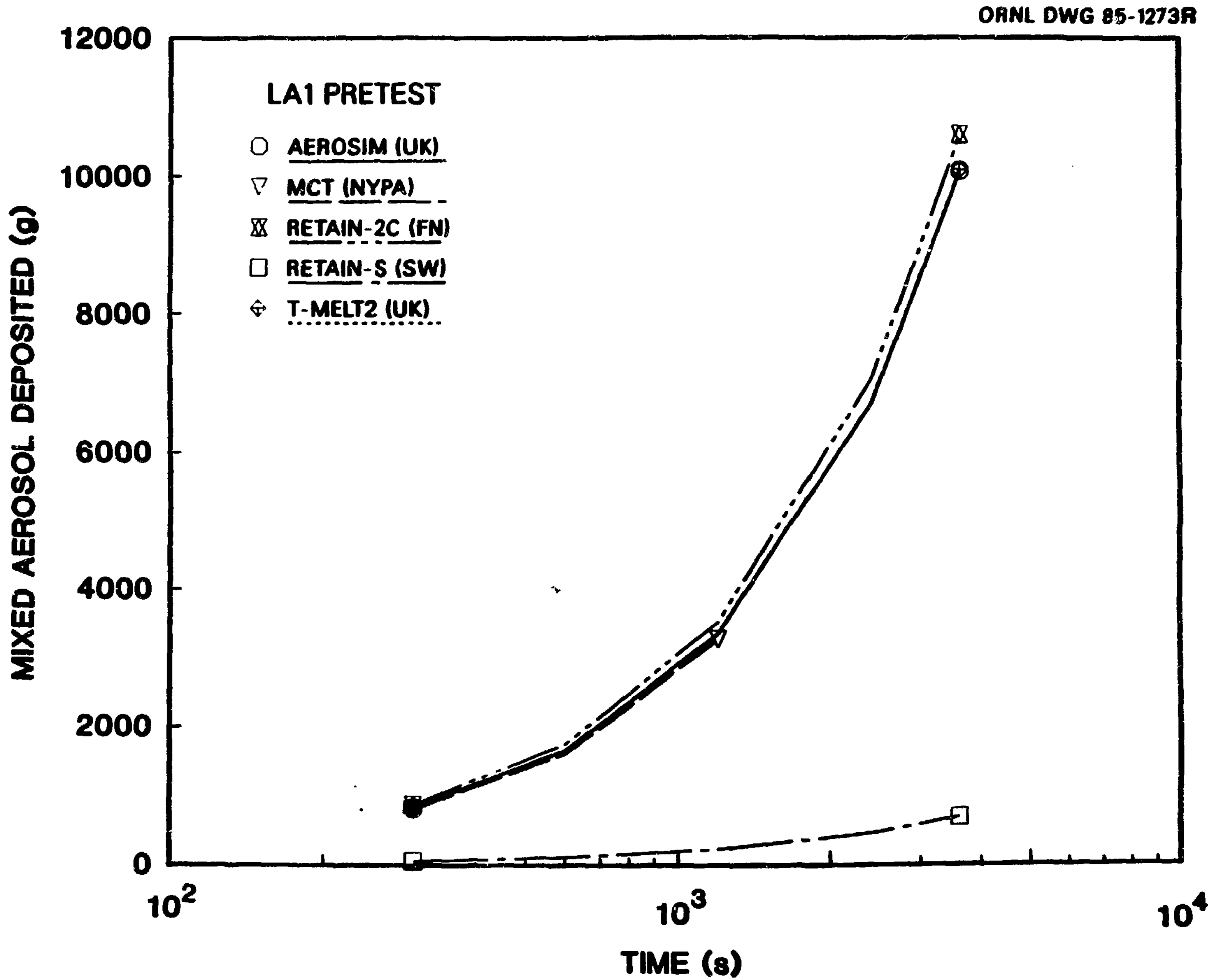
# DIRECTIONS FOR CODE CALCULATIONS

- PROVIDE VALUES FOR CODE INPUT PARAMETERS
  - SYSTEM GEOMETRY
  - AEROSOL SOURCE RATES, SIZES
  - TEMPERATURE, PRESSURE, GAS LEAKAGE RATE
- SPECIFY CODE OUTPUT PARAMETERS, TIMES
  - AIRBORNE AEROSOL CONCENTRATION
  - AEROSOL DEPOSITION
  - AEROSOL SIZE

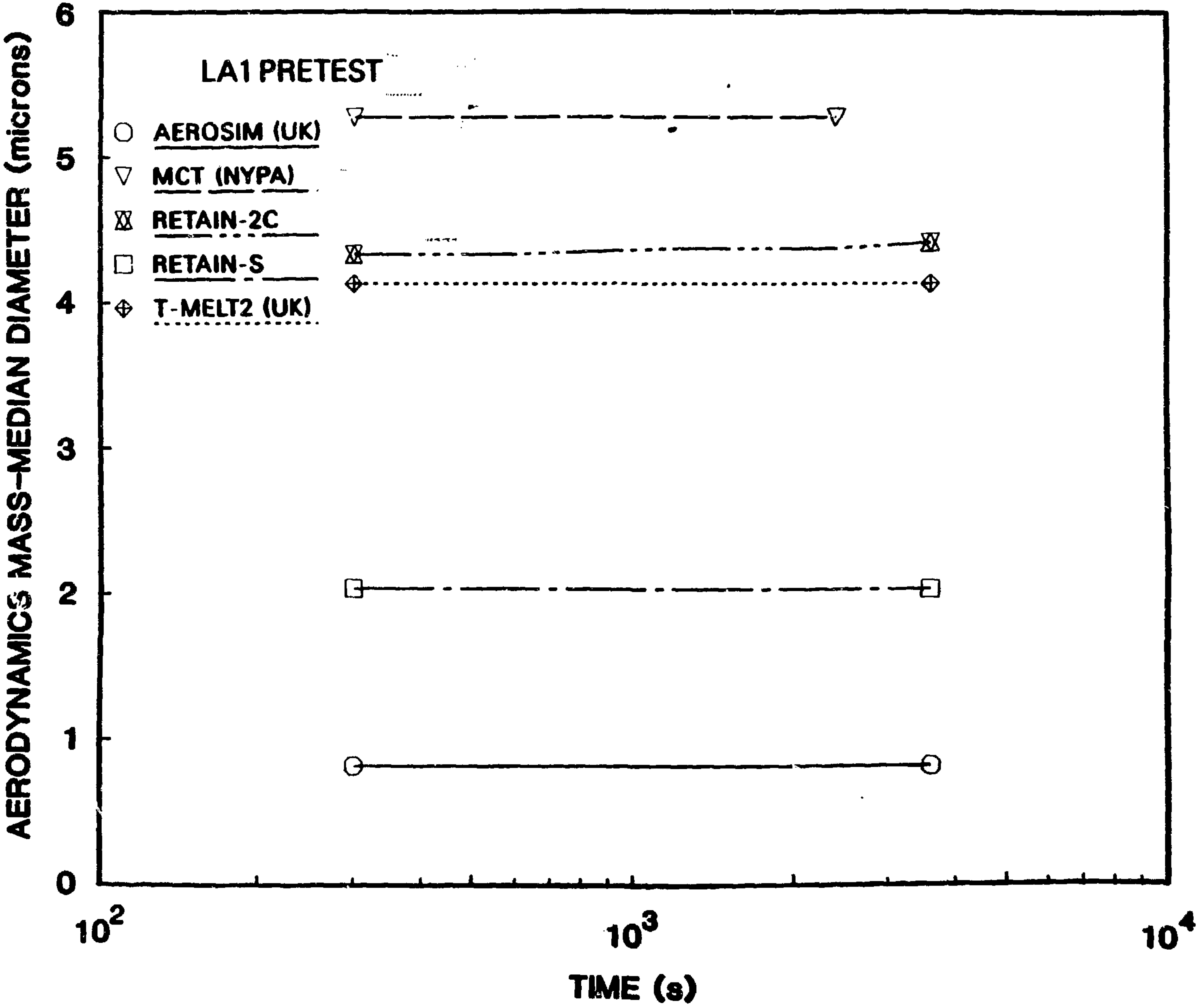
ORNL WS 47491

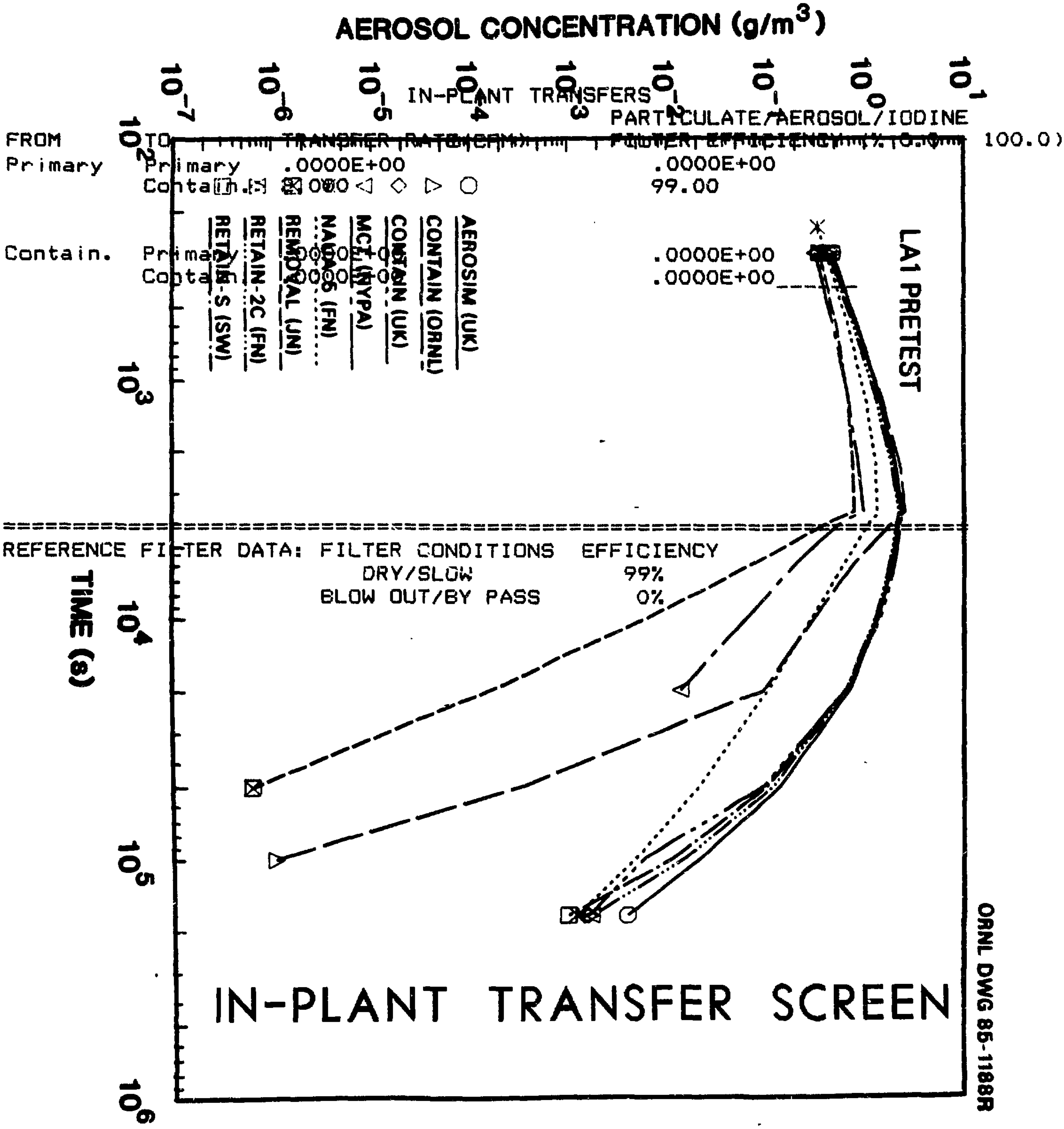
# LA1 PRETEST CODE-COMPARISON RESULTS

- CODE INPUT ERRORS (AEROSOL SIZE) PRODUCED MOST OF OBSERVED DIFFERENCES IN RESULTS
- CODING ERRORS IN TRAP-MELT2, MCT, AND REMOVAL IDENTIFIED AND CORRECTED

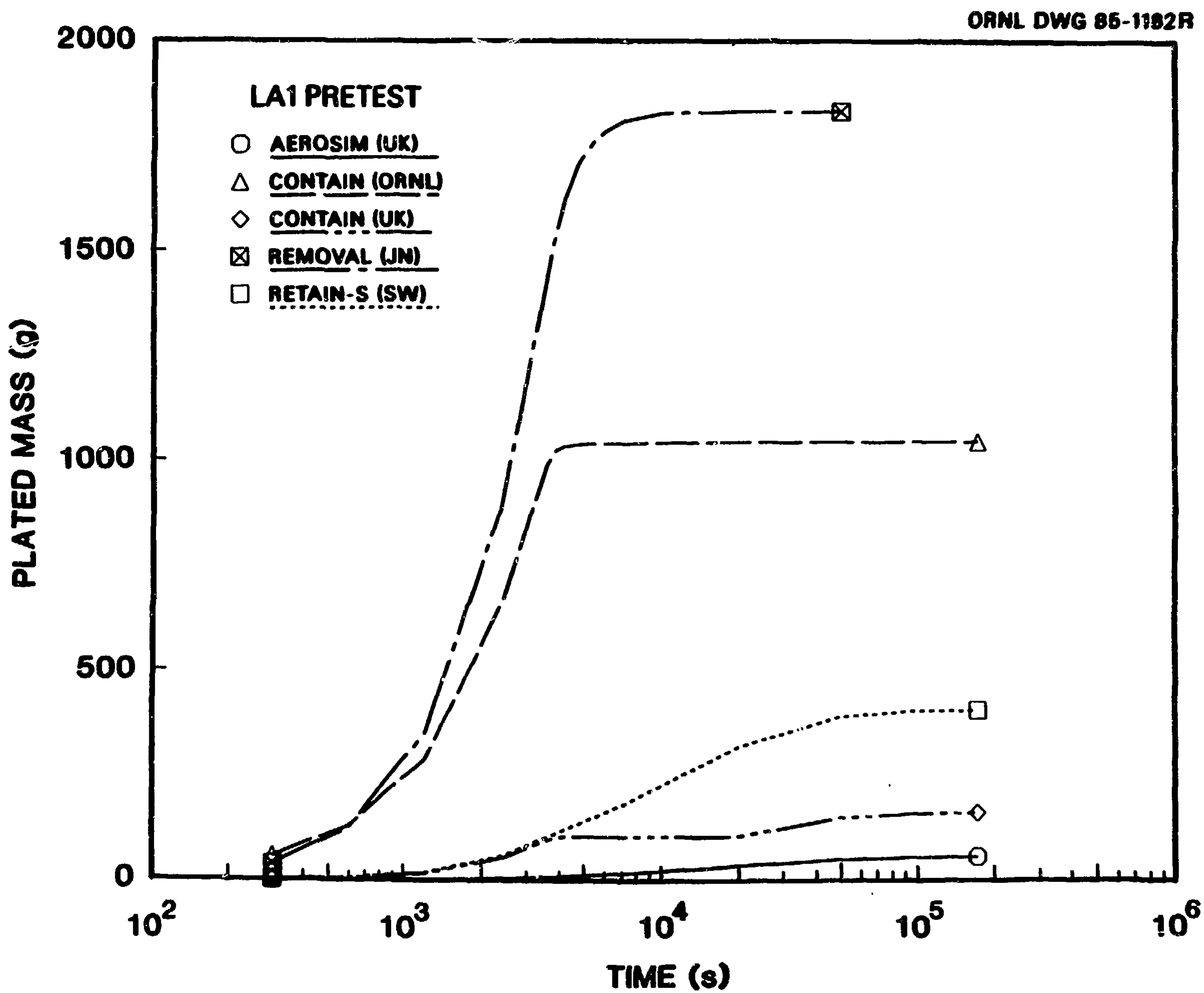

ORNL DWG 85-1273R
LA1 PRETEST
AEROSIM (UK)
MCT (NYPA)
RETAIN-2C (FN)
RETAIN-S (SW)
T-MELT2 (UK)
MIXED AEROSOL DEPOSITED (g)
12000
10000
8000
6000
4000
2000
0
$10^2$
$10^3$
$10^4$
TIME (s)

ORNL DWG 86-7372R

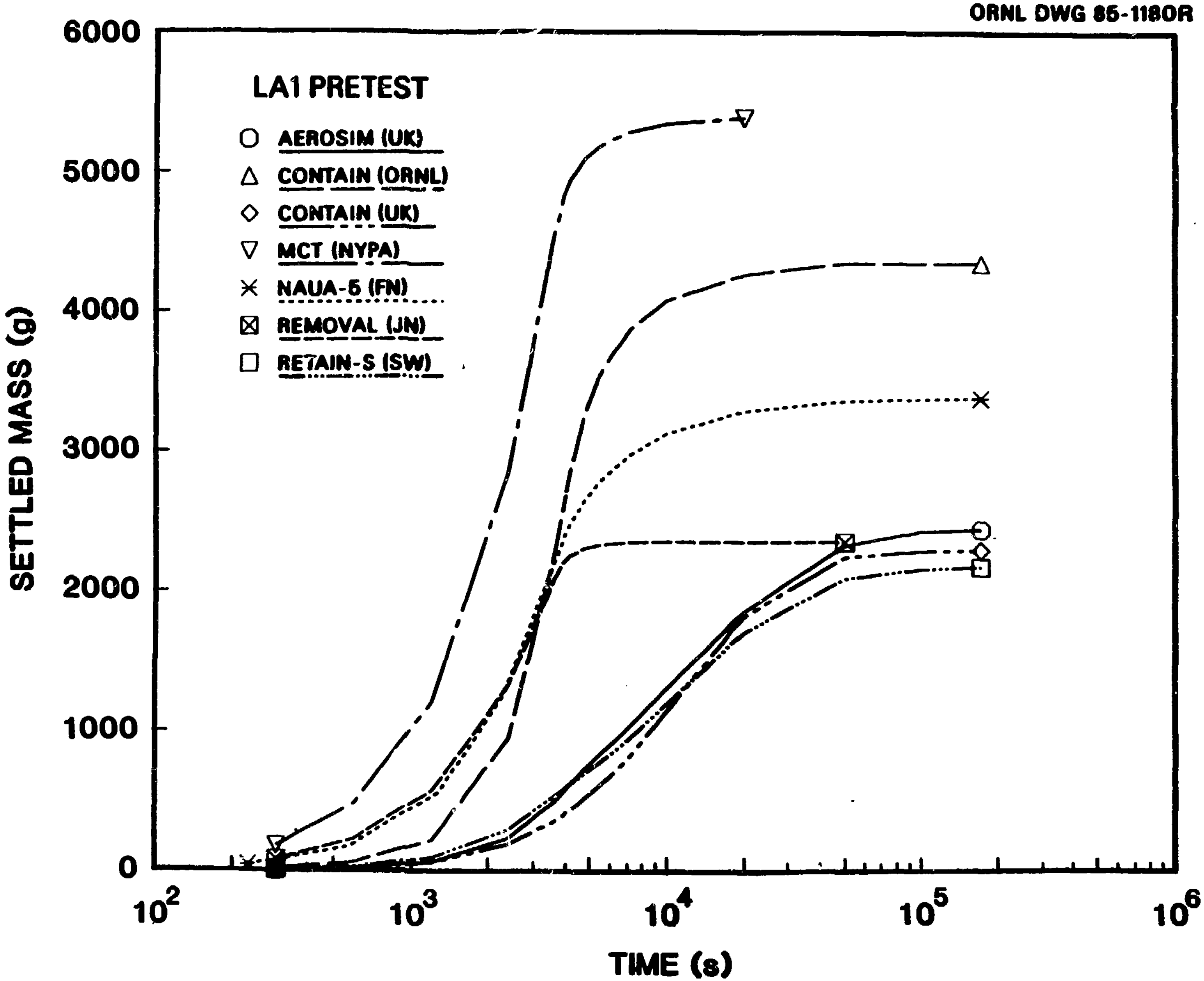


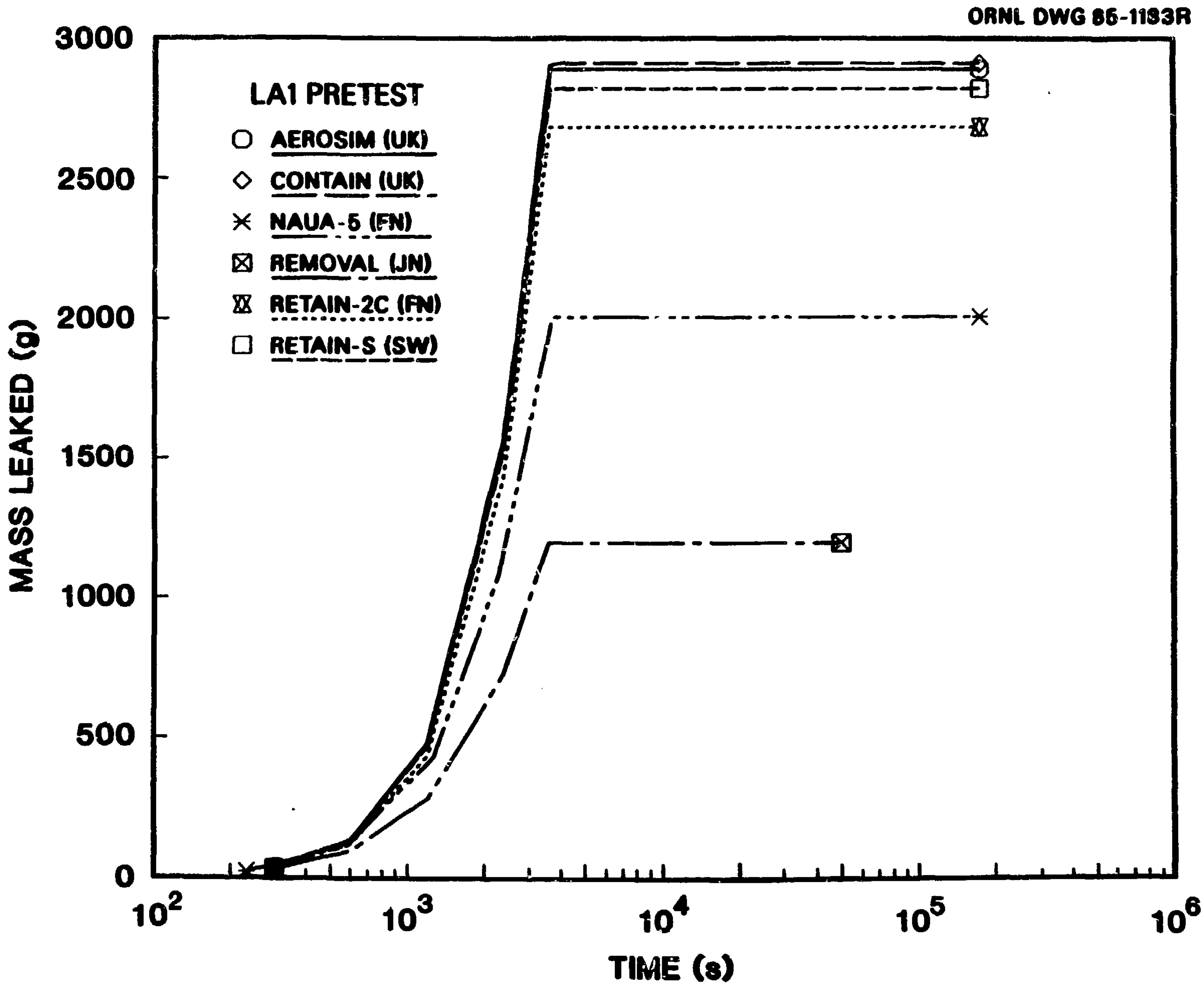


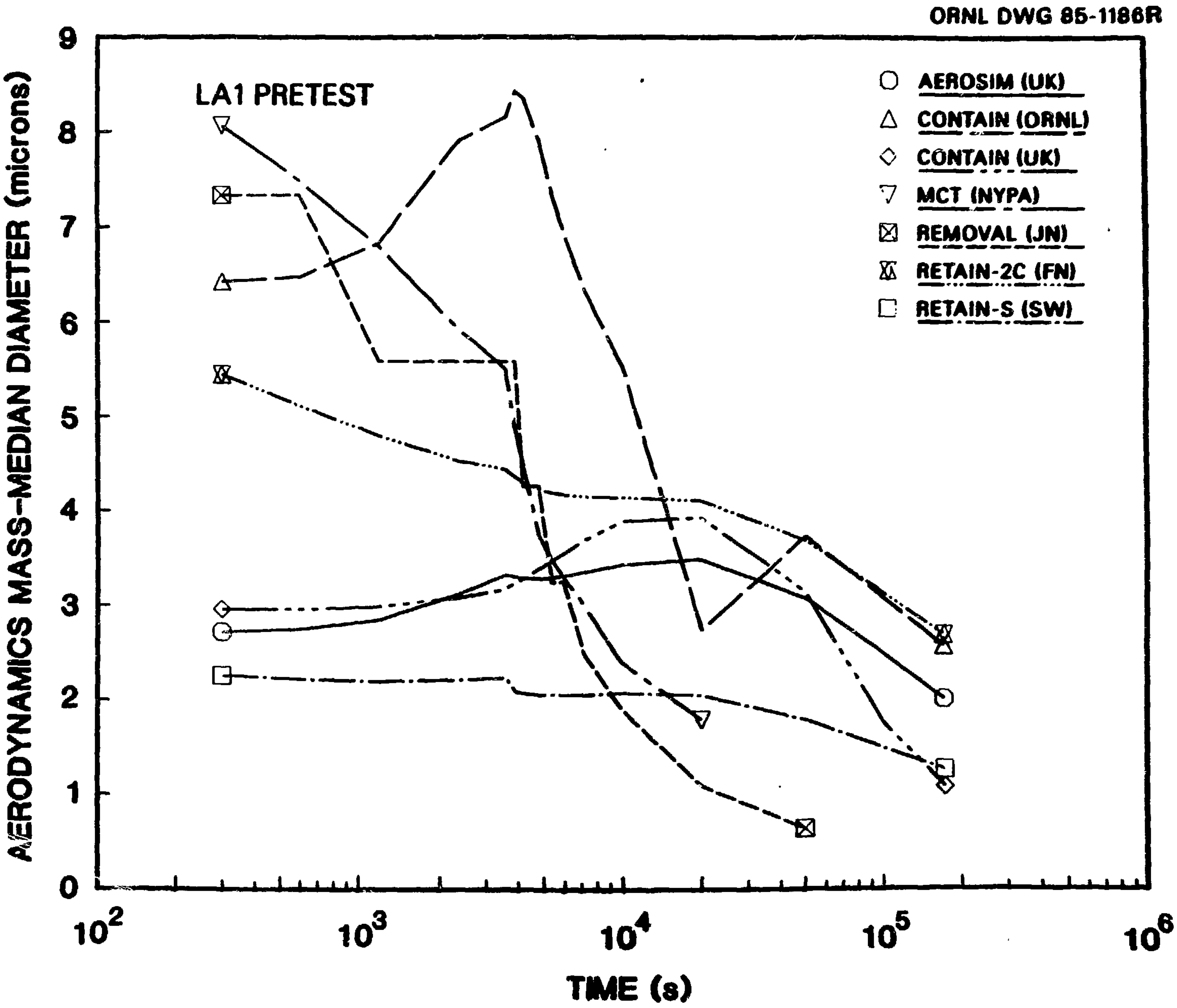
AEROSOL CONCENTRATION (g/m3)
IN-PLANT TRANSFERS
PARTICULATE/AEROSOL/IODINE
FROM TO TRANSFER RATE(CFM) FILTER EFFICIENCY(% 0.0 100.0)
Primary Primary .0000E+00 .0000E+00
Contain. .000 99.00
Contain. Primary .0000E+00 .0000E+00
Contain. .0000E+00 .0000E+00
AEROSIM (UK)
CONTAIN (ORNL)
CONTAIN (UK)
MCT (NYPA)
NAUA-5 (FN)
REMOVAL (JN)
RETAIN-2C (FN)
RETAIN-S (SW)
LA1 PRETEST
REFERENCE FILTER DATA: FILTER CONDITIONS EFFICIENCY
DRY/SLOW 99%
BLOW OUT/BY PASS 0%
TIME (s)
IN-PLANT TRANSFER SCREEN
ORNL DWG 85-1188R



ORNL DWG 85-1192R
LA1 PRETEST
AEROSIM (UK)
CONTAIN (ORNL)
CONTAIN (UK)
REMOVAL (JN)
RETAIN-S (SW)
PLATED MASS (g)
2000
1500
1000
500
0
TIME (s)
$10^2$
$10^3$
$10^4$
$10^5$
$10^6$


ORNL DWG 85-1180R
LA1 PRETEST
AEROSIM (UK)
CONTAIN (ORNL)
CONTAIN (UK)
MCT (NYPA)
NAUA-5 (FN)
REMOVAL (JN)
RETAIN-S (SW)
SETTLED MASS (g)
6000
5000
4000
3000
2000
1000
0
$10^2$
$10^3$
$10^4$
$10^5$
$10^6$
TIME (s)


ORNL DWG 85-1183R
LA1 PRETEST
AEROSIM (UK)
CONTAIN (UK)
NAUA-5 (FN)
REMOVAL (JN)
RETAIN-2C (FN)
RETAIN-S (SW)
MASS LEAKED (g)
3000
2500
2000
1500
1000
500
0
10^2
10^3
10^4
10^5
10^6
TIME (s)

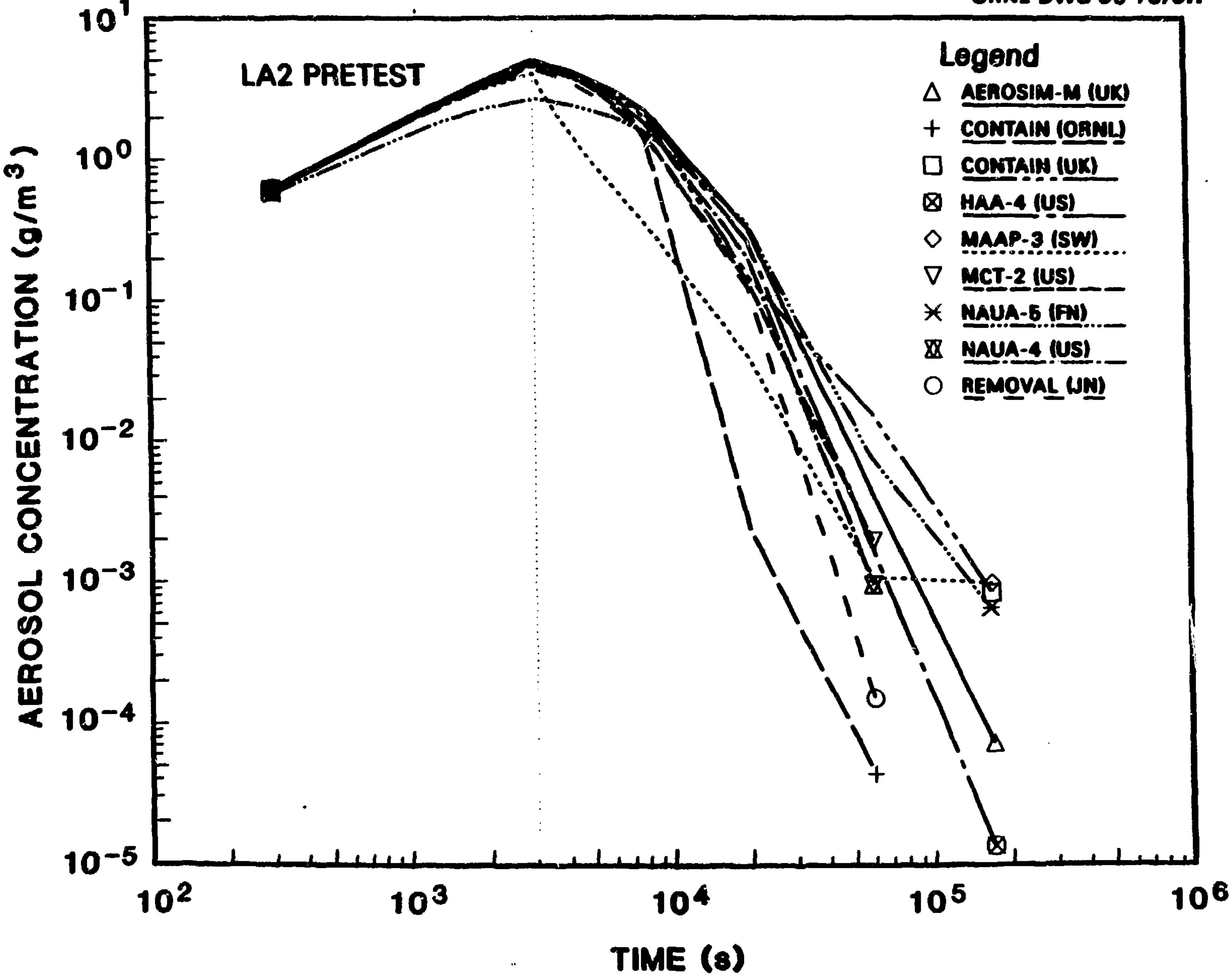

ORNL DWG 85-1186R
LA1 PRETEST
AERODYNAMICS MASS-MEDIAN DIAMETER (microns)
TIME (s)
AEROSIM (UK)
CONTAIN (ORNL)
CONTAIN (UK)
MCT (NYPA)
REMOVAL (JN)
RETAIN-2C (FN)
RETAIN-S (SW)
0
1
2
3
4
5
6
7
8
9
$10^2$
$10^3$
$10^4$
$10^5$
$10^6$

ORNL WS 47492

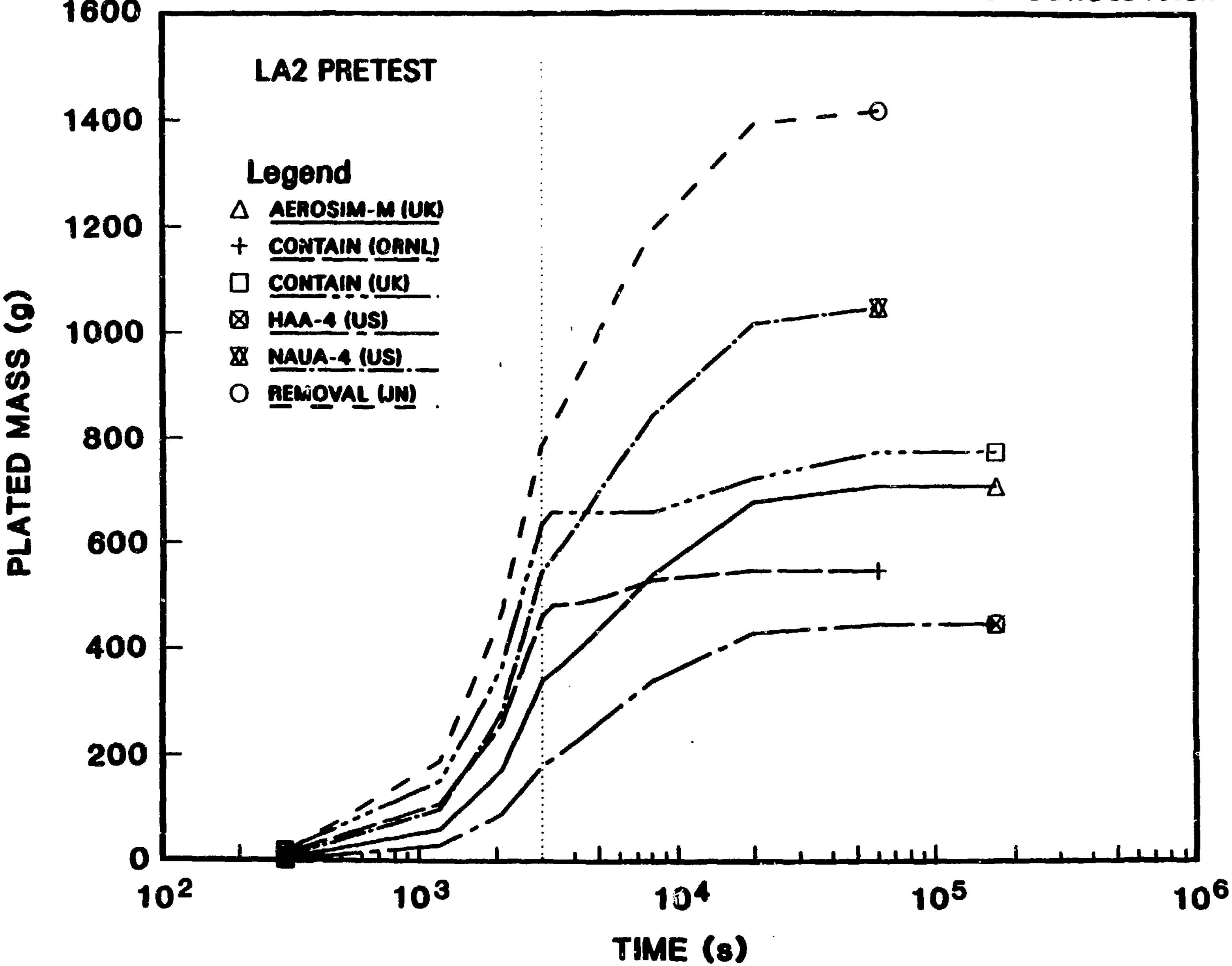
## LA2 PRETEST CODE-COMPARISON RESULTS

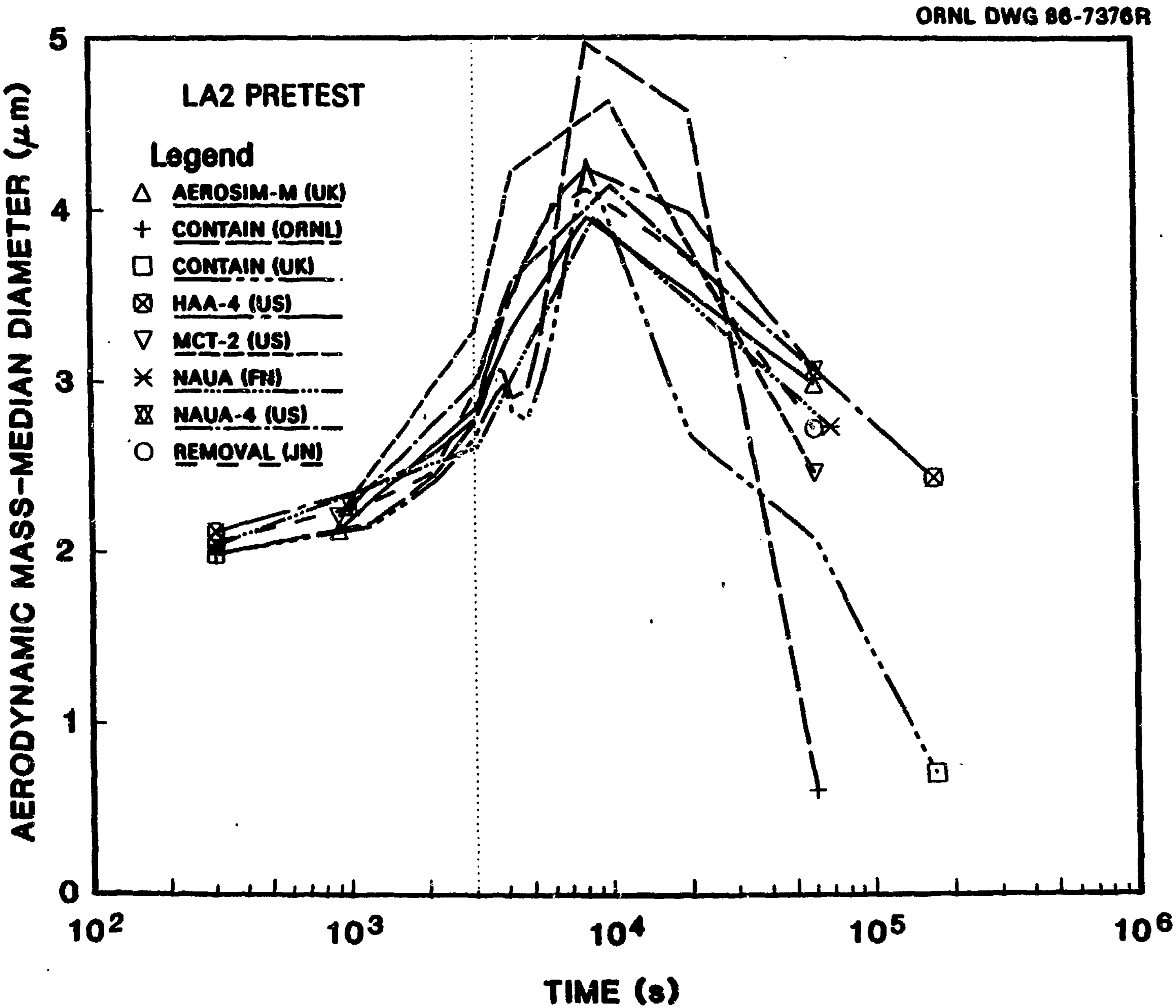
- SOME CODES FOUND TO CALCULATE AMMD INCORRECTLY
- DIFFUSIOPHORESIS MODELING ERROR CORRECTED IN REMOVAL, NAUA-4 (USA)
- ALL CALCULATIONS PERFORMED WITH CORRECT INPUT AEROSOL SIZE

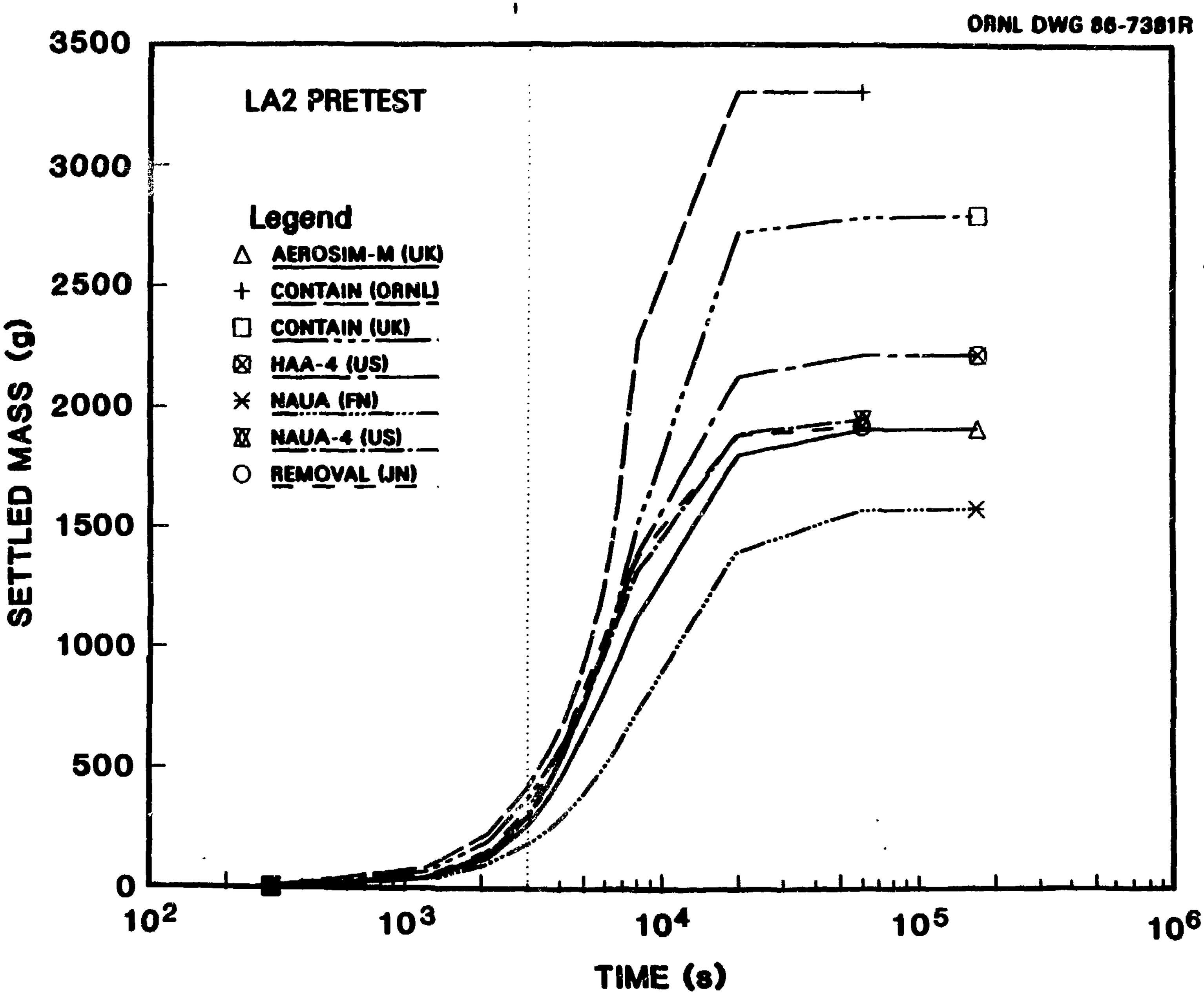
ORNL DWG 86-7378R



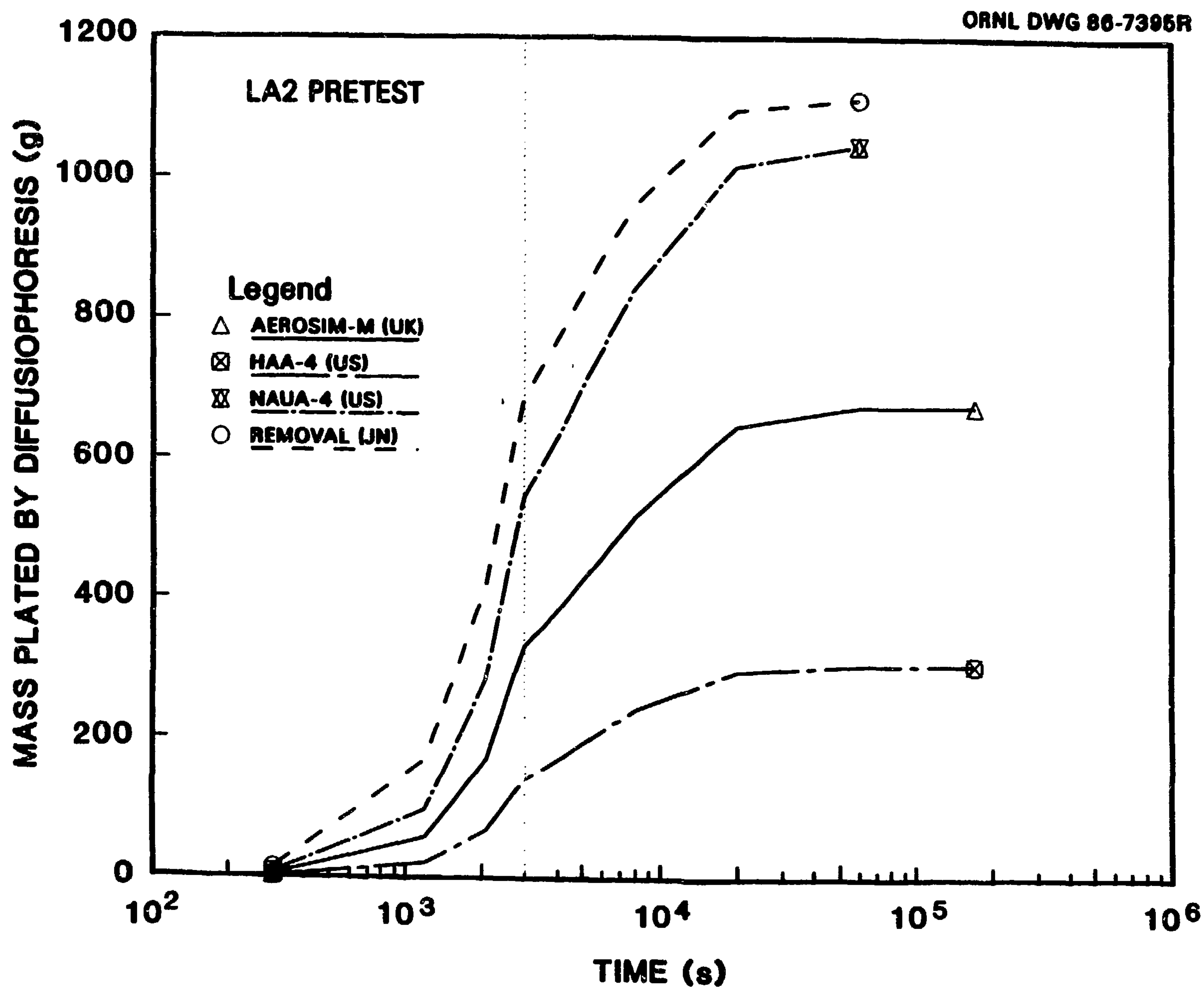
ORNL DWG 86-7382R

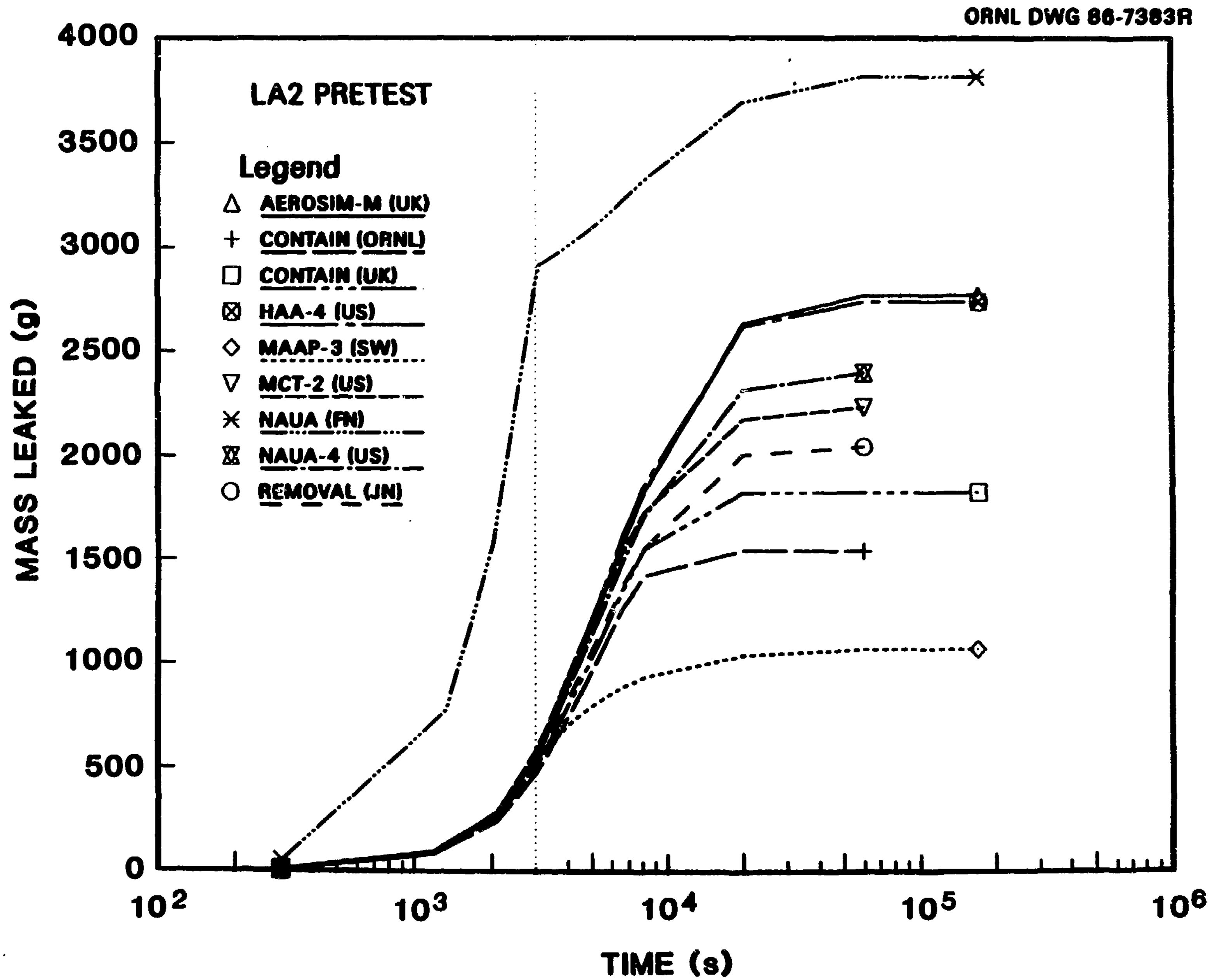


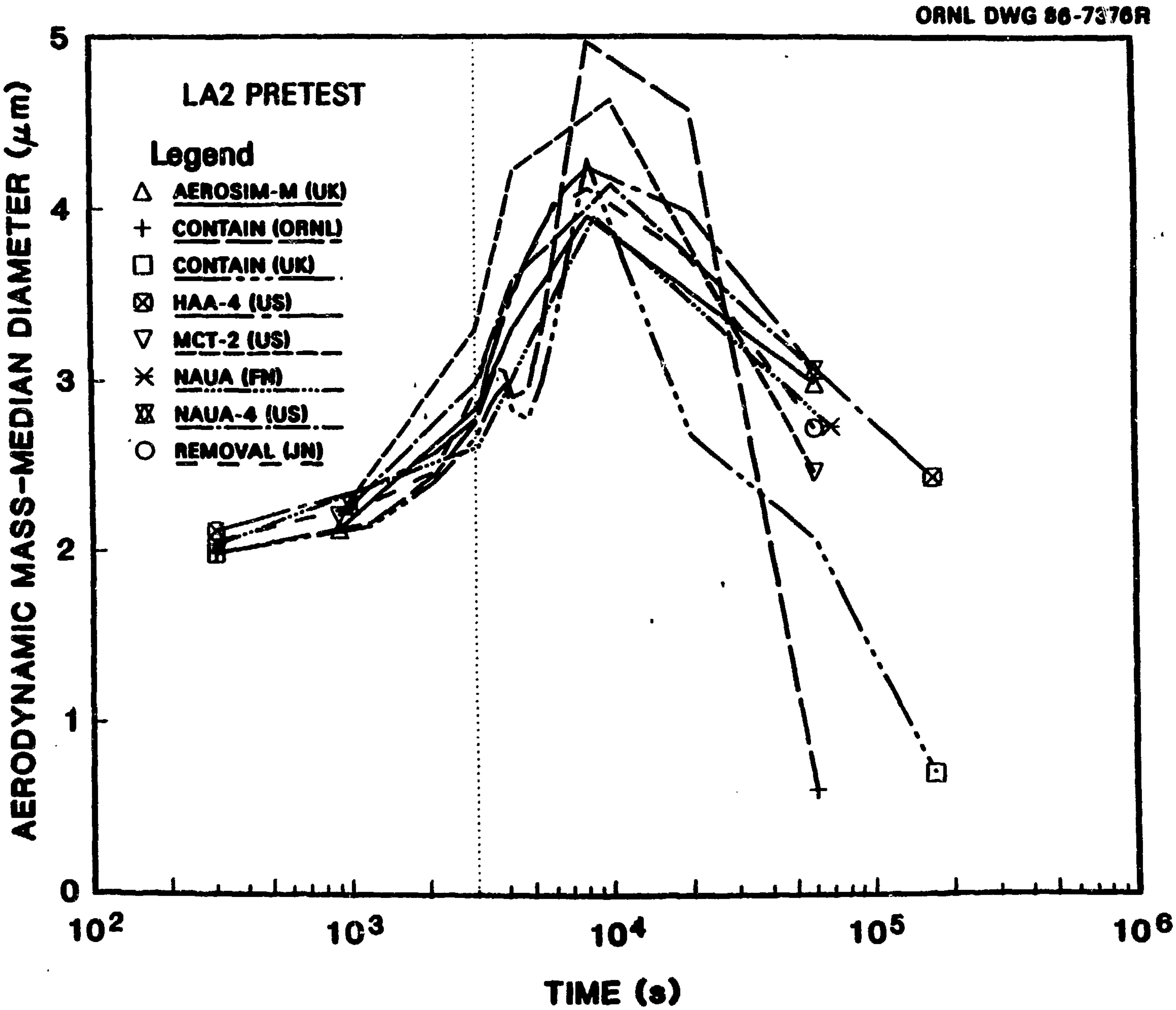

ORNL DWG 86-7376R
LA2 PRETEST
Legend
AEROSIM-M (UK)
CONTAIN (ORNL)
CONTAIN (UK)
HAA-4 (US)
MCT-2 (US)
NAUA (FN)
NAUA-4 (US)
REMOVAL (JN)
AERODYNAMIC MASS-MEDIAN DIAMETER (μm)
TIME (s)
0
1
2
3
4
5
10^2
10^3
10^4
10^5
10^6

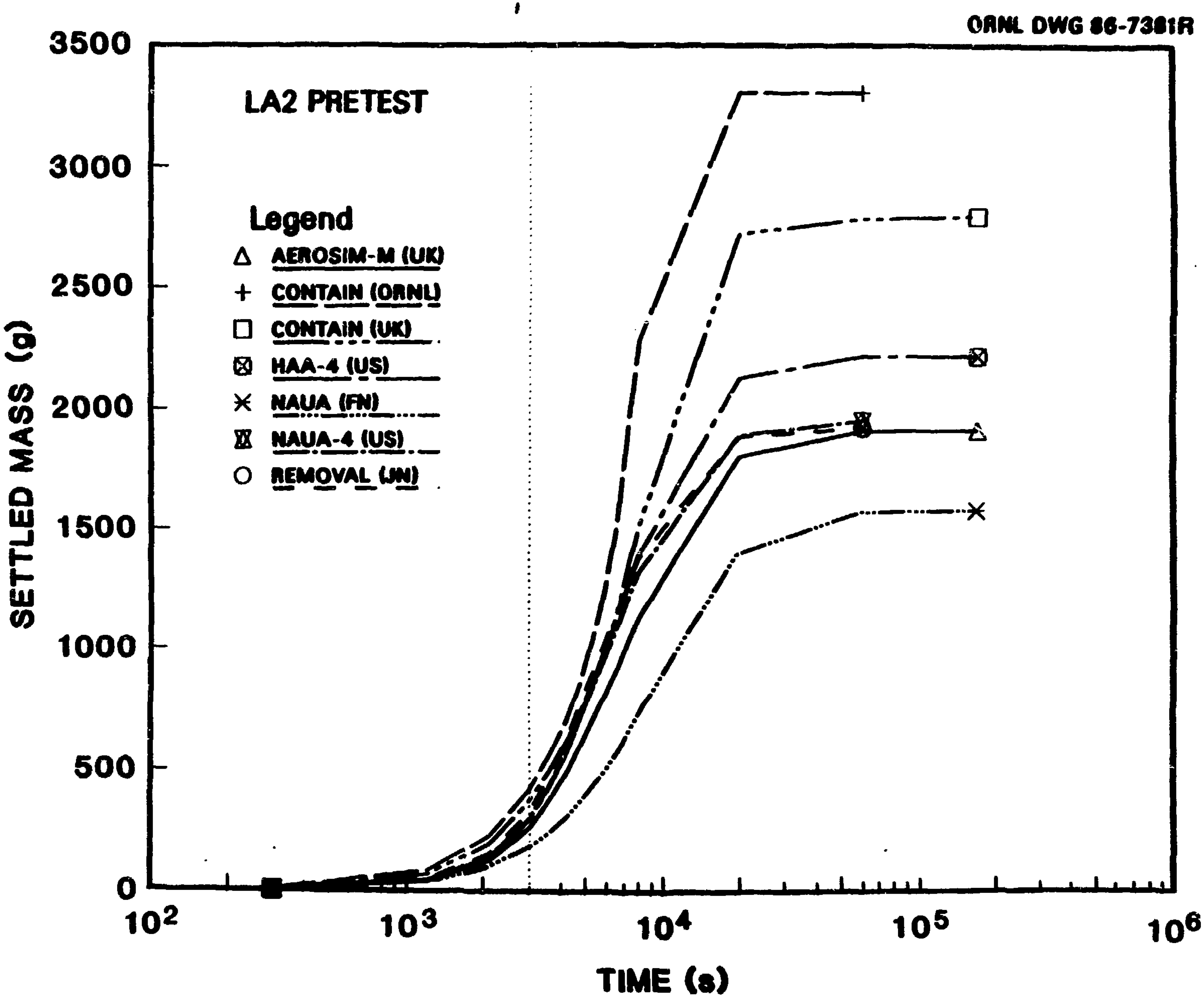


ORNL DWG 86-7381R
LA2 PRETEST
Legend
AEROSIM-M (UK)
CONTAIN (ORNL)
CONTAIN (UK)
HAA-4 (US)
NAUA (FN)
NAUA-4 (US)
REMOVAL (JN)
SETTLED MASS (g)
TIME (s)
3500
3000
2500
2000
1500
1000
500
0
$10^2$
$10^3$
$10^4$
$10^5$
$10^6$


ORNL DWG 86-7395R
LA2 PRETEST
Legend
AEROSIM-M (UK)
HAA-4 (US)
NAUA-4 (US)
REMOVAL (JN)
MASS PLATED BY DIFFUSIOPHORESIS (g)
1200
1000
800
600
400
200
0
10^2
10^3
10^4
10^5
10^6
TIME (s)


ORNL DWG 86-7383R
LA2 PRETEST
Legend
AEROSIM-M (UK)
CONTAIN (ORNL)
CONTAIN (UK)
HAA-4 (US)
MAAP-3 (SW)
MCT-2 (US)
NAUA (FN)
NAUA-4 (US)
REMOVAL (JN)
MASS LEAKED (g)
TIME (s)
4000
3500
3000
2500
2000
1500
1000
500
0
$10^2$
$10^3$
$10^4$
$10^5$
$10^6$


ORNL DWG 86-7376R
LA2 PRETEST
Legend
AEROSIM-M (UK)
CONTAIN (ORNL)
CONTAIN (UK)
HAA-4 (US)
MCT-2 (US)
NAUA (FN)
NAUA-4 (US)
REMOVAL (JN)
AERODYNAMIC MASS-MEDIAN DIAMETER (μm)
TIME (s)
0
1
2
3
4
5
10^2
10^3
10^4
10^5
10^6


ORNL DWG 86-7381R
LA2 PRETEST
Legend
AEROSIM-M (UK)
CONTAIN (ORNL)
CONTAIN (UK)
HAA-4 (US)
NAUA (FN)
NAUA-4 (US)
REMOVAL (JN)
SETTLED MASS (g)
TIME (s)
3500
3000
2500
2000
1500
1000
500
0
$10^2$
$10^3$
$10^4$
$10^5$
$10^6$