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Performance Analysis of a Screenless (Counter-Current) Granular Bed Filter on a Subpilot-Scale PFBC, Volume II

Final Report

K.B. Wilson
J.C. Haas

October 1989

Work Performed Under Contract No.: DE-AC21-84MC21335

For
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
Morgantown, West Virginia

By
Combustion Power Company, Inc.
Menlo Park, California

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This research effort was made possible by the hard work and dedication of the above METC personnel and the staff of New York University, Antonio Ferri Laboratories. We at Combustion Power Company appreciate the opportunity to operate our filter at NYU. The entire NYU staff is acknowledged for their work, in particular Dr. Victor Zakkay, Laboratory Director; Mr. Jack Spiegel, Laboratory Supervisor; and Mr. George Lipsky, Laboratory Project Manager.

Special acknowledgements are also due to Dr. W.J. Haas, Jr. and Dr. D.E. Eckels of the Ames Laboratory for performing the alkali emission measurements utilizing the METC/INEL on-line method.

Stone and Webster helped immensely during the testing phase at NYU and has been very supportive in the contract work following testing. The help of the following people is gratefully acknowledged: Mr. John Mustonen, Mr. Richard Grieve, and Mr. Steve Turk.

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VOLUME II

EXECUTIVE SUMMARY

The U.S. Department of Energy sponsored this program to develop and test the Granular Bed Filter (GBF) as part of the overall program to develop coal-fired, pressurized fluidized-bed combustors to be used in combined-cycle power generating systems. In these systems a portion of the electricity is generated using a gas turbine driven by the high-temperature, high-pressure combustion gas. A hot gas cleanup train, such as the Granular Bed Filter, must be installed before the gas turbine to prevent erosion of turbine materials and deposition of particulate within the turbine. Meeting New Source Performance Standards (NSPS) with this filter is also required to eliminate need for post-turbine particulate removal. Furthermore, it has also been shown that alkali (sodium and potassium) in trace amounts can harm gas turbine materials. The GBF was evaluated for removal of these contaminants.

The purpose of this work was to obtain information on the operational and economic feasibility of the Granular Bed Filter when applied to a pressurized fluidized-bed combustor (PFBC) as a high-temperature, high-pressure particle control device. In this program, experimental data was obtained on the design and operational life of critical components, an experimental sequence was conducted on a subpilot-scale GBF test module, and an update of a commercial-scale design was completed based on experimental data.

There were three tasks in this program. Conclusions reached in each task are reported in respective sections.

SECTION I - Life-Critical Component Testing:

The objective was to provide a sound basis for assessing the design and predicting the operational life of GBF components under PFBC conditions. Testing was carried out at the Combustion Power Company high pressure test facility in Menlo Park, California. Components supporting GBF operation in a PFBC subpilot plant were designed, built and operated. About 500 hours of testing was completed. Results showed that all components were ready for subsequent operation at the New York University subpilot-scale PFBC facility.

SECTION II - Granular Bed Filter Testing at New York University:

The objective was to successfully remove particulates to the required levels over the entire test period (200 hours) without operational or component failure. These requirements are determined by the chosen gas turbine, the process design, and NSPS requirements. According to Stone & Webster Engineering Corporation, gas turbines can normally tolerate

100-200 ppmw particles up to 5 micron size without erosion. Particles larger than 5 micron should not exceed 8 ppmw with only 1 ppmw exceeding 10 micron. NYU test results showed that GBF collection efficiencies for the moderate and larger particle sizes above is not much different than the collection efficiency below 5 micron. Meeting the NSPS environmental limit of 29 ppmw is actually less restrictive than turbine tolerance limits. Results from the last two tests at NYU averaged 7 ppmw and 4 ppmw for particle loading at the GBF outlet, respectively. Media size was 2 mm for tests yielding 7 ppmw at the GBF outlet and 3 mm for tests yielding 4 ppm at the GBF outlet. Alkalis were removed with high efficiency but due to high temperature drop across the filter during measurements (200-300°F), removal was probably due to alkali condensation.

SECTION III - Commercial-Size Granular Bed Filter:

The objective for this task was to estimate capital, installation, and operating costs of a Granular Bed Filter based on the concepts and principles developed in testing. A commercial-size design is based on the Philip Sporn PFBC Repowering Project. This is a proposed 330 MWe net power plant located in New Haven, West Virginia. The design proposed is in response to a Memorandum of Technical Requirements prepared by the Stone & Webster Engineering Corporation, Boston, Massachusetts. The hot gas cleanup train is designed for 2,885,000 lb/hr PFBC gas flow at 1550°F and 215 psia (168,525 ACFM) with a particulate loading of 500 to 2500 ppmw. In this design, 80 granular bed filter elements are divided among four pressure containment vessels that are 18' in diameter and 90' tall. The installed cost of the GBF system is $24,207,000 or $144 per ACFM in 1989 dollars.

Tests in the late 1970's and early 1980's of a subpilot-scale filter element at atmospheric pressure and at a temperature of about 1600°F demonstrated successful operation over a 1500-hour test period. Particle collection efficiencies of 99 percent were obtained and degradation of the collection media did not occur. The filter also operated successfully under upset conditions (inlet particle loadings 10 times normal and inlet gas flow rates 25 percent higher than normal). Testing at New York University demonstrated stable GBF operation downstream of a coal-fired PFBC at high temperature and pressure. Particulate was removed under steady-state and upset conditions to below the NSPS requirements and turbine tolerance limits.

---

* - .03 lb/10^6 Btu NSPS limit, approximate conversion based on:
HHV of coal = 12,223 Btu/lb
1 lb coal requires 12.5 lb combustion gas
ppm = parts per million by mass

APPENDIX IA

MEDIA TRANSPORT MODEL

APPENDIX IA

MEDIA TRANSPORT MODEL

There is a considerable body of literature in vertical transport of granular solids. (1,2) The fundamentals of vertical transport can be conceptually expressed by a simple momentum balance. (3) The qualitative results of such calculations can be shown on diagrams such as that presented in Figure 1. An "ideal" model of the applicable aerodynamics would express at least four phenomena:

- Friction Dominated Performance (A-B, Figure 1)

  This regime is characterized by a relatively dilute (lean) transport and relatively high gas and solids speeds. The pressure drop is related to flow much as might be expected in a slurry or other non-ideal fluid flow.

- Static Head-Dominated Performance (C-B, Figure 1)

  In this regime, increased throughput of transport air has significant effects on the quantity of resident solids in the system. Therefore, the effect of increased throughput of gas is to reduce pressure by reducing the weight of solids that must be supported.

- Minimum Pressure Drop for Transport (B, Figure 1)

  Since the frictional component that dominates range A-B also exists in the head-dominated range B-C, there is a smooth transition between the two regimes that represents the minimum pressure drop for circulation at a specified rate.

- Choking Velocity (C, Figure 1)

  There is a velocity at which the column of solids can no longer be maintained in smooth motion regardless of the pressure drop and the column collapses to essentially static voidage. Before transport ceases altogether, there may be an unsteady bubbling mode.

There are a number of systems of equations that can be implemented to produce quantitative estimates of lift-pipe performance. Combustion Power Company uses a system proposed by Yang (4) which involves a stepwise approximation of the voidage profile nested within an iterative loop that makes possible the independent specification of the pressure at the top of the lift- pipe to which the media is to be delivered. For purposes of illustration, Figure 2 shows the predicted results of this model applied to a pilot-sized, high-pressure, low-temperature circulation system.

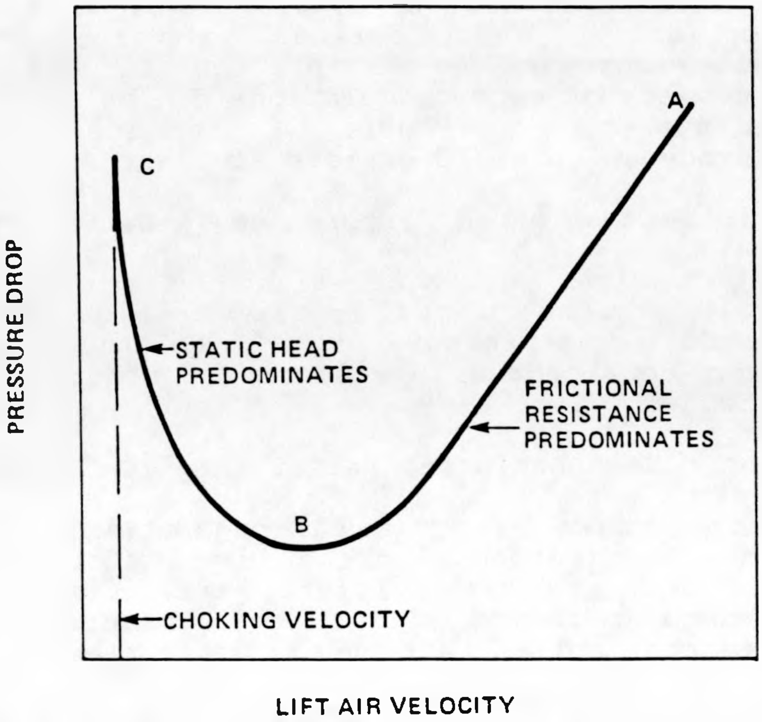

Figure 1. Conceptual Behavior of a Vertical Lift Pipe

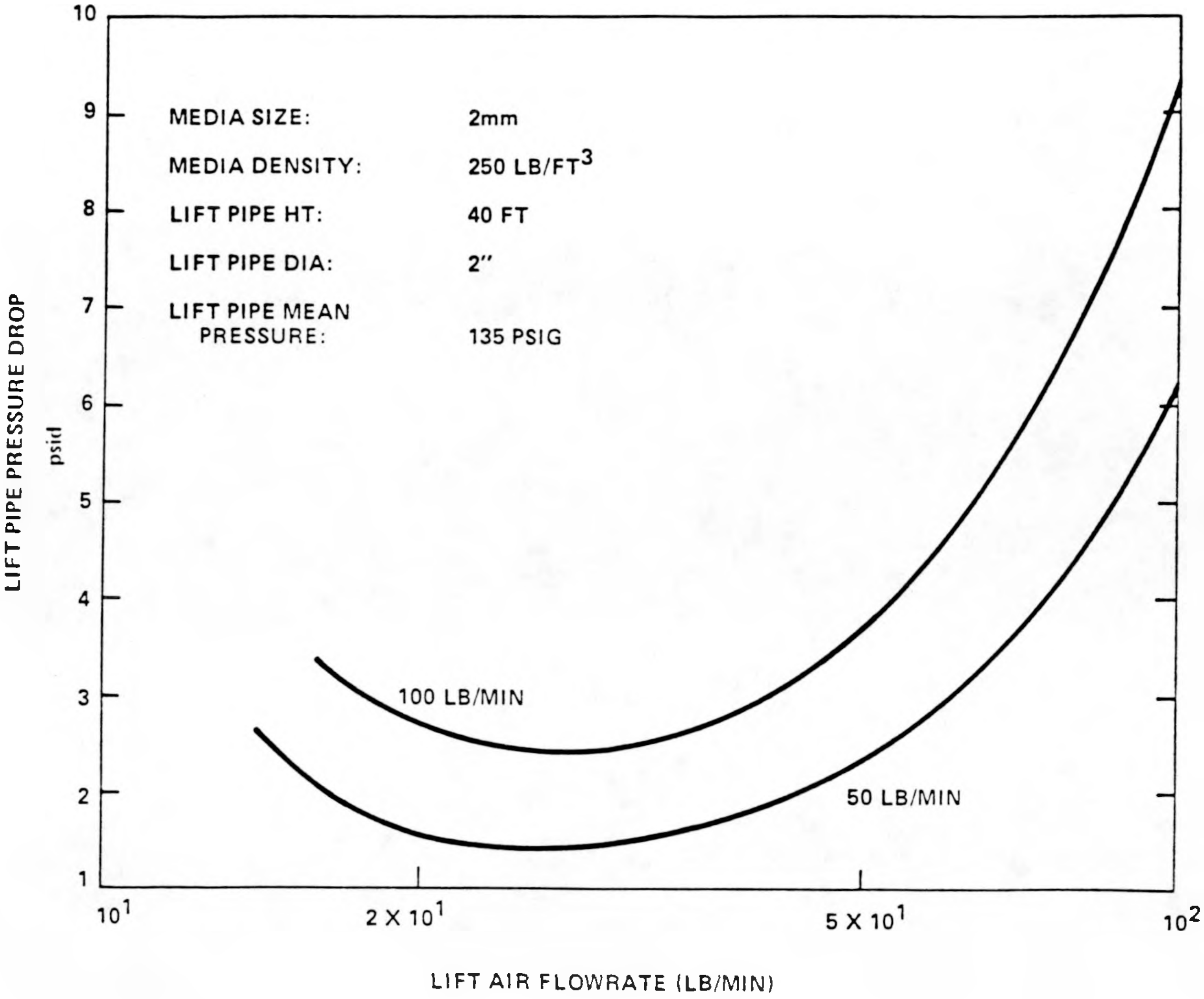

Figure 2. Performance of Lift Pipe

Unfortunately, the fact that such models exist cannot be construed to mean that accurate performance can be predicted consistently without specific test data. For example, there is generally very poor agreement between choking velocities predicted by published correlations and measured values as seen on Table I.(5) This is especially unfortunate since many systems are purposely operated on the "downslope" between choking and minimum pressure loss to provide blower stability and minimize high media velocities.[•] In addition, the friction models are generally good for the particular solids used in the experiment and the size of the experimental test system but cannot be arbitrarily extrapolated.

[•] CPC's program does not incorporate a choking model but instead finds the minimum pressure drop and predicts for a relatively short distance to the left of this minimum.

TABLE I. DEVIATIONS BETWEEN MEASURED CHOKING VELOCITIES AND THOSE CALCULATED BY VARIOUS CORRELATIONS (5)

	Investigators					
	Low Pressure Data[a]				High-Pressure Data	
Correlation Source	Zenz	Lewis	Ormiston	Capes	Knowlton	All Data
	% Relative Deviation					
Zenz, F.A. (1960)	21	39	55	47	41[b]	41
Rose, H.E. and Duckworth, R.A. (1969)	59	69	43	69	219[b]	140
Leung, L.S. *et al.* (1971)	20	39	27	18	67[c]	39
Yousfi, Y. and Gau, G. (1974)	27	14	12	68	31[b]	40
Knowlton, T.M. and Bachovchin, D.M. (1975)	522	143	200	215	6[d]	257
Yang, W.C. (1975)	36	34	31	15	76[c]	44
Present Work	36	34	31	15	8[c]	25

---

[a] Yousfi and Gau (1974) data not available for the present analysis.

[b] Based on the weighted average diameter of the feed-size distribution, $D_p = \Sigma(X_{if} D_{p_i})$

[c] Based on the weighted average diameter of the size distribution in the riser, $D_p = \Sigma(X_{it} D_{p_i})$

[d] Based on surface-to-volume mean diameter, $D_p = 1/(\Sigma X_i / D_{p_i})$

REFERENCES

1. Zenz, F.A. and D. F. Othmer Fluidization and Fluid- Particle Systems Reinhold (New York) 1960.

2. Kunii, D. and O. Levenspiel Fluidization Engineering Wiley (New York) 1969.

3. Davidson, J.F. and D.Harrison Fluidization Academic Press (London) 1971.

4. Yang, W.C. "A Unified Theory of Dilute Phase Pneumatic Transport", Journal of Powder and Bulk Solids Technology (1976).

5. Punwani, D.V., M.V. Modi and P.B. Tarman "A Generalized Correlation for Estimating Choking Velocity in Vertical Solids Transport", International Powder and Bulk Solids Handling and Processing Conference (1976).

APPENDIX IB

DETAILED TEST PLANS

LIFE CRITICAL COMPONENT TESTING

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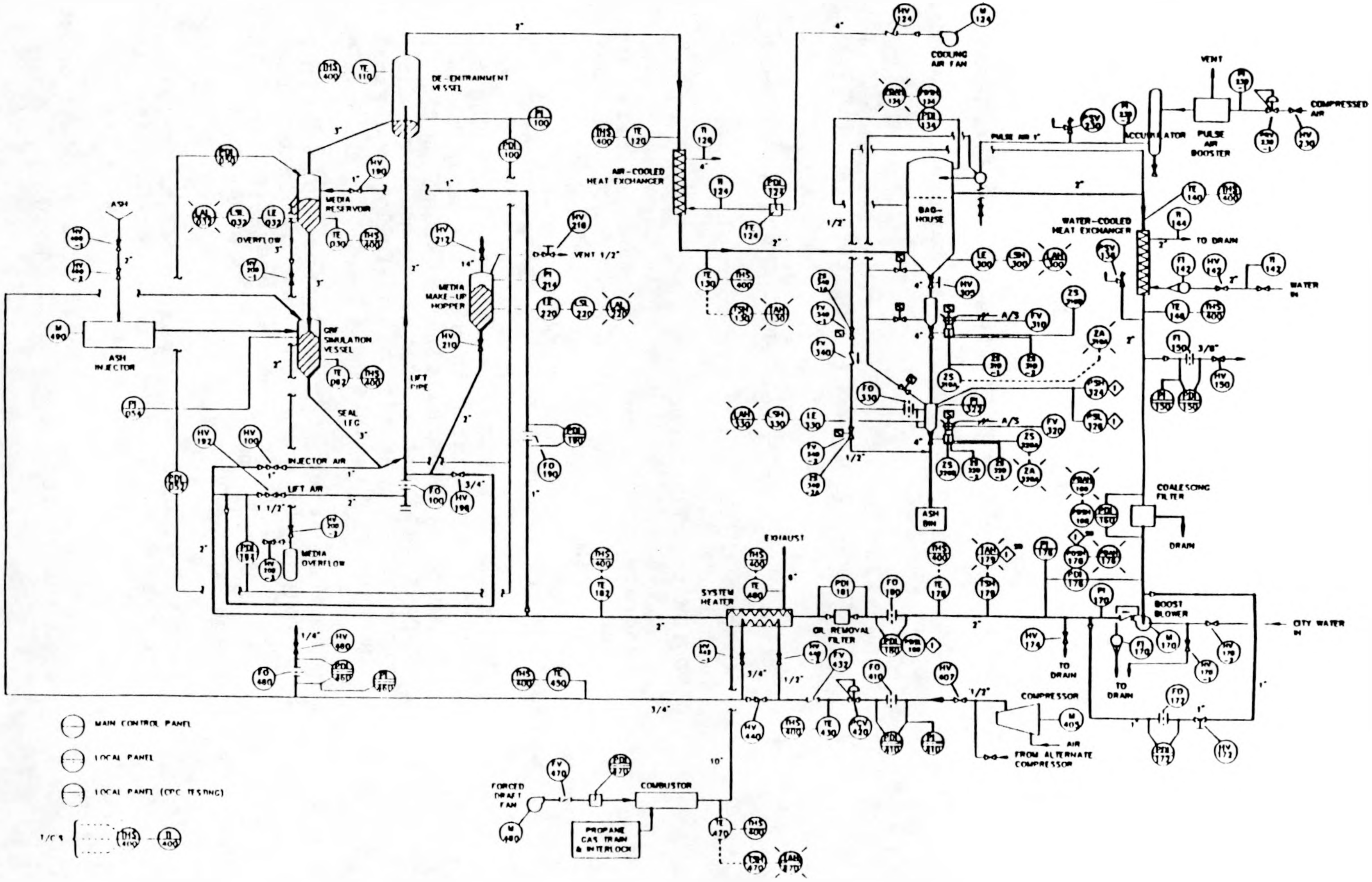


GBF Life Critical Component Test Unit

K. B. Wilson
2/12/86

DOE-GBF TEST MODULE AT CPC

CHECK-OUT: NOTE: Understand operating instructions on each item before checking it out. Also, the sequence, following, may be changed.

1. Complete pressure test per separate instructions.

2. Run cooling water through heat exchanger (HV-142) and Boost Blower (HV-170-2)

   - Check for leaks and make a preliminary check on instrument operation. (Do this on all items as is possible)

3. Run air through air-cooled heat exchanger (HV-124)

   - Check PDI-124 vs. valve operation

4. Run FD fan to COEN burner.

   - Generate a flow curve for fan. (Press vs. flow) Install a pressure gauge (0-30" H_2O) at blower outlet (upstream of HV-470) if needed.

5. Check out the baghouse pulsing operation as follows:

   a) Set regulator PSV 230-1 to 25 psig. The pulse air booster should step this pressure up to 75 psig at P1-230-2 (downstream of accumulator). Bleed compressed air off at the accumulator and observe air booster operation. Hopefully it doesn't shake the entire structure.

   b) Step the air booster <u>outlet</u> pressure up in 25 psig increments by increasing the regulated pressure at PSV-230-1. Check booster operation with flow and without flow. Push the outlet pressure to 200 psig. Check for leaks.

   c) Back the accumulator pressure off to 75 psig and run the baghouse pulsing system. Set the timer to pulse once per minute for a start.

   d) Consider pushing the header pressure high enough to open the relief valve. (250 psig)

6. Level switches:

   a) Baghouse (LE-300): Open the 6" access port and trip the high level switch by grabbing it with your hand or touching it with a stick or some way else.

      - Verify status lite operation.

   b) Ash holding vessel (LE-330): Verify operation by removing element and placing probe in ash.

   c) Media make-up hopper (LE-220): Verify operation by hand like on the baghouse.

   d) Media Reservoir (LE-032): Verify by removing probe and placing it in media.

7. Thermocouples: (Check with Guy Huffman)

   a) Verify reasonable T.C. readings and

   b) Verify proper locations.

      - Prepare a list identifying selector switch numbers vs. T.C. location.

8. Pressure Gauges:

   a) Check that all are zeroed.

   b) Pressure the system up to, say, 50 psig and verify all pressures gauges read the same.

      - All differential pressure gauges read zero. Record exceptions.

   c) Repeat "b" at 100 psig.

   d) Check the following pressure gauges with the proper, calibrated test gauge (record results and save).

      - PDI-150 (System Bleed)
      - PDI-172 (Boost Blower Bypass)
      - PDI-180 (Boost Blower Bypass)
      - PDI-410 (Compressed Air Flow)
      - PDI-460 (Compressed Air Bleed)
      - PDI-470 (FD Air Flow)
      - PDI-190 (Counterflow Air)

      Depending on the results we may go on to check the remaining differential pressure gauges.

- PDI-100 (Lift Pipe Delta P)
- PDI-194 (Diffuser + Valve Delta P)
- PDI-052 (Lower Seal-Leg Delta P)

e) If baghouse is clear, restart blower.

- Set oiler for proper rates.

f) Slowly increase blower rpm to maximum. Monitor rpm with meter.

- Do not go beyond flow range of PDI-180. Remove or change orifices first.
- Monitor PDI-176 (Blower Pressure Rise)
- Monitor PDI-181 (Oil Removing Filter)
- Minimum rpm is 725 Meas. = ____________
  Measured flow should be 30-40 scfm Act. = ___
- Maximum rpm is 1716 . Meas. = ____________
  Measured flow should be 80 scfm Act. = ______
- Set maximum and minimum rpm "stops" on motor base.

* Limit the amount of time the blower operates above 1500 rpm.

g) Shut down. Check baghouse for large debris (something that could damage the 4" Kaymr ball valves under baghouse). If clear, <u>close up 6" port in baghouse</u> and repeat step "f".

- Recheck oiler
- Set blower to minimum flow

<u>Pressured Operation</u> (Need FO-180 and FO-172)

h) Close HV-174 (Primary Oil Drain)

- Check drain on oil removal filter.

i) Adjust HV-150 (System Bleed) to 1 turn open (enough for just a little flow)

j) Pressurize to 35 psig (open HV-440 and use shop reciprocating compressor) and restart blower

- Monitor pressure drops, especially the two filters and the baghouse
- Monitor the boost blower pressure rise. (It should be well below 10 psi)
- Run blower for 10-15 minutes or long enough to see if any pressure spikes appear.

k) Increase flow to half way between minimum and maximum.

  - Any pressure spikes?
  - Oiler OK?
  - Pressure and flow gauges OK?

l) Increase pressure to 85 psig.

  - Make same checks as in step "i" and "k" Readings should make sense.

Blower Flow Control Checks (at pressure)

m) Open blower bypass and establish flow

n) Lower blower rpm towards minimum and make trade-off adjustments between blower rpm and bypass to achieve 30 ACFM flow at FO-180 (main blower flow)

o) Increase system pressure to 100 psig.

  - Checks per "j" and "k"
  - Same as "n"

p) Close HV-196 (Media make-up hopper)

  - Checks per "j" and "k"

q) Close HV-100 to 1 turn open

  - Checks per "j" and "k"

r) Repeat step "n" (for 30 ACFM)

s) Close HV-150

  - There should be no change unless PCV-420 leaks (inlet regulator from the compressor)
  - Checks per "j" and "k"

System checks on leakage

t) Open HV-460 (compressed and bleed) and establish an air flow from the compressor.

  - Establish flows from FO-460 and FO-410 should be equal.

u) Close HV-460 and open HV-150 (System bleed)

  - Establish equilibrium as in "t" and verify flows are equal (FO-410 and F1-150)

K. B. Wilson
2/12/86

ASH DUMP SYSTEM TESTING

Get Guy Huffman to help, and have the electrical schematic on hand. (53016, sheet 3)

Setup

a) Set PSH-324 to 20 psig.
b) Set PSL-326 to 1 psig.
c) Pressurize the system to 25 psig.
d) Set HV-305 to 1 turn open (limits compressed air blowdown if any problem arises).
e) Set timers per electrical schematic.
f) PI-322 should read near zero. (If it doesn't, just note this.)
g) Ash valves should indicate closed (lites on FV-310 and FV-320, actuators on FV-340-1 and FV-340-2).
h) Make sure the check valve is installed in correct direction (FV-320).
i) Install ash barrel.

Sequence

a) On "start" FV-340-1 should open to pressurize the lower ash vessel.

- Watch PI-322 pressure rise

b) In about 1 minute, FV-340-1 should close and FV- 310 should open.

- FV-310 should not open if PSH-324 is not above the set point.
- Verify FV-340-1 operation.
- Verify FV-310 stays open for 60 seconds (TD- 2) then closes.
- Verify status lites.

c) After about 1 minute from the time step "b" starts, FV-340-2 should open (providing step "b" was successfully completed) and the pressure in the lower ash vessel dissipated through the ash bin.

- Verify FV-340-2 opens after FV-310 closes.

- Verify PI-322 drops to zero within one minute.

d) When step "c" times out (1 minute) FV-340-2 closes and FV-320 opens.

- FV-320 should not open unless PSL-326 reaches its setpoint.

- Verify FV-340-2 operation.

- Verify status lites and operation of FV-320.

- Verify that FV-320 stays open for 60 seconds (TD-4), then closes.

e) When FV-320 closes, the valve status should have cycled back to the beginning.

- Verify all valve status and check status lites

f) Press "start" to reset the main cycle timer and run the sequence through enough times to verify all components are operational.

Interlocks & Alarm Lites

Test interlocks to verify they protect the ash unloading system as intended.

a) Open a poke hole on the lower ash holding vessel. This should prevent PSH-324 from reaching the set point (or reset PSH-324 to above 25 psig). Cycle should stop after step "a".

b) Reset PSL-326 to less than atmospheric pressure, if possible. Or tube a compressed air source to the lower ash holding vessel. Cycle should stop after step "c".

c) Set the cycle time for a short time and verify the cycle repeats automatically.

K. B. Wilson
3/12/86

PARAMETRIC TEST

General Procedure for Media Rates

Pressurized tests for media rate from media reservoir.

- The purpose of these tests is to compare theoretical and measured circulation rates. These tests can be run at pressures to 150 psig, and temperatures to 1600F.

Set-Up:

1) Need two test personnel, each with a walkie-talkie.
    - One man (at grade level) will adjust flows, record data and plot data points.
    - One man (at the media reservoir) will operate the media follower and relay data to grade level.

Testing:

1) Follow operating instruction to bring circulation system on line.
2) Close and pressurize system to selected level.
3) Heat the system to desired level.
4) Set lift pipe, counterflow, and bleed air rates to selected rates (1). Adjust blower speed, blower bypass, or counterflow as desired.
    - Choose optimum lift pipe flow, or higher, first.
    - Confirm lift pipe air flow to within ±5% by calculation.

---

(1) Some data points may be difficult to get because they are at the limits of the blower or too close to choking (media collapse). In these cases, adjust operating points to stay close to data sets. If in doubt, contact the project engineer.

5) Circulate media at a selected rate based on lift pipe delta P.

   - The first time through, adjust media rate over a reasonably wide range (.5 psi to 3+ psi) for a quick look.

   - To test, monitor level of media follower for 5 to 15 minutes depending on circulation rate. Record all system data plus the drop in level of media follower.

   - Reference each data set and calculation to the same time.

   - Reposition media follower for the next media rate test.

6) After each series of media rate tests, change the lift pipe air flow and repeat steps 4 and 5.

7) Optional: At a moderate circulation rate, lower lift pipe air flow until media collapse (choking). Record data, then increase air flow to blow out the lift pipe, if possible.

   - Record observations (variations in lift delta P, etc.)

K. B. Wilson
3/14/86

Pressure Balance Profile Tests

Purpose: To observe and record circulation characteristics when balancing pressures in circulation loop.

Set-Up:

1) Run these tests as an add-on to measured media rates tests at pressure above ambient.

2) See data sets for test points.

Testing:

1) After completing the test point involving measuring circulation rate, open the bleed-off valve, HV-150, enough to reverse the leakage flow in the lower seal leg.

   - PDI-052 should reverse to about 1 psi delta P with low pressure at the bottom (1 psi negative).

   - Adjust the zero of PDI-052 to 1 1/2 psi. (Use a standard calibration gauge to determine the true gauge readings.)

   - Readjust lift pipe delta P to starting v

2) Allow equilibrium to be reached and record data.

   - Equilibrium is when FO-410 flow (compressor supply) equals FI-150 (system bleed) to, say, ±10%.

   - Alternate requirements for "equilibrium" are:

     a. PDI-410 (compressed air supply) stays constant for 5-10 minutes.

     b. PDI-150 (system bleed) stays constant for 5-10 minutes.

     c. PDI-052 (seal-leg pressure drop) stays constant for 5-10 minutes.

     d. PDI-050 (GBF-Media Reservoir press. drop) stays constant for 5-10 minutes.

    e. PI-100 (Pressure at top of lift-pipe) stays constant for 5-19 minutes.

3) At equilibrium, record all system data and mark data point for reference.

K. B. Wilson
3/13/86

Ash Concentration Tests

Purpose:

To determine if there is a maximum ash/media ratio and if this maximum can be affected by pressure balancing the circulation loop.

Set-Up:

1) Install ash feeder

   - Have calibration curve on hand.

Testing:

1) Pressurize to 50 psig.

2) Heat to 400°F.

3) Circulate at optimum lift-air flow.

4) Lower circulation rate to near minimum (15-20 lb/min) and inject ash to, say, 2%, 5%, 10%, 15% of media rate. Record data and observations.

   - Pressure balance and repeat test.

K.B. Wilson
3/13/86

3 MM Media Tests

Purpose: To characterize 3 mm media circulation for testing at NYU.

Set-Up: Remove 2 mm media and refill with 3 mm media.

Testing: (Assuming the circulation system mathematical model proves reasonably accurate based on completed tests.)

1) Check media rates with media follower at atmospheric temperature and 50 psig. Choose 4 circulation rates and 3 lift-air rates.
    - Try pressure balancing at minimum and maximum circulation rates and minimum lift-air rate.
2) At 50 psig and 350-400F, run an ash concentration test at the middle lift-air rate noted above.
    - Lift-air at 13 lb/min
    - Counterflow air at 1.8 lb/min
    - rate at 20 lb/min (Confirm rate with media follower)
    - Ash rate at 2% of media rate (.02 x 20 = 0.4 lb/min). This is a potentiometer setting of "3" on ash feeder.
    - Run for 60-90 minutes (There are 2 hours ash capacity in feeder).

APPENDIX IIA

COAL AND SORBENT ANALYSIS

TABLE IIA-1 COAL ANALYSIS

CONSTITUENT		TEST HG-203	TEST HG-204 & HG-205
Proximate Analysis (As fired)			
Moisture	%	2.92	2.66
Ash	%	8.06	5.38
Volatile Matter	%	38.13	36.94
Fixed Carbon	%	50.89	55.02
HHV	Btu/lb	13446	13870
Ultimate Analysis			
C	%	74.36	77.73
H	%	4.62	5.48
O	%	7.02	5.68
N	%	1.60	1.54
S	%	1.38	1.53
Cl	%	0.04	--
Ash	%	8.06	5.38
Moisture	%	2.92	2.66
Ash Analysis			
SiO_2	%	50.69	49.20
Al_2O_3	%	26.51	27.58
Fe_2O_3	%	13.46	15.79
MgO	%	0.76	0.83
CaO	%	1.60	2.95
Na_2O	%	0.60	0.18
K_2O	%	2.42	1.57
TiO_2	%	2.26	1.10
P_2O_5	%	1.17	0.60
SO_3	%	0.53	--
Others	%	--	0.20

TABLE IIA-2 COAL PARTICLE SIZE ANALYSIS

MEAN PARTICLE DIAMETER (μm)	CUMULATIVE %	
	HG-201	HG-204 & 205
4375	91.21	96.44
3675	82.2	90.47
3090	73.3	84.15
2595	63.17	74.76
2180	53.33	65.31
1850	44.61	56.28
1555	36.06	47.19
1295	28.92	38.62
1090	22.36	30.36
925	16.56	22.85
780	12.70	18.06
655	8.43	12.68
550	5.50	8.13
460	3.63	5.58
385	2.10	3.50
323.5	1.11	1.89
273.5	0.58	0.93
230	0.35	0.50
193.5	0.29	0.36
163	0.23	0.34
137	0.17	0.33
115	0.11	0.33
96.5	0.05	0.25
81	0.02	0.25
68	0.00	0.25
57.5	0.00	0.25
48.5	0.00	0.25
22	0.00	0.00
Mean Particle Diameter (microns)	1288.4	974.0
Bulk Density (lb/ft^3)	42.6	42.0
Particle Density (lb/ft^3)	73.5	73.0

TABLE IIA-3 DOLOMITE CHEMICAL ANALYSIS FOR TESTS HG-204 AND HG-205

COMPONENT	$CaCO_3$	P_2O_5	Al_2O_3	S	SiO_2	$MgCO_3$	ZnO	SrO_2
% WEIGHT	48.26	0.62	4.67	0.01	5.32	41.04	0.01	0.07

TABLE IIA-4 DOLOMITE PARTICLE SIZE ANALYSIS

MEAN PARTICLE DIAMETER (μm)	CUMULATIVE % HG-204	CUMULATIVE % HG-205
4375	100.00	100.00
3675	100.00	100.00
3090	100.00	100.00
2595	100.00	100.00
2180	96.26	98.79
1850	74.50	86.80
1555	50.37	64.68
1295	31.87	43.73
1090	16.41	21.71
925	6.47	6.93
780	2.96	3.09
655	1.36	1.55
550	0.11	0.91
460	0.00	0.67
385	--	0.48
323.5	--	0.35
273.5	--	0.28
230.0	--	0.24
193.5	--	0.23
163.0	--	0.23
137.0	--	0.22
115.0	--	0.22
96.5	--	0.21
81.0	--	0.00
Mean Particle Diameter (microns)	**1285.0**	**1152.0**
Bulk Density (lb/ft^3)	**84.1**	**83.3**
Particle Density (lb/ft^3)	**145.0**	**143.7**

APPENDIX IIB

TEST REPORTS

Brief test reports follow in a chronological order. Emphasis is on the operating characteristics of the filter, especially unplanned PFBC upsets.

IIB.1 Shakedown Test HS-201

Operation commenced on October 16, 1987. The objectives were:

- Preheat the GBF using the kerosene combustor.
- Establish coal combustion in the PFBC at pressure (115-130 psig) and temperature (1600-1650°F). GBF inlet temperature estimated at 1550-1600°F.
- Complete trial measurements of gas, particulate and alkali contents at the GBF inlet and outlet.

IIB.1.1 Test Summary, HS-201

Preheat was delayed for 8-10 hours because of difficulty with the kerosene combustor. The start of the test occurred about 4:00 a.m. on Friday, October 16, 1987. Because of the late start, the objectives were revised to include only GBF preheat. Operation continued for 10 hours. Shutdown was about 2:00 p.m.

IIB.1.2 Results, HS-201

Although there were numerous equipment problems, this did not overshadow the basic successes. During the pressurized heatup mode, media was circulated in a steady, controllable fashion. There were no indications of any circulation problems even through one of the toughest operation modes; that is, the condensation phase of startup. This is the phase of operation where moisture is condensed out of the flue gas throughout the filter and media circulation system. While the equipment was designed to handle this phase, there is always some risk of unexpected difficulty. The filter performed satisfactorily although minor problems were experienced due to moisture and leakage in the instrument sense lines.

Initial testing showed that the NYU pressurized fluid bed system was stable enough for the artificial pressure balance technique to be feasible. For about one hour, the circulation system was maintained with a pressure profile characterized by a lower pressure at the bottom of the lower seal leg than at the top. This condition moves media, ash, and leakage gas in the same direction.

This test showed the need for the following extra work:

- Changes were necessary to the instrument sense lines to better deal with moisture in the pressurized equipment.
- The baghouse bags needed to be replaced as the hydroscopic ash that had been used in Combustion Power testing hardened to blind the bags. There was a six month gap between testing at Combustion Power and NYU.
- Many electrical problems were highlighted during the test; mainly with the ash discharge equipment.
- The opacity meter (puff detector) which was the responsibility of NYU, needs more work to make it operational.

During the two-week maintenance shutdown between tests, these plus other problems were addressed. The new baghouse bags required pre-coating with diatomaceous earth before they adequately sealed. This problem had not been encountered in Combustion Power testing, but is common to baghouse operation.

IIB.1.3 Conclusions, HS-201

Granular bed filter operation showed very promising indications. The moisture that inhibited instrument operation did not show any sign of inhibiting media circulation. Typically system pressures were steady enough to observe the filter and media circulation equipment under simulated steady state, hot, pressurized operation. All basic systems worked fine, including pressure balancing.

IIB.2 Shakedown Test HS-202

Operation commenced on October 27, 1987. The objectives were the same as for the previous shakedown; which were:

- Preheat the GBF using the kerosene combustor.
- Establish coal combustion in the PFBC at pressure (115-130 psig) and temperature (1600-1650F). GBF inlet temperature estimated at 1550-1600F.
- Complete trial measurements of gas, particulate and alkali contents at the GBF inlet and outlet. The METC/INEL alkali system was operational for this test in addition to the NYU system.

IIB.2.1 Test Summary, HS-202

Preheat started about 1:30 p.m. on October 27, 1987. This phase went as planned and the changeover to PFBC operation started at 4:30 a.m. on October 28, 1987. At 6:00 a.m. just as coal feed started, it was discovered that the coal feed line was plugged. Efforts to unplug the coal feedline were unsuccessful and also caused GBF problems. Shutdown was at about 6:30 a.m.

IIB.2.2 Results, HS-202

This test provided the first real data on GBF heatup. Time for preheat was about 12 hours, with indications that it could have been accomplished in 8 hours, as later shown.

When coal feed started, the PFBC was arranged to bypass the GBF as shown on Figure IIB-1. The PFBC was to be started up with the bypass open and the on-off, pressurization valve closed. When NYU personnel attempted to unplug the coal feedline, compressed air was used. Although the plug was not dislodged, the PFBC pressure rose erratically from 30 to 140 psig. Then the pressure fell back to 60 psig. About 60% of the combined PFBC and GBF volume is on the downstream side of the filter bed. The rapid depressurization (over 15 psi/minute) through the bypass valve with the on-off valve closed generated enough backflow to transport filter media into the inlet ducting. Calculations revealed that a 15 psi/minute rate of depressurization can induce gas flow through the 8" inlet ducting which approximates the minimum fluidization velocity of the media. These calculations depend on the volume of the GBF pressure vessel and ducting up to the on-off pressurization nozzle.

After the rapid depressurization that plugged the filter inlet ducting with media, a subsequent rapid pressurization created a pressure difference of over 90 psi between the PFBC freeboard and the on-off pressurization nozzle according to the data. It is suspected that the 8' long vertical duct leading into the filter bed sustained most of this pressure drop and as a result, the metal bellows portion of the inlet flexible seal was damaged.

This upset became the subject of an interesting study in the behavior of the GBF under rapid pressure changes and reverse gas flow. This behavior is depicted on Figure IIB-2 and IIB-3. Typical, steady-state operating values are shown as a dashed line on applicable curves. The upset began at about 0600 on 10/29/87 (zero time), just as NYU tried to start coal firing. PFBC bed pressure had been fairly steady at 35-40 psig up to the point NYU discovered that the coal line was plugged. The compressed air NYU intended for clearing the feed line bypassed around the plug and entered the fluidized bed air ducting downstream of the metering venturi as shown by the opening of valve "A" on Figure IIB-1. The first of three openings of valve "A" occurred at 8 minutes after

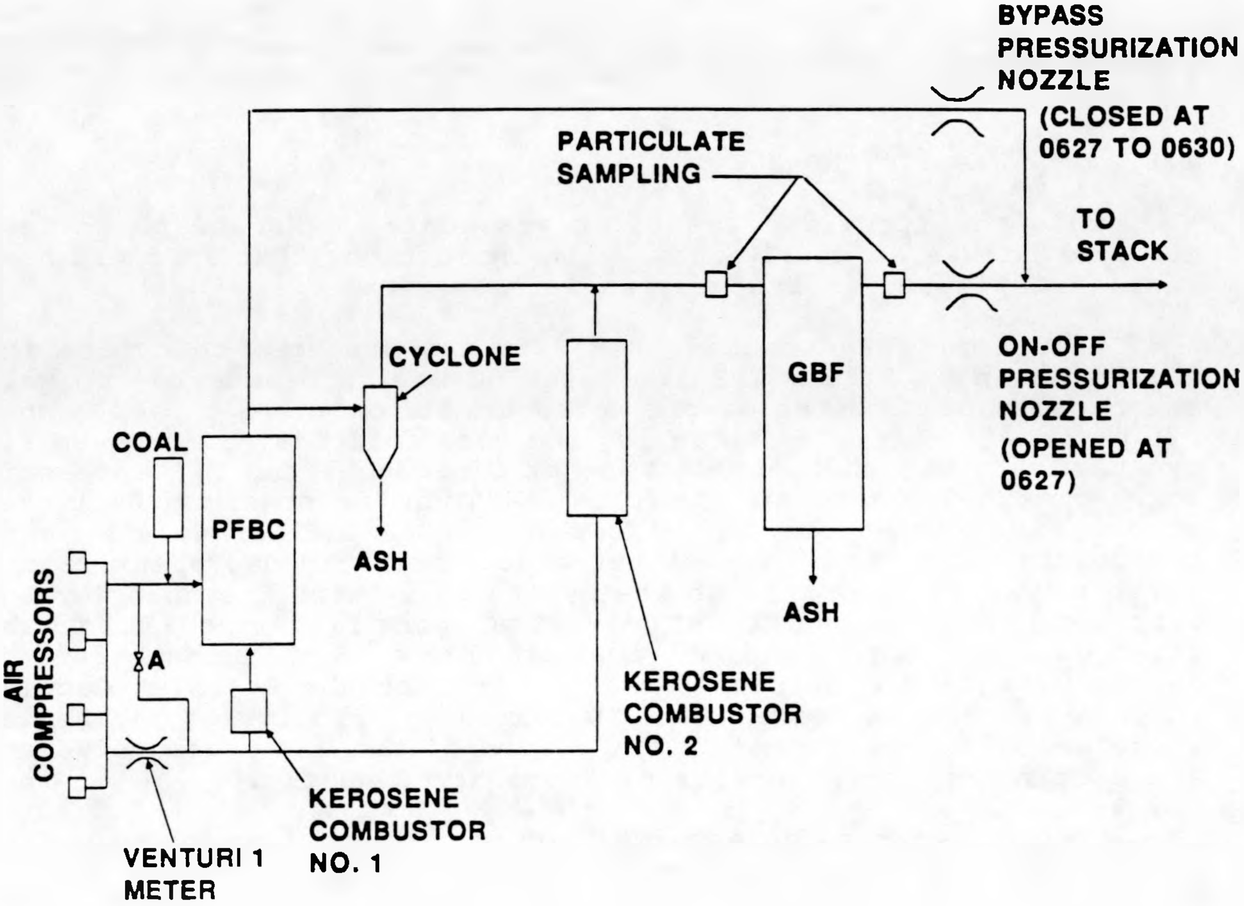


Figure IIB-1. NYU Test Equipment During HS-202

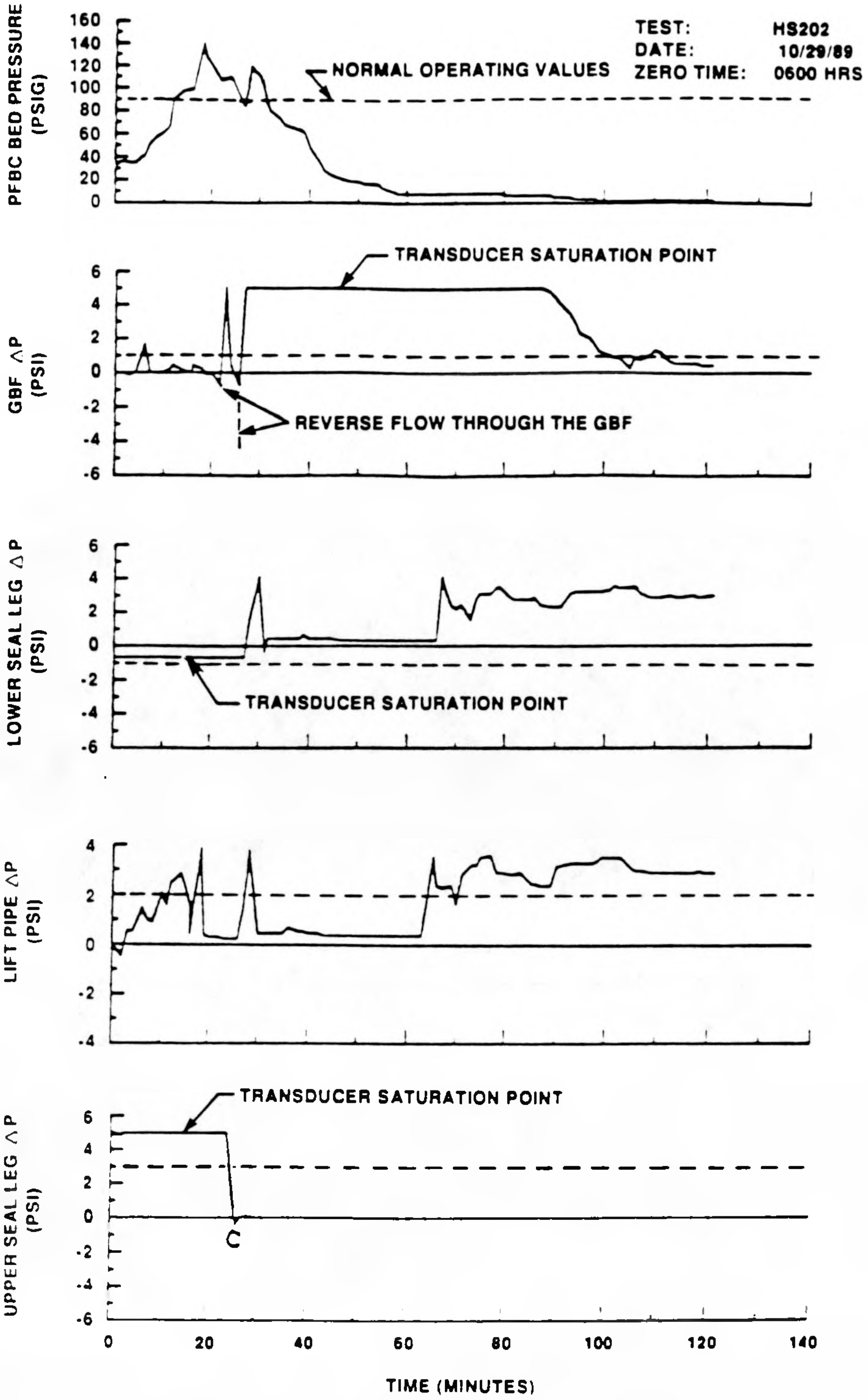


Figure IIB-2. PFBC and GBF Performance Curves for HS-202 Starting from 6 AM on 10/29/87

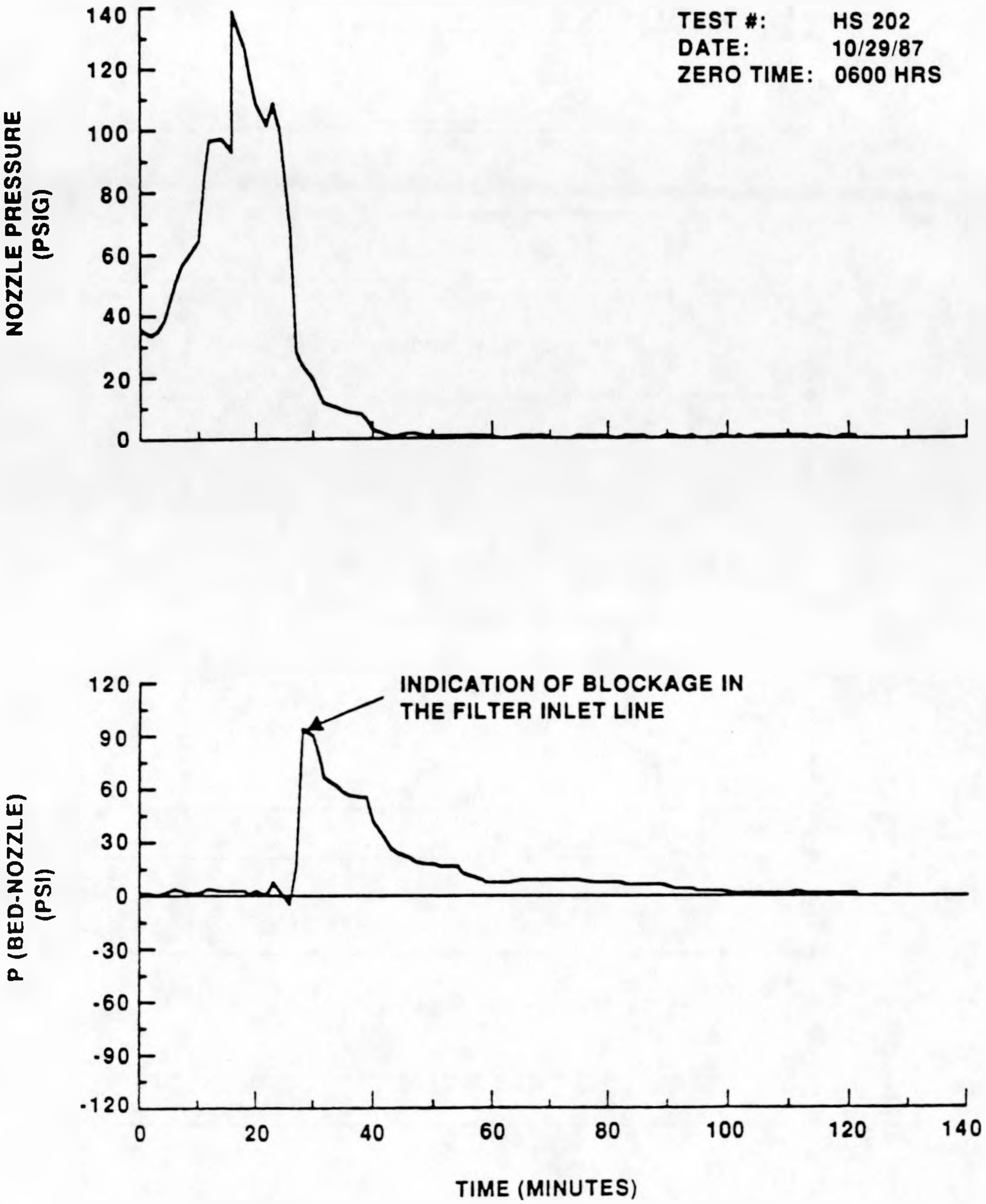


Figure IIB-3. On-Off Nozzle Pressure and DP Between the PFBC and the On-Off Nozzle for HS-202 Starting from 6 AM on 10/29/87 zero time according to NYU. At this time, the PFBC bed pressure began to rise and the GBF pressure drop spiked upward. Because the on-off valve was closed there was no continuous flow through the GBF. Consequently, the spike in pressure drop indicated that gas flow was rushing past the GBF to fill the isolated volume downstream. Since the GBF pressure drop approached the theoretical minimum for fluidization (2 psi), the media probably bubbled. This was to become one characteristic of the NYU system. The diesel driven compressors hold a large volume of 140 psig air in their storage tanks. This air could be released into the PFBC very rapidly in a variety of ways to generate high transient gas flows through the filter. As was normally the case, the transient diminished very quickly and the media settled back without much loss.

Note that the lower seal leg and the upper seal leg appeared unaffected by this first transient (at 8 minutes). That is because the system pressure had been rising for quite some time and was already leaking into the circulation system at a rate high enough to saturate the transmitter outputs. Leakage gas flows down the lower seal leg on a pressure rise and causes a negative pressure drop as desired. The transmitter saturated at -.7 psi during HS-202. (The transmitter was later recalibrated.) Likewise, the higher GBF pressure vented up the upper seal leg and saturated this transmitter at 5 psi positive. These responses were normal during rising pressures and posed no problem except for the operator who had to attend to any manual control change needed. The lift-pipe pressure drop was supposed to be zero at zero time as media circulation was shut off. This preserved the heat in the GBF. This transmitter was not accurately calibrated and the zero was off slightly to the negative. Just after zero time, media circulation was started in preparation for coal feed. Then media circulation became erratic as it responded to changing pressure and, likely, operator response.

Between 8 and 20 minutes, the PFBC bed pressure rose in response to intensified efforts to clear the coal feed line plug with compressed air. At 20 minutes the NYU technician abruptly closed valve "A". Flow reversed through the GBF as can be seen by the negative pressure drop across the GBF. We do not know how negative the pressure drop was at that time as pressures were changing very fast and data was only being recorded once every 1 1/2 minutes. Furthermore, the GBF DP transmitter saturated at -.7 psi. It was during this reversal of flow or the next one at 26 minutes, or both, that media was transported from the filter into the inlet ducting and primary cyclone. During the second reversal of GBF flow, gauge pressures recorded at the on-off nozzle and PFBC bed indicated a 5.6 psi reversal of pressure as indicated by the dashed line on the GBF pressure drop curve. This may not have been the maximum pressure reversal but certainly indicates back flow through a significant resistance such as the GBF inlet duct full of media. The PFBC bed pressure dropped rapidly at the first reversal of gas through the GBF. At the slight recovery GBF pressure drop saturated at 5 psi positive. This is an indication that the GBF inlet duct was plugged with media.

By 27 minutes after zero, enough media was transported out of the GBF to empty the media out of the upper seal leg and this pressure drop diminished to zero. With no media in the upper seal leg the lift-pipe pressure drop and the lower seal-leg pressure drop becomes equal. Notice how these two plots coincide after 27 minutes. To fully understand why lift-pipe pressure drop and lower seal leg pressure drop becomes equal refer to the P&ID, Section II, Figure 2-5. Upper seal-leg pressure drop (GBF-to-Media reservoir) plus lower seal-leg pressure drop equals lift-pipe pressure drop. When the upper seal-leg pressure drop becomes zero the other two pressure drops mathematically becomes equal. This can be seen physically because when the upper seal leg is empty, transmitters for the lower seal-leg and lift-pipe pressure drops become tubed to zones of essentially equal pressures.

The final PFBC bed pressure rise at 30 minutes may have been caused by closing the bypass valve, because at this time the pressure drop between the PFBC and on-off nozzle jumped to about 90 psi presumably because the inlet ducting to the GBF was full of media (see Figure IIB-3). It was at this moment that the bellows on the inlet flexible seal was damaged due to overpressure. On disassembly, the bellows portion of the inlet flexible seal had increased in length by 3-4 inches and the longitudinal centerline had assumed the shape of one-half a sine wave. It was a 14" bellows, 15" long, with the centerline distorted about 3" from normal. Pathway Bellows, the manufacturer, calls this type of distortion a failure by "squirm". It was most likely caused by overpressure since the bellows had a design rating of 50 psi, could distort as described at 60-70 psi and actually experienced a 90 psi pressure drop.

IIB.2.3 Conclusion, HS-202

Since it was discovered that depressurization (over 15 psi/minute) of the test module through the bypass valve with the on-off valve closed could generate enough back flow to transport filter media into the inlet ducting, operating procedures were changed. Subsequent startups of the PFBC were accomplished with the on-off valve open. This not only solved the media backflow problem, but also demonstrates the ability of the GBF to handle the products of poor combustion during the startup phase.

Although shakedown testing revealed some operational and equipment problems, the outlook was positive. Circulation was steady at steady pressure and all other aspects of the circulation system proved operational.

IIB.3 Performance Test HG-201

Operation commenced on November 3, 1987. The objectives were:

- Establish steady state GBF operation at 9-10 atm. (115-130 psig, and 1550-1600°F).
- Maintain continuous PFBC operation with coal-flue gas through the filter (GBF) at 50% minimum fluidizing velocity of the media.
- Establish three levels of media circulation, 60, 45, 30 lb/min and operate 10-20 hours at each level.
- Measure gas, particulate and alkali contents at the GBF inlet and outlet.

IIB.3.1 Test Summary, HG-201

Preheat was started in the afternoon of November 3, 1987. Coal flow was introduced at 1:15 a.m. on November 4. At 2:45 a.m., while unblocking the primary cyclone discharge, media was bubbled out of the filter element to the surrounding containment pressure vessel. Efforts to recover from this upset were unsuccessful and shutdown eventually resulted at 1:00 p.m. on November 4.

IIB.3.2 Results, HG-201

Transition to coal firing and attempts to establish steady-state operation are shown on Figure IIB-4. Data is recorded from a zero time of 1:00 a.m. on November 4, 1987 about 15 minutes before initiation of coal combustion.

For the initial 30 minutes of operation from zero time displayed on Figure IIB-4, pressure was rising at a rate averaging 1.4 psi/minute to 85 psig. Seal-leg pressure drop (both upper and lower) were within the range of the transmitters and controllable; although, the CPC operator was not trying to maintain a pressure balance represented by a -1 psi across the lower seal leg.

After the first 60 minutes of operation from zero time, it was clear that a problem with GBF pressure drop was materializing as pressure drop had exceeded 1-1/2 psi. At about 90 minutes into this operation, NYU admitted to having a problem with a plugged cyclone ash outlet which undoubtedly resulted in a high ash loading to the filter. To unplug the cyclone ash outlet, NYU operators began releasing large puffs of compressed air (up to 200 psig) into the cyclone from just below the cyclone ash outlet. This stirred up considerable amounts of ash which entered the filter all at once which temporarily overloaded and plugged the flue gas-to-media interface. Pressure upstream of the filter rose and blew out the

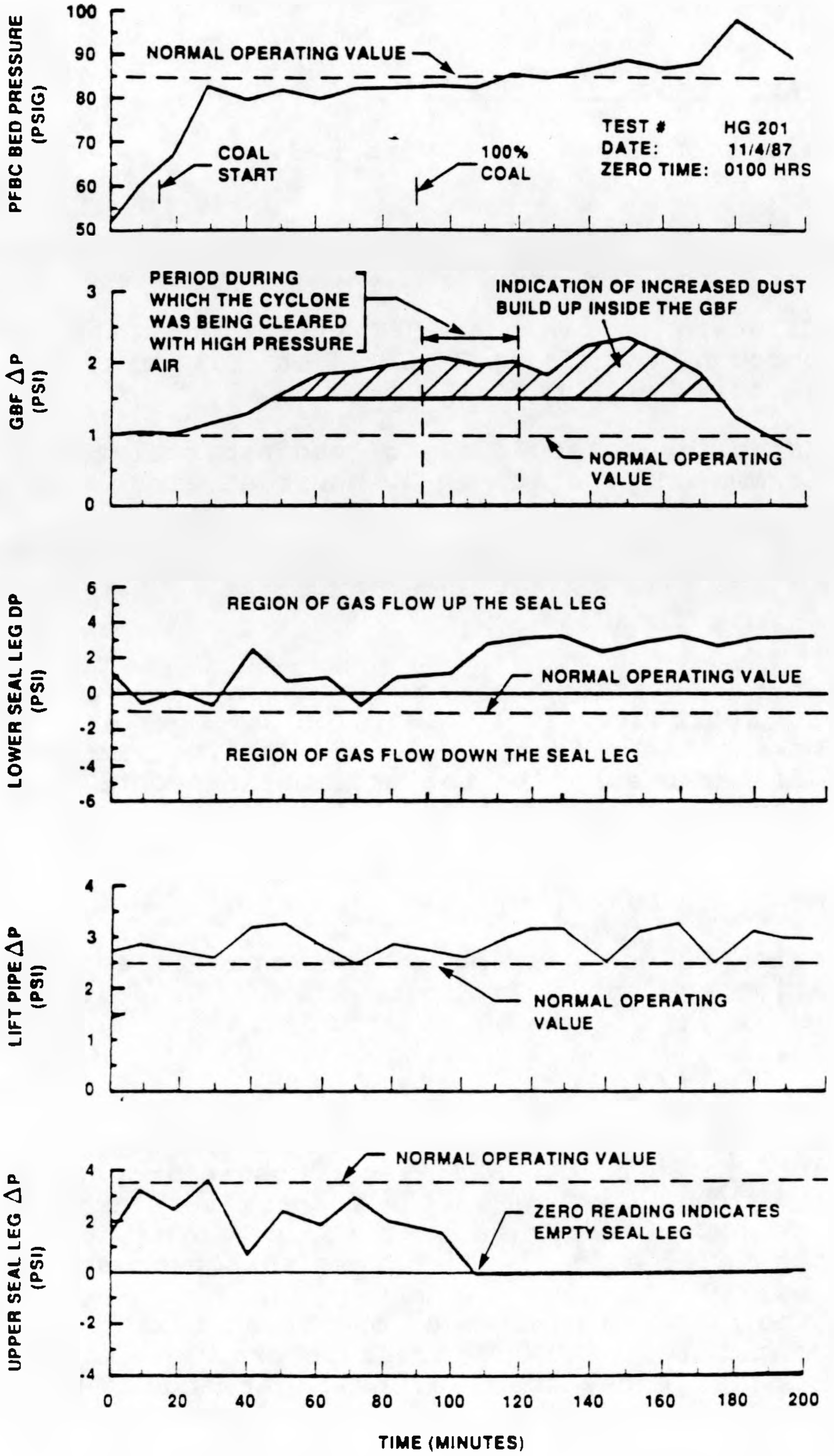


Figure IIB-4. GBF Performance Curves for HG-201 Starting From 1 AM on 11/04/87 plug removing media at the same time. There is uncertainty over how long the media remained bubbling out of the filter element but the GBF pressure drop data remained above 1 1/2 psi for about 40 minutes after the first effort to unplug the primary cyclone. Between 90 and 105 minutes from zero time, the upper seal leg pressure drop diminished to zero and remained. By then enough media had bubbled out of the filter element to empty the upper seal leg to break the seal.

The problem with bubbling media was addressed by extending the filter element sides upward to catch any fluidized particles. Access to the media follower was improved as this device can indicate, by a drop in media level, if media bubbling occurred. NYU also made changes to the cyclone and to the operating procedure to decrease the risk of cyclone pluggage.

At this time, it was not known if the media bubbling problem was caused solely by high and erratic ash loading or if gas flow also entered into the problem. Since there were considerable improvements that could be made to the primary cyclone ash system and a higher filter media circulation rate could be employed it was decided that another try at this capacity was warranted.

Measured circulation of media should be close to theoretical circulation as indicated by lift-pipe pressure drop. During this test it was observed that the measured circulation rate was getting progressively less than the theoretical expectation. As was the case during life-critical component testing, lift-pipe wear was suspected. A simple device was built to probe the lift pipe for wear. The data gathered was conclusive enough to justify disassembly for a closer check. One 5' section of lift pipe (3rd from the top) was found to be worn to about 4" ID from 2" with the appearance reminiscent of the badly worn segment from life-critical component testing. This was one of the two original sections that was stored pending NYU operations. The other stored section was also badly worn and three others were marginally worn. Two 5' lift-pipe sections lined with silicon carbide sleeves were on site for spares. The three marginally worn sections were repaired by removing the refractory and relining the pipe spools with 2" stainless steel pipe and medium density (60 lb/ft^3) insulating refractory. See Figure IIB-5 for final arrangement of lift-pipe segments. The two lift-pipe sections that were relined after the life-critical component tests using the original materials and methods were in very good shape. It is clear that improper mixing, installation, and/or cure of the refractory resulted in soft localized zones of abrasion resistant lining.

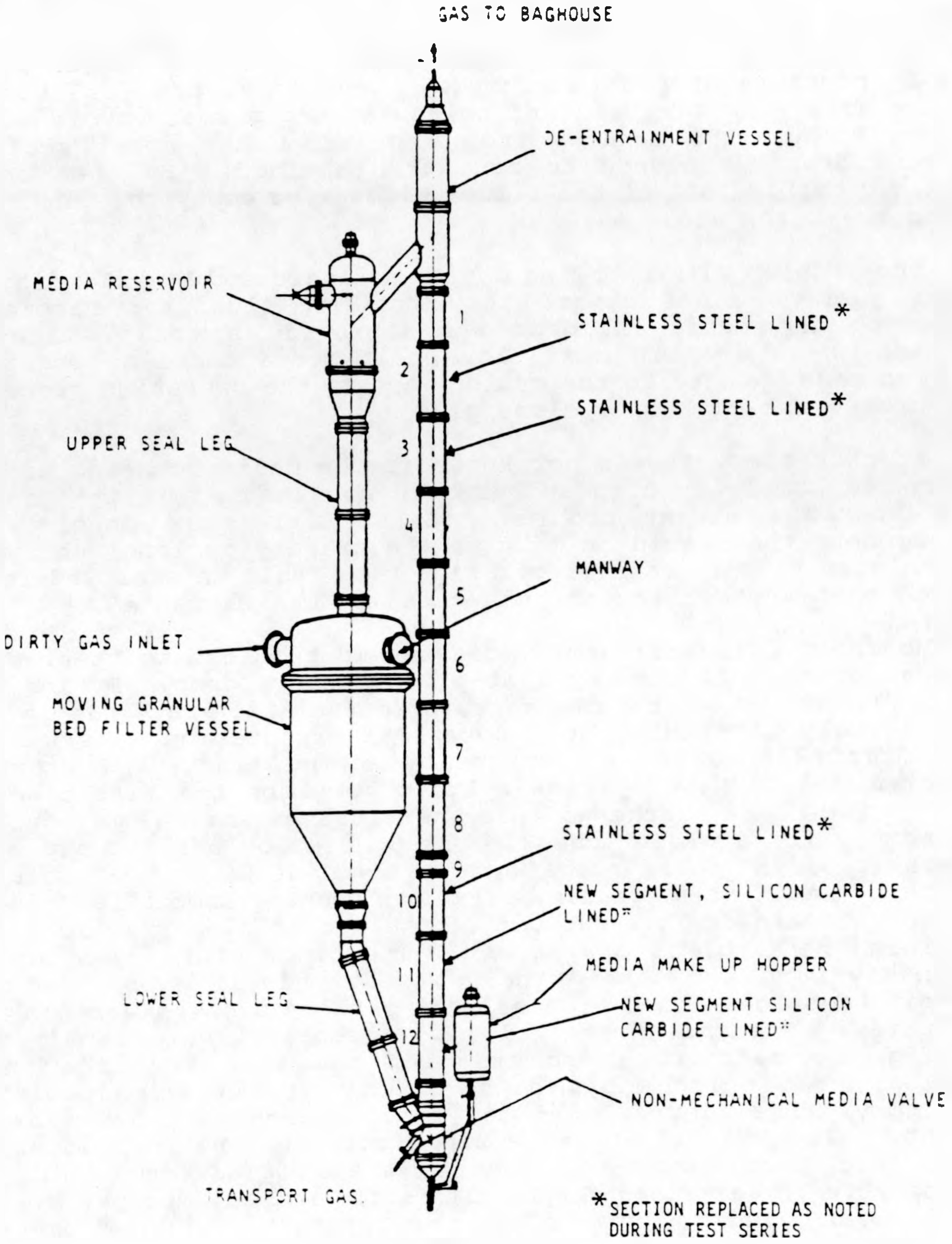


Figure IIB-5. Schematic of GBF Showing Refractory-Line Equipment

There were additional changes made after this test to increase equipment reliability and to make data gathering more comfortable during the winter months. Below is a list of alterations:

- Extend the filter element sides upward to contain media if it bubbles.
- Fix the filter inlet flexible seal.
- Re-line three lift-pipe sections with stainless steel. Install these three plus two others previously lined with silicon carbide.
- Increase heating capability for baghouse heat tracing.
- Build an enclosure in the Combustion Power operator area at base of structure for cold weather operation.
- Add grating around media reservoir for access to media follower.
- Replace gauges for coalescing filter pressure drop and boost blower pressure rise. Use gauges with higher scales.

IIB.3.3 Conclusions, HG-201

While this report dwells on problems, there were some very positive results from the testing attempted to date. There were no problems with the filter or media circulation system during the condensation phase of startup. With a relatively constant pressure, the filter ran with little or no operator intervention. The filter had undergone very high pressure fluctuations, near 10 psi/minute, and returned to equilibrium without incident. Only major upsets with specific circumstances have disturbed filter operations severely enough to cause shutdown. Nevertheless, because of the problems with the filter the PFBC equipment, some equipment modifications were necessary.

IIB.4 Shakedown Test HS-203

Operation occurred during February 17-19, 1988. The objectives were:

- Preheat the GBF using the kerosene combustor.
- Establish coal combustion in the PFBC at pressure (115-130 psig) and temperature (1600-1650F). GBF inlet temperature estimated at 1550-1600°F.
- Complete trial measurements of gas, particulate and alkali contents at the GBF inlet and outlet.

IIB.4.1 Test Summary, HS-203

Light off of the kerosene burner No. 2 was at 1930 on February 18, 1988. Heatup was uneventful for the granular bed filter; although the kerosene combustor shutdown a few times due to loss of flame. At 0615 the following morning, there was a brief, planned shutdown to change the coalescing filter. Coal was started at 0850. Gas flow to the GBF was increased to exceed 13,500 lb/hr; pressure was brought to 100 psig, and inlet temperature to 1550F. Coal firing was for 4 1/2 hours. Particulate and alkali concentrations were measured with promising results. Shutdown was a few hours premature because of NYU problems with their cyclone ash discharge system.

IIB.4.2 Results, HS-203

The single particulate sample yielded 1500 ppmw into the GBF and 60 ppmw out. While performance in the 30-40 ppmw range had been anticipated, we felt that these results were promising. Alkali measurement yielded very good results; although at the time of the sample there was a 300F temperature drop across the filter because of the heatup mode. Some alkali removal could have been from condensation due to the GBF outlet temperature of 1300F. Potassium was measured at 25.6 ppmw in and 0.10 ppmw out; sodium at 2.02 ppmw in and 0.04 ppmw out. After 4 1/2 hours of coal combustion, the GBF outlet temperature rose to within 107F of the inlet temperature (1445F out; 1552F in).

Post-test inspection revealed that the filter media had bubbled. Bubbling is a local or general fluidization of the filter media that is not well understood. Because bubbled media could be found well distributed on horizontal surfaces above and around the entire filter perifery, it is though that the entire filter bubbled at once. Alternately, bubbles may occur randomly around the entire periphery for a short duration. Media was propelled at least 5' upward during this condition based on the areas media was found on post-test inspection. Bubbling is caused by three conditions, separate or in combination. These conditions are: too high gas flow, too high ash concentration, or a PFBC upset. The most difficult PFBC upset for the GBF to endure is a sudden and sustained pressure rise. During this time the gas flow due to the rising pressure is added to the steady-state gas flow. The unsteady pressure may also deteriorate primary cyclone efficiency or dislodge ash pockets upstream of the GBF. During this shakedown there was one instance of the pressure changing at a rate greater than 10 psi/minute.

There were two other instances when the filter may have bubbled. When the media is fluidized, the pressure drop across the filter bed is 2 to 2-1/4 psi based on calculation. At one time, (2/9/88 at 1242) the filter pressure drop rose to 1.9 psi (1.25-

1.50 psi normally) at a gas flow at 51% minimum fluidization. According to measurements made during the GBF development phase (Guillory, 1983), the velocity profile across the filter is not even. Local areas exceeded the average velocity and may have fluidized. During another time (2/9/88 at 1319) the filter pressure drop rose to 2.1 psi at a gas flow equivalent to 44% minimum fluidization. The higher pressure drop at a lower relative gas flow than in the previous instance is thought to be due to higher ash flows entering the filter.

IIB.4.3 Conclusions, HS-203

During operation, the filter behavior was very good. The single particulate sample served to demonstrate the sampling system's operation as well as the GBF ability to remove ash. Likewise, the ability of the NYU equipment to measure alkalis was confirmed; although the results were not useful due to the high temperature drop across the filter.

The post-test discovery that the filter had bubbled was very disturbing. Reducing the gas flow to the filter was considered as an alternative. After learning that incorporating this change would delay the next test, Combustion Power management recommended re-running the same gas flow but circulating the media at a higher rate. This would move the ash out of the filter faster.

Had the NYU opacity meter been operational, bubbling of the filter media could have been detected as it occurred. Bubbling allows ash to pass through the filter. One would expect this to be indicated by an opacity spike.

IIB.5 Performance Test HG-202

Operation on this second performance test occurred during March 1-3, 1988. The objectives were:

- Establish steady state GBF operation at 9-10 atm. (115-130 psig), and 1550-1600°F.
- Maintain continuous PFBC operation with coal-flue gas through the filter (GBF).
- Establish three levels of media circulation, 60, 45, 30 lb/min and operate 10-20 hours at each level.
- Measure gas, particulate and alkali contents at the GBF inlet and outlet.

IIB.5.1 Test Summary, HG-202

Preheat began just before midnight on March 1, 1988. At 0800 hrs. there was a brief, planned shutdown to change the coalescing filter. Coal firing started by 1020 hrs. During the first few hours of testing, NYU had problems with their equipment. One compressor stopped at 1040 hrs. At 1110 hrs. the primary cyclone plugged. During the afternoon there were repeated problems that caused pressure to change suddenly. High levels of carbon monoxide (CO) also indicated combustion problems. Sometimes the CO was above 2000 ppm for extended periods (50 minutes between 1200 and 1400 hours). At about 1530 hrs. when the pressure was raised from 60 psig to 80 psig, and gas flow exceeded 10,000 lb/hr, bridging occurred in the upper seal leg (GBF-to-media reservoir). Problems with the PFBC and GBF finally led to shutdown at 1930 hrs.

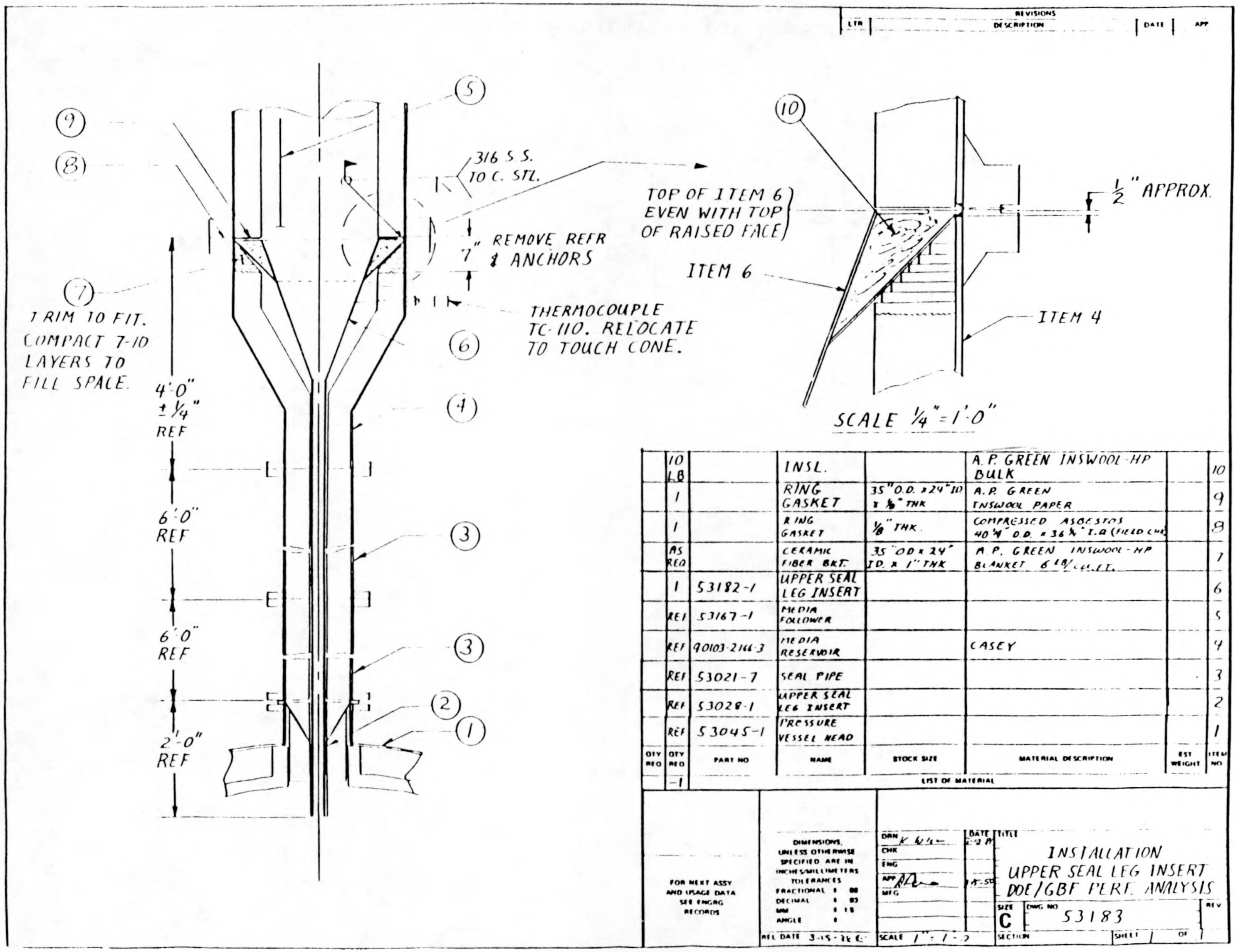
The PFBC and filter were reheated for another test start at 0600 hrs. on March 3rd. Again the GBF could not be operated within desired parameters. Furthermore, there were continued problems with PFBC operation (high CO and rapid pressure changes). By 1145 hrs. media circulation problems brought an end to the test.

IIB.5.2 Results, HG-202

Although there were numerous filter problems during this test, one accomplishment should be noted. Media circulation was measured at 100 lb/min at a lift-pipe pressure drop of 3.7 psi. This high level of circulation indicated that efforts to repair the lift pipe were successful. This, however, was the only highlight as the filter endured numerous problems during the test. These problems are discussed below.

- Refractory Wear - A post-test inspection with a fiberscope indicated significant, localized refractory erosion in the seal leg between the media reservoir and the GBF. In the 15' length of 3" ID seal leg, three local areas had worn to approximately 6" diameter. It was as if someone had chipped refractory away to form donut-shaped areas of missing refractory. These are prime locations for bridging to take place. This was another example of the refractory wear problem that plagued the lift pipe in earlier testing at Combustion Power and NYU. It is clear that improper mixing, installation, and/or cure of the refractory resulted in soft zones of abrasion resistant lining. A metal sleeve was fabricated and installed to cover the worn surface. See Figures IIB-6 and IIB-7.

- Media Bridging - This occurred in the upper seal leg (GBF to media reservoir). Localized refractory wear provided areas that could start a media bridge. A rapid pressure rise often preceded a bridge. To cause a bridge to collapse, the pressure drop across the bridge was removed by turning off media circulation and the boost blower.



QTY REQ	QTY REQ	PART NO	NAME	STOCK SIZE	MATERIAL DESCRIPTION	EST WEIGHT	ITEM NO
	10 LB		INSL.		A. P. GREEN INSWOOL-HP BULK		10
	1		RING GASKET	35" O.D. × 24" ID × 1/8" THK	A. P. GREEN INSWOOL PAPER		9
	1		RING GASKET	1/8" THK.	COMPRESSED ASBESTOS 40 1/4" O.D. × 36 3/4" I.D. (FIELD CHK)		8
	AS REQ		CERAMIC FIBER BKT.	35" OD × 24" ID × 1" THK	A. P. GREEN INSWOOL-HP BLANKET 6 LB/CU.FT.		7
	1	53182-1	UPPER SEAL LEG INSERT				6
	REF	53167-1	MEDIA FOLLOWER				5
	REF	90103-2166-3	MEDIA RESERVOIR		CASEY		4
	REF	53021-7	SEAL PIPE				3
	REF	53028-1	UPPER SEAL LEG INSERT				2
	REF	53045-1	PRESSURE VESSEL HEAD				1
	-1	LIST OF MATERIAL					

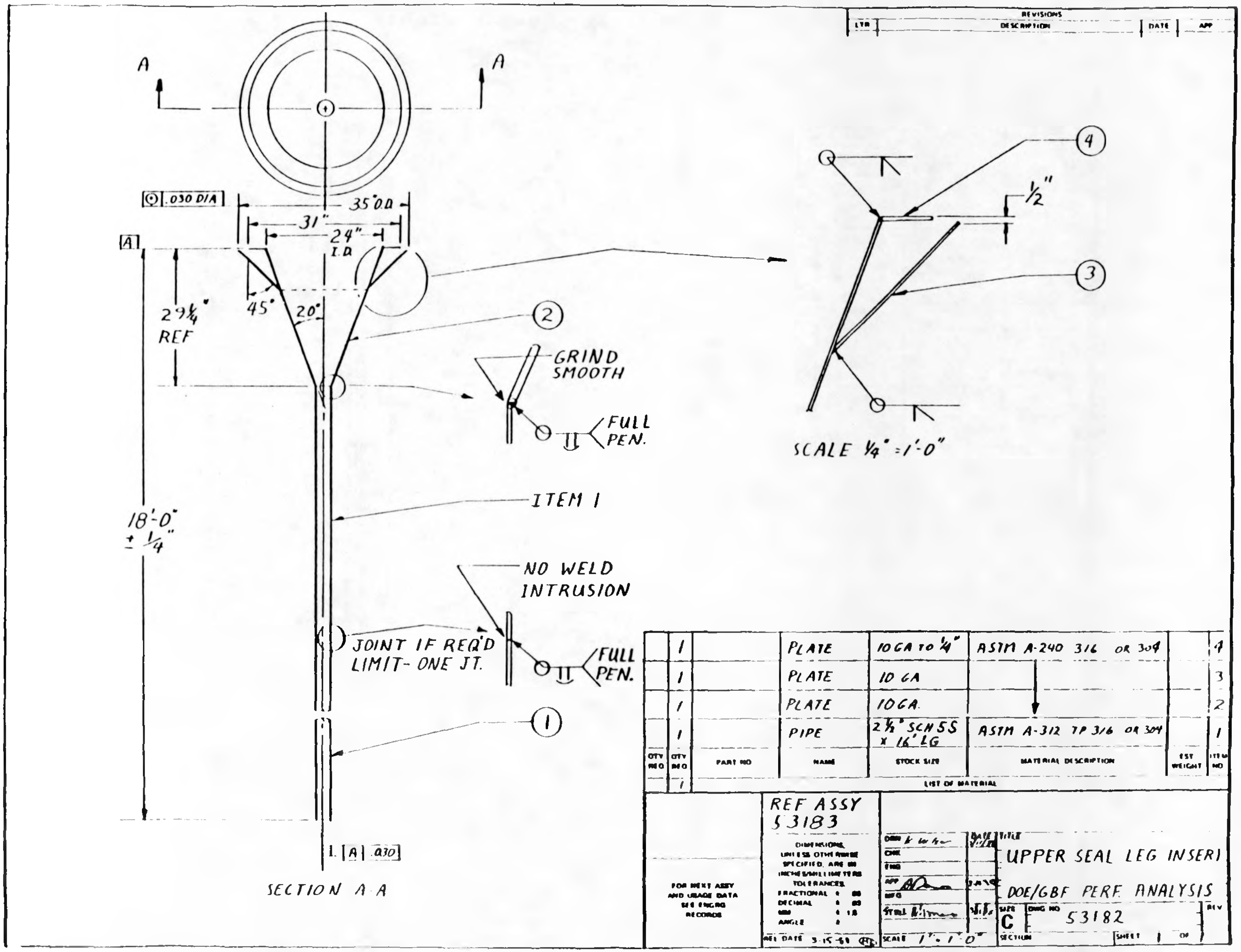
FOR NEXT ASSY AND USAGE DATA SEE ENGRG RECORDS

DIMENSIONS, UNLESS OTHERWISE SPECIFIED ARE IN INCHES/MILLIMETERS
TOLERANCES
FRACTIONAL ± .00
DECIMAL ± .03
MM ± 1.5
ANGLE ±
REL DATE 3-15-76

DRN K W
CHK
ENG
APP
MFG
SCALE 1" = 1'-2
DATE

TITLE
INSTALLATION
UPPER SEAL LEG INSERT
DOE/GBF PERF. ANALYSIS
SIZE C
DWG NO 53183
REV
SECTION
SHEET 1 OF 1

Figure IIB-6. Metal Sleeve Installation in Upper Seal Leg



QTY REQ	QTY REQ	PART NO	NAME	STOCK SIZE	MATERIAL DESCRIPTION	EST WEIGHT	ITEM NO
	1		PLATE	10 GA TO ¼"	ASTM A-240 316 OR 304		4
	1		PLATE	10 GA	↓		3
	1		PLATE	10 GA.	↓		2
	1		PIPE	2½" SCH 5S x 16' LG	ASTM A-312 TP 316 OR 304		1

Figure IIB-7. Metal Sleeve Detail for Upper Seal Leg

- Loss of Circulation - One reason circulation could be stopped is due to exceeding the media transport capacity of the lift pipe. Media can enter the lift pipe so fast it chokes off the lift-air supply; thus, it is called "choking". Operator error is the typical cause. Also a rapid pressure rise will push more media into the lift pipe because the leakage gas needed to balance the pressure serves to inject media. If media circulation is near the capacity of the lift pipe when a sudden pressure rise is experienced, quick reactions are needed to prevent choking as control is by hand valve. Automatic controls would ease this problem.

  Media that is choking the lift pipe can usually be cleared with transport air. Boost blower flow and pressure is increased slowly over 1-5 minutes until the media is cleared. Lift-pipe pressure drop may increase to 15 psi during this time (from 2-3 psi normally). An interlock shuts the boost blower off at a pressure differential of 20 psi.

  Other causes of circulation loss are: 1) broken refractory fouling the media valve and 2) media agglomerates plugging the seal leg. This situation will result in shutdown but can be avoided with proper design and operation.

- Rapid Pressure Changes - Induced by the NYU-PFBC for many reasons, pressure changes are divided into two categories. Those that cause changes greater than 4 psi/minute occurred quite often during this test (11 times) and those that cause pressure changes greater than 10 psi/minute which occurred twice. The greater the rate of pressure change, the more severe the upset and the higher potential for filter problems.

  Pressure in the circulation system changes with the GBF pressure. Gases leak through the upper and lower seal legs to bring equilibrium. When pressure is steady for a few minutes, equilibrium is approached and circulation system operation is steady. Pressure changes up to 2 psi/minute could be absorbed easily at NYU.

  A pressure rise is potentially most harmful. This causes gas to flow down the lower seal leg (GBF to media valve) and will increase the circulation rate 10-30% for pressure changes greater than 4 psi/minute. A diligent operator can cope with the change by adjusting the hand valve for media injector air. During a pressure rise, the pressure drop across the upper seal leg increases as gas flows upward. With the badly worn refractory and enough leakage velocity to retard media, bridging was initiated. As discussed above, these bridges could be broken. It was also observed that a rapidly rising pressure could increase filter pressure drop. This could be from an increase in ash loading as pockets of ash were stirred loosed from the primary cyclone and ducting. Alternately, the primary cyclone efficiency could be degraded. Additionally, the unsteady-state gas flow due to rising pressure is added to the steady-state gas flow creating a high instantaneous gas flow. To cope with rapid pressure rises, piping and valves were added after this test to connect the GBF outlet to the circulation system baghouse outlet. When a rising pressure increases the pressure drop across the upper seal leg beyond about 4 psi, the operator opened the solenoid operated ball valve connecting the GBF pressure vessel to the baghouse outlet. This allowed pressure equalizing gases to bypass the seal-legs and quickly restore the proper pressure profile. This could be automated with a pressure switch, but due to the tight schedule, materials on hand were used.

Rapid pressure drops were relatively easy to tolerate. The only concern is that the circulation can be slowed 10-30% due to pressure drop greater than 4 psi/minute. If circulation is turned off for more than 1 or 2 minutes the GBF pressure drop starts to rise. As long as the on-off valve is open there is no danger of media backflow as occurred during an earlier test with the on-off valve closed.

The biggest nuisance is that the seal-leg gauges could be pegged during pressure changes. If the incidence was severe enough, the accuracy of the gauge could deteriorate. The gauge on the lower seal leg was most sensitive to rapid pressure drop. Transmitters in parallel with the gauges did not seem to be affected. To cope with rapid pressure drops, the system bleed valve, used for artificial balancing, was opened to re-establish the proper pressure profile.

- Bubbling (fluidization) of Filter Media - This was caused by too high a gas flow or too high an ash concentration coupled with PFBC upsets. Most deleterious PFBC upsets are those that rapidly increase pressure or ash flow. It's possible that bubbling would not have occurred if it were not for PFBC upsets. Bubbling decreases the ash collection capability of the filter. It could be detected by an opacity meter.

IIB.5.3 Conclusions, HG-202

This test brought into perspective the combined effects of gas throughout at 50% minimum fluidization, rapid pressure changes, and uncertainty in ash rates. As a result of GBF response during tests up to this point, it was decided to lower the gas flow to the GBF substantially to observe response. This could be done by dividing gas flow between the filter and the bypass. For the next test, gas flow to the GBF was decreased to 25% minimum fluidization velocity.

IIB.6 Performance Test HG-203

Operation on this third performance test occurred during April 12-15, 1988. The objectives were:

- Establish steady-state GBF operation at 8-10 atm. (100-130 psig), and 1550-1600°F.
- Maintain continuous PFBC operation with coal-flue gas through the filter (GBF) at a flow rate of 25% minimum fluidizing velocity of the media.
- Establish three levels of media circulation, 60, 45, 30 lb/min and operate 10-20 hours at each level.
- Measure gas, particulate and alkali contents at the GBF inlet and outlet.

IIB.6.1 Test Summary, HG-203

This "50-hour" test was considered a success with 42.5 hours of coal combustion completed. NYU reported during the test having difficulty getting consistent particulate sampling results, and this is indicated by the reported range of 27 to 6355 PPMW. Such high loadings as were measured during this test prompted efforts in later tests towards verification of measurements by collection of multiple grab samples at equilibrium conditions, and comparison of these values with impactor samples and total catch at the GBF baghouse.

During this test, one-half of the PFBC gas flow was bypassed from the filter. Filter gas flow averaged about 25% minimum fluidization of the media.

Preheat started at 0815 hrs. on 4/12/88. Throughout the night, there was difficulty with the preheat combustor such that heat-up did not get underway until 0600 hrs. on 4/13/88. To minimize the preheat time, the GBF bypass was closed so all preheat gases were routed through the filter. This resulted in preheat at a higher pressure than usual (80-90 psig instead of 40-50 psig), but otherwise a normal preheat.

By 1800 hrs. on 4/13/88 with preheat completed, a planned shutdown occurred to change the coalescing filter. By 1900 hrs, the plant was back in operation with heatup of the PFBC initiated. Coal burning started at about 2245 hrs. Gas flow to the GBF ranged between 5500 to 6500 lb/hr at 70-90 psig and 1500F-1600F. Higher pressure operation was not achieved because equilibrium conditions and repeatable particle sampling would not be reached in time for any meaningful tests at higher pressure.

Three major pressure upsets occurred due to loss of electrical power. However, the GBF operation recovered with no significant detrimental effects. Operation with an approximately 50/50 split mass flow through the GBF and the bypass ducting worked well.

During the early morning of 4/15/88 ash plugged up the discharge system under the GBF baghouse but the pluggage was dislodged without shutdown.

Shutdown occurred as planned at 1540 hrs. on Friday afternoon 4/15/88.

IIB.6.2 Results, HG-203

Particulate sampling results are reported in the following section on performance results with qualifications as to the validity of this data. Steady-state operation during the test was not achieved due to the upsets caused by repeated power failures.

Loss of electrical power caused a rapid loss of pressure in the PFBC and GBF. Because of the PFBC system design, once power was restored there was rapid recovery in pressure. The reasons for this situation are: 1) loss of power shuts the fluidizing air supply valve, 2) the sonic orifices that create back pressure do not close on power failure, 3) the diesel driven compressors are unaffected by power failure and 4) when power is restored, the main fluidizing air valve rapidly returns to its last open position. Information on the response to the GBF due to these pressure dips was recorded at one minute intervals. A summary follows.

- Power Failure 4/13/88 @ ~2300:

  Figure IIB-8 shows traces of GBF parameters starting at 2200 hrs. or about 1 hour before power failure. Graphs during this first hour indicate typical GBF operation under steady conditions. Values are normal except for the lower seal leg pressure drop which was usually -.3 to -.7 psi. At 63 minutes past zero time, power was interrupted. The filterpressure dropped from 75 psig to 35 psig at an instantaneous rate that exceeded 32.5 psi/minute and then recovered at an instantaneous rate that exceeded 27.9 psi/minute. The data plotted was digitally recorded data at 1 minute intervals.

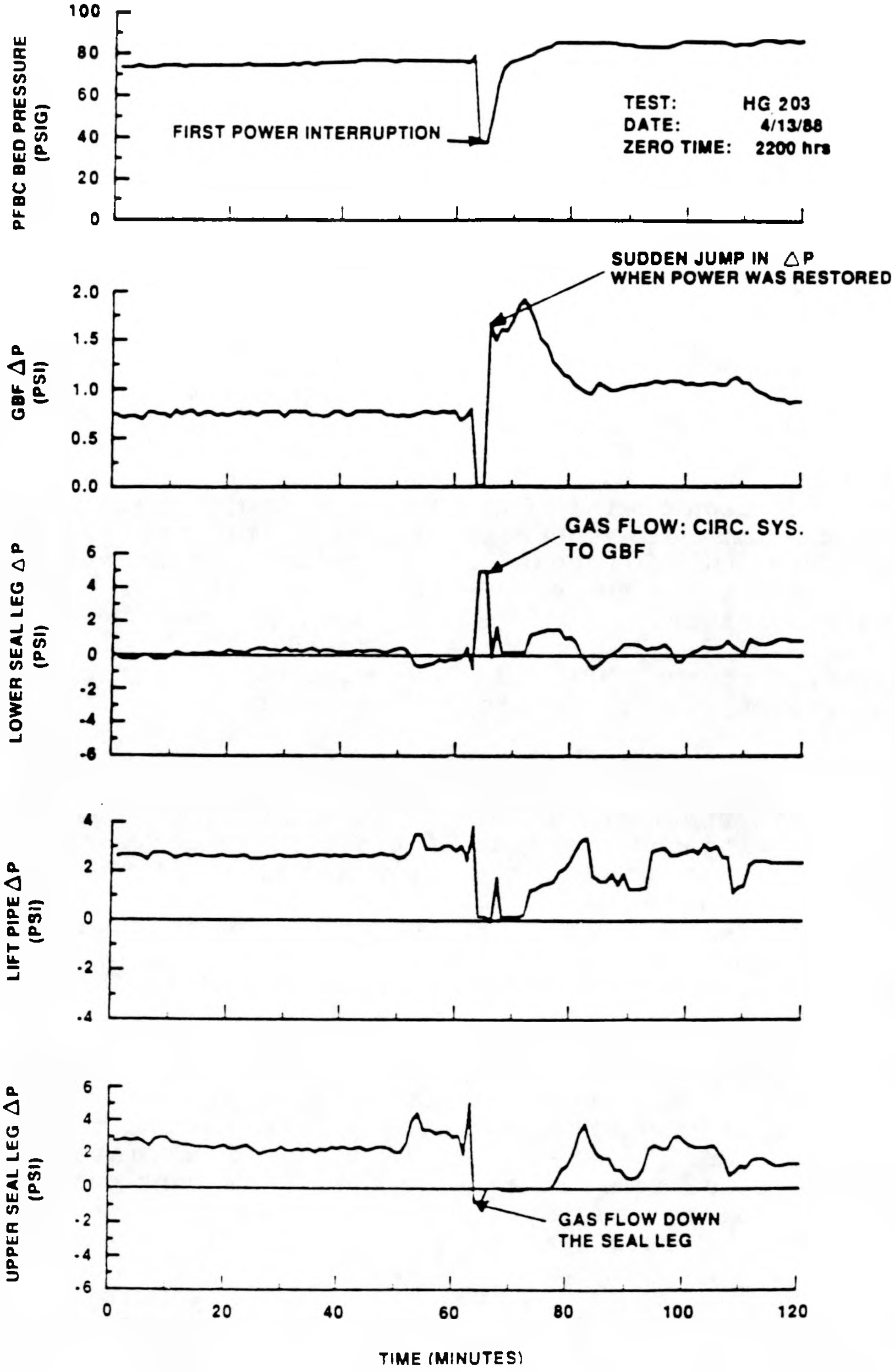


Figure IIB-8. GBF Performance Curves for HG-203 Showing System Response to the First Electrical Power Interruption

On pressure recovery the filter pressure drop rose to 1.7 psi initially and then peaked out at 1.9 psi after seven minutes. The trace for lift-pipe pressure drop shows that media circulation stopped at loss of pressure and then remained stopped for several minutes thereafter except for a brief spike. The initial stoppage of media circulation was due to the rapid pressure loss. Thereafter it was due to operator intervention. Because the upper seal-leg pressure drop remained at zero after media circulation was restored at 68 minutes and at 73 minutes after zero hour, it is suspected that the upper seal leg bridged at the top. Another explanation is that the filter media bubbled on pressure recovery at 1.7 psi GBF pressure drop and the upset in media configuration drained the upper seal leg. In either case, the GBF pressure rise between 66 and 73 minutes was due to no media circulation because of operator intervention. When circulation was restored at 73 minutes the GBF pressure drop started returning to normal. At 80 minutes the seal in the upper seal leg began to be restored. The remainder of the trace, between 80 and 120 minutes, indicates operator uncertainty as to the proper parameters.

- Power Failure 4/14/88 @ 0200:

This upset occurred only about 3 hours after the first upset giving the operator little time to contemplate lessons from the first occurrence. Between zero hour at 0130 hours on 4/14/88 to the power failure at 16 minutes after zero hour, all traces show normal GBF operation as shown on Figure IIB-9. A slight dip in PFBC pressure at 8 minutes after zero hour caused the expected response in lower seal-leg pressure drop, lift pipe and upper seal-leg pressure drop. During the pressure dip caused by power loss at 18 minutes, responses were amplified as pressure fell from 84 psig to 50 psig in 1-2 minutes, then recovered to 80 psig in 3-4 minutes. The pressure drop was at least 32.3 psi/minute and recover was at least 15.1 psi/minute. The operator did not intervene on the control of circulation rate as the lights went out during this power failure. Media circulation dropped to zero on loss of pressure and recovered to only about 1/2 psi past set point (at 3 psi) on recovery. This is acceptable. Filter pressure drop was recorded at .40 psi minimum on pressure loss and 3.46 psi maximum on recovery. As in the previous power failure bubbling of the filter bed probably occurred on recovery. The second sudden drop in PFBC bed pressure at 31 minutes isunexplained, but traces indicate that the pressure drop resulted in a subsequent rise that caused the GBF pressure drop to respond.

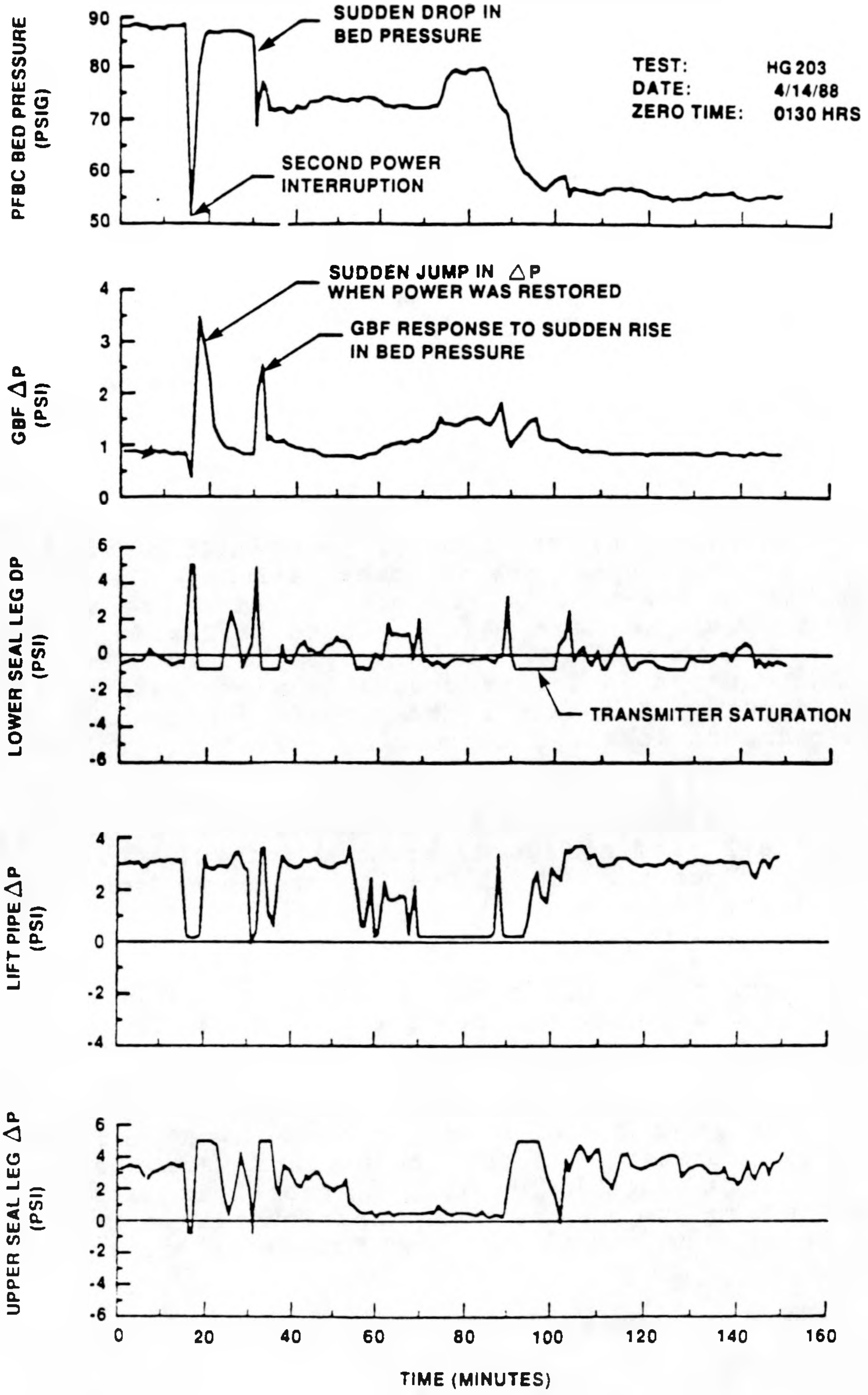


Figure IIB-9. GBF Performance Curves for HG-203 Showing System Response to the Second Electrical Power Interruption

Between 25 and 90 minutes there was difficulty with bridging at the upper seal leg. This seal was restored at 90 minutes after zero hour by the intentional drop in PFBC bed pressure from 80 to 55 psig. The bridge was broken because leakage gases flowed down the upper seal leg to effectively assist media movement. After review it was recognized that the pneumatic blaster at the baghouse could be utilized for the same purpose. (Bleeding high pressure gas into the circulation system reverses gas flow down the upper seal leg to blow out bridged media.)

- Power Failure 4/15/88 @ ~0640:

By this time, the operator was familiar with his response to a pressure upset due to power failure. The upset as shown on Figure IIB-10. At 41 minutes after zero hour, filter pressure dropped from 81.7 psig to 55.2 psig in 2-3 minutes at a maximum rate of at least 24 psi/minute. Recovery to 80.8 psig occurred in 2-3 minutes at maximum rate of at least 18 psi/minute. The filter pressure drop decreased to 0.05 psi on pressure loss and increased to 2.05 psi on recovery. As before, this probably caused bubbling in the filter bed duringpressure recovery, but no other detrimental effects. Also as in the other upsets, the filter recovered. In this case, all readings were normal within 10 minutes after the upset. Note that the lift-pipe pressure drop is plotted to a different scale, thus magnifying minor changes in circulation rate.

During the night of 4/15/88 the ash discharge system under the baghouse was being operated in the automatic mode. The operator was unaware that ash had bridged in one of the lockhoppers as the high ash level switches did not respond. To clear the ash discharge system, the knife gate valve isolating the baghouse hopper was closed and the two ball valves isolating the ash lockhoppers were opened. Ash was easily dislodged by probing. After this experience it was decided to run the ash discharge system in the manual mode which allowed the use of pneumatic blasters to dislodge ash buildups.

With this test it was becoming clear that the coalescing filter element was accumulating enough particulate to need changing after 1-2 days of operation. Some of the particulate was from minor ash leakage through the baghouse and some was corrosion debris from inside the carbon steel piping. To change the coalescing filter element required depressurizing and shutdown. To change this filter element while pressurized could be done two ways each requiring modifications. A three valve bypass could be installed around the filter or the filter could be simply isolated with valves. The latter was

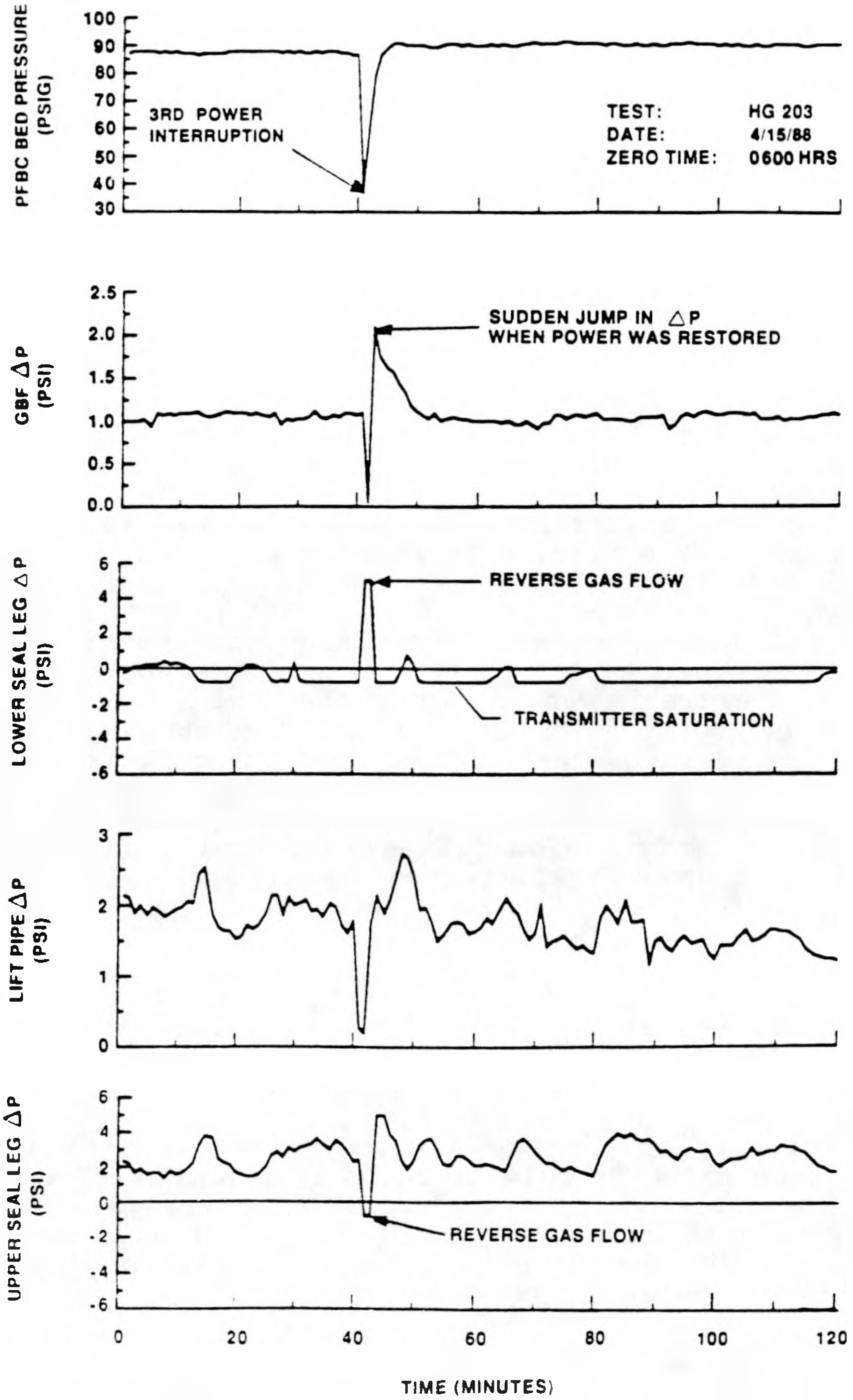


Figure IIB-10. GBF Performance Curves for HS-203 Showing System Response to the Third Electrical Power Interruption least expensive and easiest to install but would require a shutdown of circulation while the PFBC was in operation to change the coalescing filter element. A quick test was performed to determine how long the media circulation could be turned off during PFBC operation. Operation during this test is shown on Figure IIB-11. At 38 minutes after zero hour of 1400 hrs. on 4/15/88, circulation was stopped. The boost blower was also shut down to preserve heat in the circulation system. At 49 minutes, the test was repeated.

Without media flow, ash builds up in the GBF causing the pressure drop to rise. The results showed that the GBF pressure drop would rise from 1.0 psi to 1.4 psi in 6 to 7 minutes without media circulation. Once circulation was restored the filter pressure drop returned to 1 psi in about 2 minutes. The results depended heavily on how much ash was being generated by the PFBC during the test. Measurements showed the ash loading was about 2000 ppmw just prior to the test which appeared moderately high for the NYU combustor.

Therefore is was concluded that the GBF media circulation could be turned off for up to 7 minutes without filter problems. Since changing the coalescing filter element took about 3 minutes, the option for isolation valves was chosen for NYU. For a commercial plant the choice would be dual filters with isolation valves so circulation would not need to be shut down for filter maintenance.

IIB.6.3 Conclusions, HG-203

The "50-hour" test of April 12-15, 1988 was the first to show the potential of the granular bed filter. Forty-two and one-half hours of coal combustion were logged, and shutdown was voluntary late Friday afternoon. The filter was run at 85 psig, 1500-1600F inlet and about 6500 lb/hr gas flow. This corresponds to 25% of minimum fluidization for the filter media. Particulate sampling yielded a wide range of inlet loadings and an outlet loading of 3-30 ppmw. The outlet particulate emissions averaged .017 lb/million Btu which is much less than NSPS of 0.03 lb/million Btu. When combined with NYU's primary cyclone, the particulate collection efficiency well exceeded 99%.

IIB.7 Performance Test HG-204

Operation on this fourth performance test occurred during May 9-13, 1988. The objectives were:

- Steady state operation of the granular bed filter at 7-8 atm (88-102 psig) 1500-1550F for about 20 hours and 9-10 atm (115-130 psig) and 1550-1600 for about 60 hours.

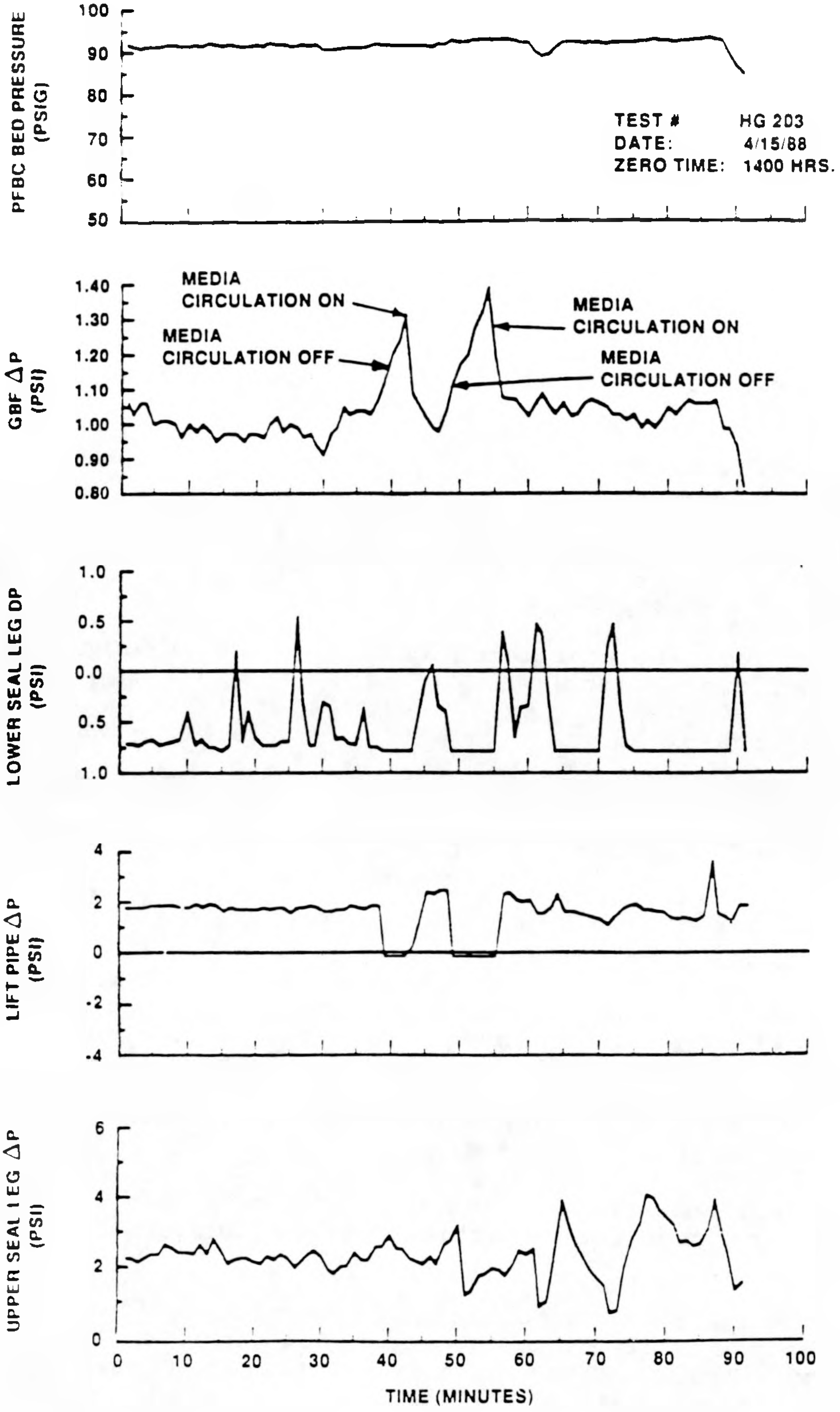


Figure IIB-11. GBF Performance Curves for HG-203 Showing the Effect of Turning Off Circulation

- Continuous operation for 80 hours under steady state on coal with both bypass and on-off valves open. In this configuration about 50% of the PFBC flue gas will flow through the GBF, or 7000 lb/hr.
- Measurement of gas, particulate and alkali contents at the inlet and outlet of the GBF.
- Circulate 2 mm media in the 20-40 lb/min range at a steady rate.

IIB.7.1 Test Summary, HG-204

Test No. HG-204 of the Combustion Power Company granular bed filter was started on May 9, 1988. Key events are as follows:

Initial kerosene combustion light-off: 8:25 pm - May 9, 1988

Restart kerosene combustor: 11:00 pm - May 9, 1988
(bad flame scanner)

Initial coal feed: 8:15 am - May 10, 1988

Termination of coal feed: 6:33 am - May 12, 1988

Restart of coal feed: 11:15 am - May 12, 1988

Final coal termination: 3:00 pm - May 13, 1988

Between 11:00 pm on May 10 and 3:00 am on May 12, the GBF operated without incident. The PFBC system had periodic trouble with loss of coal feed (three times) and plugging of the primary cyclone lockhopper. Ultimately, the primary cyclone had to be unplugged by puffing air up the ash outlet pipe from the lockhopper. This was accomplished without upset to the filter whereas in HG-201, at a higher gas flow, media bubbling resulted from this procedure.

This test was very successful with coal combustion for 74 hours and more consistent particulate sampling than in previous tests.

One blemish on this otherwise successful test was the single loss of media circulation. At about 0340 hrs. on May 12, media circulation stopped. Although it was restarted shortly thereafter, this was the beginning of problems that ultimately led to a brief shutdown at 0633 hrs. These events are shown on Figure IIB-12.

For the first 40 minutes from zero time at 0300 on Figure IIB-12, operation was normal. At 40 minutes after zero time, media circulation became erratic. Between 40 minutes and 120 minutes,

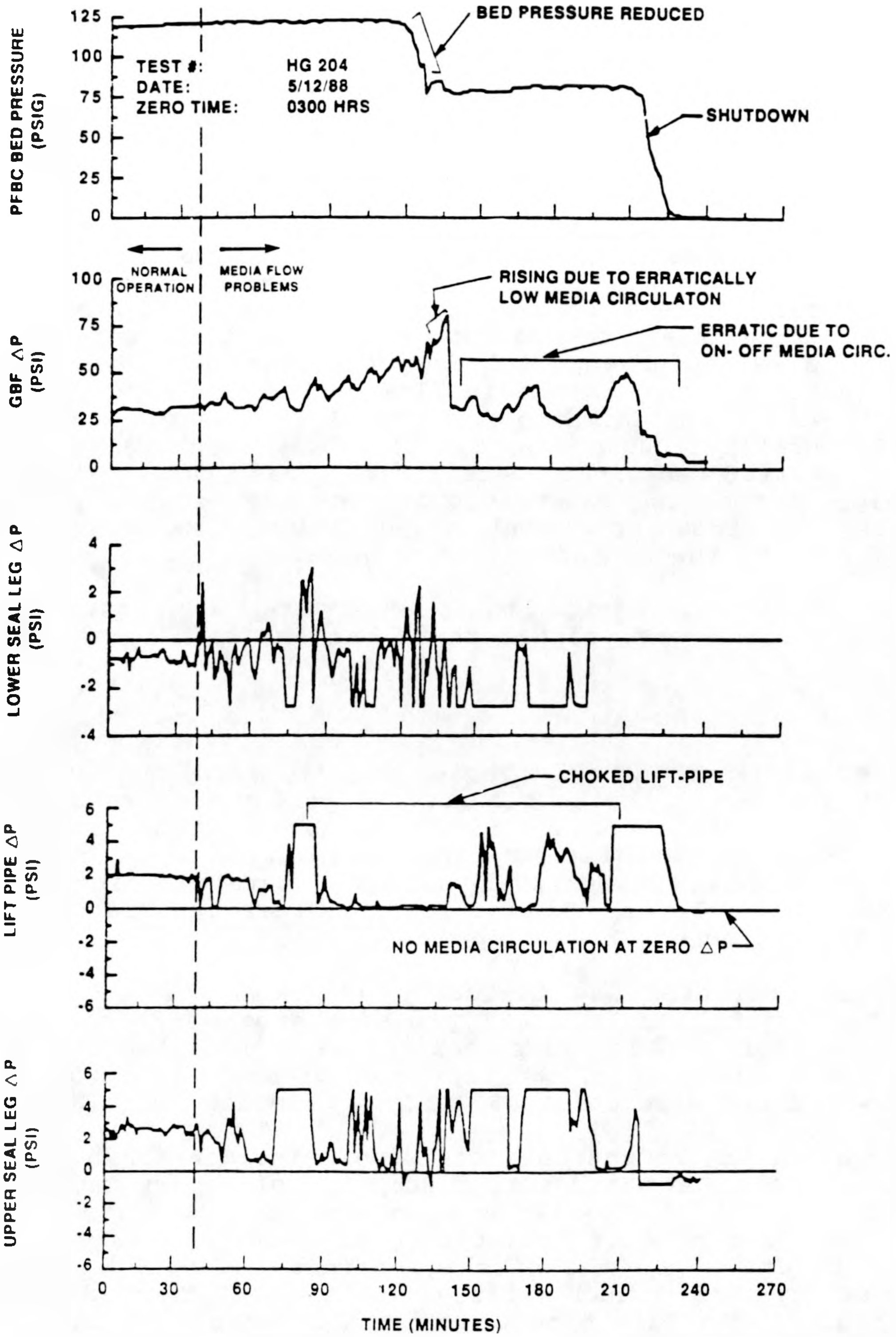


Figure IIB-12. GBF Performance Curves for HG-204 Showing the Effects of Lossing Media Circulation the Combustion Power operator experimented with bleed flow down the lower seal leg to enhance media flow. These efforts were briefly successful until at 70 minutes the lift pipe choked due to a sudden surge of media. After this was cleared on-line at 85 minutes after zero, media circulation could not be restarted until 135 minutes. During the time between 85 and 135 minutes various techniques were tried to restore circulation. One unsuccessful technique, tried at 120 minutes, was to lower PFBC bed pressure. Between 140 minutes to 205 minutes, the Combustion Power operator increased bleed flow rates more and more to assist media circulation. This resulted in lower seal leg pressure drops that were quite negative indicating a very high gas flow down the lower seal leg. At 205 minutes, a sudden surge of media flow choked the lift pipe and a PFBC shutdown was initiated to clear the lift pipe and media valve. Within 3 hours (by 1000 hrs.), all blockages were cleared and the equipment started back into operation to finish out the test. The GBF equipment operated satisfactorily for the remaining 27 hours of testing. Shutdown commenced at 1500 hours on May 13, 1988 when the coal feed to the combustor was terminated.

Throughout the entire test, dust grab samples, impactor samples and alkali analysis (both NYU and METC/INEL) was carried out.

IIB.7.2 Results, HG-204

Inlet loadings actually varied widely, from 80 ppmw to 2800 ppmw as discussed in the section on GBF performance results. NYU could change inlet loading by adjusting sorbent feed rate and bed height. The average inlet loading fell between 300 and 400 ppmw which is considerably less than the anticipated loading of 1200-1500 ppmw. Nevertheless, outlet loadings were low, between 1 and 16 ppmw and averaging around 5 ppmw.

Filter operation was typically as shown for the first 40 minutes of Figure IIB-12. GBF pressure drop was stable in the range of 24-30 IWC. The lower seal leg was manually controlled to the -.3 to -.7 psi range, and lift-pipe pressure drop was held at 2.0 psi which corresponded to 35 lb/min of media circulation.

It was first thought that the single incident involving loss of media circulation was due to pieces of refractory plugging the media valve. It was known by fiberscope examination before the test that some chunks of refractory were breaking away from the lower seal leg. When the blockage formed and was cleared, the morning of May 12th no such material was found. It could have been transported up the lift pipe and/or broken up during the efforts to clear the blockage. This possibility is supported by the onset of circulation problems 4-5 hours after restart or about the time it takes media and debris to make one circulation. This second incident, although shortlived, was much like the original except the blockage was cleared on-line, without shutdown, and with relative ease. On the other hand, a post-test fiberscope examination indicated no noticeable, additional loss of refractory in the lower seal leg.

A more likely possibility is that ash was separating from the media and agglomerating in the media valve with moisture and oil from the boost blower. Whichever the cause, the pressure profile on the circulation system indicated the pluggage was at, or very near, to the "J" portion of the media valve. Sometimes blockage was cleared by increasing circulation rate and system bleed. A high system bleed flow will induce a high gas leakage down the lower seal leg to transport any debris into the lift pipe.

IIB.7.3 Conclusions, HG-204

The "100-hour" test of May 9-13 again showed the potential of the granular bed filter. During the 74 hours of coal firing, only one upset of the GBF occurred, a loss of media circulation that caused a brief shutdown to clear blockage, then a restart. During the first 24 hours the filter was operated at 90 psig, 1500-1600F inlet temperature, and 6800 lb/hr. This corresponds to 25% of minimum fluidization for the filter media. For the remainder of the test, the filter was operated at 110-115 psig, 1500-1600F and 8200 lb/hr. This corresponds to 28% of minimum fluidization of the media. Particulate sampling yielded an inlet loading of 100-2800 ppmw and an outlet loading of 1-16 ppmw. The outlet particulate emissions were well below NSPS guidelines of 0.03 lb/million Btu (around .01 lb/million Btu). When combined with NYU's primary cyclone, the particulate collection efficiency exceeded 99%.

IIB.8 Performance Test HG-205

Operation on this fifth performance test occurred during June 6 - June 9, 1988. The objectives were:

- Establish steady state granular bed filter operation at 8-9 atm (100-115 psig) and 1550-1600°F.
- Maintain continuous PFBC operation with coal-flue gas through the GBF at a flow rate about 30% minimum fluidizing of the 3MM media.
- Establish three levels of circulation, 60, 45, 30 lb/min and operate 10-20 hours at each level to get consistent particulate sampling.
- Measure gas particulate and alkali contents at the GBF inlet and outlet.

IIB.8.1 Test Summary, HG-205

Initial kerosene combustion light-off: 1930 hrs - 6/6/88

Coal feed initiated: 0645 hrs - 6/7/88

Termination of coal feed: 1949 hrs - 6/8/88

Coal feed reinitiated: 2250 hrs - 6/8/88

Termination of coal feed: 0445 hrs - 6/9/88

Coal feed reinitiated: 0655 hrs - 6/9/88

Final coal feed termination: 1115 hrs - 6/9/88

Total hours of coal combustion: 47.32

Although the GBF experienced loss of circulation a few times during the test and required shutdown of the PFBC once to re-establish circulation, the test was otherwise largely successful. Sampling data for inlet and outlet dust loading and alkali content were taken periodically throughout the test.

At about 0530 hours on June 7, 1988 prior to switching to coal firing, it was determined that although the PFBC system bypass valve was indicating full stroke operation, there was no apparent effect on the flue gas flow conditions. Further investigation confirmed that the valve plug had apparently become separate from the valve stem. It was subsequently determined to continue the test without recourse to the bypass valve, thus allowing only about 80% of the intended full flow through the PFBC. Because of the corresponding reduction in bed superficial velocity, it was decided to reduce the operating fluid bed height to about 55 to 60 inches for the balance of the test.

During the test, media circulation was maintained at successively lower circulation rates of about 54 lb/min, 40 lb/min, and 25 lb/min. The circulation was easier to control at the higher circulation rates, and some loss of circulation was experienced at 40 lb/min and at 25 lb/min. The filter pressure drop was, however, fairly stable while circulation was maintained.

Particulate sampling continued to show consistent results for outlet samples on the order of 3-11 ppm. Inlet samples ranged from a high of near 1500 ppm to equilibrium values less than 600 ppm, with higher values occurring during startup and bed filling transients or other periods of high sorbent addition. Alkali sampling was reportedly showing results similar to previous tests as is discussed in the section on GBF performance results.

Dr. J. D. McCain of SRI was on-site at the conclusion of the test for a review of the particulate grab sampling and impactor sampling systems. Results will be amplified on in the section on GBF performance results but it was agreed that grab sampling should be reasonably accurate and impactor sampling probably erroneous.

IIB.8.2 Results, HG-205

Particulate sampling results are detailed in the following section on GBF performance results. The average inlet loading was about 900 ppmw and the average outlet loading was about 4 ppmw. The inlet loadings were verified by weighing ash collected at the GBF baghouse and calculating the respective flue gas concentrations on this basis. Outlet loadings indicate that the 3 mm media provides a very effective filtration bed. Perhaps one reason is the nonuniformity in size of the 3 mm media. Sizes of spherical alumina that comprised the 3 mm filter bed actually ranged between 2.8 and 4 mm. On the other hand, the 2 mm media is fairly uniform at 1.9 to 2.0 mm. Mass flows through the filter are equivalent to 30-31% minimum fluidization of the media or a face velocity at the exit of the filter bed of about 1 ft/sec.

Based on inspections made during the test and after the test, the circulation problems during the test were due to ash deposits that formed in the media valve. Since considerable condensate was found in this vicinity during operation, this could be the cause of the deposits forming. In this case, the problem is highly localized since the media is typically 1400-1600F. In addition to condensate, there is oil from the boost blower that collects in the back of the media valve. This could also be involved in the formation of deposits. Other possibilities are alkali condensation or ash compaction. To solve the problem, the recommendation is to filter the moisture and oil out of the injector gas, a fairly small gas stream. Heating the injector air would assure no condensation formed. As a back-up, the media valve could be modified to allow clearing any blockage during operation.

IIB.8.3 Conclusions, HG-205

This was the first time 3 mm media was used for filtration; although it had been tested in the circulation system at Combustion Power. During the 47 hours of coal combustion there was some difficulty with media circulation and one PFBC shutdown, but the filtration was very good. The granular bed filter was operated at 115 psig, 1500-1600F, and 12,500 lb/hr. This corresponds to about 30% minimum fluidization for the filter media. Particulate sampling yielded an inlet loading ranging from 500 to 1500 ppmw and averaging 904 ppmw. The outlet loadings ranged from 1 to 11 ppmw and averaged 4.3 ppmw. For New Source Performance Standards, the emissions averaged 0.004 lb/million Btu, which is well below the standard of 0.03 lb/million Btu.

Media circulation measurements demonstrated that the lift-pipe mathematical model predicted performance quite closely. With a completely renewed lift pipe, measurements should fall within the theoretical range.

Problems with media circulation were caused by ash deposits in the media valve. This can be prevented by minor redesign to remove moisture and oil from the injector gas.

APPENDIX IIC

SOUTHERN RESEARCH INSTITUTE REPORT
ON
NEW YORK UNIVERSITY
PARTICULATE SAMPLING

Southern Research Institute

June 22, 1988

Mr. John Mustonen
Stone and Webster Engineering Corp.
245 Summer Street, 6th Floor
Boston, MA 02143

Dear Mr. Mustonen,

This letter summarizes my thoughts and observations concerning the methods and techniques used by NYU for measuring the concentration and size distributions of particulate matter in the process streams of the NYU/DOE PFBC pilot plant. I noted potential problems with the hardware setups being used in doing the sampling, in the operating conditions being used for some of the sampling, and in the laboratory techniques being used. Each of these areas are discussed in detail in the following paragraphs.

Laboratory techniques

Neither the filters from the grab samplers nor the impactor collection substrates are being desiccated before weighing. Desiccation is essential if valid weights of the collected particulate matter are to be obtained. The total catch of the Balston filters used for the grab samples at the gravel bed outlet was typically about 20 mg. A few milligrams of moisture would thus result in a significant error. In the case of the impactor samples the individual stage weights were often a few tenths of a milligram or less. Hence a small amount of moisture would result in a large error. Some of the observed variability in the impactor data may well have been due to problems with moisture uptake. It is recommended that all filters and impactor substrate materials be desiccated a minimum of 12 hours before each weighing.

Operational conditions

To avoid potential problems resulting from blowoff of collected particles from the impactor stages, the maximum catch of any one stage (other than the precollector) should be 10 mg. Experience has shown that in many cases if this limit is exceeded some of the previously collected material will be blown off a stage and be carried to succeeding stages; thus biasing the results. The precollector has been shown to have a greater capacity and this limit does not apply to it.

Some of the impactor substrates showed visible evidence of having been wet and a few were not weighed because of having been wet so moisture on the impactor substrates is not an inconsequential problem. If the moisture resulted from condensation in the impactor that took place after the sample had been taken while the impactor was cooling, desiccation would be all that is needed to resolve the problem. However, if some part of the transport system is at times operating at temperatures below the dew point, entrainment of this condensate together with any particulate matter from the walls of the tubing that it picked up could obviously bias the results.

Erosion of the glass fiber impactor substrates was noted on the last stages for some of the impactor samples. The material that was removed from the substrate probably was carried down to or through subsequent stages resulting in a negative bias for the stage that was eroded and possible positive biases for the later stages. Evidence of some jets being plugged was also noted and the plugging may have resulted from such eroded substrate fibers. Two solutions are available for this problem. First, the impactor could be operated at a lower flow rate. This would reduce the erosion problem and reduce the possibility of bias due to particle bounce as well, but would require a change in the isokinetic sampling nozzle diameter. Second, the particles from the combustor appeared to be fairly "sticky" (that is, they adhered to the substrates reasonably well). So it may be possible to use bare stainless steel foils on the lower stages of the impactors rather than the glass fiber collection media, thus eliminating the erosion problem. The glass fiber media should still be used on the stages which did not show evidence of fiber erosion.

The impactors were being operated without final filters. The latter are needed to account for the mass associated with particles smaller than the cut diameter of the last impaction stage. Without this weight a negative bias is introduced in the fine particle end of the size spectrum. The UW impactors being used are intended to have a 47 mm glass fiber filter as the final collection stage so that all of the particles sampled are accounted for. A pair of support screens and a filter seal collar are provided with the impactors for this purpose. The final filter also offers some QA/QC information. High catch weights on the filter, in the absence of strong sources of small particles, usually indicate that excessive particle bounce is taking place or that erosion of substrate material in taking place under some of the jets. If either of these events takes place, the results are biased and if the problem is severe, they may be totally erroneous.

The catch weights of the filter for the outlet grab samples are quite small as compared to the tare weights of the Balston filters being used. Better precision and accuracy (and less problems from moisture uptake) might be obtainable by using a lower tare filter at that location. A 2.5 or 4 inch diameter flat glass fiber filter would probably work well.

Hardware setups and operation

The transport lines from the ducts to the samplers are relatively long and unheated - even uninsulated over much of their lengths. This would not be a problem provided that the temperature never fell below the dew point at any location in the lines. However, the lines are allowed to cool between sampling periods and are heated by running a high flow rate of process gas through them immediately prior to taking a sample. Water undoubtedly condenses in the lines for some part of this warmup, during which time any particles which contact the wet surfaces will adhere. A surface film of agglomerated material will form as the water eventually evaporates, leaving a layer (or layers) of particulate material which can be reentrained sporadically, resulting in measurement errors. Some zones may remain cool enough to cause condensation during the actual sampling period which would further compound the problem. Electrical heat tracing is needed to ensure that the lines are up to operating temperature before any process gases enter them to avoid problems from such condensation. This problem may be the source of the water which wet some of the impactor stages that I saw during my visit. It may also explain some of the erratic stage weight gains in the impactor samples.

Losses resulting from deposition in the long tortuous paths from the process ducts to the sample collection devices are potentially very serious. estimates of the magnitude of the effects of the long transport lines, the bends in the lines, and the needle valves being used as isolation (block) valves were made based on the following:

tube diameters (reported to me by Krish): 0.43 inch

gas pressures (taken from data sheets provided to me): about 110 psig.

gas temperatures in the sampling lines (taken to be the same as the impactor inlet temperatures): about 500 deg. F.

wet mol. weight of the gas (about that of standard air): 28.95

gas viscosity equal to that of standard air at the same temperature.

typical sample flow rates taken from data sheets provided by Krish.

Deposition in the transport lines would occur from three primary mechanisms: settling in horizontal sections, turbulent deposition throughout the length of the tubing, and inertial deposition in the bends and needle valves. A particle which is deposited by any of these mechanisms can (1) be permanently attached to the surface contacted, (2) be immediately reentrained with its original properties, (3) be reentrained later in its original form, (4) be reentrained immediately as a number of smaller particles in the cases of agglomerates and friable materials, (5) be reentrained immediately with other previously deposited particles as a part of an agglomerate, (6) be reentrained at a later time as a number of smaller particles for agglomerated and friable materials, or (7) be reentrained later as a part of an agglomerate. Permanent attachment of the particle to the surface it contacted results in measurement errors in both concentration and size distribution. There is no effect on the measurements of either concentration or size distribution if the particle is reentrained in its original form immediately or during the course of the sampling run in which it was deposited. All of the remaining possibilities will result in erroneous measurements of the particle size distribution. Although the formation and breakup of agglomerates during a concentration measurement (grab sample) will not affect the result, reentrainment in any form at a time after the sampling run in which a particle was deposited will result in errors.

Although it is only a minor point, the calibrations of the pressure gages at the inlet and outlet of the impactors did not appear to be very good. The pressure at the inlet of the "outlet" impactor was always higher than that of the "inlet" impactor in spite of the fact that the reverse must be true. The presure drop through the stages of the UW Mark III impactor used at the gravel bed outlet should be about 2 psi at the operating conditions used during the gravel bed testing. The UW Mark V impactors used at the gravel bed inlet should have had a pressure drop through the stages of about 9 or 10 psi. The gage pressures recorded on the sampling data sheets do not reflect these expected pressure drops or anything close to them. This means that either the gages are wrong (likely in view of the ones at the gravel bed outlet showing higher values than those at the gravel bed inlet), or the impactor flow rates are wrong, or the impactors had bad internal leakage. The latter is not very likely from the appearances of the impactor internals when they were being unloaded while I was on site.

The flow through the transport tubes was turbulent for all of the sampling done during the CPC gravel bed filter program. Reynolds numbers were about 18000 to 20000 for the impactor sampling and the inlet total concentration measurements. The Reynolds numbers were about 50000 for the outlet concentration measurements. Estimates of potential losses from settling and turbulent deposition are given in the table below. The settling losses given in the table are for the single longest horizontal run of tubing for the given location. Turbulent losses are for the full run of tubing up to the inlet of the flow splitter used for the impactors. The tubing lengths used in the calculations for the grab (concentration) samplers were the same as those used for the impactors. Particles which settle out should probably be considered as lost. Those which contact the wall from turbulence may or may not be lost. Retention of small particles will probably be higher than for large particles.

Percentages of Particles Contacting Walls

	Gravel Bed Inlet Duct			Gravel Bed Outlet Duct		
Part. Dia.	Imp. Turb.	Imp. Settling	Grab Turb.	Imp. Turb.	Imp. Settling	Grab Turb.
2	1	0.1	1.4	1	0.25	29
4	15	0.4	21	17	1.0	99.6
6	57	0.8	70	61	2.2	99.99998
8	93	1.4	98	95	3.9	100
10	99.9	2.2	99.98	99.9	6.0	
12	99.999	3.1	99.9999	99.999	8.6	
14	99.99999	4.2	100	99.99999	11.5	
16	100	5.5		100	14.9	
18		6.9			18.6	
20		8.5			22.7	
22		10.2			27.1	
24		12.1			31.7	
26		14.1			36.6	
28		16.2			41.8	
30		18.5			47.1	

In the cases of the impactors and the inlet grab samples, essentially all particles with diameters larger than 8 um will have contacted the walls at each 90 degree turn and all particles larger than 5 um will have impacted in the needle valves. For the outlet grab sample, all particles larger than about 5 um will have impacted the wall at each tubing bend and all particles larger than about 3 um will have impacted in the needle valve. Small particles are much more likely to stick on contact with a surface than are large ones and it is difficult to estimate any net loss figures. Even smaller particles would have impacted in the bends (and had high deposition rates form turbulence) when the systems were first set up with the .125 inch ID tubing for the transport lines. The greater holding forces for the smaller particles which would have contacted the walls from turbulence and impaction and the greater deposition rates for the smaller bore tubing were undoubtedly the cause of the plugging of the sampling lines that took place. Because of this plugging the transport lines were enlarged to the 0.43 inch IDs now in use.

There are indicators of transport losses and modifications to particle size distributions in the systems as evidenced by some of the results (discussed later) and by visible deposits on surfaces like the filter housing inlets.

As can be seen from the table above, potential losses and/or size distribution changes are much less severe from settling than from turbulence and impaction in the valves and tube bends. If the current transport tubes must remain in use, better data might be obtained by reducing the flow rates through the transport lines. The lower flows would reduce turbulent contact and move the minimum diameter that would impact in the bends and needle valves upward by the square root of the flow ratio. Because of this plugging the needle valves presently being used as isolation valves should really be replaced by ball valves that are sized to provide a clear bore through the transport system when they are open. The number of bends in the transport lines should also be held to an absolute minimum.

Turbulent contact can be reduced by reducing the flow rate through the main extraction probe with the current setup. However, settling becomes more important as the flow rate is reduced and no flow rate provides a satisfactory combination of losses from turbulence and settling as can be seen in the following table. The values in the table were calculated for the transport tube geometry used for the outlet impactor setup. The settling losses were calculated for the longest horizontal run in that setup.

Settling and Turbulent Losses through Extraction Line for Outlet Setup

Flow Rate at Splitter Inlet, scfh

Part. Dia.	461		230		115		58	
	Turb.	Sett.	Turb.	Sett.	Turb.	Sett.	Turb.	Sett.
10	99.9	3.9	50.8	11.7	6.5	22.6	0.6	42.4
20	100	22.7	100	42.4	66.6	74.6	9.9	100
30	100	47.1	100	81.1	99.6	100	41.3	100

If the flow splitting device being used in the impactor systems is to continue to be used, it should be tested to verify that it introduces no bias with respect to particle size. At the least, the two legs should be tested to verify that the concentrations in the two legs are equal. Problems do exist somewhere in the grab and impactor systems which result in systematic differences in measured concentrations. The concentrations from the inlet impactor data (0.28g/m^3) average only about 25% of those from the inlet grab samples (1.07 g/m^3). One or both of them must be biased. Factors which result in bias with respect to concentration in impactor measurements almost always create large distortions in the size distribution; thus if most of the problems are in the impactor data, the apparent size distributions are probably wrong. In the case of the gravel bed outlet measurements the impactor results (11 mg/m^3) average about twice those of the grab sampler (5.1 mg/m^3). The reversal in the ratios between the inlet and outlet indicates that more than one mechanism is having an effect. One possibility is that the probe tips are not in locations to take representative samples from the duct for at least two of the four samplers. Another might be a combination of transport losses and biases from the impactor systems flow dividers. The flows in the main transport lines are very nearly the same for the impactors and the inlet grab sample. However, the outlet grab sampler was operated at more than twice the flow rate used for the other three trains. The much higher potential wall losses from turbulence for the outlet grab sampler may have been realized and have caused the outlet grab sampler results to be biased very low. Alternatively, moisture in the outlet impactor substrates may have biased those results upward more than moisture in the Balston filter. None of these explanations may be the right one. If the outlet size distributions have any meaning, the small measured mean size of the outlet particulate matter makes it unlikely that the outlet differences are due to non-representative locations for the probe tips since small particles can be expected to have been uniformly distributed in the gas stream. In any case, the discrepancies in the concentrations measured with the impactors and those from the grab samplers are disturbing. If the current transport system is to continue to be used, the magnitude of the line losses should be measured and demonstrated to be acceptable. And even with low losses, the measured size distributions could still be incorrect.

A far superior arrangement for ex-situ sampling would be to sample at a transition from vertical downflow to horizontal flow in the duct. By using a tee instead of an elbow, with the stem of the tee being horizontal, the sample could be taken off through a blind flange at the bottom of the turn. The duct flow would make a 90 degree turn into a horizontal section through the stem of the tee. A straight probe of minimal length penetrating up through the blind flange could be used to carry the sample from the duct to the measurement device. The only disturbances to the flow in the probe should be the purge air inlet (needed to keep the tip clean when not sampling) and a pair of ball valves, sized to match the ID of the tubing for use as isolation valves. The sample would undergo no changes of direction from the nozzle to the measurement device with this arrangement; consequently with the vertical downflow there would be no settling losses or impaction in bends. The Reynolds number should be kept low, on the order of a few thousand at most, to minimize contact due to turbulence. Half inch ID (5/8 inch OD) tubing would be a good choice for the probe and half inch Kaymyr ball valves should then be used for isolation. Provision should also be made for a bypass around the impactor to clear any particulate matter that entered the probe in spite of the purge which would have then settled on the valves. The nozzle should be sized for isokinetic sampling at the appropriate rate for the impactor and duct conditions. The nozzle interior should taper from the tip size to the tubing ID at a seven degree total included angle.

The recommended arrangement, sampling with a minimum length vertical probe, would result in zero settling losses and turbulent contact would be reduced to the values given in the table below. The probe length used was 150 cm (1.5 m). Calculations were made for two flow rates (115 scfh and 58 scfh) and two tube IDs (0.43 inch and 0.5 inch).

Expected Turbulent Losses through Recommended Probe Arrangement

Tube Size

Part. Dia.	0.43 inch 115 scfh	0.43 inch 58 scfh	0.5 inch 115 scfh	0.5 inch 58 scfh
10	1.8	0.2	0.5	0.05
20	25.9	2.8	7.9	0.8
30	78.3	13.5	34.4	3.9

The recommended combination is the 0.5 inch ID tube at the 58 scfh flow rate. The latter flow rate is one half the impactor flow rate currently being used.

If tees cannot be installed at bends in suitable locations to permit sampling through a pure vertical downflow system as described in the previous paragraph, a marked improvement over the current setup could be obtained by sampling through a port located at the bottom of a horizontal run of duct. The system described above would be used except that a single 90 degree turn would be required to direct the nozzle into the gas stream.

Reduced data from the impactor runs

The data from inlet runs I-3 through I-7 and the corresponding outlet runs were reduced using an SRI computer program for handling impactor data. The hardware configurations, flows, temperatures and pressures used were provided by NYU. The gas composition used was that of a typical coal combustion flue gas. Estimated values were inserted for all final filter weights and for catch weights of stages which were not weighed because they had been wet. Printouts of the results are provided. A dip in the concentration versus particle size curve was noted for sizes in the 5 to 10 or 20 um range at the gravel bed inlet. This dip may be real but it falls where an artifact would be found from impaction in the needle valve. Agglomeration at that location would result in particles in the 5 to 20 micron size range being measured as being larger than that, producing just such a drop. Thus the apparent bimodal structure of the distribution may or may not be real. The lack of a similar dip in that size range at the outlet confounds the interpretation of the significance of the inlet dip.

Summary

Potentially severe losses of particles that would have been non-uniform with respect to particle size make the data obtained with the current sampling systems suspect. The large concentration discrepancies between the impactor and grab sampler results reinforce doubts concerning them. Improvements in the sampling systems and in some of the laboratory and operating techniques can be made which should result in a substantial improvement in data quality.

If you have any questions please feel free to write or call.

Yours truly,

Joseph D. McCain

Joseph D. McCain
Senior Physicist

JDM:fea
Enclosures
P-88-260
Project: 6599

IID.1 PARTICULATE DATA

IID.1.1 GRAB DATA

TEST• HG-204

PARTICULATE SAMPLING DATA

TYPE OF SAMPLING: GRAB

DESCRIPTION		SET 1		SET 2		SET 3		SET 4		SET 5		SET 6		SET 7	
		IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT
DATE		5/10/88		5/10/88		5/10/88		5/10/88		5/10/88		5/11/88		5/11/88	
STARTING TIME	HRS	11:15	11:05	14:20	14:15	16:45	16:27	19:10	19:32	21:12	22:18	1:10	1:05	4:30	4:22
COLLECTION PERIOD	MTS	30	55	30	55	30	55	30	55	30	55	30	55	30	55
WT OF SAMPLE	GMS	5.352	0.194	2.633	0.125	0.532	0.047	0.341	0.082	0.636	0.166	0.390	0.098	0.872	0.209
AVG GAS FLOW	LB/HR	5566	5625	6319	6355	6669	6688	6607	6685	6690	6675	6596	6612	6560	6588
SAMPLE GAS FLOW	LB/HR	16.20	29.11	18.64	31.6	19.72	32.9	19.11	32.39	19.67	32.5	19.46	33.02	19.03	32.12
AVG COAL FLOW	LB/HR	532	525	535	541	550	552	554	554	554	555	554	554	554	554
DUST LOADING	PPM (W)	1457	16.07	623.1	9.55	118.8	3.44	78.58	6.08	142.6	12.23	88.4	7.10	202	15.7
	LB/MBTU	1.145	0.013	0.553	0.008	0.108	0.003	0.07	0.006	0.129	0.011	0.079	0.006	0.18	0.014

TEST# HG-204

PARTICULATE SAMPLING DATA

TYPE OF SAMPLING: GRAB

DESCRIPTION		SET 8		SET 9		SET 10		SET 11		SET 12		SET 13		SET 14	
		IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT
DATE		5/11/88		5/11/88		5/11/88		5/11/88		5/11/88		5/12/88		5/12/88	
STARTING TIME	HRS	8:15	8:00	10:25	10:15	12:35	12:32	14:50	14:45	21:20	21:15	0:18	0:05	2:55	2:48
COLLECTION PERIOD	MTS	30	55	30	55	30	55	30	55	30	55	30	55	30	55
WT OF SAMPLE	GMS	6.766	0.096	6.712	0.058	4.538	0.066	0.469	0.201	0.730	0.162	1.692	0.093	3.249	0.052
AVG GAS FLOW	LB/HR	6830	6891	6924	6991	6991	7004	6995	7009	8153	8182	8191	8201	8172	8181
SAMPLE GAS FLOW	LB/HR	19.78	33.89	20.32	34.15	20.49	34.8	20.56	34.19	24.39	40.65	24.07	40.26	24.03	40.65
AVG COAL FLOW	LB/HR	584	586	587	587	587	586	586	586	629	625	618	618	619	623
DUST LOADING	PPM (W)	1508	6.8	1457	4.11	976.7	4.57	100.7	14.1	132.1	9.6	310	5.60	596.3	3.10
	LB/MBTU	1.318	0.006	1.286	0.004	0.873	0.004	0.09	0.013	0.129	0.009	0.308	0.006	0.591	0.003

TEST# HG-204

PARTICULATE SAMPLING DATA

TYPE OF SAMPLING: GRAB

DESCRIPTION		SET 15		SET 16		SET 17		SET 18		SET 19		SET 20		SET 21	
		IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT
DATE		5/12/88		5/12/88		5/12/88		5/12/88		5/12/88		5/12/88		5/13/88	
STARTING TIME	HRS	5:15	5:10	13:00	12:50	16:05	16:02	17:50	17:48	19:08	19:37	22:25	22:40	1:20	1:15
COLLECTION PERIOD	MTS	30	55	30	55	30	55	30	55	30	55	30	55	30	55
WT OF SAMPLE	GMS	1.232	0.218	1.562	0.206	1.185	0.042	2.737	0.071	0.689	0.062	1.596	0.081	1.063	0.057
AVG GAS FLOW	LB/HR	5547	5660	5528	5581	7907	7926	7872	7862	7884	7956	7928	7930	7866	7894
SAMPLE GAS FLOW	LB/HR	23.27	39.49	17.34	29.39	22.43	38.1	23.04	39.04	22.88	39.36	23.21	38.65	23.05	39.29
AVG COAL FLOW	LB/HR	554	548	466	470	630	631	624	626	627	628	628	628	628	627
DUST LOADING	PPM (W)	233.5	13.3	397.2	16.8	232.9	2.63	523.8	4.37	132.7	3.8	303.2	5.1	203.4	3.49
	LB/MBTU	0.176	0.01	0.354	0.015	0.219	0.002	0.496	0.004	0.125	0.004	0.287	0.005	0.191	0.003

TEST# HG-204

PARTICULATE SAMPLING DATA

TYPE OF SAMPLING: GRAB

DESCRIPTION		SET 22		SET 23		SET 24		SET 25		SET 26		SET		SET	
		IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT
DATE		5/13/88		5/13/88		5/13/88		5/13/88		5/13/88					
STARTING TIME	HRS	4:55	4:50	7:05	7:02	9:10	9:08	12:05	11:58	14:00	13:45				
COLLECTION PERIOD	MTS	30	55	25	55	25	55	25	55	30	55				
WT OF SAMPLE	GMS	1.434	0.083	3.763	0.046	2.002	0.042	1.275	0.051	14.578	0.011				
AVG GAS FLOW	LB/HR	7901	7927	7883	7879	7879	7891	7780	7802	7769	7788				
SAMPLE GAS FLOW	LB/HR	23.25	40.45	23.21	39.18	22.87	39.06	22.55	38.27	22.79	39.04				
AVG COAL FLOW	LB/HR	623	625	640	640	640	640	639	639	640	640				
DUST LOADING	PPM (W)	272.1	4.90	858.1	2.82	463.4	2.60	299.2	3.21	2821	1.0				
	LB/MBTU	0.259	0.005	0.794	0.003	0.428	0.002	0.273	0.003	2.57	0.001				

TEST# HG-205

PARTICULATE SAMPLING DATA

TYPE OF SAMPLING: GRAB

DESCRIPTION		SET 1		SET 2		SET 3		SET 4		SET 5		SET 6		SET 7	
		IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT
DATE		06/07/88		06/07/88		06/07/88		06/07/88		06/07/88		06/07/88		06/07/88	
STARTING TIME	HRS	09:40	09:30	11:35	11:28	13:40	13:30	16:10	16:00	17:40	17:30	19:20	19:15	21:07	21:05
COLLECTION PERIOD	MTS	20	30	20	30	20	30	20	30	20	30	20	30	20	30
WT OF SAMPLE	GMS	11.888	0.1991	6.156	0.111	2.803	0.057	8.053	0.069	6.844	0.074	8.488	0.054	2.979	0.075
AVG GAS FLOW	LB/HR	12150	12219	12111	12157	11961	12008	12529	12537	12169	12678	12641	12672	12632	12664
SAMPLE GAS FLOW	LB/HR	56.95	80.76	45.54	82.10	35.12	80.32	36.96	83.76	37.38	85.08	37.81	84.02	37.38	84.46
AVG COAL FLOW	LB/HR	927	927	979	979	1005	999	1028	1028	999	1001	999	998	973	974
DUST LOADING	PPM (W)	1381	10.9	894	6.0	528	3.1	1442	3.7	1211	3.9	1485	2.8	527	3.9
	LB/MBTU	1.359	0.011	0.830	0.006	0.472	0.003	1.319	0.003	1.107	0.004	1.410	0.003	0.514	0.004

TEST• HG-205

PARTICULATE SAMPLING DATA

TYPE OF SAMPLING: GRAB

DESCRIPTION		SET 8		SET 9		SET 10		SET 11		SET 12		SET 13		SET 14	
		IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT
DATE		06/08/88		06/08/88		06/08/88		06/08/88		06/08/88		06/08/88		06/08/88	
STARTING TIME	HRS	0:40	0:36	06:17	06:15	08:25	08:15	10:20	10:10	12:40	12:30	15:10	15:00	17:15	17:10
COLLECTION PERIOD	MTS	20	30	20	30	15	30	20	30	20	30	20	30	20	30
WT OF SAMPLE	GMS	3.223	0.069	2.802	0.136	2.602	0.107	4.842	0.052	5.149	0.069	3.397	0.067	2.778	0.016
AVG GAS FLOW	LB/HR	12760	12782	12786	12805	12727	12800	12807	12831	12592	12643	12879	12892	12790	12845
SAMPLE GAS FLOW	LB/HR	37.46	85.00	37.48	83.21	37.60	85.45	38.16	85.82	37.42	84.99	37.55	85.23	37.25	86.17
AVG COAL FLOW	LB/HR	975	974	998	998	977	973	977	978	1004	1004	1003	1003	1003	1003
DUST LOADING	PPM (W)	569	3.6	495	7.2	610	5.5	839	2.6	910	3.6	598	3.5	493	0.8
	LB/MBTU	0.559	0.004	0.476	0.007	0.597	0.005	0.826	0.003	0.857	0.003	0.577	0.003	0.472	0.001

TEST# HG-205

PARTICULATE SAMPLING DATA

TYPE OF SAMPLING: GRAB

DESCRIPTION		SET 15		SET 16		SET		SET		SET		SET		SET	
		IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT
DATE		06/09/88		06/09/88											
STARTING TIME	HRS	04:23	04:27	09:40	10:10										
COLLECTION PERIOD	MTS	19	17	20	40										
WT OF SAMPLE	GMS	8.144	0.034	0.859	0.079										
AVG GAS FLOW	LB/HR	12152	12126	12338	12270										
SAMPLE GAS FLOW	LB/HR	36.10	82.17	35.64	81.86										
AVG COAL FLOW	LB/HR	898	898	912	834										
DUST LOADING	PPM (W)	1571	3.2	159	3.2										
	LB/MBTU	1.596	0.003	0.162	0.004										

IID.1.2 CASCADE IMPACTOR DATA

The impactor data includes the impactor sampling conditions, the weight of dust collected on each plate and the processed data using a computer program developed by Washington University.

TEST# HG-204

PARTICULATE SAMPLING DATA

TYPE OF SAMPLING: IMPACTOR

DESCRIPTION		SET 1		SET 2		SET 3		SET 4		SET 5		SET 6		SET 7	
		IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT
DATE		5/10/88		5/11/88		5/12/88		5/12/88		5/13/88					
STARTING TIME	HRS	18:30	18:15	4:38	4:27	0:25	0:10	18:30	19:10	14:50					
COLLECTION PERIOD	MTS	30	55	30	55	30	55	30	55	17					
WT OF SAMPLE	GMS	0.214	0.012	0.135	0.014	0.221	0.009	0.269	0.011	0.404					
AVG GAS FLOW	LB/HR	6643	6639	6579	6596	8196	8205	7616	7830	7742					
SAMPLE GAS FLOW	LB/HR	4.77	4.77	4.72	5.28	5.93	5.95	5.80	5.75	5.62					
AVG COAL FLOW	LB/HR	544	556	554	554	617	617	625	626	637					
DUST LOADING	PPM (W)	197.8	6.05	126.2	6.56	164.2	3.64	205	4.56	560					
	LB/MBTU	0.181	0.005	0.112	0.006	0.164	0.004	0.187	0.004	0.511					

TEST• HG- 205

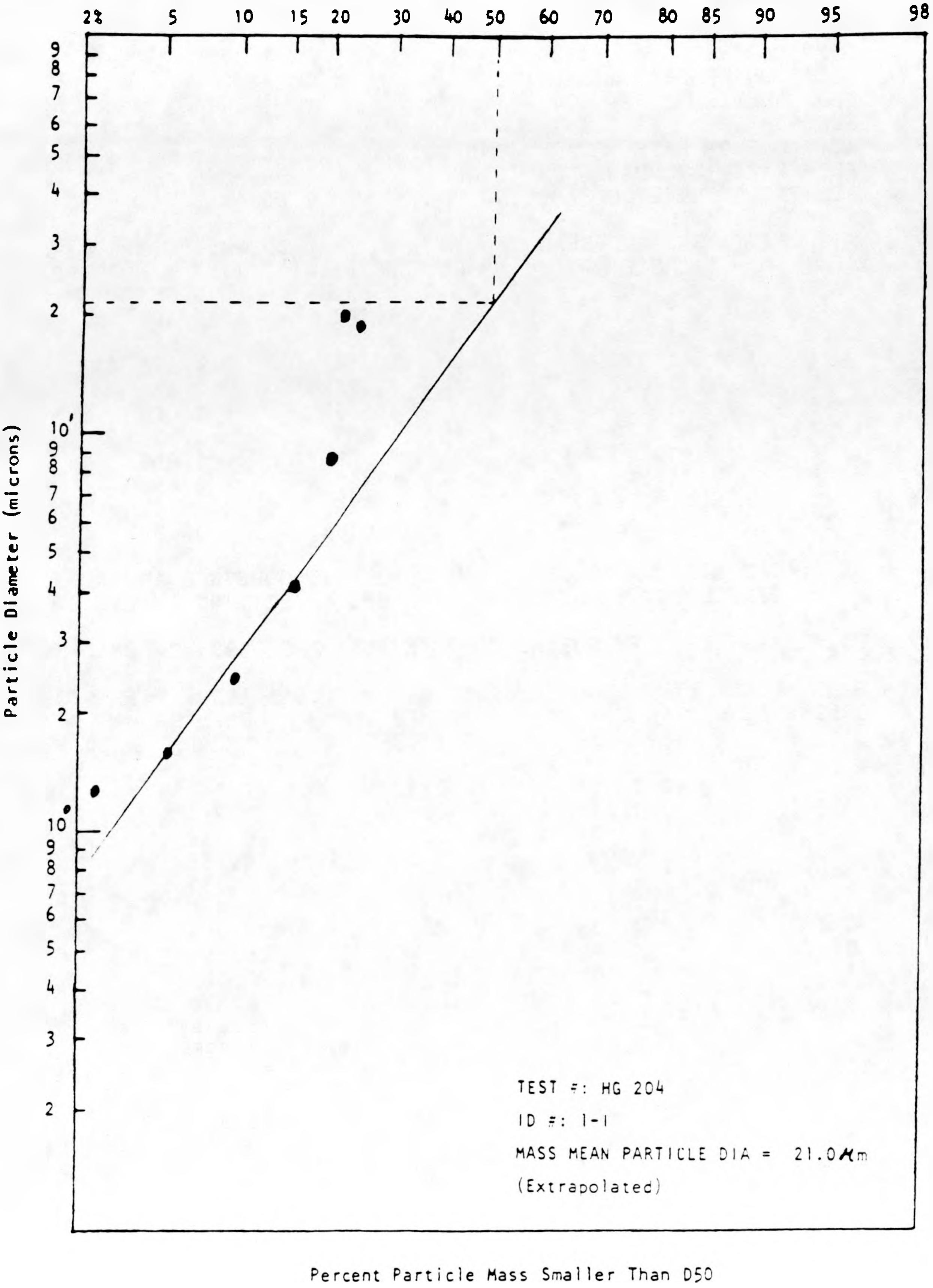
PARTICULATE SAMPLING DATA

TYPE OF SAMPLING: IMPACTOR

DESCRIPTION			SET 1		SET 2		SET 3		SET 4		SET 5		SET 6		SET 7	
			IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT
DATE			06/07/88		06/08/88		06/08/88		06/08/88		06/09/88					
STARTING TIME		HRS	14:30	14:15	03:45	03:40	13:10	13:10	17:50	17:50	09:16	09:15				
COLLECTION PERIOD		MTS	30	45	30	45	20	40	20	60	10	40				
WT OF SAMPLE		GMS	0.324	0.040	0.612	0.007	0.254	0.058	0.516	0.017	0.072	0.007				
AVG GAS FLOW		LB/HR	12283	12307	12850	12870	12819	12856	12871	12895	12358	12337				
SAMPLE GAS FLOW		LB/HR	9.31	9.03	9.27	9.36	9.14	9.14	8.92	9.27	8.86	8.91				
AVG COAL FLOW		LB/HR	1025	1013	884	884	1003	1002	1017	1024	925	881				
DUST LOADING	PPM (W)		153	13.1	291	2.3	184	20.8	383	3.9	107	0.22				
	LB/MBTU		0.138	0.012	0.317	0.003	0.176	0.020	0.364	0.004	0.108	0.000				

```
*****     P A R T I C L E   S I Z E   A N A L Y S I S     *****

                        ****     INPUT DATA     ****

DATE OF TEST         05/10/88
TIME OF TEST         1830
LOCATION OF TEST     NYU-PFBC
TEST NUMBER          204
PART. DIAM. TYPE     C     (I=IMP AERO, C=CLAS AERO, P=PHYSICAL)
TEST TYPE            INLET
RUN NUMBER           1-I - FILE NAME: B:T204R1-I.INT
REMARKS:
IMPACTOR TYPE        UWVNYU


WATER VAPOR           3.00%
CARBON DIOXIDE       14.77%
CARBON MONOXIDE       0.00%
OXYGEN                4.34%
SULFUR DIOXIDE        0.00%
NITROGEN             80.89%
PARTICLE DENSITY      1.00 GRAMS/CM^3

GAS METER VOLUME                        7.270  CUBIC FEET
IMPACTOR DELTA P                        0.00   INCHES HG
ORIFICE DELTA P                         0.00   INCHES H2O
STACK PRESS. (BELOW ATMOS.)             0.00   INCHES H2O
BAROMETRIC PRESS.                     %202.99   INCHES HG
STACK TEMPERATURE                     411.3    DEGREES F
METER TEMPERATURE                     411.3    DEGREES F
IMPACTOR TEMPERATURE                  411.3    DEGREES F
SAMPLE TIME                            30.00   MINUTES
AV. VELOCITY OF STACK GAS               0.00   FEET/MINUTE
GAS METER PRESSURE                      0.00   IN HG
NOZZLE DIAMETER                         0.43   INCHES
MAXIMUM AERODYN. DIAMETER            1000.00   MICRONS

MASS GAIN ON STAGE  1                     159.90 MG
MASS GAIN ON STAGE  2                       4.30 MG
MASS GAIN ON STAGE  3                       5.00 MG
MASS GAIN ON STAGE  4                      10.60 MG
MASS GAIN ON STAGE  5                      11.20 MG
MASS GAIN ON STAGE  6                      10.60 MG
MASS GAIN ON STAGE  7                       6.90 MG
MASS GAIN ON STAGE  8                       2.70 MG
MASS GAIN ON STAGE  9                       1.40 MG
MASS GAIN ON STAGE  10                      0.80 MG
MASS GAIN ON STAGE  11                      0.10 MG
MASS GAIN ON FINAL FILTER                   0.60 MG
```

```
                         ****          RESULTS          ****

  DATE OF TEST          05/10/88
  TIME OF TEST          1830
  LOCATION OF TEST      NYU-PFBC
  TEST NUMBER           204  -
  RUN NUMBER            1-I
  ACTUAL FLOW RATE (STACK CONDITIONS)      0.250 CFM
  FLOW RATE (STANDARD CONDITIONS)          0.997 CFM
  PERCENT ISOKINETIC SAMPLING              0.00  %

  VISCOSITY OF GAS STREAM                  0.0002459 GRAMS/CM-SEC
  STAGE          CCF          DP(CLAS AERO) DP(IMP AERO)   CUM FRACTION
     1          1.002           18.631        18.651         0.2528
     2          1.002           19.380        19.401         0.2327
     3          1.005            8.606         8.627         0.2093
     4          1.010            4.154         4.175         0.1598
     5          1.017            2.399         2.419         0.1075
     6          1.026            1.585         1.605         0.0579
     7          1.030            1.365         1.385         0.0257
     8          1.041            0.983         1.003         0.0131
     9          1.048            0.837         0.857         0.0065
    10          1.056            0.724         0.744         0.0028
    11          1.066            0.616         0.636         0.0023

  NOTE: THE MASS ON STAGES 1 AND 2 WILL BE COMBINED AND ASSIGNED TO
        THE OUTPUT ON STAGE 1 , FOR SPLINE FITTING ANALYSIS.

  TOTAL MASS PER DRY NORMAL CUBIC METER  252.9393 MG/CUBIC METER

  PART. DIAM. TYPE   C    (I=IMP AERO, C=CLAS AERO, P=PHYSICAL)
PARTICLE SIZE      CUMFR          CUMFR          CUM.MASS        dM/dLOG D
  (MICRONS)     (STD. DEV.)    (PER CENT)        (MG/DRY N.CU.METER)

    0.20         -3.2379          0.1             0.153          0.447
    0.25         -3.1566          0.1             0.203          0.579
    0.40         -2.9860          0.1             0.359          0.978
    0.50         -2.9050          0.2             0.466          1.241
    0.75         -2.7156          0.3             0.839         10.555
    1.00         -2.2090          1.4             3.440         16.687
    1.50         -1.7131          4.3            10.964        144.061
    2.00         -1.2546          9.9            25.156         46.014
    2.50         -1.2300         10.9            27.658         30.467
    4.00         -1.0130         15.6            39.338         67.113
    5.00         -0.9227         17.8            45.039         50.134
    7.50         -0.8284         20.4            51.526         26.209
   10.00         -0.7897         21.5            54.343         19.910
   15.00         -0.7486         22.7            57.427         15.791
   20.00         -0.7292         23.3            58.921          1.273
   25.00         -0.7274         23.4            59.061          1.719
   40.00         -0.7193         23.6            59.690          5.096
   50.00         -0.7111         23.9            60.332          6.367
```


2%
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10'
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10⁰
9
8
7
6
5
4
3
2
Particle Diameter (microns)
TEST #: HG 204
ID #: 1-1
MASS MEAN PARTICLE DIA = 21.0µm
(Extrapolated)
Percent Particle Mass Smaller Than D50

```
*****     P A R T I C L E   S I Z E   A N A L Y S I S     *****

                    ****     INPUT DATA     ****

DATE OF TEST          05/10/88
TIME OF TEST          1815
LOCATION OF TEST      NYU-PFBC
TEST NUMBER           204
PART. DIAM. TYPE      C    (I=IMP AERO, C=CLAS AERO, P=PHYSICAL)
TEST TYPE             OUTLET
RUN NUMBER            1-0 - FILE NAME: B:T204R1-I.OUT
REMARKS:
IMPACTOR TYPE         UW3NYU


WATER VAPOR           3.00%
CARBON DIOXIDE       14.77%
CARBON MONOXIDE       0.00%
OXYGEN                4.34%
SULFUR DIOXIDE        0.00%
NITROGEN             80.89%
PARTICLE DENSITY     1.00 GRAMS/CM^3

GAS METER VOLUME                      13.260 CUBIC FEET
IMPACTOR DELTA P                       0.00  INCHES HG
ORIFICE DELTA P                        0.00  INCHES H2O
STACK PRESS. (BELOW ATMOS.)            0.00  INCHES H2O
BAROMETRIC PRESS.                     %208.89  INCHES HG
STACK TEMPERATURE                    432.9   DEGREES F
METER TEMPERATURE                    432.9   DEGREES F
IMPACTOR TEMPERATURE                 432.9   DEGREES F
SAMPLE TIME                           55.00  MINUTES
AV. VELOCITY OF STACK GAS              0.00  FEET/MINUTE
GAS METER PRESSURE                     0.00  IN HG
NOZZLE DIAMETER                        0.43  INCHES
MAXIMUM AERODYN. DIAMETER           1000.00  MICRONS

MASS GAIN ON STAGE  1                    3.80 MG
MASS GAIN ON STAGE  2                    1.20 MG
MASS GAIN ON STAGE  3                    0.70 MG
MASS GAIN ON STAGE  4                    0.60 MG
MASS GAIN ON STAGE  5                    1.40 MG
MASS GAIN ON STAGE  6                    2.80 MG
MASS GAIN ON STAGE  7                    1.10 MG
MASS GAIN ON FINAL FILTER                0.40 MG
```

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                         ****        RESULTS        ****

   DATE OF TEST          05/10/88
   TIME OF TEST          1815
   LOCATION OF TEST      NYU-PFBC
   TEST NUMBER           204  -
   RUN NUMBER            1-0
   ACTUAL FLOW RATE (STACK CONDITIONS)      0.249 CFM
   FLOW RATE (STANDARD CONDITIONS)          0.995 CFM
   PERCENT ISOKINETIC SAMPLING              0.00  %

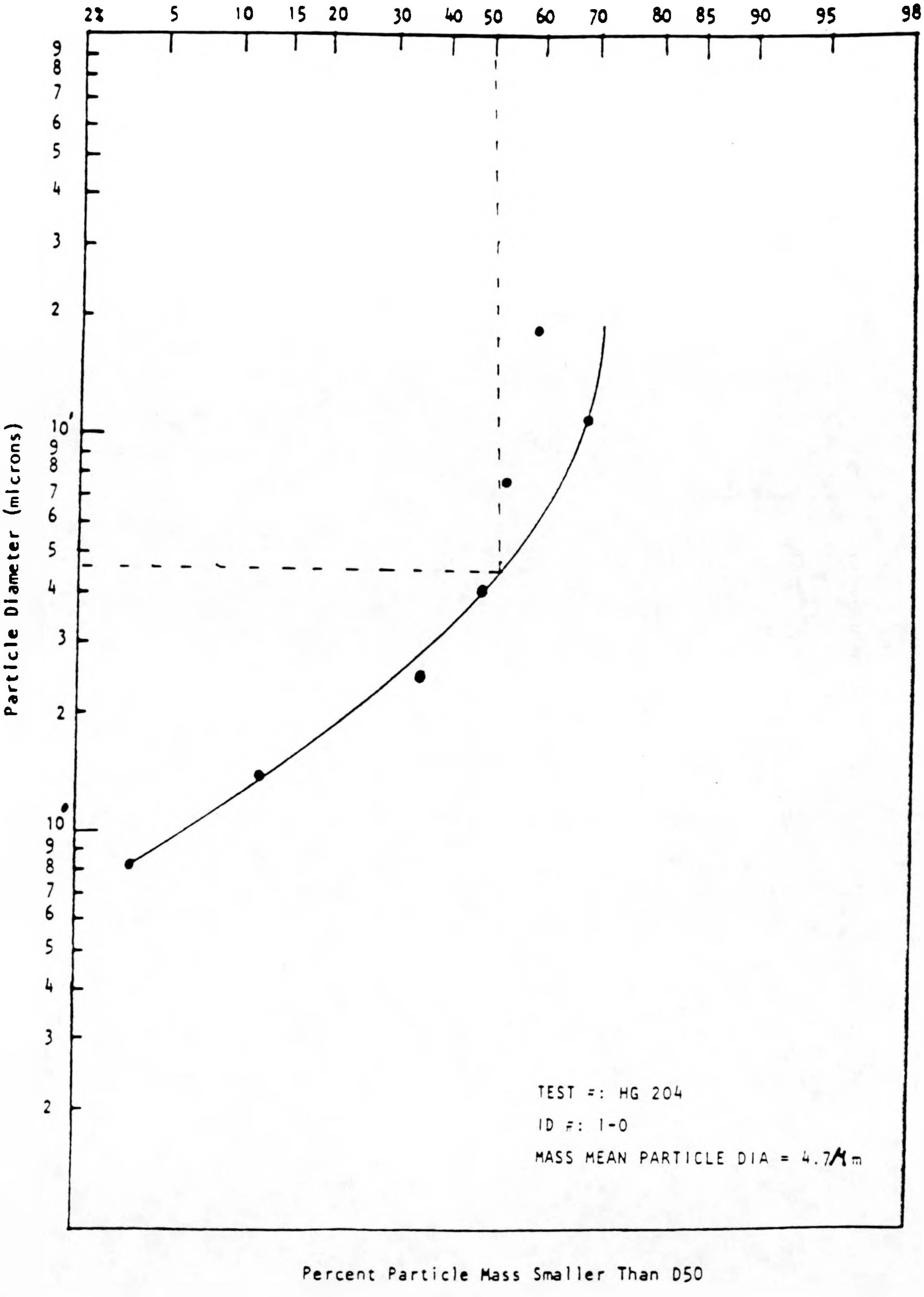
   VISCOSITY OF GAS STREAM                  0.0002503 GRAMS/CM-SEC
   STAGE          CCF          DP(CLAS AERO) DP(IMP AERO)   CUM FRACTION
     1           1.004           11.300        11.320          0.6833
     2           1.002           19.605        19.625          0.5833
     3           1.005            7.996         8.016          0.5250
     4           1.010            4.179         4.199          0.4750
     5           1.017            2.427         2.447          0.3583
     6           1.029            1.381         1.401          0.1250
     7           1.051            0.795         0.815          0.0333

   NOTE: THE MASS ON STAGES 1 AND 2 WILL BE COMBINED AND ASSIGNED TO
         THE OUTPUT ON STAGE 1 , FOR SPLINE FITTING ANALYSIS.

   TOTAL MASS PER DRY NORMAL CUBIC METER    7.7445 MG/CUBIC METER

   PART. DIAM. TYPE   C    (I=IMP AERO, C=CLAS AERO, P=PHYSICAL)
PARTICLE SIZE      CUMFR          CUMFR           CUM.MASS       dM/dLOG D
  (MICRONS)     (STD. DEV.)    (PER CENT)       (MG/DRY N.CU.METER)

     0.20         -3.3199          0.0             0.004           0.031
     0.25         -3.0796          0.1             0.008           0.067
     0.40         -2.5735          0.5             0.039           0.279
     0.50         -2.3332          1.0             0.076           0.504
     0.75         -1.8965          2.9             0.224           1.268
     1.00         -1.5682          5.8             0.452           2.477
     1.50         -1.0296         15.2             1.174           6.256
     2.00         -0.6019         27.4             2.119           8.280
     2.50         -0.3324         37.0             2.864           6.548
     4.00         -0.0730         47.1             3.647           1.804
     5.00         -0.0296         48.8             3.781           1.100
     7.50          0.0436         51.7             4.007           1.918
    10.00          0.1524         56.1             4.341           3.228
    15.00          0.4192         66.2             5.130           4.817
    20.00          0.6326         73.6             5.704           4.336
    25.00          0.7995         78.8             6.103           3.886
    40.00          1.1568         87.7             6.790           2.839
    50.00          1.3355         90.9             7.041           2.344
```


2% 5 10 15 20 30 40 50 60 70 80 85 90 95 98
9 8 7 6 5 4 3 2 10' 9 8 7 6 5 4 3 2 10⁰ 9 8 7 6 5 4 3 2
Particle Diameter (microns)
TEST #: HG 204
ID #: 1-0
MASS MEAN PARTICLE DIA = 4.7µm
Percent Particle Mass Smaller Than D50

```
*****    P A R T I C L E   S I Z E   A N A L Y S I S    *****

                    ****     INPUT DATA      ****

LATE OF TEST        05/11/88
TIME OF TEST        0438
LOCATION OF TEST    NYU-PFBC
TEST NUMBER         204
PART. DIAM. TYPE    C    (I=IMP AERO, C=CLAS AERO, P=PHYSICAL)
TEST TYPE           INLET
RUN NUMBER          2-I - FILE NAME: B:T204R2-I.INT
REMARKS:
IMPACTOR TYPE       UWVNYU


WATER VAPOR          3.00%
CARBON DIOXIDE      14.30%
CARBON MONOXIDE      0.00%
OXYGEN               4.40%
SULFUR DIOXIDE       0.00%
NITROGEN            81.30%
PARTICLE DENSITY    1.00 GRAMS/CM^3

GAS METER VOLUME                   7.360 CUBIC FEET
IMPACTOR DELTA P                   0.00  INCHES HG
ORIFICE DELTA P                    0.00  INCHES H20
STACK PRESS. (BELOW ATMOS.)        0.00  INCHES H20
BAROMETRIC PRESS.                %200.95  INCHES HG
STACK TEMPERATURE                413.3   DEGREES F
METER TEMPERATURE                413.3   DEGREES F
IMPACTOR TEMPERATURE             413.3   DEGREES F
SAMPLE TIME                       30.00  MINUTES
AV. VELOCITY OF STACK GAS          0.00  FEET/MINUTE
GAS METER PRESSURE                 0.00  IN HG
NOZZLE DIAMETER                    0.43  INCHES
MAXIMUM AERODYN. DIAMETER       1000.00  MICRONS

MASS GAIN ON STAGE  1               44.90 MG
MASS GAIN ON STAGE  2                3.90 MG
MASS GAIN ON STAGE  3               10.80 MG
MASS GAIN ON STAGE  4               26.70 MG
MASS GAIN ON STAGE  5               18.80 MG
MASS GAIN ON STAGE  6               14.50 MG
MASS GAIN ON STAGE  7                8.40 MG
MASS GAIN ON STAGE  8                3.70 MG
MASS GAIN ON STAGE  9                1.70 MG
MASS GAIN ON STAGE  10               0.60 MG
MASS GAIN ON STAGE  11               0.20 MG
MASS GAIN ON FINAL FILTER            0.70 MG
```

```
                        ****        RESULTS        ****

DATE OF TEST         05/11/88
TIME OF TEST         0438
LOCATION OF TEST     NYU-PFBC
TEST NUMBER          204  -
RUN NUMBER           2-I
ACTUAL FLOW RATE (STACK CONDITIONS)     0.253 CFM
FLOW RATE (STANDARD CONDITIONS)         0.996 CFM
PERCENT ISOKINETIC SAMPLING             0.00  %

VISCOSITY OF GAS STREAM                 0.0002464 GRAMS/CM-SEC
STAGE         CCF            DP(CLAS AERO) DP(IMP AERO)   CUM FRACTION
   1         1.002              18.536        18.556         0.6672
   2         1.002              19.282        19.302         0.6383
   3         1.005               8.562         8.583         0.5582
   4         1.010               4.133         4.153         0.3603
   5         1.017               2.386         2.407         0.2209
   6         1.026               1.577         1.597         0.1134
   7         1.030               1.358         1.378         0.0511
   8         1.042               0.978         0.998         0.0237
   9         1.049               0.832         0.852         0.0111
  10         1.057               0.720         0.741         0.0067
  11         1.067               0.613         0.633         0.0052

NOTE: THE MASS ON STAGES 1 AND 2 WILL BE COMBINED AND ASSIGNED TO
      THE OUTPUT ON STAGE 1 , FOR SPLINE FITTING ANALYSIS.

TOTAL MASS PER DRY NORMAL CUBIC METER  159.4698 MG/CUBIC METER

PART. DIAM. TYPE   C    (I=IMP AERO, C=CLAS AERO, P=PHYSICAL)
PARTICLE SIZE     CUMFR          CUMFR            CUM.MASS       dM/dLOG D
  (MICRONS)     (STD. DEV.)    (PER CENT)        (MG/DRY N.CU.METER)

    0.20         -3.1745          0.1              0.120          0.518
    0.25         -3.0527          0.1              0.182          0.758
    0.40         -2.7961          0.3              0.414          1.604
    0.50         -2.6743          0.4              0.599          2.239
    0.75         -2.4529          0.7              1.132          3.948
    1.00         -2.2959          1.1              1.731          5.733
    1.50         -2.0745          1.9              3.034          9.299
    2.00         -1.9174          2.8              4.401         12.722
    2.50         -1.7956          3.6              5.786         15.951
    4.00         -1.5390          6.2              9.870         24.467
    5.00         -1.4172          7.8             12.471         29.295
    7.50         -1.1959         11.6             18.476         39.119
   10.00         -1.0388         14.9             23.830         46.623
   15.00         -0.8175         20.7             32.983         57.257
   20.00         -0.6604         25.5             40.585         64.302
   25.00         -0.5386         29.5             47.058         69.174
   40.00         -0.2820         38.9             62.028         76.854
   50.00         -0.1602         43.6             69.595         78.952
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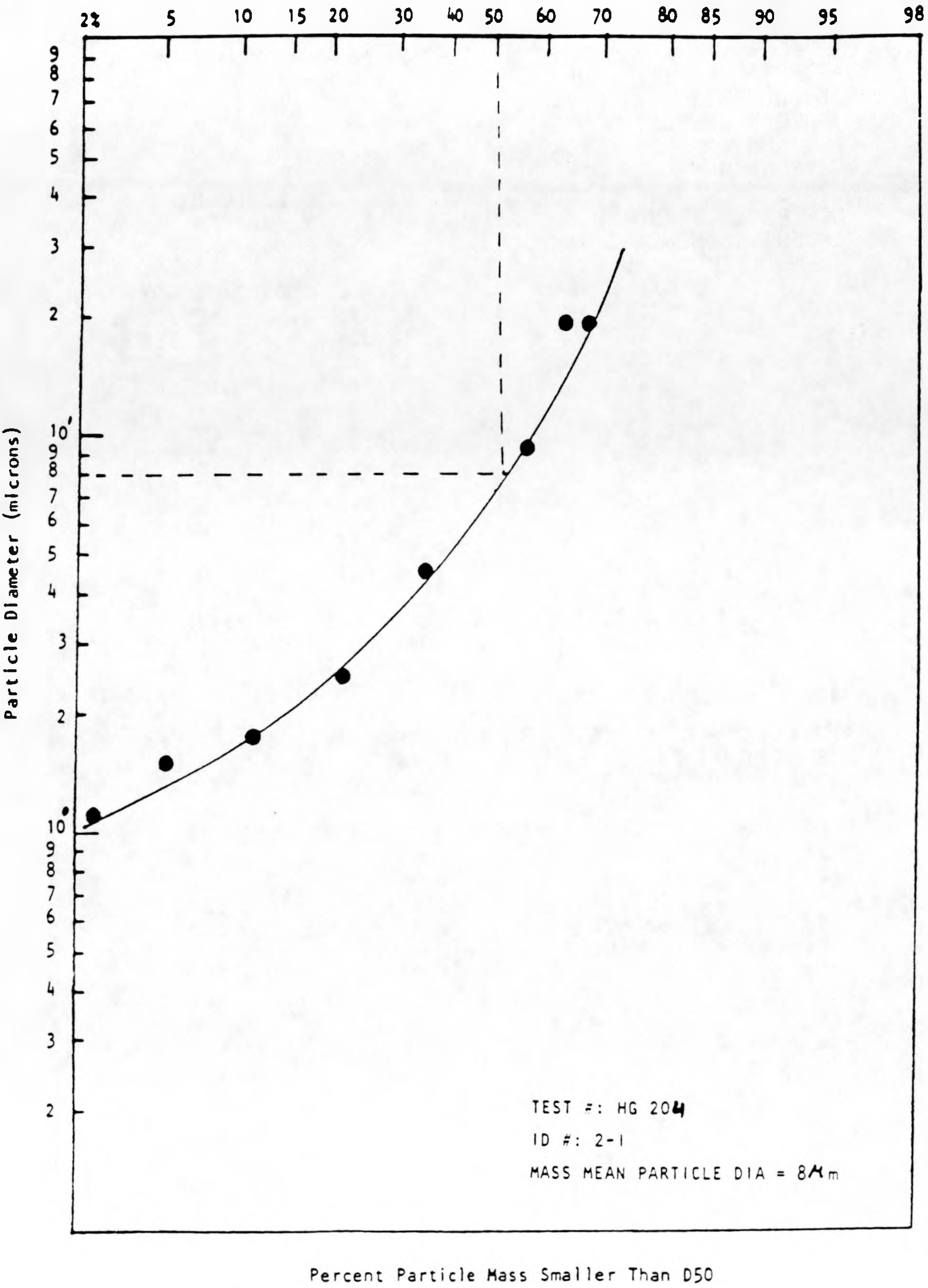
2%
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15
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80
85
90
95
98
Particle Diameter (microns)
9
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10'
9
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3
2
10°
9
8
7
6
5
4
3
2
TEST #: HG 204
ID #: 2-1
MASS MEAN PARTICLE DIA = 8μm
Percent Particle Mass Smaller Than D50

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*****     P A R T I C L E   S I Z E   A N A L Y S I S     *****

                    ****      INPUT DATA      ****

DATE OF TEST        05/11/88
TIME OF TEST        0427
LOCATION OF TEST    NYU-PFBC
TEST NUMBER         204
PART. DIAM. TYPE    C     (I=IMP AERO, C=CLAS AERO, P=PHYSICAL)
TEST TYPE           OUTLET
RUN NUMBER          2-D - FILE NAME: B:T204R2-I.OUT
REMARKS:
IMPACTOR TYPE       UW3NYU


WATER VAPOR          3.00%
CARBON DIOXIDE      14.30%
CARBON MONOXIDE      0.00%
OXYGEN               4.32%
SULFUR DIOXIDE       0.00%
NITROGEN            81.38%
PARTICLE DENSITY    1.00 GRAMS/CM^3

GAS METER VOLUME                    13.260 CUBIC FEET
IMPACTOR DELTA P                     0.00  INCHES HG
ORIFICE DELTA P                      0.00  INCHES H2O
STACK PRESS. (BELOW ATMOS.)          0.00  INCHES H2O
BAROMETRIC PRESS.                   %209.50  INCHES HG
STACK TEMPERATURE                  388.0   DEGREES F
METER TEMPERATURE                  388.0   DEGREES F
IMPACTOR TEMPERATURE               388.0   DEGREES F
SAMPLE TIME                         55.00  MINUTES
AV. VELOCITY OF STACK GAS            0.00  FEET/MINUTE
GAS METER PRESSURE                   0.00  IN HG
NOZZLE DIAMETER                      0.43  INCHES
MAXIMUM AERODYN. DIAMETER         1000.00  MICRONS

MASS GAIN ON STAGE  1                1.30 MG
MASS GAIN ON STAGE  2                1.40 MG
MASS GAIN ON STAGE  3                1.40 MG
MASS GAIN ON STAGE  4                1.40 MG
MASS GAIN ON STAGE  5                2.00 MG
MASS GAIN ON STAGE  6                3.90 MG
MASS GAIN ON STAGE  7                2.80 MG
MASS GAIN ON FINAL FILTER            0.20 MG
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                    ****        RESULTS        ****

   DATE OF TEST        05/11/88
   TIME OF TEST        0427
   LOCATION OF TEST    NYU-PFBC
   TEST NUMBER         204  -
   RUN NUMBER          2-0
   ACTUAL FLOW RATE (STACK CONDITIONS)      0.249 CFM
   FLOW RATE (STANDARD CONDITIONS)          1.051 CFM
   PERCENT ISOKINETIC SAMPLING              0.00  %

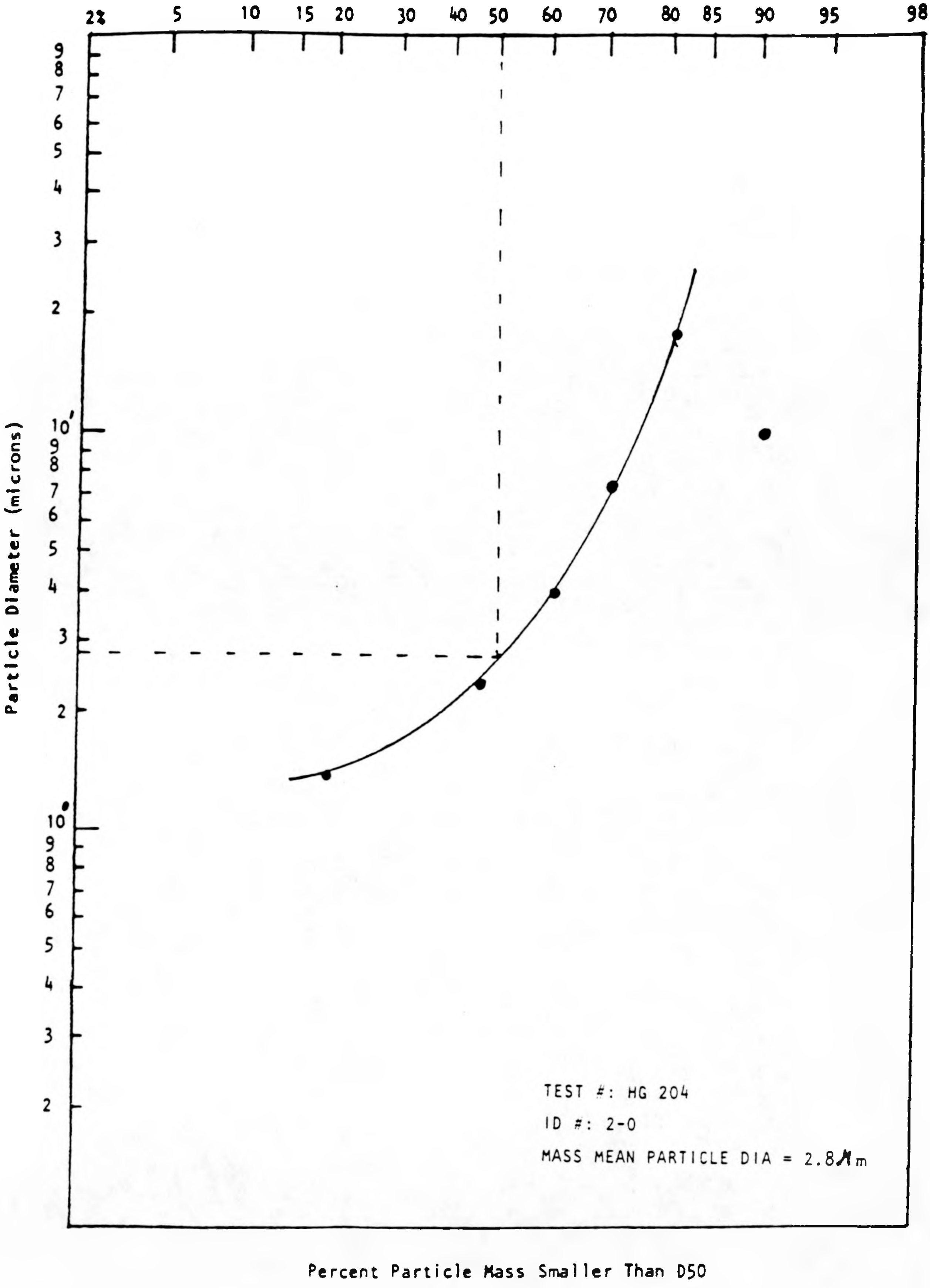
   VISCOSITY OF GAS STREAM                  0.0002412 GRAMS/CM-SEC
   STAGE          CCF          DP(CLAS AERO) DP(IMP AERO)   CUM FRACTION
     1           1.003           11.092         11.111          0.9097
     2           1.002           19.243         19.262          0.8125
     3           1.005            7.849          7.868          0.7153
     4           1.009            4.102          4.121          0.6181
     5           1.016            2.383          2.402          0.4792
     6           1.028            1.357          1.376          0.2083
     7           1.049            0.780          0.799          0.0139

   NOTE: THE MASS ON STAGES 1 AND 2 WILL BE COMBINED AND ASSIGNED TO
         THE OUTPUT ON STAGE 1 , FOR SPLINE FITTING ANALYSIS.

   TOTAL MASS PER DRY NORMAL CUBIC METER     8.8003 MG/CUBIC METER

   PART. DIAM. TYPE   C    (I=IMP AERO, C=CLAS AERO, P=PHYSICAL)
PARTICLE SIZE      CUMFR          CUMFR           CUM.MASS        dM/dLOG D
  (MICRONS)     (STD. DEV.)    (PER CENT)        (MG/DRY N.CU.METER)

    0.20          -7.1885         0.0             0.000           0.000
    0.25          -6.3710         0.0             0.000           0.000
    0.40          -4.6492         0.0             0.000           0.001
    0.50          -3.8318         0.0             0.001           0.019
    0.75          -2.3464         0.9             0.083           1.888
    1.00          -1.5255         6.4             0.559           6.609
    1.50          -0.6271        26.5             2.335          11.342
    2.00          -0.2272        41.0             3.609           8.815
    2.50          -0.0100        49.6             4.365           6.900
    4.00           0.2894        61.4             5.402           3.308
    5.00           0.3685        64.4             5.665           2.376
    7.50           0.5379        70.5             6.201           4.436
   10.00           0.7617        78.3             6.889           5.941
   15.00           1.3544        91.2             8.028           5.006
   20.00           1.8008        96.4             8.485           2.484
   25.00           2.1485        98.4             8.661           1.256
   40.00           2.8889        99.8             8.783           0.198
   50.00           3.2464        99.9             8.795           0.067
```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4
3
2
Particle Diameter (microns)
TEST #: HG 204
ID #: 2-0
MASS MEAN PARTICLE DIA = 2.8 μm
Percent Particle Mass Smaller Than D50

```
*****     P A R T I C L E   S I Z E   A N A L Y S I S     *****

                    ****     INPUT DATA      ****

DATE OF TEST          05/12/88
TIME OF TEST          0025
LOCATION OF TEST      NYU=PFBC
TEST NUMBER           204
PART. DIAM. TYPE      C    (I=IMP AERO, C=CLAS AERO, P=PHYSICAL)
TEST TYPE             INLET
RUN NUMBER            3-I - FILE NAME: B:T204R3-I.INT
REMARKS:
IMPACTOR TYPE         UWVNYU


WATER VAPOR           3.00%
CARBON DIOXIDE       14.03%
CARBON MONOXIDE       0.00%
OXYGEN                5.90%
SULFUR DIOXIDE        0.00%
NITROGEN             80.07%
PARTICLE DENSITY     1.00 GRAMS/CM^3

GAS METER VOLUME                    7.380 CUBIC FEET
IMPACTOR DELTA P                    0.00  INCHES HG
ORIFICE DELTA P                     0.00  INCHES H2O
STACK PRESS. (BELOW ATMOS.)         0.00  INCHES H2O
BAROMETRIC PRESS.                 %253.48  INCHES HG
STACK TEMPERATURE                 416.0   DEGREES F
METER TEMPERATURE                 416.0   DEGREES F
IMPACTOR TEMPERATURE              416.0   DEGREES F
SAMPLE TIME                        30.00  MINUTES
AV. VELOCITY OF STACK GAS           0.00  FEET/MINUTE
GAS METER PRESSURE                  0.00  IN HG
NOZZLE DIAMETER                     0.43  INCHES
MAXIMUM AERODYN. DIAMETER        1000.00  MICRONS

MASS GAIN ON STAGE  1                 147.80 MG
MASS GAIN ON STAGE  2                   6.50 MG
MASS GAIN ON STAGE  3                   7.30 MG
MASS GAIN ON STAGE  4                  34.60 MG
MASS GAIN ON STAGE  5                  10.00 MG
MASS GAIN ON STAGE  6                   6.50 MG
MASS GAIN ON STAGE  7                   3.80 MG
MASS GAIN ON STAGE  8                   2.20 MG
MASS GAIN ON STAGE  9                   0.80 MG
MASS GAIN ON STAGE  10                  0.20 MG
MASS GAIN ON STAGE  11                  0.60 MG
MASS GAIN ON FINAL FILTER               0.60 MG
```

```
                    ****         RESULTS         ****

DATE OF TEST          05/12/88
TIME OF TEST          0025
LOCATION OF TEST      NYU=PFBC
TEST NUMBER           204  -
RUN NUMBER            3-I
ACTUAL FLOW RATE (STACK CONDITIONS)       0.254 CFM
FLOW RATE (STANDARD CONDITIONS)           1.256 CFM
PERCENT ISOKINETIC SAMPLING               0.00  %

VISCOSITY OF GAS STREAM                   0.0002476 GRAMS/CM-SEC
STAGE         CCF          DP(CLAS AERO) DP(IMP AERO)   CUM FRACTION
  1          1.002            18.561        18.577         0.3309
  2          1.002            19.307        19.324         0.3015
  3          1.004             8.576         8.592         0.2684
  4          1.008             4.142         4.158         0.1118
  5          1.014             2.393         2.409         0.0665
  6          1.021             1.582         1.599         0.0371
  7          1.024             1.364         1.380         0.0199
  8          1.033             0.983         0.999         0.0100
  9          1.039             0.837         0.853         0.0063
 10          1.045             0.725         0.741         0.0054
 11          1.053             0.617         0.633         0.0027

NOTE: THE MASS ON STAGES 1 AND 2 WILL BE COMBINED AND ASSIGNED TO
      THE OUTPUT ON STAGE 1 , FOR SPLINE FITTING ANALYSIS.

TOTAL MASS PER DRY NORMAL CUBIC METER  207.0946 MG/CUBIC METER

PART. DIAM. TYPE   C    (I=IMP AERO, C=CLAS AERO, P=PHYSICAL)
PARTICLE SIZE       CUMFR          CUMFR           CUM.MASS        dM/dLOG D
  (MICRONS)      (STD. DEV.)    (PER CENT)        (MG/DRY N.CU.METER)

    0.20          -5.6844          0.0            0.000           0.000
    0.25          -5.1094          0.0            0.000           0.001
    0.40          -3.8983          0.0            0.010           0.246
    0.50          -3.3232          0.0            0.093           1.960
    0.75          -2.4987          0.6            1.293          12.128
    1.00          -2.0826          1.9            3.863          31.458
    1.50          -1.4962          6.7           13.937          89.840
    2.00          -1.0801         14.0           29.002         153.548
    2.50          -0.7573         22.4           46.477         206.546
    4.00          -0.0776         46.9           97.144         274.322
    5.00           0.2452         59.7          123.604         267.001
    7.50           0.8316         79.7          165.094         194.709
   10.00           1.2477         89.4          185.131         126.331
   15.00           1.8342         96.7          200.194          51.174
   20.00           2.2503         98.8          204.562          21.878
   25.00           2.5730         99.5          206.049          10.046
   40.00           3.2528         99.9          206.976           1.387
   50.00           3.5755        100.0          207.058           0.461
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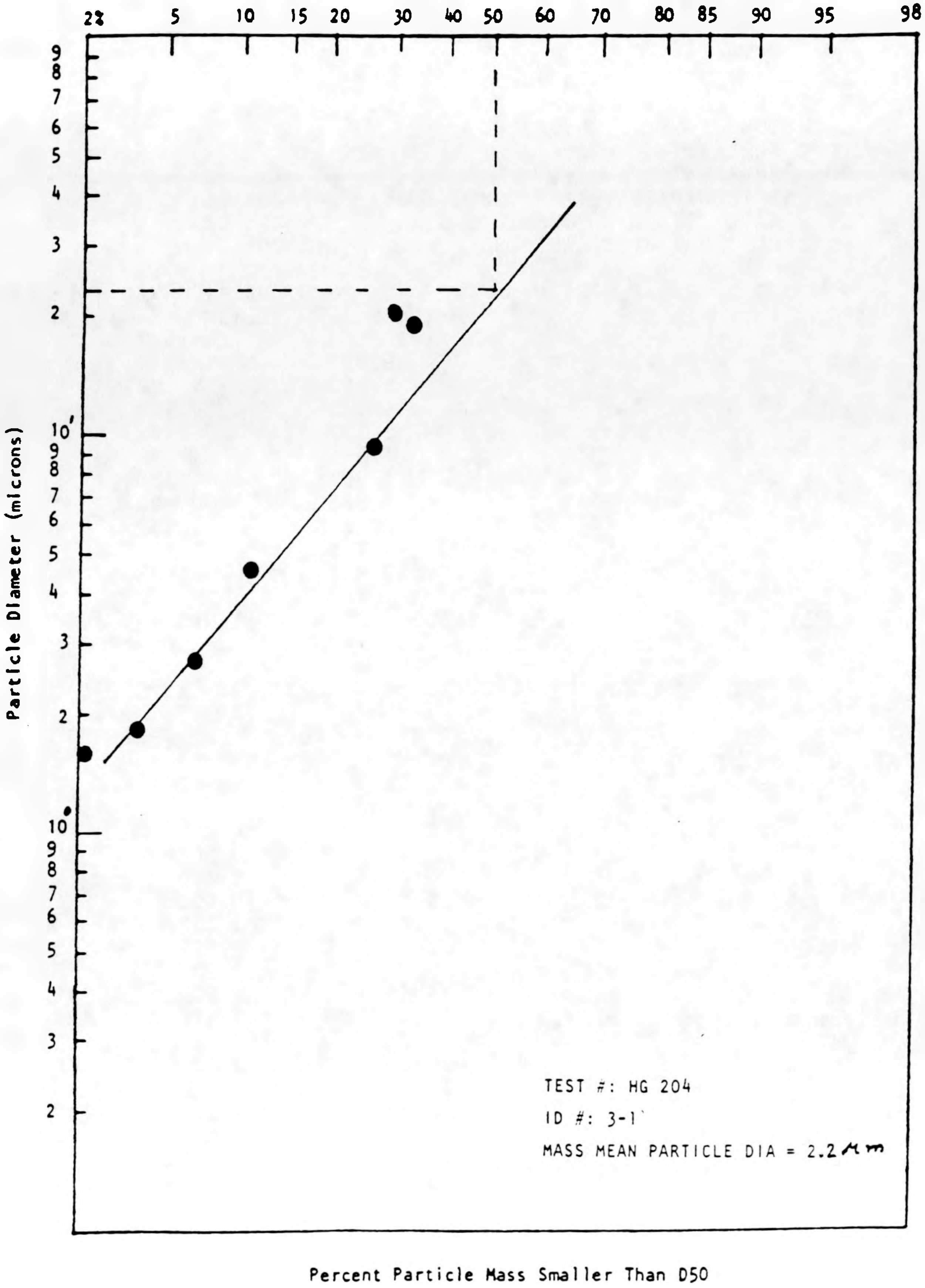
2% 5 10 15 20 30 40 50 60 70 80 85 90 95 98
9 8 7 6 5 4 3 2 10' 9 8 7 6 5 4 3 2 10° 9 8 7 6 5 4 3 2
Particle Diameter (microns)
TEST #: HG 204
ID #: 3-1
MASS MEAN PARTICLE DIA = 2.2 µm
Percent Particle Mass Smaller Than D50

```
*****     P A R T I C L E   S I Z E   A N A L Y S I S     *****

                    ****     INPUT DATA     ****

DATE OF TEST        05/12/88
TIME OF TEST        0010
LOCATION OF TEST    NYU-PFBC
TEST NUMBER         204
PART. DIAM. TYPE    C    (I=IMP AERO, C=CLAS AERO, P=PHYSICAL)
TEST TYPE           OUTLET
RUN NUMBER          3-O - FILE NAME: B:T204R3-O.OUT
REMARKS:
IMPACTOR TYPE       UW3NYU


WATER VAPOR          3.00%
CARBON DIOXIDE      14.20%
CARBON MONOXIDE      0.00%
OXYGEN               5.76%
SULFUR DIOXIDE       0.00%
NITROGEN            80.04%
PARTICLE DENSITY    1.00 GRAMS/CM^3

GAS METER VOLUME                 13.560 CUBIC FEET
IMPACTOR DELTA P                  0.00  INCHES HG
ORIFICE DELTA P                   0.00  INCHES H2O
STACK PRESS. (BELOW ATMOS.)       0.00  INCHES H2O
BAROMETRIC PRESS.                %261.93  INCHES HG
STACK TEMPERATURE               462.0   DEGREES F
METER TEMPERATURE               462.0   DEGREES F
IMPACTOR TEMPERATURE            462.0   DEGREES F
SAMPLE TIME                      55.00  MINUTES
AV. VELOCITY OF STACK GAS         0.00  FEET/MINUTE
GAS METER PRESSURE                0.00  IN HG
NOZZLE DIAMETER                   0.43  INCHES
MAXIMUM AERODYN. DIAMETER      1000.00  MICRONS

MASS GAIN ON STAGE  1                0.60 MG
MASS GAIN ON STAGE  2                0.70 MG
MASS GAIN ON STAGE  3                1.10 MG
MASS GAIN ON STAGE  4                1.00 MG
MASS GAIN ON STAGE  5                1.40 MG
MASS GAIN ON STAGE  6                2.00 MG
MASS GAIN ON STAGE  7                1.20 MG
MASS GAIN ON FINAL FILTER            1.00 MG
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                    ****        RESULTS        ****

     DATE OF TEST         05/12/88
     TIME OF TEST         0010
     LOCATION OF TEST     NYU-PFBC
     TEST NUMBER          204  -
     RUN NUMBER           3-0
     ACTUAL FLOW RATE (STACK CONDITIONS)      0.254 CFM
     FLOW RATE (STANDARD CONDITIONS)          1.236 CFM
     PERCENT ISOKINETIC SAMPLING              0.00  %

     VISCOSITY OF GAS STREAM                  0.0002569 GRAMS/CM-SEC
     STAGE          CCF          DP(CLAS AERO) DP(IMP AERO)   CUM FRACTION
        1          1.003            11.323        11.340         0.9333
        2          1.002            19.643        19.660         0.8556
        3          1.004             8.014         8.031         0.7333
        4          1.008             4.190         4.206         0.6222
        5          1.014             2.434         2.451         0.4667
        6          1.024             1.387         1.404         0.2444
        7          1.042             0.799         0.816         0.1111

     NOTE: THE MASS ON STAGES 1 AND 2 WILL BE COMBINED AND ASSIGNED TO
           THE OUTPUT ON STAGE 1 , FOR SPLINE FITTING ANALYSIS.

     TOTAL MASS PER DRY NORMAL CUBIC METER     4.6773 MG/CUBIC METER

     PART. DIAM. TYPE   C     (I=IMP AERO, C=CLAS AERO, P=PHYSICAL)
 PARTICLE SIZE      CUMFR            CUMFR          CUM.MASS       dM/dLOG D
   (MICRONS)     (STD. DEV.)      (PER CENT)         (MG/DRY N.CU.METER)

      0.20         -2.3803            0.9           0.041           0.212
      0.25         -2.1934            1.4           0.066           0.324
      0.40         -1.8000            3.6           0.168           0.712
      0.50         -1.6131            5.3           0.250           0.979
      0.75         -1.2737           10.1           0.474           1.598
      1.00         -1.0148           15.5           0.725           2.398
      1.50         -0.6077           27.2           1.271           3.900
      2.00         -0.2887           38.6           1.807           4.504
      2.50         -0.0577           47.7           2.231           4.110
      4.00          0.2893           61.4           2.871           2.030
      5.00          0.3755           64.6           3.023           1.298
      7.50          0.5655           71.4           3.340           2.854
     10.00          0.8859           81.2           3.799           3.959
     15.00          1.6852           95.4           4.462           2.308
     20.00          2.3252           99.0           4.630           0.641
     25.00          2.8231           99.8           4.666           0.179
     40.00          3.8794          100.0           4.677           0.005
     50.00          4.3870          100.0           4.677           0.001
```

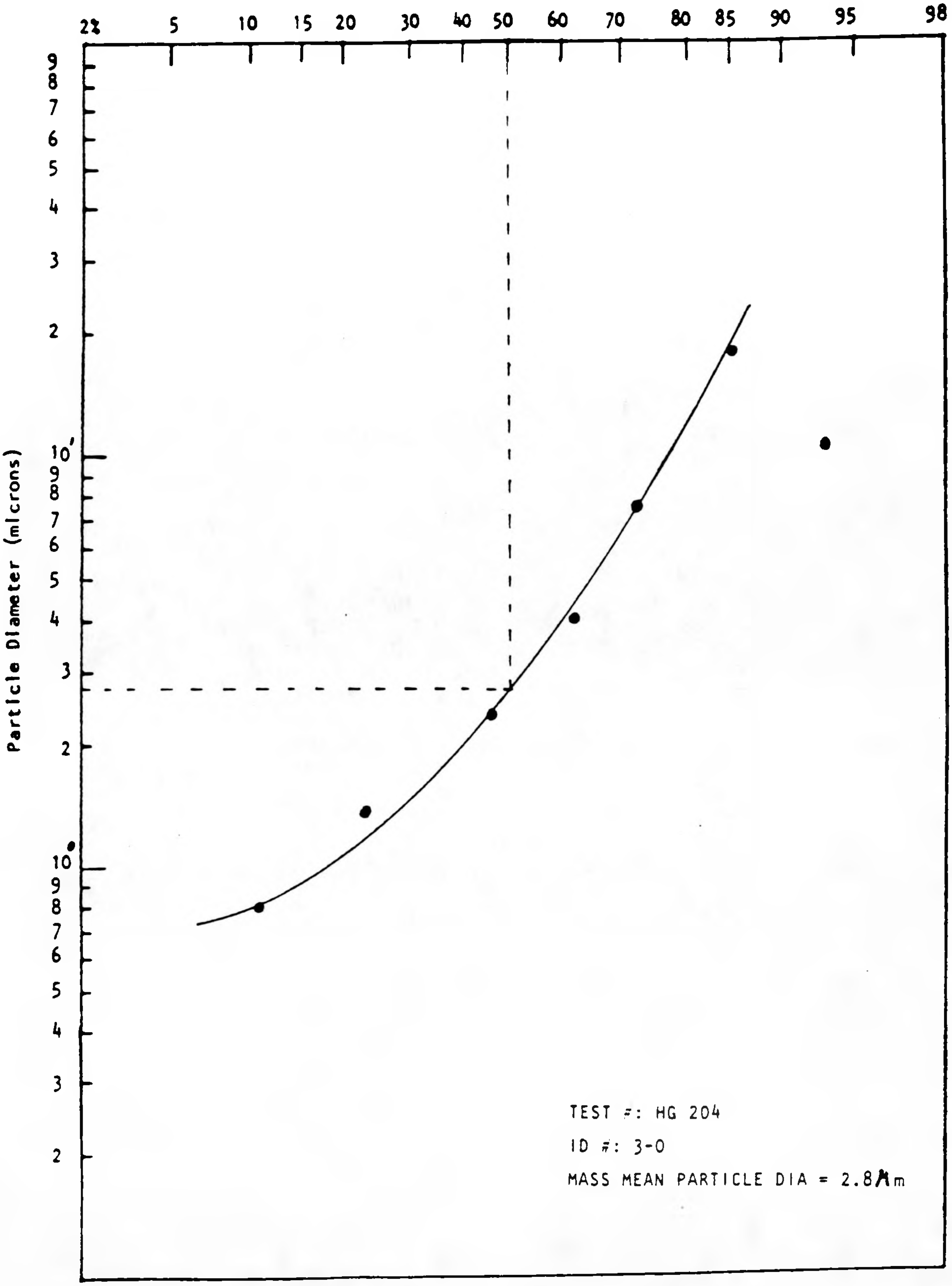

Percent Particle Mass Smaller Than D50

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     *****     P A R T I C L E   S I Z E   A N A L Y S I S     *****

                         ****     INPUT DATA     ****

DATE OF TEST        05/12/88
TIME OF TEST        1830
LOCATION OF TEST    NYU-PFBC
TEST NUMBER         204
PART. DIAM. TYPE    C    (I=IMP AERO, C=CLAS AERO, P=PHYSICAL)
TEST TYPE           INLET
RUN NUMBER          4-I - FILE NAME: B:T204R4-I.INT
REMARKS:
IMPACTOR TYPE       UWVNYU


WATER VAPOR          3.00%
CARBON DIOXIDE      14.28%
CARBON MONOXIDE      0.00%
OXYGEN               5.61%
SULFUR DIOXIDE       0.00%
NITROGEN            80.11%
PARTICLE DENSITY    1.00 GRAMS/CM^3

GAS METER VOLUME                 7.260 CUBIC FEET
IMPACTOR DELTA P                 0.00  INCHES HG
ORIFICE DELTA P                  0.00  INCHES H2O
STACK PRESS. (BELOW ATMOS.)      0.00  INCHES H2O
BAROMETRIC PRESS.               %243.10  INCHES HG
STACK TEMPERATURE              404.3   DEGREES F
METER TEMPERATURE              404.3   DEGREES F
IMPACTOR TEMPERATURE           404.3   DEGREES F
SAMPLE TIME                     30.00  MINUTES
AV. VELOCITY OF STACK GAS        0.00  FEET/MINUTE
GAS METER PRESSURE               0.00  IN HG
NOZZLE DIAMETER                  0.43  INCHES
MAXIMUM AERODYN. DIAMETER     1000.00  MICRONS

MASS GAIN ON STAGE  1             138.90 MG
MASS GAIN ON STAGE  2               4.20 MG
MASS GAIN ON STAGE  3               7.20 MG
MASS GAIN ON STAGE  4              21.30 MG
MASS GAIN ON STAGE  5              12.50 MG
MASS GAIN ON STAGE  6               8.90 MG
MASS GAIN ON STAGE  7               5.20 MG
MASS GAIN ON STAGE  8               3.20 MG
MASS GAIN ON STAGE  9               1.70 MG
MASS GAIN ON STAGE  10              1.00 MG
MASS GAIN ON STAGE  11              0.20 MG
MASS GAIN ON FINAL FILTER           0.10 MG
```

```
                          ****        RESULTS        ****

    DATE OF TEST         05/12/88
    TIME OF TEST         1830
    LOCATION OF TEST     NYU-PFBC
    TEST NUMBER          204  -
    RUN NUMBER           4-I
    ACTUAL FLOW RATE (STACK CONDITIONS)     0.249 CFM
    FLOW RATE (STANDARD CONDITIONS)         1.201 CFM
    PERCENT ISOKINETIC SAMPLING             0.00  %

    VISCOSITY OF GAS STREAM                 0.0002451 GRAMS/CM-SEC
    STAGE          CCF          DP(CLAS AERO) DP(IMP AERO)   CUM FRACTION
       1          1.002           18.615        18.632         0.3205
       2          1.002           19.364        19.381         0.2999
       3          1.004            8.601         8.618         0.2647
       4          1.008            4.154         4.170         0.1605
       5          1.014            2.400         2.416         0.0993
       6          1.021            1.587         1.604         0.0558
       7          1.025            1.367         1.384         0.0303
       8          1.034            0.985         1.002         0.0147
       9          1.040            0.839         0.856         0.0064
      10          1.046            0.727         0.744         0.0015
      11          1.054            0.619         0.635         0.0005

    NOTE: THE MASS ON STAGES 1 AND 2 WILL BE COMBINED AND ASSIGNED TO
          THE OUTPUT ON STAGE 1 , FOR SPLINE FITTING ANALYSIS.

    TOTAL MASS PER DRY NORMAL CUBIC METER  200.3977 MG/CUBIC METER

    PART. DIAM. TYPE   C    (I=IMP AERO, C=CLAS AERO, P=PHYSICAL)
 PARTICLE SIZE      CUMFR           CUMFR           CUM.MASS       dM/dLOG D
   (MICRONS)     (STD. DEV.)     (PER CENT)       (MG/DRY N.CU.METER)

     0.20          -3.9120           0.0            0.009          0.048
     0.25          -3.7905           0.0            0.015          0.076
     0.40          -3.5345           0.0            0.041          0.194
     0.50          -3.4129           0.0            0.065          0.296
     0.75          -2.9125           0.2            0.360          5.291
     1.00          -2.3378           1.0            1.946         23.916
     1.50          -1.5279           6.3           12.677        114.434
     2.00          -0.9533          17.0           34.111        233.433
     2.50          -0.5076          30.6           61.299        323.263
     4.00           0.4313          66.7          133.635        335.053
     5.00           0.8770          81.0          162.272        250.319
     7.50           1.6869          95.4          191.217         88.633
    10.00           2.2615          98.8          198.018         28.504
    15.00           3.0714          99.9          200.183          3.289
    20.00           3.6461         100.0          200.371          0.477
    25.00           4.0918         100.0          200.393          0.085
    40.00           5.0505         100.0          200.396          0.001
    50.00           5.4763         100.0          200.398          0.000
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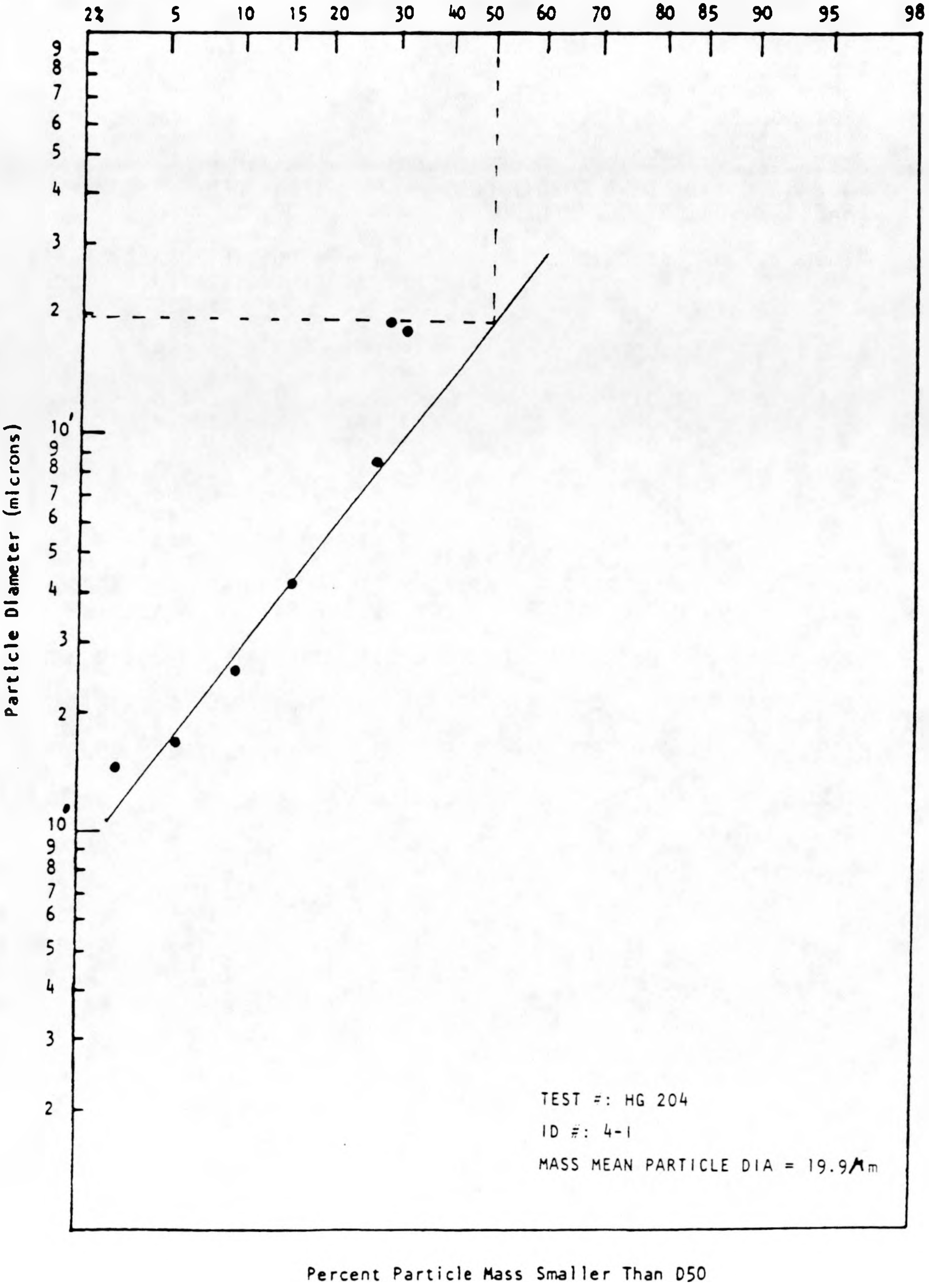
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2
Particle Diameter (microns)
TEST #: HG 204
ID #: 4-1
MASS MEAN PARTICLE DIA = 19.9 μm
Percent Particle Mass Smaller Than D50

```
*****     P A R T I C L E   S I Z E   A N A L Y S I S     *****

                    ****     INPUT DATA     ****

DATE OF TEST         05/12/88
TIME OF TEST         1910
LOCATION OF TEST     NYU-PFBC
TEST NUMBER          204
PART. DIAM. TYPE     C    (I=IMP AERO, C=CLAS AERO, P=PHYSICAL)
TEST TYPE            OUTLET
RUN NUMBER           4-O - FILE NAME: B:T204R4-O.OUT
REMARKS:
IMPACTOR TYPE        UW3NYU


WATER VAPOR           3.00%
CARBON DIOXIDE       13.96%
CARBON MONOXIDE       0.00%
OXYGEN                5.86%
SULFUR DIOXIDE        0.00%
NITROGEN             80.18%
PARTICLE DENSITY     1.00 GRAMS/CM^3

GAS METER VOLUME                  13.480 CUBIC FEET
IMPACTOR DELTA P                   0.00  INCHES HG
ORIFICE DELTA P                    0.00  INCHES H2O
STACK PRESS. (BELOW ATMOS.)        0.00  INCHES H2O
BAROMETRIC PRESS.                %241.70  INCHES HG
STACK TEMPERATURE                436.0   DEGREES F
METER TEMPERATURE                436.0   DEGREES F
IMPACTOR TEMPERATURE             436.0   DEGREES F
SAMPLE TIME                       55.00  MINUTES
AV. VELOCITY OF STACK GAS          0.00  FEET/MINUTE
GAS METER PRESSURE                 0.00  IN HG
NOZZLE DIAMETER                    0.43  INCHES
MAXIMUM AERODYN. DIAMETER       1000.00  MICRONS

MASS GAIN ON STAGE  1                0.10 MG
MASS GAIN ON STAGE  2                0.70 MG
MASS GAIN ON STAGE  3                0.50 MG
MASS GAIN ON STAGE  4                1.40 MG
MASS GAIN ON STAGE  5                1.30 MG
MASS GAIN ON STAGE  6                3.60 MG
MASS GAIN ON STAGE  7                2.00 MG
MASS GAIN ON FINAL FILTER            1.40 MG
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                        ****         RESULTS          ****

     DATE OF TEST          05/12/88
     TIME OF TEST          1910
     LOCATION OF TEST      NYU-PFBC
     TEST NUMBER           204  -
     RUN NUMBER            4-0
     ACTUAL FLOW RATE (STACK CONDITIONS)       0.253 CFM
     FLOW RATE (STANDARD CONDITIONS)           1.167 CFM
     PERCENT ISOKINETIC SAMPLING               0.00  %

     VISCOSITY OF GAS STREAM                   0.0002517 GRAMS/CM-SEC
     STAGE          CCF           DP(CLAS AERO) DP(IMP AERO)   CUM FRACTION
        1          1.003             11.241        11.258         0.9909
        2          1.002             19.501        19.519         0.9273
        3          1.004              7.955         7.973         0.8818
        4          1.008              4.158         4.176         0.7545
        5          1.015              2.416         2.434         0.6364
        6          1.026              1.376         1.394         0.3091
        7          1.045              0.792         0.810         0.1273

     NOTE: THE MASS ON STAGES 1 AND 2 WILL BE COMBINED AND ASSIGNED TO
           THE OUTPUT ON STAGE 1 , FOR SPLINE FITTING ANALYSIS.

     TOTAL MASS PER DRY NORMAL CUBIC METER    6.0562 MG/CUBIC METER

     PART. DIAM. TYPE   C    (I=IMP AERO, C=CLAS AERO, P=PHYSICAL)
 PARTICLE SIZE     CUMFR           CUMFR          CUM.MASS         dM/dLOG D
   (MICRONS)     (STD. DEV.)    (PER CENT)      (MG/DRY N.CU.METER)

      0.20        -2.2719          1.2            0.070             0.347
      0.25        -2.0883          1.8            0.111             0.517
      0.40        -1.7017          4.4            0.269             1.076
      0.50        -1.5181          6.4            0.391             1.446
      0.75        -1.1846         11.8            0.715             2.269
      1.00        -0.8990         18.4            1.116             4.043
      1.50        -0.3656         35.7            2.164             8.272
      2.00         0.0980         53.9            3.265             8.392
      2.50         0.3836         64.9            3.933             5.078
      4.00         0.6679         74.8            4.529             2.287
      5.00         0.8072         79.0            4.786             2.904
      7.50         1.1354         87.2            5.280             2.439
     10.00         1.3659         91.4            5.536             1.696
     15.00         1.6528         95.1            5.758             0.970
     20.00         1.8500         96.8            5.861             0.692
     25.00         2.0044         97.7            5.920             0.519
     40.00         2.3374         99.0            5.997             0.263
     50.00         2.5015         99.4            6.019             0.182
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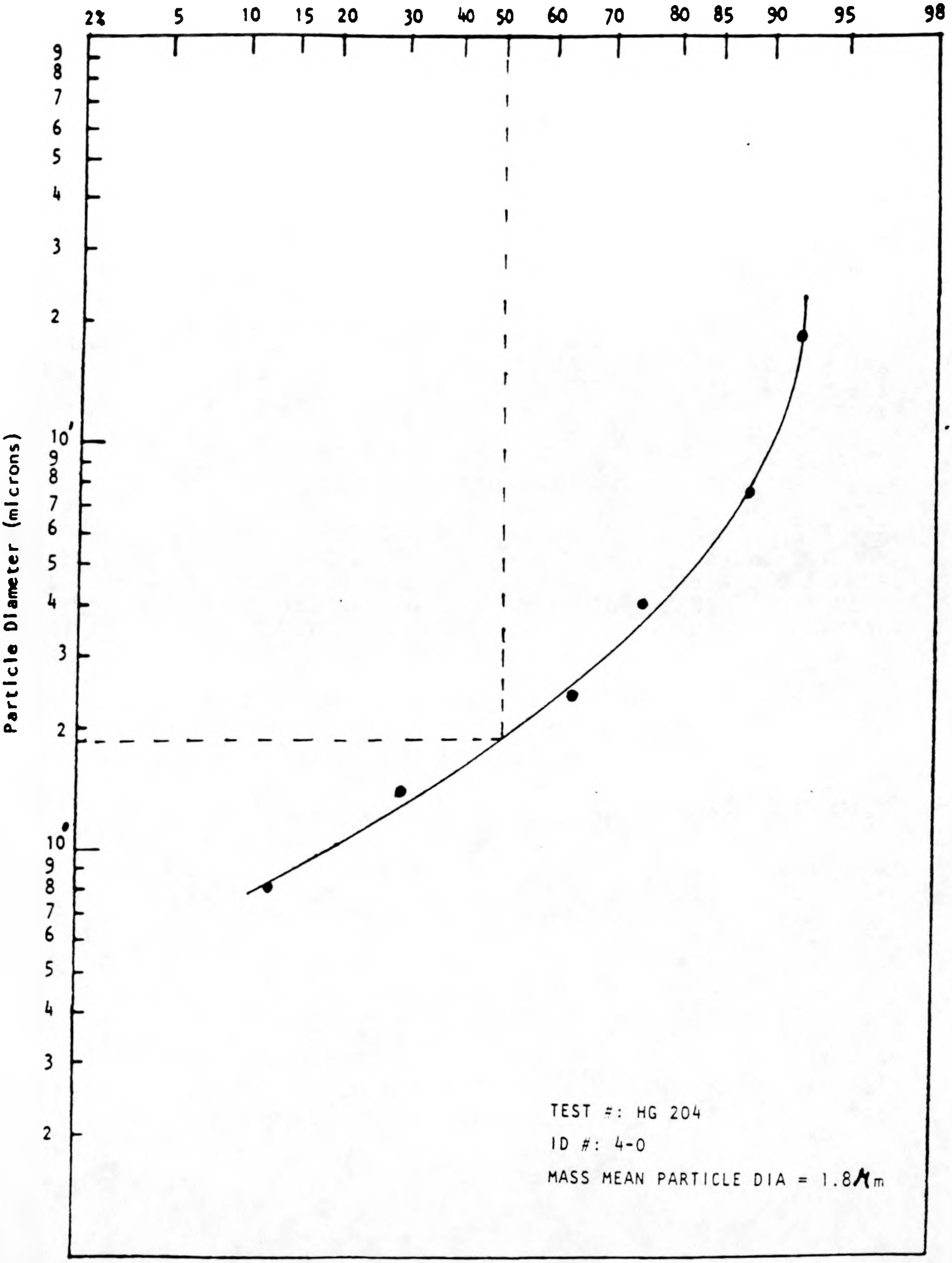

Percent Particle Mass Smaller Than D50

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     *****      PARTICLE SIZE ANALYSIS      *****

                      ****     INPUT DATA     ****

DATE OF TEST         05/13/88
TIME OF TEST         1450
LOCATION OF TEST     NYU-PFBC
TEST NUMBER          204
PART. DIAM. TYPE     C    (I=IMP AERO, C=CLAS AERO, P=PHYSICAL)
TEST TYPE            INLET
RUN NUMBER           5-I - FILE NAME: B:T204R5-I.INT
REMARKS:
IMPACTOR TYPE        UWVNYU


WATER VAPOR          3.00%
CARBON DIOXIDE      13.47%
CARBON MONOXIDE      0.00%
OXYGEN               5.26%
SULFUR DIOXIDE       0.00%
NITROGEN            81.27%
PARTICLE DENSITY    1.00 GRAMS/CM^3

GAS METER VOLUME                     4.350 CUBIC FEET
IMPACTOR DELTA P                     0.00  INCHES HG
ORIFICE DELTA P                      0.00  INCHES H2O
STACK PRESS. (BELOW ATMOS.)          0.00  INCHES H2O
BAROMETRIC PRESS.                  %241.10  INCHES HG
STACK TEMPERATURE                  470.0   DEGREES F
METER TEMPERATURE                  470.0   DEGREES F
IMPACTOR TEMPERATURE               470.0   DEGREES F
SAMPLE TIME                         17.00  MINUTES
AV. VELOCITY OF STACK GAS            0.00  FEET/MINUTE
GAS METER PRESSURE                   0.00  IN HG
NOZZLE DIAMETER                      0.43  INCHES
MAXIMUM AERODYN. DIAMETER         1000.00  MICRONS

MASS GAIN ON STAGE  1                  372.70 MG
MASS GAIN ON STAGE  2                    2.70 MG
MASS GAIN ON STAGE  3                    2.80 MG
MASS GAIN ON STAGE  4                    6.50 MG
MASS GAIN ON STAGE  5                    7.60 MG
MASS GAIN ON STAGE  6                    6.30 MG
MASS GAIN ON STAGE  7                    3.00 MG
MASS GAIN ON STAGE  8                    1.60 MG
MASS GAIN ON STAGE  9                    0.50 MG
MASS GAIN ON STAGE  10                   0.10 MG
MASS GAIN ON STAGE  11                   0.10 MG
MASS GAIN ON FINAL FILTER                0.10 MG
```

```
                         ****        RESULTS        ****

DATE OF TEST          05/13/88
TIME OF TEST          1450
LOCATION OF TEST      NYU-PFBC
TEST NUMBER           204  -
RUN NUMBER            5-I
ACTUAL FLOW RATE (STACK CONDITIONS)     0.264 CFM
FLOW RATE (STANDARD CONDITIONS)         1.171 CFM
PERCENT ISOKINETIC SAMPLING             0.00  %

VISCOSITY OF GAS STREAM                 0.0002584 GRAMS/CM-SEC
STAGE          CCF           DP(CLAS AERO) DP(IMP AERO)   CUM FRACTION
   1          1.002             18.588        18.607         0.0775
   2          1.002             19.336        19.355         0.0708
   3          1.004              8.588         8.606         0.0639
   4          1.009              4.146         4.165         0.0478
   5          1.015              2.395         2.413         0.0290
   6          1.023              1.583         1.601         0.0134
   7          1.027              1.364         1.382         0.0059
   8          1.038              0.982         1.001         0.0020
   9          1.044              0.836         0.854         0.0007
  10          1.051              0.724         0.743         0.0005
  11          1.060              0.616         0.634         0.0002

NOTE: THE MASS ON STAGES 1 AND 2 WILL BE COMBINED AND ASSIGNED TO
      THE OUTPUT ON STAGE 1 , FOR SPLINE FITTING ANALYSIS.

TOTAL MASS PER DRY NORMAL CUBIC METER  717.2106 MG/CUBIC METER

PART. DIAM. TYPE   C    (I=IMP AERO, C=CLAS AERO, P=PHYSICAL)
PARTICLE SIZE     CUMFR          CUMFR          CUM.MASS      dM/dLOG D
  (MICRONS)     (STD. DEV.)   (PER CENT)       (MG/DRY N.CU.METER)

    0.20          -5.2470         0.0           0.000         0.001
    0.25          -4.8973         0.0           0.000         0.006
    0.40          -4.1607         0.0           0.011         0.180
    0.50          -3.8110         0.0           0.050         0.725
    0.75          -3.2525         0.1           0.412         3.907
    1.00          -2.9143         0.2           1.283        11.085
    1.50          -2.4376         0.7           5.309        39.694
    2.00          -2.0994         1.8          12.837        85.491
    2.50          -1.8371         3.3          23.740       143.273
    4.00          -1.2846         9.9          71.333       339.402
    5.00          -1.0222        15.3         109.965       459.325
    7.50          -0.5456        29.3         209.919       667.423
   10.00          -0.2074        41.8         299.687       758.049
   15.00           0.2693        60.6         434.739       746.944
   20.00           0.6075        72.8         522.295       644.016
   25.00          -1.4703         7.1          50.727         0.297
   40.00          -1.4661         7.1          51.135         4.533
   50.00          -1.4598         7.2          51.761         8.665
```

Mass Mean Particle Diameter
From Impactor Log-probability Plots
Test # HG - 204

I D No.	FILTER INLET (microns)	FILTER OUTLET (microns)
HG204-1	21.0*	4.7
HG204-2	8.0	2.8
HG204-3	22.0	2.8
HG204-4	19.9	1.8

* Probability curve extrapolated.

```
*****     P A R T I C L E   S I Z E   A N A L Y S I S     *****

                   ****     INPUT DATA     ****

 DATE OF TEST         06/07/88
 TIME OF TEST         1430
 LOCATION OF TEST     NYU-PFBC
 TEST NUMBER          205
 PART. DIAM. TYPE     C    (I=IMP AERO, C=CLAS AERO, P=PHYSICAL)
 TEST TYPE            INLET
 RUN NUMBER           3-I - FILE NAME: B:T205R3-I.INT
 REMARKS:             DATA ANALYSIS
 IMPACTOR TYPE        UWVNYU


 WATER VAPOR           3.00%
 CARBON DIOXIDE       17.20%
 CARBON MONOXIDE       0.00%
 OXYGEN                3.00%
 SULFUR DIOXIDE        0.00%
 NITROGEN             79.80%
 PARTICLE DENSITY     1.00 GRAMS/CM^3

 GAS METER VOLUME                 13.670 CUBIC FEET
 IMPACTOR DELTA P                   0.00  INCHES HG
 ORIFICE DELTA P                    0.00  INCHES H2O
 STACK PRESS. (BELOW ATMOS.)        0.00  INCHES H2O
 BAROMETRIC PRESS.                %237.10  INCHES HG
 STACK TEMPERATURE                532.5   DEGREES F
 METER TEMPERATURE                532.5   DEGREES F
 IMPACTOR TEMPERATURE             532.5   DEGREES F
 SAMPLE TIME                       30.00  MINUTES
 AV. VELOCITY OF STACK GAS          0.00  FEET/MINUTE
 GAS METER PRESSURE                 0.00  IN HG
 NOZZLE DIAMETER                    0.43  INCHES
 MAXIMUM AERODYN. DIAMETER       1000.00  MICRONS

 MASS GAIN ON STAGE  1              151.80 MG
 MASS GAIN ON STAGE  2               16.30 MG
 MASS GAIN ON STAGE  3               36.70 MG
 MASS GAIN ON STAGE  4               56.40 MG
 MASS GAIN ON STAGE  5               31.00 MG
 MASS GAIN ON STAGE  6               18.50 MG
 MASS GAIN ON STAGE  7                8.00 MG
 MASS GAIN ON STAGE  8                2.60 MG
 MASS GAIN ON STAGE  9                1.00 MG
 MASS GAIN ON STAGE  10               0.40 MG
 MASS GAIN ON STAGE  11               1.00 MG
 MASS GAIN ON FINAL FILTER            0.40 MG
```

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                          ****        RESULTS        ****

    DATE OF TEST        06/07/88
    TIME OF TEST        1430
    LOCATION OF TEST    NYU-PFBC
    TEST NUMBER         205  -
    RUN NUMBER          3-I
    ACTUAL FLOW RATE (STACK CONDITIONS)     0.470 CFM
    FLOW RATE (STANDARD CONDITIONS)         1.921 CFM
    PERCENT ISOKINETIC SAMPLING             0.00  %

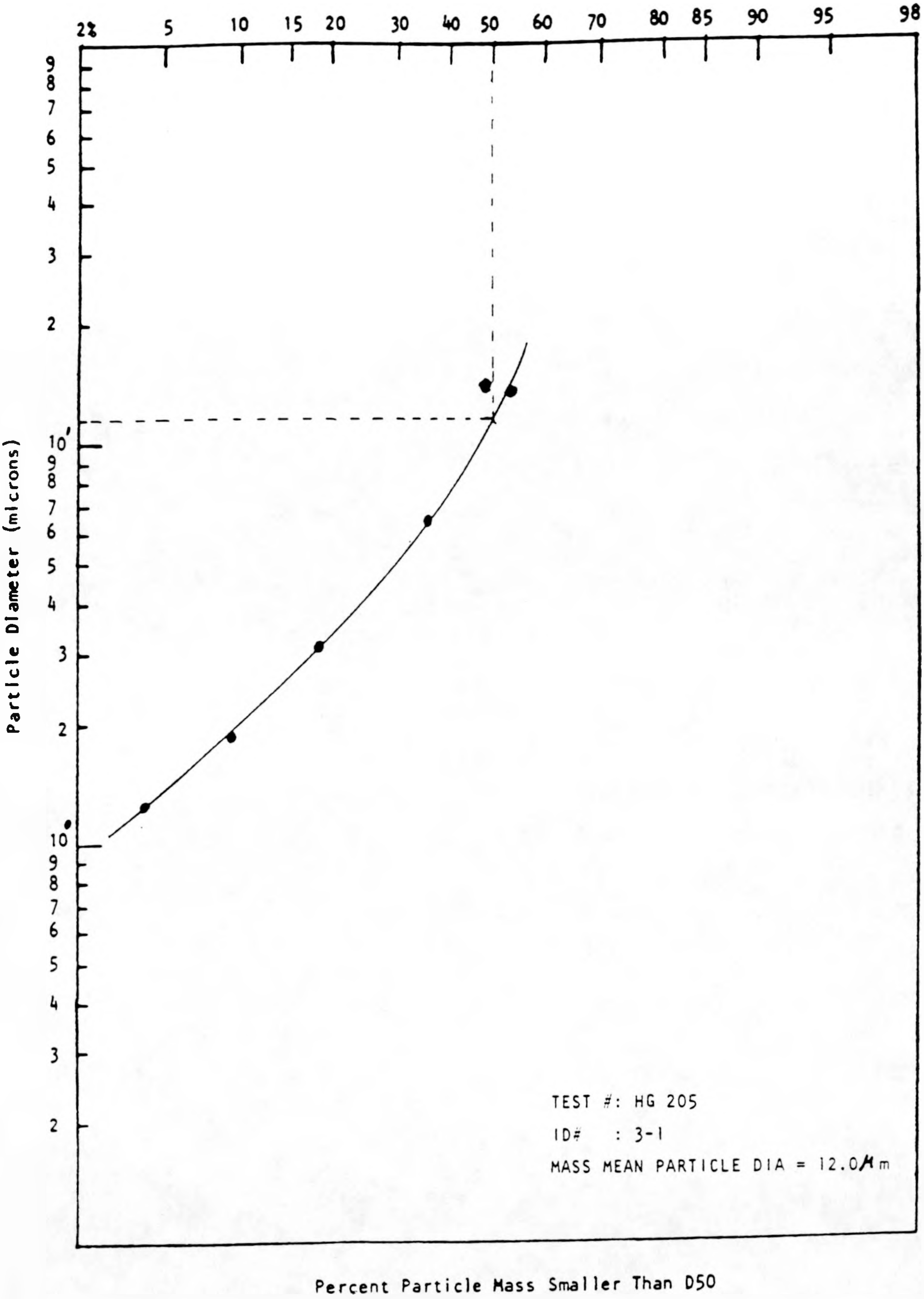
    VISCOSITY OF GAS STREAM                 0.0002692 GRAMS/CM-SEC
    STAGE         CCF          DP(CLAS AERO) DP(IMP AERO)   CUM FRACTION
      1          1.003             14.210        14.231         0.5316
      2          1.003             14.783        14.803         0.4813
      3          1.006              6.562         6.582         0.3681
      4          1.013              3.165         3.185         0.1941
      5          1.022              1.826         1.846         0.0984
      6          1.033              1.205         1.225         0.0413
      7          1.039              1.037         1.057         0.0167
      8          1.054              0.746         0.766         0.0086
      9          1.064              0.634         0.654         0.0056
     10          1.073              0.548         0.568         0.0043
     11          1.087              0.465         0.485         0.0012

    NOTE: THE MASS ON STAGES 1 AND 2 WILL BE COMBINED AND ASSIGNED TO
          THE OUTPUT ON STAGE 1 , FOR SPLINE FITTING ANALYSIS.

    TOTAL MASS PER DRY NORMAL CUBIC METER  198.6911 MG/CUBIC METER

    PART. DIAM. TYPE   C    (I=IMP AERO, C=CLAS AERO, P=PHYSICAL)
 PARTICLE SIZE      CUMFR          CUMFR          CUM.MASS       dM/dLOG D
   (MICRONS)     (STD. DEV.)   (PER CENT)       (MG/DRY N.CU.METER)

     0.20         -6.7525          0.0           0.000          0.000
     0.25         -5.7685          0.0           0.000          0.000
     0.40         -3.6959          0.0           0.022          0.870
     0.50         -2.8524          0.2           0.432          7.643
     0.75         -1.8602          3.1           6.246         79.174
     1.00         -1.1562         12.4          24.597        228.919
     1.50         -0.1640         43.5          86.404        440.669
     2.00          0.5400         70.5         140.156        386.037
     2.50          1.0861         86.1         171.129        247.640
     4.00          2.2362         98.7         196.172         36.652
     5.00          2.7822         99.7         198.153          9.312
     7.50          3.7744        100.0         198.675          0.360
    10.00          4.4784        100.0         198.690          0.020
    15.00          5.4706        100.0         198.691          0.000
    20.00          6.1746        100.0         198.691          0.000
    25.00          6.7207        100.0         198.691          0.000
    40.00          7.8708        100.0         198.691          0.000
    50.00          8.4168        100.0         198.691          0.000
```


2% 5 10 15 20 30 40 50 60 70 80 85 90 95 98
9 8 7 6 5 4 3 2 10' 9 8 7 6 5 4 3 2 10⁰ 9 8 7 6 5 4 3 2
Particle Diameter (microns)
TEST #: HG 205
ID# : 3-1
MASS MEAN PARTICLE DIA = 12.0 μm
Percent Particle Mass Smaller Than D50

```
*****    P A R T I C L E   S I Z E   A N A L Y S I S    *****

                    ****     INPUT DATA     ****

DATE OF TEST       06/07/88
TIME OF TEST       1415
LOCATION OF TEST   NYU-PFBC
TEST NUMBER        205
PART. DIAM. TYPE   C    (I=IMP AERO, C=CLAS AERO, P=PHYSICAL)
TEST TYPE          OUTLET
RUN NUMBER         3-O - FILE NAME: B:T205R3-O.OUT
REMARKS:           DATA ANALYSIS
IMPACTOR TYPE      UW3NYU


WATER VAPOR         3.00%
CARBON DIOXIDE     17.20%
CARBON MONOXIDE     0.00%
OXYGEN              3.00%
SULFUR DIOXIDE      0.00%
NITROGEN           79.80%
PARTICLE DENSITY   1.00 GRAMS/CM^3

GAS METER VOLUME                 19.130 CUBIC FEET
IMPACTOR DELTA P                  0.00  INCHES HG
ORIFICE DELTA P                   0.00  INCHES H2O
STACK PRESS. (BELOW ATMOS.)       0.00  INCHES H2O
BAROMETRIC PRESS.               %245.75  INCHES HG
STACK TEMPERATURE               499.0   DEGREES F
METER TEMPERATURE               499.0   DEGREES F
IMPACTOR TEMPERATURE            499.0   DEGREES F
SAMPLE TIME                      45.00  MINUTES
AV. VELOCITY OF STACK GAS         0.00  FEET/MINUTE
GAS METER PRESSURE                0.00  IN HG
NOZZLE DIAMETER                   0.43  INCHES
MAXIMUM AERODYN. DIAMETER      1000.00  MICRONS

MASS GAIN ON STAGE  1               0.60 MG
MASS GAIN ON STAGE  2               2.10 MG
MASS GAIN ON STAGE  3               3.40 MG
MASS GAIN ON STAGE  4               3.70 MG
MASS GAIN ON STAGE  5               9.10 MG
MASS GAIN ON STAGE  6              13.50 MG
MASS GAIN ON STAGE  7               7.90 MG
MASS GAIN ON FINAL FILTER           1.00 MG
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                              ****        RESULTS        ****

   DATE OF TEST          06/07/88
   TIME OF TEST          1415
   LOCATION OF TEST      NYU-PFBC
  TEST NUMBER         205  -
  RUN NUMBER          3-0
  ACTUAL FLOW RATE (STACK CONDITIONS)      0.438 CFM
  FLOW RATE (STANDARD CONDITIONS)          1.923 CFM
  PERCENT ISOKINETIC SAMPLING              0.00  %

  VISCOSITY OF GAS STREAM                  0.0002626 GRAMS/CM-SEC
  STAGE          CCF          DP(CLAS AERO) DP(IMP AERO)   CUM FRACTION
     1          1.004              8.713         8.731         0.9855
     2          1.002             15.119        15.138         0.9346
     3          1.006              6.165         6.183         0.8523
     4          1.012              3.220         3.239         0.7627
     5          1.020              1.869         1.887         0.5424
     6          1.035              1.063         1.081         0.2155
     7          1.061              0.610         0.628         0.0242

  NOTE: THE MASS ON STAGES 1 AND 2 WILL BE COMBINED AND ASSIGNED TO
        THE OUTPUT ON STAGE 1 , FOR SPLINE FITTING ANALYSIS.

  TOTAL MASS PER DRY NORMAL CUBIC METER   16.8667 MG/CUBIC METER

  PART. DIAM. TYPE  C    (I=IMP AERO, C=CLAS AERO, P=PHYSICAL)
PARTICLE SIZE     CUMFR          CUMFR           CUM.MASS       dM/dLOG D
  (MICRONS)     (STD. DEV.)   (PER CENT)        (MG/DRY N.CU.METER)

     0.20         -4.9700         0.0             0.000          0.000
     0.25         -4.3704         0.0             0.000          0.003
     0.40         -3.1072         0.1             0.016          0.333
     0.50         -2.5076         0.6             0.103          1.795
     0.75         -1.5086         6.6             1.108         10.989
     1.00         -0.9036        18.3             3.088         20.164
     1.50         -0.2105        41.7             7.027         22.832
     2.00          0.1995        57.9             9.767         20.645
     2.50          0.4817        68.5            11.553         15.708
     4.00          0.8183        79.3            13.382          3.974
     5.00          0.9026        81.7            13.774          4.842
     7.50          1.2869        90.1            15.196          9.659
    10.00          1.8530        96.8            16.328          6.900
    15.00          2.8588        99.8            16.831          0.646
    20.00          3.5742       100.0            16.864          0.065
    25.00          4.1310       100.0            16.866          0.008
    40.00          5.3128       100.0            16.867          0.000
    50.00          5.8806       100.0            16.867          0.000
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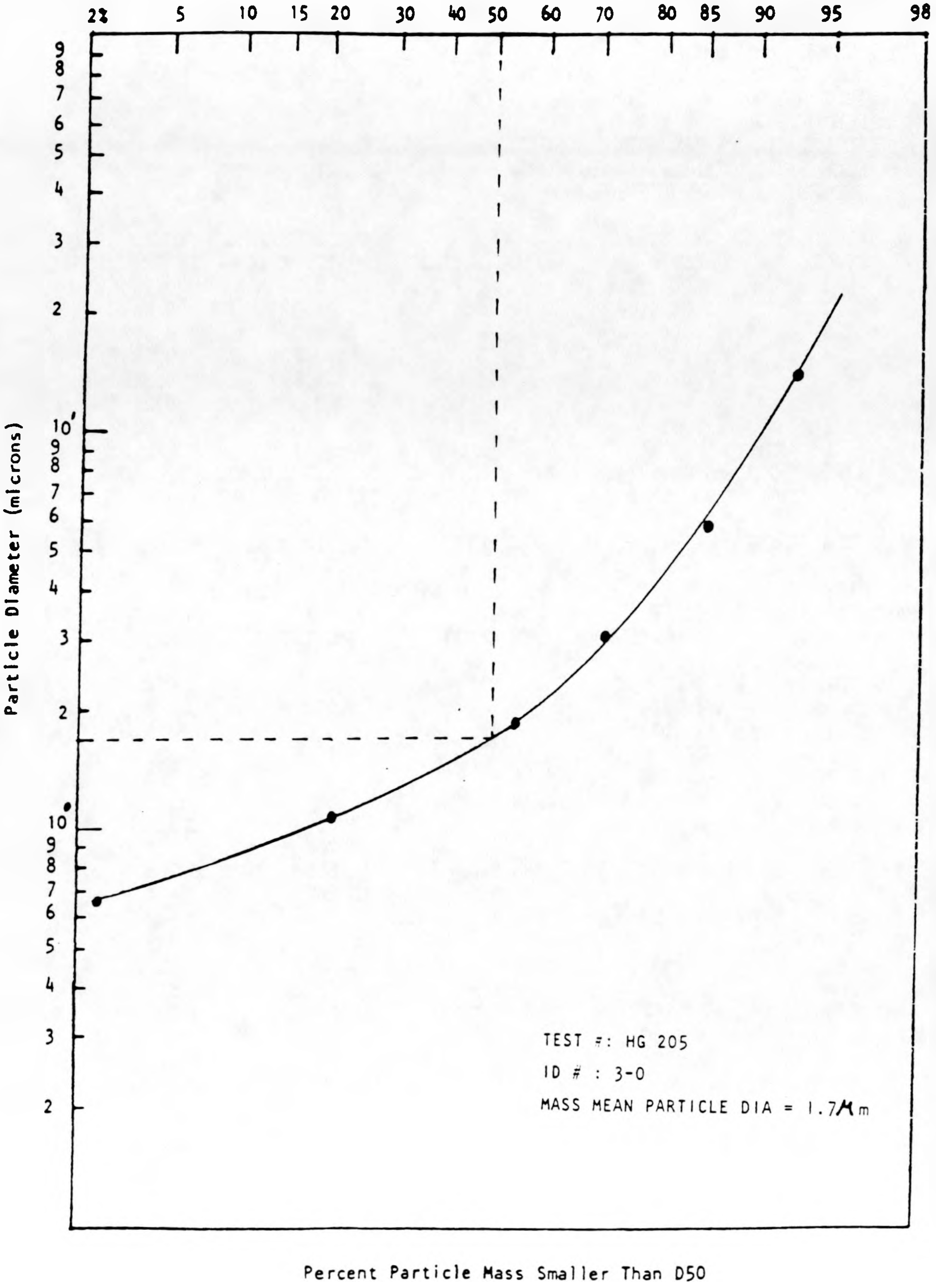
2%
5
10
15
20
30
40
50
60
70
80
85
90
95
98
Particle Diameter (microns)
9
8
7
6
5
4
3
2
10'
9
8
7
6
5
4
3
2
10°
9
8
7
6
5
4
3
2
TEST #: HG 205
ID # : 3-0
MASS MEAN PARTICLE DIA = 1.7μm
Percent Particle Mass Smaller Than D50

```
*****     P A R T I C L E   S I Z E   A N A L Y S I S     *****

                    ****      INPUT DATA      ****

DATE OF TEST        06/08/88
TIME OF TEST        0345
LOCATION OF TEST    NYU-PFBC
TEST NUMBER         205
PART. DIAM. TYPE    C    (I=IMP AERO, C=CLAS AERO, P=PHYSICAL)
TEST TYPE           INLET
RUN NUMBER          4-I - FILE NAME: B:T205R4-I.INT
REMARKS:            DATA ANALYSIS
IMPACTOR TYPE       UWVNYU


WATER VAPOR          3.00%
CARBON DIOXIDE      14.65%
CARBON MONOXIDE      0.00%
OXYGEN               3.57%
SULFUR DIOXIDE       0.00%
NITROGEN            81.78%
PARTICLE DENSITY    1.00 GRAMS/CM^3

GAS METER VOLUME                  12.740 CUBIC FEET
IMPACTOR DELTA P                   0.00  INCHES HG
ORIFICE DELTA P                    0.00  INCHES H2O
STACK PRESS. (BELOW ATMOS.)        0.00  INCHES H2O
BAROMETRIC PRESS.                %252.26  INCHES HG
STACK TEMPERATURE                506.0   DEGREES F
METER TEMPERATURE                506.0   DEGREES F
IMPACTOR TEMPERATURE             506.0   DEGREES F
SAMPLE TIME                       30.00  MINUTES
AV. VELOCITY OF STACK GAS          0.00  FEET/MINUTE
GAS METER PRESSURE                 0.00  IN HG
NOZZLE DIAMETER                    0.43  INCHES
MAXIMUM AERODYN. DIAMETER       1000.00  MICRONS

MASS GAIN ON STAGE  1              339.00 MG
MASS GAIN ON STAGE  2               48.60 MG
MASS GAIN ON STAGE  3               45.20 MG
MASS GAIN ON STAGE  4               57.90 MG
MASS GAIN ON STAGE  5               32.90 MG
MASS GAIN ON STAGE  6               26.90 MG
MASS GAIN ON STAGE  7               20.60 MG
MASS GAIN ON STAGE  8               15.80 MG
MASS GAIN ON STAGE  9               10.20 MG
MASS GAIN ON STAGE  10               9.10 MG
MASS GAIN ON STAGE  11               5.40 MG
MASS GAIN ON FINAL FILTER            2.50 MG
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                        ****         RESULTS         ****

   DATE OF TEST          06/08/88
   TIME OF TEST          0345
   LOCATION OF TEST      NYU-PFBC
   TEST NUMBER           205  -
   RUN NUMBER            4-I
   ACTUAL FLOW RATE (STACK CONDITIONS)      0.438 CFM
   FLOW RATE (STANDARD CONDITIONS)          1.957 CFM
   PERCENT ISOKINETIC SAMPLING              0.00  %

   VISCOSITY OF GAS STREAM                  0.0002646 GRAMS/CM-SEC
   STAGE          CCF         DP(CLAS AERO) DP(IMP AERO)   CUM FRACTION
     1           1.003             14.597       14.616        0.4480
     2           1.002             15.185       15.203        0.3688
     3           1.005              6.742        6.760        0.2952
     4           1.011              3.253        3.271        0.2009
     5           1.020              1.877        1.895        0.1474
     6           1.030              1.240        1.258        0.1036
     7           1.035              1.067        1.086        0.0700
     8           1.048              0.768        0.786        0.0443
     9           1.057              0.653        0.671        0.0277
    10           1.065              0.565        0.583        0.0129
    11           1.077              0.480        0.499        0.0041

   NOTE: THE MASS ON STAGES 1 AND 2 WILL BE COMBINED AND ASSIGNED TO
         THE OUTPUT ON STAGE 1 , FOR SPLINE FITTING ANALYSIS.

   TOTAL MASS PER DRY NORMAL CUBIC METER  369.5450 MG/CUBIC METER

   PART. DIAM. TYPE   C     (I=IMP AERO, C=CLAS AERO, P=PHYSICAL)
PARTICLE SIZE     CUMFR          CUMFR          CUM.MASS      dM/dLOG D
  (MICRONS)     (STD. DEV.)   (PER CENT)       (MG/DRY N.CU.METER)

    0.20         -5.2382          0.0           0.000          0.001
    0.25         -4.5782          0.0           0.001          0.028
    0.40         -3.1881          0.1           0.266          6.231
    0.50         -2.5420          0.6           2.040         34.931
    0.75         -1.7250          4.2          15.619         75.342
    1.00         -1.5413          6.2          22.769         84.437
    1.50         -1.1049         13.5          49.733         80.867
    2.00         -1.0323         15.1          55.781         53.911
    2.50         -0.9549         17.0          62.751         87.963
    4.00         -0.7448         22.8          84.325        113.566
    5.00         -0.6498         25.8          95.313        112.074
    7.50         -0.5034         30.7         113.576         92.247
   10.00         -0.4234         33.6         124.166         78.452
   15.00         -0.3334         36.9         136.522         13.466
   20.00         -0.3211         37.4         138.241         14.283
   25.00         -0.3107         37.8         139.699         15.994
   40.00         -0.2825         38.9         143.664         24.075
   50.00         -0.2639         39.6         146.312         30.995
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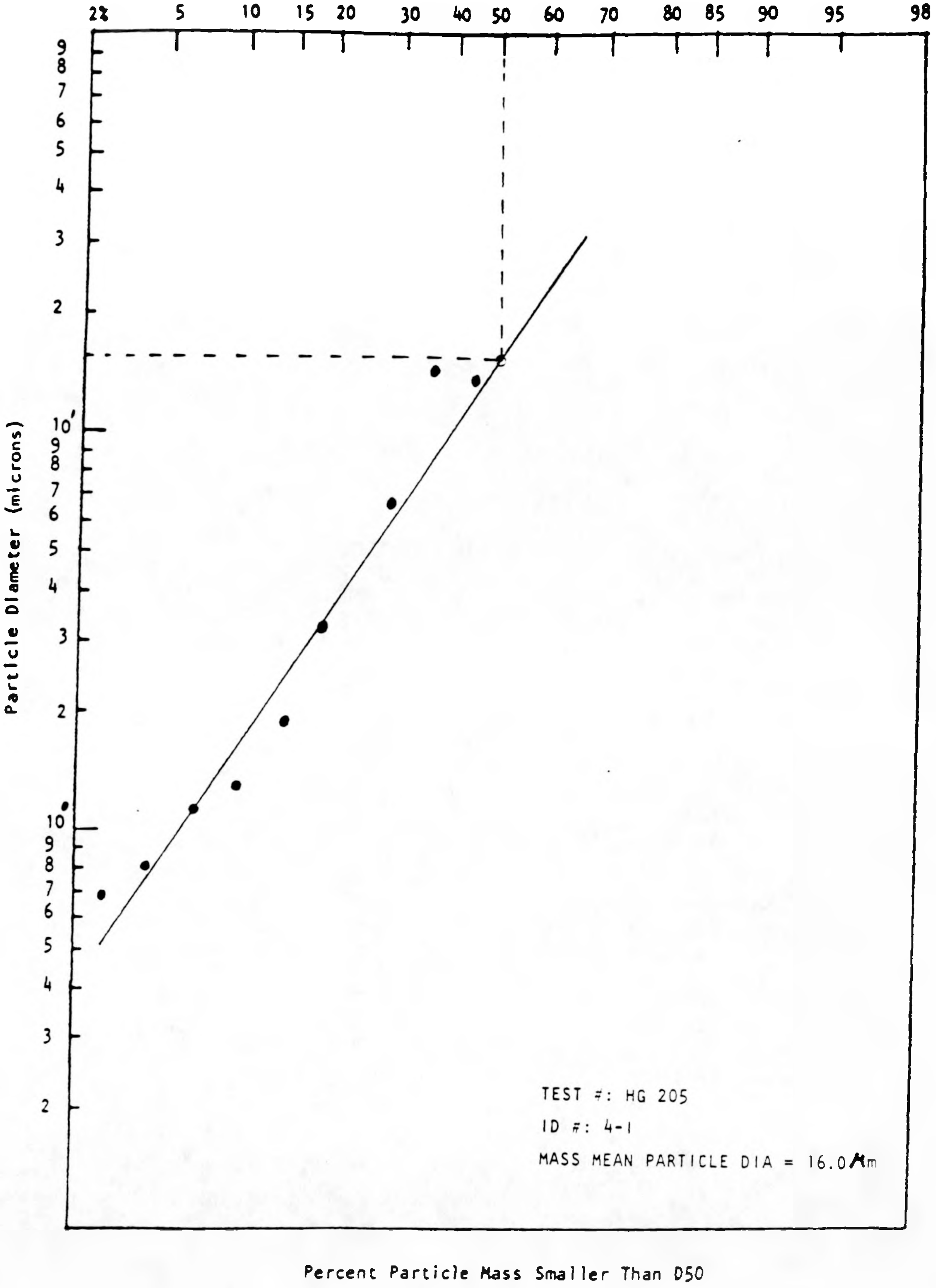

TEST #: HG 205

ID #: 4-1

MASS MEAN PARTICLE DIA = 16.0 μm

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*****      P A R T I C L E   S I Z E   A N A L Y S I S      *****

                    ****      INPUT DATA      ****

DATE OF TEST          06/08/88
TIME OF TEST          0340
LOCATION OF TEST      NYU-PFBC
TEST NUMBER           205
PART. DIAM. TYPE      C    (I=IMP AERO, C=CLAS AERO, P=PHYSICAL)
TEST TYPE             OUTLET
RUN NUMBER            4-O - FILE NAME: B:T205R4-O.OUT
REMARKS:              DATA AQNALYSIS
IMPACTOR TYPE         UW3NYU


WATER VAPOR           3.00%
CARBON DIOXIDE       14.65%
CARBON MONOXIDE       0.00%
OXYGEN                3.57%
SULFUR DIOXIDE        0.00%
NITROGEN             81.78%
PARTICLE DENSITY     1.00 GRAMS/CM^3

GAS METER VOLUME                18.940 CUBIC FEET
IMPACTOR DELTA P                 0.00   INCHES HG
ORIFICE DELTA P                  0.00   INCHES H2O
STACK PRESS. (BELOW ATMOS.)      0.00   INCHES H2O
BAROMETRIC PRESS.               %258.98  INCHES HG
STACK TEMPERATURE              510.0    DEGREES F
METER TEMPERATURE              510.0    DEGREES F
IMPACTOR TEMPERATURE           510.0    DEGREES F
SAMPLE TIME                     45.00   MINUTES
AV. VELOCITY OF STACK GAS        0.00   FEET/MINUTE
GAS METER PRESSURE               0.00   IN HG
NOZZLE DIAMETER                  0.43   INCHES
MAXIMUM AERODYN. DIAMETER     1000.00   MICRONS

MASS GAIN ON STAGE  1              0.30 MG
MASS GAIN ON STAGE  2              0.60 MG
MASS GAIN ON STAGE  3              0.50 MG
MASS GAIN ON STAGE  4              1.40 MG
MASS GAIN ON STAGE  5              2.10 MG
MASS GAIN ON STAGE  6              2.50 MG
MASS GAIN ON STAGE  7              2.50 MG
MASS GAIN ON FINAL FILTER          1.20 MG
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                        ****       RESULTS        ****

 DATE OF TEST        06/08/88
 TIME OF TEST        0340
 LOCATION OF TEST    NYU-PFBC
 TEST NUMBER         205  -
 RUN NUMBER          4-0
 ACTUAL FLOW RATE (STACK CONDITIONS)     0.434 CFM
 FLOW RATE (STANDARD CONDITIONS)         1.983 CFM
 PERCENT ISOKINETIC SAMPLING             0.00  %

 VISCOSITY OF GAS STREAM                 0.0002654 GRAMS/CM-SEC
 STAGE           CCF           DP(CLAS AERO) DP(IMP AERO)   CUM FRACTION
   1            1.004              8.804         8.822         0.9730
   2            1.002             15.276        15.294         0.9189
   3            1.006              6.229         6.247         0.8739
   4            1.011              3.254         3.272         0.7477
   5            1.019              1.889         1.907         0.5586
   6            1.034              1.074         1.092         0.3333
   7            1.059              0.617         0.635         0.1081

 NOTE: THE MASS ON STAGES 1 AND 2 WILL BE COMBINED AND ASSIGNED TO
       THE OUTPUT ON STAGE 1 , FOR SPLINE FITTING ANALYSIS.

 TOTAL MASS PER DRY NORMAL CUBIC METER     4.3946 MG/CUBIC METER

 PART. DIAM. TYPE   C    (I=IMP AERO, C=CLAS AERO, P=PHYSICAL)
PARTICLE SIZE     CUMFR          CUMFR          CUM.MASS      dM/dLOG D
  (MICRONS)     (STD. DEV.)   (PER CENT)         (MG/DRY N.CU.METER)

    0.20        -3.3548          0.0           0.002          0.027
    0.25        -2.9352          0.2           0.007          0.102
    0.40        -2.0512          2.0           0.088          0.926
    0.50        -1.6316          5.1           0.226          2.006
    0.75        -0.9331         17.5           0.771          3.983
    1.00        -0.5211         30.1           1.323          4.612
    1.50        -0.0726         47.1           2.070          3.892
    2.00         0.2025         58.0           2.550          3.866
    2.50         0.4223         66.4           2.916          3.606
    4.00         0.8322         79.7           3.504          2.140
    5.00         0.9921         83.9           3.689          1.715
    7.50         1.2793         90.0           3.953          1.311
   10.00         1.5005         93.3           4.101          1.053
   15.00         1.8272         96.6           4.246          0.615
   20.00         2.0607         98.0           4.308          0.394
   25.00         2.2437         98.8           4.340          0.269
   40.00         2.6382         99.6           4.376          0.107
   50.00         2.8321         99.8           4.384          0.065
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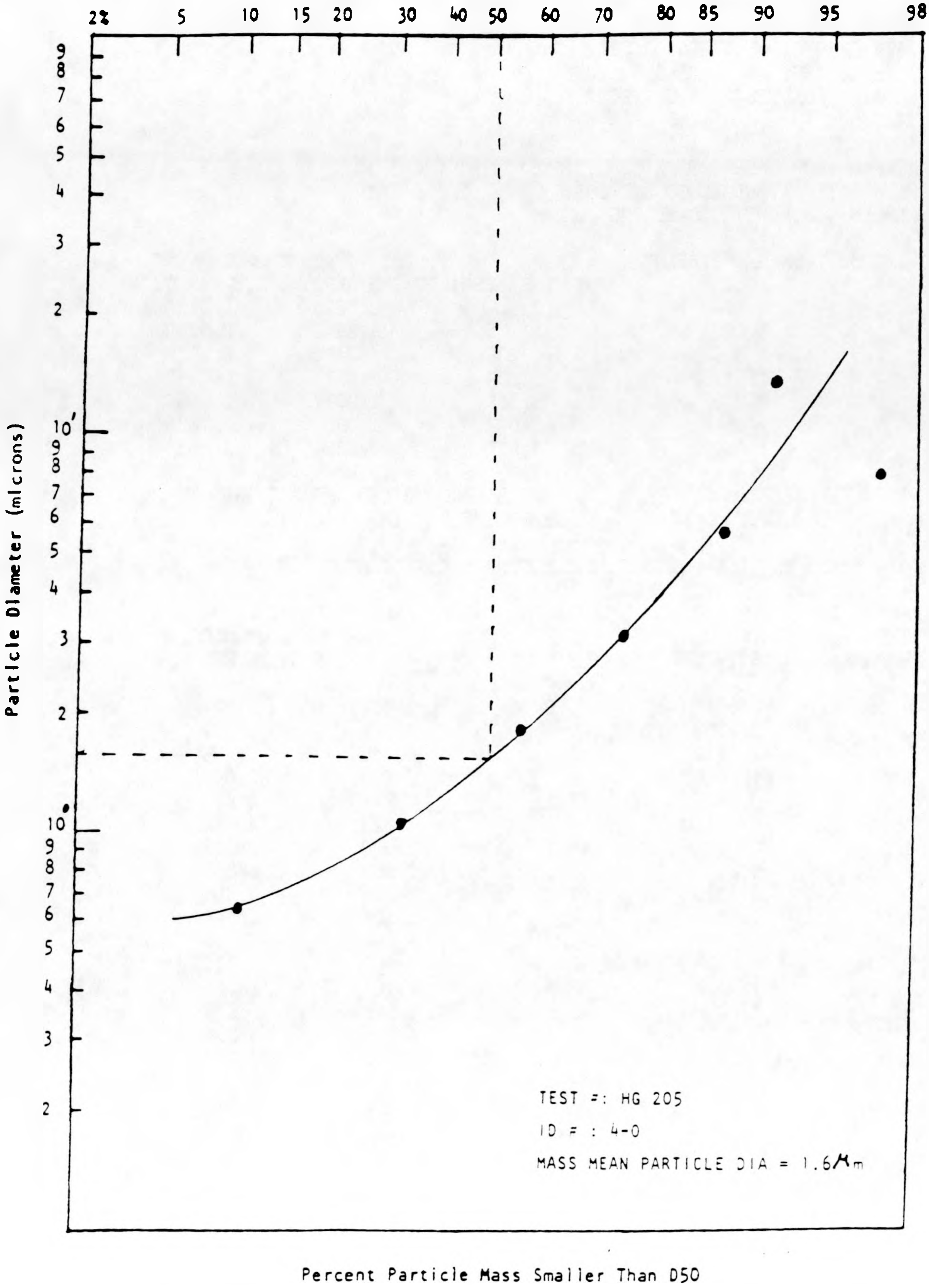
2% 5 10 15 20 30 40 50 60 70 80 85 90 95 98
9 8 7 6 5 4 3 2 10' 9 8 7 6 5 4 3 2 10 9 8 7 6 5 4 3 2
Particle Diameter (microns)
TEST #: HG 205
ID # : 4-0
MASS MEAN PARTICLE DIA = 1.6 μm
Percent Particle Mass Smaller Than D50

```
*****     P A R T I C L E   S I Z E   A N A L Y S I S     *****

                    ****     INPUT DATA      ****

  DATE OF TEST         06/08/88
  TIME OF TEST         1310
  LOCATION OF TEST     NYU-PFBC
  TEST NUMBER          205
  PART. DIAM. TYPE     C    (I=IMP AERO, C=CLAS AERO, P=PHYSICAL)
  TEST TYPE            INLET
  RUN NUMBER           5-I - FILE NAME: B:T205R5-I.INT
  REMARKS:             DATA ANALYSIS
  IMPACTOR TYPE        UWVNYU


  WATER VAPOR           3.00%
  CARBON DIOXIDE       14.52%
  CARBON MONOXIDE       0.00%
  OXYGEN                3.74%
  SULFUR DIOXIDE        0.00%
  NITROGEN             81.74%
  PARTICLE DENSITY     1.00 GRAMS/CM^3

  GAS METER VOLUME                   8.250 CUBIC FEET
  IMPACTOR DELTA P                   0.00   INCHES HG
  ORIFICE DELTA P                    0.00   INCHES H2O
  STACK PRESS. (BELOW ATMOS.)        0.00   INCHES H2O
  BAROMETRIC PRESS.                %253.88   INCHES HG
  STACK TEMPERATURE                507.5    DEGREES F
  METER TEMPERATURE                507.5    DEGREES F
  IMPACTOR TEMPERATURE             507.5    DEGREES F
  SAMPLE TIME                       20.00   MINUTES
  AV. VELOCITY OF STACK GAS          0.00   FEET/MINUTE
  GAS METER PRESSURE                 0.00   IN HG
  NOZZLE DIAMETER                    0.43   INCHES
  MAXIMUM AERODYN. DIAMETER       1000.00   MICRONS

  MASS GAIN ON STAGE  1               131.20 MG
  MASS GAIN ON STAGE  2                16.10 MG
  MASS GAIN ON STAGE  3                32.90 MG
  MASS GAIN ON STAGE  4                38.70 MG
  MASS GAIN ON STAGE  5                16.30 MG
  MASS GAIN ON STAGE  6                 5.40 MG
  MASS GAIN ON STAGE  7                 1.90 MG
  MASS GAIN ON STAGE  8                 1.10 MG
  MASS GAIN ON STAGE  9                 0.50 MG
  MASS GAIN ON STAGE  10                1.00 MG
  MASS GAIN ON STAGE  11                0.10 MG
  MASS GAIN ON FINAL FILTER             0.50 MG
```

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                    ****        RESULTS        ****

DATE OF TEST         06/08/88
TIME OF TEST         1310
LOCATION OF TEST     NYU-FFBC
TEST NUMBER          205  -
RUN NUMBER           5-I
ACTUAL FLOW RATE (STACK CONDITIONS)     0.425 CFM
FLOW RATE (STANDARD CONDITIONS)         1.910 CFM
PERCENT ISOKINETIC SAMPLING             0.00  %

VISCOSITY OF GAS STREAM                 0.0002650 GRAMS/CM-SEC
STAGE          CCF          DP(CLAS AERO) DP(IMP AERO)   CUM FRACT
   1          1.002            14.822        14.841        0.4660
   2          1.002            15.419        15.437        0.4005
   3          1.005             6.846         6.864        0.2666
   4          1.011             3.303         3.322        0.1091
   5          1.019             1.906         1.925        0.0427
   6          1.029             1.259         1.277        0.0208
   7          1.034             1.084         1.102        0.0130
   8          1.047             0.780         0.798        0.0085
   9          1.055             0.663         0.682        0.0065
  10          1.064             0.574         0.592        0.0024
  11          1.075             0.488         0.506        0.0020

NOTE: THE MASS ON STAGES 1 AND 2 WILL BE COMBINED AND ASSIGNED TO
      THE OUTPUT ON STAGE 1 , FOR SPLINE FITTING ANALYSIS.

TOTAL MASS PER DRY NORMAL CUBIC METER  227.2179 MG/CUBIC METER

  PART. DIAM. TYPE   C    (I=IMP AERO, C=CLAS AERO, P=PHYSICAL)
PARTICLE SIZE     CUMFR          CUMFR          CUM.MASS       dM/dLOG D
 (MICRONS)      (STD. DEV.)   (PER CENT)      (MG/DRY N.CU.METER)

   0.20          -3.1918         0.1           0.161          0.457
   0.25          -3.1120         0.1           0.212          0.588
   0.40          -2.9441         0.2           0.369          0.978
   0.50          -2.8644         0.2           0.476          1.233
   0.75          -2.7196         0.3           0.744          1.847
   1.00          -2.6168         0.4           1.010          2.430
   1.50          -2.4720         0.7           1.529          3.513
   2.00          -2.3692         0.9           2.028          4.505
   2.50          -2.2895         1.1           2.508          5.424
   4.00          -2.1216         1.7           3.851          7.855
   5.00          -2.0419         2.1           4.679          9.272
   7.50          -1.8970         2.9           6.571         12.333
  10.00          -1.7942         3.6           8.269         14.909
  15.00          -1.6494         5.0          11.255         19.133
  20.00          -1.5466         6.1          13.854         22.547
  25.00          -1.4669         7.1          16.176         25.425
  40.00          -0.2721        39.3          89.247          0.248
  50.00          -0.2696        39.4          89.460          4.392
```

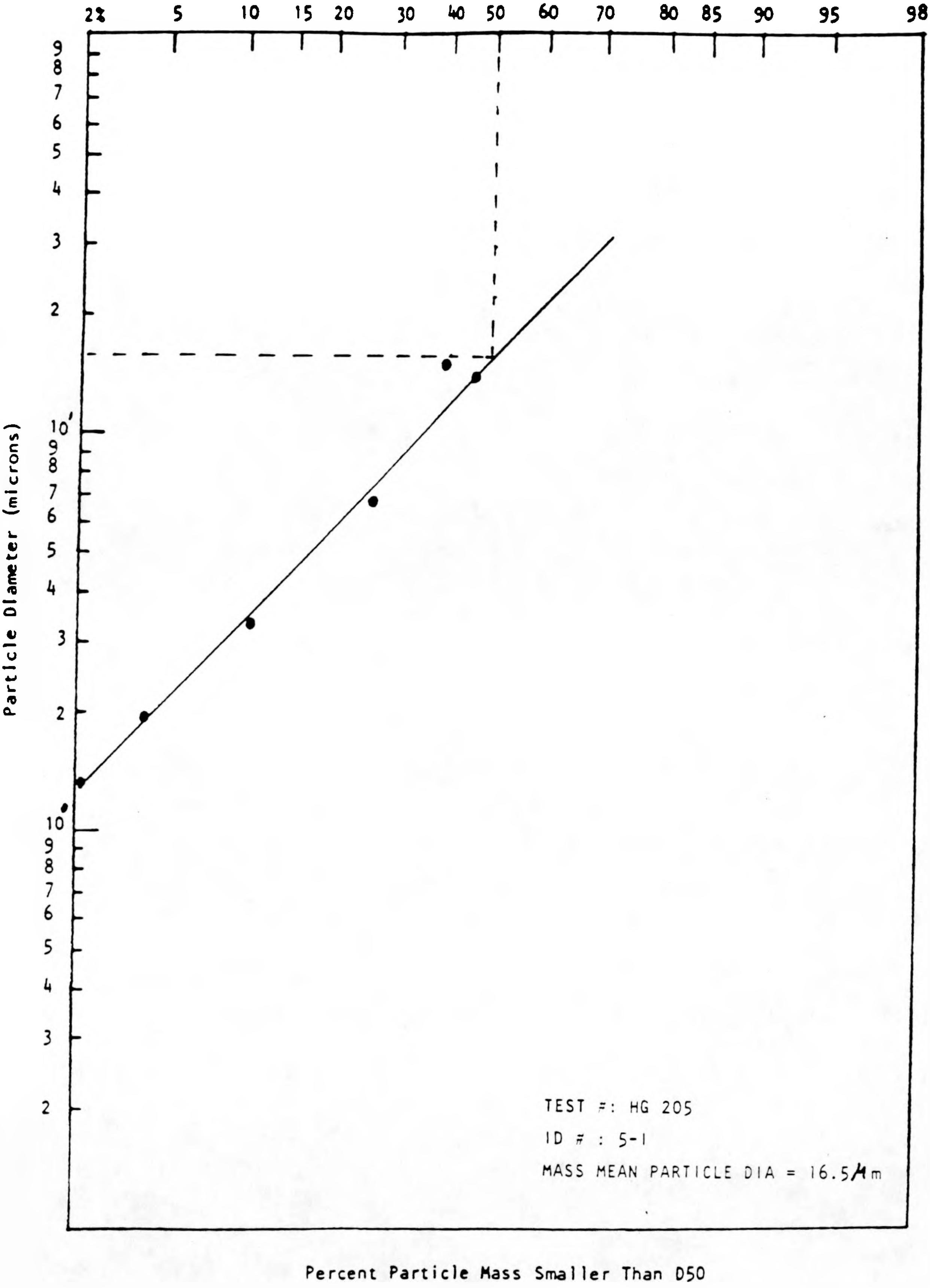

TEST #: HG 205

ID # : 5-1

MASS MEAN PARTICLE DIA = 16.5 μm

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*****     P A R T I C L E   S I Z E   A N A L Y S I S     *****

                         ****     INPUT DATA     ****

DATE OF TEST           06/08/88
TIME OF TEST           1310
LOCATION OF TEST       NYU-PFBC
TEST NUMBER            205
PART. DIAM. TYPE       C    (I=IMP AERO, C=CLAS AERO, P=PHYSICAL)
TEST TYPE              OUTLET
RUN NUMBER             5-O - FILE NAME: B:T205R5-O.OUT
REMARKS:               DATA ANALYSIS
IMPACTOR TYPE          UW3NYU


WATER VAPOR             3.00%
CARBON DIOXIDE         14.35%
CARBON MONOXIDE         0.00%
OXYGEN                  3.94%
SULFUR DIOXIDE          0.00%
NITROGEN               81.71%
PARTICLE DENSITY       1.00 GRAMS/CM^3

GAS METER VOLUME                 16.410 CUBIC FEET
IMPACTOR DELTA P                  0.00  INCHES HG
ORIFICE DELTA P                   0.00  INCHES H2O
STACK PRESS. (BELOW ATMOS.)       0.00  INCHES H2O
BAROMETRIC PRESS.                %264.10  INCHES HG
STACK TEMPERATURE               532.5   DEGREES F
METER TEMPERATURE               532.5   DEGREES F
IMPACTOR TEMPERATURE            532.5   DEGREES F
SAMPLE TIME                      40.00  MINUTES
AV. VELOCITY OF STACK GAS         0.00  FEET/MINUTE
GAS METER PRESSURE                0.00  IN HG
NOZZLE DIAMETER                   0.43  INCHES
MAXIMUM AERODYN. DIAMETER      1000.00  MICRONS

MASS GAIN ON STAGE  1              27.20 MG
MASS GAIN ON STAGE  2              20.70 MG
MASS GAIN ON STAGE  3               0.80 MG
MASS GAIN ON STAGE  4               1.50 MG
MASS GAIN ON STAGE  5               2.50 MG
MASS GAIN ON STAGE  6               3.50 MG
MASS GAIN ON STAGE  7               1.30 MG
MASS GAIN ON FINAL FILTER           0.60 MG
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                    ****        RESULTS        ****

  DATE OF TEST         06/08/88
  TIME OF TEST         1310
  LOCATION OF TEST     NYU-PFBC
  TEST NUMBER          205  -
  RUN NUMBER           5-0
  ACTUAL FLOW RATE (STACK CONDITIONS)     0.423 CFM
  FLOW RATE (STANDARD CONDITIONS)         1.927 CFM
  PERCENT ISOKINETIC SAMPLING             0.00  %

  VISCOSITY OF GAS STREAM                 0.0002700 GRAMS/CM-SEC
  STAGE          CCF          DP(CLAS AERO) DP(IMP AERO)   CUM FRACTION
     1          1.004             8.994         9.012          0.5318
     2          1.002            15.606        15.624          0.1756
     3          1.006             6.364         6.382          0.1618
     4          1.011             3.325         3.343          0.1360
     5          1.019             1.930         1.948          0.0929
     6          1.033             1.098         1.116          0.0327
     7          1.058             0.630         0.648          0.0103

  NOTE: THE MASS ON STAGES 1 AND 2 WILL BE COMBINED AND ASSIGNED TO
        THE OUTPUT ON STAGE 1 , FOR SPLINE FITTING ANALYSIS.

  TOTAL MASS PER DRY NORMAL CUBIC METER   26.6378 MG/CUBIC METER

  PART. DIAM. TYPE   C     (I=IMP AERO, C=CLAS AERO, P=PHYSICAL)
PARTICLE SIZE     CUMFR          CUMFR          CUM.MASS        dM/dLOG D
  (MICRONS)     (STD. DEV.)    (PER CENT)      (MG/DRY N.CU.METER)

     0.20         -3.2106          0.1           0.018           0.110
     0.25         -3.0364          0.1           0.032           0.190
     0.40         -2.6696          0.4           0.101           0.541
     0.50         -2.4955          0.6           0.168           0.849
     0.75         -2.1749          1.5           0.395           1.872
     1.00         -1.9294          2.7           0.715           3.446
     1.50         -1.5362          6.2           1.658           7.168
     2.00         -1.2989          9.7           2.583           6.851
     2.50         -1.1839         11.8           3.149           4.831
     4.00         -1.0607         14.4           3.846           2.568
     5.00         -1.0234         15.3           4.077           2.239
     7.50         -0.9615         16.8           4.479           2.448
    10.00         -0.9136         18.0           4.807           2.855
    15.00         -0.8411         20.0           5.331           3.113
    20.00         -0.7881         21.5           5.736           3.380
    25.00         -0.7451         22.8           6.076           3.659
    40.00         -0.6456         25.9           6.907           4.563
    50.00         -0.5917         27.7           7.379           5.221
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*****    P A R T I C L E   S I Z E   A N A L Y S I S   *****

                  ****     INPUT DATA     ****

DATE OF TEST         06/08/88
TIME OF TEST         1750
LOCATION OF TEST     NYU-PFBC
TEST NUMBER          205
PART. DIAM. TYPE     C    (I=IMP AERO, C=CLAS AERO, P=PHYSICAL)
TEST TYPE            INLET
RUN NUMBER           6-I - FILE NAME: B:T205R6-I.INT
REMARKS:             DATA ANALYSIS
IMPACTOR TYPE        UWVNYU


WATER VAPOR          3.00%
CARBON DIOXIDE      14.42%
CARBON MONOXIDE      0.00%
OXYGEN               4.12%
SULFUR DIOXIDE       0.00%
NITROGEN            81.46%
PARTICLE DENSITY    1.00 GRAMS/CM^3

GAS METER VOLUME                     8.450 CUBIC FEET
IMPACTOR DELTA P                     0.00   INCHES HG
ORIFICE DELTA P                      0.00   INCHES H2O
STACK PRESS. (BELOW ATMOS.)          0.00   INCHES H2O
BAROMETRIC PRESS.                  %250.30   INCHES HG
STACK TEMPERATURE                  517.5    DEGREES F
METER TEMPERATURE                  517.5    DEGREES F
IMPACTOR TEMPERATURE               517.5    DEGREES F
SAMPLE TIME                         20.00   MINUTES
AV. VELOCITY OF STACK GAS            0.00   FEET/MINUTE
GAS METER PRESSURE                   0.00   IN HG
NOZZLE DIAMETER                      0.43   INCHES
MAXIMUM AERODYN. DIAMETER         1000.00   MICRONS

MASS GAIN ON STAGE  1                367.70 MG
MASS GAIN ON STAGE  2                 13.20 MG
MASS GAIN ON STAGE  3                 36.70 MG
MASS GAIN ON STAGE  4                 52.10 MG
MASS GAIN ON STAGE  5                 26.40 MG
MASS GAIN ON STAGE  6                 12.20 MG
MASS GAIN ON STAGE  7                  5.00 MG
MASS GAIN ON STAGE  8                  1.60 MG
MASS GAIN ON STAGE  9                  0.50 MG
MASS GAIN ON STAGE  10                 0.40 MG
MASS GAIN ON STAGE  11                 0.40 MG
MASS GAIN ON FINAL FILTER              0.20 MG
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                          ****        RESULTS        ****

    DATE OF TEST        06/08/88
    TIME OF TEST        1750
    LOCATION OF TEST    NYU-PFBC
    TEST NUMBER         205  -
    RUN NUMBER          6-I
    ACTUAL FLOW RATE (STACK CONDITIONS)     0.436 CFM
    FLOW RATE (STANDARD CONDITIONS)         1.909 CFM
    PERCENT ISOKINETIC SAMPLING             0.00  %

    VISCOSITY OF GAS STREAM                 0.0002672 GRAMS/CM-SEC
    STAGE          CCF          DP(CLAS AERO) DP(IMP AERO)   CUM FRACTIO
       1          1.003            14.704        14.723         0.2880
       2          1.002            15.296        15.315         0.2624
       3          1.006             6.791         6.810         0.1913
       4          1.012             3.276         3.295         0.0904
       5          1.020             1.891         1.909         0.0393
       6          1.030             1.248         1.267         0.0157
       7          1.035             1.075         1.094         0.0060
       8          1.049             0.773         0.792         0.0029
       9          1.057             0.658         0.676         0.0019
      10          1.066             0.569         0.588         0.0012
      11          1.078             0.484         0.502         0.0004

    NOTE: THE MASS ON STAGES 1 AND 2 WILL BE COMBINED AND ASSIGNED TO
          THE OUTPUT ON STAGE 1 , FOR SPLINE FITTING ANALYSIS.

    TOTAL MASS PER DRY NORMAL CUBIC METER  477.8091 MG/CUBIC METER

    PART. DIAM. TYPE   C    (I=IMP AERO, C=CLAS AERO, P=PHYSICAL)
 PARTICLE SIZE      CUMFR         CUMFR          CUM.MASS       dM/dLOG D
   (MICRONS)      (STD. DEV.)   (PER CENT)      (MG/DRY N.CU.METER)

     0.20          -5.8784         0.0           0.000          0.000
     0.25          -5.2425         0.0           0.000          0.001
     0.40          -3.9030         0.0           0.023          0.616
     0.50          -3.2973         0.0           0.234          3.715
     0.75          -2.5095         0.6           2.893         36.588
     1.00          -1.9506         2.6          12.214        127.252
     1.50          -1.1628        12.2          58.508        433.756
     2.00          -0.6038        27.3         130.436        710.660
     2.50          -0.1703        43.2         206.598        840.502
     4.00           0.7429        77.1         368.499        647.127
     5.00           1.1765        88.0         420.618        426.867
     7.50           1.9642        97.5         465.979        123.887
    10.00           2.5232        99.4         475.026         35.349
    15.00           3.3110       100.0         477.586          3.551
    20.00           3.8699       100.0         477.783          0.477
    25.00           4.3035       100.0         477.805          0.081
    40.00           5.2166       100.0         477.809          0.001
    50.00           5.6502       100.0         477.809          0.000
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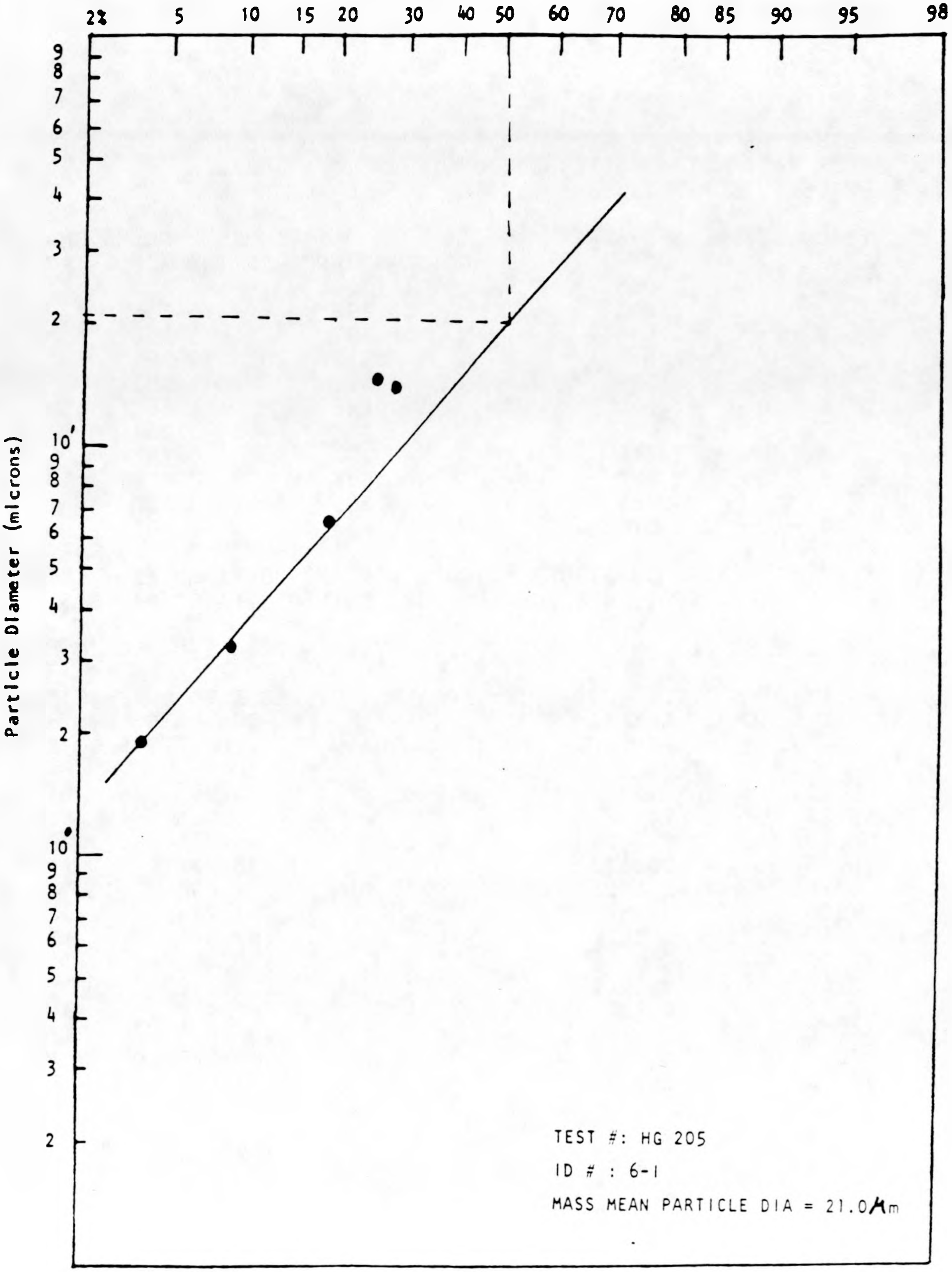

Percent Particle Mass Smaller Than D50

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*****     P A R T I C L E   S I Z E   A N A L Y S I S     *****

                    ****     INPUT DATA     ****

DATE OF TEST        06/03/88
TIME OF TEST        1750
LOCATION OF TEST    NYU-PFBC
TEST NUMBER         205
PART. DIAM. TYPE    C    (I=IMP AERO, C=CLAS AERO, P=PHYSICAL)
TEST TYPE           OUTLET
RUN NUMBER          6-O - FILE NAME: B:T205R6-O.OUT
REMARKS:            DATA ANALYSIS
IMPACTOR TYPE       UW3NYU


WATER VAPOR          3.00%
CARBON DIOXIDE      14.67%
CARBON MONOXIDE      0.00%
OXYGEN               3.71%
SULFUR DIOXIDE       0.00%
NITROGEN            81.62%
PARTICLE DENSITY    1.00 GRAMS/CM^3

GAS METER VOLUME                  25.600 CUBIC FEET
IMPACTOR DELTA P                   0.00  INCHES HG
ORIFICE DELTA P                    0.00  INCHES H2O
STACK PRESS. (BELOW ATMOS.)        0.00  INCHES H2O
BAROMETRIC PRESS.                 %260.00  INCHES HG
STACK TEMPERATURE                538.0   DEGREES F
METER TEMPERATURE                538.0   DEGREES F
IMPACTOR TEMPERATURE             538.0   DEGREES F
SAMPLE TIME                       60.00  MINUTES
AV. VELOCITY OF STACK GAS          0.00  FEET/MINUTE
GAS METER PRESSURE                 0.00  IN HG
NOZZLE DIAMETER                    0.43  INCHES
MAXIMUM AERODYN. DIAMETER       1000.00  MICRONS

MASS GAIN ON STAGE  1                0.50 MG
MASS GAIN ON STAGE  2                1.10 MG
MASS GAIN ON STAGE  3                1.90 MG
MASS GAIN ON STAGE  4                3.10 MG
MASS GAIN ON STAGE  5                4.20 MG
MASS GAIN ON STAGE  6                5.80 MG
MASS GAIN ON STAGE  7                0.10 MG
MASS GAIN ON FINAL FILTER            0.50 MG
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                    ****        RESULTS        ****

DATE OF TEST          06/08/88
TIME OF TEST          1750
LOCATION OF TEST      NYU-PFBC
TEST NUMBER           205  -
RUN NUMBER            6-0
ACTUAL FLOW RATE (STACK CONDITIONS)        0.440 CFM
FLOW RATE (STANDARD CONDITIONS)            1.962 CFM
PERCENT ISOKINETIC SAMPLING                0.00  %

VISCOSITY OF GAS STREAM                    0.0002709 GRAMS/CM-SEC
STAGE          CCF          DP(CLAS AERO) DP(IMP AERO)   CUM FRACTION
  1           1.004             8.833         8.852         0.9709
  2           1.002            15.328        15.347         0.9070
  3           1.006             6.250         6.269         0.7965
  4           1.011             3.265         3.283         0.6163
  5           1.020             1.895         1.913         0.3721
  6           1.035             1.077         1.096         0.0349
  7           1.060             0.618         0.637         0.0291

NOTE: THE MASS ON STAGES 1 AND 2 WILL BE COMBINED AND ASSIGNED TO
      THE OUTPUT ON STAGE 1 , FOR SPLINE FITTING ANALYSIS.

TOTAL MASS PER DRY NORMAL CUBIC METER     5.1631 MG/CUBIC METER

PART. DIAM. TYPE   C    (I=IMP AERO, C=CLAS AERO, P=PHYSICAL)
PARTICLE SIZE      CUMFR          CUMFR          CUM.MASS       dM/dLOG D
  (MICRONS)     (STD. DEV.)    (PER CENT)     (MG/DRY N.CU.METER)

   0.20          -2.0603          2.0           0.102          0.083
   0.25          -2.0276          2.1           0.110          0.089
   0.40          -1.9588          2.5           0.129          0.102
   0.50          -1.9262          2.7           0.140          0.109
   0.75          -1.8668          3.1           0.160          0.122
   1.00          -1.8247          3.4           0.176          0.131
   1.50          -0.9656         16.7           0.863          8.909
   2.00          -0.2131         41.6           2.146          8.963
   2.50           0.1017         54.1           2.791          4.643
   4.00           0.4239         66.4           3.429          2.949
   5.00           0.5963         72.5           3.741          3.520
   7.50           1.0760         85.9           4.435          3.882
  10.00           1.5761         94.3           4.866          2.800
  15.00           2.4056         99.2           5.121          0.538
  20.00           2.9959         99.9           5.156          0.110
  25.00           3.4555        100.0           5.162          0.025
  40.00           4.4328        100.0           5.163          0.001
  50.00           4.9035        100.0           5.163          0.000
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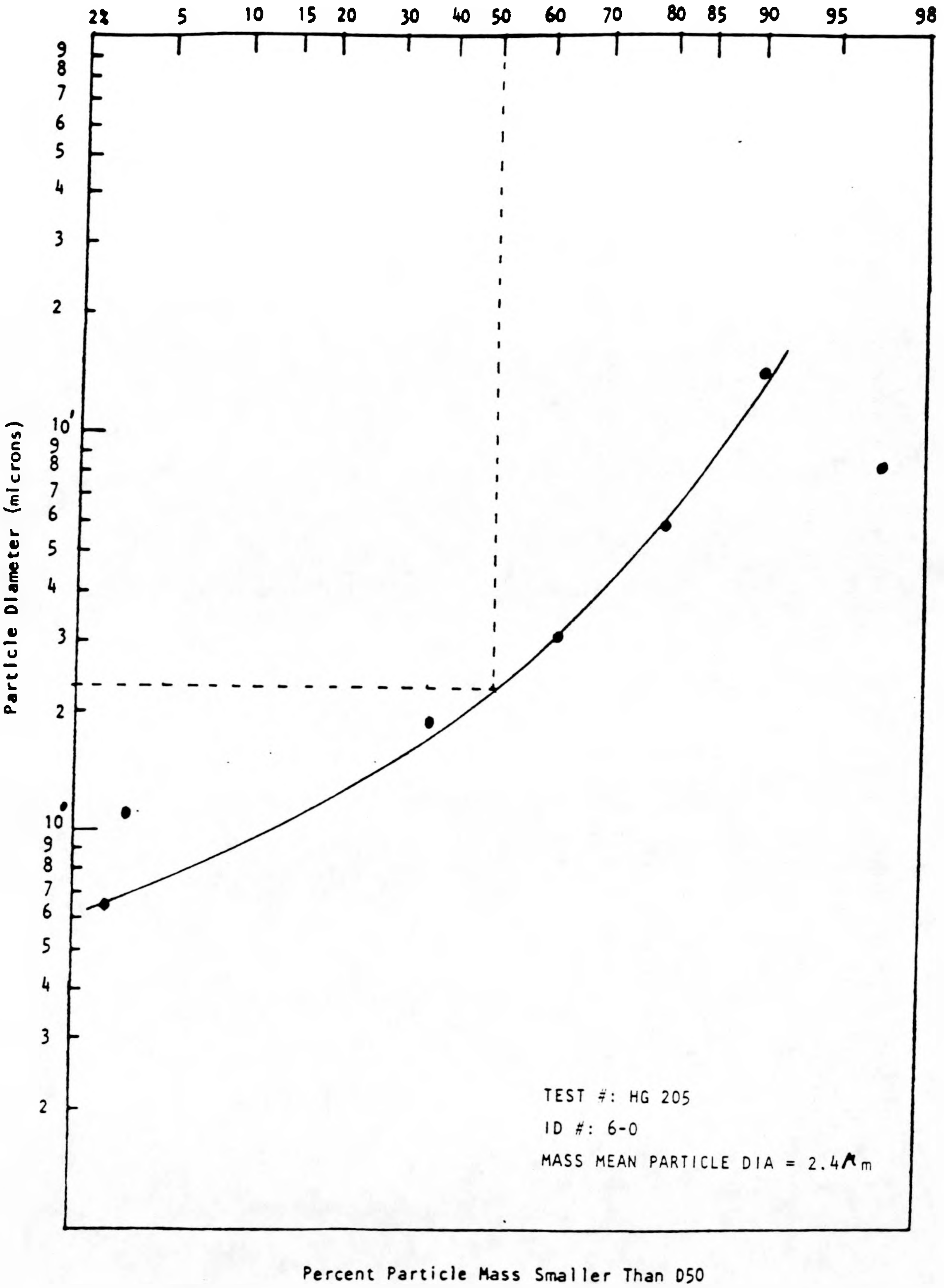

TEST #: HG 205

ID #: 6-0

MASS MEAN PARTICLE DIA = 2.4 µm

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     *****     P A R T I C L E   S I Z E   A N A L Y S I S     *****

                            ****     INPUT DATA     ****

DATE OF TEST         06/09/88
TIME OF TEST         0916
LOCATION OF TEST     NYU-PFBC
TEST NUMBER          205
PART. DIAM. TYPE     C    (I=IMP AERO, C=CLAS AERO, P=PHYSICAL)
TEST TYPE            INLET
RUN NUMBER           7-I - FILE NAME: B:T205R7-I.INT
REMARKS:             DATA ANALYSIS
IMPACTOR TYPE        UWVNYU


WATER VAPOR           3.00%
CARBON DIOXIDE       14.00%
CARBON MONOXIDE       0.00%
OXYGEN                4.58%
SULFUR DIOXIDE        0.00%
NITROGEN             81.42%
PARTICLE DENSITY     1.00 GRAMS/CM^3

GAS METER VOLUME                    4.460 CUBIC FEET
IMPACTOR DELTA P                    0.00  INCHES HG
ORIFICE DELTA P                     0.00  INCHES H2O
STACK PRESS. (BELOW ATMOS.)         0.00  INCHES H2O
BAROMETRIC PRESS.                  %228.10  INCHES HG
STACK TEMPERATURE                 523.3   DEGREES F
METER TEMPERATURE                 523.3   DEGREES F
IMPACTOR TEMPERATURE              523.3   DEGREES F
SAMPLE TIME                        10.00  MINUTES
AV. VELOCITY OF STACK GAS           0.00  FEET/MINUTE
GAS METER PRESSURE                  0.00  IN HG
NOZZLE DIAMETER                     0.43  INCHES
MAXIMUM AERODYN. DIAMETER        1000.00  MICRONS

MASS GAIN ON STAGE  1                 20.10 MG
MASS GAIN ON STAGE  2                  2.60 MG
MASS GAIN ON STAGE  3                 13.10 MG
MASS GAIN ON STAGE  4                 21.50 MG
MASS GAIN ON STAGE  5                  6.70 MG
MASS GAIN ON STAGE  6                  4.80 MG
MASS GAIN ON STAGE  7                  2.00 MG
MASS GAIN ON STAGE  8                  0.30 MG
MASS GAIN ON STAGE  9                  0.10 MG
MASS GAIN ON STAGE  10                 0.20 MG
MASS GAIN ON STAGE  11                 0.50 MG
MASS GAIN ON FINAL FILTER              0.25 MG
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                    ****        RESULTS        ****

 DATE OF TEST          06/09/88
 TIME OF TEST          0916.
 LOCATION OF TEST      NYU-PFBC
 TEST NUMBER           205  -
 RUN NUMBER            7-I
 ACTUAL FLOW RATE (STACK CONDITIONS)       0.460 CFM
 FLOW RATE (STANDARD CONDITIONS)           1.826 CFM
 PERCENT ISOKINETIC SAMPLING               0.00  %

 VISCOSITY OF GAS STREAM                   0.0002686 GRAMS/CM-SEC
 STAGE          CCF           DP(CLAS AERO) DP(IMP AERO)   CUM FRACTION
    1          1.003              14.346        14.367         0.7214
    2          1.003              14.924        14.945         0.6854
    3          1.006               6.624         6.645         0.5038
    4          1.013               3.195         3.216         0.2058
    5          1.023               1.842         1.863         0.1130
    6          1.034               1.216         1.236         0.0464
    7          1.040               1.047         1.067         0.0187
    8          1.056               0.752         0.773         0.0146
    9          1.065               0.639         0.660         0.0132
   10          1.076               0.553         0.574         0.0104
   11          1.089               0.469         0.490         0.0035

 NOTE: THE MASS ON STAGES 1 AND 2 WILL BE COMBINED AND ASSIGNED TO
       THE OUTPUT ON STAGE 1 , FOR SPLINE FITTING ANALYSIS.

 TOTAL MASS PER DRY NORMAL CUBIC METER  139.6147 MG/CUBIC METER

 PART. DIAM. TYPE   C    (I=IMP AERO, C=CLAS AERO, P=PHYSICAL)
RTICLE SIZE     CUMFR          CUMFR           CUM.MASS       dM/dLOG D
 (MICRONS)    (STD. DEV.)    (PER CENT)        (MG/DRY N.CU.METER)

   0.20        -6.2969          0.0            0.000           0.000
   0.25        -5.3562          0.0            0.000           0.000
   0.40        -3.3747          0.0            0.052           1.819
   0.50        -2.5509          0.5            0.751          11.724
   0.75        -1.5915          5.6            7.782          85.518
   1.00        -0.9108         18.1           25.296         200.420
   1.50         0.0485         51.9           72.511         303.100
   2.00         0.7292         76.7          107.094         232.606
   2.50         1.2572         89.6          125.049         137.680
   4.00         2.3693         99.1          138.369          18.327
   5.00         2.8973         99.8          139.351           4.563
   7.50         3.8567        100.0          139.607           0.179
  10.00         4.5374        100.0          139.614           0.010
  15.00         5.4968        100.0          139.615           0.000
  20.00         6.1775        100.0          139.615           0.000
  25.00         6.7055        100.0          139.615           0.000
  40.00         7.8176        100.0          139.615           0.000
  50.00         8.3456        100.0          139.615           0.000
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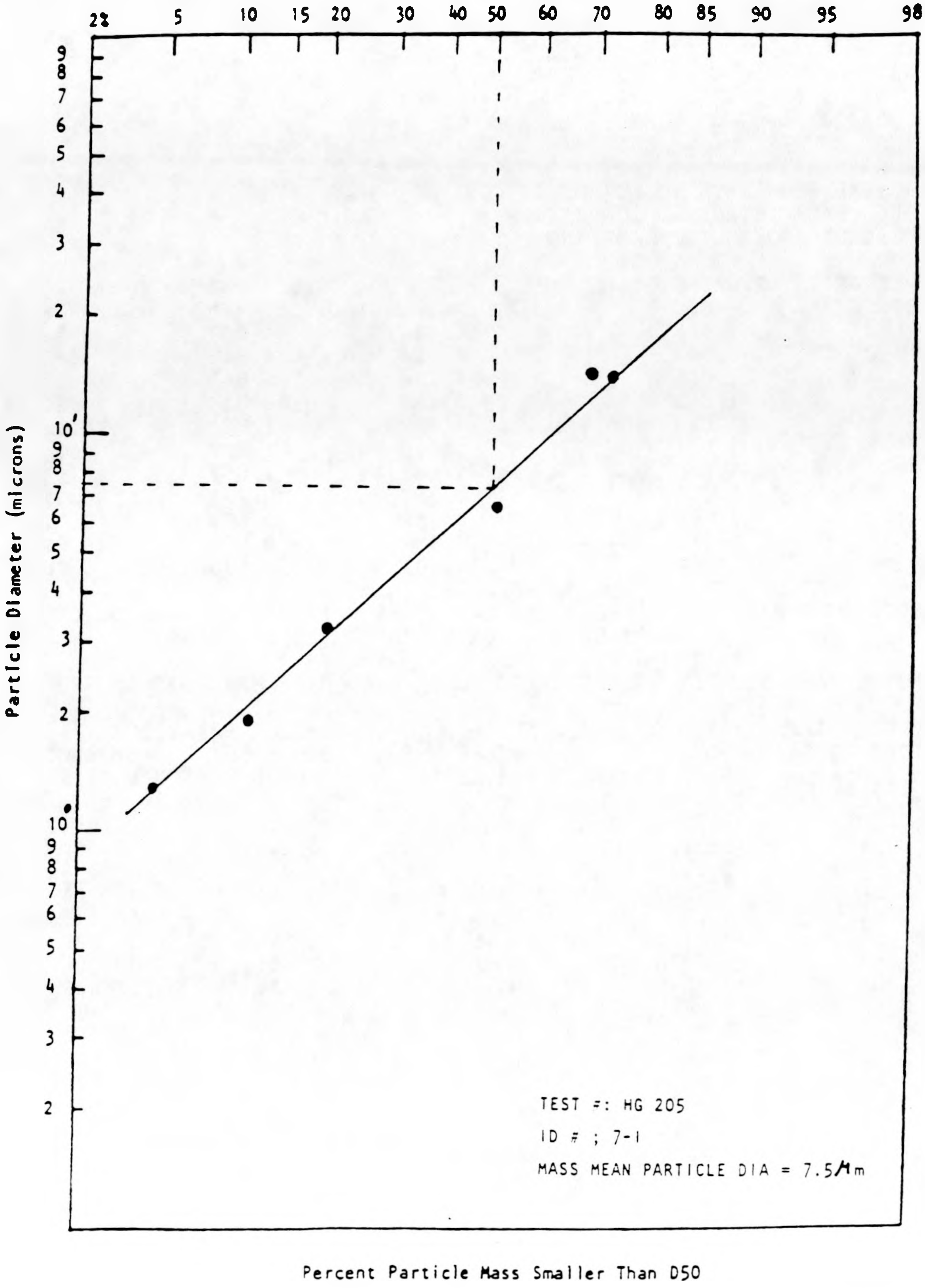
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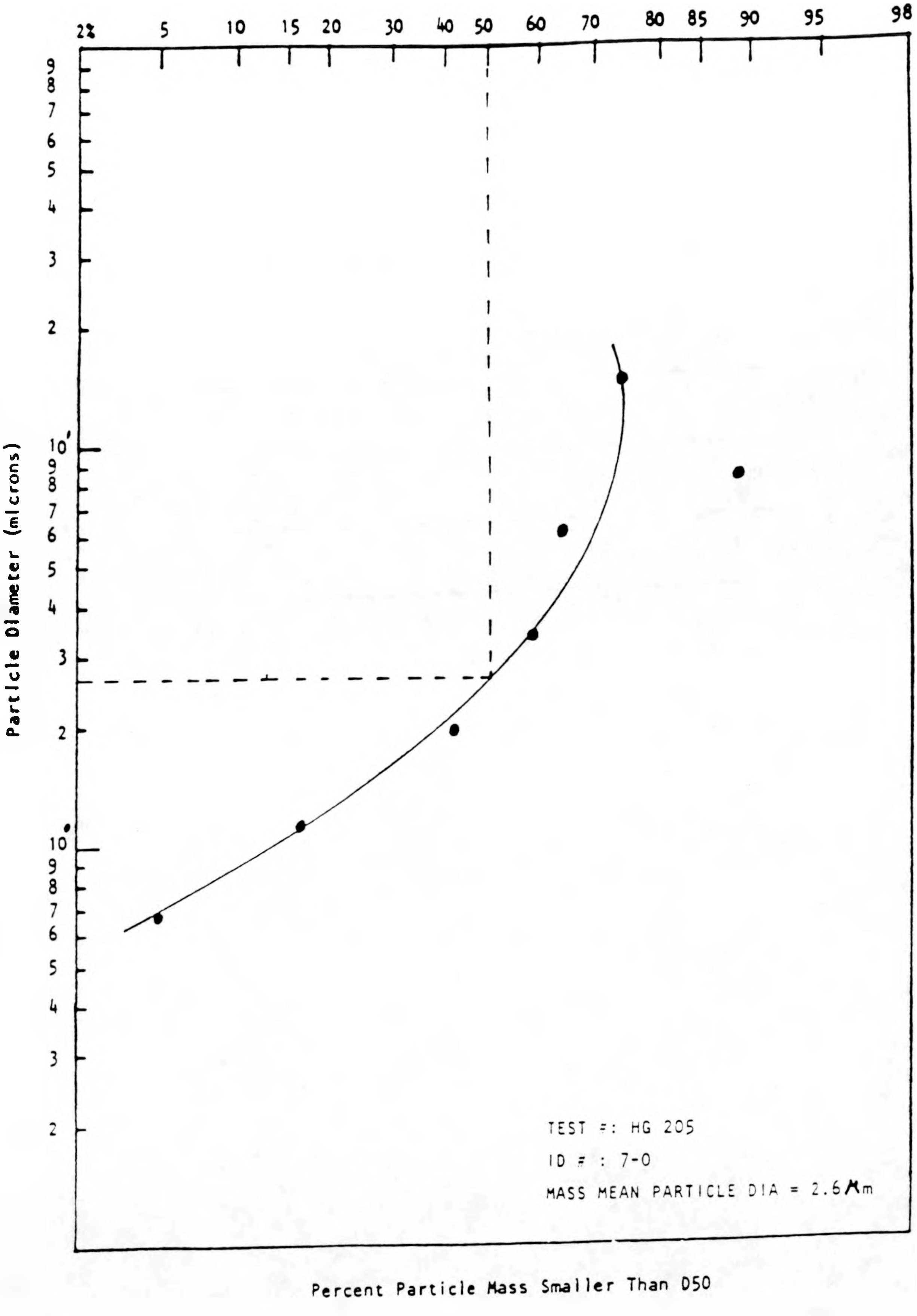
2
Particle Diameter (microns)
TEST #: HG 205
ID # ; 7-1
MASS MEAN PARTICLE DIA = 7.5µm
Percent Particle Mass Smaller Than D50

```
*****     P A R T I C L E   S I Z E   A N A L Y S I S     *****

                    **** .     INPUT DATA        ****

DATE OF TEST         06/09/88
TIME OF TEST         0915
LOCATION OF TEST     NYU-PFBC
TEST NUMBER          205
PART. DIAM. TYPE     C     (I=IMP AERO, C=CLAS AERO, P=PHYSICAL)
TEST TYPE            OUTLET
RUN NUMBER           7-O - FILE NAME: B:T205R7-O.OUT
REMARKS:             DATA ANALYSIS
IMPACTOR TYPE        UW3NYU


WATER VAPOR          3.00%
CARBON DIOXIDE      13.89%
CARBON MONOXIDE      0.00%
OXYGEN               4.95%
SULFUR DIOXIDE       0.00%
NITROGEN            81.16%
PARTICLE DENSITY    1.00 GRAMS/CM^3

GAS METER VOLUME                 14.390 CUBIC FEET
IMPACTOR DELTA P                   0.00  INCHES HG
ORIFICE DELTA P                    0.00  INCHES H2O
STACK PRESS. (BELOW ATMOS.)        0.00  INCHES H2O
BAROMETRIC PRESS.                %235.57  INCHES HG
STACK TEMPERATURE                355.0   DEGREES F
METER TEMPERATURE                355.0   DEGREES F
IMPACTOR TEMPERATURE             355.0   DEGREES F
SAMPLE TIME                       40.00  MINUTES
AV. VELOCITY OF STACK GAS          0.00  FEET/MINUTE
GAS METER PRESSURE                 0.00  IN HG
NOZZLE DIAMETER                    0.43  INCHES
MAXIMUM AERODYN. DIAMETER       1000.00  MICRONS

MASS GAIN ON STAGE  1               0.90 MG
MASS GAIN ON STAGE  2               1.10 MG
MASS GAIN ON STAGE  3               0.80 MG
MASS GAIN ON STAGE  4               0.40 MG
MASS GAIN ON STAGE  5               1.30 MG
MASS GAIN ON STAGE  6               2.00 MG
MASS GAIN ON STAGE  7               0.90 MG
MASS GAIN ON FINAL FILTER           0.40 MG
```

```
                        ****        RESULTS        ****

    DATE OF TEST           06/09/88
    TIME OF TEST           0915
    LOCATION OF TEST       NYU-PFBC
    TEST NUMBER            205  -
    RUN NUMBER             7-0
    ACTUAL FLOW RATE (STACK CONDITIONS)       0.371 CFM
    FLOW RATE (STANDARD CONDITIONS)           1.835 CFM
    PERCENT ISOKINETIC SAMPLING               0.00  %

    VISCOSITY OF GAS STREAM                   0.0002346 GRAMS/CM-SEC
    STAGE          CCF           DP(CLAS AERO) DP(IMP AERO)   CUM FRACTION
      1           1.004              8.954         8.970          0.8846
      2           1.002             15.536        15.552          0.7436
      3           1.005              6.336         6.352          0.6410
      4           1.010              3.311         3.327          0.5897
      5           1.017              1.923         1.939          0.4231
      6           1.029              1.095         1.111          0.1667
      7           1.051              0.629         0.645          0.0513

    NOTE: THE MASS ON STAGES 1 AND 2 WILL BE COMBINED AND ASSIGNED TO
          THE OUTPUT ON STAGE 1 , FOR SPLINE FITTING ANALYSIS.

    TOTAL MASS PER DRY NORMAL CUBIC METER     3.7544 MG/CUBIC METER

    PART. DIAM.  TYPE   C     (I=IMP AERO, C=CLAS AERO, P=PHYSICAL)
 PARTICLE SIZE      CUMFR          CUMFR            CUM.MASS        dM/dLOG D
   (MICRONS)     (STD. DEV.)    (PER CENT)         (MG/DRY N.CU.METER)

     0.20         -2.8178          0.2              0.009          0.067
     0.25         -2.5871          0.5              0.018          0.125
     0.40         -2.1013          1.8              0.067          0.392
     0.50         -1.8707          3.1              0.115          0.620
     0.75         -1.4337          7.6              0.285          1.420
     1.00         -1.0863         13.9              0.521          2.456
     1.50         -0.5216         30.1              1.130          4.253
     2.00         -0.1481         44.1              1.656          3.862
     2.50          0.0679         52.7              1.979          2.742
     4.00          0.2628         60.4              2.266          0.340
     5.00          0.2846         61.2              2.298          0.489
     7.50          0.4848         68.6              2.576          2.696
    10.00          0.8441         80.1              3.006          4.153
    15.00          1.5420         93.8              3.523          1.811
    20.00          2.0389         97.9              3.677          0.747
    25.00          2.4261         99.2              3.726          0.316
    40.00          3.2508         99.9              3.752          0.031
    50.00          3.6489        100.0              3.754          0.008
```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2
10°
9
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7
6
5
4
3
2
Particle Diameter (microns)
TEST #: HG 205
ID # : 7-0
MASS MEAN PARTICLE DIA = 2.6 μm
Percent Particle Mass Smaller Than D50

Mass Mean Particle Diameter

From Impactor Log-probability Plots

Test # HG - 205

I D No.	FILTER INLET (microns)	FILTER OUTLET (microns)
HG205-3	12.0	1.7
HG205-4	16.0	1.6
HG205-5	16.5	-
HG205-6	21.0	2.4
HG205-7	7.5	2.6

IID.2 ALKALI DATA

The alkali data presented in this section were obtained from the NYU Total Alkali method and the METC/INEL on-line alkali sampling system. During the METC/INEL sampling period, only the outlet of the GBF was sampled.

IID.2.1 RESULTS FROM NYU ALKALI METHOD

Test No. : HG 203

NYU ALKALI ANALYSIS DATA

Type Of Sampling : Total Condensate Method

Description	Run No. 1		Run No. 2		Run No. 3		Run No. 4		Run No. 5		Run No. 6		Run No. 7	
	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet
Date	4/14/88		4/14/88		4/14/88		4/15/88		4/15/88					
Sampling Time hrs.	* 19:47 - 20:40		22:06 - 22:50		23:06 -23:45		12:20-12:52		12:55-2:07					
Sample Flow Rate scfm	20.38	20.2	9.31	9.05	9.602	9.14	9.37	9.99	9.31	9.99				
Volume Of Condensate ml	100	140	90	125	70	70	80	80	165	160				
Pottassium Concentration mg/l	29	<0.5	22	<0.5	8.8	<0.5	10	1.2	18	0.8				
Sodium Concentration mg/l	26	<0.5	21	0.3	8.5	0.5	14	1.0	38	0.7				
Sulphate Concentration mg/l	8400	23	6600	25	2000	<25	3800	< 50	5000	30				
Chloride Concentration mg/l	4100	4000	806	3000	1100	3000	1700	7000	1900	2000				
PH	7.8	1.2	7.2	1.0	8.4	1.0	7.4	1.3	5.6	1.3				

* For Run 203-1, sampling at the GBF outlet was performed between 19:47 and 20:27.

Test No. : HG 204

NYU ALKALI ANALYSIS DATA

Type Of Sampling : Total Condensate Method

Description	Run No. 1		Run No. 2		Run No. 3		Run No. 4		Run No. 5		Run No. 6		Run No. 7	
	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet
Date	5/10/88		5/10/88		5/11/88		5/12/88		5/12/88		5/13/88			
Sampling Time hrs.	16:28 -17:25		18:08 -19:20		12:11-13:30		16:03-17:03		17:45-18:25		7:18 - 8:00			
Sample Flow Rate scfm	4.63	-	4.63	4.63	4.63	4.63	5.2	5.2	5.2	5.2	5.78	5.78		
Volume Of Condensate ml	50	-	43	10	70	200	56	127	105	60	45	90		
Pottassium Concentration mg/l	31	-	34	2.5	95	< 0.2	14	0.5	12	0.5	18	0.2		
Sodium Concentration mg/l	21	-	16	2.2	60	<0.2	7.8	1.3	13.7	0.8	13	0.3		
Sulphate Concentration mg/l	7000	-	7200	5000	3100	590	1700	220	2400	500	3500	400		
Chloride Concentration mg/l	3500	-	2300	2600	19,100	1680	2100	2600	1900	2950	1500	2900		
PH	7.3	-	8.3	2.6	3.8	2.8	7.4	1.8	6.3	1.2	7.0	1.1		

Test No. : HG 205

NYU ALKALI ANALYSIS DATA

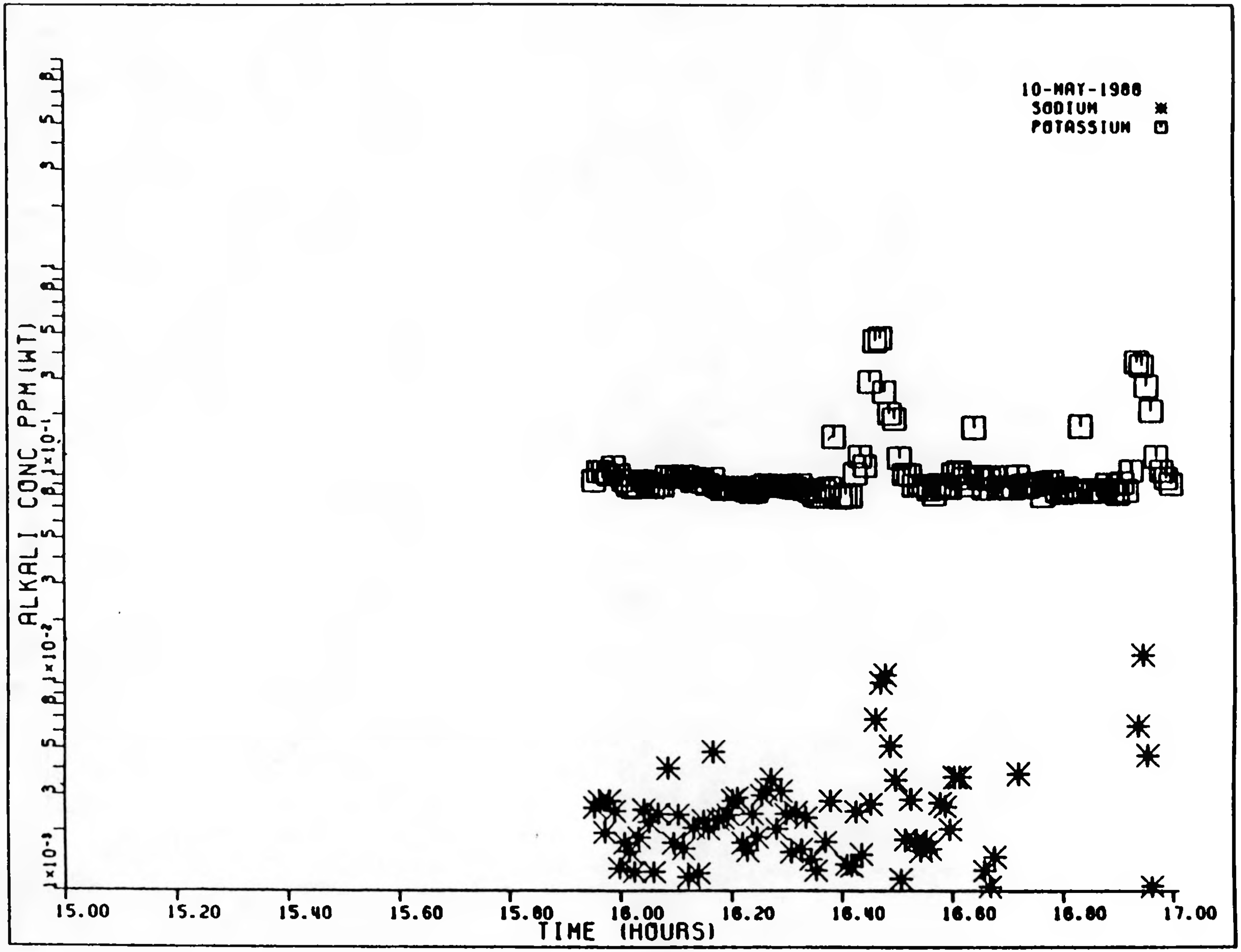
Type Of Sampling : Total Condensate Method

Description	Run No. 1		Run No. 2		Run No. 3		Run No. 4		Run No. 5		Run No. 6		Run No. 7	
	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet
Date	6/7/88		6/7/88		6/7/88		6/8/88		6/8/88		6/9/88			
Sampling Time hrs.	11:38 - 12:30		14:30-15:05		17:31 -18:08		10:15 -10:58		15:07-15:45		9:55 - 10:45			
Sample Flow Rate scfm	8.52	8.08	9.21	9.21	9.21	9.21	9.21	9.21	9.21	9.21	6.975	9.975		
Volume Of Condensate ml	74	66	97	81	108	76	87	49	86	65	100	61		
Pottassium Concentration mg/l	63	0.75	34	0.5	19	0.5	71	<0.5	35	<0.5	44	0.8		
Sodium Concentration mg/l	44	2.3	42	1.1	20	0.8	70	0.9	40	0.5	39	2.8		
Sulphate Concentration mg/l	5000	37	3100	2500	2400	2100	2400	700	2400	160	4800	95		
Chloride Concentration mg/l	4100	3000	3600	3000	2200	3000	4200	3000	4600	4000	3700	4000		
PH	3.1	1.1	6.1	1.1	4.1	1.1	8.8	1.1	7.1	1.0	7.1	0.9		

IID.2.2 RESULTS FROM

METC/INEL ON-LINE ALKALI SAMPLING

IID.2.2.1 TEST HG-204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POTASSIUM ☐
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3
5
8
1×10⁻²
2
3
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1×10⁻¹
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15.00
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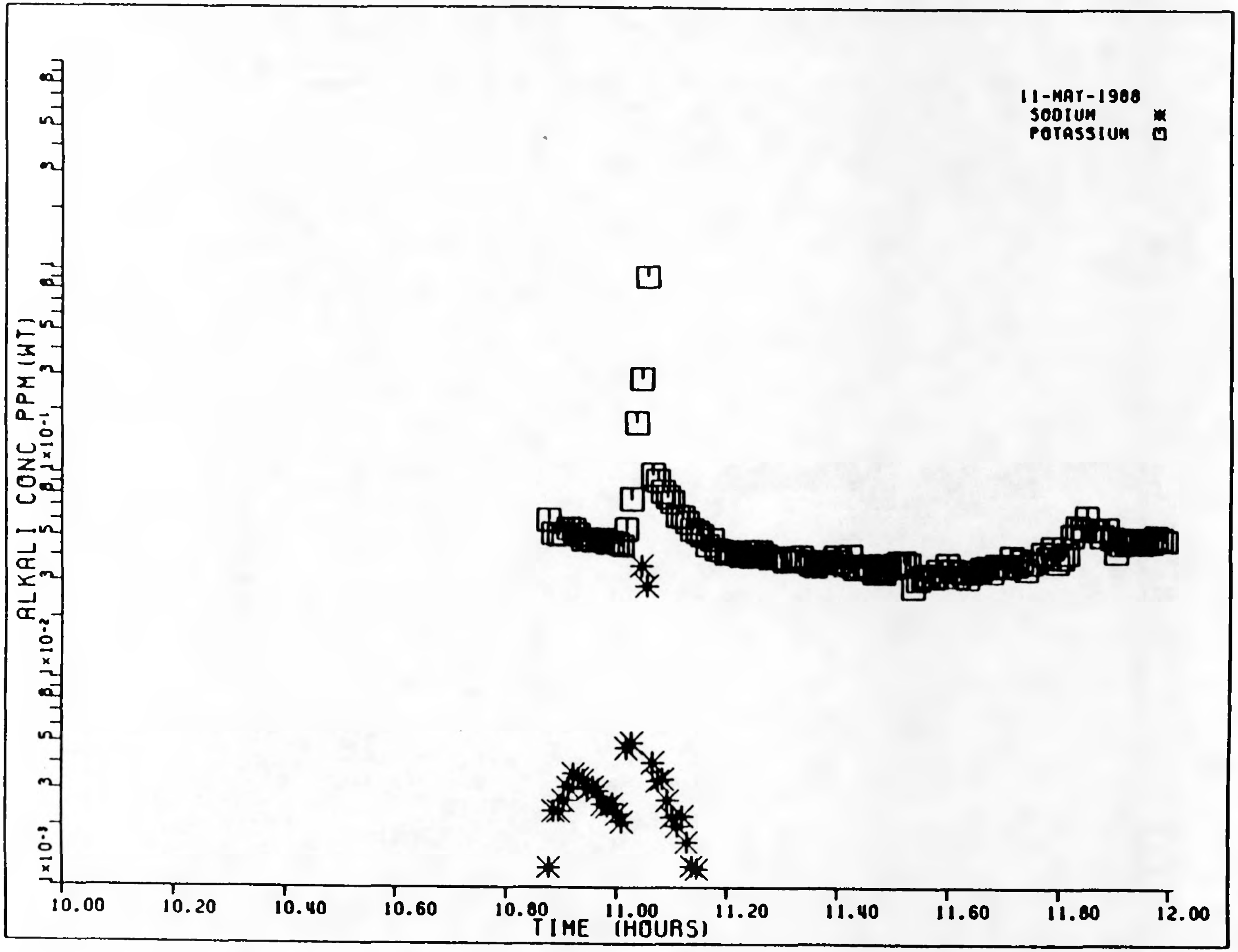
16.00
16.20
16.40
16.60
16.80
17.00
TIME (HOURS)


11-MAY-1988
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POTASSIUM ⊡
ALKALI CONC PPM(WT)
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1×10⁻²
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1×10⁻¹
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TIME (HOURS)
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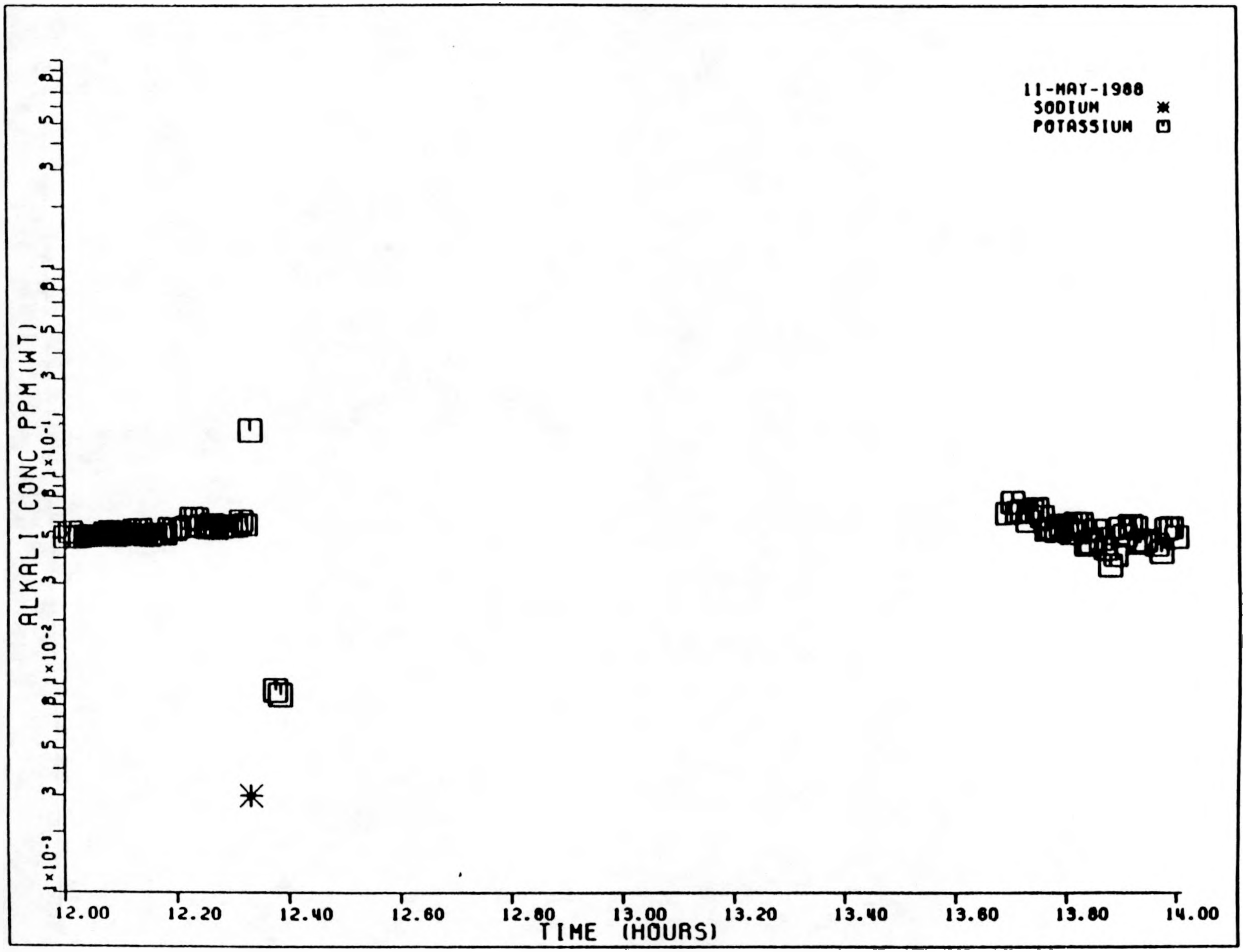
12.00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POTASSIUM □
ALKALI CONC PPM(WT)
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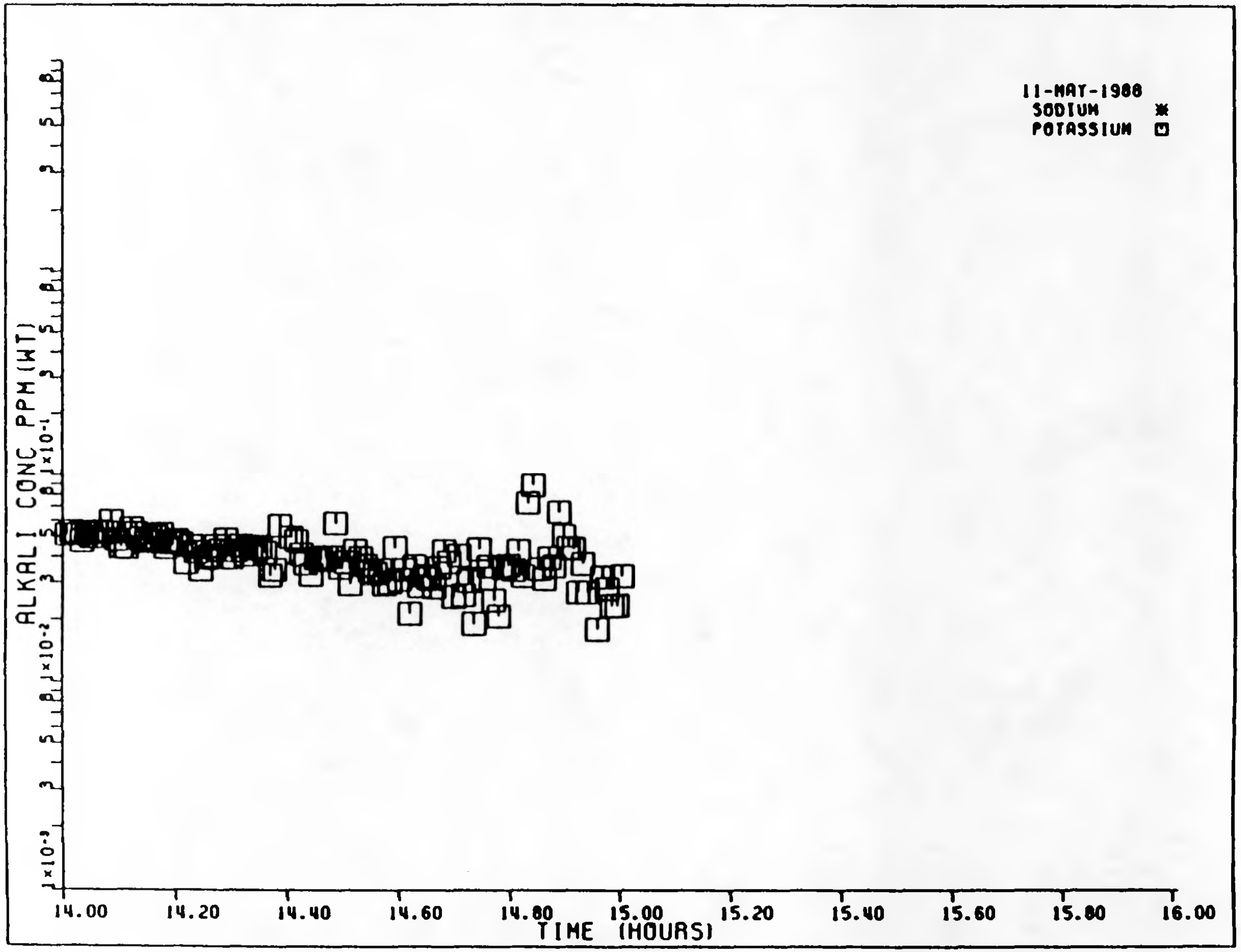
TIME (HOURS)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POTASSIUM ▢
ALKALI CONC PPM(WT)
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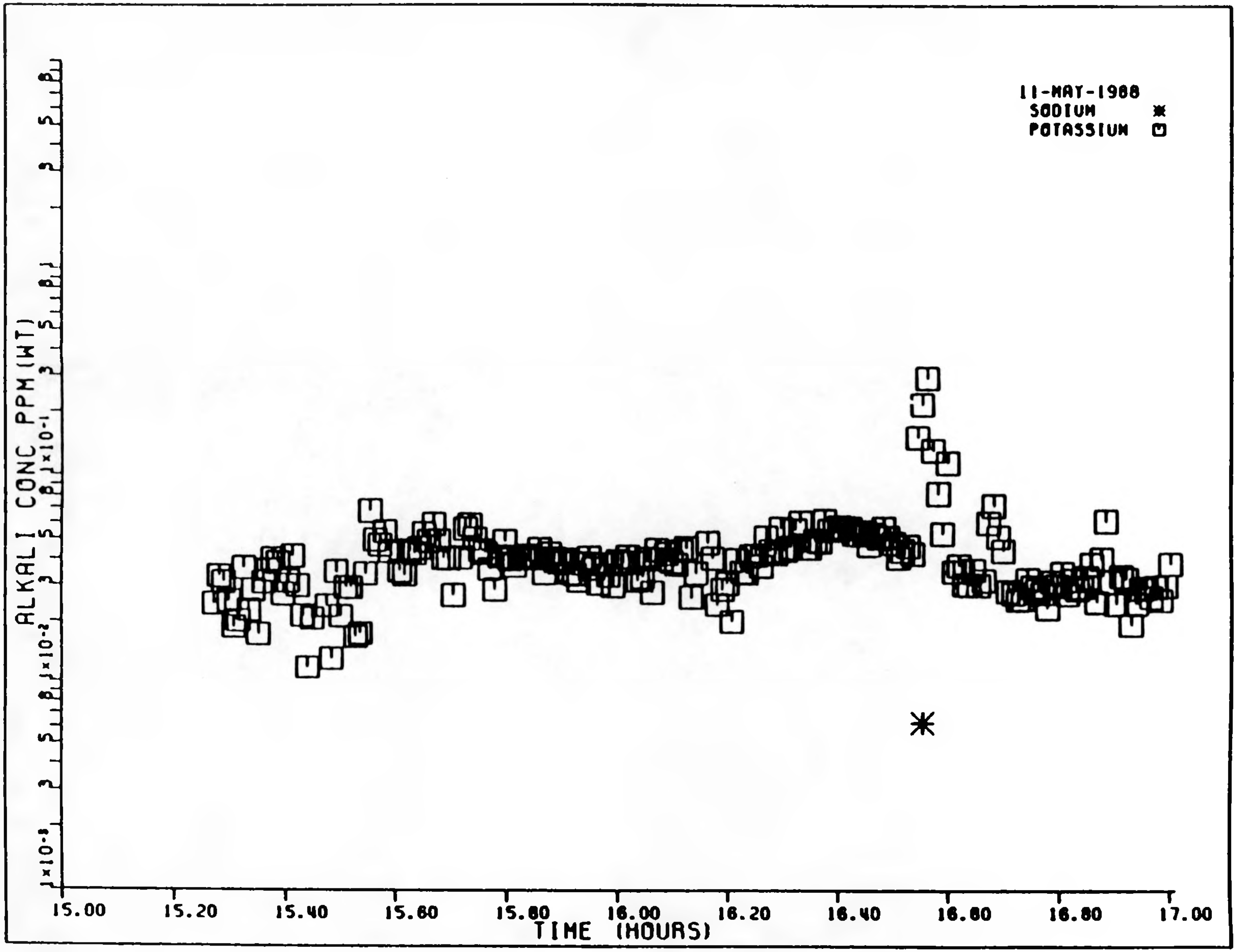
TIME (HOURS)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POTASSIUM □
ALKALI CONC PPM (WT)
TIME (HOURS)
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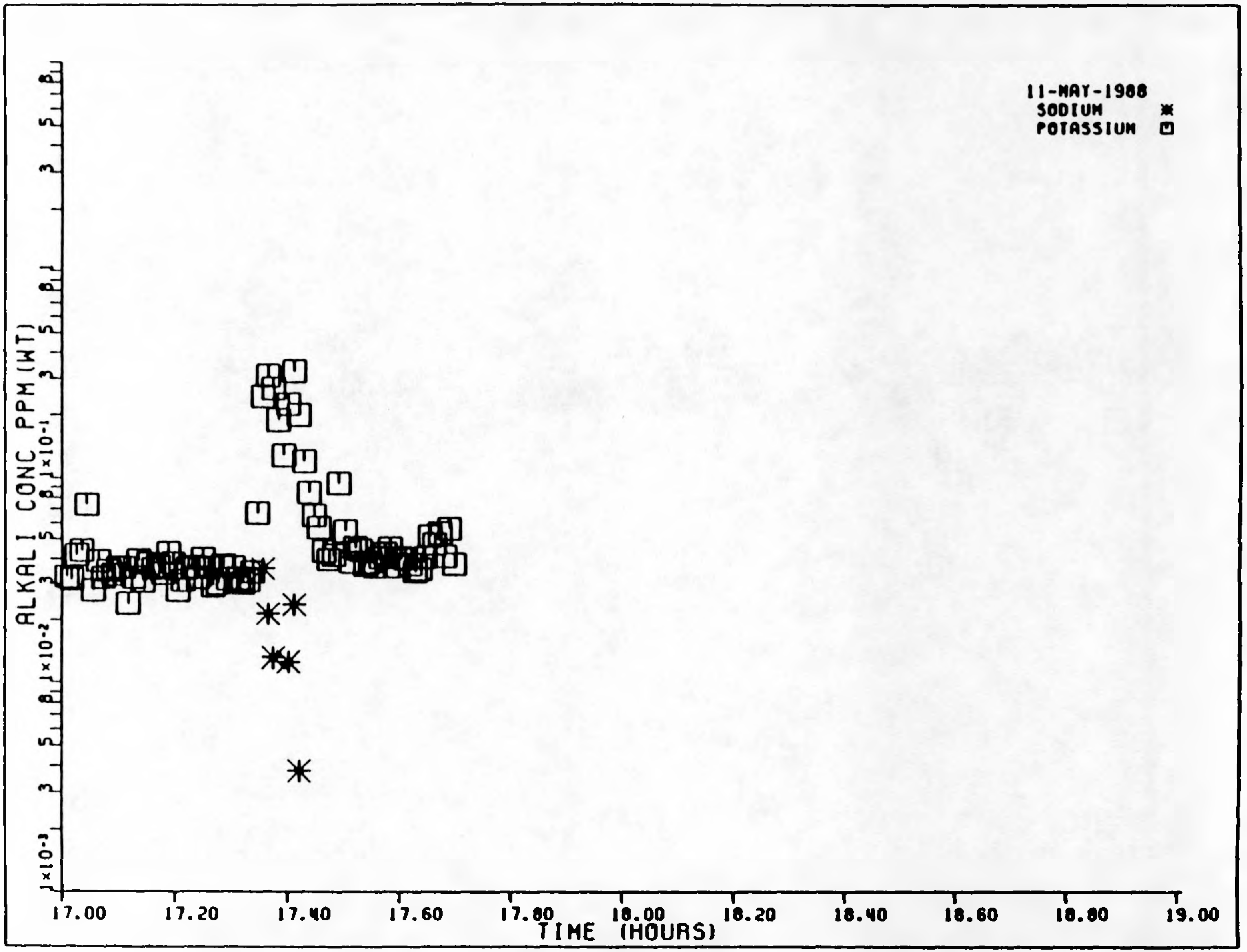
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ALKALI CONC PPM(WT)
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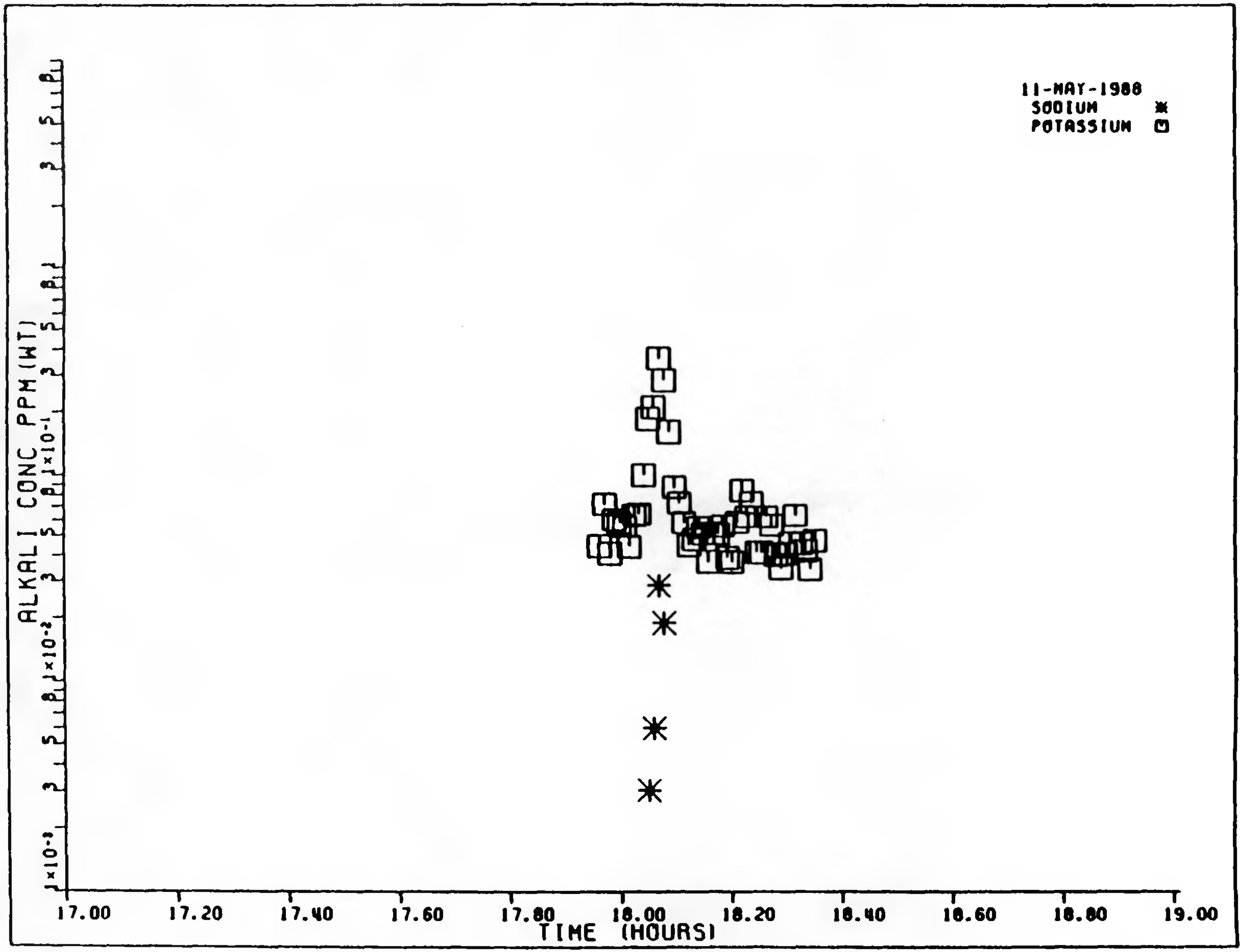
TIME (HOURS)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POTASSIUM □
ALKALI CONC PPM (WT)
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TIME (HOURS)
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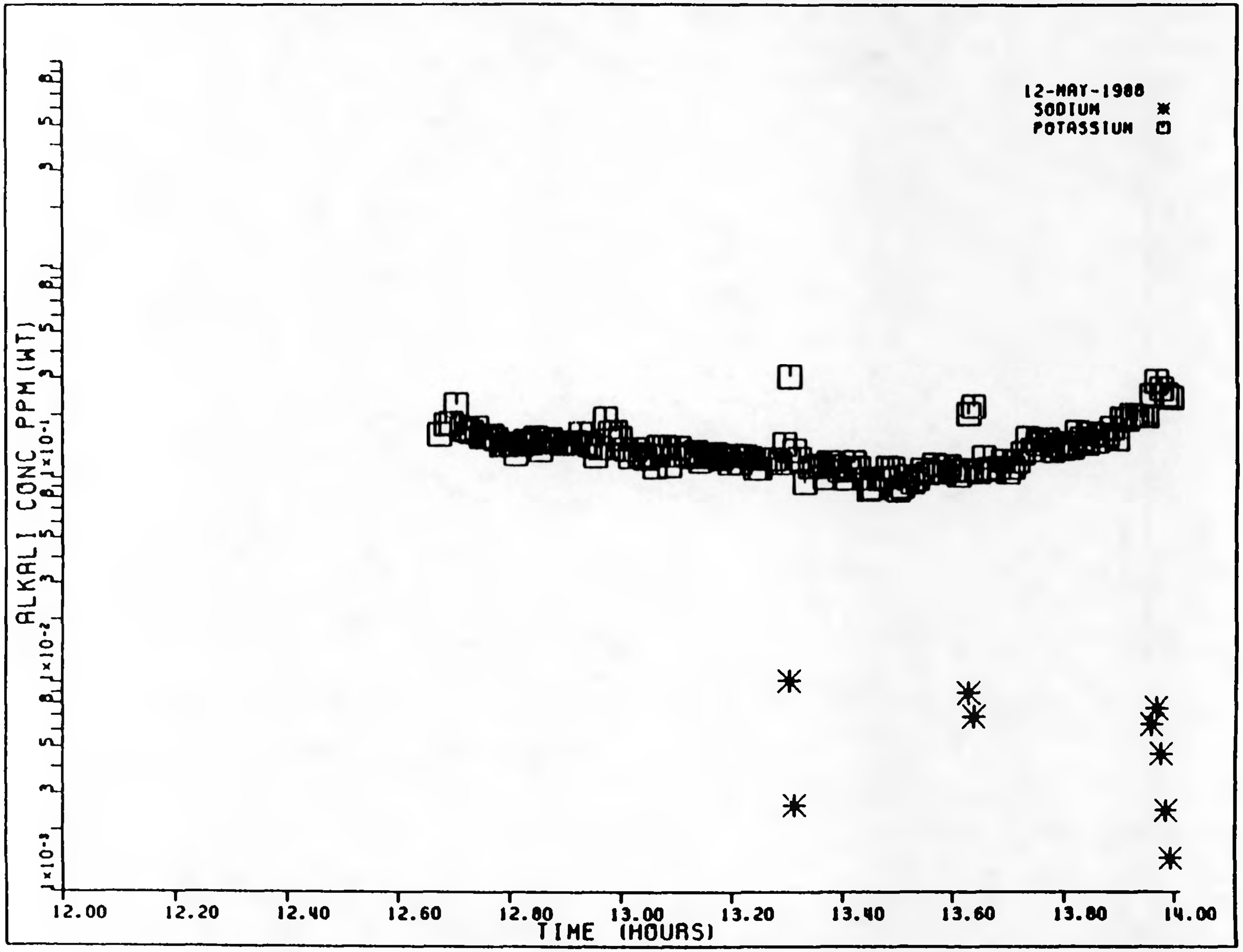
19.00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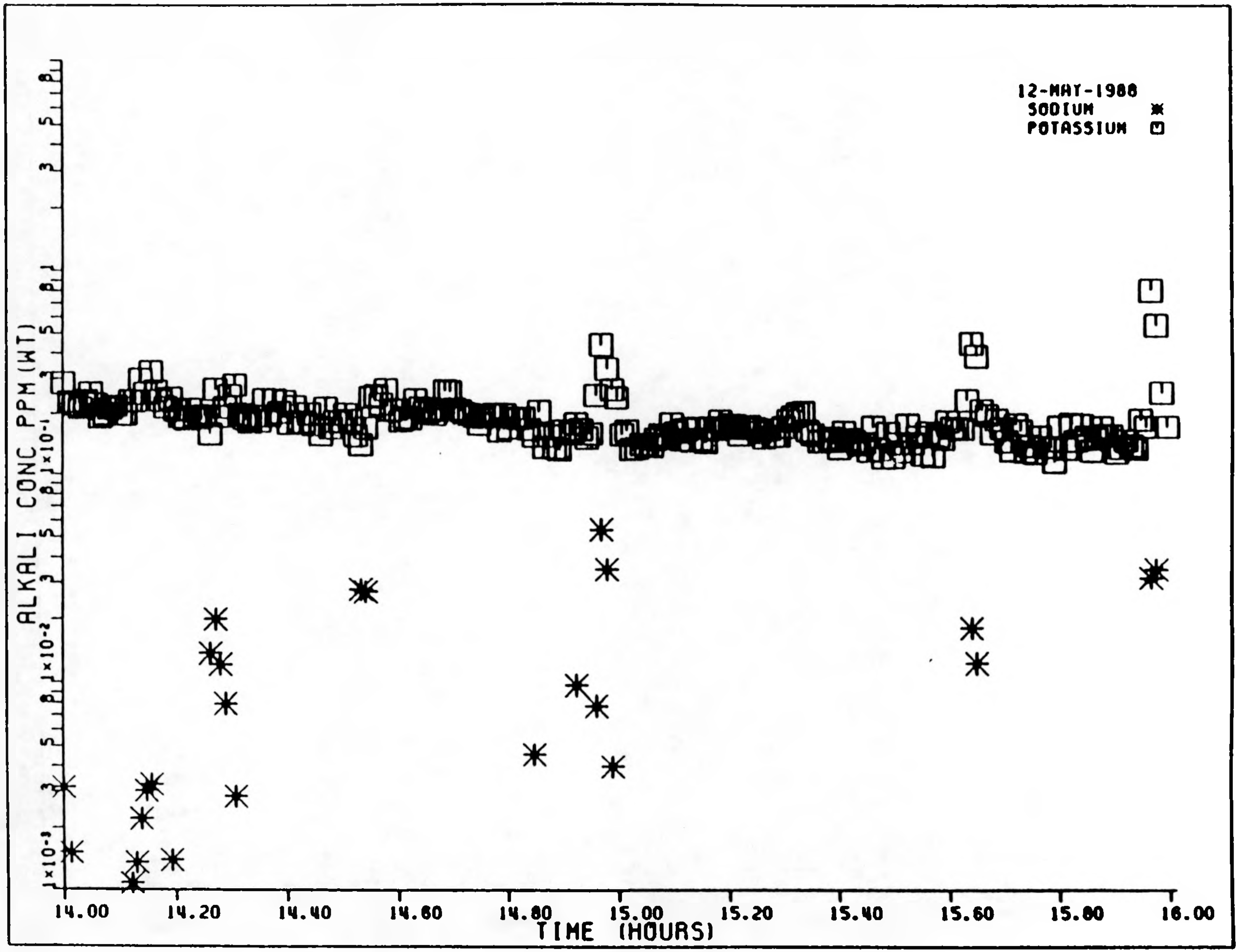
14.00
TIME (HOURS)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POTASSIUM □
ALKALI CONC PPM(WT)
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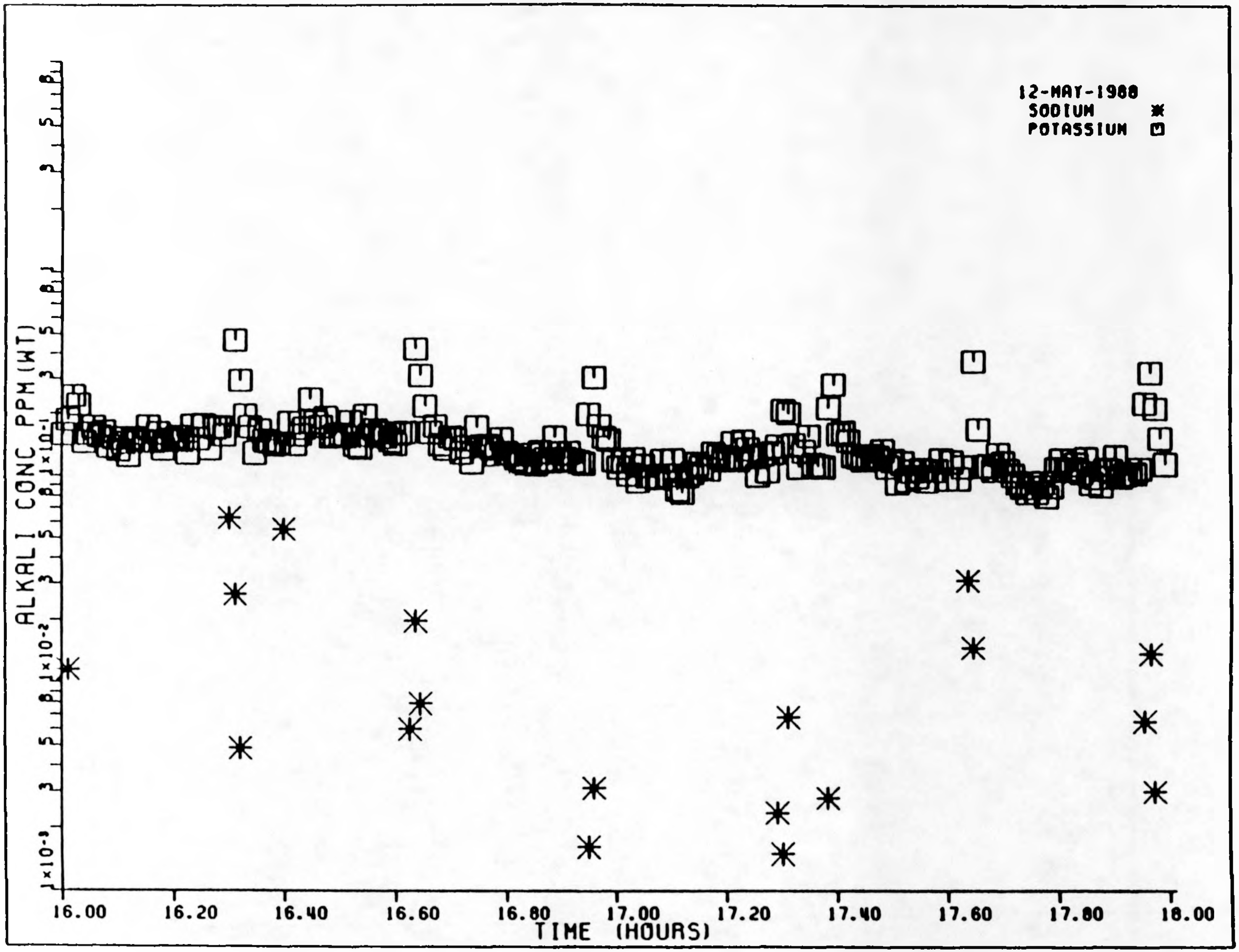
TIME (HOURS)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POTASSIUM ◻
ALKALI CONC PPM(WT)
TIME (HOURS)
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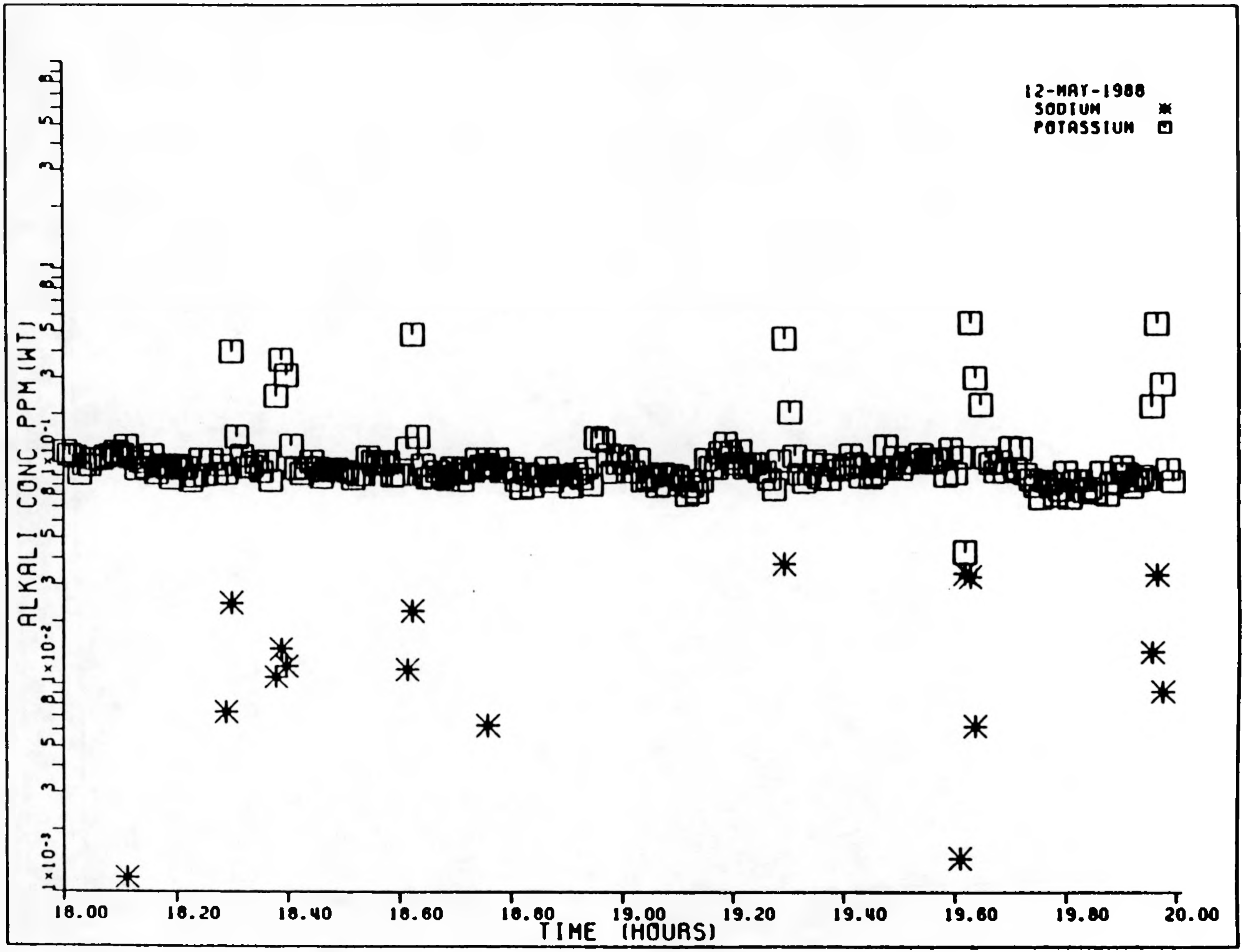
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POTASSIUM ☐
ALKALI CONC PPM (WT)
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1×10⁻²
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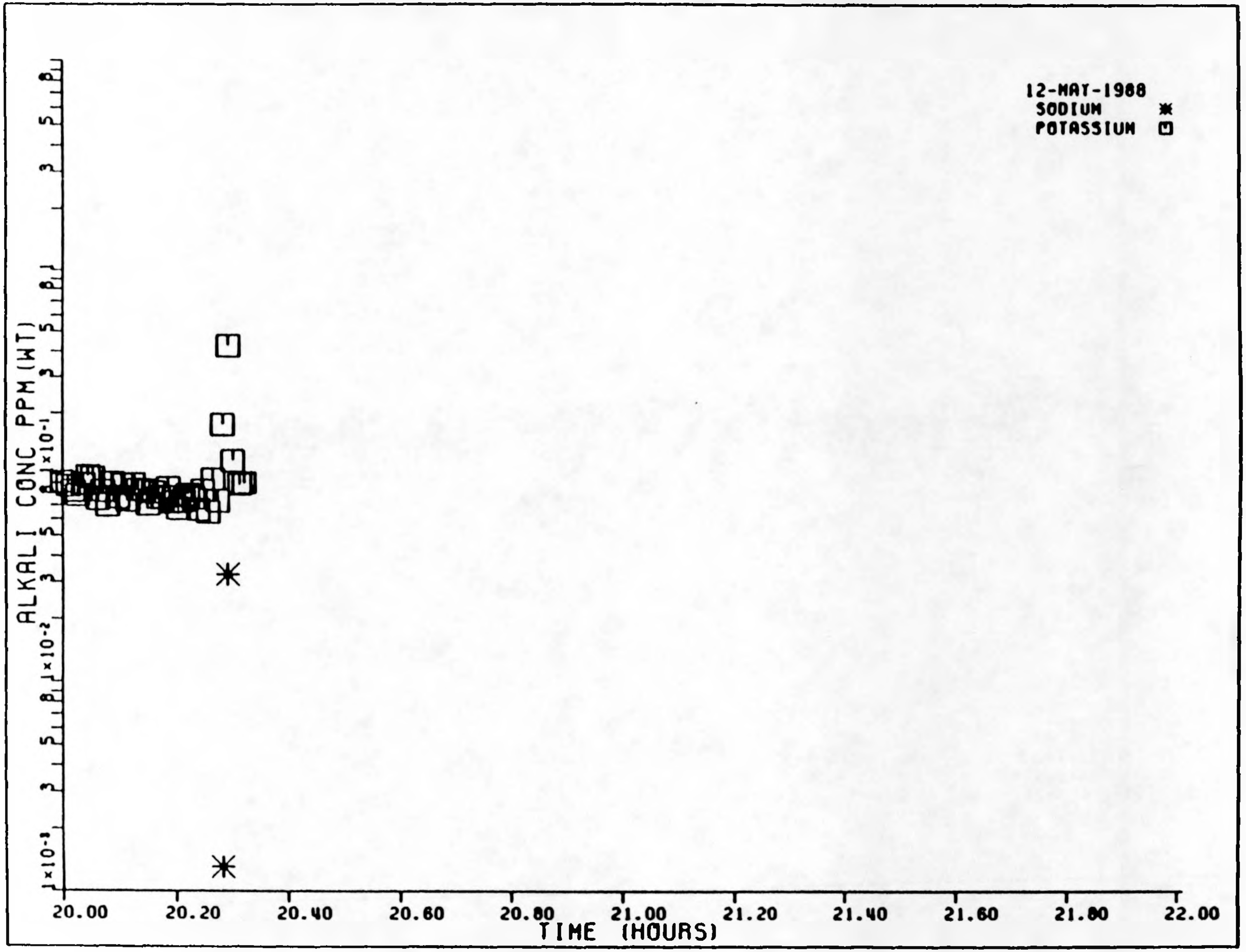
19.80
20.00
TIME (HOURS)


12-MAY-1988
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POTASSIUM ⊡
ALKALI CONC PPM(WT)
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1×10⁻²
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1×10⁻¹
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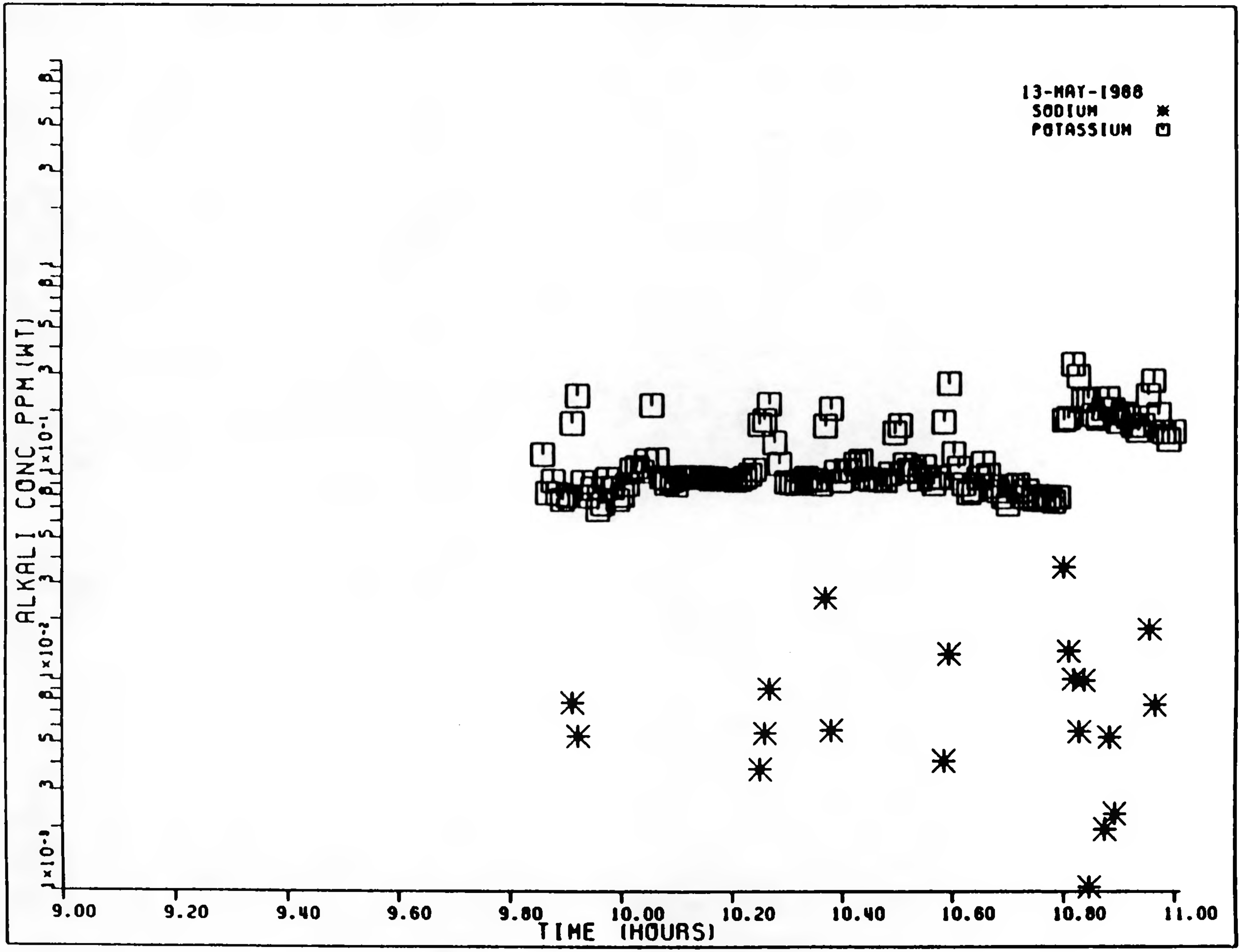
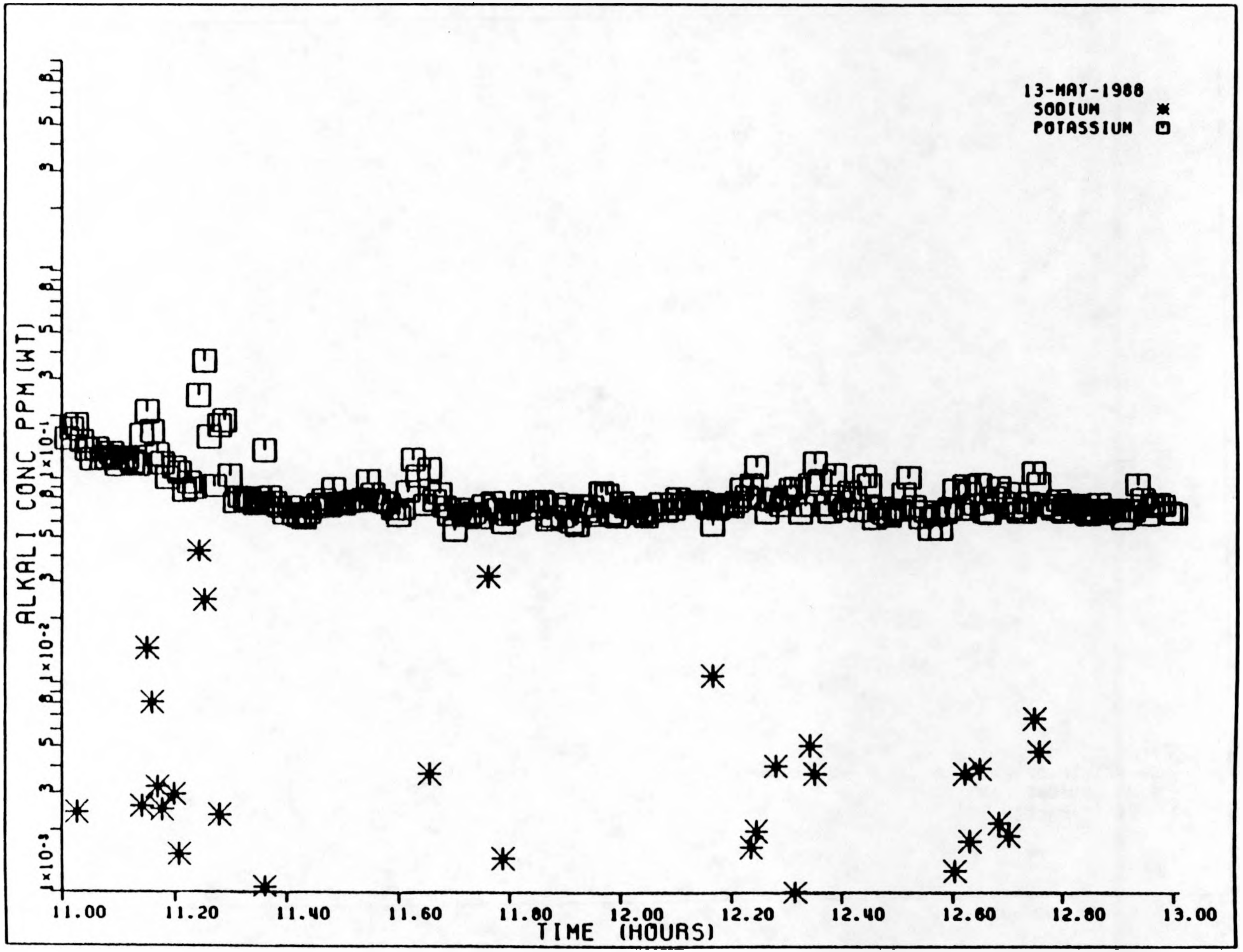
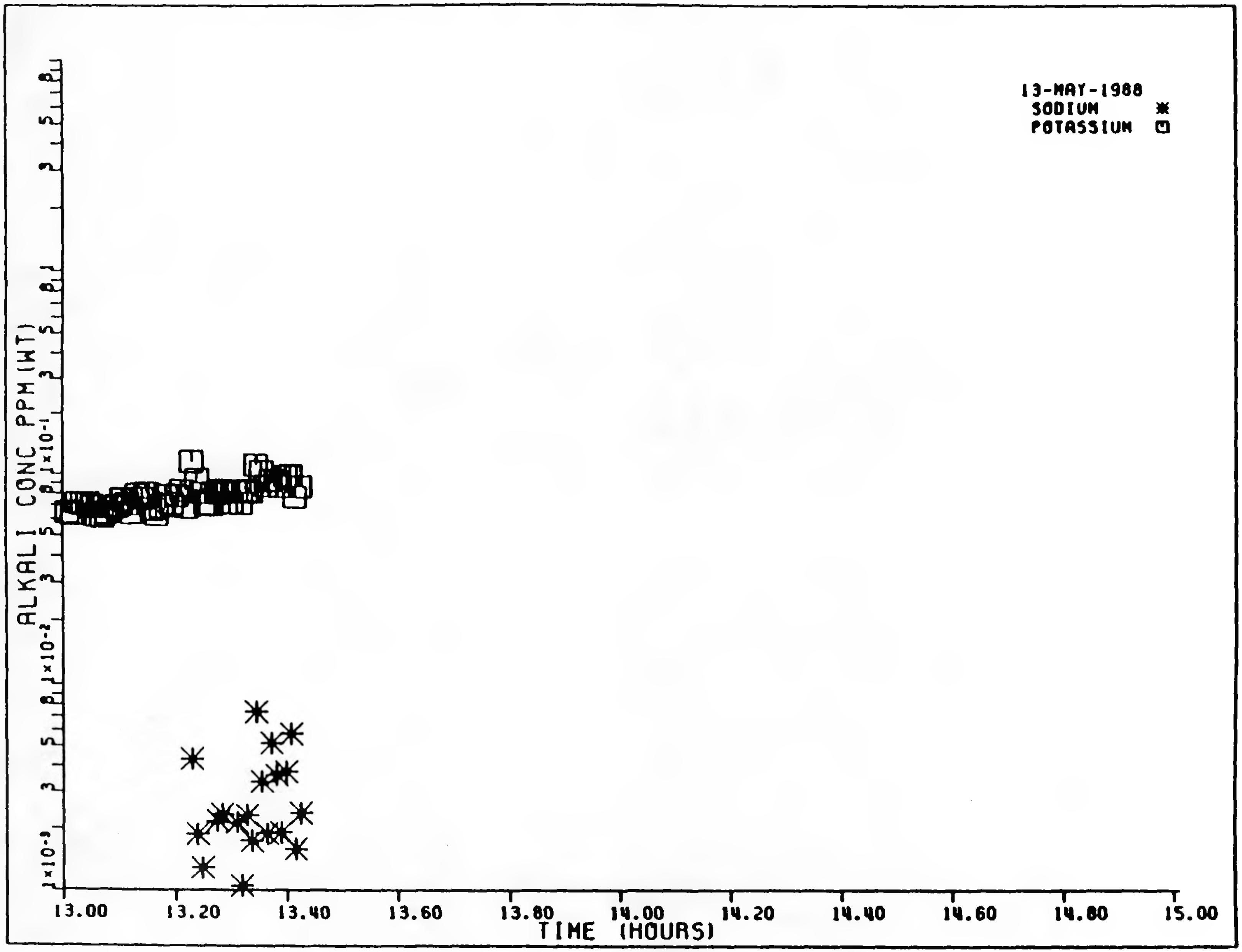
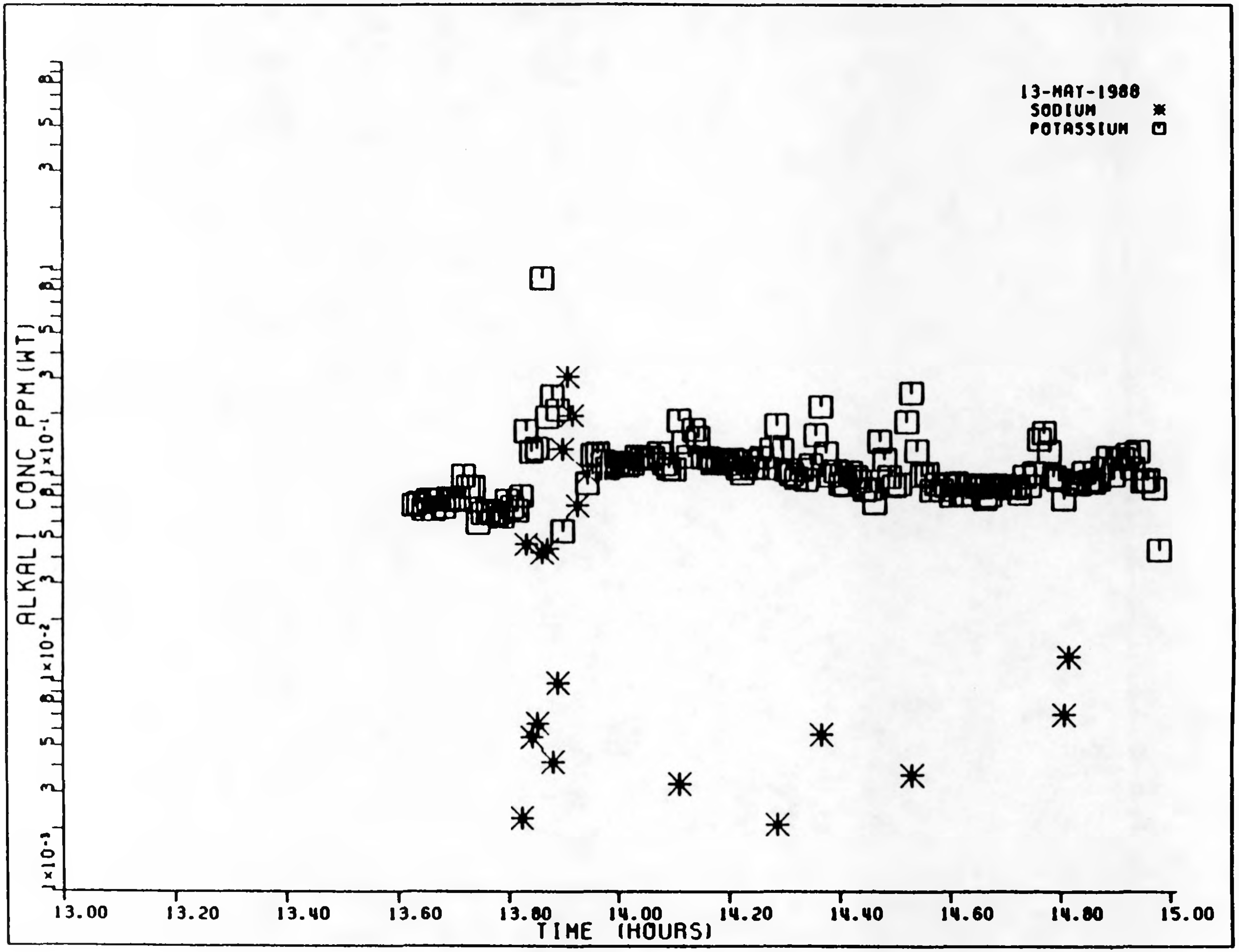
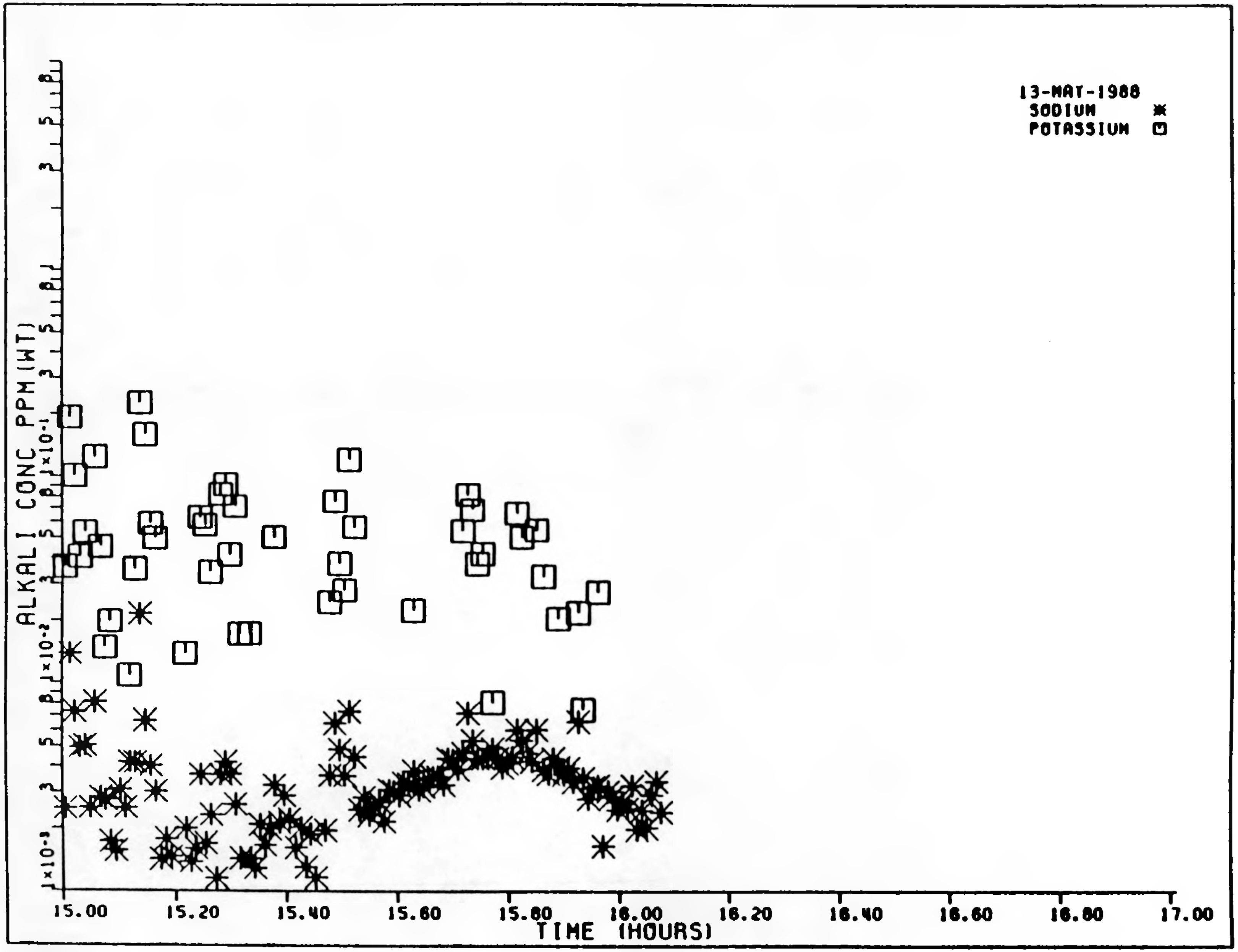
20.80
21.00
21.20
21.40
21.60
21.80
22.00
TIME (HOURS)

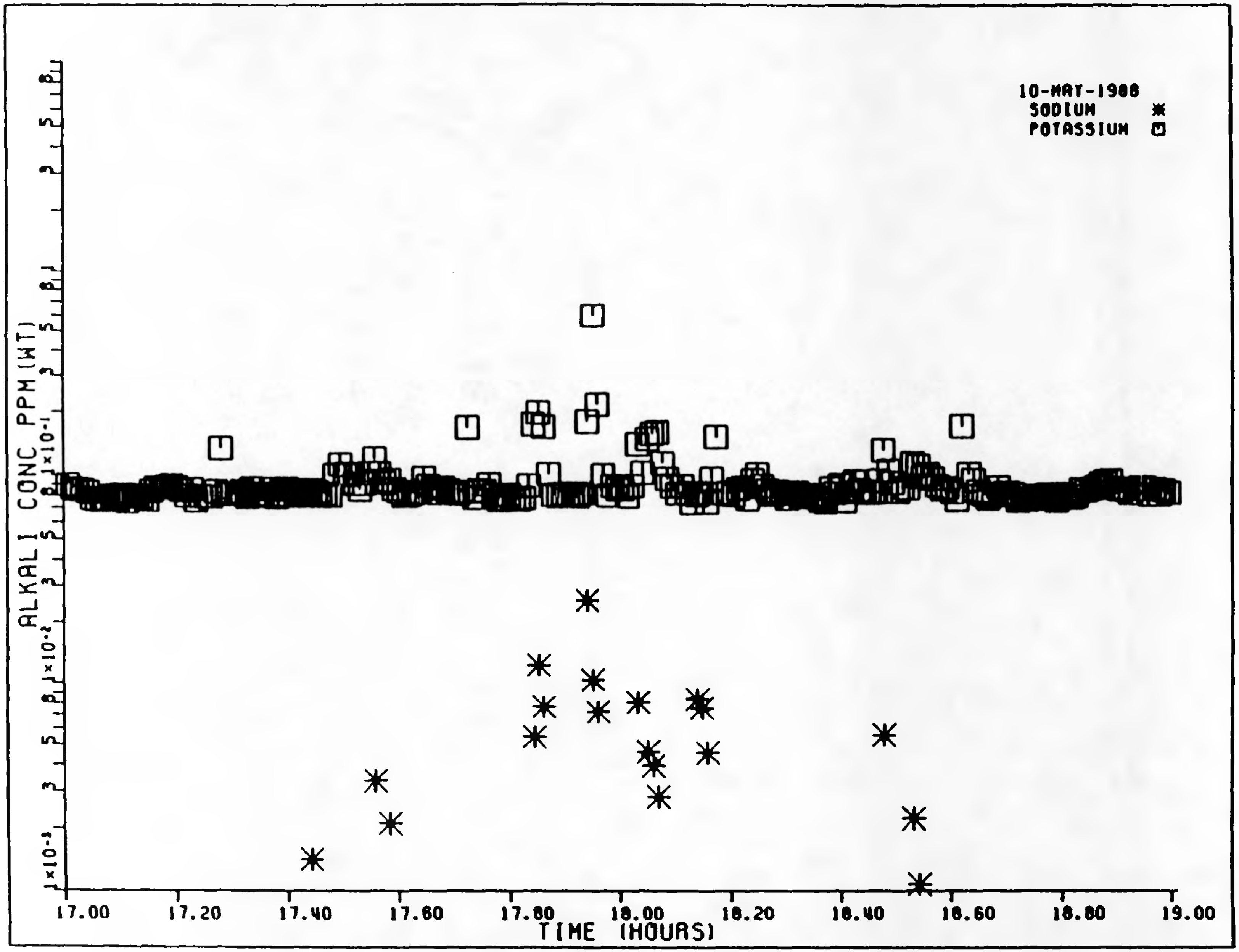

13-MAY-1988
SODIUM ✱
POTASSIUM ☐
ALKALI CONC PPM(WT)
1×10⁻³
2
3
5
8
1×10⁻²
2
3
5
8
1×10⁻¹
2
3
5
8
1
2
3
5
8
9.00
9.20
9.40
9.60
9.80
10.00
10.20
10.40
10.60
10.80
11.00
TIME (HOURS)

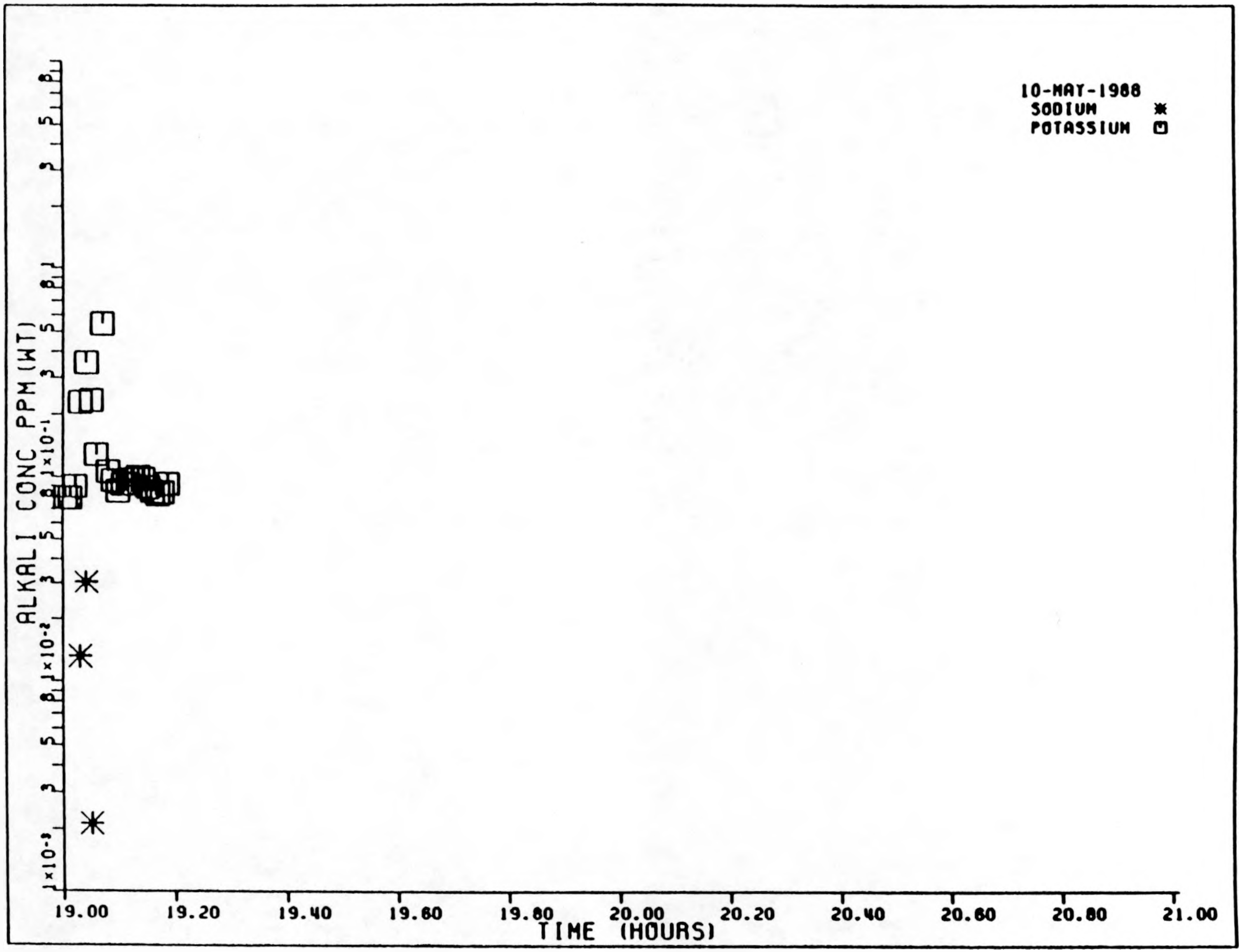

13-MAY-1988
SODIUM ✱
POTASSIUM ⊡
ALKALI CONC PPM(WT)
1×10⁻³
3
5
8
1×10⁻²
3
5
8
1×10⁻¹
3
5
8
3
5
8
11.00
11.20
11.40
11.60
11.80
12.00
12.20
12.40
12.60
12.80
13.00
TIME (HOURS)


13-MAY-1988
SODIUM ✱
POTASSIUM □
ALKALI CONC PPM(WT)
1×10⁻³
3
5
8
1×10⁻²
3
5
8
1×10⁻¹
3
5
8
1
3
5
8
TIME (HOURS)
13.00
13.20
13.40
13.60
13.80
14.00
14.20
14.40
14.60
14.80
15.00

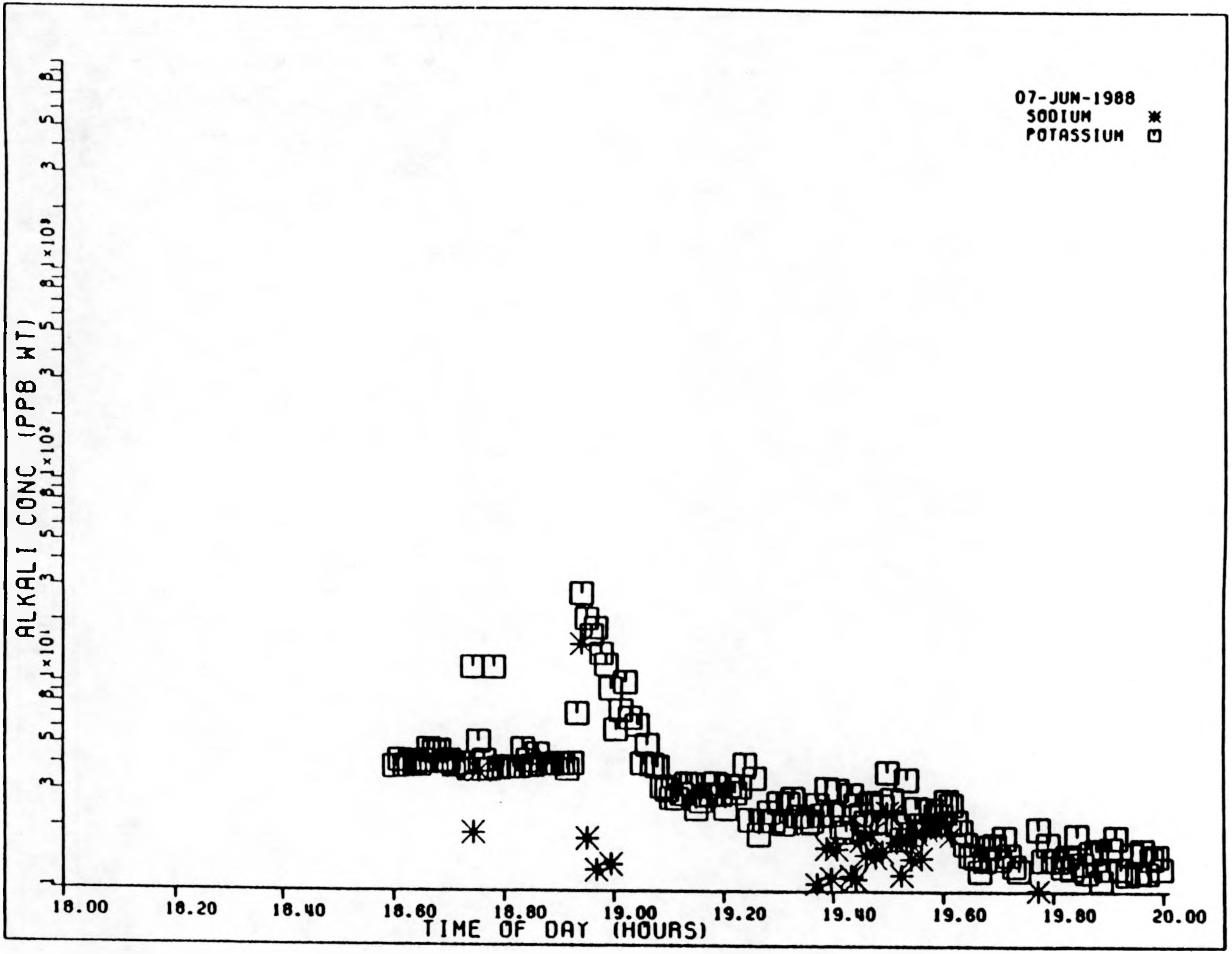

13-MAY-1988
SODIUM ✳
POTASSIUM ▢
ALKALI CONC PPM(WT)
1×10⁻³
3
5
8
1×10⁻²
3
5
8
1×10⁻¹
3
5
8
1
3
5
8
13.00
13.20
13.40
13.60
13.80
14.00
14.20
14.40
14.60
14.80
15.00
TIME (HOURS)

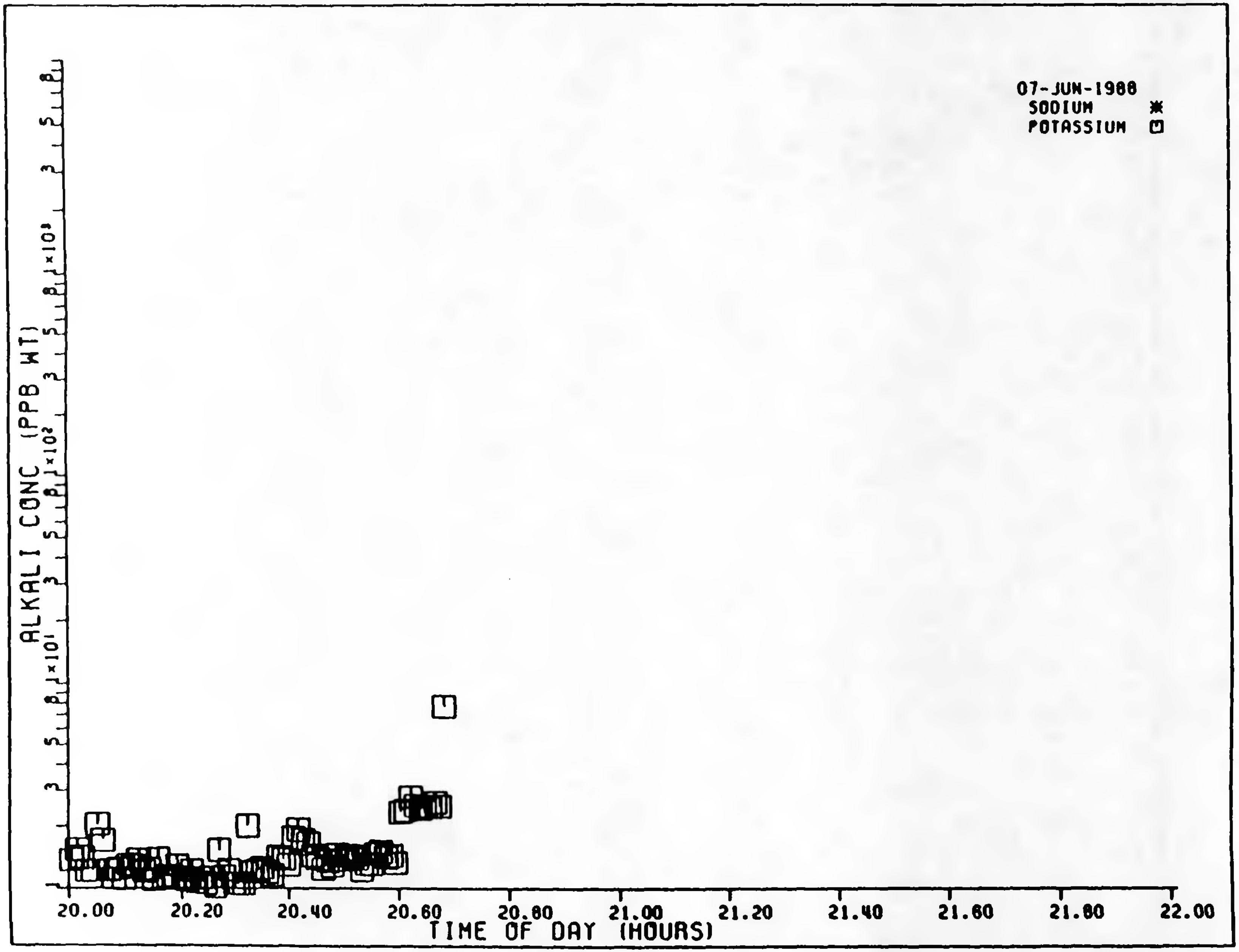

13-MAY-1988
SODIUM ✱
POTASSIUM ▣
ALKALI CONC PPM(WT)
TIME (HOURS)
15.00
15.20
15.40
15.60
15.80
16.00
16.20
16.40
16.60
16.80
17.00
1×10-3
3
5
8
1×10-2
3
5
8
1×10-1
3
5
8
3
5
8

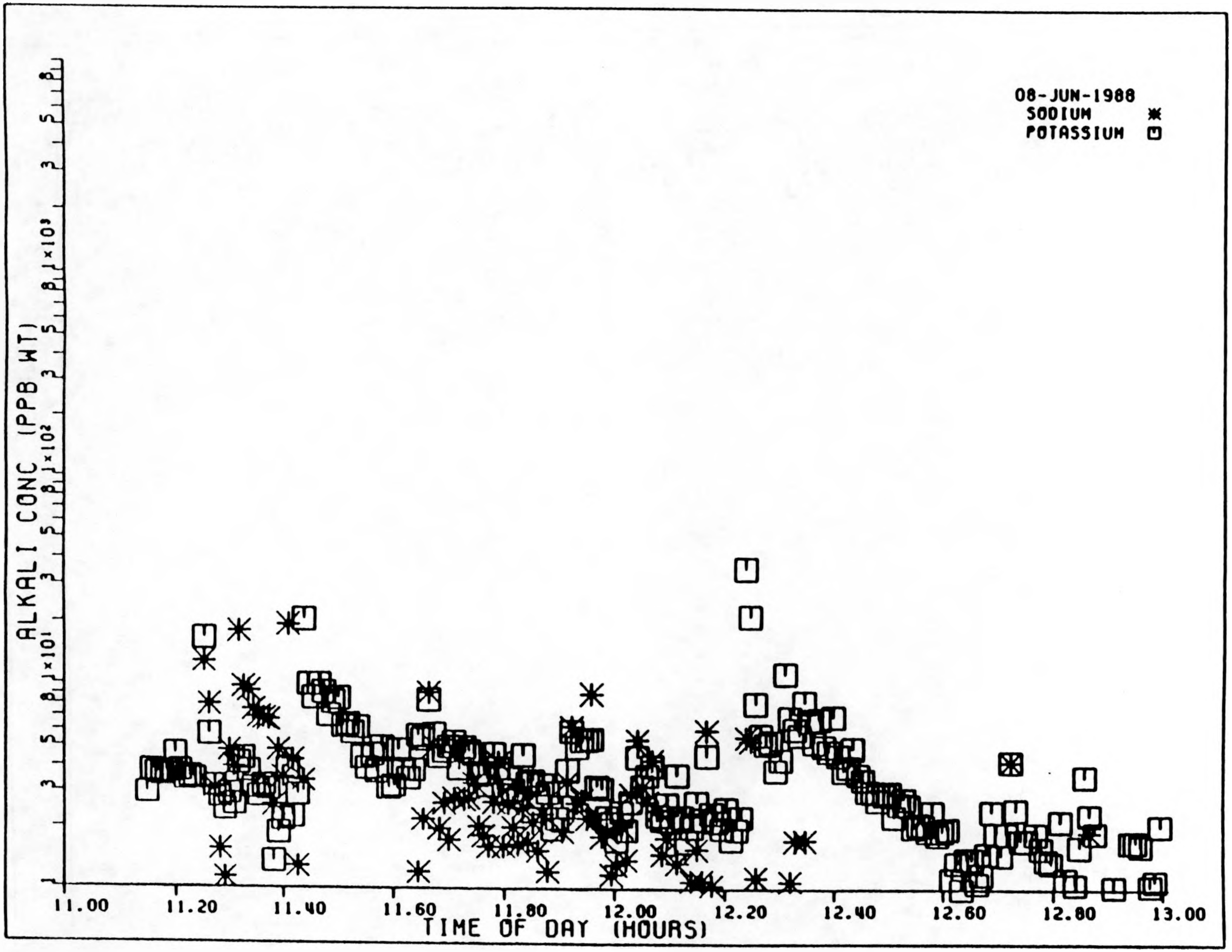

10-MAY-1988
SODIUM ✱
POTASSIUM ⊡
ALKALI CONC PPM(WT)
1×10⁻³
3
5
8
1×10⁻²
3
5
8
1×10⁻¹
3
5
8
1
3
5
8
17.00
17.20
17.40
17.60
17.80
18.00
18.20
18.40
18.60
18.80
19.00
TIME (HOURS)

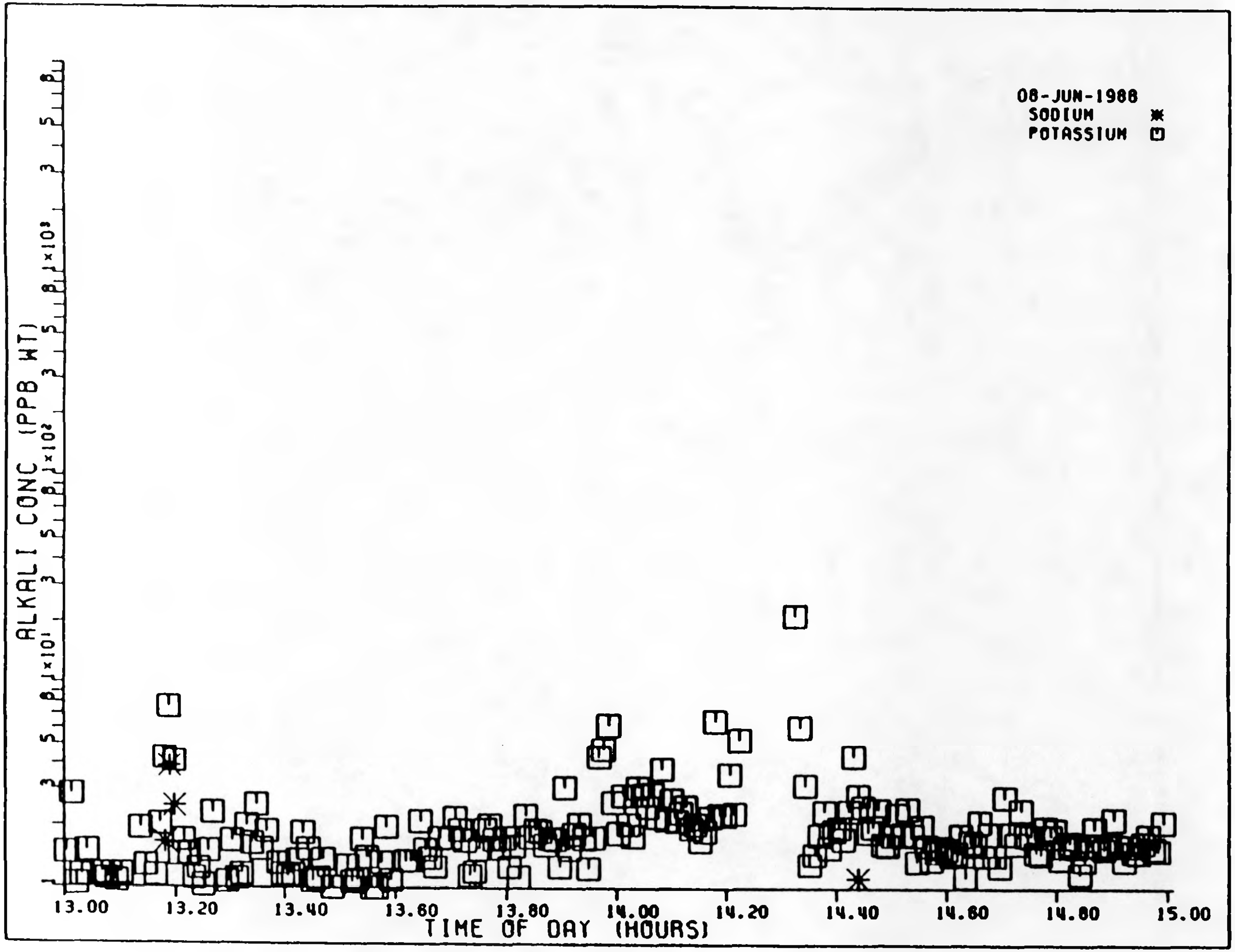

10-MAY-1988
SODIUM ✳
POTASSIUM ▣
ALKALI CONC PPM (WT)
TIME (HOURS)
19.00
19.20
19.40
19.60
19.80
20.00
20.20
20.40
20.60
20.80
21.00
1×10⁻³
3
5
8
1×10⁻²
3
5
8
1×10⁻¹
3
5
8
1
3
5
8

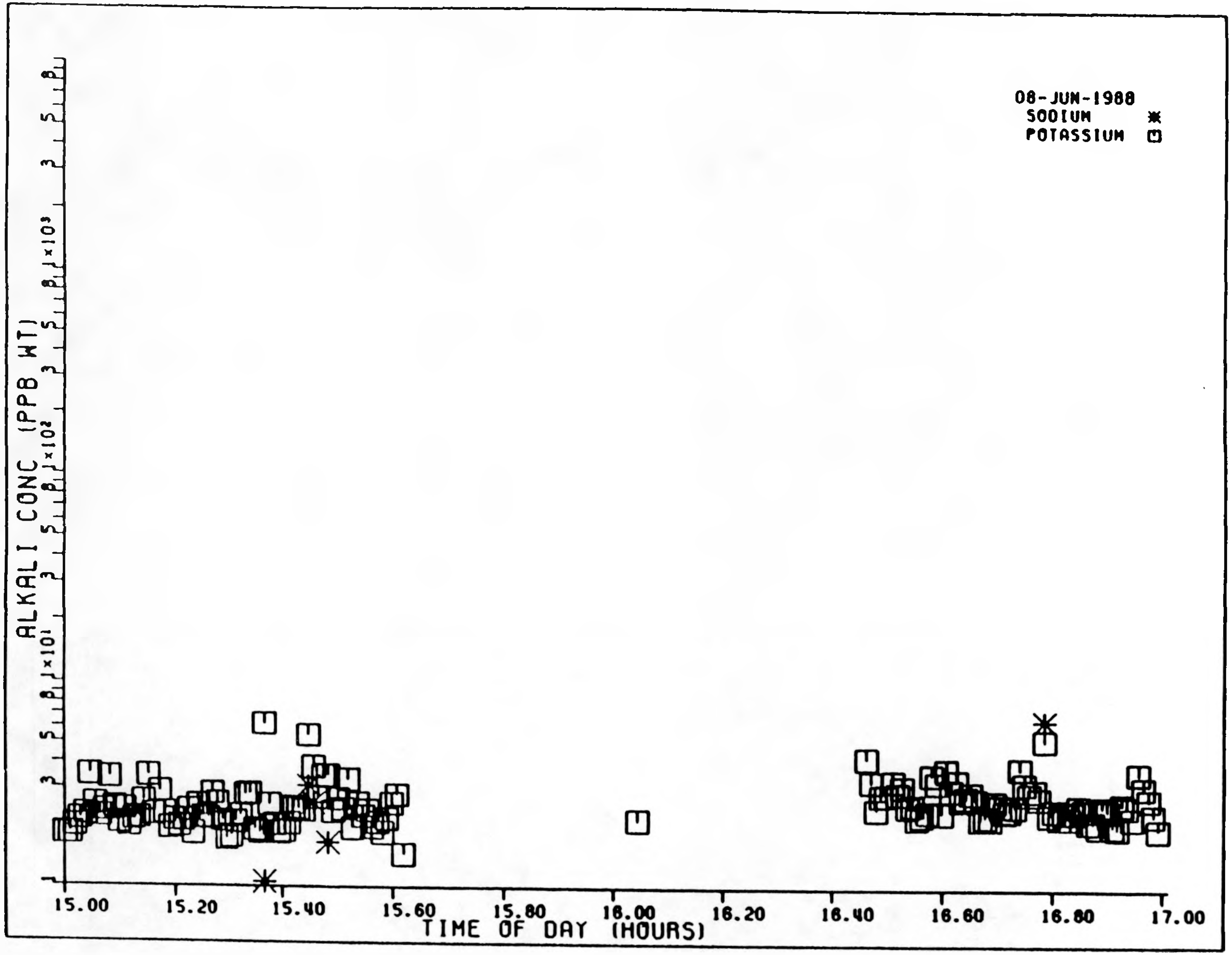
IID.2.2.2 TEST HG-205

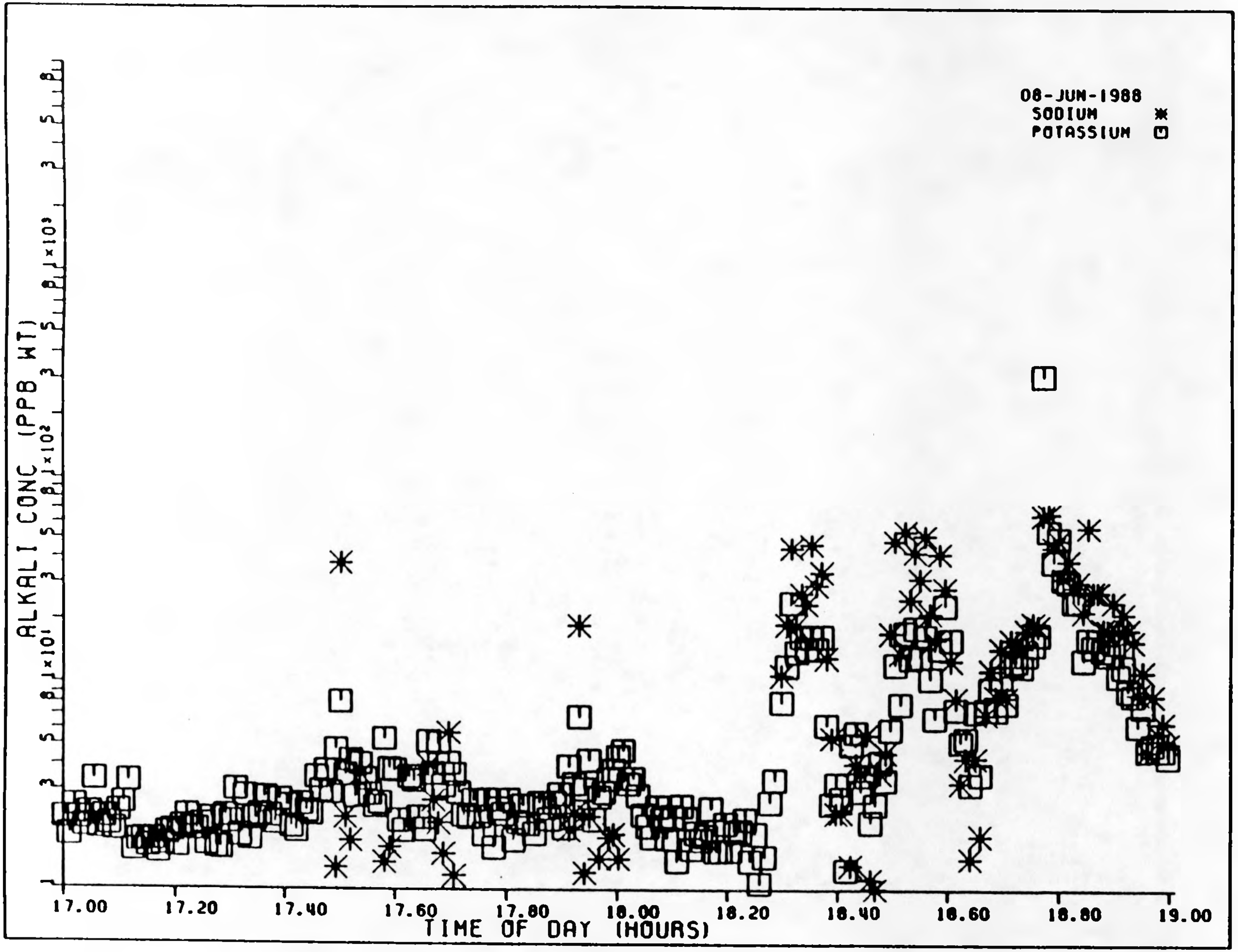

07-JUN-1988
SODIUM ✱
POTASSIUM □
ALKALI CONC (PPB WT)
1×10¹
1×10²
1×10³
3
5
8
TIME OF DAY (HOURS)
18.00
18.20
18.40
18.60
18.80
19.00
19.20
19.40
19.60
19.80
20.00

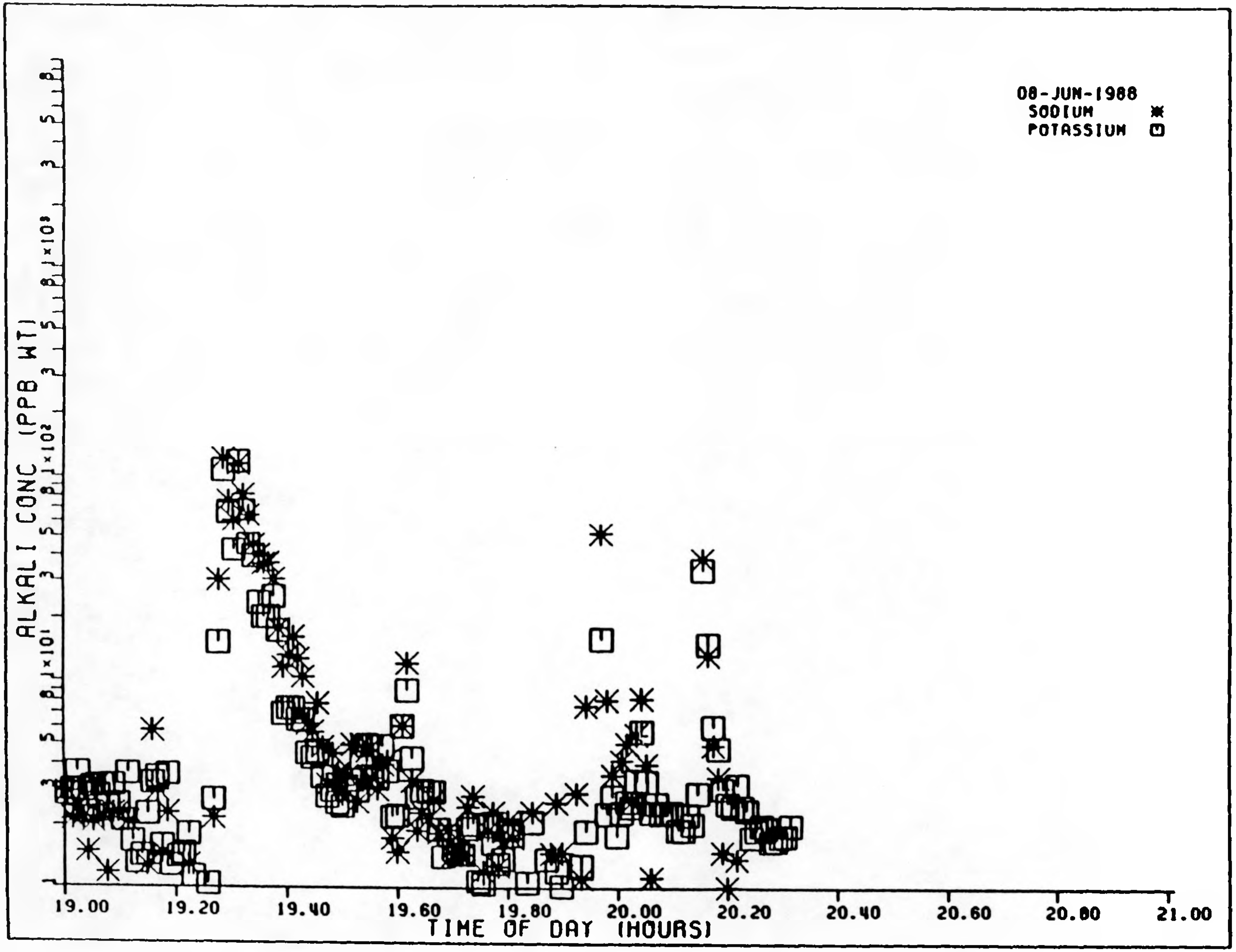

07-JUN-1988
SODIUM ✱
POTASSIUM ☐
ALKALI CONC (PPB WT)
3
5
8
1×10¹
3
5
8
1×10²
3
5
8
1×10³
3
5
8
20.00
20.20
20.40
20.60
20.80
21.00
21.20
21.40
21.60
21.80
22.00
TIME OF DAY (HOURS)

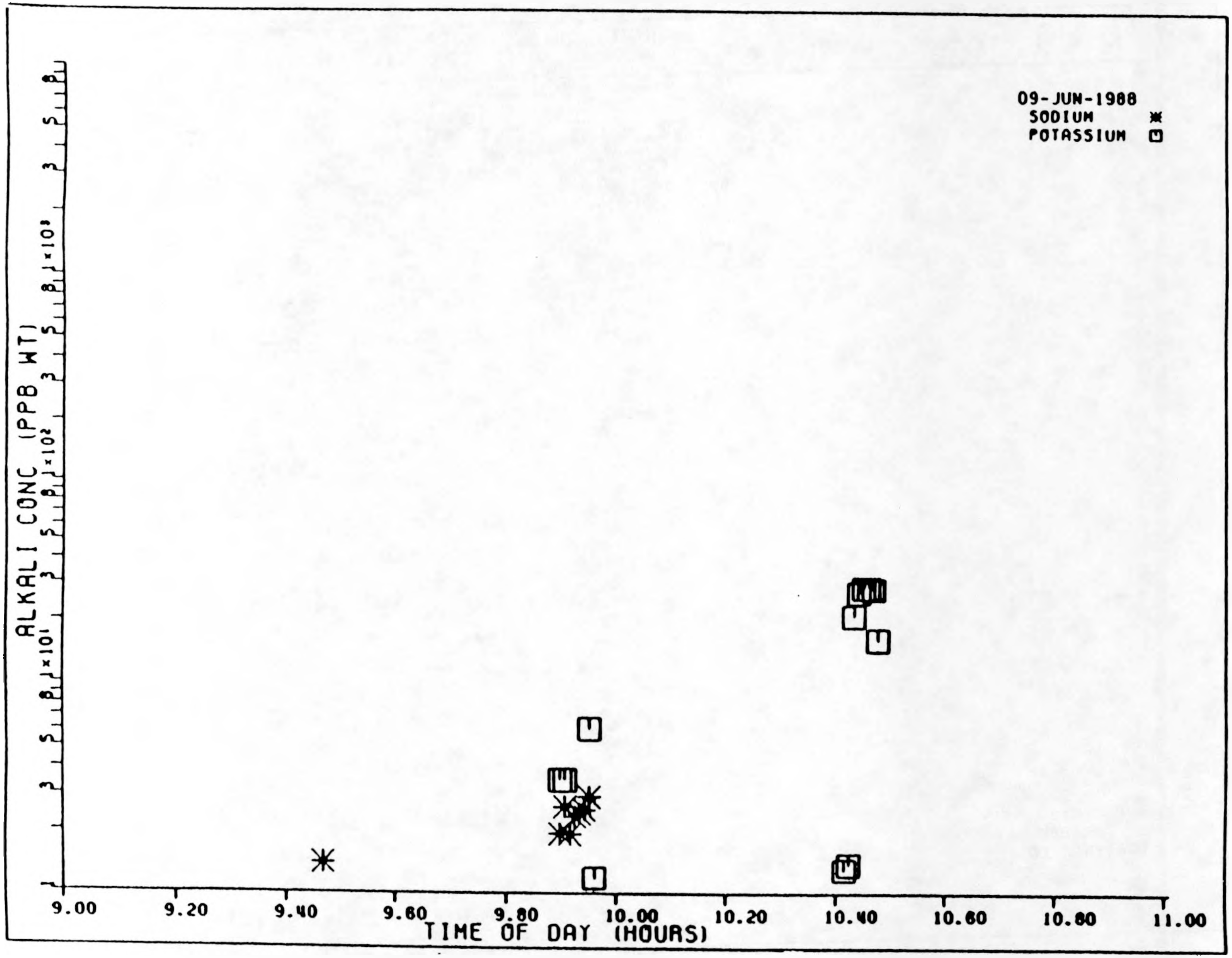

08-JUN-1988
SODIUM ✱
POTASSIUM ▢
ALKALI CONC (PPB WT)
1
3
5
8
1×10¹
3
5
8
1×10²
3
5
8
1×10³
3
5
8
11.00
11.20
11.40
11.60
11.80
12.00
12.20
12.40
12.60
12.80
13.00
TIME OF DAY (HOURS)

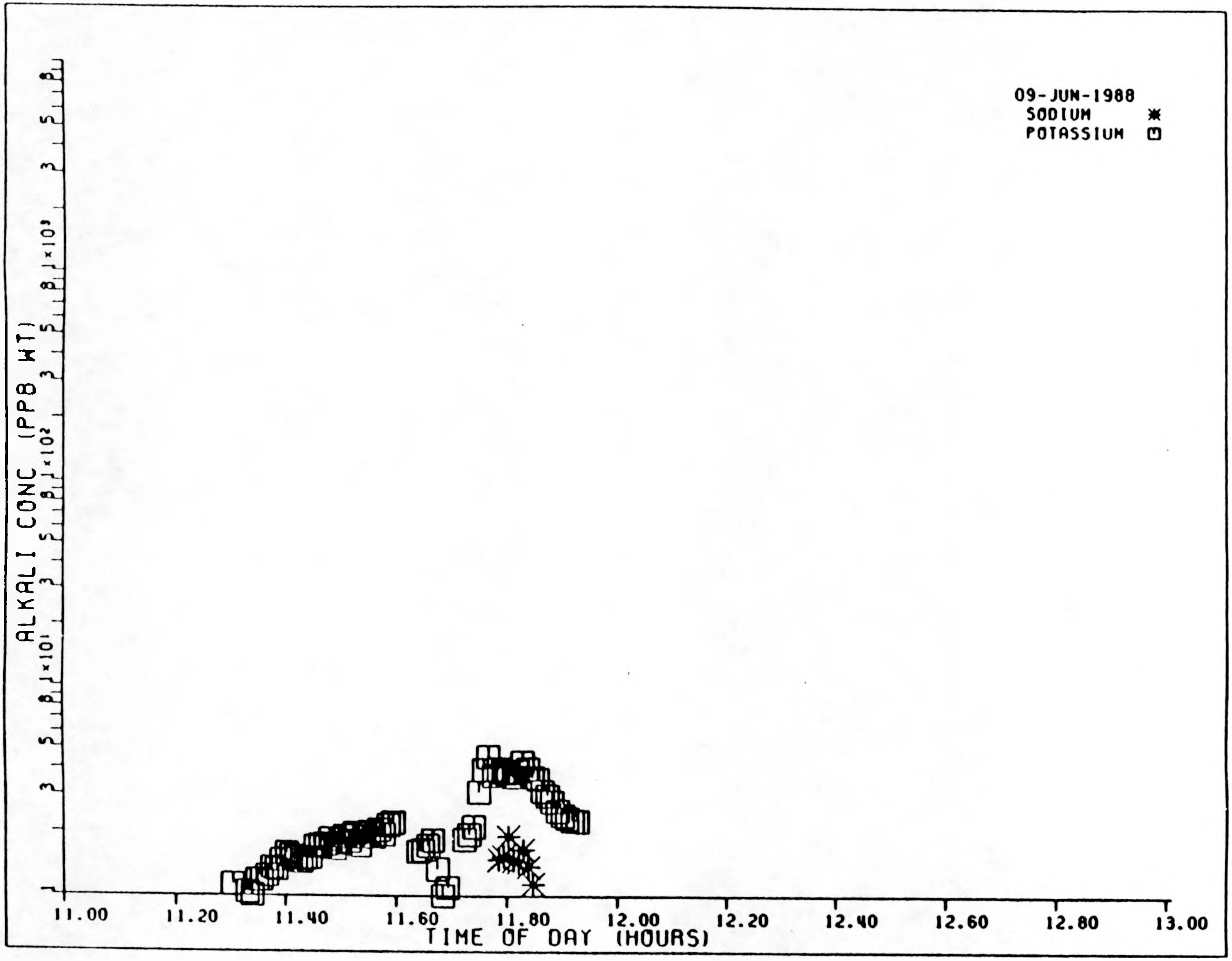

08-JUN-1988
SODIUM ✱
POTASSIUM ☐
ALKALI CONC (PPB WT)
3
5
.8
.1×10¹
3
5
.8
.1×10²
3
5
.8
.1×10³
3
5
.8
13.00
13.20
13.40
13.60
13.80
14.00
14.20
14.40
14.60
14.80
15.00
TIME OF DAY (HOURS)


08-JUN-1988
SODIUM ✱
POTASSIUM ☐
ALKALI CONC (PPB WT)
1
3
5
8 ×10¹
3
5
8 ×10²
3
5
8 ×10³
3
5
8
15.00
15.20
15.40
15.60
15.80
16.00
16.20
16.40
16.60
16.80
17.00
TIME OF DAY (HOURS)


08-JUN-1988
SODIUM ✱
POTASSIUM ◻
ALKALI CONC (PPB WT)
1
3
5
8 ×10¹
3
5
8 ×10²
3
5
8 ×10³
3
5
8
17.00
17.20
17.40
17.60
17.80
18.00
18.20
18.40
18.60
18.80
19.00
TIME OF DAY (HOURS)


08-JUN-1988
SODIUM ✱
POTASSIUM ☐
ALKALI CONC (PPB WT)
1
3
5
8
1×10¹
3
5
8
1×10²
3
5
8
1×10³
3
5
8
19.00
19.20
19.40
19.60
19.80
20.00
20.20
20.40
20.60
20.80
21.00
TIME OF DAY (HOURS)


09-JUN-1988
SODIUM ✱
POTASSIUM ⊡
ALKALI CONC (PPB WT)
1
3
5
8
1×10¹
3
5
8
1×10²
3
5
8
1×10³
3
5
8
9.00
9.20
9.40
9.60
9.80
10.00
10.20
10.40
10.60
10.80
11.00
TIME OF DAY (HOURS)


09-JUN-1988
SODIUM ✱
POTASSIUM □
ALKALI CONC (PPB WT)
TIME OF DAY (HOURS)
11.00
11.20
11.40
11.60
11.80
12.00
12.20
12.40
12.60
12.80
13.00
1×10¹
1×10²
1×10³
3
5
8

APPENDIX IIE

COMPARISON OF PARTICULATE COLLECTED
BY THE
GBF AND GRAB SAMPLING

COMPARISON OF PARTICULATE COLLECTED

BY THE

GBF AND GRAB SAMPLING

To confirm the validity of grab sampling data, it was compared against estimated inlet particulate loadings calculated from the ash removal by the GBF. To make this comparison, grab sampling data was plotted for the same periods that GBF baghouse was collected. These plots are presented in Figures IIE-1 through IIE-4. These plots represent discrete points of data gathered during operation. Each point represents a 20 to 60 minute operating period. These points were connected and areas under the curves calculated from which average dust loadings were obtained over the same time spans that dust was collected and weighed at the GBF baghouse. Since the grab sample data is for discrete periods of time, connecting data points as done in Figures IIE-1 to IIE-4 will introduce some minor error into the results.

GBF ash capture was calculated by periodically weighing ash removed at the GBF baghouse and averaging this over the period of time and gas flow rate. There is a time lag of 1 to 1 1/2 hours between ash entering the GBF and the same ash entering the baghouse, but this is a relatively short time compared to the time spans in which data is compared. Consequently, this time lag has been disregarded. The results are summarized on Table IIE-1. A comparison shows that for HG-204, grab sample measurements are low compared to the dust collected by the GBF. This casts doubt on the validity of these inlet grab sample measurements. On the other hand, for HG-205, the comparison is much more reasonable which helps confirm this data.

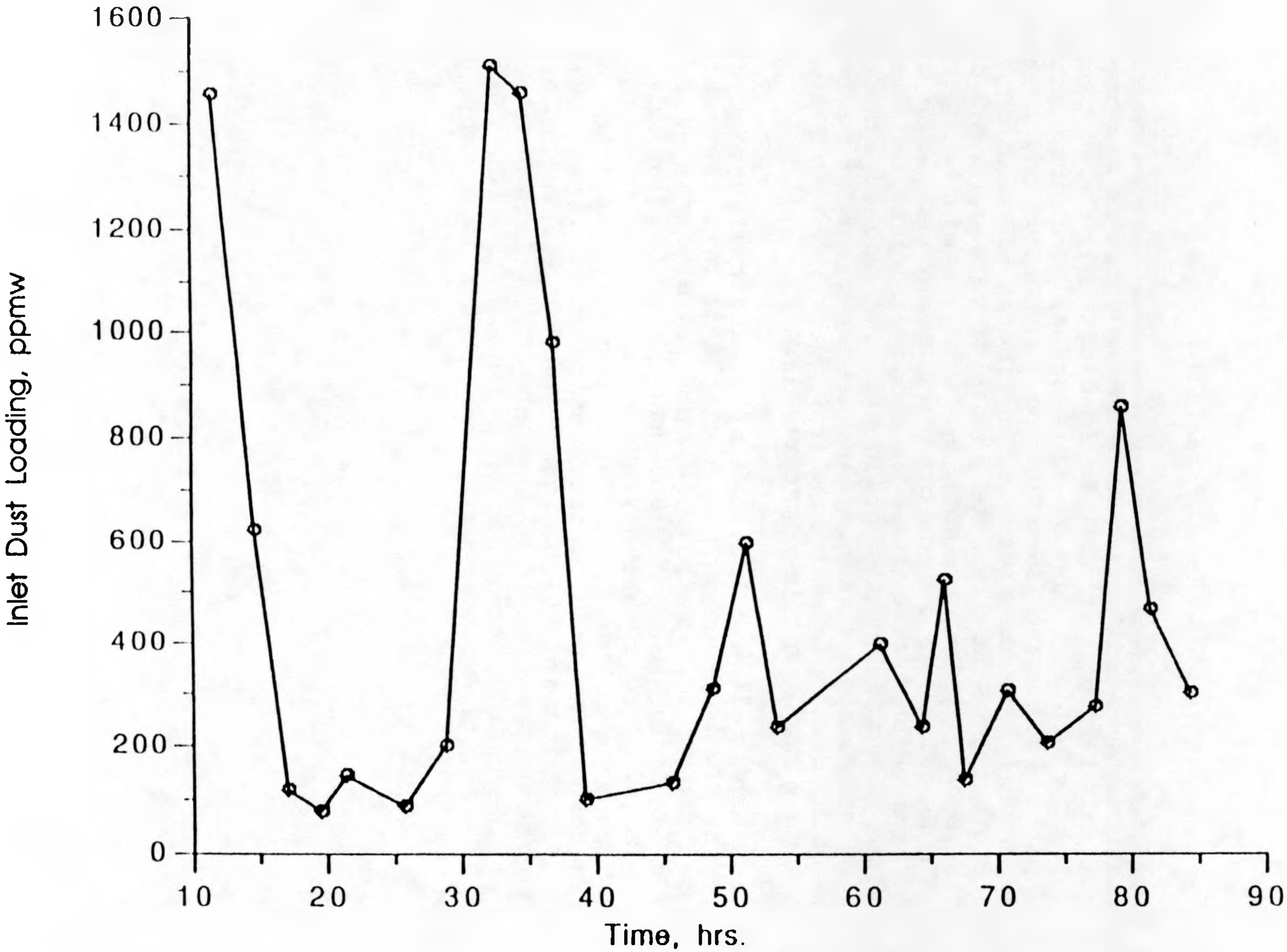


Figure IIE-1. GBF inlet dust loading profile measured using the Grab sampling technique Vs. PFBC-GBF run time during test HG-204

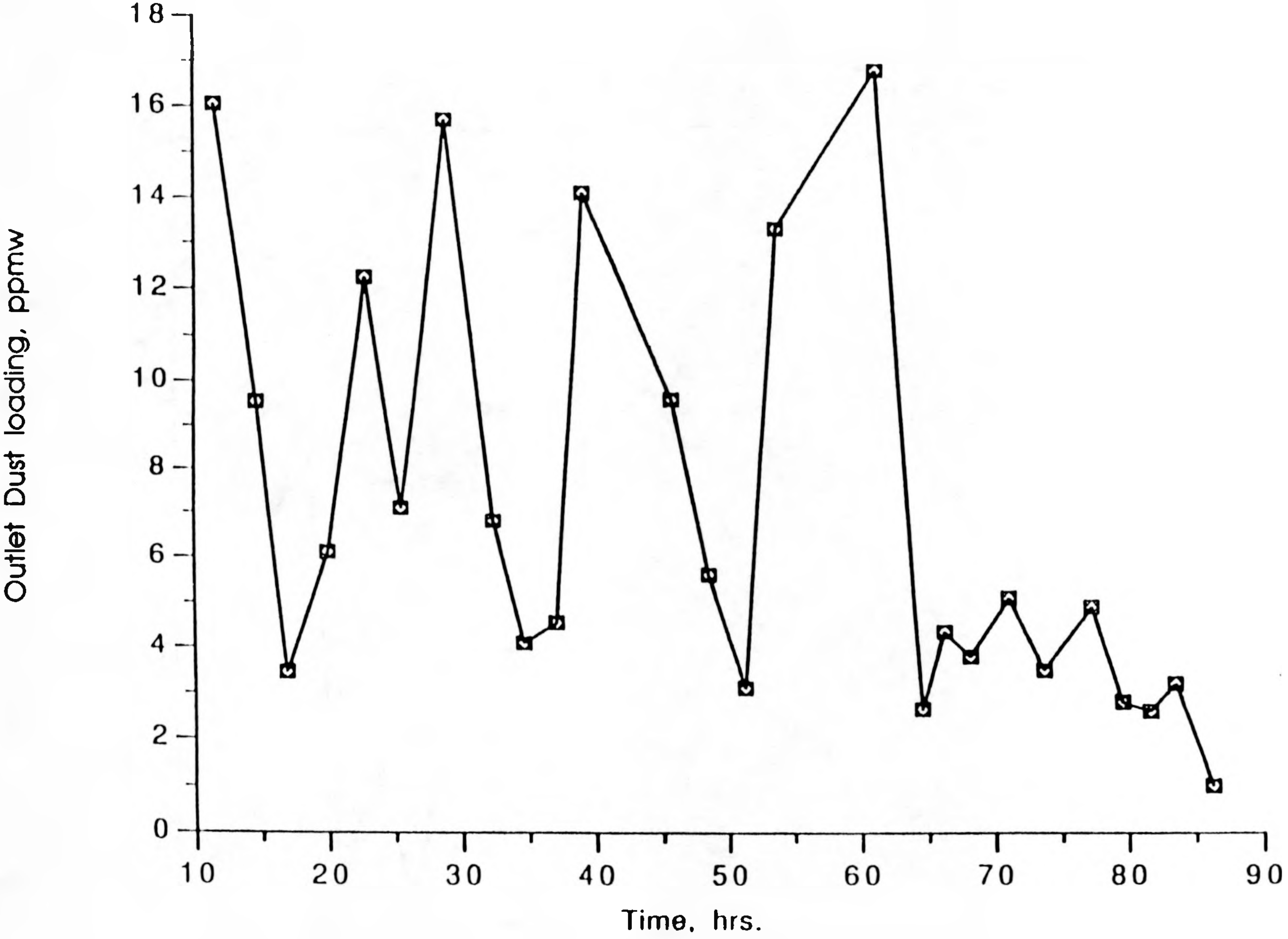


Figure IIE-2. GBF outlet dust loading profile measured using the Grab sampling technique Vs. PFBC-GBF run time for test HG-204

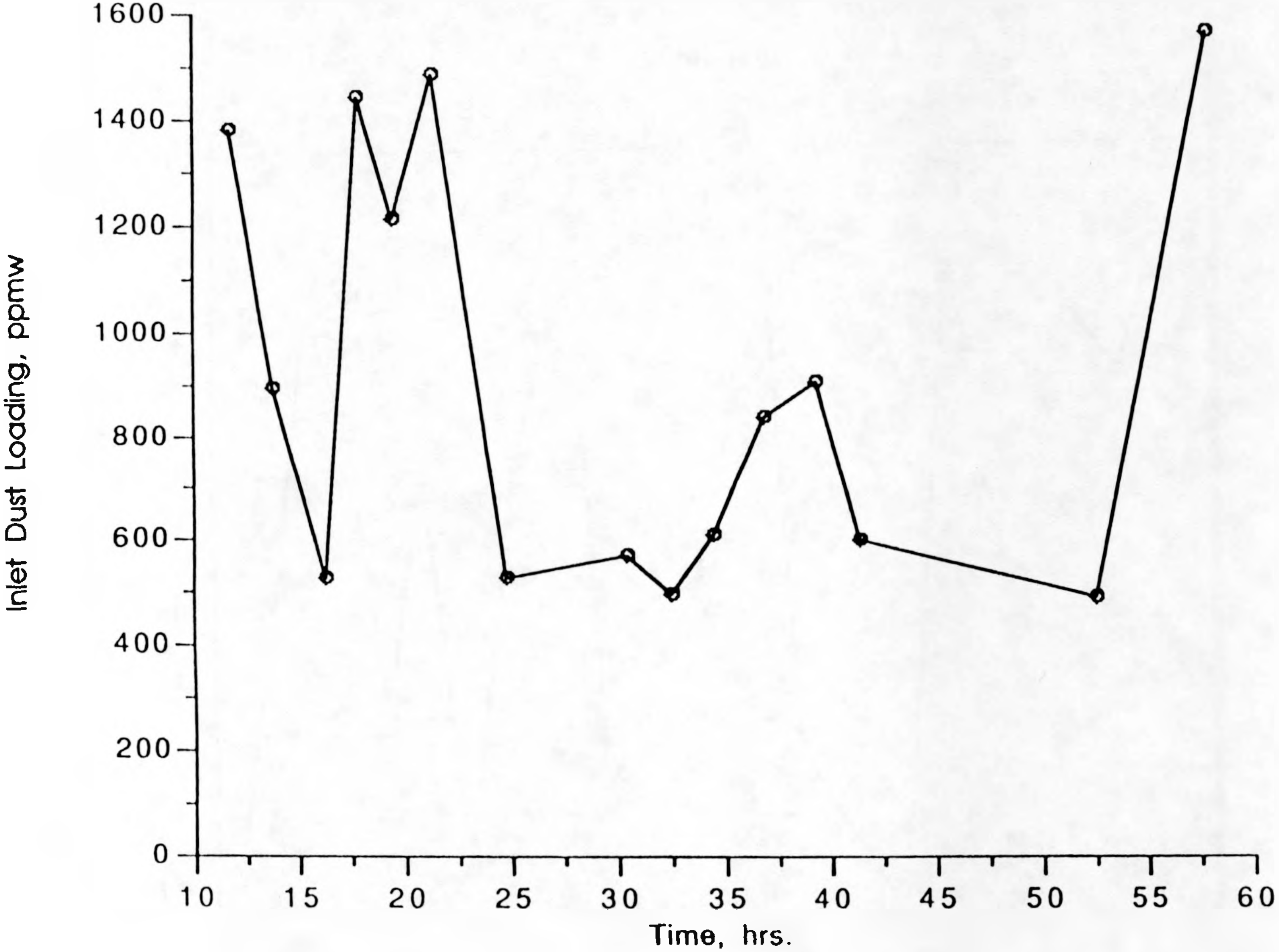


Figure IIE-3. GBF inlet dust loading profile measured using the Grab sampling technique Vs. PFBC-GBF run time during test HG-205

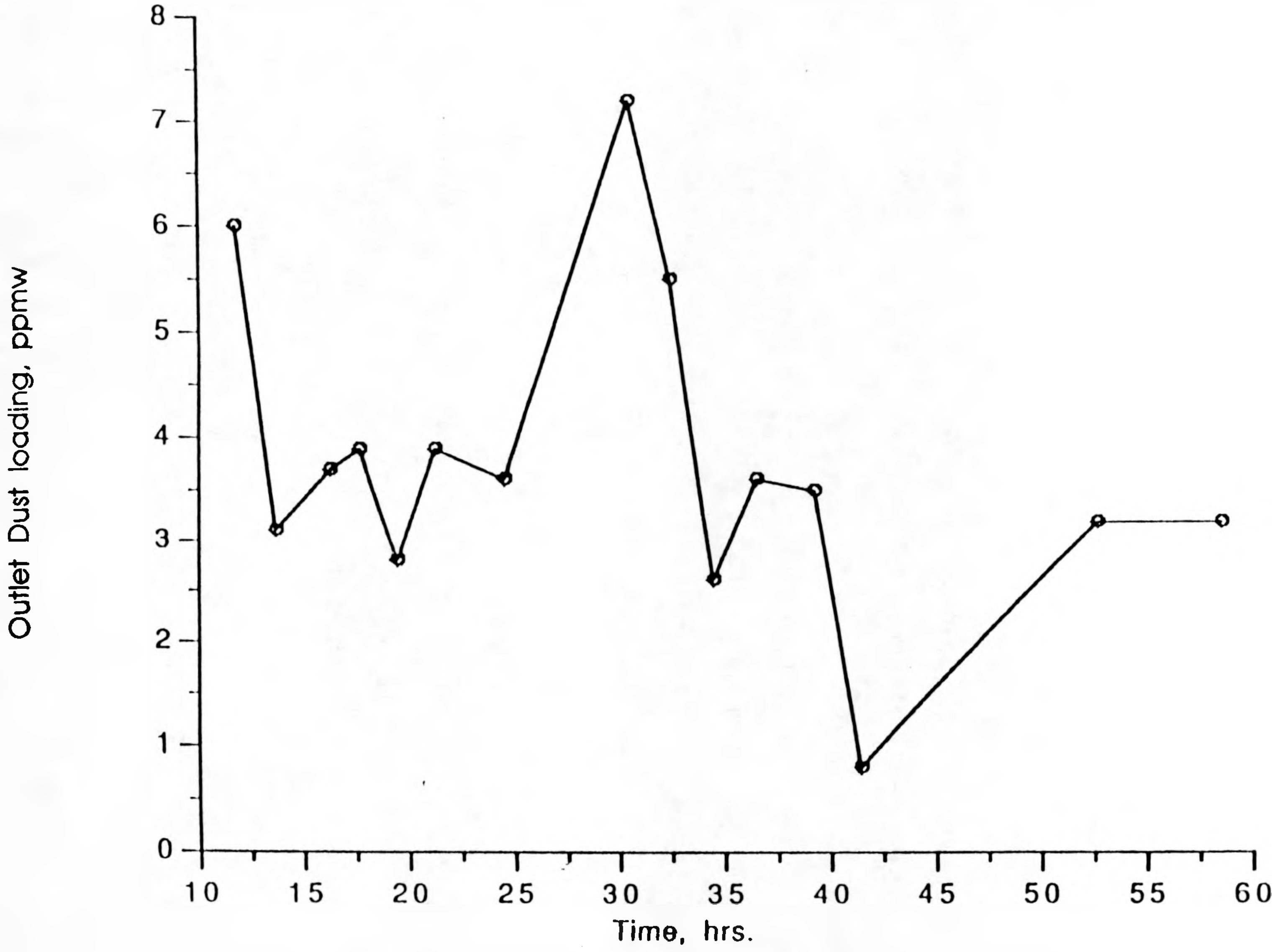


Figure IIE-4. GBF outlet dust loading profile measured using the Grab sampling technique Vs. PFBC-GBF run time for test HG-205

TABLE IIE-1 COMPARISON OF PARTICULATE COLLECTED BY GBF AND GRAB MEASUREMENT

Date	Time Period (hr)	Avg. Dust Collected by GBF (ppmw)	Avg. Dust Collected by GBF Estimated Data from Grab Sample (ppmw)
HG-204			
5/10/88	10:00-22:00	1128	445
5/10/88-5/11/88	22:00-07:00	1061	273
5/10/88-5/11/88	22:00-10:00	901	553
5/11/88	07:00-10:00	423	1396
5/11/88	10:00-22:00	1044	423
5/12/88	11:40-20:30	1138	314
5/12/88-5/13/88	20:30-07:30	1164	322
5/13/88	07:30-16:00	1772	797
HG-205			
6/7/88	09:00-21:00	603	1004
6/7/88-6/8/88	21:00-10:00	750	605
6/9/88	01:00-05:00 07:00-11:00	992	923

APPENDIX IIF

AVERAGE FLUE GAS COMPOSITION
DOWNSTREAM OF THE GBF

TABLE IIF-1 AVERAGE FLUE GAS COMPOSITION (DRY BASIS, BY VOLUME)

TEST NO.	CO (ppm)	CO_2 (%)	SO_2 (ppm)	NO (ppm)	O_2 (%)
HS-201[1]	0.0	3.0	5.0	73.0	18.4
HS-202[1]	10.0	2.9	-	97.5	15.7
HS-203[2]	99.2	14.2	8.5	193.8	5.8
HG-201[1]	18.2	3.4	-	98.5	16.5
HG-202[2]	94.1	10.6	7.5	236.1	8.8
HG-203[2]	34.8	15.1	10.2	194.0	3.7
HG-204[2]	58.5	13.3	4.3	221.0	5.8
HG-205[2]	29.4	14.5	5.3	212.6	4.2

[1] - For Kerosene Combustion [2] - For Coal Combustion