THE CHARACTERIZATION OF PARTICULATE AND OTHER UNREGULATED POLLUTANTS FROM PRODUCTION AND PROTOTYPE FUTURE VEHICLE CONTROL DEVICES

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TABLE OF CONTENTS

I. INTRODUCTION

This report summarizes the experimental procedures used, and the data generated during the course of an investigation of the exhaust emissions from several government furnished vehicles. The work was performed by members of the Functional Fluids R&D group of the Ag-Organics Department, Dow Chemical USA under the terms of E.P.A. Contract #68-01-0480.

Each test vehicle was operated at 60 m.p.h. steady state and under the conditions of the 23 minute Federal test procedure (hot start) and the 41 minute Federal test procedure (cold start). Vehicle exhaust was monitored to determine levels of emitted particulate matter including *mass-size distribution concentrations of particulate* associated trace metals, benzo-α-pyrene, sulfure and sulfate, and levels of gaseous CO, NO_x, unburned hydrocarbons, ammonia and aldehydes.

All data generated is presented in the Appendix to this report in the form that it was originally given to EPA at the completion of each vehicle test series.

No attempt is made to draw conclusions from this study because of the variety of different vehicles tested. It is anticipated, however, that the data generated will be of value to EPA in determining an overall emission profile for the vehicles studied.

II. EXPERIMENTAL PROCEDURES

1. Chassis Dynamometer Procedures

A Clayton CT-200-0 chassis dynamometer with a variable inertia flywheel assembly was used in all tests conducted under this program. A Chelsa direct-drive Model PLDUP-200A fan was located in front of the test vehicle, and operated at 1750 rpm providing 18,750 scfm air flow.

The following summary indicates specific procedures employed to prepare the vehicle for test runs:

A. General Vehicle Inspection

Exhaust System:

a) Inspected for holes or cracks, dents, and collapse
b) Inspected for leaking joints

Engine, checked

a) All fluid levels
b) All coolant hoses
c) Air pump fan, power steering, and belts
d) Check heat riser (if applicable) for fullness of operation
e) Check automatic choke operation and adjustment
f) Recheck all scope patterns for normal appearance

B. Instrumentation and Equipment Installation

Thermocouples - installed thermocouples in

a) Engine oil - dipstick
b) Coolant - upper radiator hose - engine out
c) Carb air - air filter element

Vacuum and RPM monitors

a) Attached tackometer to ignition coil
b) Installed throttle cable (if running under cruise mode)

Wheels

a) Removed rear wheels
b) Installed test tires and wheel assemblies to insure safe operation

C. Procedure for Cold, Hot Starts, and Engine Temperature Stabilization

Cold Start

a) The vehicle was placed on the dynamometer rolls and the inertia weights set for the test vehicle.
b) The vehicle was allowed at least a 12-hour soak period.
c) The vehicle tailpipe was connected to dilution tube.
d) The vehicle was started and the individual test begun.

Hot Start

The hot start procedure was the same as for the cold start except that the vehicle was warmed up and allowed to sit for 10 minutes before starting.

D. The following data was collected at each load condition:

a) Load
b) Ambient air temperature
c) Carburetor air temperature
d) Coolant temperature
e) Oil temperature
f) Barometer reading
g) Wet and dry bulb temperature

E. Vehicle Test Mode

For each test vehicle, exhaust emission measurements were conducted under the following test conditions:

a) 60 m.p.h. steady state - 2 hour test run
b) 41 minute Federal test procedure (cold start)
c) 23 minute Federal test procedure (hot start)

2. Particulate Collection

Exhaust particles were collected after air dilution of the exhaust in the large dilution tube described below. The entire exhaust stream was fed into the dilution tube for all tests conducted.

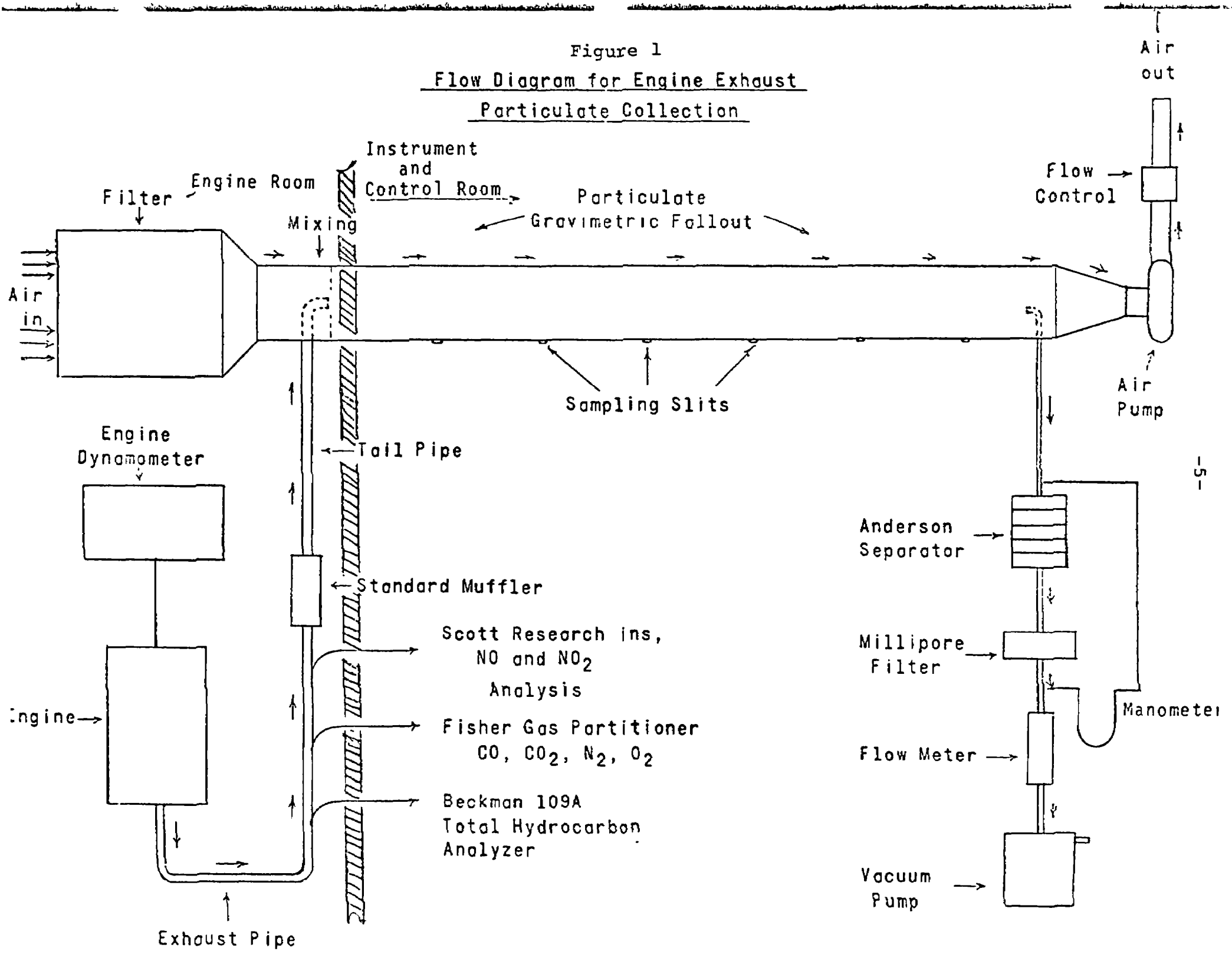
A. Dilution Tube (see Figure 1)

Air dilution and cooling of the exhaust was accomplished by a dilution tube 16 inches in diameter and 27 feet in length constructed of extruded polyvinyl chloride (PVC) pipe in several sections with butt joints which were taped during assembly prior to each run (Figure 1). The diluent air coming into the tube was filtered by means of a Dri-Pak. Series 1100 Class II PIN 114-110 020 untreated cotton filter assembly. This filter assembly was 24" x 24" and had 36 filter socks which extended to 36 inches in length. This filter will pass particles 0.3 μ in size and smaller. Pressure drop at 600 cfm flow rate is minimal. The flow rate of dilution air in the tunnel was set at 550 cfm for all tests.

Exhaust was delivered to the tube via a tailpipe extension which was brought into the bottom of the tube downstream of the filter assembly. The extension was bent 90 degrees inside the tube, thus allowing the introduction of the exhaust stream parallel to the tube axis. Within the dilution tube, along the perpendicular plane of the end of the exhaust extension was a mixing baffle which has an 8-inch center hole and was attached to the inside diameter of the tube. The baffle presented a restriction to the incoming dilution air in the same plane as the end of the exhaust extension and performed three essential functions.

Figure 1

Flow Diagram for Engine Exhaust Particulate Collection



a) Provided a turbulent mixing zone of exhaust gas and dilution air.
b) Eliminated engine exhaust pulsations in the tube.
c) Caused the tube to perform as a constant volume device over a wide range of engine exhaust output volumes.

B. Sampling Devices

The particulate sampling zone for particles smaller than 15μ was located at the exhaust end of the dilution tube. Four isokinetic sample probe elbows were located in the exhaust-air stream. One probe was connected to an Andersen Impact Sampler Model 0203, a filter assembly, and a vacuum pump, in that sequence. The probes were 0.754 inch ID stainless steel tubes which were located as shown in Figure 1. A mercury manometer was connected between the dilution tube probe and the exhaust side of the filter assembly, to measure the pressure drop across the filter. A flow meter was used to monitor and regulate the flow through the Andersen Sampler during the course of each run. Two sample probes were both connected to 1 cfm Millipore filter holder (142 mm) fitted with Gelman Type A glass fiber filter pads and vacuum pumps. The fourth filter was a 47 mm, 1 cfm glass fiber.

Prior to use, all the filters were stored in an instrument room which is temperature- and humidity-controlled. The filters were placed on the tray of the Mettler Analytical Balance, allowed to reach equilibrium, and then weighed out to 0.1 milligram (mg).

After the test, the filters were removed from the holders and again allowed to reach equilibrium, noted by no further change in weight, and then weighed to 0.1 mg. This was done in the same room in which the papers were stored. The

Millipore filter pads used were 142 mm Type AAWP 0.8μ. The fiber filter pads used were Gelman 0.3μ Type A.

Andersen Sampler Model 0203 with a back-up 142 mm Millipore filter was used as the basic particle collection device for determining mass size distribution. Sample probes sized to deliver an isokinetic sample from the dilution tube were connected to the Andersen Sampler through which a proportional sample was drawn at 1 cfm. The D_{50} cut-off values for the Andersen stages are listed in Table 1. The D_{50} value is the size at which 50% of those particles are collected, while the remaining 50% pass on through to be collected on the next stage.

TABLE 1

D_{50} VALUE - ANDERSEN MODEL 0203

Stage 1	D_{50} 9
Stage 2	D_{50} 5.45
Stage 3	D_{50} 2.95
Stage 4	D_{50} 1.55
Stage 5	D_{50} 0.95
Stage 6	D_{50} 0.54

Preweighed glass collection plates were used in this study. Back-up filters were either Millipore Type AAWP 0.8μ or Gelman 0.3μ Type A 142 mm diameter. Gelman glass fiber filters were routinely used while the Millipore filters were used for special analytical applications. Particulate larger than 15μ was evident as gravimetric fallout in the dilution tube, but was not weighed or analyzed in this study.

C. Condensate Collection

Exhaust gas condensate was collected for aldehyde and NH_3 analyses. A tap was placed into the raw exhaust gas stream, as close to the tailpipe of the vehicle as practical (about 12 inches). Raw exhaust was drawn through a three-stage cold trap at the rate of 1 cfm. The cold trap consisted of three flasks connected in series containing 40 grams each of DI water, immersed in an ice water bath. The exhaust gas flow bubbled through the water in the flasks. Condensate was collected for 41 minutes during a Modified Federal Cycle Cold Start, and for 23 minutes during a Federal Cycle Hot Start. Sampling was terminated at ~25 minutes during steady-state runs.

The condensate from the exhaust gas was analyzed for ppm of HCHO and NH_3. It was felt desirable to express this analysis in volume percent to compare to the other components analyzed in the exhaust gas. The procedure for this calculation is as follows:

The "Ideal Gas Law" was used:

$$PV = n\,RT$$

$$V = \frac{n\,RT}{P}$$

The total liters of exhaust that was put through the condenser was known, the liters of the aldehyde can be calculated from the formula above, so the volume percent can be calculated. This volume percent is reported as volume parts per million in the exhaust.

III. ANALYTICAL PROCEDURES

Collected exhaust particles were analyzed for both physcial and chemical character. Detailed descriptions of the specific analytical procedures employed follow. Table 2 is a summary of the techniques used on the exhaust emissions.

TABLE 2

ANALYTICAL TECHNIQUES FOR EXHAUST SPECIES

O_2, N_2, CO, CO_2	Fisher Gas Partitioner
Total Hydrocarbons	Beckman Model 109A Flame Ionization Detector
Oxides of Nitrogen	Beckman UV and IR Analyzer
C, H	Pyrolysis
Benzo-α-pyrene	Chromatograph, Fluorescence
Trace Metals	Emission Spectroscopy, Atomic Absorption
Aldehydes	Polarography
NH_3	Steam Distillation, Titration
CO	Analysis was also measured using 2 different Beckman Infrared Analyzers. A 0-3000 ppm Model 315 and 0-280 ppm Model 315B.
NO_x	Two Chemeluminescent Analyzers were used, a Prototype built by EPA, Raleigh, N.C. and a Model A Thermoelectron.
SO_4	X-ray Fluorescence & Turbidometric Method
S	Induced Electron Emission Method

2. Exhaust Gases

Engine exhaust gases were analyzed routinely several times during sampling runs. Schematically, exhaust gas sample points were shown earlier in Figure 1. The engine exhaust gas was analyzed for oxygen, nitrogen, carbon monoxide, carbon dioxide, and total unburned hydrocarbons. These analyses were done by gas chromatography, chemical absorption, and a total hydrocarbon analyzer. Data reduction was via an IBM 1800 computer through a Bell Telephone ASR 33 Teletype interface.

A. Hydrocarbons, CO, CO_2, Nitrogen and Oxygen

Total unburned hydrocarbons were obtained from a Beckman Model 109A FID Total Hydrocarbon Analyzer. A Fisher Gas Partitioner was used for the analysis of oxygen, nitrogen, carbon monoxide, and carbon dioxide. The partition column consisted of a 6-foot section containing hexamethyl phosphoramide and a 6 1/2-foot section containing 13x molecular sieves in series.

The output of the gas chromatograph was coupled with a Hewlett-Packard Model 3370A Digital Intergrator which has an ASCII coded output to drive an ASR 33 Teletype and punch paper tape.

Sampling

A Neptune Dyna-Pump was used to draw the sample from the exhaust pipe sampling point through 1/4" OD stainless steel tubing and transfer it to the total hydrocarbon analyzer and the gas sampling valve of the gas chromatograph through 1/8" OD stainless steel tubing. A manifold system was provided to allow the operator to calibrate the equipment with the appropriate standards.

Standardization

A gas mixture containing known concentrations of oxygen, nitrogen, argon, carbon monoxide, carbon dioxide, and n-hexane was used as a reference standard for the total hydrocarbon analyzer and the Fisher Gas Partitioner.

Operation

The operator typed the proper computer code and program number on the teletypewriter, injected the reference standard, and pressed the integrator start button. As the peaks emerged, the time and area information was encoded and stored on punched paper tape. Each succeeding exhaust gas was identified along with the total hydrocarbon level, and run in the same manner as the standard. When the series was finished, the punched tape was sent to the computer by teletype over regular telephone lines.

Data Reduction

A typical output format for the gas analysis is shown in Figure 2. Identification of the components in the standard was based upon each peak size in descending order. Estimated retention time was the updated time of each peak in the standard. Retention time windows were 4 seconds plus 2 percent of the retention time. Actual percent was a direct ratio of the area counts in the unknown sample to the area counts in the standard times the volume percent in the standard. The total percent actual is normally 97-98 percent since water is removed from the saturated sample after the sampling valve.

A correction for the unresolved argon in oxygen was made based upon response factors and the amount of argon found in a number of exhaust gas samples by mass spectroscopy.

The actual percent was normalized to 100 percent in the next column on a moisture free basis, and an Exhaust Gas Analysis report was issued (Figure 2). The air-to-fuel ratio was calculated from this analysis, the total hydrocarbon content, and the percent carbon in the fuel.

B. Oxides of Nitrogen

Equipment

a. Prototype built by EPA of Research Triangle Park, N.C.
b. Model A Thermo Electron Unit.

Calibrating Gases

a. Zero air nitric oxide, 51 ppm and 208 ppm.
b. These standard gases were purchased from Scott Research Inc.
c. Nitrogen was used as zero calibrating gas.

Procedure

a. Before making NO-NO_2 measurements the instrument was warmed up. Flow through the loop was balanced according to the operating procedures described in a report "A Method for Analysis of Oxides of Nitrogen (NO, NO_2) in Auto Exhaust" by John Sigsby, Frank Black, Tom Bellar, and Don Klosterman of EPA.

The instrument was calibrated as described in the above report. The zero standardizing was done using zero air and the up-scale calibration was done using a series of calibrating gases with varying levels of NO.

After calibration, the auto exhaust gases were passed through the analyzer at the same flow rate as used during standardization. The NO and NO_x values were read from a digital read out meter and recorded.

FIGURE 2

G. C. ANALYSIS - TECHNICAL DATA - 11-13-73 114

GØV RUN #279C NØV 13 1973 FINAL
ENG STD 2HRS SS 6ØMPH HS ØGA472 FUEL ADD WITH CØNV SAT
HC 5. PPM

PEAK NØ.	TIME ACT.	TIME EST.	PCT. VØL. ACTUAL	PCT. VØL. NØRM.	CØMPØUND IDENTIFICATIØN
1	42.	42.	0.000	0.000	CØMPØSITE
2	92.	93.	8.892	8.950	CARBØN DIØXIDE
3	130.	130.	8.037	8.089	ØXYGEN
			0.900	0.905	ARGØN
4	163.	163.	81.518	82.053	NITRØGEN
--	---.	290.	-.---	-.---	CARBØN MØNØXIDE
			99.347	099.999	TØTALS
			0.653		BALANCE BY DIFFERENCE
			0.653		TØTAL CØNTAMINATIØN LEVEL

EXHAUST GAS ANALYSIS 11-13-73

GØV RUN #279C NØV 13 1973 FINAL
ENG STD 2HRS SS 6ØMPH HS ØGA472 FUEL ADD WITH CØNV SAT
HC 5. PPM

TIME	PERCENT	IDENTIFICATIØN
130.	0.9	ARGØN
163.	82.1	NITRØGEN
130.	8.1	ØXYGEN
0.	0.03	CARBØN MØNØXIDE
93.	9.0	CARBØN DIØXIDE
	100.0	TØTAL

FRACTIØN CARBØN IN FUEL 0.8625

TØTAL HYDRØCARBØN CØNTENT 5. PPM.

AIR/FUEL RATIØ 23.5

b. As in the prior procedure, the Thermal Electron Model A analyzer was standardized as prescribed by the manufacturer. After calibration, the exhaust gases were passed through at the same flow as used during the standardization and the values in ppm of NO and NO_x were read from the indicating meter and recorded.

3. Exhaust Particles

The collection and classification techniques employed allowed the calculation of mass emission rates in grams/mile of exhaust particulate. Additionally, cumulative mass distribution data can be calculated. The specific techniques for chemical analysis of particulate matter follow:

A. Carbon and Hydrogen

The percentage of carbon and hydrogen in the particulate was determined by pyrolysis and collection of the combustion products. An entire 142 mm glass fiber filter containing the particulate was placed in a large platinum boat. The boat was then transferred to a combustion tube, and the sample was combusted at 1100°C for 3/4 hour. Carbon dioxide and water were absorbed in micro absorption tubes and weighed in the conventional manner. The C and H values were then calculated from the increase in weight using the given weight of the particulate.

In general, this technique is quite accurate for carbon and hydrogen analysis. However, the small sample sizes generated in a 23-minute cycle make it difficult to obtain precise results. The inherent inaccuracy of weighings (even using a 5-place balance) plus the large blank size make the results of a small sample only meaningful in a gross comparative sense.

B. Benzo-α-pyrene

Samples of exhaust particulate were collected on Gelman 142 mm glass fiber filter pads in a Millipore filter holder operating at 1 cfm. The samples on the glass filter pads were analyzed for benzo-α-pyrene in the following manner.

When available a sample of at least 10 mg (on either one or two filter papers) was used for analysis. The filters were folded and rolled with the particulates toward the inside of the roll and tied with copper wire. The rolls were Soxhlet extracted for at least 6 hours (with siphoning four to six times per hour) with 75 ml of benzene. The extracts were evaporated under a stream of filtered air at room temperature to approximately 3 ml. This concentrate was filtered through a M-fritted glass filter into a tared vial. The flask and filter were washed three times with approximately 2 ml of benzene for each wash. The combined filtrates were evaporated to dryness at room temperature with a stream of filtered air.

The residues obtained from both sample and blank filters were weighed and the difference between them designated "benzene soluble weight" for each sample. The residue was dissolved in 0.2 ml of methylene chloride and a 10-40 µl aliquot was spotted in 2 µl increments on a pre-conditioned Alumina TLC plate along with a known standard of benzo-α-pyrene in methylene chloride. The TLC plates were conditioned by heating at 120°C for 1.5 hours and desiccating overnight in a 45 percent relative humidity chamber (saturated aqueous zinc nitrate). The TLC plate was developed in an unsaturated tank containing 20 ml of ethyl ether in 200 ml of n-pentane to a height of 15 cm (approximately 45 minutes).

The benzo-α-pyrene spots were identified by comparison of R_f's with that of the standard spot under an ultraviolet lamp. The spots, marked with a pencil, were circumscribed with a #15 cork borer and scraped from the plate into vials. All TLC work was performed as much as possible in a dimly lighted area to avoid decomposition of the benzo-α-pyrene.

Five ml of 5 percent acetone in n-pentane was added to the alumina in the vial and it was agitated for 15 minutes on a mechanical shaker. The slurry was filtered through a F sintered glass filter into a vial, washing the alumina four times with approximately 2 ml of 5 percent acetone in n-pentane with a 45-second soak period between each wash. The combined filtrates were evaporated to dryness at room temperature using a stream of filtered air. The benzo-α-pyrene residue was taken up in 2.0 ml of concentrated sulfuric acid. This solution was evacuated for five minutes to remove trapped air bubbles and its fluorescence was measured in a one-cm cell at 540 nm while exciting at 470 nm on an Amino-Bowman Spectrophotofluorometer using a #4 slit arrangement and a sensitivity of 30.

Standard and blanks were carried through the entire TLC procedure. The blanks were subtracted from all fluorescence readings and the net fluorescence values for each sample were used to calculate the amount of benzo-α-pyrene present. Throughout all steps in the procedure the samples were refrigerated when not actually being processed and exposure of the samples to light was kept at a minimum.

C. Trace Metals

Emission spectrometry (ES) and x-ray fluorescence were used for determination of metals in the particulate. Trace metals were determined by ES on Millipore filters while lead was determined as a percent of the particulate collected on the 142 mm, 1 cfm fiberglass filter.

Emission Spectrometry

a. Principle

Organic matter in the sample was destroyed by wet ashing in sulfuric, nitric and perchloric acids. The resulting solution was taken to dryness and the residue taken up in a spectroscopic buffer solution containing the internal reference element, palladium. A portion of the solution was dried on pure graphite electrodes. The electrodes thus prepared were excited in an a.c. arc discharge and the spectrum is photographed. The intensity ratios of selected lines were determined photometrically and the concentration of each element read from an analytical curve relating intensity ratio to concentration.

b. Apparatus

1. Excitation - Excitation was obtained by the use of a 2400 volt a.c. arc discharge, Jarrel-Ash Custom Varisource or equivalent.

2. Spectrograph - Baird 3 meter grating spectrograph. Reciprocal dispersion was 5.55 A/mm in the first order.

3. Developing equipment - Jarrel-Ash Company. Plates were developed in a thermostatically controlled developing machine, washed and dried over heat in a stream of air.

4. Densitometer - Spectral lines were measured with a non-recording projection-type densitometer. Densitometer Comparator, Baird Associates Inc.

5. Calculating equipment - A calculating board was employed to convert densitometer readings to log intensity ratios. Jarrel-Ash Company.

6. Wet ashing equipment - A micro Kjeldahl digestion rack was used for wet ashing the organic solvents.

c. Reagents and Materials

1. Distilled nitric and perchloric acids. Perchloric acid is an intense oxidizing agent. Organic matter should not be heated in perchloric acid unless in the presence of sulfuric or nitric acid.

2. Sodium nitrate, reagent grade ($NaNO_3$).

3. Palladium diamine nitrite, $Pd(NH_3)_2\ (NO_2)_2$.

4. Water soluble salts of the elements Al, Ca, Cu, Fe, Mg, Mn, Ni, Pb, Sn, and Zn.

5. Electrodes, high purity graphite, 1/4" diameter by 3/4" length. Ultra Carbon Corporation.

6. Photographic plates - Eastman Spectrum Analysis No. 3.

7. Kjeldahl flasks, 10-ml.

d. Calibration

1. 0.2182 gm of palladium diamine nitrite $Pd(NH_3)_2(NO_2)_2$ were dissolved in water. Ten ml of concentrated reagent grade nitric acid were added and the mixture diluted to volume with water in a 100 ml volumetric flask. This solution contains 1 mg Pd per ml.

2. A buffer solution was prepared by dissolving 20 gm of sodium nitrate in water. 5.0 ml of the palladium solution above and 7.5 ml of concentrated reagent grade nitric acid were added and the whole diluted to 100 ml.

3. A stock solution containing 0.01% (0.1 mg/ml) each of the elements Al, Ca, Cu, Fe, Mg, Mn, Ni, Pb, Sn, and Zn was prepared. Two aliquots of this solution were diluted ten-fold and one hundred-fold to provide 0.001% and 0.0001% solutions.

4. Standard additions of the impurity elements were made to Kjeldahl flasks as shown in Table 3.

5. 0.5 ml of concentrated reagent grade sulfuric acid was added to the Kjeldahl flasks and the solution evaporated to dryness. After cooling, 1 ml of concentrated nitric acid was added and the mixture was evaporated to dryness again. The residue was taken up in 5 ml of buffer solution, warming, if necessary, to put the salts into solution.

6. The end of the 3/4" graphite electrodes was polished on filter paper and placed in a stainless steel drying tray. A drop of kerosene was placed on the top of each electrode to seal the porosity and the electrode allowed to dry. One pair of electrodes was prepared for each of the standard addition solutions by pipetting 0.03 ml of the solution onto the end of each electrode. The electrodes were dried slowly over micro burners in a gas drying oven and stored in a desiccator until run.

7. The samples were excited in water-cooled electrode holders using the following conditions:

a) Current, 4.0 amps, a.c. arc.
b) Spectral region, 2150-3550A.
c) Slit width, 50 μ.
d) Electrode gap, 2 mm.

e) Pre-burn period, 10 seconds.
f) Exposure period, 90 seconds.

8. The emulsion was calibrated by use of a stepped filter or by other recommended methods described in the "Recommended Practice of Photographic Photometry in Spectrochemical Analysis" A.S.T.M. designation: E116, Methods for Emission Spectrochemical Analysis, (1964).

9. The emulsion was processed according to the following conditons.

a) Developer (D19, 20.5°C), 3 1/2 minutes.
b) Stop bath (SB-4), 1 minute.
c) Fixing bath (Kodak Rapid Fixer), 2 minutes.
d) Washing, 3 minutes.
e) Drying, in a stream of warm air.

10. The relevant analytical line pairs were selected from Table 4. The relative transmittances of the internal standard line and each analytical line were measured with a densitometer. The transmittance measurements of the analytical line pairs were converted to intensity ratios by the use of an emulsion calibration curve and a calculating board.

11. Analytical curves were constructed by plotting concentration as a function of intensity ratio on log-log graph paper. For best results, the average of at least four determinations recorded on two plates were plotted.

e. Procedure

The available sample was weighed directly into a Kjeldahl flask. Wet oxidation was carried out with nitric and perchloric acid only. Extreme caution was exercised in the use

TABLE 3

Concentration	ml of Standard Addition Impurity Solution	
Blank		
0.00001%	0.5 ml	0.0001% solution
0.000025%	1.25 ml	0.0001% "
0.00005%	0.25 ml	0.001% "
0.0001%	0.5 ml	0.001% "
0.00025%	1.25 ml	0.001% "
0.0005%	2.5 ml	0.001% "
0.00075%	0.375 ml	0.01% "
0.001%	0.5 ml	0.01% "
0.0025%	1.25 ml	0.01% "
0.005%	2.5 ml	0.01% "
0.01%	5.0 ml	0.01% "

TABLE 4

ANALYTICAL LINE PAIRS

Element	Analytical Line A	Internal Standard Line A	Concentration Range %
Al	3092.71	3027.91 Pd	0.000025-0.0010
Ca	3179.33	"	0.00025-0.010
Cu	3273.96	"	0.00001-0.00025
Fe	3021.07	"	0.0001-0.010
Fe	3020.64	"	0.000025-0.0050
Mg	2802.69	"	0.000025-0.0010
Mg	2779.83	"	0.0005-0.010
Mn	2933.03	"	0.0005-0.010
Mn	2794.82	"	0.00001-0.0010
Ni	3414.77	"	0.000025-0.0010
Ni	3037.94	"	0.0005-0.010
Pb	2873.32	"	0.0010-0.010
Pb	2833.07	"	0.00005-0.0050
Sn	3175.02	"	0.00005-0.0050
Sn	2863.33	"	0.00075-0.010
Zn	3345.02	Background	0.0001-0.010

of this technique. Concentrated nitric acid was added dropwise, a few tenths ml at a time, to the hot mixture to aid in oxidation. A few drops of concentrated perchloric acid may be added to the hot solution after most of the free carbon has been destroyed, to hasten complete oxidation. When the solution became water clear, it was evaporated to dryness. After cooling, 0.5 ml of nitric acid was added and the mixture evaporated to dryness. The addition of 0.5 ml of nitric acid was repeated and the solution evaporated to dryness again. The inorganic residue was dissolved in dilute nitric acid and the volume adjusted to a known concentration, usually 10 mg/ml. If the original sample size was below 30 mg, a less concentrated solution was usually made up. Aliquots of this solution were taken to dryness and then the buffer solution (d2) added in an amount to give a dilution factor of 100x. One sample was analyzed by the direct reader while a second was examined photographically. Some samples had to be run at factors larger than 100x in order to get the concentration for some elements to fall within the range of the analytical curves. By varying the sample to buffer ratio any number of concentration or dilution factors could be achieved. A blank of the acids used was carried through in the same manner as the sample.

f. Calculations

The intensity ratios were converted to concentration by use of the analytical curve.

g. Precision and Accuracy

Representative precision and accuracy of the method are given in Table 5. Each of the twelve samples A_1, A_2, A_3, B_1, B_2, B_3, C_1, C_2, C_3, D_1, D_2, D_3, was analyzed by means of duplicate excitation.

TABLE 5

REPRESENTATIVE PRECISION AND ACCURACY OF EMISSION SPECTROSCOPY

Sample	% Al	% Ca	% Cu	% Fe	% Mg	% Mn	% Ni	% Pb	% Sn	% Zn
A_1	0.000044	0.00043	0.000048	0.00043	0.00049	0.00046	0.00047	0.00056	0.00052	0.00040
	0.000052	0.00050	0.000054	0.00055	0.00052	0.00057	0.00055	0.00059	0.00059	0.00045
A_2	0.000045	0.00043	0.000046	0.00044	0.00047	0.00051	0.00045	0.00050	0.00053	0.00054
	0.000052	0.00037	0.000047	0.00043	0.00050	0.00050	0.00051	0.00051	0.00050	0.00040
A_3	0.00004	0.00043	0.000050	0.00046	0.00053	0.00049	0.00047	0.00052	0.00050	0.00052
	0.000052	0.00050	0.000048	0.00046	0.00049	0.00046	0.00048	0.00053	0.00046	0.00012
B_1	0.00012	0.00105	0.00012	0.0010	0.00105	0.0010	0.0010	0.00105	0.0011	0.00094
	0.000097	0.00003	0.00010	0.00094	0.00095	0.0012	0.00096	0.00098	0.00094	0.0012
B_2	0.000097	0.00096	0.000099	0.00090	0.00092	0.0011	0.0010	0.0010	0.00105	0.00125
	0.000094	0.00088	0.000095	0.00105	0.00091	0.00066	0.00105	0.00105	0.00105	0.0010
B_3	0.000082	0.00085	0.000095	0.0010	0.0010	0.00086	0.0010	0.0010	0.00099	0.00096
	0.00011	0.00074	0.000096	0.0010	0.00090	0.00092	0.00105	0.0010	0.0010	0.00115
C_1	0.00023	0.0023	0.00023	0.0025	0.0023	0.00265	0.00245	0.00235	0.00255	0.0014
	0.00030	0.0018	0.00028	0.0030	0.0023	0.00195	0.00265	0.00255	0.0027	0.00215
C_2	0.00020	0.00225	0.00023	0.0023	0.0023	0.00265	0.0023	0.00245	0.00215	0.00225
	0.00023	0.00233	0.00025	0.00235	0.0024	0.00275	0.00245	0.0026	0.0023	0.0030
C_3	0.00024	0.0025	0.00026	0.00275	0.0023	0.00245	0.0026	0.0025	0.0025	0.0030
	0.00028	0.00275	0.00028	0.00285	0.0024	0.0025	0.00255	0.00245	0.00265	0.0020
D_1	0.00074	0.0070	--	0.0035	0.0057	0.0059	0.0065	0.0058	0.0064	0.0058
	0.00084	0.0084	--	0.0063	0.0051	0.0058	0.0058	0.0045	0.0059	0.0050
D_2	0.00059	0.0049	--	0.0057	0.0048	0.0045	0.0056	0.0045	0.0053	0.0050
	0.00063	0.0057	--	0.0059	0.0047	0.0048	0.0057	0.0048	0.0057	0.0060
D_3	0.0059	0.0048	--	0.0050	0.0045	0.0047	0.0050	0.0043	0.0054	0.0037
	0.00053	0.0060	--	0.0055	0.0055	0.0054	0.0055	0.0049	0.0049	0.0041

A_1, A_2, and A_3 contain 0.00005% of Al and Cu, and 0.0005% of each other element.

B_1, B_2, and B_3 contain 0.0001% of Al and Cu, and 0.0010% of each other element.

C_1, C_2, and C_3 contain 0.00025% of Al and Cu and 0.0025% of each other element.

D_1, D_2, and D_3 contain 0.0005% of Al and Cu and 0.0050% of each other element.

Induced Electron Emissions

The samples were analyzed for sulfur using IEE (Induced Electron Emission, also known as ESCA "Electron Spectroscopy for Chemical Analysis"). In this method of analysis, the sample was irradiated with x-rays, which produce photoelectrons, the energies of which are dependent on the elements present and the valence states of the elements. The electrons are energy analyzed and counted.

The electron spectrons were measured using a Varian IEE-15 spectrometer. The region of the electron spectrum containing the sulfur 2p line (binding energies from 159 e.v. to 179 e.v.) was scanned for a total of 1000 seconds (100 ten second scans), using an x-ray power of 1 KW and an analyzer voltage of 100V, for maximum sensitivity.

Standard Sample Handling: A piece .75" by 1.18" was cut from the center of each filter and mounted on a 3/8" diameter by 3/4" long aluminum cylinder with double-stick scotch tape.

X-Ray Fluorescence

The samples were received on filter discs measuring 3.5 cm in diameter. Weight of the samples ranged from 25 mg to 0.3 mg. Due to the small mass of sample on the discs, data measurements and interpretation was approached with the idea that each element of interest present on the discs was as an infinitely thin sample. An infinitely thin sample is a sample containing the element of interest only on the surface of the bulk material and having a mass/area concentration less than the experimental relationship of $0.1/\mu/\rho$ (regult in g/cm^2); μ/ρ being the total mass absorption coefficient of the sample with respect to the element of interest. Usually μ/ρ is the mass absorption of the major element present in the bulk matrice; carbon in the case of the filter disc, unless large amounts of some metal are present on the filter disc. Having an infinitely thin sample, direct comparison may be made on the amount of surface mass without taking in account matrices effects, greatly simplifying the data interpretation.

The samples were analyzed by wavelength dispersive x-ray fluorescence, using a Norelco Philips spectrometer and associated electronics, at an operating voltage of 50 kilovolts and current of 20 milliamps. A tungsten x-ray tube, LiF crystal, and NaI scintillation detector were used for the Pt, Pd, Ni, Cu analysis, while a chromium x-ray tube, EDDT crystal (ethylene diamine d-tartrate) crystal, and proportional flow counter was used for the sulfur analysis.

For each element analyzed, the K_α radiation was scanned and measured. Net peak heights for each element were compared with known infinitely thin standards of Pt, S, Ni, Cu and Pd. In the case where the samples turned out not to infinitely thin, infinitely thick standards were used for the comparison with corrections made for sample size and matrice.

Turbidimetric Determination of Inorganic Sulfate

a. Scope

The method is applicable to the determination of 1 to 10 mg of Na_2SO_4. See Note 10(a) for types of samples which can be analyzed.

b. Principle

An acid solution of the sample is treated with a barium chloride-gelatin solution and the resulting turbidity is measured on a spectrophotometer.

c. Interferences

The interferences would be those which cause a turbidity in the solution that could not be filtered prior to adding the gelatin mixture, by highly colored solutions and those which would normally be encountered in gravimetric analysis.

d. Safety Precautions

Use caution when handling concentrated acids and wear appropriate safety equipment.

e. Apparatus

Klett-Summerson colorimeter equipped with a No. 40 filter and a 4-cm cell, or a Dow Diagnostest colorimeter equipped with a 420 nm filter and a digital read-out concentration meter.

f. Reagents

1. Hydrochloric acid (1:1). Carefully mix equal volumes of concentrated hydrochloric acid and distilled water.

2. Barium chloride-gelatin mixture. Heat about 900 ml of distilled water to boiling and transfer the beaker to a steam bath. Add 25 grams of purified calfskin gelatin

to the beaker and heat and stir until the gelatin is dissolved. Add 100 grams of reagent grade barium chloride dihydrate to the beaker and dissolve. Cool and dilute to 1000 ml. Add 3 crystals of Thymol as a preservative. See Note 10(b).

3. Sodium sulfate solution, 1 ml = 1 mg Na_2SO_4. Dissolve 1.000 gram of anhydrous sodium sulfate in water and dilute to 1 liter.

g. Preparation of Calibration Curve

1. Transfer 0.0, 1.0, 2.0, 4.0, 6.0, 8.0, and 10.10 ml of sodium sulfate standard solution (1 ml = 1 mg Na_2SO_4) into 100-ml volumetric flasks, add 1.0 ml of 1 to 1 hydrochloric acid solution, dilute to about 50 mls, add 2.0 ml of barium chloride-gelatin solution and dilute to volume. Mix well and let stand for 5 minutes.

2. Zero the instrument on distilled water and obtain readings on the blank and standard solutions. Subtract the blank solution reading from the others and plot the readings vs. concentration on graph paper. See Note 10(c).

h. Procedure

1. Pipet a clear solution of the sample which contains from 2.0 to 10 mg of sodium sulfate into a 100-ml volumetric flask. See Notes 10(e), (f), and (g). Add 1 drop of phenolphthalein solution, neutralize with 1 to 1 hydrochloric acid solution and add 1 ml in excess. Dilute to about 50 mls, add 2.0 mls of barium chloride-gelatin solution and dilute to volume. Mix well and let stand for 5 minutes. See Note 10(d). Prepare a blank using 1 ml of 1 to 1 hydrochloric acid and 2.0 ml of barium chloride-gelatin solution in 100 ml.

2. Zero the instrument on distilled water and read the blank and sample solutions. Subtract the blank reading from the sample reading and obtain the mg of sodium sulfate from the calibration curve.

i. Calculation

$$\% \ Na_2SO_4 = \frac{mg \ Na_2SO_4}{10 \times grams \ of \ sample}$$

j. Notes

1. Samples that have been analyzed successfully are brine, salt samples, 10% caustic samples, aqueous samples, and Dowfax type materials after extraction.

2. The gelatin solution is stable for at least three months.

3. The curve is reproducible but should be checked occasionally. A new curve should be prepared for each new batch of gelatin.

4. The solutions are stable for at least 30 minutes.

5. For greatest accuracy in determining low amounts of sulfate in high amounts of other salts, standards should be prepared from solutions containing equal amounts of these salts.

6. Acidity appears to be very important in determining low amounts (1 mg and less) of sodium sulfate. Therefore, neutralize with 1 to 1 hydrochloric acid to phenolphthalein and add only one or two drops in excess before adding the barium chloride-gelatin mixture.

7. Not more than 5 grams of 50% sodium hydroxide should be used for analysis. 2.5 grams of 100% or 73% caustic may be used. Prepare a curve with an equivalent amount of ACS reagent grade caustic.

k. Precision and Accuracy

The method can be expected to yield results which are accurate to within 1 to 2 percent relative error. Samples analyzed gravimetrically and turbidimetrically agreed to within 1%. Duplicate samples agreed to within 1%.

D. Condensate Analyses

Condensate was collected from the raw exhaust as described earlier. The condensate was analyzed for aldehydes and NH_3 using the procedures outlined below.

Aldehydes

The analytical method for the determination of carbonyl compounds in automotive exhaust emissions employed polarographic techniques. Samples for analysis were collected from undiluted exhaust effluent using ice-water cooled cold traps and via a sample probe welded into the engine or vehicle exhaust system.

The theory for the polarographic analysis of auto exhaust condensate is described in detail in an EPA Report APTD 1567 dated March 1973 and is not included in this report. Since that time a portable hanging drop polarograph was developed by J. D. McLean and J. F. Holland of Dow Chemical Co. and was used for all determinations covered in this report. The procedure for the aldehyde measurements was as follows:

Procedure

For a typical sample analysis, 0.1 ml of exhaust condensate was pipetted into a clean, dry 10-ml volumetric flask. Five ml of pH 4 buffer acetate and 1 ml of aqueous hydrazine solution were added and then enough DI water was added to make 10 ml. The preceeding mixture was shaken well and then transferred to a clean, dry polarographic cell and deaerated with oxygen-free nitrogen for 5 min. The nitrogen sparger was lifted above the liquid level in the cell and a nitrogen blanket was maintained over the sample during scanning. The electrodes were inspected for trapped air which was removed. A mercury drop was hung by turning the micrometer knob of the hanging drop electrode. The first droplet was always discarded and a new drop formed using a prescribed number of micrometer units. The number of units for droplet formation was kept constant. The polarograph was turned on and the up-scale deflections shown on the digital read-out meter were recorded. This measurement was made 3 times for each sample with a fresh mercury drop.

The cell was lowered and 0.1 ml of HCHO (known concentration) was added. The cell was again deaerated as before and a mercury droplet was formed as before and 3 scans were made.

To correct for the effect of the reagents alone, a blank was always run to establish the meter up-scale deflection. These values were substracted from the values obtained during the scanning of the condensate sample which were then used for calculation.

Calculation: (Standard 11.98 g/10 ml)

Sample 38, 35, 36 } Ave. of 3 = 34.6 units

Sample + HCHO 58, 60, 59 } Ave. of 3 = 59.0 units

or 59.0 - 34.6 units = 24.4 units

$$\text{Std. } \frac{11.9}{24.4} = \frac{(34.6 - \text{reagent blank})}{.1 \text{ ml}} = \text{ppm Aldehyde}$$

Table 6 shows a comparison of results obtained from the portable polarograph and the laboratory polarograph. As can be seen the results are very comparable.

TABLE 6

COMPARISON OF RESULTS FROM A DIFFERENTIAL PULSE LABORATORY POLAROGRAPH AND THE PORTABLE POLAROGRAPH

Sample	Laboratory*, ppm, as HCHO	Portable**, ppm as HCHO
191X	17	17
192X	20	22
193X	24	25
194X	71	77
195X	26	29
196X	170	140
CD600-2-50L	170	180
CD600-2-54L	12	15
CD600-2-56L	22	24
CD600-2-57H	93	100
CD600-2-60L	7.3	7.8

*Single determination
**Average of duplicate determinations

b. Ammonia

Ammonia is present in the exhaust gas condensate and is analyzed in the following manner.

A 5-10 cc aliquot of condensate is added to a 50 percent potassium hydroxide solution. This mixture is then steam distilled into an excess of 0.010 N hydrochloric acid. The excess acid is determined by adding potassium iodide and iodate and titrating the liberated iodine with 0.010 N sodium thiosulfate.

This technique is capable of determining ammonia as low as 0.3 ppm. Figure 3 is a sketch of the apparatus used for the determination.

The analytical procedures given herein have been adapted from literature sources or developed upon the basis of experimental data which are believed to be reliable. In the hands of a qualified analyst they are expected to yield results of sufficient accuracy for their intended purposes. However, The Dow Chemical Company makes no representation or warranty whatsoever concerning the procedures or results to be obtained and assumes no liability in connection with their use. Users are cautioned to confirm the suitability of the methods by appropriate tests.

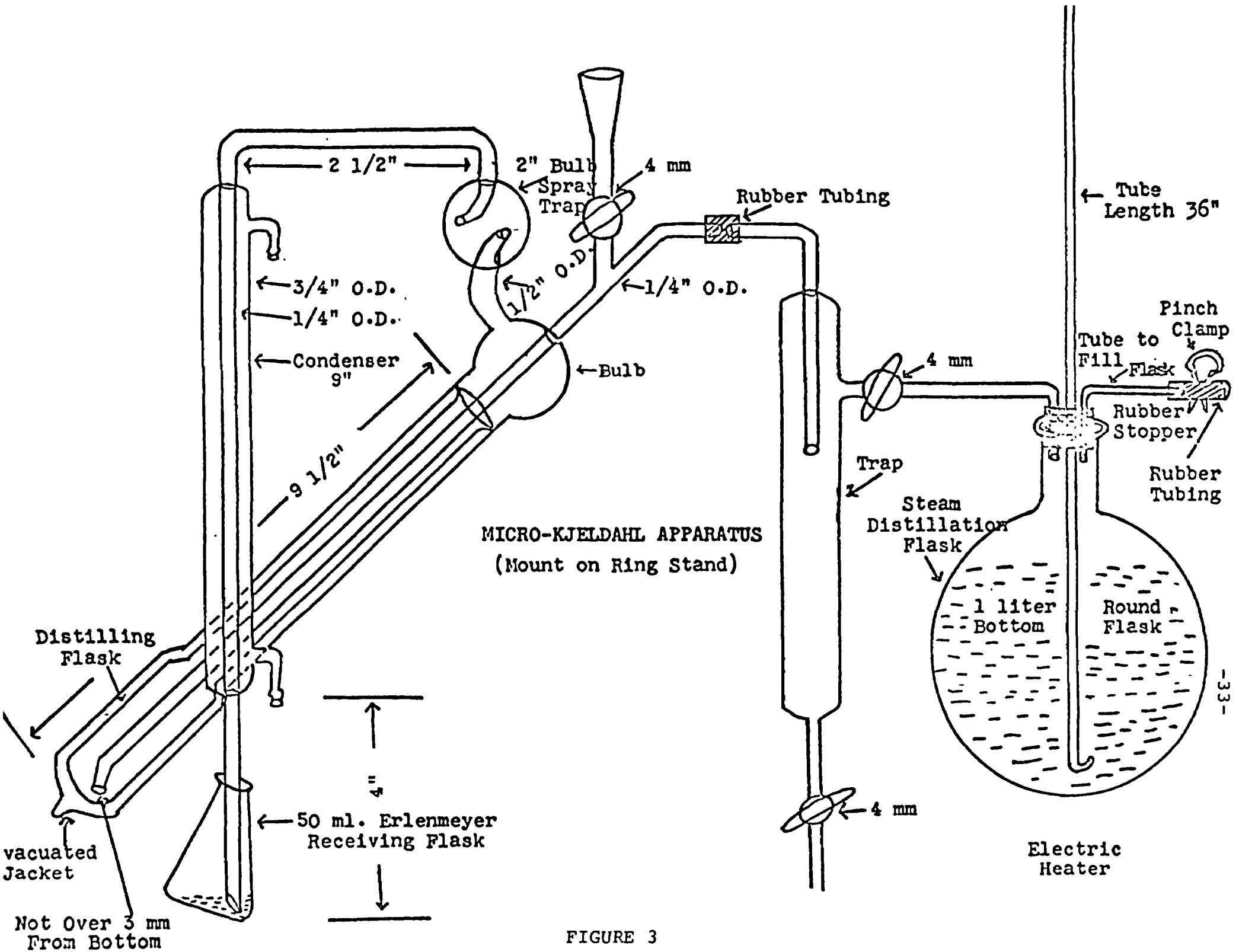


FIGURE 3

APPARATUS FOR DETERMINATION OF NH_3

ACKNOWLEDGEMENTS

The authors wish to acknowledge James E. Gentel and O. J. Manary for their significant contributions made in carrying out this study.

APPENDIX

CHASSIS DYNAMOMETER

VEHICLE TEST REPORT #1

Vehicle: Honda Prototype

Test Conditions: Weather: Cloudy and Cold.

Barametric pressure	29.76	Relative Humidity	15%
Room Temperature	84°F.		
Wet Bulb	55°F.		
Dry Bulb	80°F.		

Procedures:

One federal cycle cold start, 2 hot starts, and 1 60 mph steady state run.

Comments:

Andersen mass size distributions were not done on the hot starts. No gaseous analyses were done on the federal cyle runs due to equipment limitations at the time the runs were made. Special precautions were taken to prevent overheating of the car, such as additional fans on the exhaust system, extra insulation between floor and exhaust, and ice blocks to keep the trunk floor cool.

Signed: Lowell E. Smith **Date:** 7/11/73

CHASSIS DYNAMOMETER TEST

CAR NUMBER: None
VEHICLE TYPE: Honda Prototype Car
FUEL: Lead Free
CONVERTER: NO

Vehicle Test No.	Car Miles	Test Miles	Test Mode	Grams per 1.61 km (1 mile)					Vehicle Test No.
				Andersen Sampler	Follow-up glass Filter	Andersen + Filter	Glass Filter 142 mm (Avg. of two)	Glass Filter 4 cfm	
232 A	None	-	FC 1975	.0826	.2174	.3000	.0348	.0261	232 A
232 B	None	-	60 mph	.0050	.0180	.0230	.0130	.0114	232 B
232 C	None	-	FC HS	-	-	-	.0267	.0108	232 C
232 D	None	-	FC HS	-	-	-	.0200	.0083	232 D

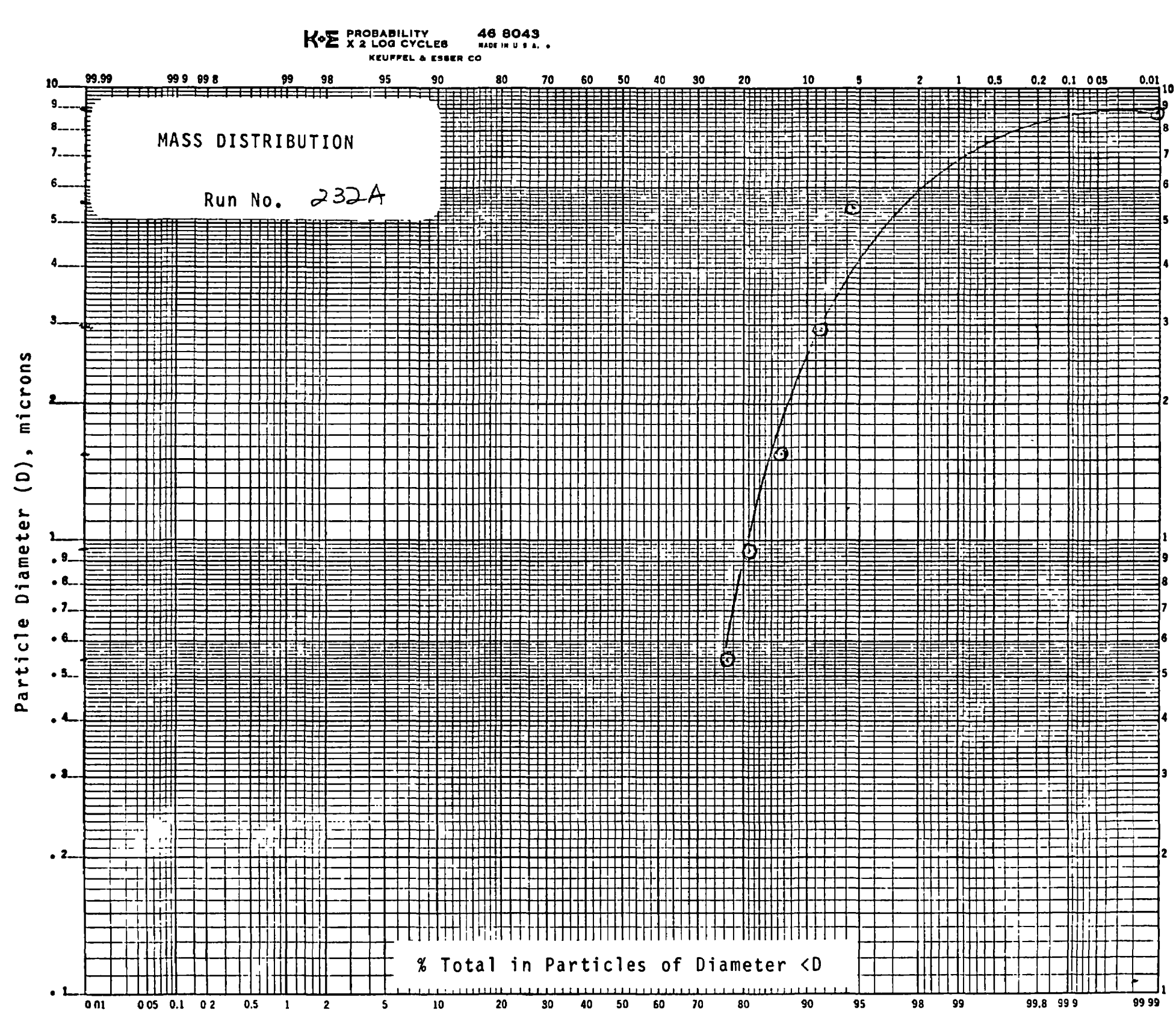
EXHAUST GAS ANALYSIS

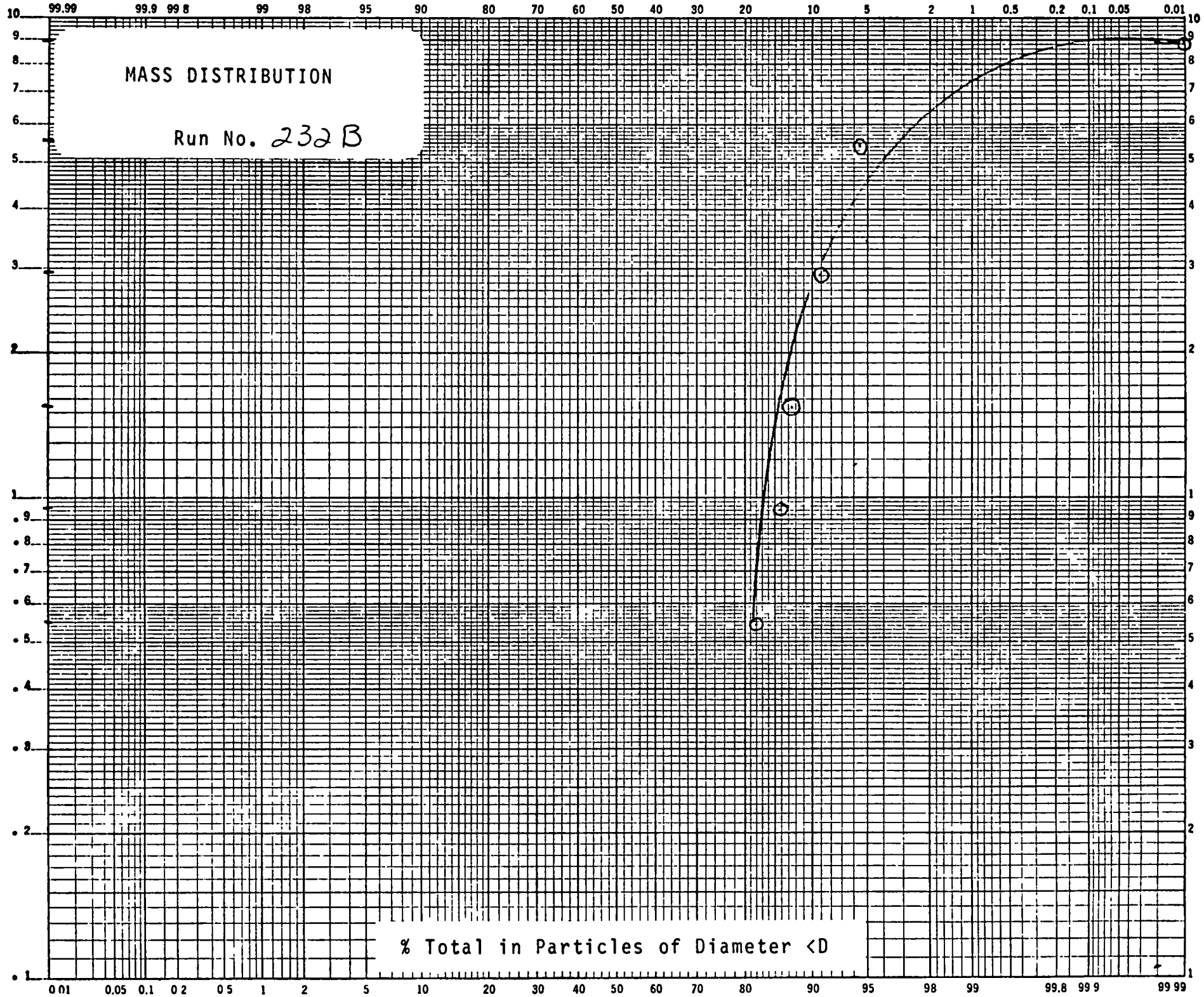
Run No.	% by Volume				Parts Per Million				Exhaust Condensate	
	CO_2	O_2	N_2	CO	H.C.	NO_2	NO	NO_x	PPM HCHO	PPM NH_3
232 A	-	-	-	-	-	-	-	-	1.7	3.5
232 B	13.6	2.7	82.8	.03	5	47	750	-	64.5	9.0
232 C	-	-	-	-	-	-	-	-	-	-
232 D	-	-	-	-	-	-	-	-	-	-

ANALYSIS OF EXHAUST PARTICULATE

Trace Metals on Millipore Filter (%)

Vehicle Test No.	Fe	Ni	Cu	Al	Ca	Mg	Mn	Cr	Sn	Zn	Ti	Pb	%C	%H	%N	$\%SO_4$	PPM BAP
232 A	.2	.04	.2	.08	1.36	.28	<.04	<.04	<.04	.2	<.04	.12	71.8	4.8			
232 B	.23	.046	.186	.09	1.48	.279	<.046	<.09	<.04	.23	<.04	1.3	9.4	1.7			
232 C																	
232 D																	


K•E PROBABILITY X 2 LOG CYCLES
46 8043
MADE IN U S A.
KEUFFEL & ESSER CO
MASS DISTRIBUTION
Run No. 232A
Particle Diameter (D), microns
% Total in Particles of Diameter <D
99.99 99.9 99.8 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0.2 0.1 0.05 0.01
0.01 0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9 99.99



CHASSIS DYNAMOMETER

VEHICLE TEST REPORT #2

Vehicle: 1973 Opel Diesel

Test Conditions: Weather: Clear and Cold.

Room Temperature	85°F	Relative Humidity:	5.0%
Wet Bulb	55°F		
Dry Bulb	87°F		

Procedures:

One federal cycle (1975) Cold Start, two federal cycle hot starts, one 2 hours 60 mph steady state.

Comments:

These runs were made before collection of samples for sulfate analyses were agreed on. No gaseous analyses on diesel samples are possible because the diesel exhaust fouls the equipment. Nitrogen was not tested for in the particulate.

Signed: Carl J. Landel **Date:** 7/16/73

CHASSIS DYNAMOMETER TEST

CAR NUMBER:

VEHICLE TYPE: Opel Diesel, 1973

FUEL: Diesel Fuel

CONVERTER: none

Vehicle Test No.	Car Miles	Test Miles	Test Mode	Grams per 1.61 km (1 mile) Andersen Sampler	Follow-up glass Filter	Andersen + Filter	Glass Filter 142 mm (Avg. of two)	Millipore 142 mm	Net Gms Millipore 4 CFM
234 A	4679		FC 1975	.0879	.1783	.2652	.4343	.2565	.3804
235 B	Kilometers		FC HS	.1333	.2533	.3866	.3467	.1268	.2933
235 C			FC HS	.1333	.2667	.4000	.3600	.1400	.3150
235 D			60 mph ss	.0277	.1786	.2013	.2042	.2042	.1740

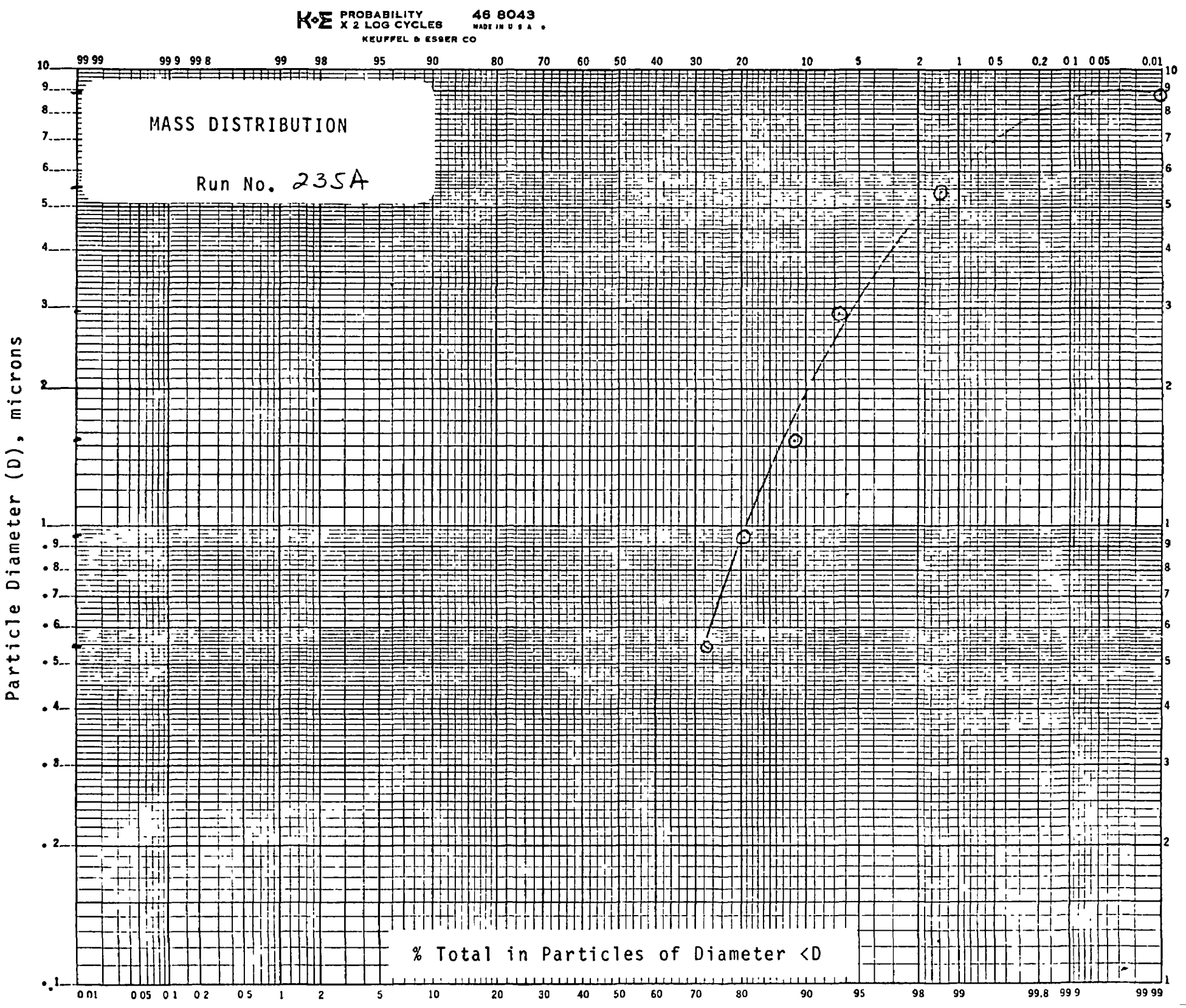
EXHAUST GAS ANALYSIS

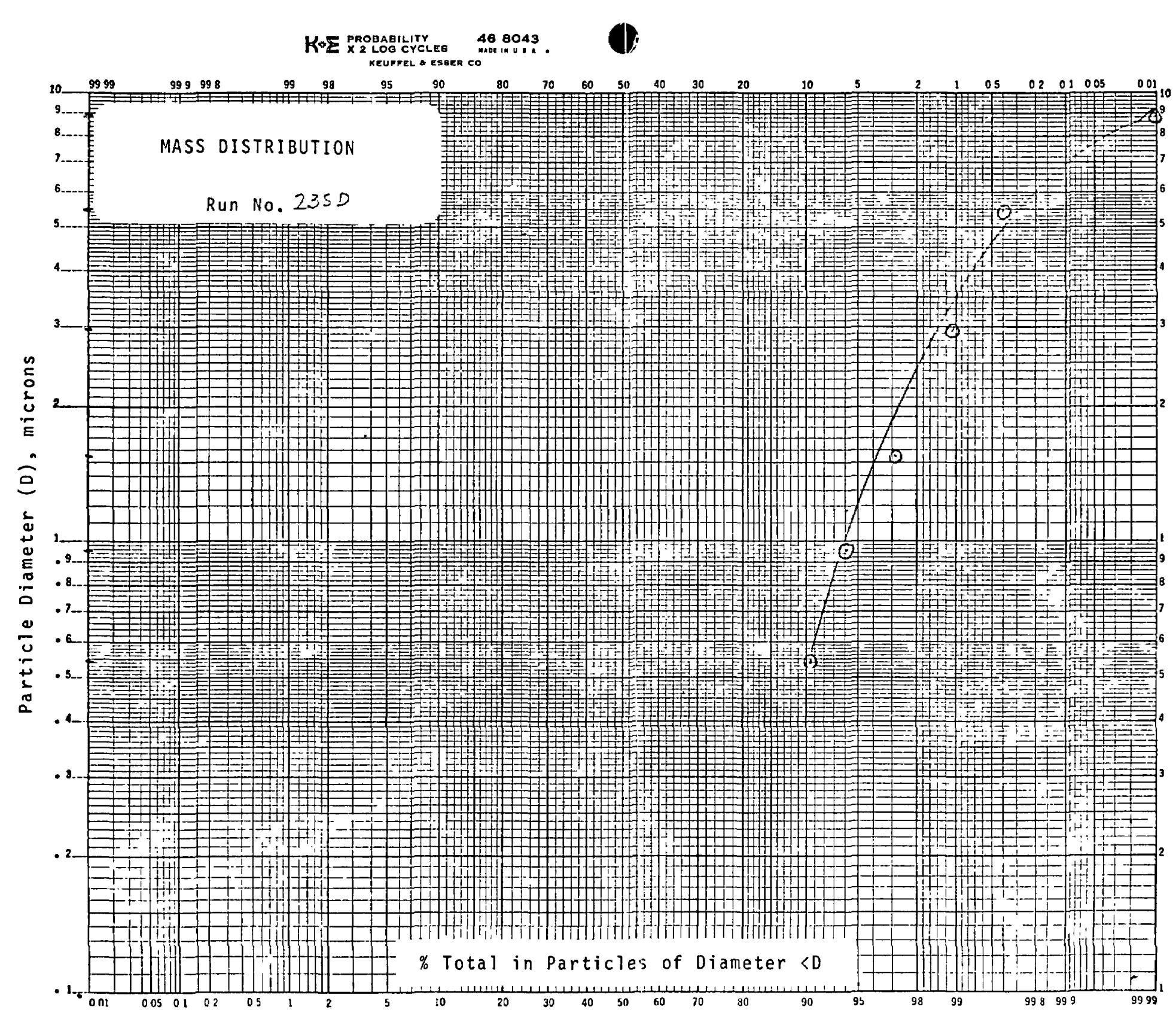
Vehicle Test	% by Volume				Parts Per Million				Exhaust Condensate	
	CO_2	O_2	N_2	CO	H.C.	NO_2	NO	NO_x	PPM HCHO	PPM NH_3
235 A									17.8	19.4
235 B									40.0	49.1
235 C	No gaseous analyses on Diesel Cars								-	-
235 D									18.5	38.9

ANALYSIS OF EXHAUST PARTICULATE

Trace Metals on Millipore Filter (%)

Vehicle Test No.	Fe	Ni	Cu	Al	Ca	Mg	Mn	Cr	Sn	Zn	Ti	Pb	%C	%H	%N	$\%SO_4$	PPM BAP
235 A	.6	<.01	.1	.1	1.4	.2	.01	<.1	<.1	<.1	<.1	.03	14.48	2.76			9.4
235 B	.7	.05	.3	.3	.3	.6	.03	<.1	<.1	<.1	<.1	<.2	77.08	5.61			9.4
235 C	-	-	-	-	-	-	-	-	-	-	-	-	-	-			-
235 D	.07	<.01	.05	.02	.02	.04	<.01	<.1	<.1	<.1	<.1	.02	69.91	2.74			3.8
tube sweepings	50	.18	.25	2.0	3.0	1.8	.6	.35	<.1	<.1	.4	1.6					


K•E PROBABILITY
X 2 LOG CYCLES
KEUFFEL & ESSER CO
46 8043
MADE IN U S A
MASS DISTRIBUTION
Run No. 235A
Particle Diameter (D), microns
% Total in Particles of Diameter <D
99 99 99 9 99 8 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0 5 0.2 0 1 0 05 0.01
0 01 0 05 0 1 0 2 0 5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99 9 99 99


K&E PROBABILITY
X 2 LOG CYCLES
46 8043
MADE IN U S A
KEUFFEL & ESSER CO
MASS DISTRIBUTION
Run No. 235D
Particle Diameter (D), microns
% Total in Particles of Diameter <D
99 99 99 9 99 8 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0 5 0 2 0 1 0 05 0 01
0 01 0 05 0 1 0 2 0 5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99 8 99 9 99 99

CHASSIS DYNAMOMETER

VEHICLE TEST REPORT #3

Vehicle: Peugeot - 4 SPd Transmission
Diesel Fuel #2 Amoco
Date 6/13/73

Test Conditions: Dilution velocity 420 ft/min = 550 cfm

Barmometric press	29.47	29.50	
wet bulb temp. °F	67.0	61.0	
dry bulb temp. °F	71.0	82.0	
room temp. °F	71.0	82.0	RH-21-25%

Procedures:
Modified Federal Cycle Cold start - 43 min.
Federal cycle hot start - 23 min. 2 runs
1 hour steady state 60 mph hot start

Comments:

Dilution tube and all connecting pipe, etc. was all washed Clean before run, tube was dissmantled and fallout was swept and weighed. .2185 gms were collected which was approximately 1/4 of that which was present.

Signed: _____ Date: 7/16/73

* Mileage Col = lometers
**MFCCS = modified fed. cycle
FC HS = Fed. cycle hot start
SS = 60 mph steady state
hot start

CHASSIS DYNAMOMETER TEST

CAR NUMBER:

VEHICLE TYPE: Peugeot

FUEL: Diesel fuel, #2 Amoco

CONVERTER: none

Vehicle Test No.	Car Miles*	Test Miles*	Test Mode**	Grams per 1.61 km (1 mile)				Net Gms
				Andersen Sampler	Follow-up glass Filter	Andersen + Filter	Glass Filter 142 mm (Avg. of two)	Millipore 142 mm	Millipore 47mm 4 CFM
252 A	6141	18	MFCCS	.17217	.33478	.50695	.54043	.43999	.0104
252 B	6159	12	FC HS	-	.37399	-	.38621	.31533	.0071
252 C	6171	12	FC HS	-	.40333	-	.42044	.21999	.0072
252 D	6183	127	1 hr. ss	.02671	.12244	.14915	.15843	.14173	.0130

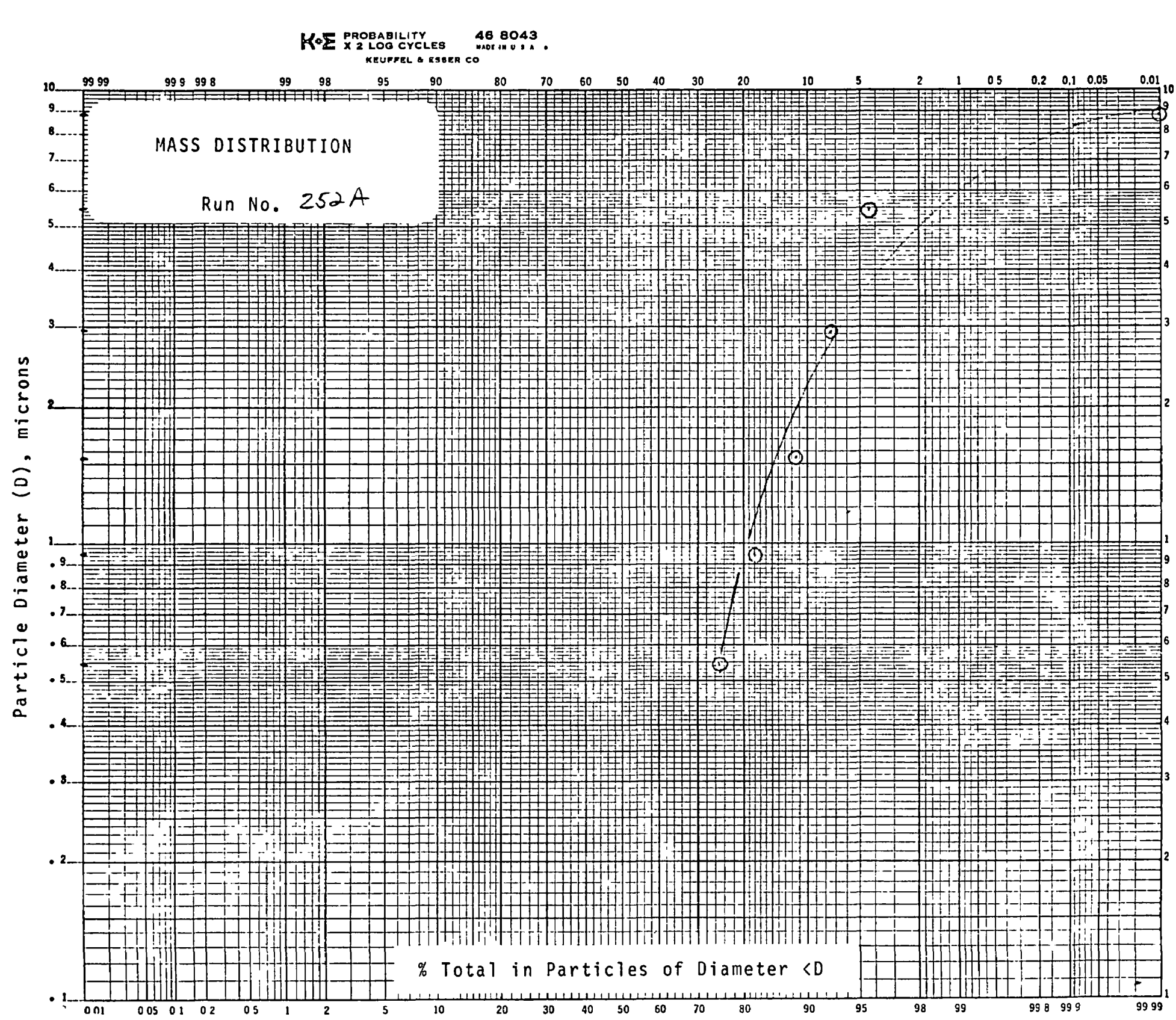
EXHAUST GAS ANALYSIS

Run No.	% by Volume				Parts Per Million				Exhaust Condensate	
	CO_2	O_2	N_2	CO	H.C.	NO_2	NO	NO_x	PPM HCHO	PPM NH_3
252 A									602.47	11.08
252 B									585.55	12.50
252 C									294.43	4.83
252 D									253.89	7.28

ANALYSIS OF EXHAUST PARTICULATE

Trace Metals on Millipore Filter (%)

Vehicle Test No.	Fe	Ni	Cu	Al	Ca	Mg	Mn	Cr	Sn	Zn	Ti	Pb	%C	%H	%N	$\%SO_4$	PPM BAP
252 A	.3	<.1	.1	<.1	.6	.3	.4	<.1	<.1	.3	<.1	<.3	58.06	3.07	0.45		26.0
252 B	.3	<.1	.1	<.1	1.1	.3	.4	<.1	<.1	.5	<.1	<.3	49.11	2.28	none or trace		51.0
252 C	.3	<.1	.1	<.1	1.7	.5	.3	<.1	<.1	1.0	<.1	<.3	46.38	6.01	0.35		36.0
252 D	.05	<.01	.03	<.01	.3	.06	.06	<.01	<.01	.2	<.01	.03	39.98	4.40	1.01		23.0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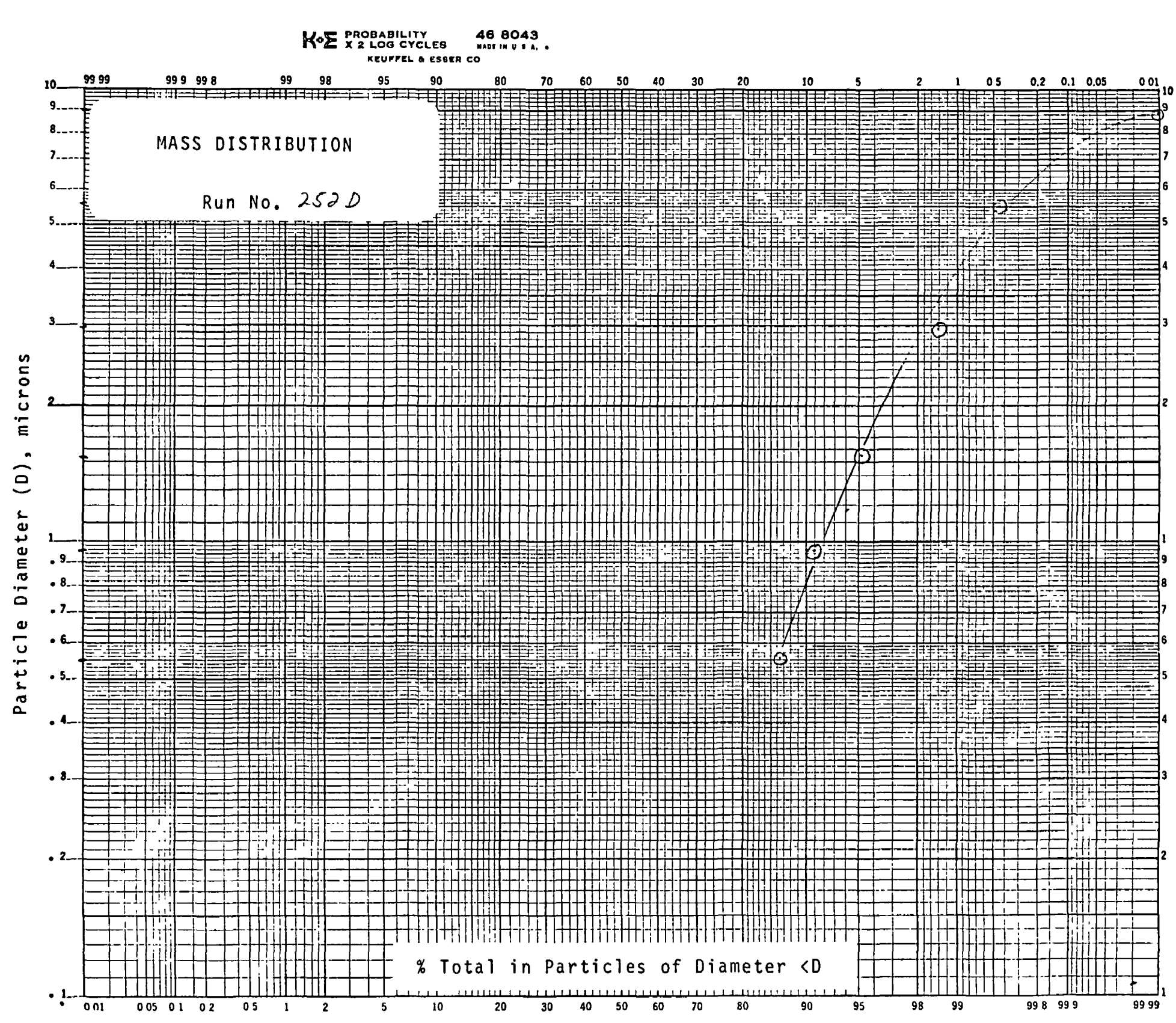
X 2 LOG CYCLES
KEUFFEL & ESSER CO
46 8043
MADE IN U S A
MASS DISTRIBUTION
Run No. 252A
Particle Diameter (D), microns
% Total in Particles of Diameter <D
99 99 99 9 99 8 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0 5 0.2 0.1 0.05 0.01
0 01 0 05 0 1 0 2 0 5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99 8 99 9 99 99


K&E PROBABILITY
X 2 LOG CYCLES
46 8043
MADE IN U S A.
KEUFFEL & ESSER CO
MASS DISTRIBUTION
Run No. 252 D
Particle Diameter (D), microns
% Total in Particles of Diameter <D
99 99 99 9 99 8 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0 5 0.2 0.1 0.05 0 01
0 01 0 05 0 1 0 2 0 5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99 8 99 9 99 99

CHASSIS DYNAMOMETER

VEHICLE TEST REPORT # 4

Date of test: 7-11-73

Vehicle: RX2 Mazda D1527

Test Conditions: Clear - Mild to cool

Bar.	29.50	29.46
Wet Bulb	60.0°F	56°F
Dry Bulb	82.0°F	67°F
Rel. Humidity	29%	45%

Procedures:

Modified Fed. Cycle Cold Start
Fed. Cycle Hot Start (2)
2 hrs. SS 60 MPH HS

Comments:

This vehicle is equipped with a thermal reactor and a reactor by-pass pipe, both the exhaust and by-pass pipe were connected to the dilution tube inlet pipe. During the 60 MPH SS-HS it was noted that the by-pass valve opened after about 10 min. on stream. It also has air pump and EGR.

Signed: James E. Hewitt Date: August 13, 1973

VEHICLE TEST REPORT

CHASSIS DYNAMOMETER TEST

CAR NUMBER: RXZ Mazda D1527
VEHICLE TYPE:
FUEL:
CONVERTER:

Vehicle Test No.	Car Miles	Test Miles	Test Mode	Grams per 1.61 km (1 mile) Andersen Sampler	Follow-up glass Filter	Andersen + Filter	Glass Filter 142 mm (Avg. of two)	Millipore 142 mm	Net Gms Millipore 47mm 4 CFM
259 A	1115.0	11.5	Mod. Fed C.S.	.12434	.04304	.16738	.83695	.09565	.0011
259 B	1126.5	120.0	60 MPH SS HS	.010759	.01484	.021243	.018367	.012615	.0020
259 C	1148.0	7.5	FC HS	--	--	--	.092887	.15400	.0007
259 D		7.5	FC HS	--	--	--	.114887	.17600	.0008

EXHAUST GAS ANALYSIS

Vehicle Test No.	% by Volume				Parts Per Million				Exhaust Condensate	
	CO_2	O_2	N_2	CO	H.C.	NO_2	NO	NO_x - N_x	PPM HCHO	PPM NH_3
259 A	11.2	4.6	82.8	0.47	390		156	202	924.55	8.8
259 B	9.7	6.1	81.9	1.56	630		467	513	2341.60	32.9
259 C	11.8	3.6	83.0	0.53	125		107	160	645.42	45.0
259 D	11.5	4.1	82.8	0.67	330		128	159	--	

ANALYSIS OF EXHAUST PARTICULATE

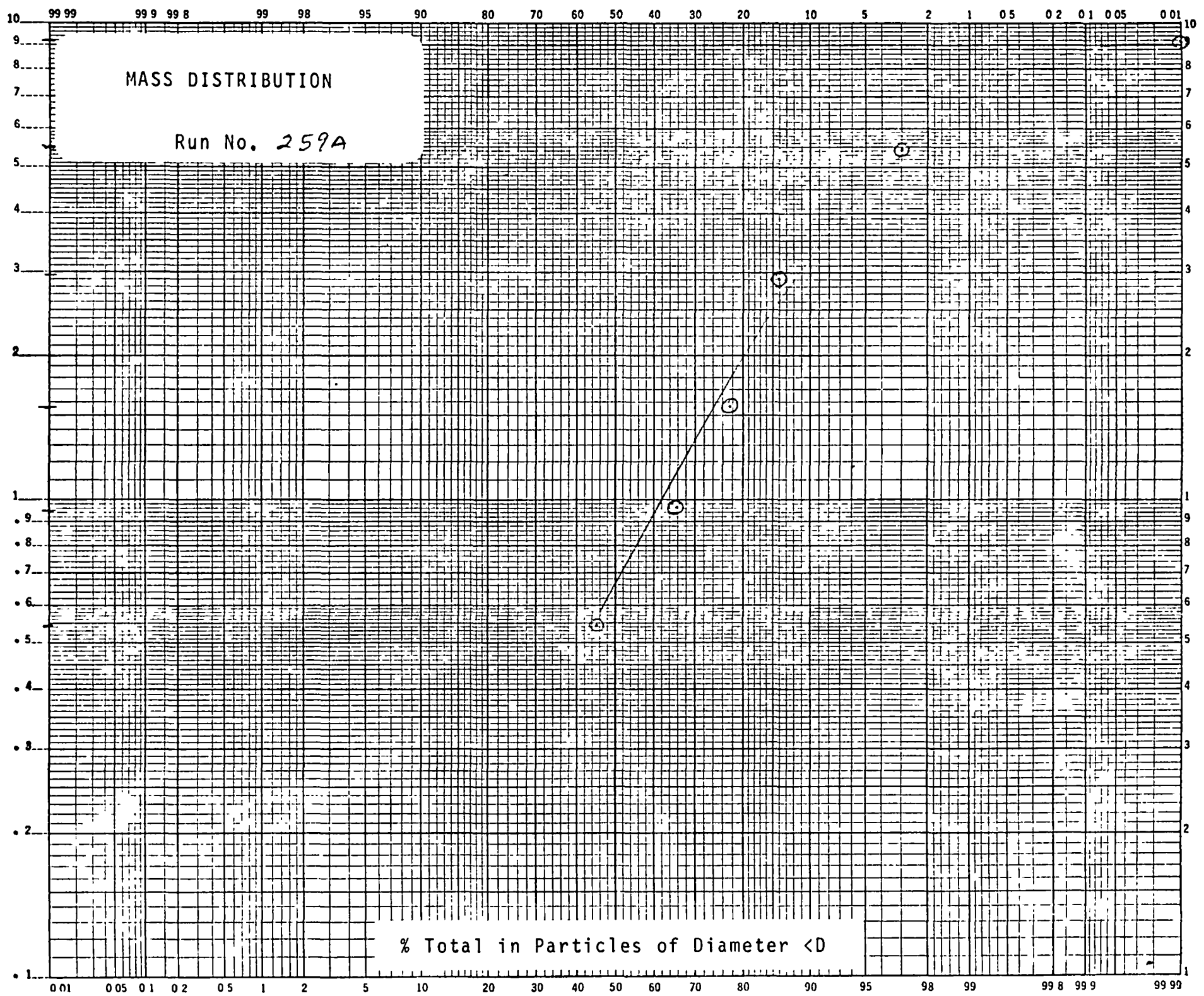
Trace Metals on Millipore Filter (%)

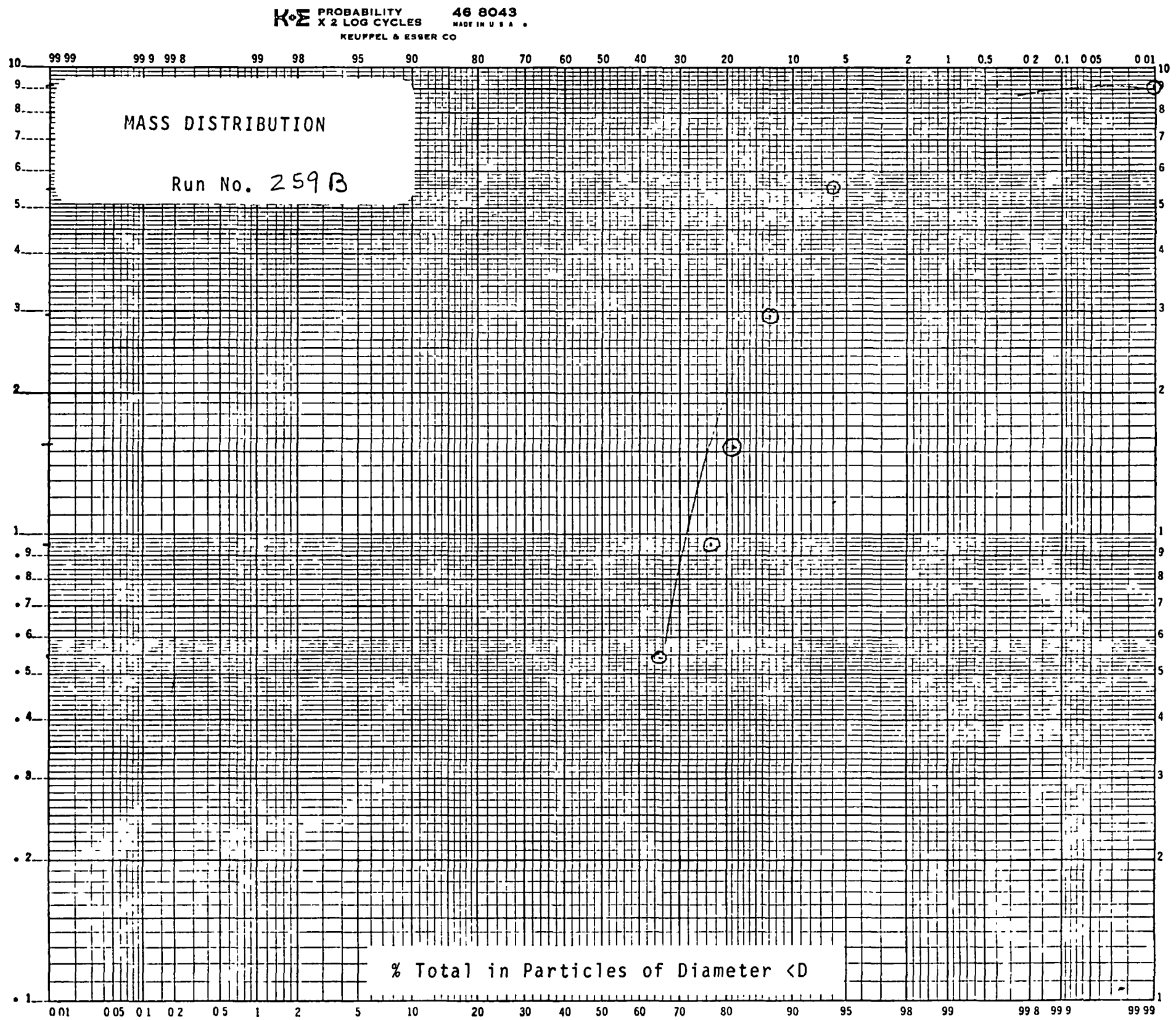
Vehicle Test No.	Fe	Ni	Cu	Al	Ca	Mg	Mn	Cr	Sn	Zn	Ti	Rb	$\%SO_4$
259 A	1.2	<0.1	.2	.3	2.7	.7	.1	.2	<0.1	<0.3	<0.1	<0.3	
259 B	0.3	<0.1	.08	.1	1.7	1.1	<0.05	<0.1	<0.1	<0.3	<0.1	<0.3	
259 C	0.5	<0.1	.07	.1	2.8	.6	.05	.1	<0.1	<0.3	<0.1	<0.3	
259 D	0.4	<0.1	.04	.1	2.2	.5	<0.05	<0.1	<0.1	<0.3	<0.1	<0.3	

Glass Fiber Filters

Vehicle Test No.	%C	%H	%N	PPM BAP
259 A	26.39	15.39	5.59	310
259 B	40.33	7.17	2.45	5030
259 C	20.71	15.47	4.60	72
259 D	40.75	17.11	4.64	98

Vehicle Test No.	AA
259 A	1.0
259 B	0.3
259 C	0.7
259 D	0.6


K&E PROBABILITY
X 2 LOG CYCLES
46 8043
MADE IN U S A
KEUFFEL & ESSER CO
MASS DISTRIBUTION
Run No. 259A
Particle Diameter (D), microns
% Total in Particles of Diameter <D
99 99 99 9 99 8 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0 5 0 2 0 1 0 05 0 01
0 01 0 05 0 1 0 2 0 5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99 8 99 9 99 99


K&E PROBABILITY
X 2 LOG CYCLES
46 8043
MADE IN U S A
KEUFFEL & ESSER CO
MASS DISTRIBUTION
Run No. 259B
Particle Diameter (D), microns
% Total in Particles of Diameter <D
99 99 99 9 99 8 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0 2 0.1 0 05 0 01
0 01 0 05 0 1 0 2 0 5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99 8 99 9 99 99

CHASSIS DYNAMOMETER

VEHICLE TEST REPORT #5

Date of test: 7-18-73

Vehicle: EPA William's Gas Turbine

Test Conditions:

Barometer	29.60
Wet Bulb	65.0°F
Dry Bulb	71.5°F
Rel. Humidity	49%

Procedures:

Modified Fed. Cold Start 41 Min.
Federal Cycle Hot Start 23 Min- (2)
1 Hr. SS 50 MPH Hot Start

Comments:

Only 1/2 engine exhaust was used. A 5" SS flexible tube was used to couple exhaust pipe to exhaust inlet to dilution tube. There was a possibility of exhaust leakage in the exhaust adapter which was installed by the EPA people upon arrival. The fuel tank had to be vented using a 20'1/4" rubber tube due to excess heating of fuel tank with exhaust adapters. Steady state run was made at 50 MPH for only 1 hr. due to the fuel tank heating problem.
Had fire department stand by during entire testing period.

NOTE: Could not maintain a 4 CFM flow through the millipore 47MM filter for the duration of each test.

Signed: James E. Gentel Date: Aug 13 1973

VEHICLE TEST REPORT #

CHASSIS DYNAMOMETER TEST

CAR NUMBER: Prototype
VEHICLE TYPE: Williams Gas Turbine EPA
FUEL: Indolene O
CONVERTER: No

Vehicle Test No.	Car Miles	Test Miles	Test Mode	Grams per 1.61 km (1 mile) Andersen Sampler	Follow-up glass Filter	Andersen + Filter	Glass Filter 142 mm (Avg. of two)	Millipore 142 mm	Net Gms Millipore 47mm 4 CFM
260 A		11.5	MFCCS	.26296	.48835	.75131	.68243	.67617	.0042
260 B		7.5	FCHS	--	--	--	.7488	.2880	.0037
260 C		7.5	FCHS	--	--	--	.4707	.2688	.0027
260 D		50.0	50 MPH SS	.06545	.16858	.23403	.22312	.13882	.0061

EXHAUST GAS ANALYSIS

Vehicle Test No.	% by Volume				Parts Per Million				Exhaust Condensate	
	CO_2	O_2	N_2	CO	H.C.	NO_2	NO	NO_x - N_x	PPM HCHO	PPM NH_3
260 A	2.4	17.6	79.1	.03	10		14/7	17/8	349.05	15.14
260 B	2.3	17.7	79.1	.03	15		13	16	375.91	18.15
260 C	2.3	17.7	79.0	.03	15		17	19	--	--
260 D	2.4	17.8	79.0	.03	10		26	30	80.53	28.20

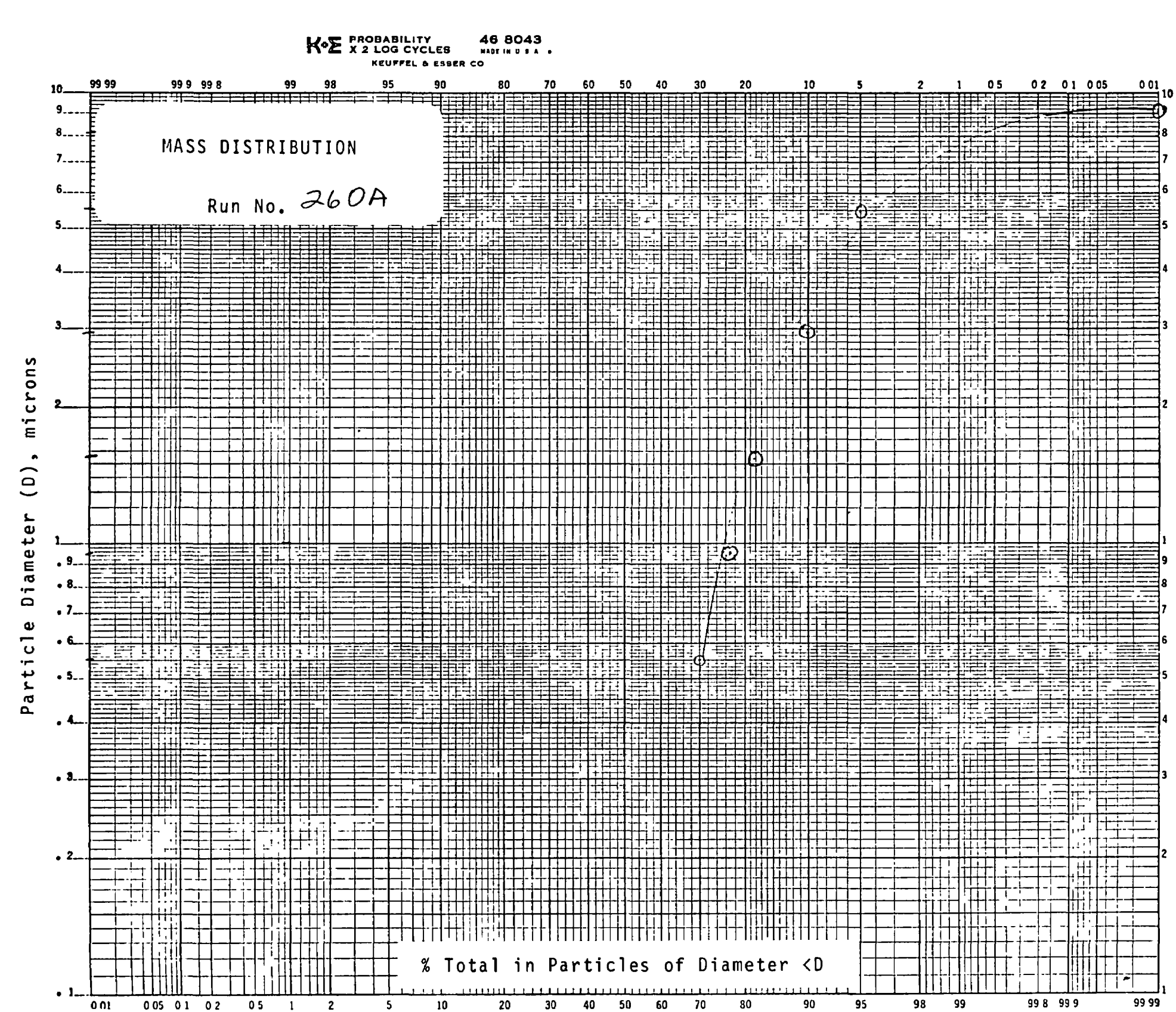
VEHICLE TEST REPORT #

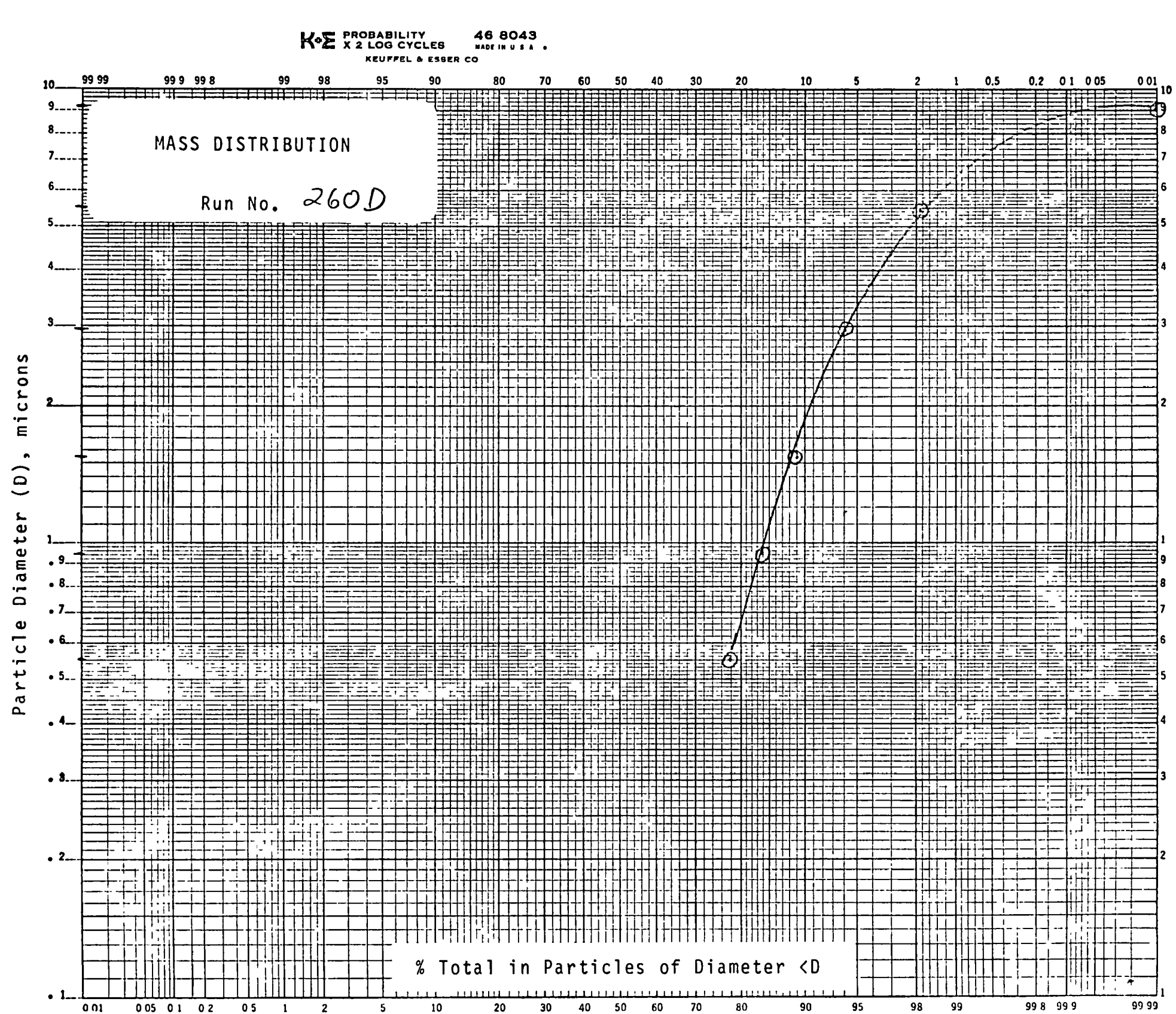
ANALYSIS OF EXHAUST PARTICULATE

Trace Metals on Millipore Filter (%)

Vehicle Test No.	Fe	Ni	Cu	Al	Ca	Mg	Mn	Cr	Sn	Zn	Ti	Rb	$\%SO_4$	Glass Fiber Filters %C	%H	%N	PPM BAP
260 A	0.3	0.4	.06	< .1	1.1	0.2	<.05	<0.1	<0.1	0.3	<0.1	<0.3		58.89	10.47	2.06	340
260 B	0.5	0.7	.12	0.2	3.4	0.6	<.05	<0.1	<0.1	0.8	<0.1	<0.3		54.27	8.92	0.93	115
260 C	0.5	0.6	.07	0.2	3.6	0.7	<.05	<0.1	<0.1	1.1	<0.1	<0.3		59.73	7.52	trace	100
260 D	<0.1	0.3	.08	<0.1	0.7	<0.1	<.05	<0.1	<0.1	<0.3	<0.1	<0.3		65.24	11.48	2.45	228
		AA*															
260 A		<0.6															
260 B		<0.6															
260 C		<1.2															
260 D		<0.3															
TUBE SWEEPINGS FOR ALL 4 TESTS ABOVE																	
Magnetic	30	2.0	.2	1	5	.5	.4	3	<0.1	2	.3	1					
Non Mag.	20	4.0	.2	1	5	.5	.5	6	<0.1	2	.4	1					

*AA = Atomic Absorption


K•E PROBABILITY X 2 LOG CYCLES
46 8043
MADE IN U S A
KEUFFEL & ESSER CO
MASS DISTRIBUTION
Run No. 260A
Particle Diameter (D), microns
% Total in Particles of Diameter <D
99 99 99 9 99 8 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0 5 0 2 0 1 0 05 0 01
0 01 0 05 0 1 0 2 0 5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99 8 99 9 99 99


K&E PROBABILITY
X 2 LOG CYCLES
46 8043
MADE IN U S A
KEUFFEL & ESSER CO
MASS DISTRIBUTION
Run No. 260D
Particle Diameter (D), microns
% Total in Particles of Diameter <D
99 99 99 9 99 8 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0.2 0 1 0 05 0 01
0 01 0 05 0 1 0 2 0 5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99 8 99 9 99 99

CHASSIS DYNAMOMETER

VEHICLE TEST REPORT # 6

Date of test: 7/26/73 & 7/27/73

Vehicle: Yellow Mazda Rx3

Test Conditions:

Barometer	21.12	29.20
Wet Bulb	68.0°F	68°F
Dry Bulb	76.0°F	80°F
Rel. Humidity	66%	54%

Procedures:

Mod. Federal Cycle Cold Start 41 min
Fed. Cycle Hot Start 23 min (2)
2 Hrs Steady State 60 MPH Hot Start

Comments:

This vehicle is equiped with a thermal reactor which has a reactor by-pass. Both the exhaust pipe and by-pass pipe were connected to the dilution tube inlet. During SS 60 MPH it was noted that the by-pass opened after about 10 minutes on stream time. The vehicle also has air pump and EGR.

Signed: James E Hentel Date: 9/5/73

CHASSIS DYNAMOMETER TEST

CAR NUMBER:

VEHICLE TYPE: MAZDA RX3 YELLOW COUPE

FUEL: INDOCENE NON LEAD

CONVERTER: THERMAL REACTOR-AIR PUMP AND EGR

Vehicle Test No.	Car Miles	Test Miles	Test Mode	Grams per 1.61 km (1 mile) Andersen Sampler	Follow-up glass Filter	Andersen + Filter	Glass Filter 142 mm (Avg. of two)	Millipore 142 mm	Net Gms Millipore 47mm 4 CFM
261A	1026.3	11.5	MFCCS	.105217	.105217	.210434	.117173	.176956	.0014*
261B	1037.8	7.5	FCHS	-------	-------	-------	.09777	.17599	.0008
261C	1045.3	7.5	FCHS	-------	-------	-------	.09285	.168667	.0008
261D	1052.8	120	60 MPH SS	.008477	.015895	.024372	.018721	.013069	.0016*

* Could not maintain a 4CFM Flow for duration of test

EXHAUST GAS ANALYSIS

Vehicle Test No.	% by Volume				Parts Per Million				Exhaust Condensate	
	CO_2	O_2	N_2	CO	H.C.	NO_2	NO	NO_x - N_x	PPM HCHO	PPM NH_3
	11.5	3.95	83.15	.43	170	23 min	108	118		
261A	5.55	12.90	80.45	.20	195	10 min + 505 sec	114	123	381.55	9.32
261B	11.95	3.60	83.15	.47	95		133	141	253.43	9.04
261C	12.10	3.50	83.35	.17	75		130	139	------	----
261D	10.90	5.0	82.50	.71	465	Start	652	513		
	10.55	5.0	82.35	1.125	570	Finish	713	550	1541.33	89.37

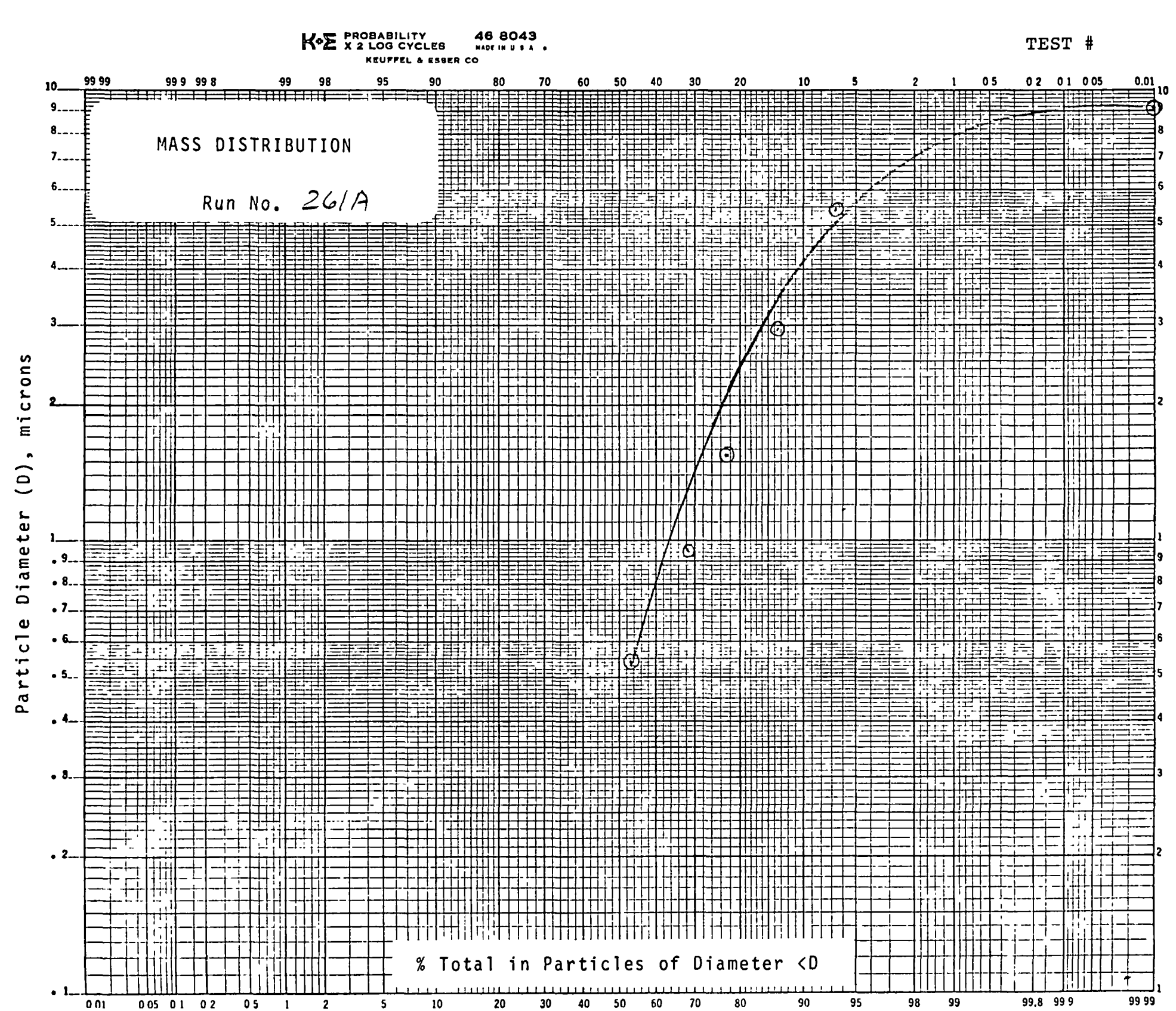
ANALYSIS OF EXHAUST PARTICULATE

Trace Metals on Millipore Filter (%)

Glass Fiber Filters

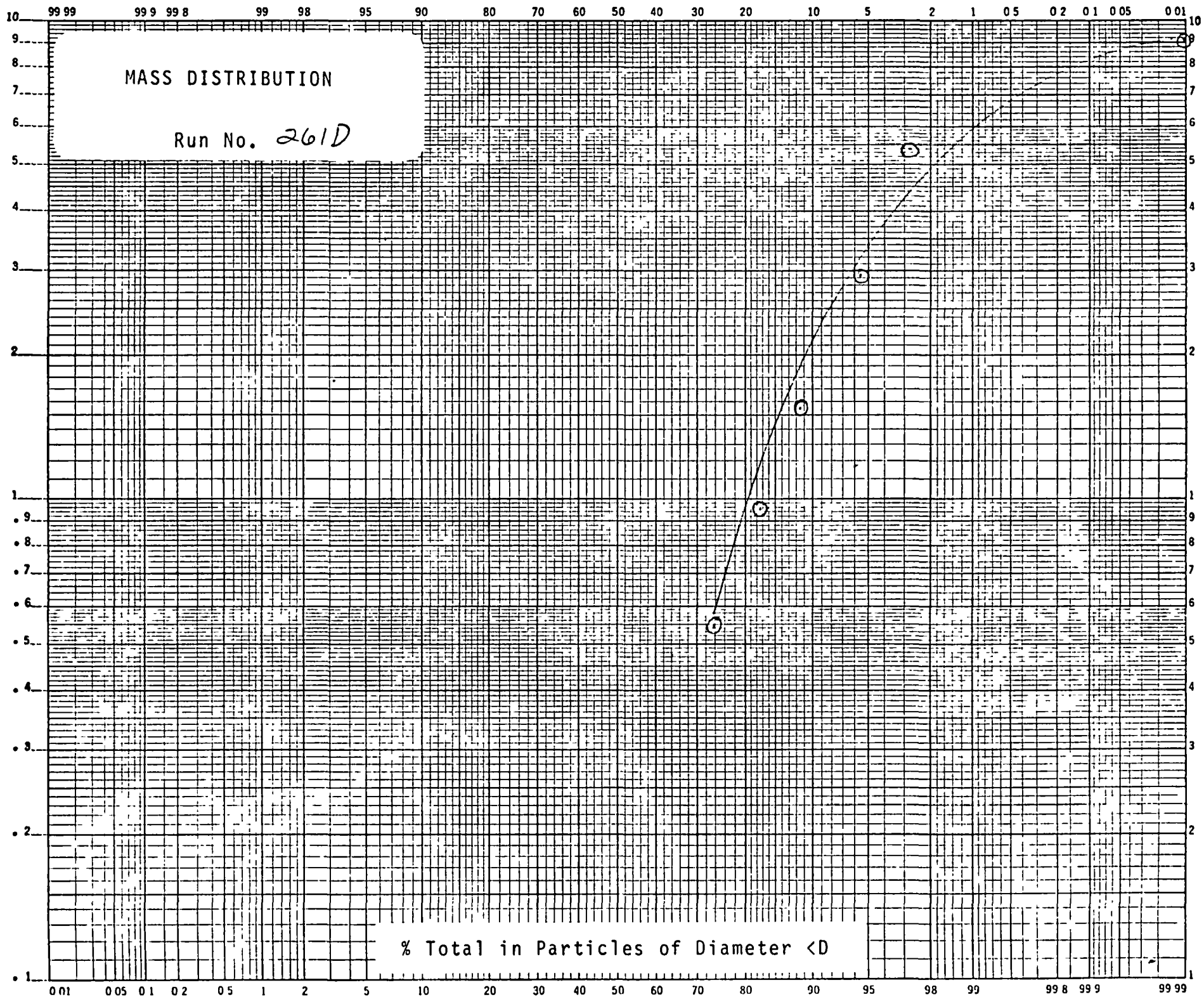
Vehicle Test No.	Fe	Ni	Cu	Al	Ca	Mg	Mn	Cr	Sn	Zn	Ti	Rb	$\%SO_4$	%C	%H	%N	PPM BAP
261A	.3	.03	.03	.03	.5	.05	.1	< .01	<01	< .01	< .01	.1		22.71	4.12	5.43	38
261B	.3	.04	.08	.06	1.3	.2	.02	< .02	< .02	< .02	< .02	.06		8.95	2.99	5.26	< 40
261C	.2	.02	.08	.04	1.5	.2	< .005	< .02	< .02	< .02	< .02	.06		16.36	4.38	5.18	< 40
261D	.5	.01	.2	.05	1.6	.8	.01	.08	.03	.4	< .01	2.8		33.91	3.61	3.83	250
261A*												2.9					
261B												4.5					
261C												4.3					
261D												1.7					
TUBE SWEEPINGS																	
	17	.2	.09	1	.9	.7	.2	.6	< .05	15	.1	3					

* Pb by ATOMIC ABSORPTION


K&E PROBABILITY
X 2 LOG CYCLES
KEUFFEL & ESSER CO
46 8043
MADE IN U S A
TEST #
MASS DISTRIBUTION
Run No. 26/A
Particle Diameter (D), microns
% Total in Particles of Diameter <D
99 99
99 9
99 8
99
98
95
90
80
70
60
50
40
30
20
10
5
2
1
0 5
0 2
0 1
0 05
0.01
0 01
0 05
0 1
0 2
0 5
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.8
99 9
99 99

K&E PROBABILITY 46 8043
X 2 LOG CYCLES MADE IN U S A
KEUFFEL & ESSER CO

TEST # 6



CHASSIS DYNAMOMETER

VEHICLE TEST REPORT # 7

Date of test: 8/14/73 & 8/15/73

Vehicle: 72 EPA FORD with Durability Catalyst
Vehicle No. 24A51

Test Conditions:	AM	PM
Barometer	29.34	29.36
Wet Bulb	65°F	69.5
Dry Bulb	75°F	82.5
Rel. Humidity	58%	60%

Procedures:
Modified Federal Cycle Cold Start 41 min.
Federal Cycle Hot Start 23 min. (2)
2 Hrs. Steady State 60 MPH Hot Start

Comments:

The vehicle was driven up from Ann Arbor without the Catalytic Converters in the exhaust system. These were installed by Dow the night before and were not warmed up in any manner prior to test run.

Signed: James E. Sentel Date: 9/7/73

CHASSIS DYNAMOMETER TEST

CAR NUMBER: 24A51 - EPA
VEHICLE TYPE: 72 FORD 351 CID
FUEL: INDOLENE NON LEAD
CONVERTER: DURABILITY CATALYST

Vehicle Test No.	Car Miles	Test Miles	Test Mode	Grams per 1.61 km (1 mile) Andersen Sampler	Follow-up glass Filter	Andersen + Filter	Glass Filter 142 mm (Avg. of two)	Millipore 142 mm	Net Gms Millipore 47mm 4 CFM
262A	58,448.0	11.5	MFCCS	.11000	.05261	.16261	.08131	.13391	.0009
262B		7.5	FCHS	------	------	------	.05622	.14667	.0005
262C		7.5	FCHS	------	------	------	.05867	.08067	.0005
262D		120.0	SS 60 MPH	.01274	.020467	.033207	.033209	.013129	.0027

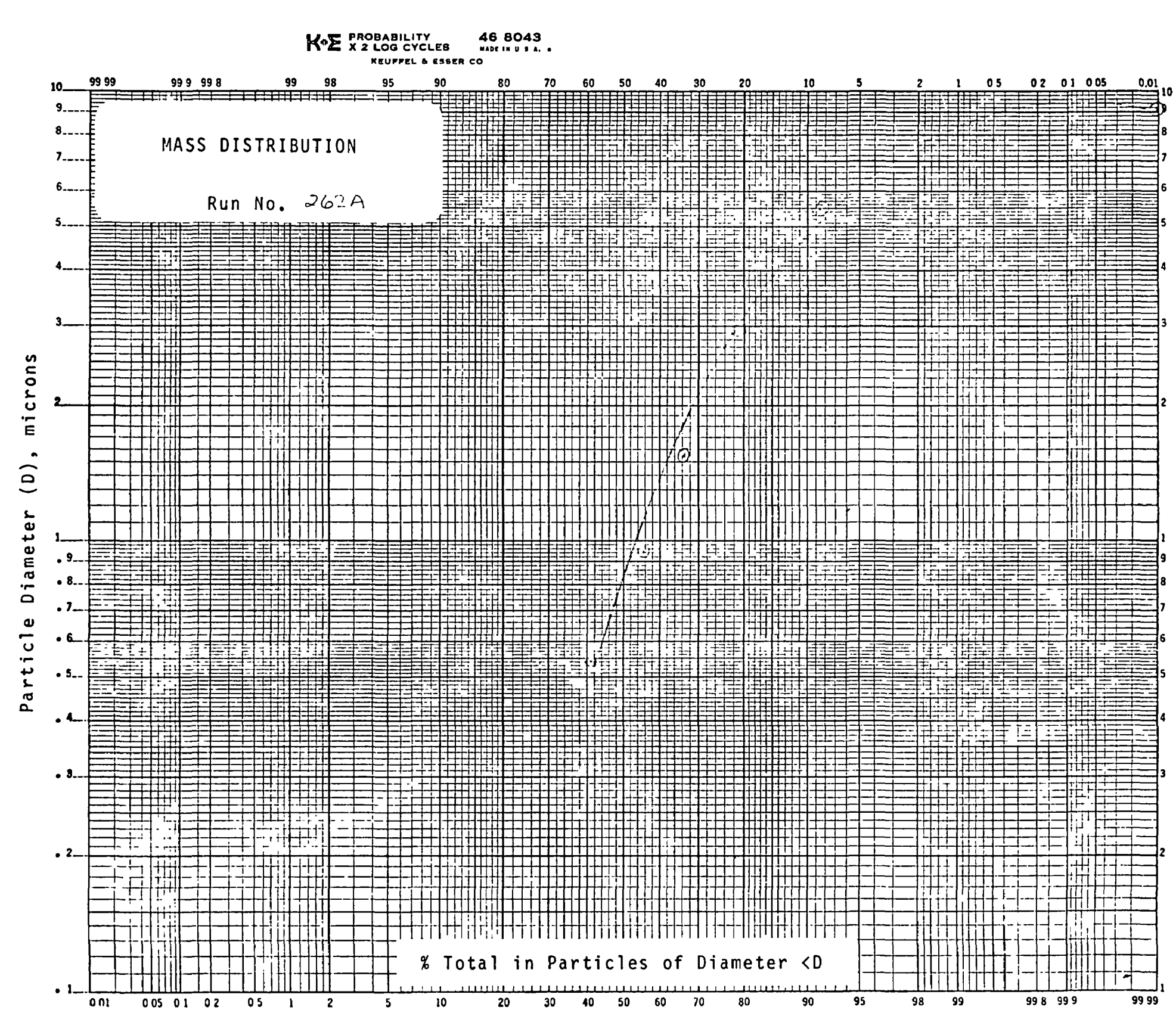
ANALYSIS OF EXHAUST PARTICULATE

Trace Metals on Millipore Filter (%)

Vehicle Test No.	Fe	Ni	Cu	Al	Ca	Mg	Mn	Cr	Sn	Zn	Ti	AA Pb	$\%SO_4$	Glass Fiber Filters %C	%H	%N	PPM BAP
262A	.5	.1	.1	<.1	1.5	.5	<.05	<.1	<.1	<.3	<.1	2.2		<0.1	5.14	1.51	150
262B	.5	<.1	.2	.2	2.5	.5	<.05	<.1	<.1	.4	<.1	5.9		8.2	3.42	2.74	34
262C	.4	<.1	.2	.1	3.6	.7	<.05	<.1	<.1	.3	<.1	5.9		11.91	6.27	2.51	270
262D	.2	<.1	.1	<.1	1.3	.3	<.05	<.1	<.1	<.3	<.1	0.5		0.92	5.97	2.42	52

EXHAUST GAS ANALYSIS

Vehicle Test No.	% by Volume				Parts Per Million				Exhaust Condensate	
	CO_2	O_2	N_2	CO	H.C.	NO_2	NO	$NO_x - N_x$	PPM HCHO	PPM NH_3
262A	8.9	8.2	82.0	0.03	45	23 min/ 41 min	135/ 112	152/ 131	14.67	3.37
262B	11.5	4.3	83.2	0.03	60		151	167	9.11	1.63
262C	11.9	3.6	83.4	0.12	50		155	168	-----	----
262D Start	12.6	3.1	83.4	0.03	7		258	151	3.10	0.88
Final	13.3	2.0	83.7	0.03	5		271	154		


K&E PROBABILITY
X 2 LOG CYCLES
KEUFFEL & ESSER CO
46 8043
MADE IN U S A
MASS DISTRIBUTION
Run No. 262A
Particle Diameter (D), microns
% Total in Particles of Diameter <D
99 99
99 9
99 8
99
98
95
90
80
70
60
50
40
30
20
10
5
2
1
0 5
0 2
0 1
0 05
0.01
0 01
0 05
0 1
0 2
0 5
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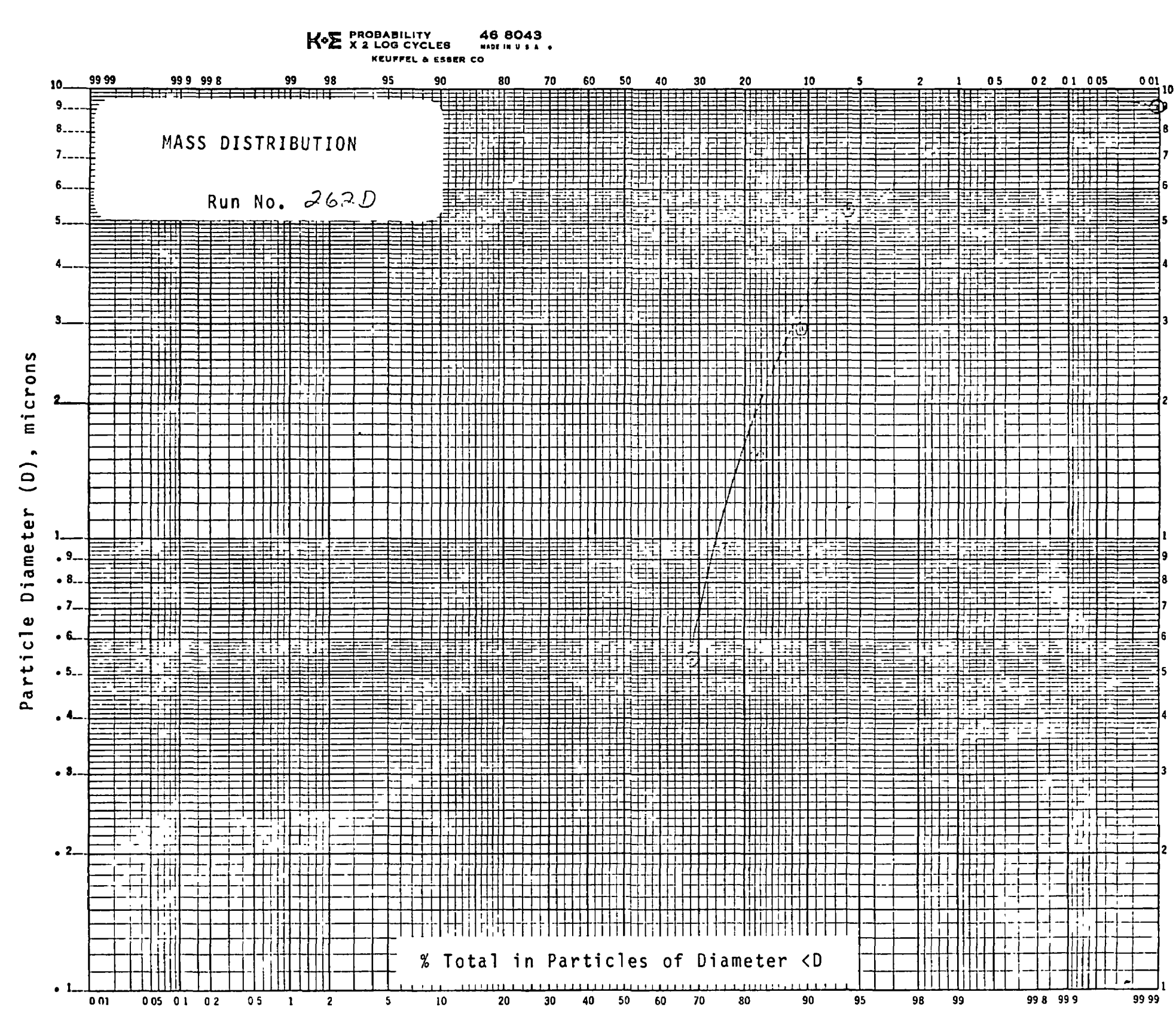
90
95
98
99
99 8
99 9
99 99


K•E PROBABILITY X 2 LOG CYCLES
46 8043
MADE IN U S A
KEUFFEL & ESSER CO
MASS DISTRIBUTION
Run No. 262D
Particle Diameter (D), microns
% Total in Particles of Diameter <D
99 99 99 9 99 8 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0 5 0 2 0 1 0 05 0 01
0 01 0 05 0 1 0 2 0 5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99 8 99 9 99 99

CHASSIS DYNAMOMETER

VEHICLE TEST REPORT # 8

Date of test: 8/15/73 & 8/16/73

Vehicle: 72 EPA FORD with SLAVE CATALYST VEHICLE NO. 24 A51

Test Conditions:	8/15/73	8/16/73
Barometer	29.49	29.54
Wet Bulb	66°F	58°F
Dry Bulb	84°F	69°F
Rel. Humidity	46%	55%

Procedures:

Modified Federal Cycle Cold Start 41 min.
Federal Cycle Hot Start 23 min. (2)
2 Hrs. Steady State 60 MPH Hot Start

Comments:

At the conclusion of Test #7 upon cooling the Durability Catalytic Converter was removed and the slave Catalytic Converters were installed. These were not warmed up in any manner prior to test run.

Signed: James E Dentel Date: 9/7/73

CHASSIS DYNAMOMETER TEST

CAR NUMBER: 24A51 EPA
VEHICLE TYPE: 72 FORD 351 CID
FUEL: INDOLENE NON LEAD
CONVERTER: SLAVE CATALYST

Vehicle Test No.	Car Miles	Test Miles	Test Mode	Grams per 1.61 km (1 mile) Andersen Sampler	Follow-up glass Filter	Andersen + Filter	Glass Filter 142 mm (Avg. of two)	Millipore 142 mm	Net Gms Millipore 47mm 4 CFM
263A	58,598	120	SS 60 MPH	.07897	.01993	.09890	.03347	.02219	------*
263B		11.5	MFCCS	.03826	.13869	.17695	.07413	.13869	.0008
263C		7.5	FCHS	------	------	------	.05867	.11733	.0004
263D		7.5	FCHS	------	------	------	.03667	.0440	.0004

* Could not remove filter paper from filter holder in one piece.

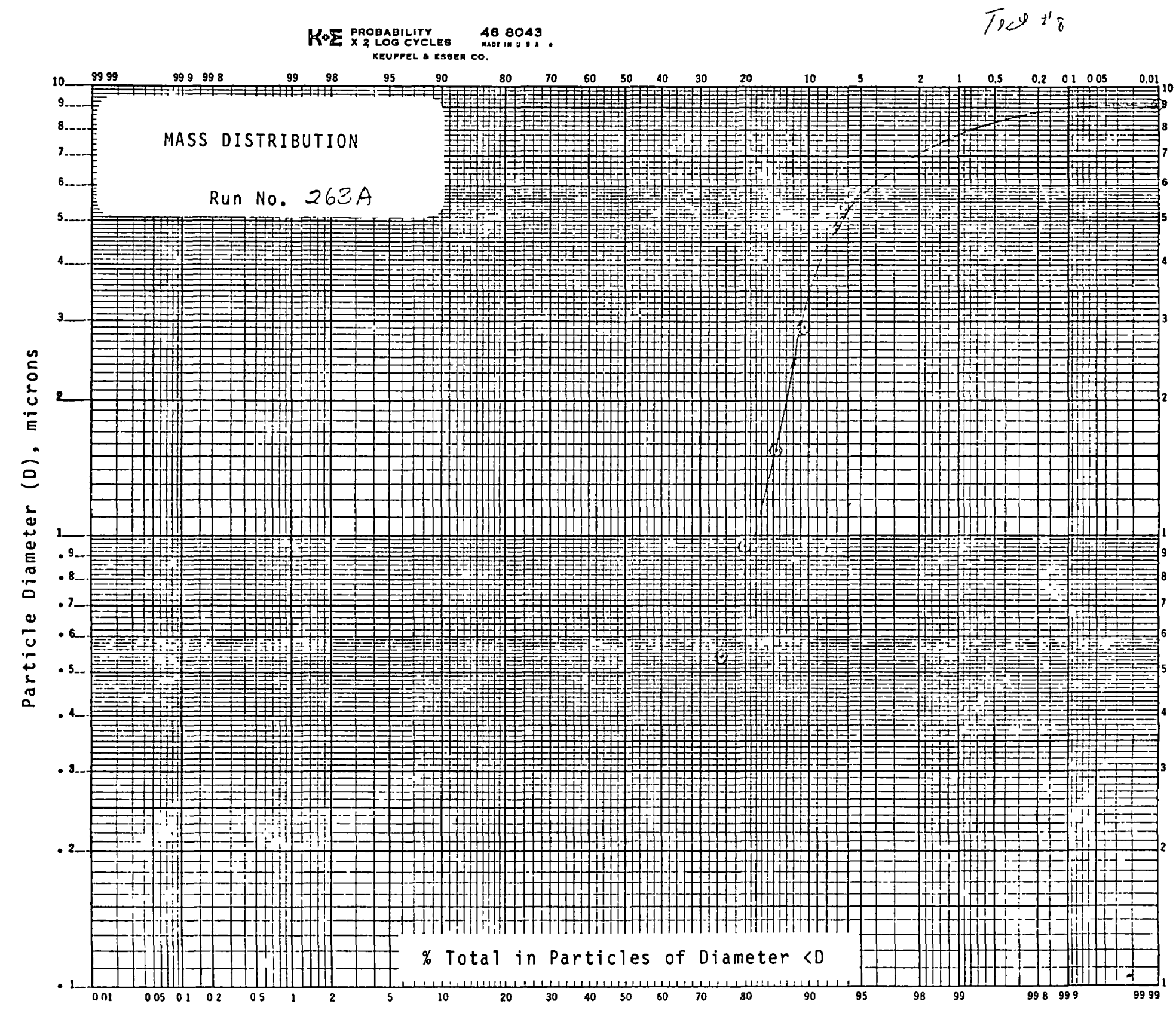
EXHAUST GAS ANALYSIS

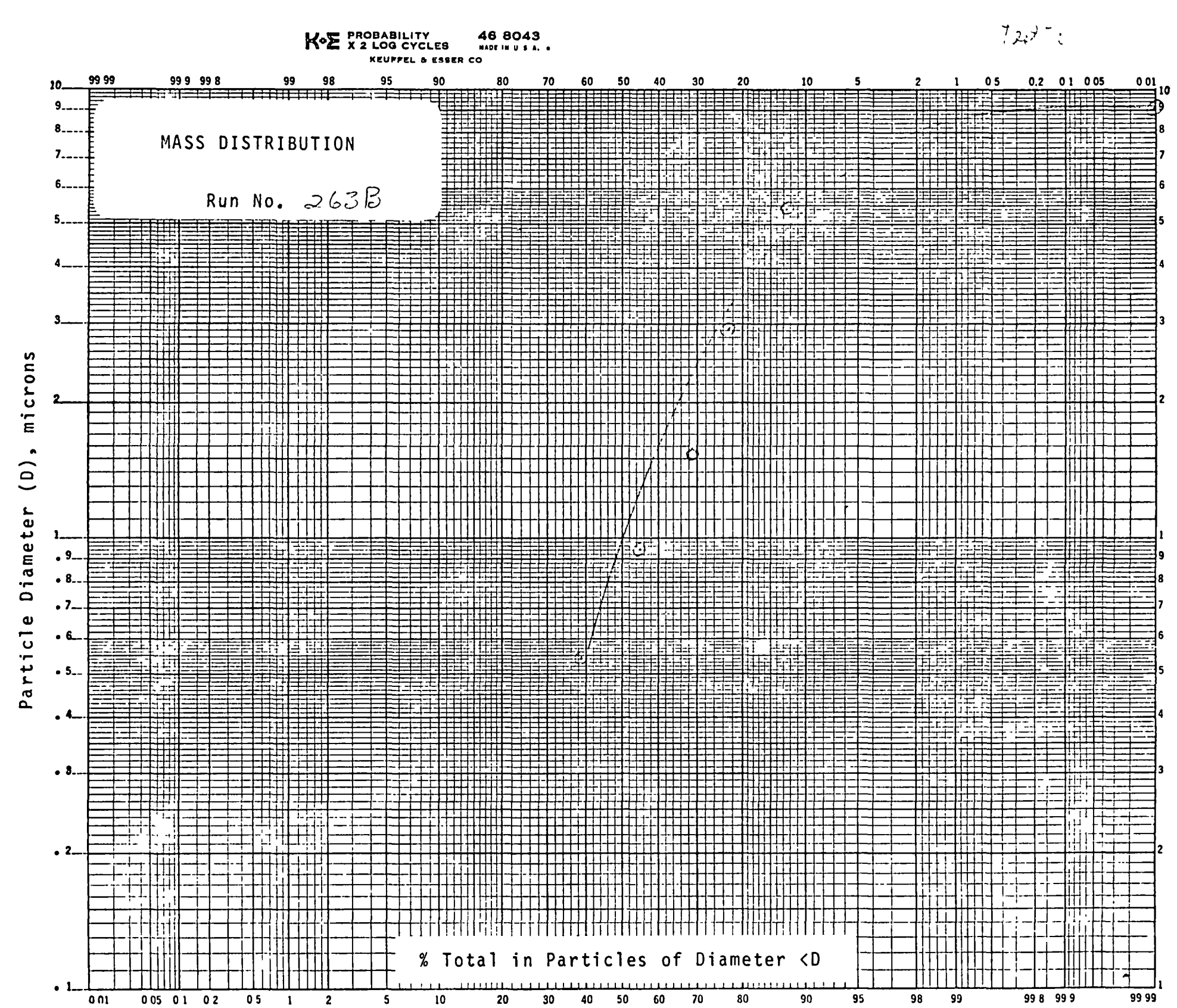
Vehicle Test No.	% by Volume				Parts Per Million				Exhaust Condensate	
	CO_2	O_2	N_2	CO	H.C.	NO_2	NO	$NO_x - N_x$	PPM HCHO	PPM NH_3
	12.7	2.7	83.7	0.03	7.0	Start	274	194		
263A	13.5	1.7	83.9	0.03	5.0	Final	287	196	26.29	0.74
263B	11.75	4.1	83.25	0.03	60.0	23 min	146	158	74.04	2.52
	11.70	4.4	83.0	0.03	45.0	41 min	205	212		
263C	11.95	4.1	83.1	0.03	30		175	191	33.30	0.47
263D	11.90	4.1	83.1	0.03	30		177	196	-----	----

ANALYSIS OF EXHAUST PARTICULATE

Trace Metals on Millipore Filter (%)

Vehicle Test No.	Fe	Ni	Cu	Al	Ca	Mg	Mn	Cr	Sn	Zn	Ti	AA RD	%SO_4	Glass Fiber Filters %C	%H	%N	PPM BAP
263A	<.1	<.1	<.1	<.1	.2	<.1	<.05	<.1	<.1	<.3	<.1	0.5		1.25	5.79	2.33	14
263B	.6	<.1	.2	.2	1.9	.4	<.05	<.1	<.1	<.3	<.1	8.5		<0.1	4.20	<0.1	49
263C	.4	<.1	.2	.2	3.3	.5	<.05	<.1	<.1	<.3	<.1	5.9		10.89	7.03	7.03	59
263D	1.0	<.1	.4	.4	8.0	1.2	<.05	.2	<.1	.5	<.1	9.5		62.17	8.29	8.29	110


K•E PROBABILITY
X 2 LOG CYCLES
46 8043
MADE IN U S A
KEUFFEL & ESSER CO.
MASS DISTRIBUTION
Run No. 263A
Particle Diameter (D), microns
% Total in Particles of Diameter <D


K•E PROBABILITY
X 2 LOG CYCLES
46 8043
MADE IN U S A.
KEUFFEL & ESSER CO
MASS DISTRIBUTION
Run No. 263B
Particle Diameter (D), microns
% Total in Particles of Diameter <D
99 99 99 9 99 8 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0 5 0.2 0 1 0 05 0 01
0 01 0 05 0 1 0 2 0 5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99 8 99 9 99 99

CHASSIS DYNAMOMETER

VEHICLE TEST REPORT #9

Date of test: 8/20/73 8/21/73

Vehicle: Mazda D 1527 Rx2 Silver

Test Conditions:	8/20	8/21
Barometer	29.40	29.53
Wet Bulb	68.0°F	57.0°F
Dry Bulb	82.0°F	67.0°F
Rel. Humidity	48%	53.0%

Procedures:

Modified Fed. Cycle Cold Start 41 min.
Federal Cycle Hot Start 23 min. (2)
2 Hrs. Steady State 60 MPH Hot Start

Comments:

The equipment is the same as in run #259 A, B, C & D Test #4

Signed: James E. Hendel Date: 10/9/73

EXHAUST GAS ANALYSIS

Vehicle Test No.	% by Volume				Parts Per Million				Exhaust Condensate	
	CO_2	O_2	N_2	CO	H.C.	NO_2	NO	$NO_x - N_x$	PPM HCHO	PPM NH_3
264 A	~~10.3~~ ~~10.25~~	~~5.5~~ ~~5.5~~	~~82.5~~ ~~82.5~~	~~0.83~~ ~~0.83~~	~~990~~ ~~960~~		~~197~~ ~~282~~	~~211~~ ~~316~~	862.9	5.81
264 B	~~9.6~~ ~~9.6~~	~~6.2~~ ~~6.1~~	~~82.1~~ ~~82.0~~	~~1.21~~ ~~1.38~~	~~630~~ ~~660~~		~~487~~ ~~530~~	~~433~~ ~~497~~	1385.1	32.50
264 C	11.4	4.2	83.6	0.03	220		180	219	1137.2	8.51
264 D	11.4	4.15	83.55	0.03	270		177	208	------	

VEHICLE TEST REPORT

CHASSIS DYNAMOMETER TEST

CAR NUMBER: D 1527
VEHICLE TYPE: Mazda Rx2
FUEL: No Lead Amoco Pump
CONVERTER: Thermal Reactor

Vehicle Test No.	Car Miles	Test Miles	Test Mode	Grams per 1.61 km (1 mile)					Net Gms Millipore 47mm 4 CFM
				Andersen Sampler	Follow-up glass Filter	Andersen + Filter	Glass Filter 142 mm (Avg. of two)	Millipore 142 mm	
264 A	3009.0	11.5	MFCCS	.09087	.03826	.12913	.0741	.09087	.0010
264 B		120.0	SS 60 MPH	.008766	.012577	.021343	.024011	.022486	.0059
264 C		7.5	FCHS	-------	-------	-------	.11000	.13200	.0007
264 D		7.5	FCHS	-------	-------	-------	.10633	.11000	.0007

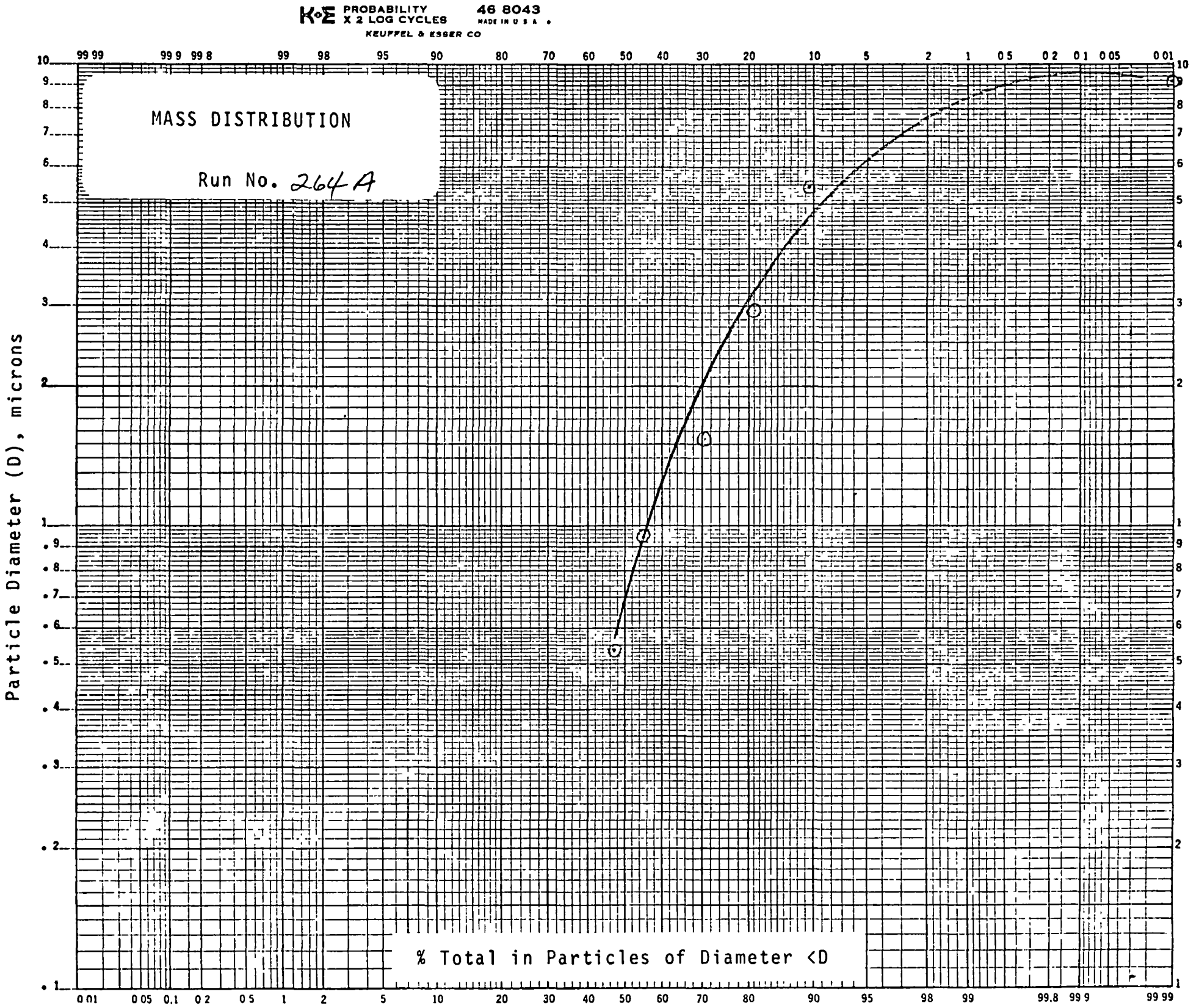
ANALYSIS OF EXHAUST PARTICULATE

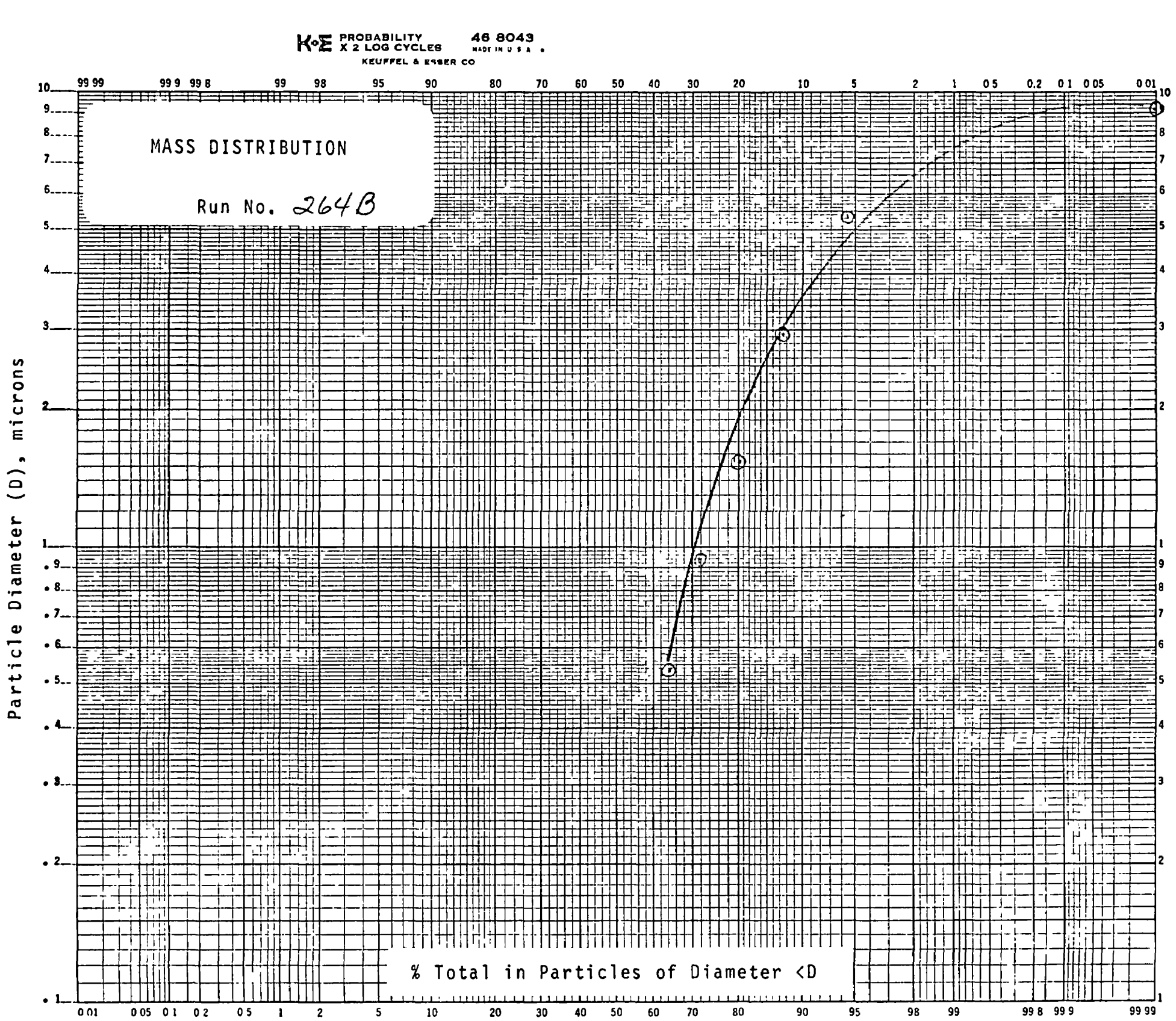
Trace Metals on Millipore Filter (%)

Vehicle Test No.	Fe	Ni	Cu	Al	Ca	Mg	Mn	Cr	Sn	Zn	Ti	AA Rb.	%SO_4
264 A	.5	<.1	.2	.1	2.0	.5	<.05	<.1	<.1	.3	<.1	3.1	
264 B	.2	<.1	.1	<.1	.8	1.2	<.05	<.1	<.1	.6	<.1	2.7	
264 C	.4	<.1	.2	.1	2.6	.6	<.05	<.1	<.1	<.3	<.1	2.0	
264 D	.4	<.1	.2	.1	2.8	.7	<.05	<.1	<.1	.3	<.1	1.8	

Glass Fiber Filters

%C	%H	%N	PPM BAP
67.68	14.88	1.11	60
49.23	6.23	2.61	720
30.83	8.14	0.68	60
27.38	7.66	0.0	30


K&E PROBABILITY
X 2 LOG CYCLES
46 8043
MADE IN U S A
KEUFFEL & ESSER CO
MASS DISTRIBUTION
Run No. 264A
Particle Diameter (D), microns
% Total in Particles of Diameter <D
99 99 99 9 99 8 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0 5 0 2 0 1 0 05 0 01
0 01 0 05 0.1 0 2 0 5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99 9 99 99


K&E PROBABILITY
X 2 LOG CYCLES
46 8043
MADE IN U S A
KEUFFEL & ESSER CO
MASS DISTRIBUTION
Run No. 264B
Particle Diameter (D), microns
% Total in Particles of Diameter <D
99 99 99 9 99 8 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0 5 0.2 0 1 0 05 0 01
0 01 0 05 0 1 0 2 0 5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99 8 99 9 99 99

CHASSIS DYNAMOMETER

VEHICLE TEST REPORT # 10

Date of test: 8/22/73

Vehicle: Pontiac 1972 GM 2477 with 1975 Hardware with 30,768.0 Miles

Test Conditions:	AM	PM
Barometer	29.63	29.65
Wet Bulb	60°F	61.5°F
Dry Bulb	76°F	79.5°F
Rel. Humidity	38%	34%

Procedures:
Modified Federal Cycle Cold Start. 41 min.
Federal Cycle Hot Start 23 min.
2 Hrs Steady State 60 MPH Hot Start

Comments:

This vehicle is equipped with Catalytic converter, air pump, EGR and Double Dyaphram Distribution which is equivalent to hardware scheduled for 1975. Data from this vehicle can also be found in previous contract EHS-70-101 March 1973.

Signed: James E Hendel Date: 10/9/73

CHASSIS DYNAMOMETER TEST

CAR NUMBER:
VEHICLE TYPE:
FUEL:
CONVERTER:

Vehicle Test No.	Car Miles	Test Miles	Test Mode	Grams per 1.61 km (1 mile) Andersen Sampler	Follow-up glass Filter	Andersen + Filter	Glass Filter 142 mm (Avg. of two)	Millipore 142 mm	Net Gms Millipore 47mm 4 CFM
265 A	30,768	11.5	MFCCS	.1100	.01920	.12920	.04300	.04780	.0008
265 B		120	SS 60 MPH	.008437	.015775	.024212	.018526	.014307	.0029
265 C		7.5	FCHS	-------	-------	-------	.02933	.07333	.0004
265 D		7.5	FCHS	-------	-------	-------	.03144	.06660	.0005

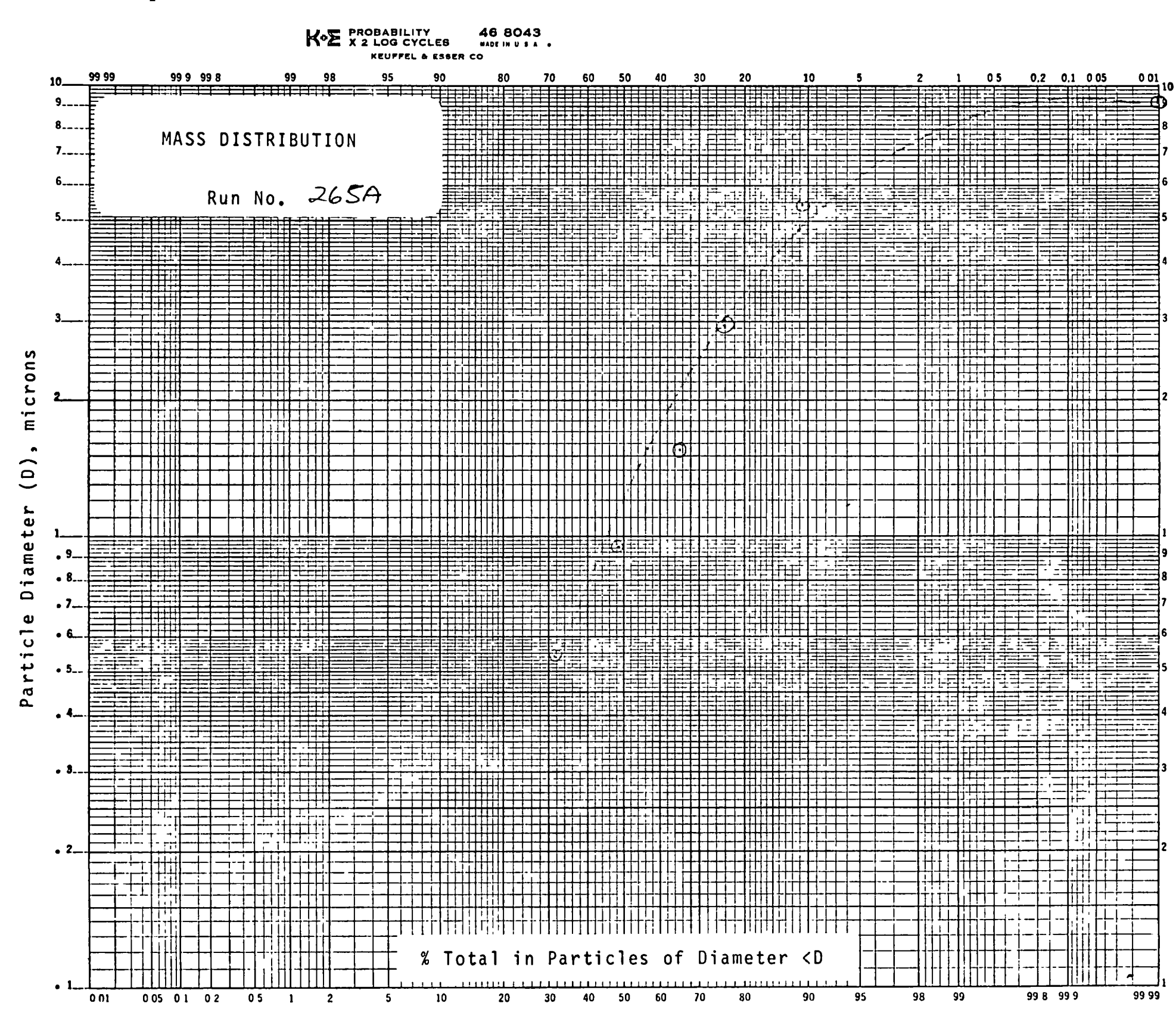
EXHAUST GAS ANALYSIS

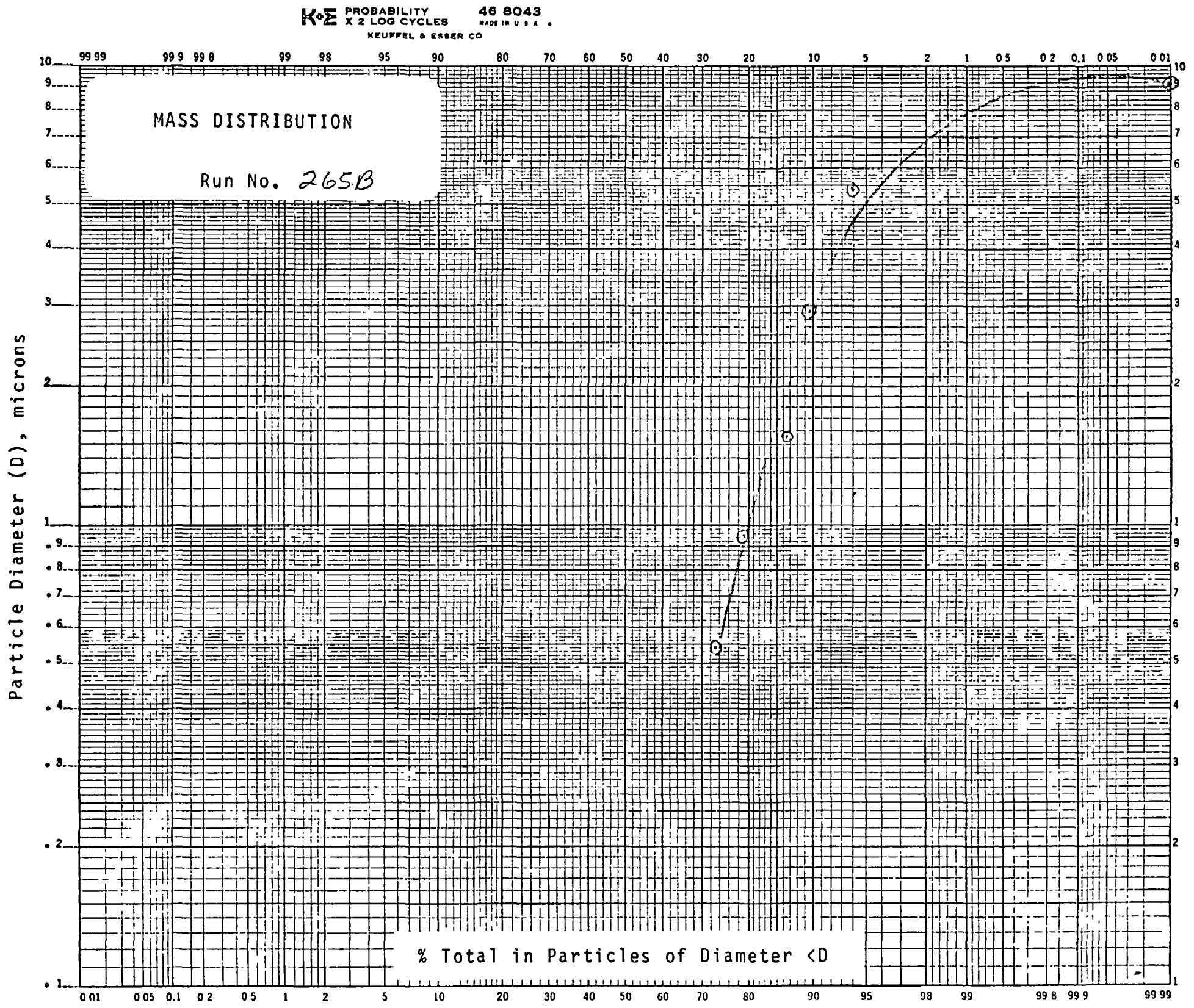
Vehicle Test No.	% by Volume				Parts Per Million				Exhaust Condensate	
	CO_2	O_2	N_2	CO	H.C.	NO_2	NO	$NO_x - N_x$	PPM HCHO	PPM NH_3
265 A Part 1	11.7	4.3	83.15	0.03	68		280	342	21.41	20.7
265 A Part 2	11.3	5.0	82.75	0.03	80		445	520	-----	----
265 B Start	12.2	3.75	83.15	0.03	30		1327	1750	23.30	17.35
265 B Final	13.2	2.30	83.6	0.03	20		1335	1435	-----	-----
265 C	11.8	3.90	83.2	0.03	60		275	324	13.27	8.49
265 D	11.05	5.15	82.75	0.03	65		273	356	-----	-----

ANALYSIS OF EXHAUST PARTICULATE

Trace Metals on Millipore Filter (%)

Vehicle Test No.	Fe	Ni	Cu	Al	Ca	Mg	Mn	Cr	Sn	Zn	Ti	AA RD	$\%SO_4$	Glass Fiber Filters %C	%H	%N	PPM BAP
265 A	2.2	<.1	.5	1.1	4.9	.9	<.05	.3	<.1	.5	<.1	6.8		50.60	17.82	2.87	220
265 B	.3	<.1	.2	<.1	1.0	.3	<.05	<.1	<.1	<.3	<.1	0.7		10.66	6.52	12.12	30
265 C	.7	<.1	.5	.5	5.0	1.0	<.05	.2	<.1	.4	<.1	32.1		13.87	12.56	3.78	500
265 D	.8	<.1	.4	.7	4.8	1.0	<.05	.3	<.1	.3	<.1	15.8		6.87	8.85	00.0	350


K•E PROBABILITY X 2 LOG CYCLES
46 8043
MADE IN U S A
KEUFFEL & ESSER CO
MASS DISTRIBUTION
Run No. 265A
Particle Diameter (D), microns
% Total in Particles of Diameter <D
99 99 99 9 99 8 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0 5 0.2 0.1 0 05 0 01
0 01 0 05 0 1 0 2 0 5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99 8 99 9 99 99


K&E PROBABILITY
X 2 LOG CYCLES
46 8043
MADE IN U S A
KEUFFEL & ESSER CO
MASS DISTRIBUTION
Run No. 265B
Particle Diameter (D), microns
% Total in Particles of Diameter <D
99 99 99 9 99 8 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0 5 0 2 0.1 0 05 0 01
0 01 0 05 0.1 0 2 0 5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99 8 99 9 99 99

CHASSIS DYNAMOMETER

VEHICLE TEST REPORT #11

Date of test: 9/12/73 9/13/73

Vehicle: Yellow Mazda Rx3

Test Conditions:

Barometer	29.40	29.32	Rel. Humidity	30.0%	51.0%
Wet Bulb	59.0°F	58°F			
Dry Bulb	78.0°F	69°F			

Procedures:
Mod. Federal Cycle Cold Start 41 min.
Fed. Cycle Hot Start 23 min. (2)
2 Hrs. Steady State 60 MPH Hot Start

Comments:

This vehicle is equiped with a thermal reactor which has a reactor by-pass. Both the exhaust pipe and by-pass pipe were connected to the delutron tube inlet. During SS 60 MPH it was noted that the by-pass opened after about 10 minutes on stream time. The vehicle also has air pump and EGR.

Signed: James E. Sentel Date: 10/9/73

CHASSIS DYNAMOMETER TEST

CAR NUMBER:
VEHICLE TYPE:
FUEL:
CONVERTER:

Vehicle Test No.	Car Miles	Test Miles	Test Mode	Grams per 1.61 km (1 mile) Andersen Sampler	Follow-up glass Filter	Andersen + Filter	Glass Filter 142 mm (Avg. of two)	Millipore 142 mm	Net Gms Millipore 47mm 4 CFM
271 A	3356.0	11.5	MFCCS	.08608	.04782	.13390	.07412	.13391	.0018
271 B		120	60 MPH SS	.01786	.01843	.03629	.02125	.03123	.0037
271 C		7.5	FCHS	------	------	------	.09534	.20534	.0013
271 D		7.5	FCHS	------	------	------	.08800	.16867	.0013

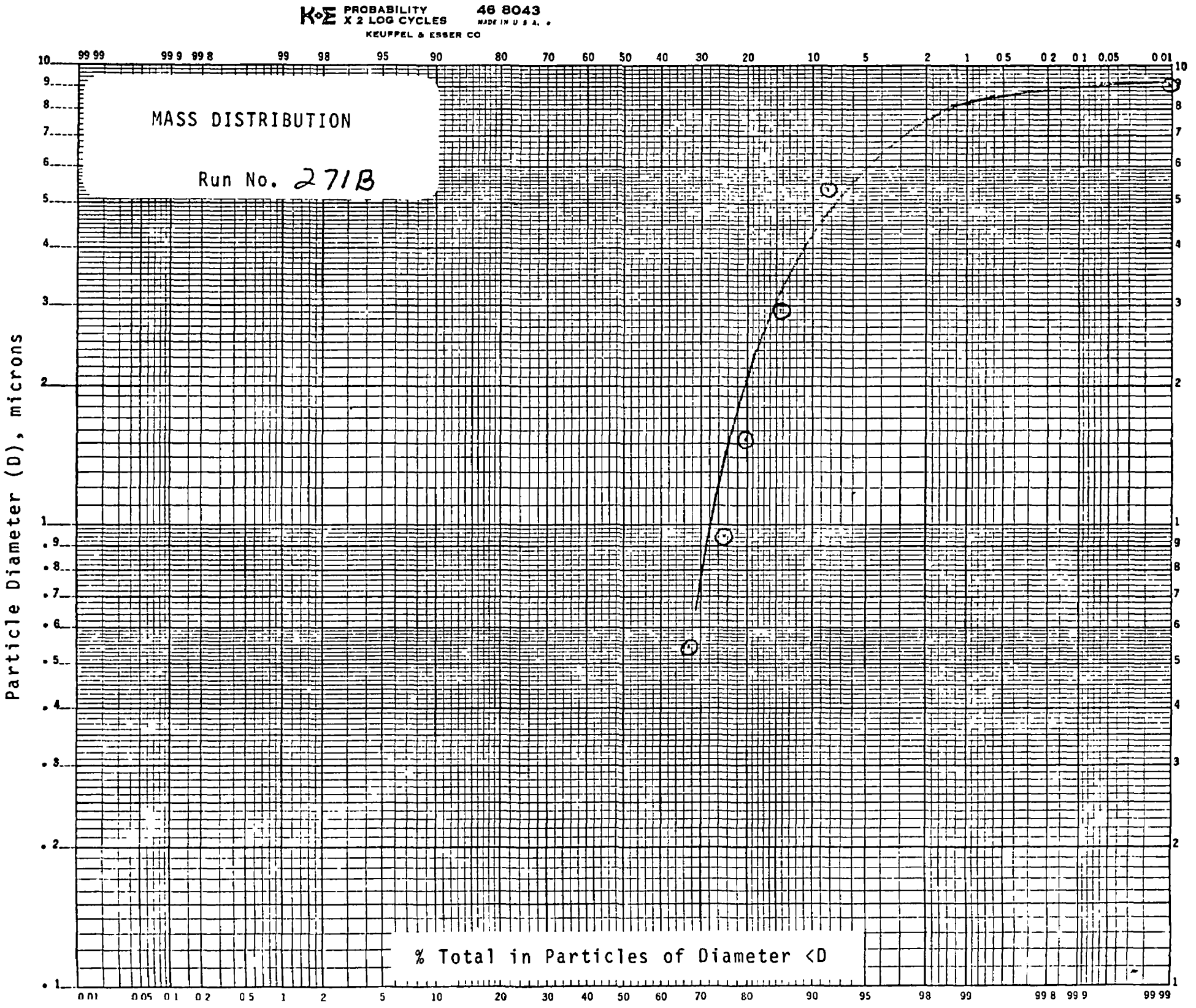
EXHAUST GAS ANALYSIS

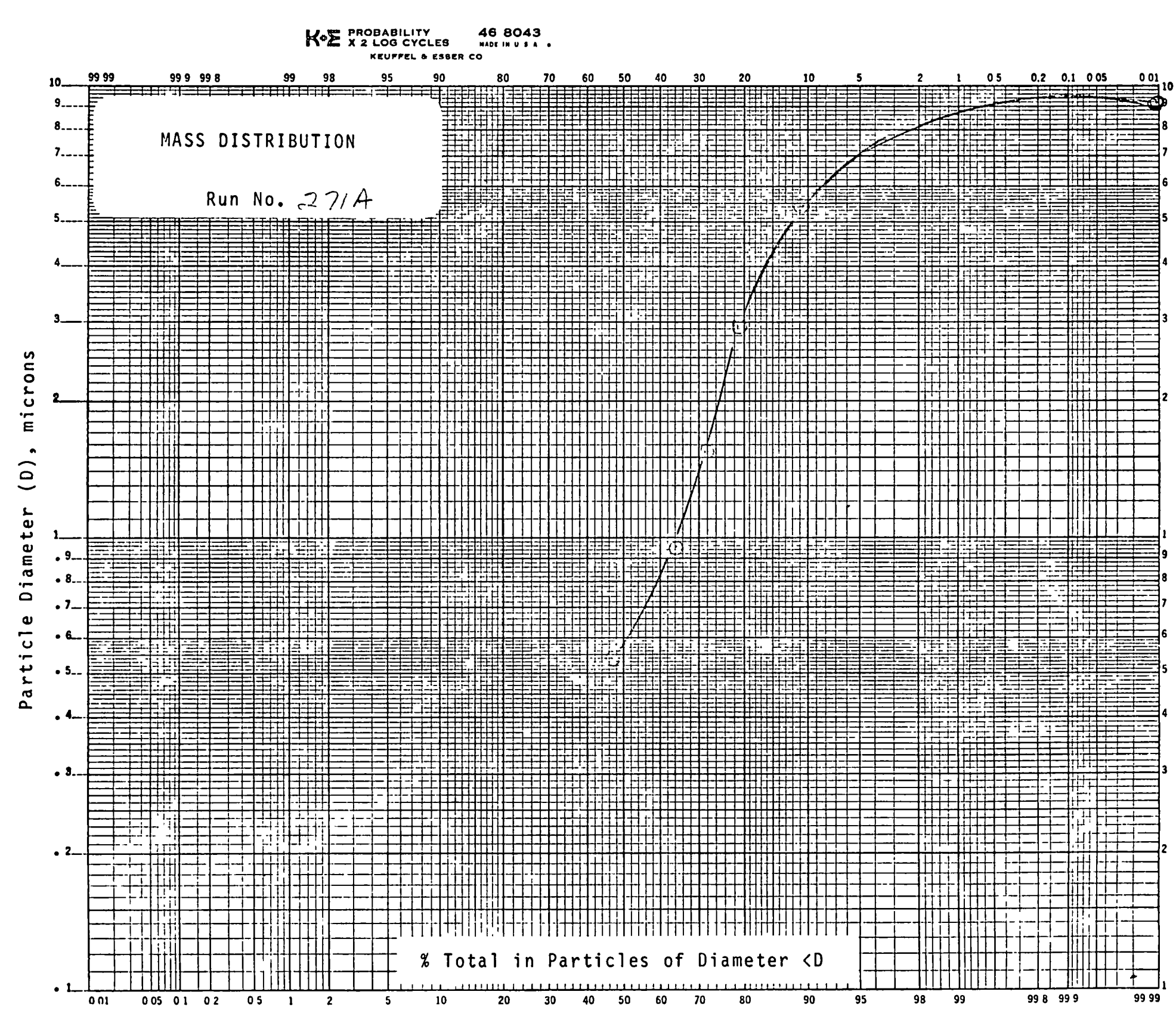
Vehicle Test No.	% by Volume				Parts Per Million				Exhaust Condensate	
	CO_2	O_2	N_2	CO	H.C.	NO_2	NO	NO_x - N_x	PPM HCHO	PPM NH_3
271 A	10.3	6.0	82.45	0.31	150		124 101	148 148	345.56	10.92
271 B	10.2 10.15	5.95 5.70	83.00 82.40	0.03 0.85	575 565		493 543	538 595	1479.8	36.0
271 C	10.3	5.95	82.55	0.275	135		142	183	395.6	27.28
271 D	10.3	6.0	82.50	0.25	145		131	162	------	-----

ANALYSIS OF EXHAUST PARTICULATE

Trace Metals on Millipore Filter (%)

Vehicle Test No.	Fe	Ni	Cu	Al	Ca	Mg	Mn	Cr	Sn	Zn	Ti	AA Pb	$\%SO_4$	Glass Fiber Filters %C	%H	%N	PPM BAP
271 A	.62	<.1	.20	.1	1.5	.54	<.05	<.1	<.1	.4	<.1	5.5		27.81	1.94	1.29	70
271 B	.13	<.1	.06	<.1	.4	.50	<.05	<.1	<.1	.3	<.1	2.4		39.84	2,37	3.06	430
271 C	.34	<.1	.15	<.1	1.4	.48	<.05	<.1	<.1	.3	<.1	5.8		17.58	0.80	2.00	110
271 D	.33	<.1	.17	<.1	1.7	.41	<.05	<.1	<.1	<.3	<.1	6.3		15.34	1.84	2.90	<30


K•E PROBABILITY X 2 LOG CYCLES
46 8043
MADE IN U S A.
KEUFFEL & ESSER CO
MASS DISTRIBUTION
Run No. 271B
Particle Diameter (D), microns
% Total in Particles of Diameter <D


K&E PROBABILITY
X 2 LOG CYCLES
46 8043
MADE IN U S A
KEUFFEL & ESSER CO
MASS DISTRIBUTION
Run No. 271A
Particle Diameter (D), microns
% Total in Particles of Diameter <D
99 99 99 9 99 8 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0 5 0.2 0.1 0 05 0 01
0 01 0 05 0 1 0 2 0 5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99 8 99 9 99 99

CHASSIS DYNAMOMETER

VEHICLE TEST REPORT #12

Date of test: 10/31/73

Vehicle: EPA Ford 1973 A342-25

Test Conditions:

Barometer 28.96	28.88
Wet Bulb 55.0°F	55.0°F
Dry Bulb 65.0°F	66.0°F
Rel. Humidity 52.0%	50.0%

Procedures:

Modified Federal cycle cold start 41 min.
Federal cycle hot start 23 min. (2)
60 MPH HS SS 2 hrs.

Comments:

The car was driven up from Ann Arbor by EPA people. Upon inspection prior to test run it was found that the vac. advance hose to the distributor was off. It was connected for test runs here.

Signed: _____ Date: 12/1/73

CHASSIS DYNAMOMETER TEST

CAR NUMBER: A342-25
VEHICLE TYPE: 1973 LTD Ford (EPA)
FUEL: Non Lead
CONVERTER: Yes

Vehicle Test No.	Car Miles	Test Miles	Test Mode	Grams per 1.61 km (1 mile) Andersen Sampler	Follow-up glass Filter	Andersen + Filter	Glass Filter 142 mm (Avg. of two)	Millipore 142 mm	Net Gms Millipore 47mm 4 CFM
278A	6,861	11.5	MFCCS	.12435	.27739	.40174	.05978	.119565	.0018
278B		120.0	60 MPH SS	.006222	.01830	.024522	.011346	.01464	.0029
278C		7.5	MFCHS	--	--	--	.031775	.036666	.0004
278D		7.5	MFCHS	--	--	--	.0268883	.021999	.0003

EXHAUST GAS ANALYSIS

Vehicle Test No.	% by Volume				Parts Per Million				Exhaust Condensate	
	CO_2	O_2	N_2	CO	H.C.	NO_2	NO	NO_x - N_x	PPM HCHO	PPM NH_3
278A	10.0	6.5	82.45	0.255	46.0		220	252	71.67	25.31
	9.75	7.0	82.35	0.03	23.0		247	279		
278B	11.95	3.8	83.30	0.03	19.0		1464	1834	149.83	7.28
	12.15	3.85	83.15	0.03	20.0		1900	>2000		
278C	9.8	7.1	82.2	0.03	15/0		205	317	162.71	1.91
278D	9.8	7.1	82.2	0.03	19.0		--	--	--	--

ANALYSIS OF EXHAUST PARTICULATE

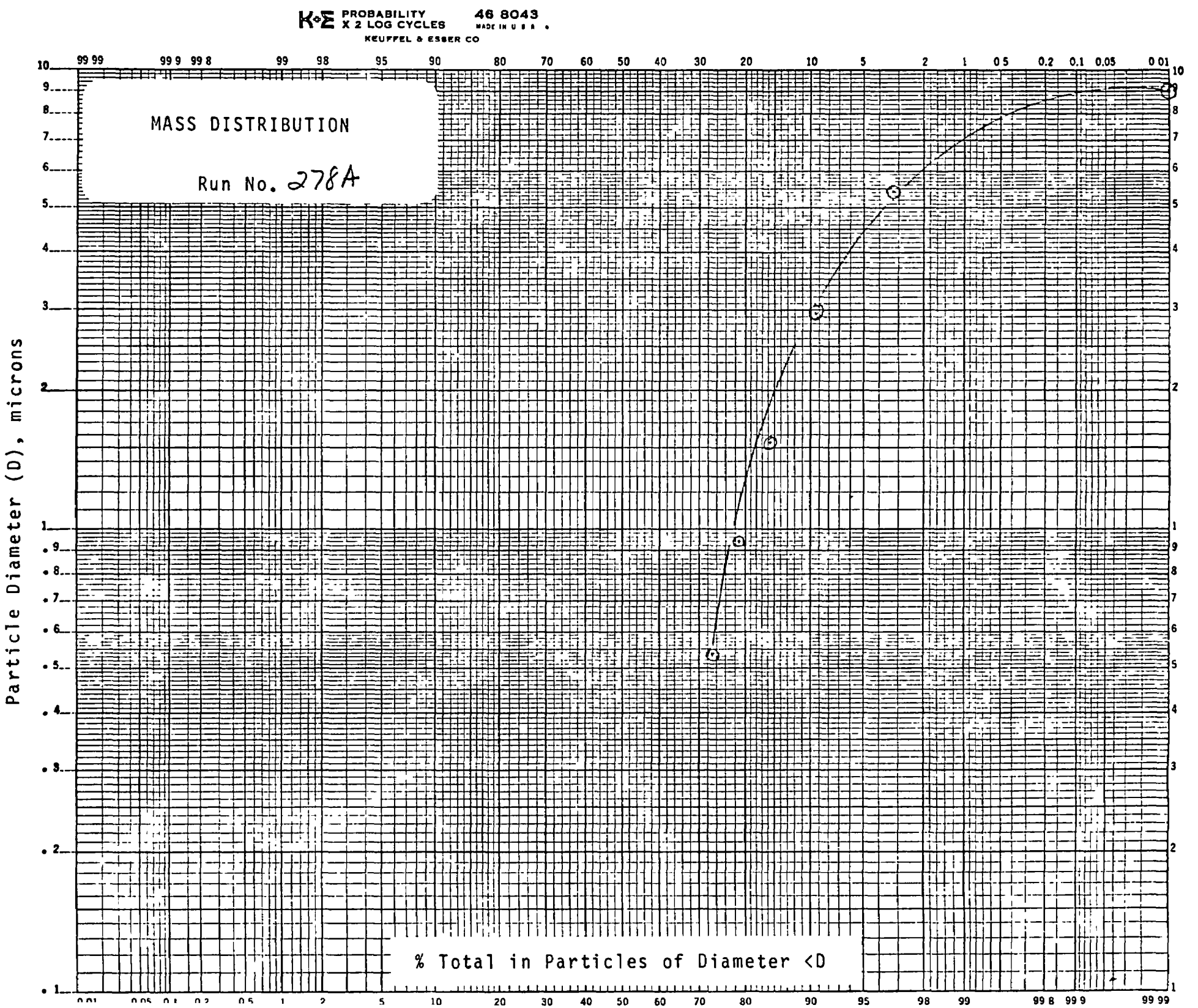
Trace Metals on Millipore Filter (%)

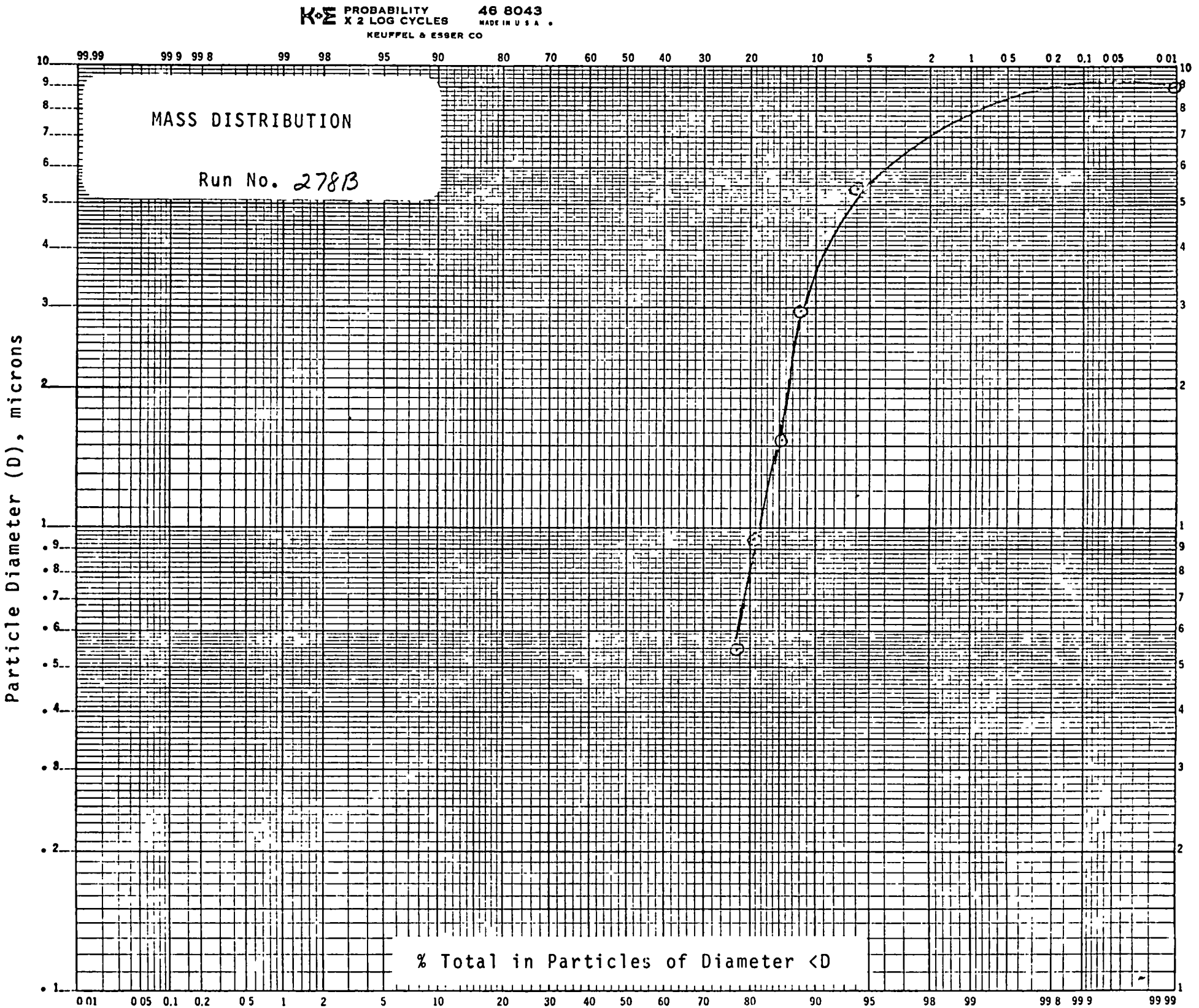
Vehicle Test No.	Fe	Ni	Cu	Al	Ca	Mg	Mn	Cr	Sn	Zn	Ti	Rb	$\%SO_4$	Glass Fiber Filters %C	%H	%N	PPM BAP
278A	1.9	<.05	.2	.4	3.3	.4	<.03	.06	<.05	.5	.05	1.2		<0.1	<0.1	<.01	105
278B	0.3	<.05	.1	.08	1.4	.3	<.03	<.05	<.05	.2	<.05	<.2		<0.1	<0.1	4.70	10
278C 278D-	2.1	<.1	.8	.9	14.0	2.4	<.05	<.3	<.1	1.2	.2	.5		8.80	0.0	6.00	140

	PERCENT			
TEST NO.	PLATINUM	PLADIUM	SULFUR*	SULFATE**
278A	<.0535	<.1069	2.8329	--

* BY X_RAY

** BY TURBIDOMETRIC METHOD


K&E PROBABILITY
X 2 LOG CYCLES
46 8043
MADE IN U S A
KEUFFEL & ESSER CO
MASS DISTRIBUTION
Run No. 278A
Particle Diameter (D), microns
% Total in Particles of Diameter <D
99 99 99 9 99 8 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0 5 0.2 0.1 0.05 0 01
10 9 8 7 6 5 4 3 2 1 .9 .8 .7 .6 .5 .4 .3 .2 .1
0.01 0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99 8 99 9 99 99


K&E PROBABILITY
X 2 LOG CYCLES
46 8043
MADE IN U S A
KEUFFEL & ESSER CO
MASS DISTRIBUTION
Run No. 2781B
Particle Diameter (D), microns
% Total in Particles of Diameter <D
99.99 99.9 99.8 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0.2 0.1 0.05 0.01
0.01 0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9 99.99

CHASSIS DYNAMOMETER

VEHICLE TEST REPORT # 13

Date of test: 12-20 and 12-21-73

Vehicle: Mazda RX 3

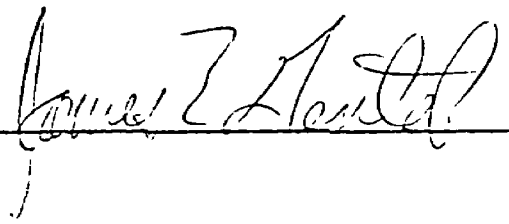
Test Conditions:	AM	PM
Barometer	29.49	29.45
Wet Bulb °F	53	52
Dry Bulb °F	73	74
Rel. Humiidty %	22	17

Procedures:

Modified Federal Cycle Cold Start	41 min.
Federal Cycle Hot Start	23 min. (2)
2 Hrs. SS 60 MPH HS	

Comments:

This vehicle is equiped with a thermal reactor and a thermal reactor cooling exit pipe side by side at rear of car. During our tests both of these pipes were connected to the inlet by the dilution tube. The vehicle also has an air pump and E.G.R. system. We were interested as to what the compositions of each exit pipe was. Gaseous analysis of each outlet pipe was made and is included with this data.

Signed:  Date: 1/28/74

CHASSIS DYNAMOMETER TEST

CAR NUMBER:

VEHICLE TYPE: Mazda RX 3

FUEL: Indolene O No Lead

CONVERTER: Thermal Reactor

Vehicle Test No.	Car Miles	Test Miles	Test Mode	Grams per 1.61 km (1 mile) Andersen Sampler	Follow-up glass Filter	Andersen + Filter	Glass Filter 142 mm (Avg. of two)	Millipore 142 mm	Net Gms Millipore 47mm 4 CFM
284 A	5373.0	11.5	MFCCS	.05739	.13869	.19608	.16500	.20087	.0042
284 B		120	2 hrs. SS	.004933	.020488	.025421	.022007	.01897	.0015*
284 C		7.5	FCHS	--	--	--	.063557	.08067	.0011
284 D		7.5	FCHS	--	--	--	.056220	.05133	.0005

EXHAUST GAS ANALYSIS

Vehicle Test No.	% by Volume				Parts Per Million				Exhaust Condensate	
	CO_2	O_2	N_2	CO	H.C.	NO_2	NO	NO_x - N_x	PPM HCHO	PPM NH_3
284 A	11.65 10.45	4.0 5.0	82.9 83.1	.58 .49	245 235	Part 1 * Part 2	154 258	220 403	592.94	14.03
284 B	10.05 10.35	6.9 5.0	81.85 82.60	.75 1.13	495 635	Start Finish	463 519	519 555	1564.1	36.50
284 C	11.20	4.75	82.85	0.30	180		137	198	221.95	4.48
284 D	11.45	4.40	82.95	0.27	120		150	176	-----	
284 E	10.5	5.55	82.85	.14	40.0		140	162	Exhaust Pipe Only	
284 F	6.4	12.10	80.35	.165	90.0		94	140	By-Pass Pipe Only	

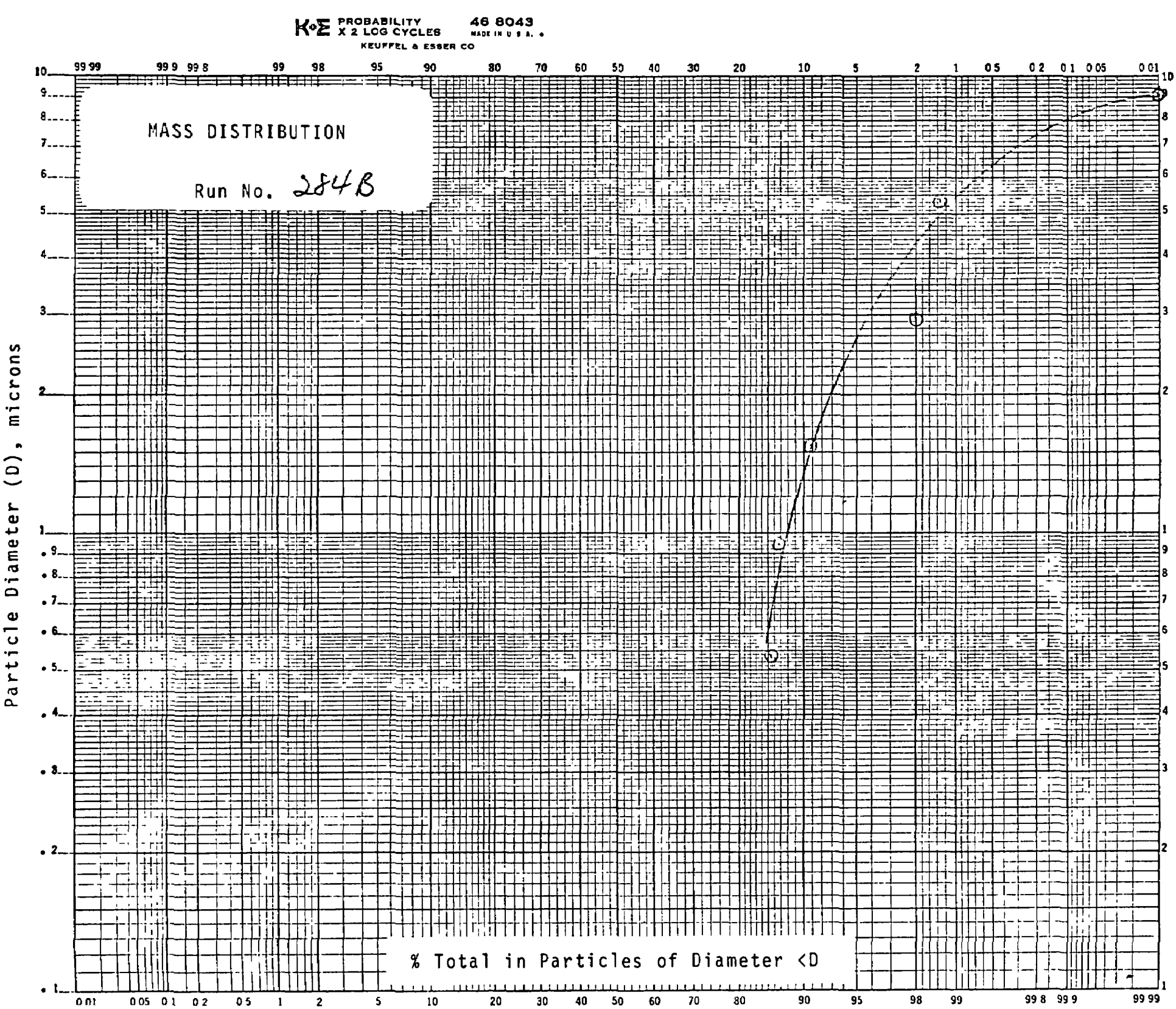
* Part 1 First 23 min.

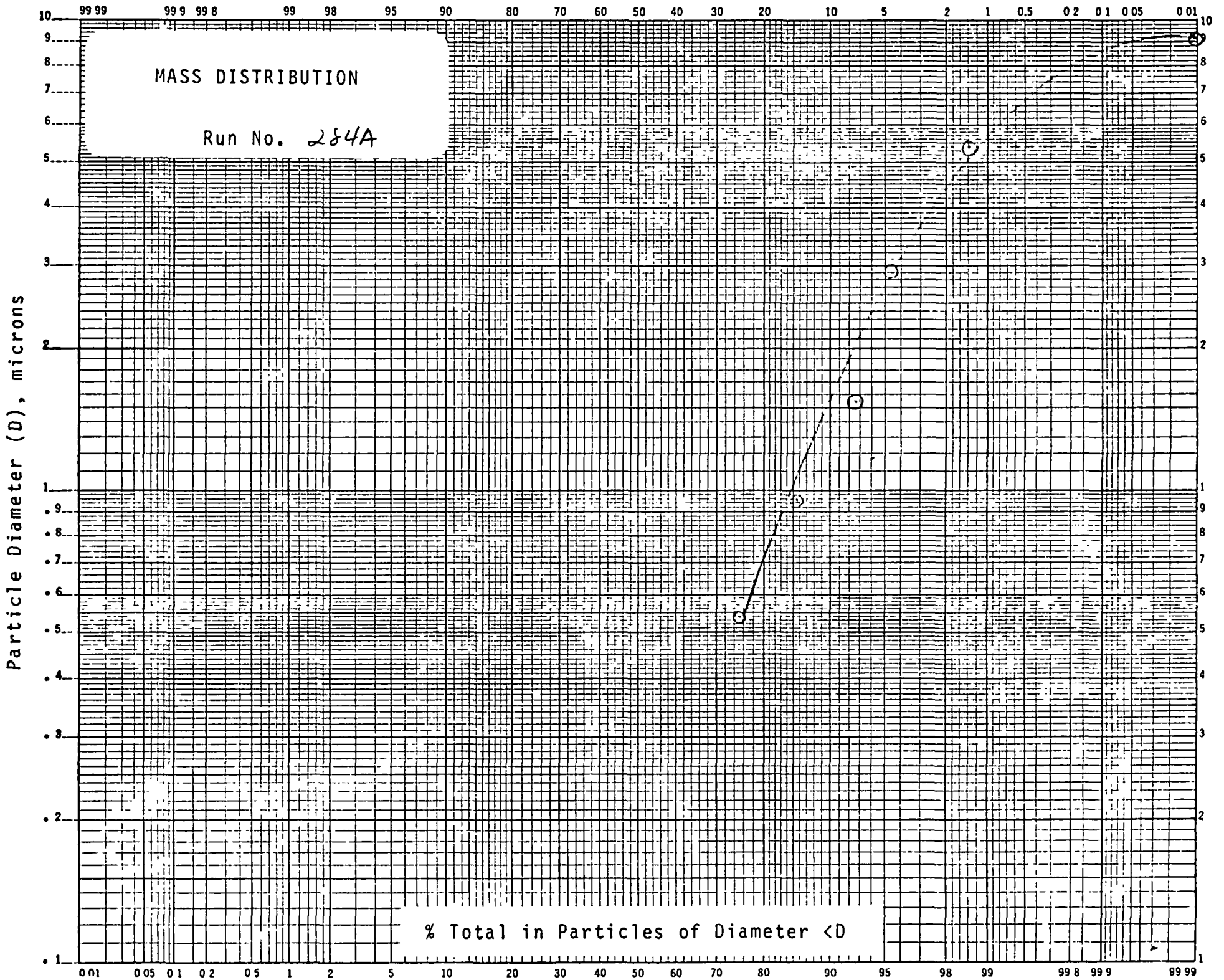
Part 2 Last 505 Sec.

ANALYSIS OF EXHAUST PARTICULATE

Trace Metals on Millipore Filter (%)

Vehicle Test No.	Fe	Ni	Cu	Al	Ca	Mg	Mn	Cr	Sn	Zn	Ti	Rb	$\%SO_4$	Glass Fiber Filters %C	%H	%N	PPM BAP
284 A	.4	.05	.1	.08	.8	.4	..02	.06	.05	.5	.05	1.0		23.77	3.73	28.5	300
284 B	.2	"	.1	.05	.8	1.2	"	.05	"	.5	"	1.7		27.16	3.76	1.20	190
284 C	.5	"	.4	.3	3.8	.9	.04	.12	"	.6	.05	1.7		10.82	3.11	0.0	55


K•E PROBABILITY X 2 LOG CYCLES
46 8043
MADE IN U S A.
KEUFFEL & ESSER CO
MASS DISTRIBUTION
Run No. 284B
Particle Diameter (D), microns
% Total in Particles of Diameter <D
99.99 99.9 99.8 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0.2 0.1 0.05 0.01
10 9 8 7 6 5 4 3 2 1 .9 .8 .7 .6 .5 .4 .3 .2 .1



CHASSIS DYNAMOMETER

VEHICLE TEST REPORT # 14

Date of test: 1-16-74

Vehicle: 1974 Capri EPA No. 0191

Test Conditions:	AM	PM
Barometer	29.15	29.11
Wet Bulb °F	55.0	54
Dry Bulb °F	79.0	74
Rel. Humidity	15.0	

Procedures:

Modified Federal Cycle Cold Start 41 min.
60 mph, 2 hrs., SS Hot Start
Federal Cycle Hot Start 23 Min. (2)

Comments:

This car was brought up on a trailer, put on chassis dynamomter for 12 hrs. soak at 70°F. This vehicle was equipped with fuel injection and stratified charge, electronic ignition, hi performance wiring. It also had an air injection system into the exhaust manifold, however, did not have air pump.

Signed: James E Dental Date: 3/18/74

EXHAUST GAS ANALYSIS

Vehicle Test No.	% by Volume			Parts Per Million					Exhaust Condensate	
	CO_2	O_2	N_2	CO	C_6 H.C.	NO_2	NO	$NO_x - N_x$	PPM HCHO	PPM NH_3
288A Part 1	10.6	5.75	82.75	54.0	29.0		182	258	38.86	6.53
288A Part 2	9.6	7.2	82.2	41.2	9.0		251	299	---	---
288B Start	8.2	9.2	81.65	33.9	4.0		500	556	31.46	13.67
288B Finish	8.3	9.0	81.8	70.2	4.0		415	468	---	---
288C	10.7	5.7	82.7	33.9	13.0		224	305	29.42	0.43
288D	10.8	5.6	82.7	33.9	13.0		234	312	---	---

CHASSIS DYNAMOMETER TEST

CAR NUMBER: EPA No. 0191
VEHICLE TYPE: 1974 Capri
FUEL: No Pb indolence
CONVERTER: No, but did have thermal reactor

Vehicle Test No.	Car Miles	Test Miles	Test Mode	Grams per 1.61 km (1 mile) Andersen Sampler	Follow-up glass Filter	Andersen + Filter	Glass Filter 142 mm (Avg. of two)	Millipore 142 mm	Net Gms Millipore 47mm 4 CFM
288A	456.0	11.5	MFCCS	.114783	.047826	.162609	.100435	.401739	.0038
288B		120.0	2 HRS SS	.010623	.048922	.059545	.057720	.059575	.0015* .0044
288C		7.5	FCHS	--	--	--	.066000	.095333	.0009
288D		7.5	FCHS	--	--	--	.053778	.058667	.006

ANALYSIS OF EXHAUST PARTICULATE

Trace Metals on Millipore Filter (%)

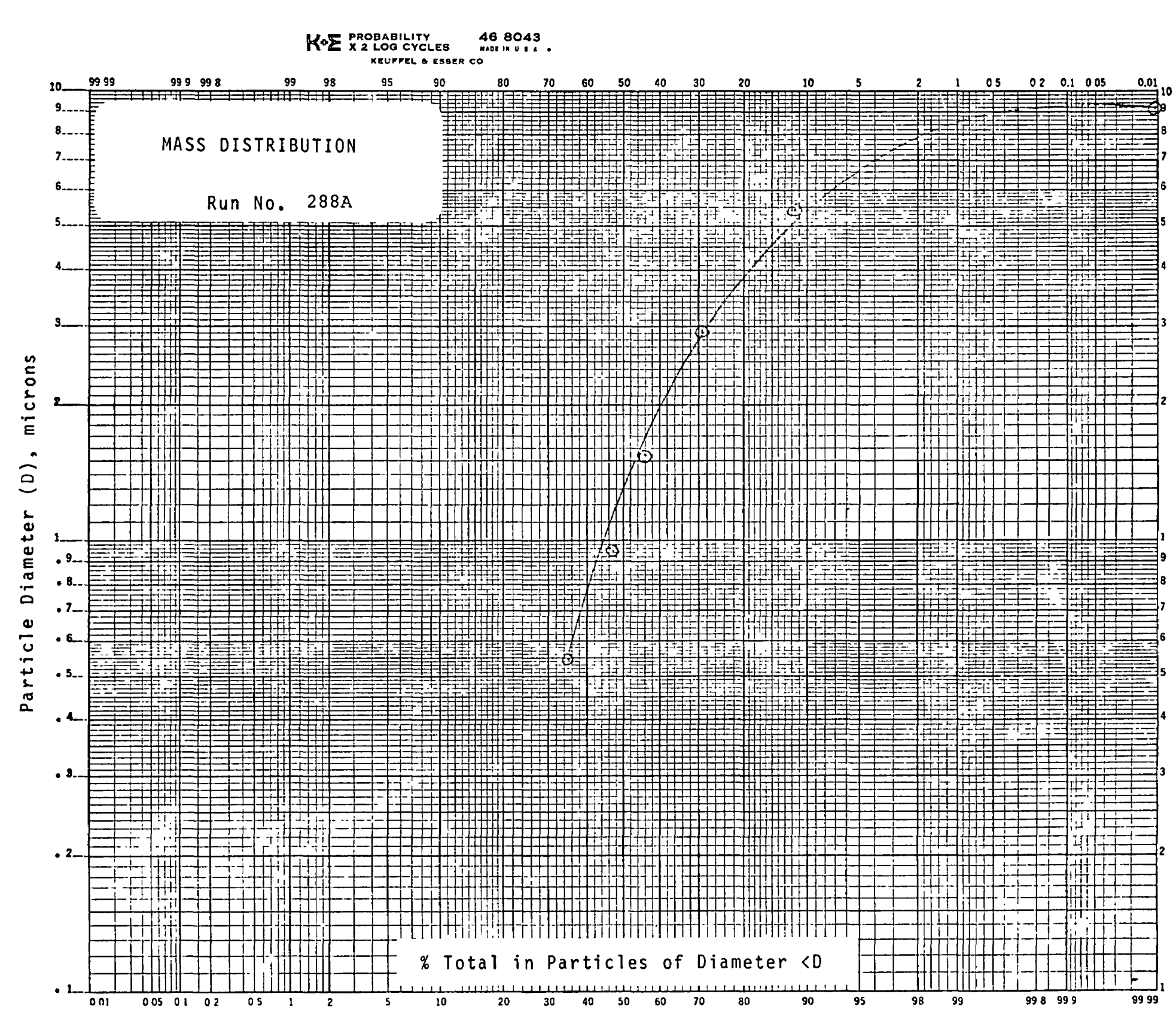
Glass Fiber Filters

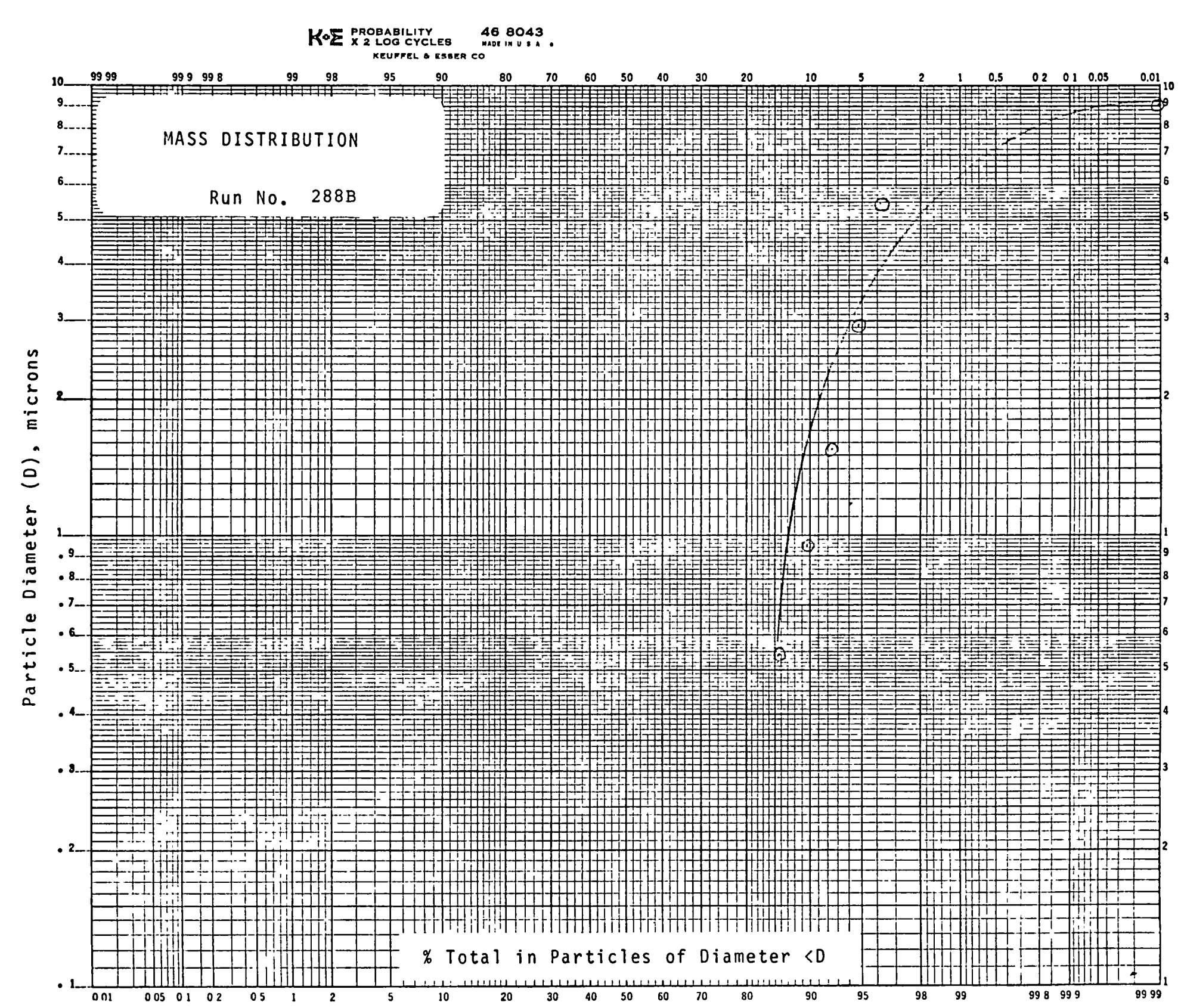
Vehicle Test No.	Fe	Ni	Cu	Al	Ca	Mg	Mn	Cr	Sn	Zn	Ti	Rb	$\%SO_4$	%C	%H	%N	PPM BAP
288A	5.1	.01	.07	.39	.53	.17	.04	.02	<.01	.17	<.01	.3		17.86	4.88	1.66	35
288B	1.9	<.01	.04	.33	.36	.11	.01	.02	<.01	.06	<.01	.2		22.03	2.77	4.96	5
288C	1.9	<.05	.5	.69	.62	1.2	.04	.13	<.05	.36	<.05	<.2		25.71	9.21	8.63	40

TEST NO.	PERCENT			
	PLATINUM	PLADIUM	SULFUR*	SULFATE**
288a	--	--	3.1842	6.57
288B	--	--	15.2955	56.909

* BY X_RAY

** BY TURBIDOMETRIC METHOD


K&E PROBABILITY
X 2 LOG CYCLES
KEUFFEL & ESSER CO
46 8043
MADE IN U S A
MASS DISTRIBUTION
Run No. 288A
Particle Diameter (D), microns
% Total in Particles of Diameter <D
99 99 99 9 99 8 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0 5 0 2 0.1 0 05 0.01
0 01 0 05 0 1 0 2 0 5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99 8 99 9 99 99


K&E PROBABILITY X 2 LOG CYCLES 46 8043
MADE IN U S A
KEUFFEL & ESSER CO
MASS DISTRIBUTION
Run No. 288B
Particle Diameter (D), microns
% Total in Particles of Diameter <D
99 99 99 9 99 8 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0 2 0 1 0.05 0.01
0 01 0 05 0 1 0 2 0 5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99 8 99 9 99 99

CHASSIS DYNAMOMETER

VEHICLE TEST REPORT # 15 and 16

Date of test: 3/5/74

Vehicle: EPA Cricket TCCS #8

	#15		#16	
Test Conditions:	AM	PM	AM	PM
Barometer	29.13	29.24	29.22	29.20
Wet Bulb °F	57.5	55.0	57.0	55.0
Dry Bulb °F	80.0	79.0	77.0	77.0
Relative Humidity %	20.0	19.0	24.0	20.0

Procedures:

Modified Federal Cycle Cold Start 41 Min.
(2) Federal Cycle Hot Starts 23 Min.
60 MPH HS SS , 1 Hr., 20 Min.

Comments:

This car was a prototype engine vehicle which was equipped with fuel injection, electronic ignition, catalytic converter

Signed: James E Deutsch Date: 4/23/74

CHASSIS DYNAMOMETER TEST

CAR NUMBER:

VEHICLE TYPE: EPA Criket TCCS

FUEL: #214-38-TCCP for Run #15 and Tank #7 445 DC #71-3199 for Run #16

CONVERTER: Yes

Vehicle Test No.	Car Miles	Test Miles	Test Mode	Grams per 1.61 km (1 mile) Andersen Sampler	Follow-up glass Filter	Andersen + Filter	Glass Filter 142 mm (Avg. of two)	Millipore 142 mm	Net Gms Millipore 47mm 4 CFM
Run #15									
294A	3410.9	11.5	MFCCS	.14347	.13391	.27738	.23674	.33000	.0080
294B	3422.4	7.5	FCHS	--	--	--	.149109	.29333	.0031
294C	3430.0	7.5	FCHS	--	--	--	.146666	.322667	.0033
294D	3437.6	80.0	60 MPH SS	.030054	.06894	.098994	.104009	.117857	.0055*
Run #16									
295A	3520.3	11.5	MFCCS	.05739	.23435	.29174	.26282	.30131	.0048
295B	3531.9	7.5	FCHS	--	--	--	.435111	.432667	.0044
295C	Abort	--	FCHS	--	--	--	--	--	--
295D		120.0	60 MPH SS	.010107	.063529	.073636	.071650	.068582	.0012* .0073

*Polycarbonate filter media.

EXHAUST GAS ANALYSIS

Run #15

	Vehicle Test No.	% by Volume				Parts Per Million				Exhaust Condensate	
		CO_2	O_2	N_2	CO	C_6 H.C.	NO_2	NO	$NO_x - N_x$	PPM HCHO	PPM NH_3
294A	Part 1	4.65	14.1	80.3	157	60.0		150	257	524.6	1.72
	Part 2	4.50	14.25	80.35	130	67.0		262	343		
	294B	4.30	14.67	80.15	87.1	76.0		149	259	612.2	2.14
	294C	4.25	14.65	80.10	96.8	87.0		159	273		
294D	Start	5.85	12.5	80.75	24.2	5.0		468	594		
	Finish	5.95	12.15	80.9	48.4	5.0		422	542	181.9	1.29
Run #16											
	USING DIESEL FUEL										
	295A	--	--	--	--	--		--	--	805.2	1.32
	295B	--	--	--	--	--		--	--	1483.7	3.02
	295D	--	--	--	--	--		--	--	204.1	.57

ANALYSIS OF EXHAUST PARTICULATE

Trace Metals on Millipore Filter (%)

Run #15

Glass Fiber Filters

Vehicle Test No.	Fe	Ni	Cu	Al	Ca	Mg	Mn	Cr	Sn	Zn	Ti	Pb	$\%SO_4$	%C	%H	%N	PPM BAP
294A	1.5	.02	.08	.22	1.2	.20	.04	.03	<.01	.08	<.01	.2		31.87	0.52	1.17	51
294C	0.3	<.01	.11	.09	1.2	.23	.009	.03	<.01	.08	.01	.08		29.34	0	0	100
294D	0.6	.02	.04	.12	0.4	.04	.008	<.01	<.01	.08	<.01	.3		24.23	2.69	3.16	6
Run #16																	
295A	0.2	<.01	.09	.08	0.9	.18	.006	.02	<.01	.05	.01	<.03		46.4	2.81	0.89	40
295B	0.1	<.01	.07	.05	0.9	.17	<.005	.02	<.01	.04	.01	<.03		34.1	2.78	0	110
295D	0.1	<.01	.03	.06	0.3	.05	<.005	<.01	<.01	<.03	<.01	<.03		32.51	4.36	2.54	6

TEST NO.	PERCENT			
	PLATINUM	PLADIUM	SULFUR*	SULFATE**
294A	<.25	.0375	3.5875	7.12
294C	<.61	<.0303	2.8182	6.06
294D	<.363	.21818	10.8364	31.63

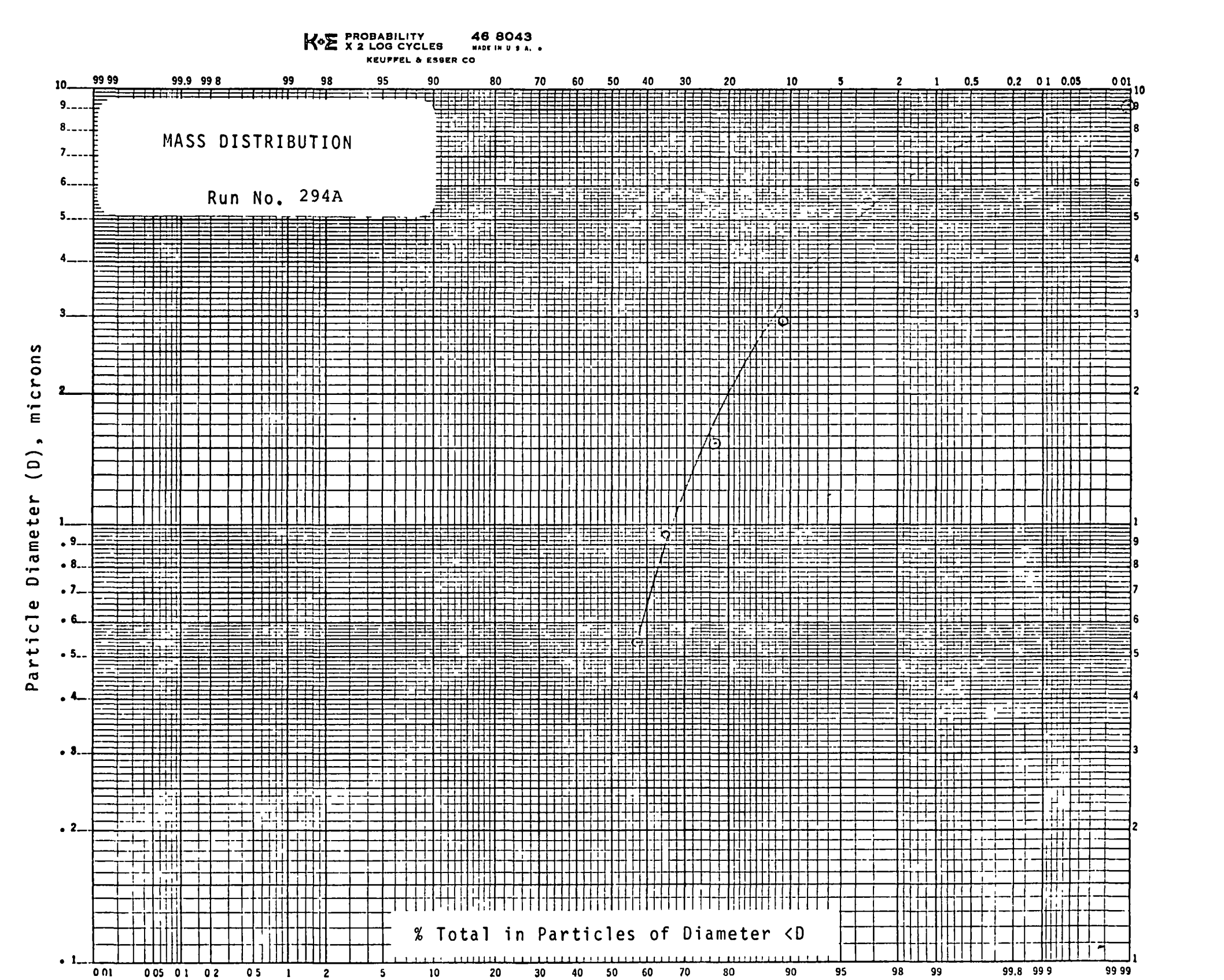
* BY X_RAY

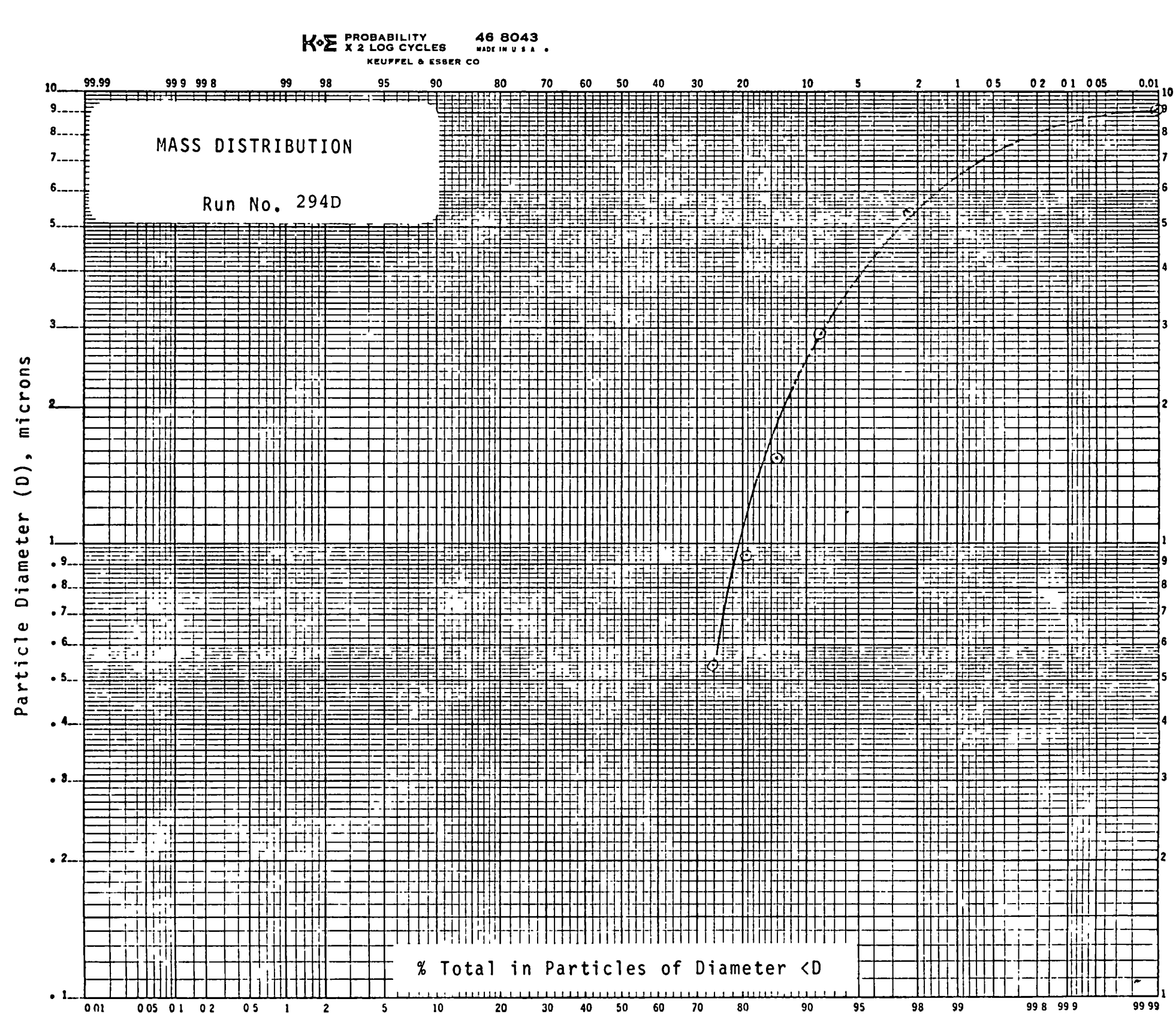
** BY TURBIDOMETRIC METHOD

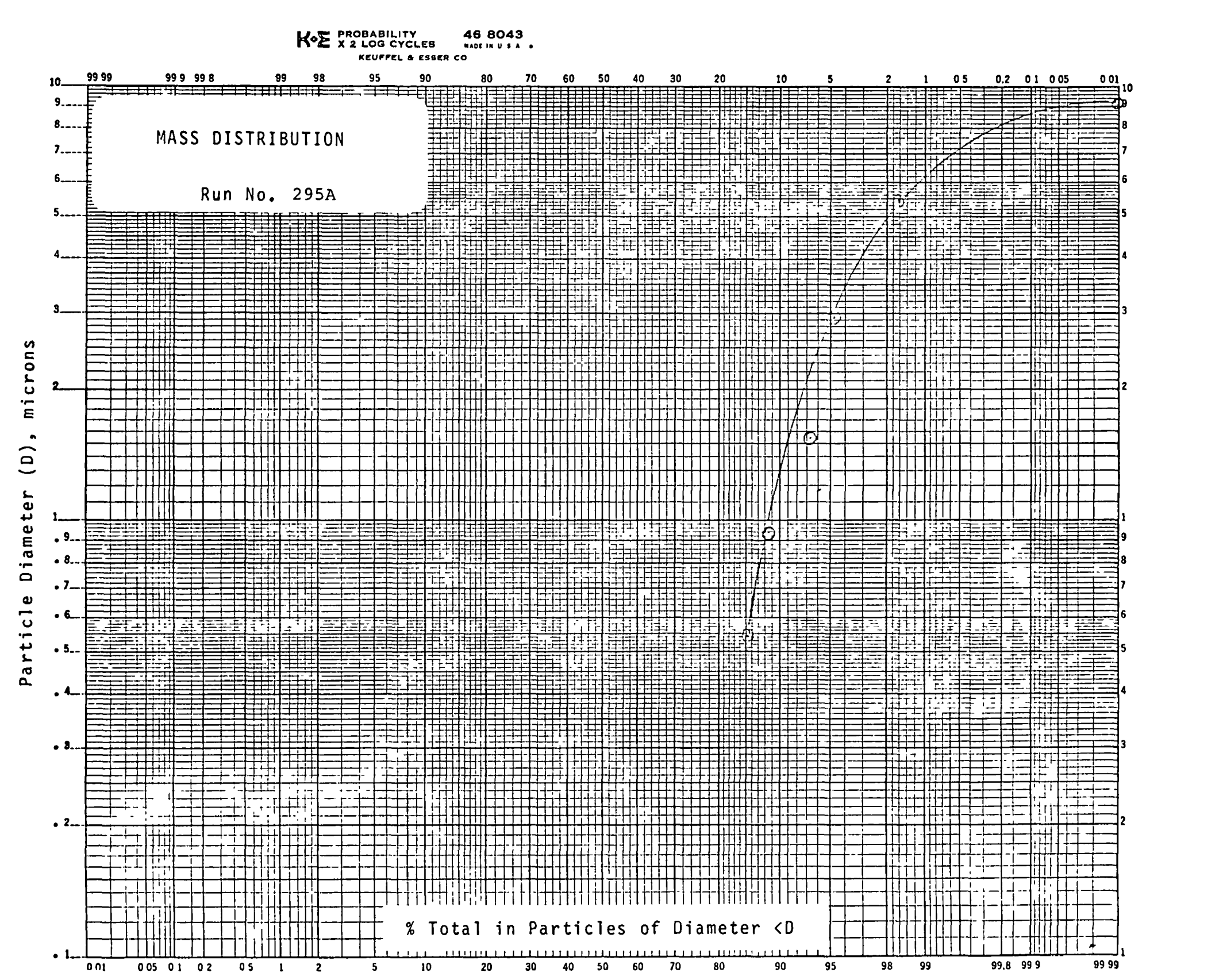
TEST NO.	PERCENT			
	PLATINUM	PLADIUM	SULFUR*	SULFATE**
295A	<.4167	.0625	.8542	1.979
295B	<.4545	.2272	.5682	1.591
295D	<1.667	.6667	65.9167	9.167

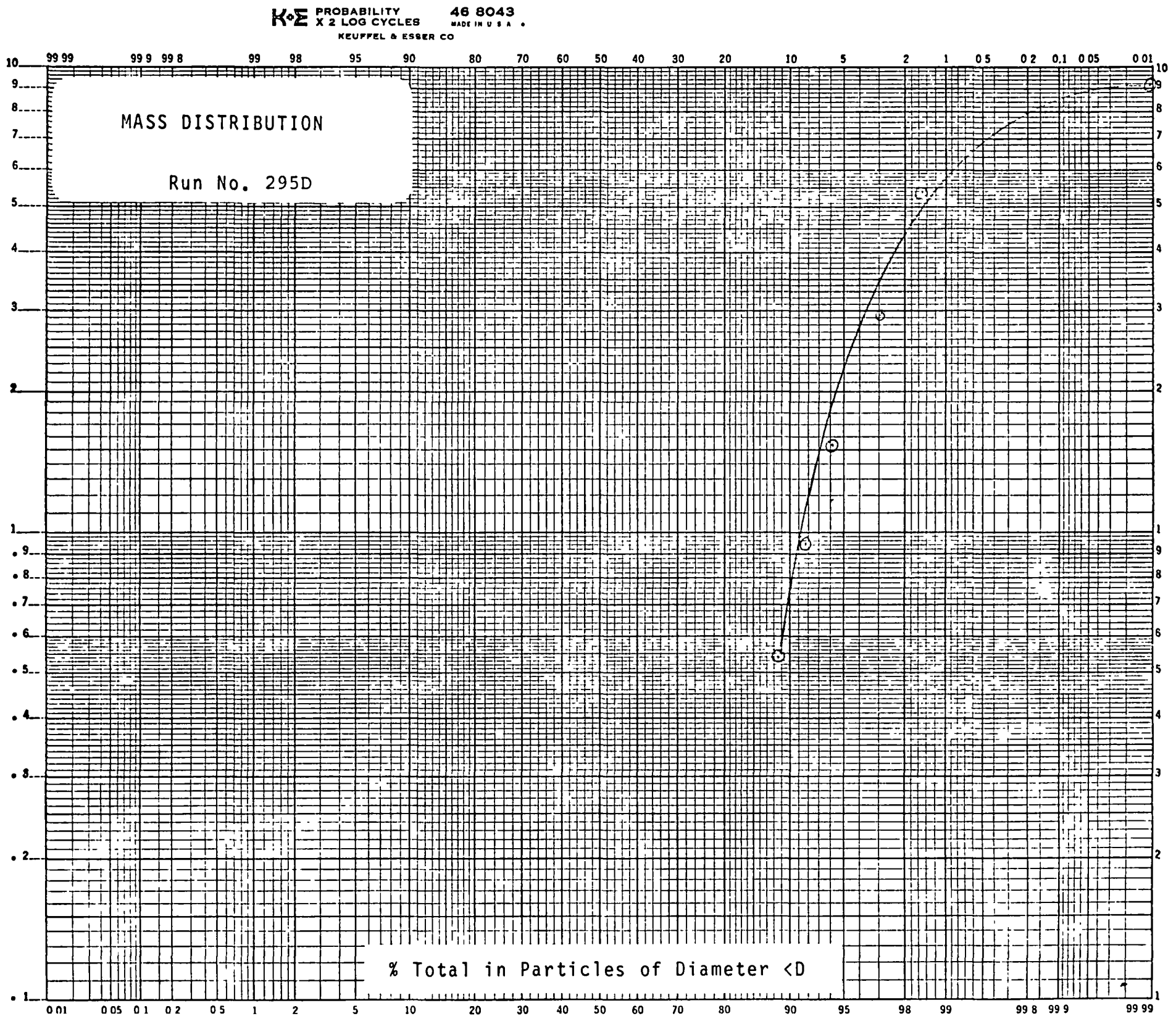
* BY X_RAY

** BY TURBIDOMETRIC METHOD


K&E PROBABILITY
X 2 LOG CYCLES
KEUFFEL & ESSER CO
46 8043
MADE IN U S A.
MASS DISTRIBUTION
Run No. 294A
Particle Diameter (D), microns
% Total in Particles of Diameter <D
99 99 99.9 99 8 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0.2 0 1 0.05 0 01
0 01 0 05 0 1 0 2 0 5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99 9 99 99


K&E PROBABILITY
X 2 LOG CYCLES
KEUFFEL & ESSER CO
46 8043
MADE IN U S A
MASS DISTRIBUTION
Run No. 294D
Particle Diameter (D), microns
% Total in Particles of Diameter <D
99.99 99 9 99 8 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0 5 0 2 0 1 0 05 0.01
0 01 0 05 0 1 0 2 0 5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99 8 99 9 99 99


K&E PROBABILITY
X 2 LOG CYCLES
46 8043
MADE IN U S A
KEUFFEL & ESSER CO
MASS DISTRIBUTION
Run No. 295A
Particle Diameter (D), microns
% Total in Particles of Diameter <D
99 99
99 9
99 8
99
98
95
90
80
70
60
50
40
30
20
10
5
2
1
0 5
0.2
0 1
0 05
0 01
0 01
0 05
0 1
0 2
0 5
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.8
99 9
99 99


K&E PROBABILITY
X 2 LOG CYCLES
KEUFFEL & ESSER CO
46 8043
MADE IN U S A
MASS DISTRIBUTION
Run No. 295D
Particle Diameter (D), microns
% Total in Particles of Diameter <D
99 99 99 9 99 8 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0 5 0 2 0.1 0 05 0 01
0 01 0 05 0 1 0 2 0 5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99 8 99 9 99 99

CHASSIS DYNAMOMETER

VEHICLE TEST REPORT # 17

Date of test: 3/14/74

Vehicle: Mazda RX3 7226.0 miles

Test Conditions:	AM	PM
Barometer	29.76	29.75
Wet Bulb °F	49	49
Dry Bulb °F	72	72
Relative Humidity %	12	12

Procedures:

Modified Federal Cold Start	41 Min.
Federal Cycle Hot Start	23 Min. (2)
2 Hrs. SS 60 MPH HS	

Comments:

This vehicle is equipped with a thermal reactor and a thermal reactor cooler exit pipe mounted side by side at rear of car. During our test both of these exhaust exit pipes were connected to the inlet pipe to the dilution tube.

Signed: James E Hartel Date: 4/23/74

CHASSIS DYNAMOMETER TEST

CAR NUMBER:
VEHICLE TYPE: Mazda RX3
FUEL: Indolene O, No Pb
CONVERTER: Thermal Reactor

Vehicle Test No.	Car Miles	Test Miles	Test Mode	Grams per 1.61 km (1 mile) Andersen Sampler	Follow-up glass Filter	Andersen + Filter	Glass Filter 142 mm (Avg. of two)	Millipore 142 mm	Net Gms Millipore 47mm 4 CFM
297A	7226	11.5	MFCCS	.047826	.043043	.090869	.090870	.167391	.0027
297B	7237.5	1200	60 MPH SS	.003102	.013962	.017064	.022300	.029862	.0014* .0013
297C	7358.0	7.5	FCHS	--	--	--	.068444	.234667	.0008
297D	7365.5	7.5	FCHS	--	--	--	.073333	.22733	.0007

*Polycarbonate Filter for 1 1/4 hrs.
Millipore Filter for 3/4 hrs.

EXHAUST GAS ANALYSIS

Vehicle Test No.	% by Volume				Parts Per Million				Exhaust Condensate	
	CO_2	O_2	N_2	CO	C_6 H.C.	NO_2	NO	$NO_x - N_x$	PPM HCHO	PPM NH_3
	11.7	4.05	82.9	0.375	262.0		154	198	665.7	5.74
297A	11.0	4.95	82.6	0.54	280.0		282	330		
	9.8	6.10	82.1	1.16	630.0		440	516	706.1	10.26
297B	8.9	7.60	81.8	0.85	495.0		494	548		
297C	12.1	3.85	83.05	0.35	64.0		165	194	160.9	2.14
297D	11.95	4.00	83.1	0.39	124.0		161	194		

ANALYSIS OF EXHAUST PARTICULATE

Trace Metals on Millipore Filter (%)

Vehicle Test No.	Fe	Ni	Cu	Al	Ca	Mg	Mn	Cr	Sn	Zn	Ti	Rb.	%SO_4
297A	0.5	.03	.06	.06	1.0	.39	.03	.07	<.01	.3	<.01	0.4	
297B	0.1	.01	.06	.04	0.6	.84	.007	.03	<.01	.2	<.01	0.3	
297C	0.2	<.01	.06	.06	1.4	.38	.01	.04	<.01	.1	.01	0.06	

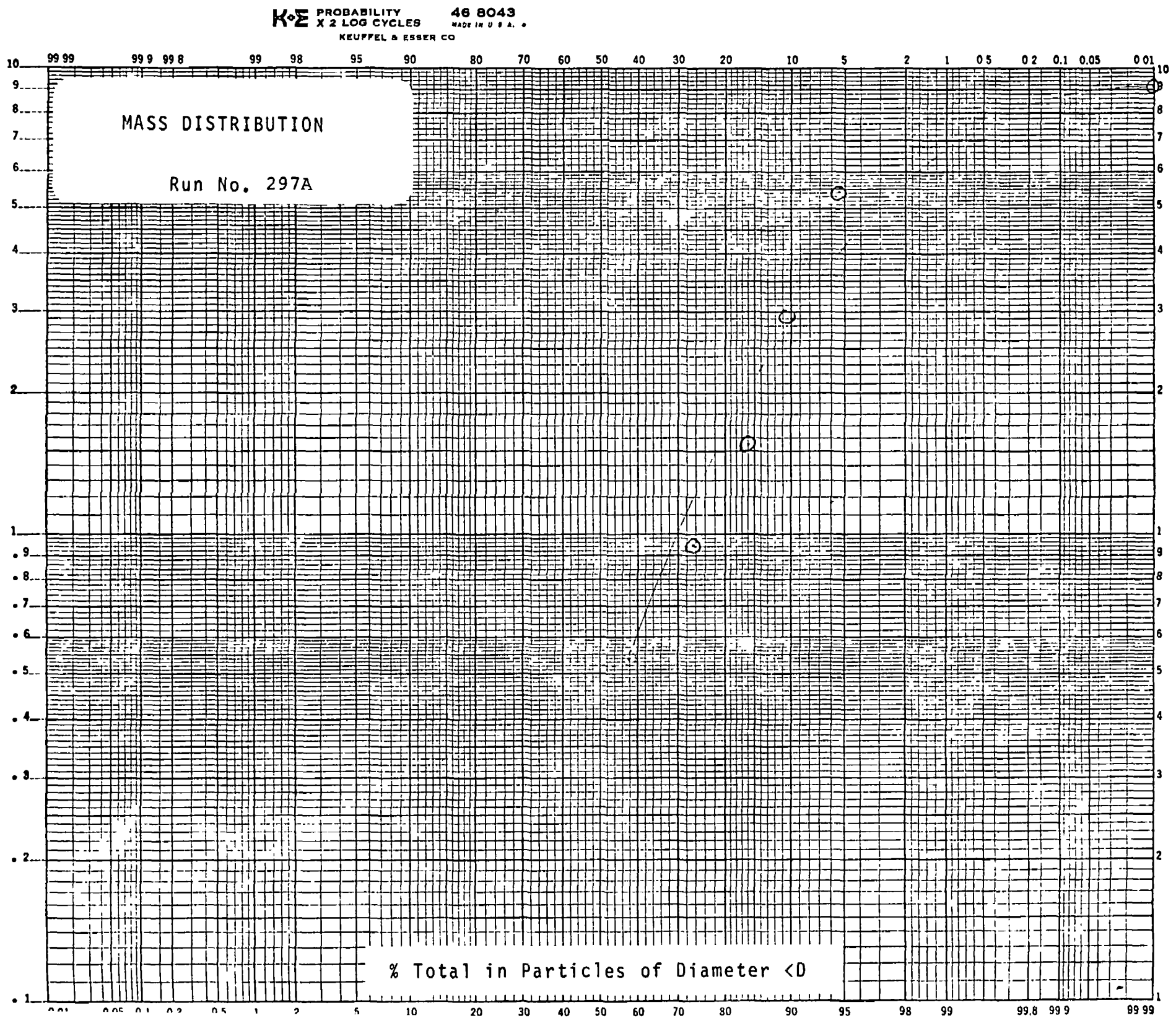
Glass Fiber Filters

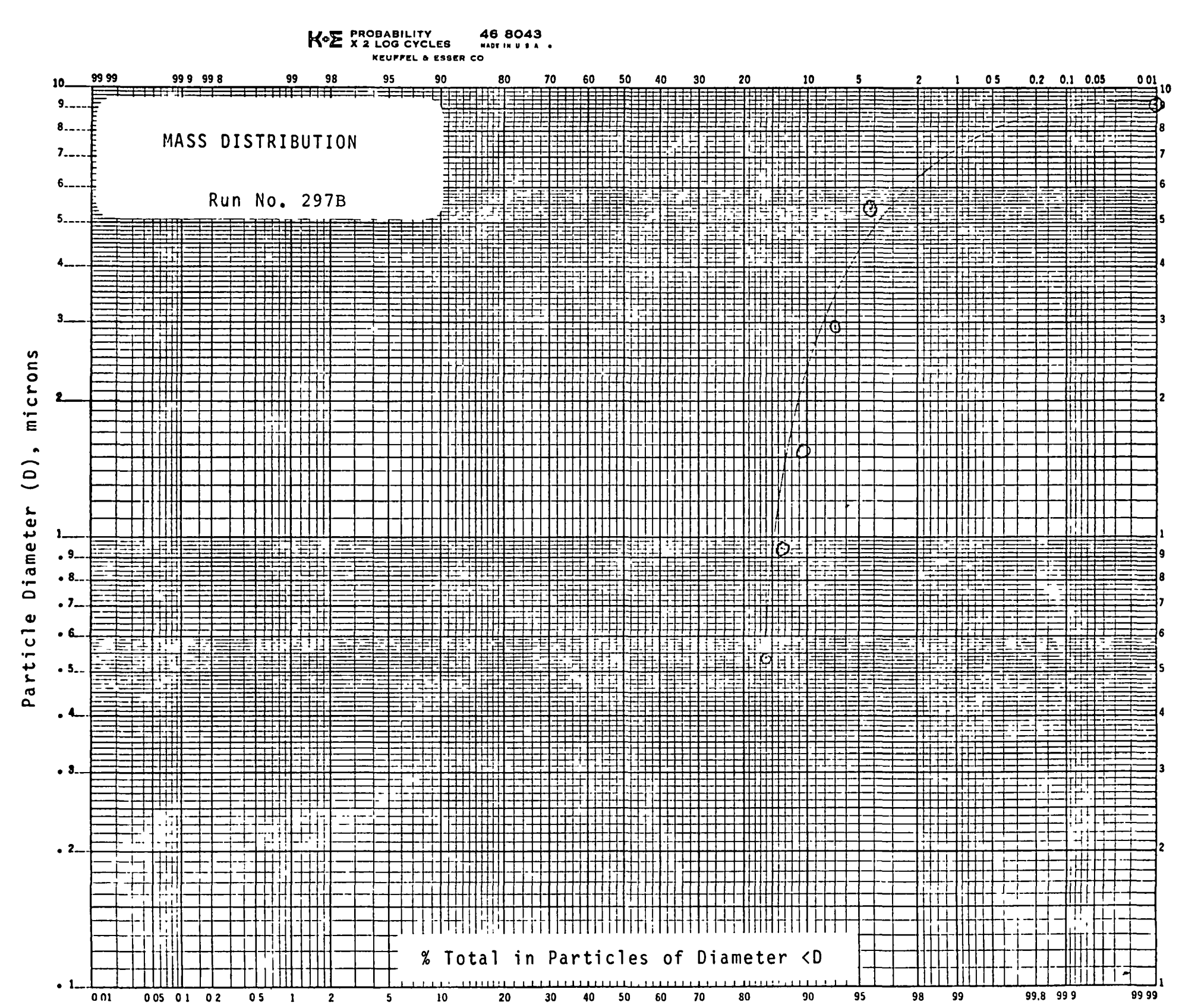
%C	%H	%N	PPM BAP
35.5	2.95	0	140
42.34	3.92	8.92	300
27.2	0.94	0	< 30

TEST NO.	PERCENT			
	PLATINUM	PLADIUM	SULFUR*	SULFATE**
297A	--	--	1.4815	4.00
297B	--	--	10.214	32.86
297C	--	--	.7000	4.00

* BY X_RAY

** BY TURBIDOMETRIC METHOD


K•E PROBABILITY
X 2 LOG CYCLES
46 8043
MADE IN U S A.
KEUFFEL & ESSER CO
MASS DISTRIBUTION
Run No. 297A
Particle Diameter (D), microns
% Total in Particles of Diameter <D


K&E PROBABILITY X 2 LOG CYCLES 46 8043
MADE IN U S A
KEUFFEL & ESSER CO
MASS DISTRIBUTION
Run No. 297B
Particle Diameter (D), microns
% Total in Particles of Diameter <D
99 99 99 9 99 8 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0 5 0.2 0.1 0.05 0 01
0 01 0 05 0 1 0 2 0 5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99 9 99 99

CHASSIS DYNAMOMETER

VEHICLE TEST REPORT #18

Date of test: 4-18-74

Vehicle: Mazda RX3 9,069.3 Miles

Test Conditions:

	AM	PM
Barometer	29.49	29.55
Wet Bulb °F	53	53
Dry Bulb °F	73	73
Rel. Humidity %	23	23

Procedures:

Modified Federal Cycle Cold Start 41 min.
Federal Cycle Hot Start 23 min. (2)
2 Hrs. SS 60 MPH HS

Comments:

This vehicle is equipped with a thermal reactor and a thermal reactor cooler exit pipe mounted side by side at rear of the vehicle. During our tests, both of these exhaust exit pipes were connected to the inlet pipe to the dilution tube. This vehicle is being used as a test for mileage accumulation here at Dow running on non lead fuel exclusively.

Signed: J. C. Valenta Date: _____

EXHAUST GAS ANALYSIS

Vehicle Test No.	% by Volume				Parts Per Million				Exhaust Condensate	
	CO_2	O_2	N_2	CO	C_6 H.C.	NO_2	NO	NO_x - N_x	PPM HCHO	PPM NH_3
	11.0	5.1	82.7	0.34	242		95	115	540.11	12.73
298A	11.2	4.7	82.7	0.56	250		310	410		
298B	12.0	3.8	82.9	0.43	170		170	225	332.78	17.71
298C	12.4	3.3	83.1	0.32	60		165	210		
	7.1	9.6	81.5	0.53	365		565	750		
298D	8.5	8.2	81.8	0.54	275		590	760	2219.83	57.27

CHASSIS DYNAMOMETER TEST

CAR NUMBER:
VEHICLE TYPE: Mazda RX3
FUEL: Indolene No Pb
CONVERTER: Thermal Reactor

Vehicle Test No.	Car Miles	Test Miles	Test Mode	Grams per 1.61 km (1 mile) Andersen Sampler	Follow-up glass Filter	Andersen + Filter	Glass Filter 142 mm (Avg. of two)	Millipore 142 mm	Net Gms Millipore 47mm 4 CFM
298A	9,069.3	11.5	MFCCS	.052608	.081304	.133912	.83695	.105217	.0016
298B		7.5	FCHS	-------	-------	-------	.066000	.07333	.0006
298C		7.5	FCHS	-------	-------	-------	.060744	.07333	.0005
298D		12.0	60 MPH SS	.0027939	.016097	.0188909	.017295	.015754	.0015

ANALYSIS OF EXHAUST PARTICULATE

Trace Metals on Millipore Filter (%)

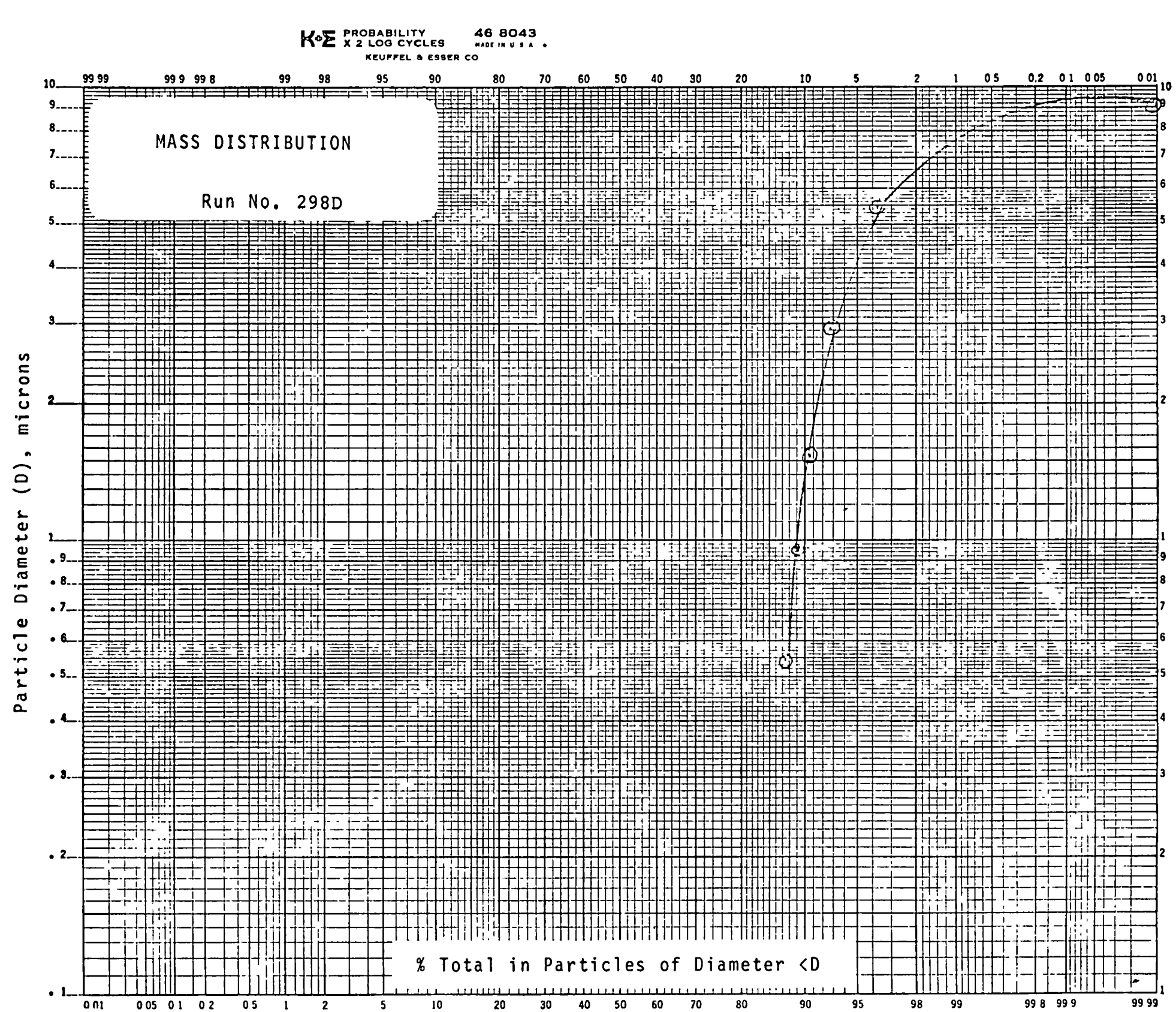
Glass Fiber Filters

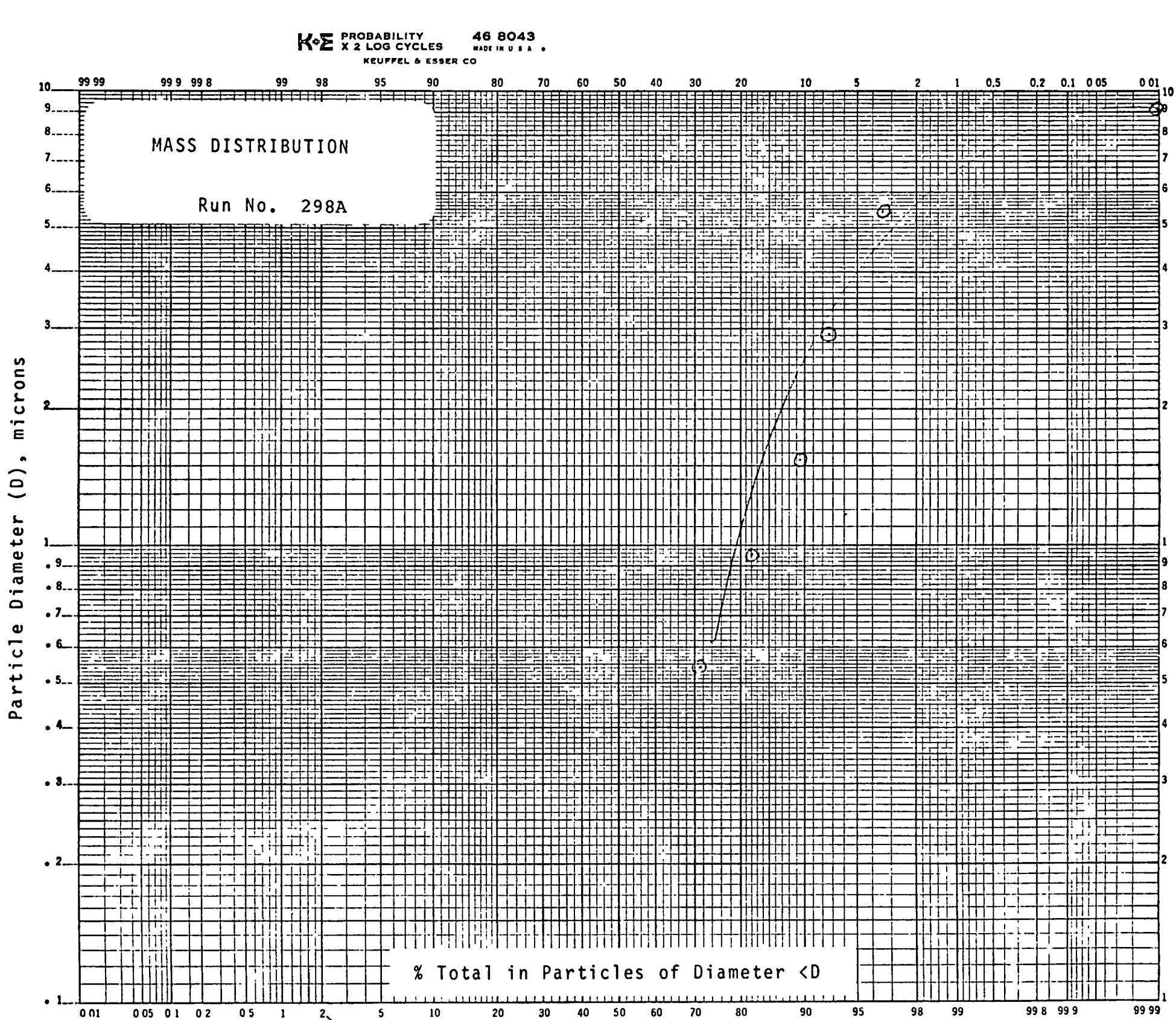
Vehicle Test No.	Fe	Ni	Cu	Al	Ca	Mg	Mn	Cr	Sn	Zn	Ti	Rb	$\%SO_4$	%C	%H	%N	PPM BAP
298A	.45	<.09	.27	.09	1.81	.55	<.09	<.09	<.09	.27	<.09			23.60	3.10	0.0	250
298B	.60	<.2	.70	<.2	5.0	.10	<.2	<.2	<.2	<.6	<.2			22.30	0.60	0.0	300
298D	.22	<.04	.22	<.04	1.09	1.13	<.04	<.04	<.04	.39	<.04			35.12	3.79	2.29	160

TEST NO.	PERCENT			
	PLATINUM	PLADIUM	SULFUR*	SULFATE**
298A	--	--	.7313	3.44
298B	--	--	1.3833	4.67
298D	--	--	1.8267	5.47

* BY X_RAY

** BY TURBIDOMETRIC METHOD


K&E PROBABILITY
X 2 LOG CYCLES
46 8043
MADE IN U S A
KEUFFEL & ESSER CO
MASS DISTRIBUTION
Run No. 298D
Particle Diameter (D), microns
% Total in Particles of Diameter <D
99 99 99 9 99 8 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0 5 0.2 0 1 0 05 0 01
0 01 0 05 0 1 0 2 0 5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99 8 99 9 99 99


K&E PROBABILITY
X 2 LOG CYCLES
KEUFFEL & ESSER CO
46 8043
MADE IN U S A
MASS DISTRIBUTION
Run No. 298A
Particle Diameter (D), microns
% Total in Particles of Diameter <D
99 99 99 9 99 8 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0.2 0.1 0 05 0 01
0 01 0 05 0 1 0 2 0 5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99 8 99 9 99 99

CHASSIS DYNAMOMETER

VEHICLE TEST REPORT #19 & 20

Date of test: 5-1 & 5-2-74

Vehicle: GM 74 Chevrolet #83031

	5-1-74		5-2-74	
Test Conditions:	AM	PM	AM	PM
Barometer	29.50	29.65	29.50	29.40
Wet Bulb °F	54.0	53.0	53.0	50.5
Dry Bulb °F	70.0	73.0	74.0	75.0
Rel. Humidity %	33.0	22.0	20.0	9.0

Procedures:

Modified Federal Cycle Cold Start 41 min.
Federal Cycle Hot Start 23 min. (2)
2 Hrs. SS 60 MPH HS

Repeated on following day

Comments:

This vehicle was towed up from Ann Arbor. It was equipped with 1975 emissions hardware. Catalylic converter, electronic iqnition and air valve carburetor.

Signed: J C Valenta Date: _____

CHASSIS DYNAMOMETER TEST

CAR NUMBER: GM 83031
VEHICLE TYPE: 1974 Chevrolet
FUEL: Indolene O No Lead
CONVERTER: Bead Type

Vehicle Test No.	Car Miles	Test Miles	Test Mode	Grams per 1.61 km (1 mile) Andersen Sampler	Follow-up glass Filter	Andersen + Filter	Glass Filter 142 mm (Avg. of two)	Millipore 142 mm	Net Gms Millipore 47mm 4 CFM
299A	3800.7	11.5	MFCCS	.09565	.004783	.10043	.009565	.014348	.0002
299B		7.5	FCHS	------	-------	------	.007333	.014667	.0002
299C		7.5	FCHS	------	-------	------	.007333	.014667	.0001
299D		120.0	60 MPH SS	.005832	.011299	.017131	.006014	.003280	.0009
300A		11.5	MFCCS	.062174	.009565	.071739	.011956	.019130	.0003
300B		7.5	FCHS	-------	-------	-------	.012222	.02200	.0005
300C		7.5	FCHS	-------	-------	-------	.017111	.029333	.0003
300D	4159.4	120.0	60 MPH SS	.005392	.011503	.016895	.007369	.012581	.0013

ANALYSIS OF EXHAUST PARTICULATE

Trace Metals on Millipore Filter (%)

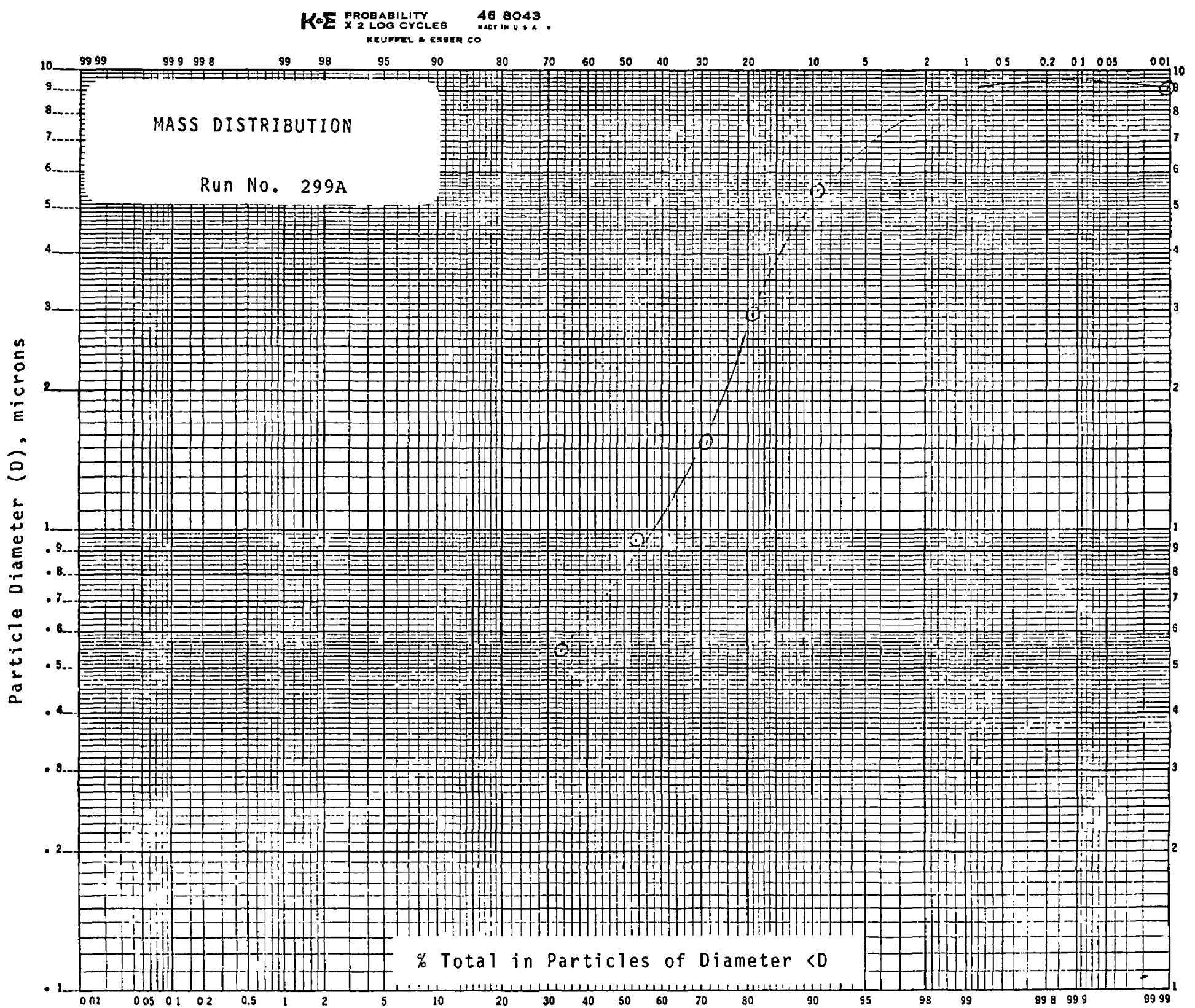
Vehicle Test No.	Fe	Ni	Cu	Al	Ca	Mg	Mn	Cr	Sn	Zn	Ti	Rb	$\%SO_4$	Glass Fiber Filters %C	%H	%N	PPM BAP
299A	3.34	<.34	1.7	.68	15.67	3.00	<.17	<.17	<.34	<1.02	<.34	1.3		53.60	20.17	5.11	<200
299B	5.00	<.50	4.0	1.0	32.0	6.00	<.25	0.50	<.50	1.5	<.50	1.5		25.56	46.40	0.0	<200
299D	5.78	<.11	0.55	.55	5.78	1.22	<.05	0.11	<.11	1.1	<.11	1.2		8.30	5.52	11.38	< 25
300A	5.50	<.25	1.75	.75	13.25	2.50	<.12	0.50	<.25	1.25	<.25	1.75		25.91	20.71	27.70	<200
300C	2.75	<.68	4.08	2.04	12.50	6.80	<.34	0.68	<.68	2.72	<.68	0.75		20.80	42.09	6.88	<200
300D	1.02	<.06	0.18	.12	1.49	0.30	<.03	0.03	<.06	.18	<.03	0.23		8.18	4.92	11.31	< 19

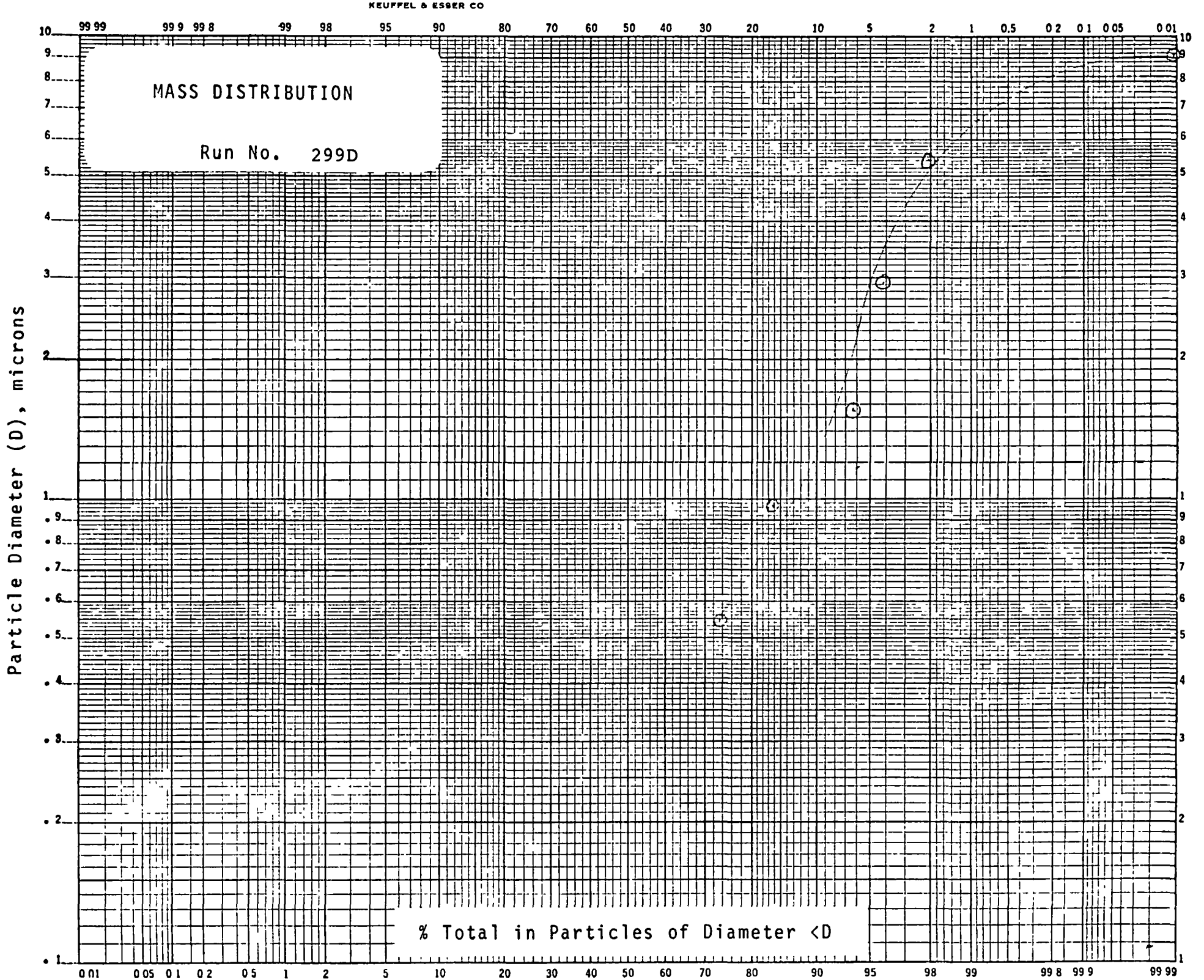
EXHAUST GAS ANALYSIS

Vehicle Test No.	% by Volume			Parts Per Million					Exhaust Condensate	
	CO_2	O_2	N_2	CO	C_6 H.C.	NO_2	NO	$NO_x - N_x$	PPM HCHO	PPM NH_3
	13.05	2.65	83.2	2250	89		230	310	77.75	6.14
299A	12.95	2.95	83.1	960	49		380	440		
299B	13.4	2.40	83.25	600	39		250	310	59.91	3.82
299C	13.7	1.95	83.25	1600	36		330	390		
	13.05	2.70	83.3	3000+	4		1550	1670	32.07	
299D	12.15	3.40	83.4	3000+	46		860	930		47.78
	13.0	2.55	83.3	3000+	103		275	330		42.96
300A	12.85	3.00	83.15	400	45		410	480	97.43	
300B	13.05	2.80	83.25	320	41		240	295	97.80	3.69
300C	13.00	2.85	83.25	240	25		230	285		
	13.65	2.00	83.40	3000+	4		1420	1540	10.86	
300D	13.50	1.70	83.70	3000+	16		1090	1150		2.41

IEE Analysis of Auto Exhaust Particulates

Run Number	Test Mode	Filter Sample %covered	Sulfate BE(ev)	Sulfate Peak height cps	$\%SO_4^=$	Sulfide BE(ev)	Sulfide Peak height cps	$\% S^=$
299A	MFCCS - 41 min.	53±5	168.1	340	2.1±0.4	-	<20	<.05
299B	FCHS - 23 min.	25±8	168	200	2.4±1.1	-	≤20	≤.1
299D	SS - 60 MPH	79±2	169.4	3611	14.7±1.6	-	<50	<.07
300A	MFCCS - 41 min.	63±4	168.3	362	1.9±0.2	-	≤50	≤.08
300C	FCHS - 23 min.	<20	169.3	966	>16	-	<20	
300D	SS - 60 MPH	60±4	169.1	6517	35±5	-	<50	<.08


K&E PROBABILITY X 2 LOG CYCLES 46 8043
KEUFFEL & ESSER CO
MASS DISTRIBUTION
Run No. 299A
Particle Diameter (D), microns
% Total in Particles of Diameter <D


K•E PROBABILITY
X 2 LOG CYCLES
46 8043
MADE IN U S A
KEUFFEL & ESSER CO
MASS DISTRIBUTION
Run No. 299D
Particle Diameter (D), microns
% Total in Particles of Diameter <D
99 99 99 9 99 8 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0 2 0 1 0 05 0 01
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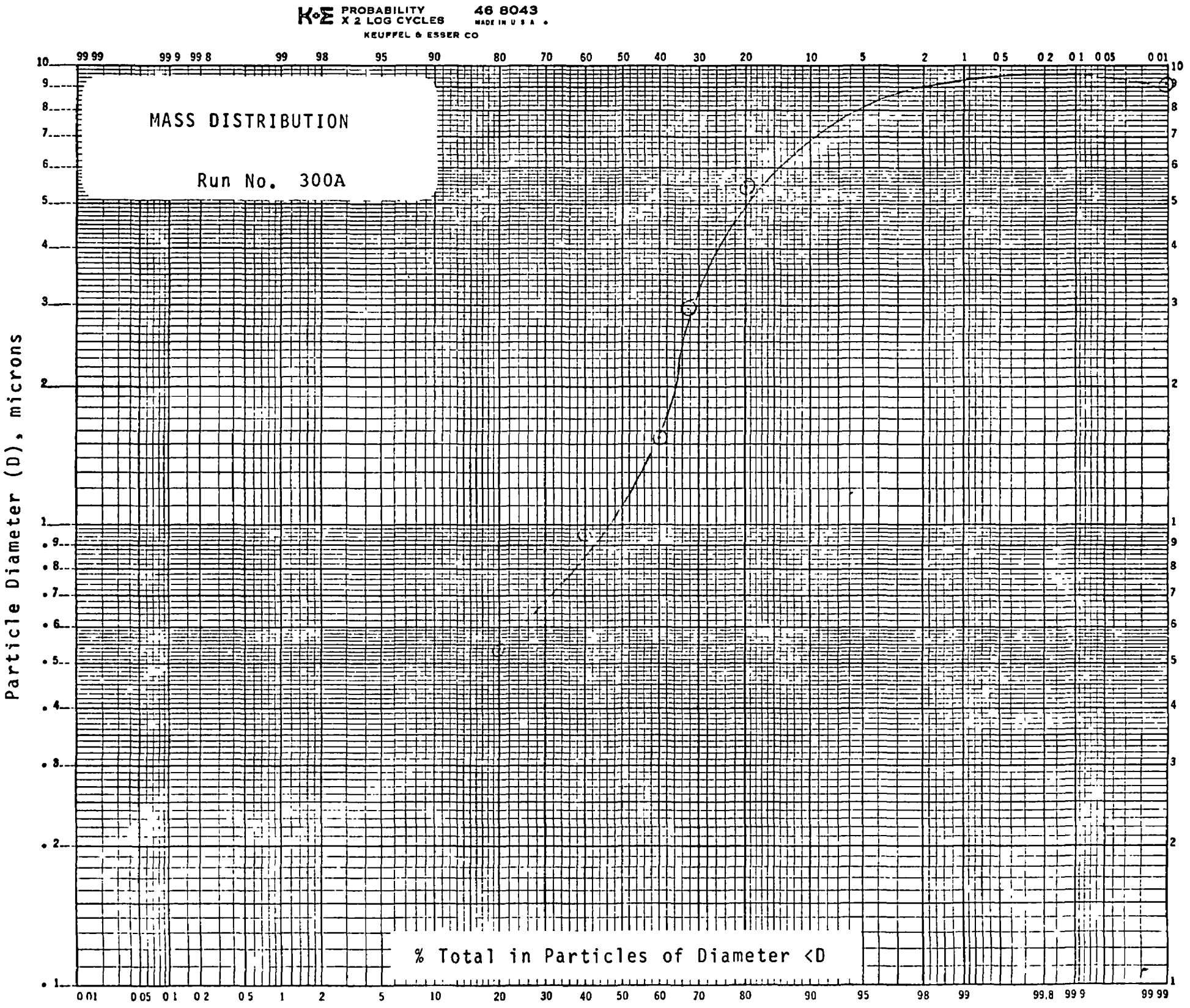
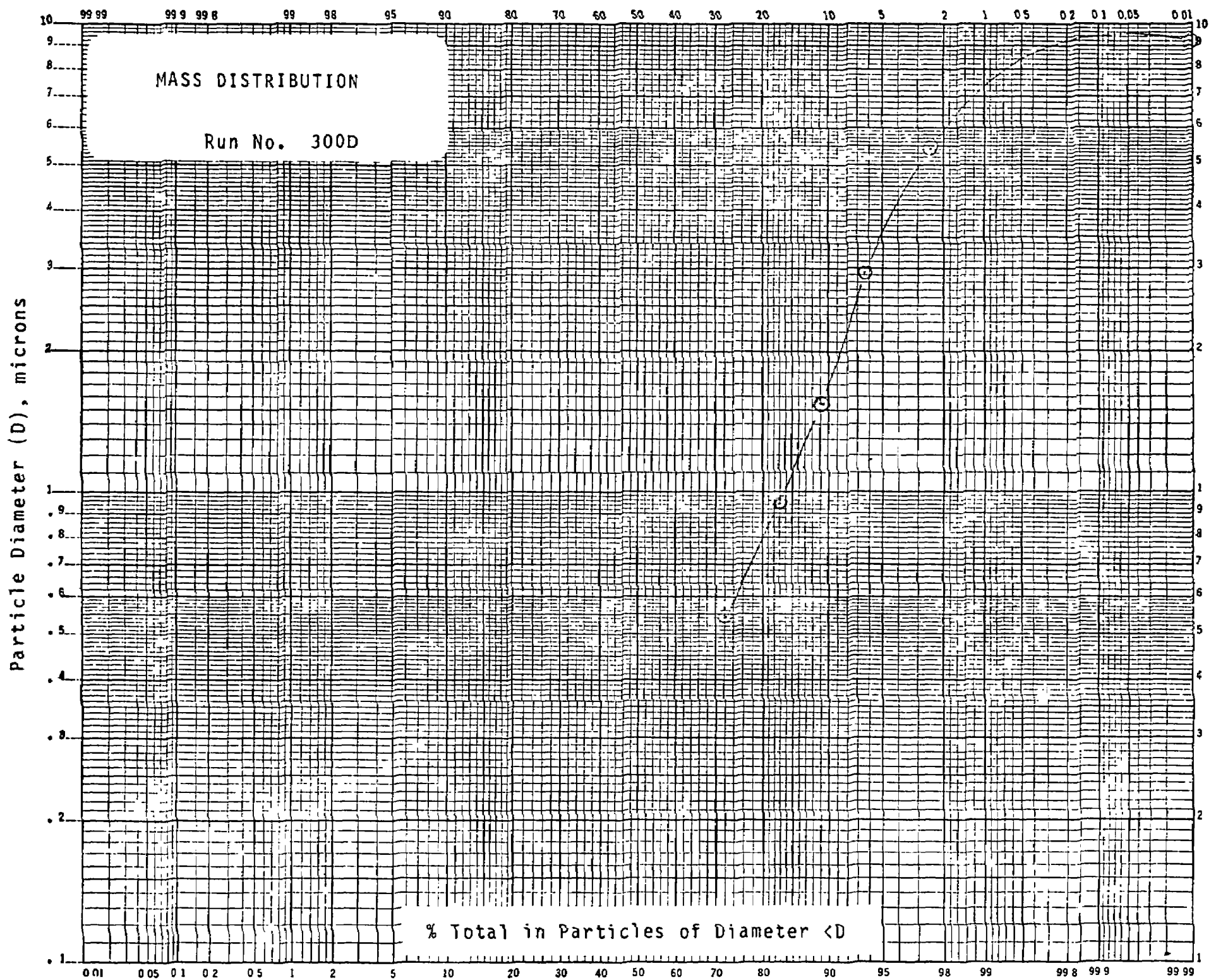

K&E PROBABILITY X 2 LOG CYCLES
46 8043
MADE IN U S A
KEUFFEL & ESSER CO
MASS DISTRIBUTION
Run No. 300A
Particle Diameter (D), microns
% Total in Particles of Diameter <D
99 99 99 9 99 8 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0 5 0 2 0 1 0 05 0 01
0 01 0 05 0 1 0 2 0 5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99 9 99 99


K&E PROBABILITY
X 2 LOG CYCLES
46 8043
KEUFFEL & ESSER CO
MASS DISTRIBUTION
Run No. 300D
Particle Diameter (D), microns
% Total in Particles of Diameter <D

CHASSIS DYNAMOMETER

VEHICLE TEST REPORT #21

Date of test: 5-29-74

Vehicle: Audi Fox 80 8442000011 1974

Test Conditions:

Barometer	29.18
Wet Bulb °F	63.0
Dry Bulb °F	74.0
Rel. Humidity %	54

Procedures:

Modified Federal Cycle Cold Start 41 min.
Federal Cycle Hot Start 23 min.

Comments:

This car was brought up on a trailer. The vehicle was a front wheel drive Audi Fox equipped with fuel injection EGR, special spark plugs and catalytic converter. It had a 4 speed transmission and radial ply tires. The humidity was very high and there was some doubt whether a reliable test could be made. There was no moisture detected in the rotameters during the test period. The humidity monitor at the sampling zone read very high during all phases of the tests. Due to the tight schedule for the car, it could not be held over to run on the following day. Two representatives from Audi Germany accompanied the car and observed the testing procedure.

Signed: J C Valenta Date: 8/16/74

CHASSIS DYNAMOMETER TEST

CAR NUMBER: 8442000011
VEHICLE TYPE: Audi Fox 80
FUEL: Non Lead
CONVERTER: Oxidation

Vehicle Test No.	Car Miles	Test Miles	Test Mode	Grams per 1.61 km (1 mile) Andersen Sampler	Follow-up glass Filter	Andersen + Filter	Glass Filter 142 mm (Avg. of two)	Millipore 142 mm	Net Gms Millipore 47mm 4 CFM
301A	2187.9	11.5	MFCCS	.062174	.009565	.071739	.021521	.028696	.0005
301B	2198.9	7.5	FCHS	---	---	---	.024444	.036667	.0003
2076-1-61A 62A									

EXHAUST GAS ANALYSIS

Vehicle Test No.	% by Volume				Parts Per Million				Exhaust Condensate	
	CO_2	O_2	N_2	CO	$H.C_{C_6}$	NO_2	NO	$NO_x - N_x$	PPM HCHO	PPM NH_3
301A Part 1	13.3	2.10	83.55	1250	41.0		245	280	55.86	74.48
Part 2	13.4	2.15	83.5	230	29.0		275	335		
301B	13.7	1.70	83.6	200	24.0		250	270	65.72	23.10

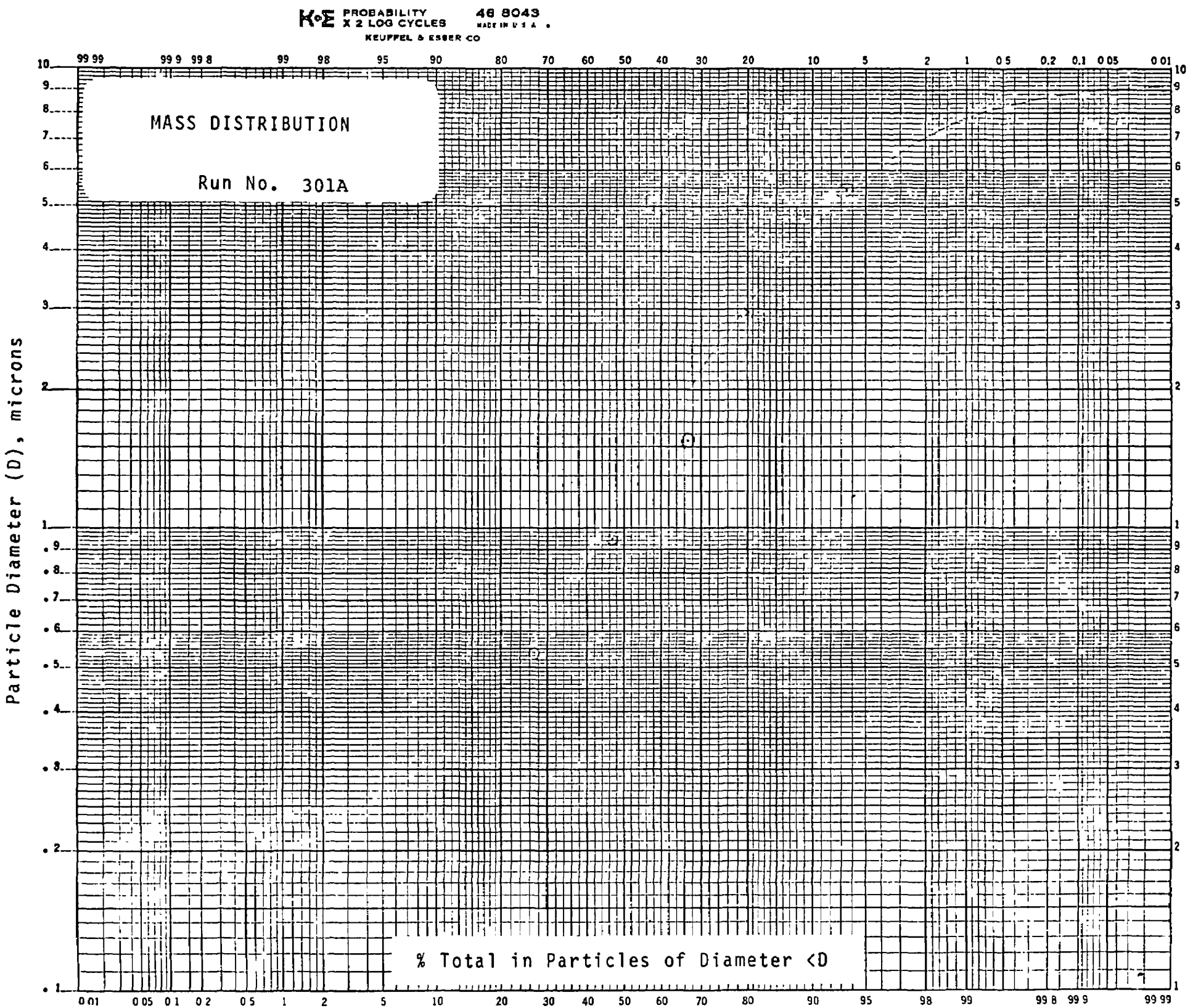
ANALYSIS OF EXHAUST PARTICULATE

Trace Metals on Millipore Filter (%)

Vehicle Test No.	Fe	Ni	Cu	Al	Ca	Mg	Mn	Cr	Sn	Zn	Ti	Pb	$\%SO_4$	Glass Fiber Filters %C	%H	%N	PPM BAP
301A	3	<.1	1.0	.5	9.0	2.0	<.1	.3	<.1	.7	.1	.5		5.20	1.00	12.25	160
301B	2	<.1	2.0	.6	13.0	3.0	.1	.4	.1	.7	.1	<.3		18.23	3.90	5.35	700

IEE Analysis of Auto Exhaust Particulates

Run Number	Test Mode	Filter Sample %covered	Sulfate BE(ev)	Sulfate Peak height cps	$\%SO_4^=$	Sulfide BE(ev)	Sulfide Peak height cps	$\% S^=$
301A	MFCCS - 41 min.	40±6	169.3	600	4.8±.9	∿162	∿60	.15±.08
301B	FCHS - 23 min.	>20	169.4	470	>8	∿162	≤50	


K•E PROBABILITY 46 8043
X 2 LOG CYCLES
KEUFFEL & ESSER CO
MASS DISTRIBUTION
Run No. 301A
Particle Diameter (D), microns
% Total in Particles of Diameter <D
99 99 99 9 99 8 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0 5 0.2 0.1 0 05 0 01
0 01 0 05 0 1 0 2 0 5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99 8 99 9 99 99
10 9 8 7 6 5 4 3 2 1 • 9 • 8 • 7 • 6 • 5 • 4 • 3 • 2 • 1

CHASSIS DYNAMOMETER

VEHICLE TEST REPORT # 22

Date of test: 9-4-74

Vehicle: Mazda RX3 14,351.0
FINAL

Test Conditions:			
	Barometer	29.60	29.64
	Wet Bulb °F	53.0	58.0
	Dry Bulb °F	66.0	75.0
	Rel. Humidity	36.0%	34.0%

Procedures:

Modified Federal Cycle Cold Start 41 min.
Federal Cycle Hot Start 23 min. (2)
2 Hrs. SS 60MPH HS

Comments:

This vehicle is equipped with a thermal reactor and a thermal reactor cooler exit pipes mounted side by side at the rear of the vehicle. During our tests, both of these pipes were connected to the inlet pipe which is connected to the dilution tube. This vehicle is being used in a study for the effects of mileage accumulation on exhaust emissions.

Signed: J. C. Valente Date: 10/31/74

CHASSIS DYNAMOMETER TEST

CAR NUMBER:
VEHICLE TYPE: Mazda RX3 14351.0
FUEL: No Pb
CONVERTER: Thermal Reactor

Vehicle Test No.	Car Miles	Test Miles	Test Mode	Grams per 1.61 km (1 mile) Andersen Sampler	Follow-up glass Filter	Andersen + Filter	Glass Filter 142 mm (Avg. of two)	Millipore 142 mm	Net Gms Millipor 47mm 4 CFM
302A	14351.0	11.5	MFCCS	.0861	.1004	.1865	.1196	.1004	.0031
302B		120.0	60 MPH SS	.0068	.0181	.0249	.0153	.0130	.0013
302C		7.5	FCHS	--	--	--	.0513	.0734	.0005
302D		7.5	FCHS	--	--	--	.0464	.0806	.0007

EXHAUST GAS ANALYSIS

Vehicle Test No.	% by Volume				Parts Per Million				Exhaust Condensate	
	CO_2	O_2	N_2	CO	C_6 H.C.	NO_2	NO	NO_x - N_x	PPM HCHO	PPM NH_3
302A	12.80	3.25	83.15	.03	250		160	310	567.9	
	10.85	5.30	83.10	.03	290		180	360		7.24
302B	9.35	7.05	82.80	.03	330		1000	1200	1034.2	
	9.95	6.35	82.85	.03	225		1150	1320		51.20
302C	12.25	3.40	83.50	.03	115		187	230	207.0	6.70
302D	12.65	3.10	83.05	.32	127		175	205	--	

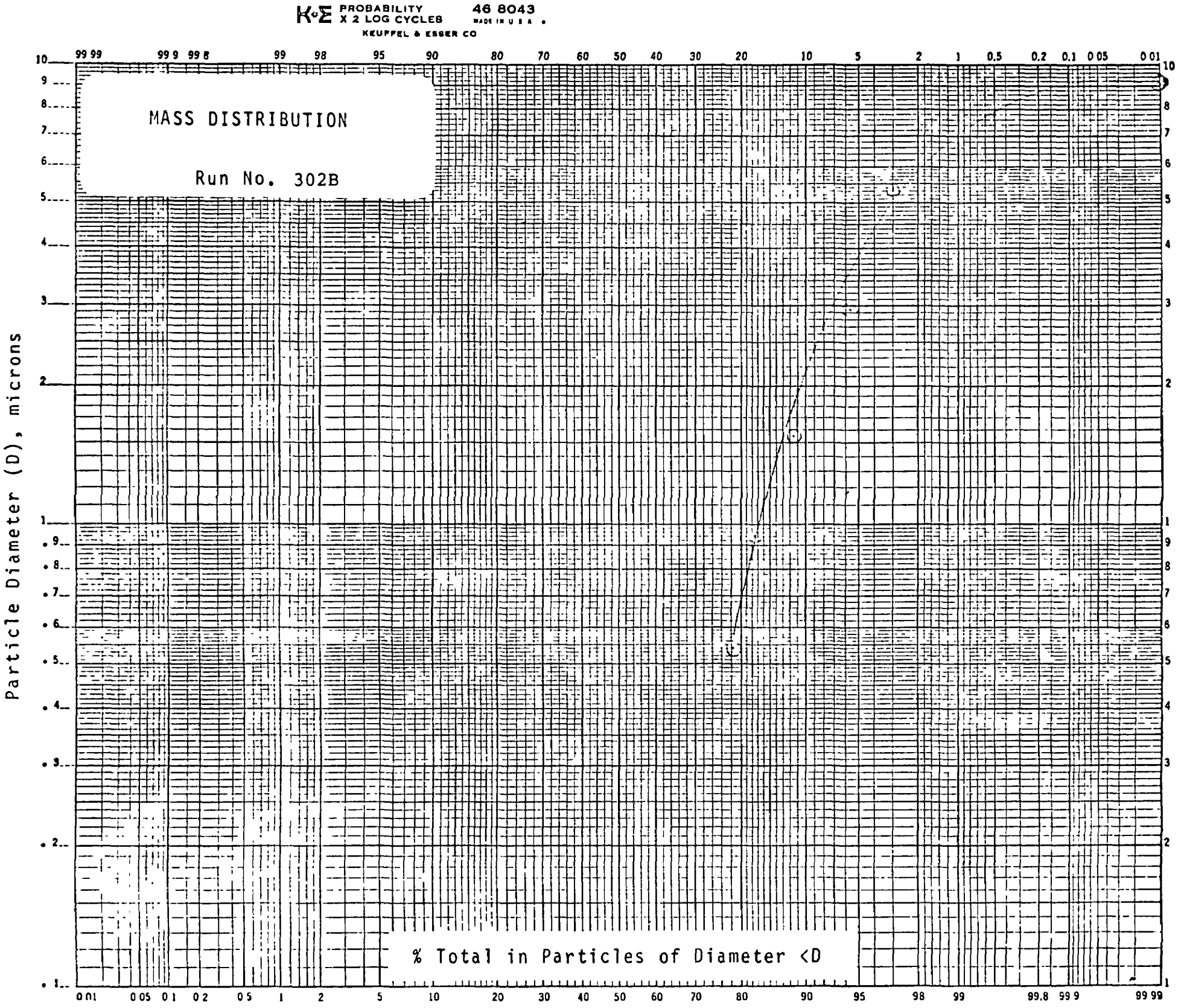
ANALYSIS OF EXHAUST PARTICULATE

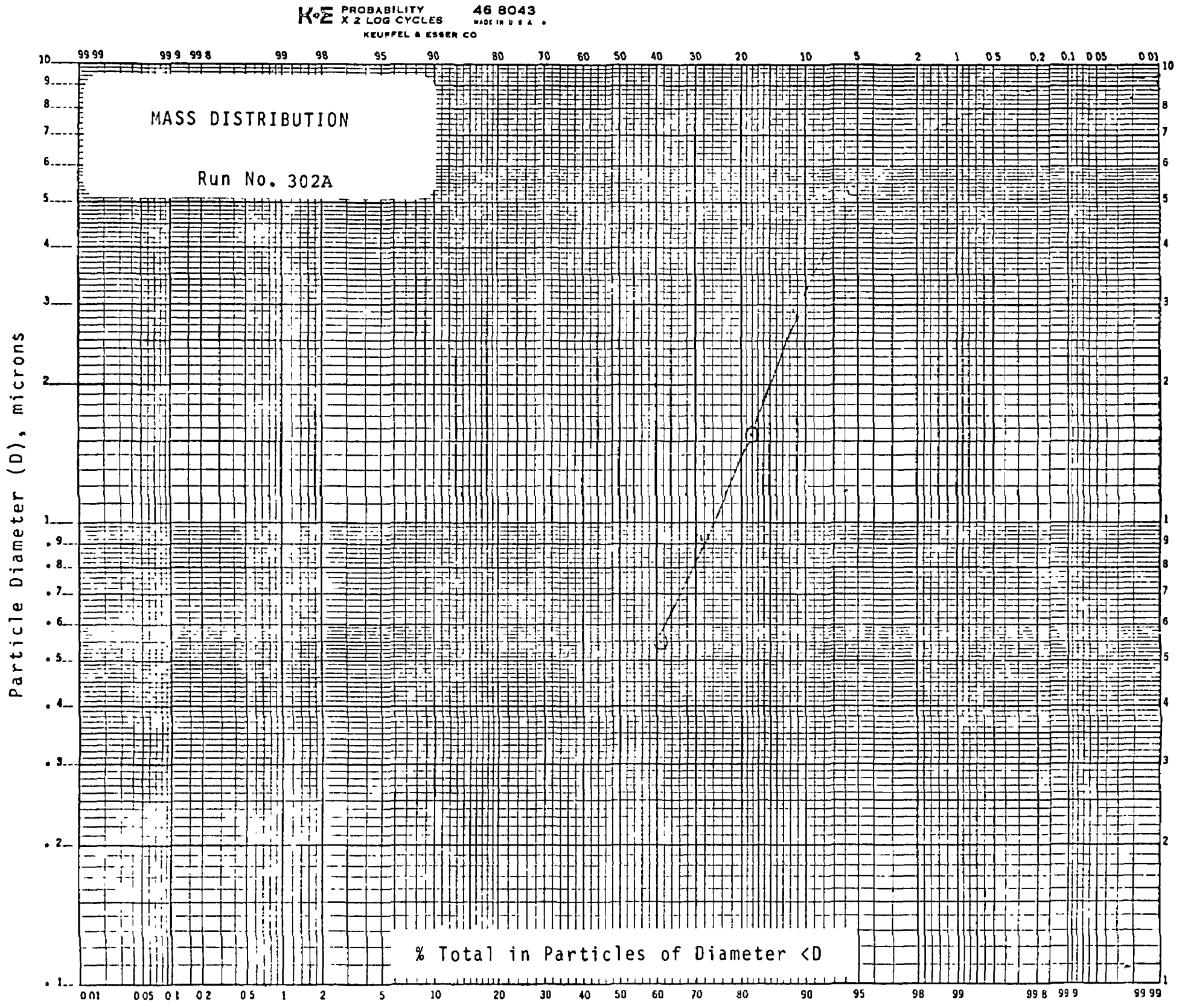
Trace Metals on Millipore Filter (%)

Vehicle Test No.	Fe	Ni	Cu	Al	Ca	Mg	Mn	Cr	Sn	Zn	Ti	Rb	$\%SO_4$	Glass Fiber Filters %C	%H	%N	PPM BAP
302A	0.9	<0.1	.28	.16	2.6	1.7	<.05	<0.1	<0.1	1.1	<0.1	1.5		18.06	4.50	3.88	620
302B	0.8	<0.1	.15	<0.1	1.4	1.1	<.05	<0.1	<0.1	<0.3	<0.1	0.6		24.62	4.63	3.09	150
302C	0.7	<0.1	.45	.17	4.8	1.0	<.05	<0.1	<0.1	<0.3	<0.1	<0.3		17.80	4.35	0.63	610

IEE Analysis of Auto Exhaust Particulates

Run Number	Test Mode	Filter Sample %covered	Sulfate BE(ev)	Sulfate Peak height cps	$\%SO_4^=$	Sulfide BE(ev)	Sulfide Peak height cps	% $S^=$
302A	MFCCS - 41 min.	≥99	168.6	470	1.5±0.2	∿164	∿100	.1±.05
302B	SS - 60 MPH	≥97	168.9	1420	4.6±0.5	∿164	∿230	.2±.05
302C	FCHS - 23 min.	≥99	168	260	0.8±0.2	∿163	∿70	.1±.05


K&E PROBABILITY
X 2 LOG CYCLES
46 8043
MADE IN U.S.A.
KEUFFEL & ESSER CO
MASS DISTRIBUTION
Run No. 302B
Particle Diameter (D), microns
% Total in Particles of Diameter <D
99 99 99 9 99 8 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0.2 0.1 0 05 0 01
0 01 0 05 0 1 0 2 0 5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99 9 99 99


K&E PROBABILITY
X 2 LOG CYCLES
KEUFFEL & ESSER CO
46 8043
MADE IN U.S.A.
MASS DISTRIBUTION
Run No. 302A
Particle Diameter (D), microns
% Total in Particles of Diameter <D
99.99 99.9 99.8 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0.2 0.1 0.05 0.01
10 9 8 7 6 5 4 3 2 1 .9 .8 .7 .6 .5 .4 .3 .2 .1
0.01 0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9 99.99

CHASSIS DYNAMOMETER

VEHICLE TEST REPORT # 23, 24, and 25

Date of test: 9-12, 9-13 and 9-16

Vehicle: DuPont Pinto with Pb trap

Test Conditions:	Date 9/12	9/13	9/16
Barometer	29.30	29.40	29.60
Wet Bulb °F	70	60	58
Dry Buld °F	80	72	74
Rel. Humidity %	61	49	36

Procedures:

Modified Federal Cycle
AMA Durability Cycle

Comments:

The vehicle was driven up from DuPont by Mr. G. W. Kunz, who stayed to observe the setting up and the first day of testing. Because of the high humidity, the tests could not be completed while he was here. The fuel, a special lead blend, was supplied by Ann Arbor EPA as was the driving cycle promptor. The dilution flow was 550 CFM at 420 F/min velocity. The particulate was sampled at 1 CFM.

Signed: J. C Valiunta Date: 10/31/74

CHASSIS DYNAMOMETER TEST

CAR NUMBER: P1 20
VEHICLE TYPE: Pinto 1972
FUEL: 2.2g Pb/Gal Indolene
CONVERTER: Pb Trap

Vehicle Test No.	Car Miles	Test Miles	Test Mode	Grams per 1.61 km (1 mile) Andersen Sampler	Follow-up Millipore Filter	Andersen + Filter	Glass Filter 142 mm (Avg. of two)	Millipore 142 mm	Net Gms Millipore 47mm 4 CFM
303A	34216.0	10.8	MFCCS	.07638	.04074*	.11712	.05601	.17314	
303B	34226.8	93.0	AMA	.01419	.04081	.0550	.03312	.04081	
304A	34319.6	10.7	MFCCS	.07710	.15421	.2313	.04883	.14906	
304B	34330.3	92.7	AMA	.01186	.02017	.03203	.03263	.02669	
305A	34428.0	92.4	AMA	.01429	.02559	.03988	.03184	.03571	

*Glass Fiber Filter was used.

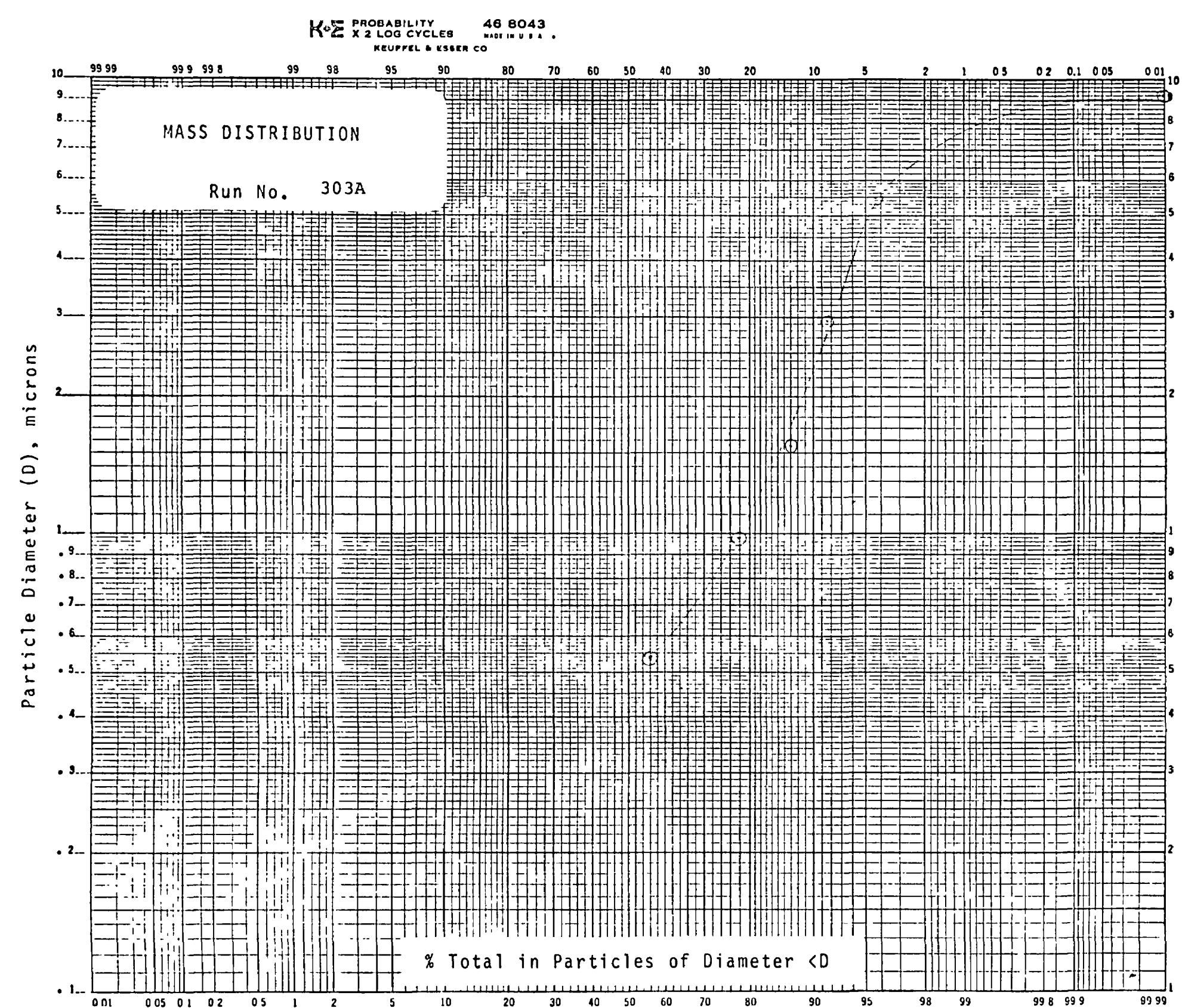
ANALYSIS OF EXHAUST PARTICULATE

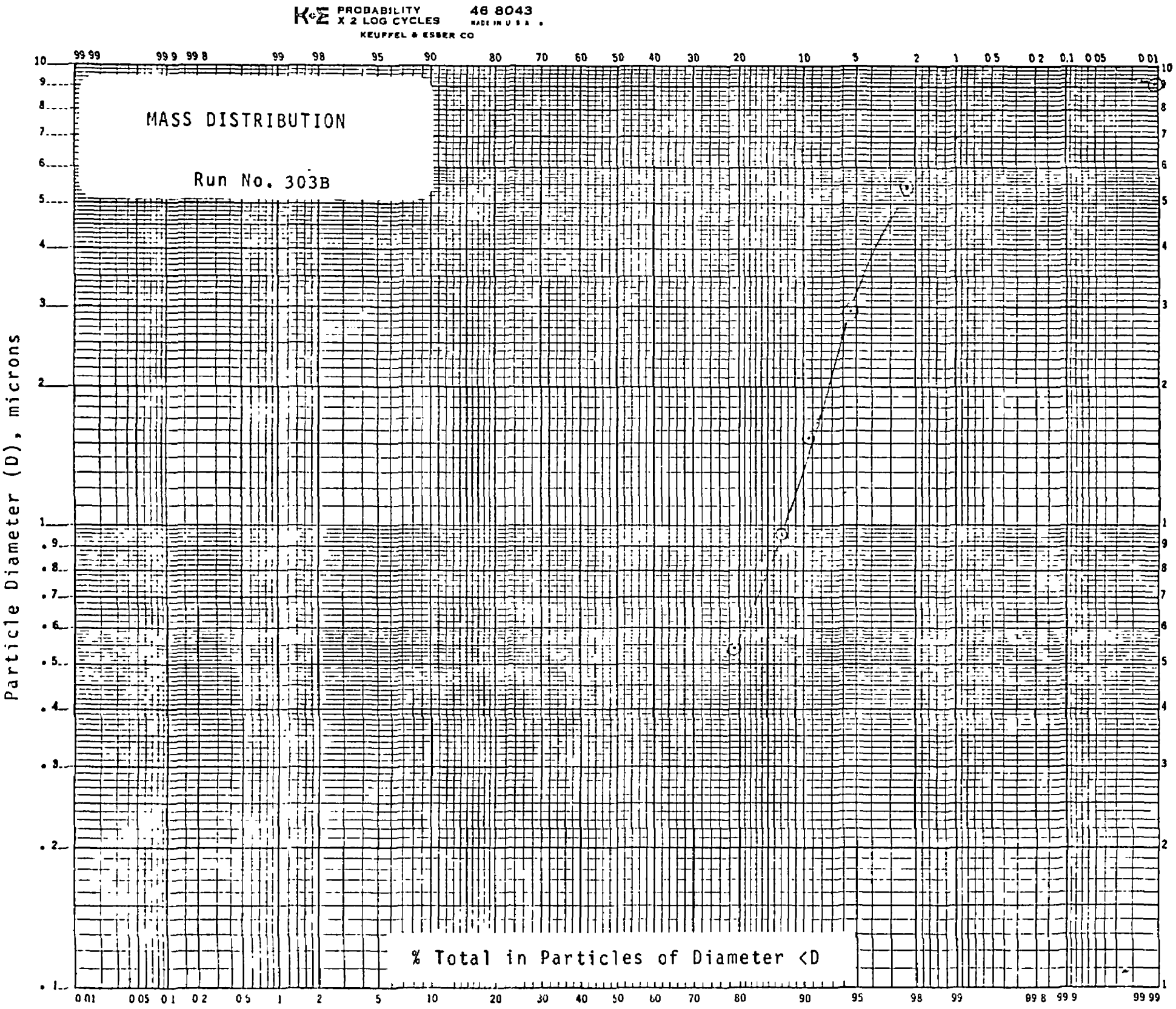
Trace Metals on Millipore Filter (%)

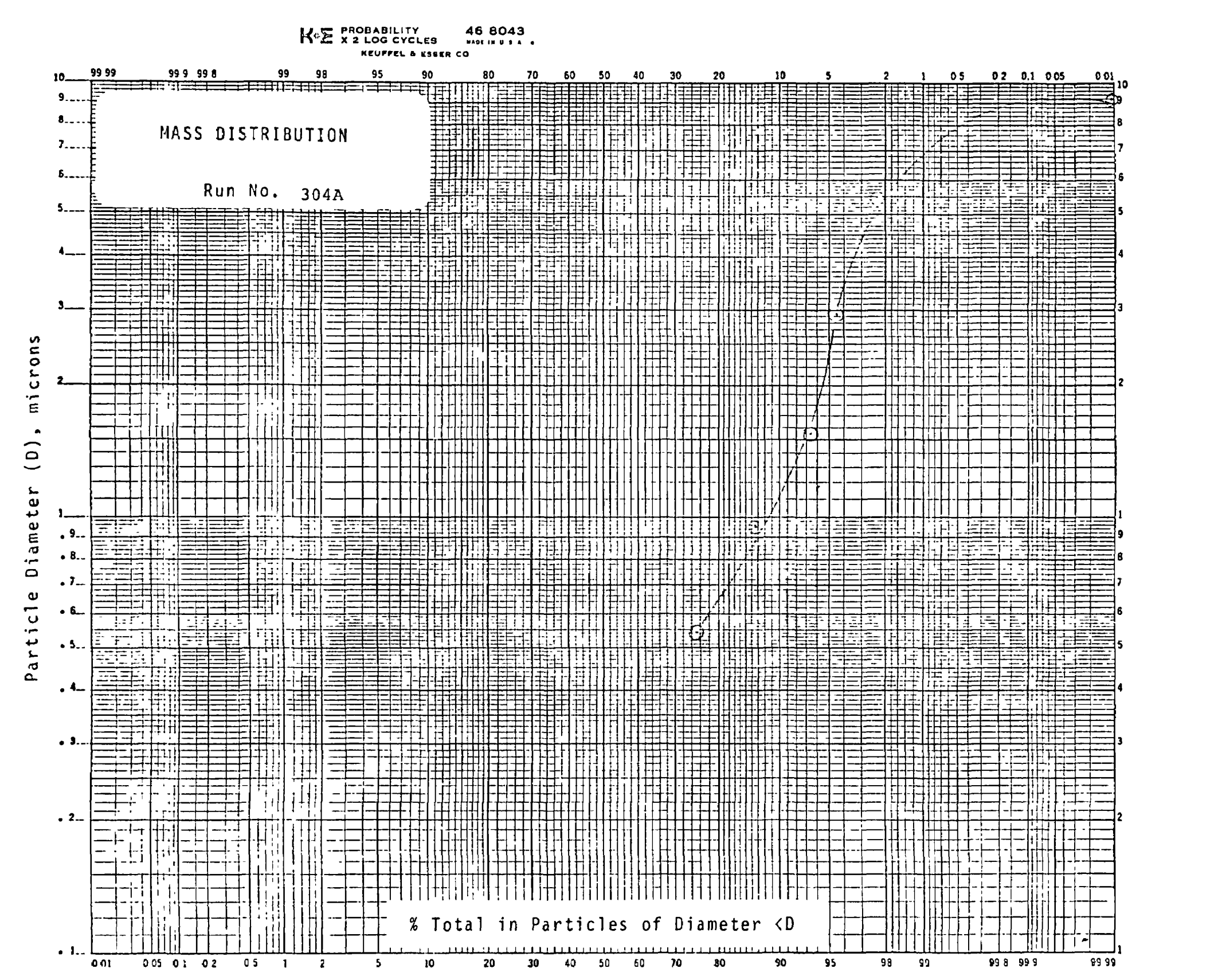
Vehicle Test No.	Fe	Ni	Cu	Al	Ca	Mg	Mn	Cr	Sn	Zn	Ti	Pb	%SO_4
303A	0.5	<0.05	.13	.18	1.45	.30	<0.02	<0.05	<0.05	<0.2	<0.05	1.30	
303B	0.1	<0.05	.09	.09	.64	.15	<0.02	<0.05	<0.05	<0.2	<0.05	5.02	
304A	0.2	<0.05	.16	.10	1.38	.26	<0.02	<0.05	<0.05	<0.2	<0.05	1.12	
304B	0.2	<0.05	.19	.12	1.62	.26	<0.02	<0.05	<0.05	<0.2	<0.05	5.79	
305A	0.2	<0.05	.12	.18	1.15	.24	<0.02	<0.05	<0.05	<0.2	<0.05	3.40	

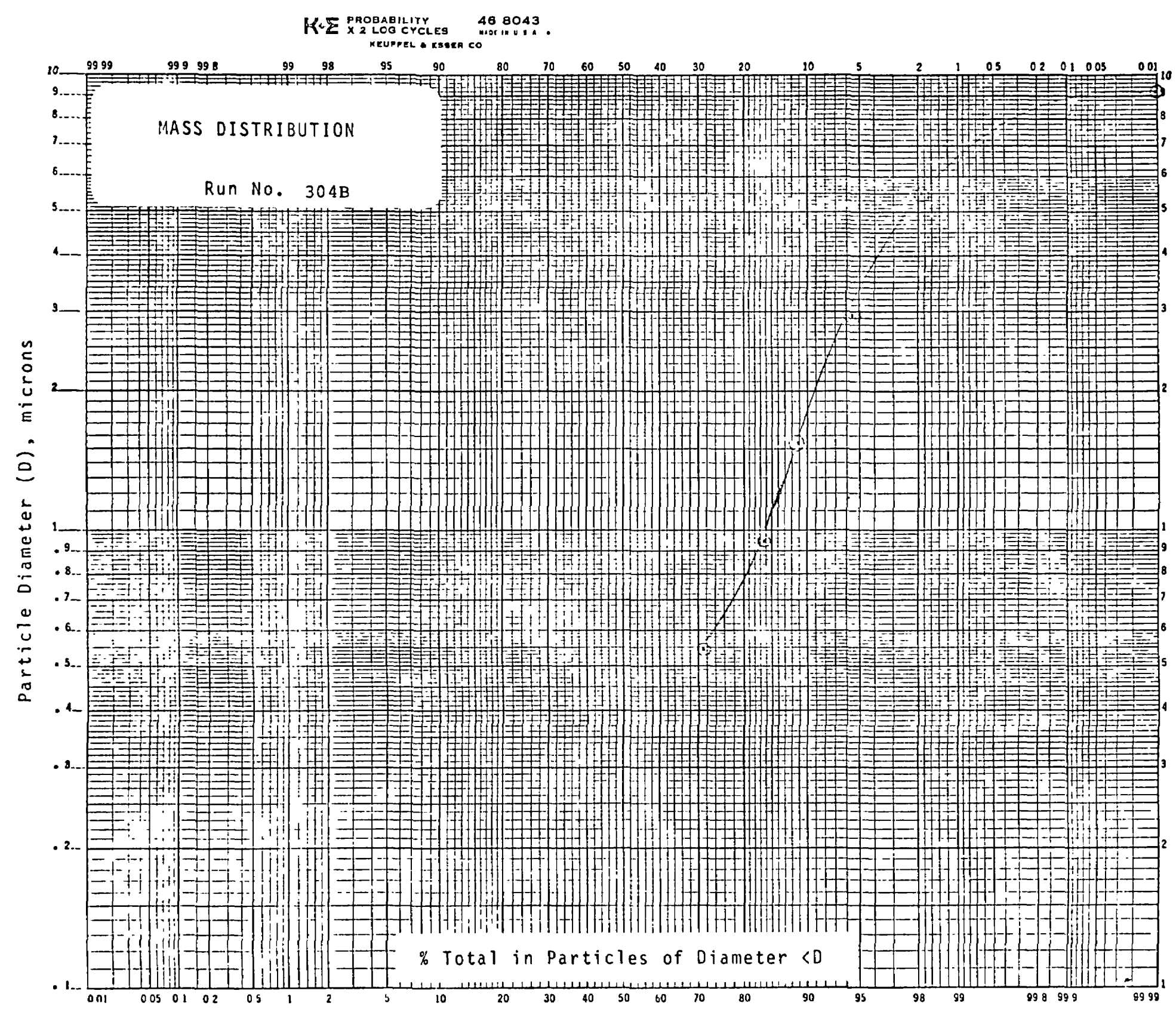
Glass Fiber Filters

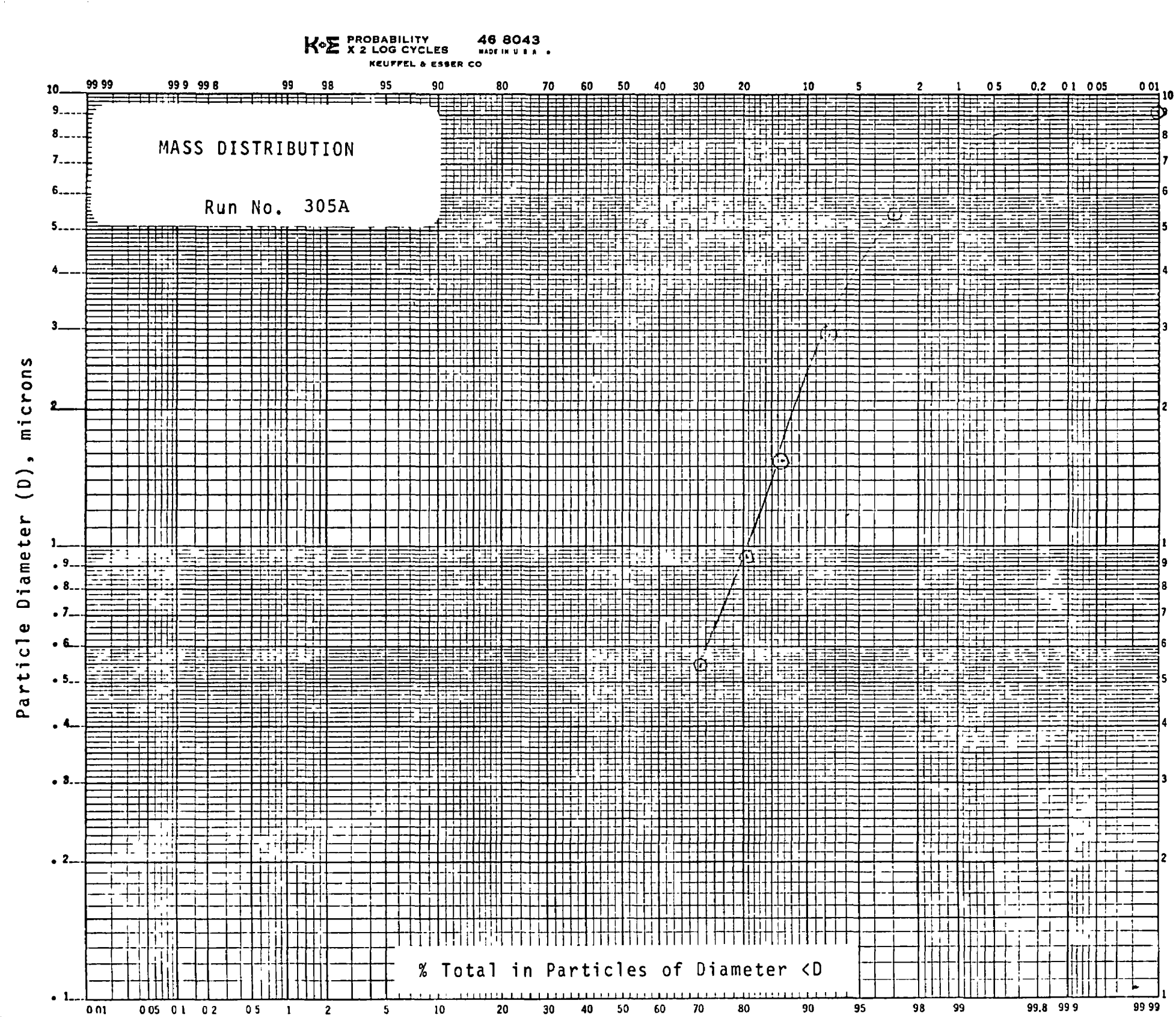
Vehicle Test No.	%C	%H	%N	PPM BAP
303A	23.90	0.45	29.43	300
303B	9.58	0.32	4.20	240
304A	24.73	0.56	24.20	200
304B	10.42	0.83	3.43	390
305A	13.10	0.94	5.22	240


K&E PROBABILITY
X 2 LOG CYCLES
KEUFFEL & ESSER CO
46 8043
MADE IN U S A
MASS DISTRIBUTION
Run No. 303A
Particle Diameter (D), microns
% Total in Particles of Diameter <D
99 99 99 9 99 8 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0 5 0 2 0.1 0 05 0 01
0 01 0 05 0 1 0 2 0 5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99 8 99 9 99 99


K&E PROBABILITY
X 2 LOG CYCLES
46 8043
KEUFFEL & ESSER CO
MASS DISTRIBUTION
Run No. 303B
Particle Diameter (D), microns
% Total in Particles of Diameter <D


K&E PROBABILITY
X 2 LOG CYCLES
46 8043
KEUFFEL & ESSER CO
MASS DISTRIBUTION
Run No. 304A
Particle Diameter (D), microns
% Total in Particles of Diameter <D
99 99 99 9 99 8 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0 5 0 2 0 1 0 05 0 01
0 01 0 05 0 1 0 2 0 5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99 8 99 9 99 99


K&E PROBABILITY
X 2 LOG CYCLES
KEUFFEL & ESSER CO
46 8043
MASS DISTRIBUTION
Run No. 304B
Particle Diameter (D), microns
% Total in Particles of Diameter <D


K&E PROBABILITY
X 2 LOG CYCLES
46 8043
MADE IN U S A
KEUFFEL & ESSER CO
MASS DISTRIBUTION
Run No. 305A
Particle Diameter (D), microns
% Total in Particles of Diameter <D
99 99 99 9 99 8 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0 5 0.2 0 1 0 05 0 01
0 01 0 05 0 1 0 2 0 5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99 9 99 99

DuPont Pinto with Pb Trap

Tube Flow Set to 420 F/Min = 550 CFM

9/13/74

Time	Dial Readings T	H	% Relative Humidity
MFCCS - 41 Min.	Run #304A		
1:18	57	13	19+
1:25	59	8	19+
1:32	59	40	21+
1:36	59	33	20+
1:50	57	55	22+
1:55	58	70	24+
2:00	59	50	22+
AMA Run #304B			
2:17	58	15	20+
2:28	59	22	20+
2:50	61	8	19+
3:10	61	6	19+
3:16	60	30	22+
4:10	60	70	27+
4:30	60	70	27+
4:42	61	18	21+
4:50	61	5	17+
5:10	61	4	16+
5:20	61	30	29+
5:28	61	2	18+
5:40	62	13	20+

Barometer 29.40
Wet Bulb 60°F
Dry Bulb 72°F
Rel. Humidity 49%

DuPont Pinto with Pb Trap

Tube Flow Adjusted to 420'/Min = 550 CFM

9/13/74

Time	Dial Readings T	H	% Relative Humidity
MFCCS - 41 Min.	Run # 303A		
1:20	62	92	32+
1:25	63	98	34+
1:30	63	85	29+
1:35	64	73	26+
1:40	64	83	30+
2:00	65	92	31+
2:10	65	90	29+
AMA Cycle	Run #303B		
2:20	60	60	29+
2:25	65	92	31+
2:35	65	60	24+
2:45	68	40	21+
3:05	66	70	25+
3:15	68	25	20+
3:30	68	70	25+
3:50	68	7	15+
4:25	67	11	18+
4:50	68	10	18+
5:30	68	17	18+

Barometer	29.30
Wet Bulb	70°F
Dry Bulb	80°F
Rel. Humidity	61%

DuPont Pinto with Pb Trap

Tube Flow Set to 420 F/Min = 550 CFM

9/16/74

Time	Dial Readings T	H	% Relative Humidity
AMA Run #305A			
12:58	60	31	22+
1:10	62	2	17+
1:18	62	2	17+
1:28	64	5	18+
1:37	64	2	17+
2:10	64	1	16+
2:43	64	1	16+
3:03	64	1	16+
3:15	65	1	16+
4:00	65	1	16+

Barometer	29.60
Wet Bulb	58°F
Dry Bulb	74°F
Rel. Humidity	36%

SAMPLE TAKEN AT 1 CFM FLOW

Run No.	Test Mode	Source	Ug Pb	Sample Weight	% Pb
303B	AMA	Plate #1	~10	0.2	~5.0
		2	<5	0.3	<2.0
		3	<5	0.4	<1.3
		4	20	0.4	5.0
		5	65	0.6	11.0
		6	45	0.5	9.0
304B	AMA	1	<5	0.1	<5.0
		2	<5	0.2	<2.5
		3	10	0.3	3.0
		4	30	0.3	10.0
		5	90	0.7	13.0
		6	12.5	0.4	3.0
305A	AMA	1	<10.0	0.2	<5.0
		2	<10.0	0.3	<3.3
		3	<10.0	0.4	<2.0
		4	20.0	0.4	5.0
		5	88.0	0.7	13.0
		6	33.0	0.4	8.2
303A	MFCCS	Millipore Filter	35.0	1.7	2.0
303B	AMA	"	360.0	6.9	5.2
304A	MFCCS	"	80.0	2.9	2.8
304B	AMA	"	425.0	4.5	9.4
305A	AMA	"	320.0	6.0	5.3

Tube Sweepings at End of All Tests 14.0

ANALYTICAL DATA

Test Report #26 Date 10/31/74

Analysis per your letter of April 23, 1974

Analysis per your note of September 10, 1974

April 23, 1974 Analysis requested

18 Samples Trace metals, Carbon, Hydrogen, Nitrogen, Sulfur (X-ray), Sulfate (Turbidometric) Bap

September 10, 1974

4 Samples, X-ray, for Sulfur, Nickel, Copper, Platinum and Pladium.

The work above was done as described in the add on to Contract 68-01-0480.

Analytical Data Requested April 23, 1974

ANALYSIS OF EXHAUST PARTICULATE

Trace Metals on Millipore Filter

MICROGRAM ELEMENT PER SAMPLE

Vehicle Test No.	Fe	Ni	Cu	Al	Ca	Mg	Mn	Cr	Sn	Zn	Ti	Rb	$\%SO_4$	Glass Fiber Filters %C	%H	%N	PPM BAP
FP47-29	8	<1	6	40	3	<3	<.5	<.5	<1	<3	<1	7					
FP47-39	10	<1	0.7	126	4	<3	<.5	<.5	<1	<3	<1	3					
FP47-55	38	<1	16.0	174	2	<3	<.5	<.5	<1	4	<1	13					
FP47-75	21	<1	3.0	200	4	<3	<.5	<.5	<1	4	1	5					
6GA47-9	4	<1	3.0	12	18	10	<.5	<.5	<1	4	<1	<3					
A47-51														77.40	7.85	2.27	
A47-49																	10
FP47-31																	27
FP47-35																	73
FP47-53																	<9
FP47-73																	<14

Analytical Data Requested April 23, 1974

Sulfur (X Ray)

Reference	Total S ug	Sample Wt. ug	%
FP47-33	1.0	2613:0	.0383
FP47-37	1.4	3978.0	.0352
FP47-57	25.0	2201.0	1.1358
FP47-79	23.0	1665.0	1.3814
GGA47-11	145.0	5381	2.6947

SO_4 (Turbidometric)

Reference	Total S ug	Sample Wt. ug	%
FP47-33	23.0	2613.0	.8802
FP47-37	34.0	3978.0	.8547
FP47-57	24.0	2201.0	1.0904
FP47-79	32.0	1665.0	1.9219
GGA47-11	220.0	5381.0	4.0885

Analytical Data Requested September 10, 1974

X-RAY ANALYSIS

Reference	Mg Weight	Values in Percent					
		S	Pt	Pd	Cu	Ni	Fe
331-75-401	1.2	3.0 ± .3	<.07	<.03	2.0 ± .4	22.0 ± 2	2.0
331-72-402	0.9	1.0 ± .1	<.09	<.04	2.0 ± .4	22.0 ± 2	---
331-60-202	0.8	11.0 ± 1	<.1	<.04	0.3 ± .06	1.0 ± .1	---
331-HE-201	0.4	9.0 ± .9	<.2	<.09	1.0 ± .2	8.0 ± .8	---