SoRI-EAS-86-467

PROCEDURES MANUAL FOR THE RECOMMENDED ARB SIZED CHEMICAL SAMPLE METHOD (Cascade Cyclones)

(Using Cascade Cyclones To Obtain Size Fractionated Samples For Chemical Analysis)

May 1986

Attachment No. 2 to the Final Report for
ARB Contract A3-092-32
"Recommended Methodology for the Determination of Particle Size Distribution in Ducted Sources"
October 1984

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NOTICE

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Foreword

Broadly speaking, one can divide the ARB current or potential needs with respect to particle sizing into three classes: (1) regulatory, including setting of emission standards and compliance testing; (2) control strategy development (emission inventories) and permitting (control device selection, etc.); and (3) basic research and development. Of course, considerable overlap exists in the types of information needed for each of these activities.

As currently foreseen, possible regulatory action on emission may take place based on one or both of two particle size classes. The first, and more likely, of these possible regulatory actions is related to the PM_{10} class (particles having aerodynamic diameters smaller than 10 µm) for which a state ambient air regulatory standard has already been set. The second class for possible action concerns fine particles, those particles having aerodynamic diameters smaller than 2.5 µm. In either case, the regulations may be chemical species and/or industry or process specific as well as particle size specific. If particle size specific regulations are set, compliance test methods would be a concomitant necessity. Development of an emissions inventory would be a preliminary activity prior to such regulatory action - such an inventory is currently being constructed within the ARB for the PM_{10} class based on such information as is now available. The number of size classes (and the resolution) required for these activities is obviously limited - only one or two size cuts are needed and relatively simple and inexpensive techniques are desirable if they are to be used as compliance tools.

Greater resolution than that needed for compliance testing is desirable for activities related to permitting. The performance of many (or most) particulate control devices can be predicted for a given source from a broad base of experimental data and models provided that the gas stream conditions and the particle size distribution of the material to be collected are known. In most cases, the critical size range for estimating the probability of achieving a required level of control in this fashion is from about 0.1 µm to 20 µm. Resolution into about eight size classes, evenly spaced in terms of the logarithm of particle diameter, over the latter range is generally sufficient. In some instances specific target chemical species are of interest which may not be homogeneously distributed with respect to particle size. In those cases, size segregated samples suitable for chemical analysis may be needed in addition to data for overall size distribution. Three to five size fractions may be adequate for this application.

The needs of the agency with respect to basic research presently fall into three areas. The first is providing support for the activities previously described; the second is the development of a data base characterizing the principal types of industrial emission in the state; and the third is concerned with particulate chemistry. At present the main concerns in the area of particulate chemistry are primarily emissions of toxic substances and substances which act as catalysts in secondary aerosol formation.

This document describes detailed procedures for using cascade (series) cyclones to obtain size fractionated particulate samples from industrial flue gases for subsequent post test chemical analysis (organics, inorganics, and trace elements). The instrumentation described collects bulk quantities (tens of grams) for each of six size fractions with nominal cuts of 6.0 μm, 2.8 μm, 1.4 μm, 1.0 μm, .42 μm, and filter. This method is not intended for use as a possible compliance method nor is it well suited for measuring particle size distributions of emissions from stationary sources. Although it might be used for either of those purposes in some situations, alternative methods which are specific to those purposes are described in companion reports (Attachments 1 and 3 to the project final report).

Abstract

This report is an attachment to the Final Report of ARB contract A3-092-32 and concerns the use of Cascade (Series) Cyclones to obtain size fractionated particulate samples from industrial flue gases at stationary sources. The instrumentation and procedures described herein are designed to protect the purity of the collected samples so that post test chemical analysis may be performed for organic and inorganic compounds, including instrumental analysis for trace elements. The instrumentation described collects bulk quantities for each of six size fractions (up to tens of grams in some fractions). The exact diameter boundaries for these size fractions depend on the actual flue conditions (temperature, pressure, gas composition, etc.) and the selected flow rate, but nominal values in units of micrometer (10^{-6}m) diameter are as follows: (1) greater than 6.0, (2) 6.0 to 2.8, (3) 2.8 to 1.4, (4) 1.4 to 1.0, (5) 1.0 to 0.42, and (6) less than 0.42 (filter catch).

Although the purpose of this method is to collect size segregated samples for chemical analysis, the same instrumentation may be used to obtain particle size distribution information. This report describes the operating principles, calibration, and empirical modeling of small cyclone performance. It also discusses the preliminary calculations, operation, sample retrieval, and data analysis associated with the use of cyclones to obtain size segregated samples and to measure particle size distributions. Sample calculations are presented and documentation is given for a microcomputer program which at the user's option may be used to perform all the calculations associated with instrument setup, operation, data reduction, analysis, and graphical presentation of size distribution information. All programs have been written for the Apple II series of personal computers. Although cyclones may be used to measure size distributions, the additional steps required to obtain the information may conflict with the main objective of obtaining clean segregated samples for chemical analysis. A different technique (cascade impactors) has been recommended as the preferred instrumentation for obtaining size distribution information. A procedures manual for the use of cascade impactors is available as Attachment 1 to the Project Final Report.

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ACKNOWLEDGEMENTS

This report was submitted in partial fulfillment of ARB Contract No. A3-092-32, "Recommended Methodology for the Determination of Particle Size Distributions in Ducted Sources" by Southern Research Institute under the sponsorship of the California Air Resources Board.

SECTION 1

INTRODUCTION

The environmental effects of particulate emissions from stationary sources depend on both the composition and particle size distributions of the emissions. Although composition information obtained from bulk samples can be used in estimating potential effects, the possibility - indeed, probability in many cases - of the composition of emissions being inhomogeneous with respect to particle size makes it desirable to have the capability of determining composition by particle size. Redispersion and separation of bulk samples might be used for this purpose; however, if all or part of the aerosol material were capable of coalescing it would be impossible to reconstitute the original size and composition distributions. Further, even in the case of dry solids, it becomes difficult or impossible to remove submicron particles from the surfaces of larger ones once contact has been made. Therefore, redispersion and subsequent partitioning by size of a bulk sample is a poor choice for the purpose. A method in which the particles are separated by size as they are collected is needed.

Two forms of inertial particle size separators are commonly used in source sampling - cascade impactors and cyclones. Impactors have a number of advantages for use in measuring particle size distributions and have been recommended the CARB for that purpose. But they are not well suited for providing samples for chemical analysis. The quantities of material that can be collected on an impactor stage are limited to a few milligrams at most and many stages in an impactor sample will have catches of only fractions of a milligram. (The fact that only small amounts of material can be collected is no problem in a size distribution measurement. In fact, the need to collect only small amounts can be advantageous because it reduces the time required to do the sampling.) Omission of stages in impactors frequently results in operational failures because of particle bounce so that approach cannot be used to reduce the number of fractions and increase catch sizes. Moreover, the adhesives or surface coatings used for particle retention in impactors can result in intolerably high backgrounds and/or interferences. Cyclones, on the other hand, do not suffer problems from particle bounce or retention, have capacities of the order of grams, and require no surface coatings which might lead to interferences. Therefore, they were recommended as the means to obtain size fractionated samples for chemical analysis. Cyclones may also be used to good advantage for measuring particle size distributions when the particulate concentration in the stream to be sampled is very high. In such circumstances cascade impactors which are normally used for size distribution measurement may be impractical for the application because of too rapid overloading.

The use of cyclones is not without drawbacks. First, particulate catches are frequently distributed over rather large surface areas within the cyclone, making sample recovery difficult, especially if the recovery is to be sufficiently complete that the data can be used reliably for concentration measurement. This is not a problem if the catches are large, but long sampling durations may be required to obtain them. Second, current theories on cyclone operation are rudimentary at best, and none do well in predicting cyclone performance from geometrical and flow considerations. Therefore, extensive calibrations are needed so that good empirical relationships can be developed for use in calculating the sizes of the collected particles. This results in less flexibility in construction and operation being available to the user than is the case with impactors.

Target cutoffs for particle size fractions for chemical analysis were set as follows: A cut at or near a diameter of ten (10) micrometers was desired to provide samples which conform to the PM10 ambient air standard. Isolation of the fraction commonly designated as respirable suggests that a cut near 2.5 to 3 micrometers is desirable. Isolation of the one (1) micron and smaller fraction was desired by researchers working in the field of catalytic effects in the atmosphere, and finally, a cut near 0.25 micrometers was suggested since many combustion aerosols contain a sub-micron mode in their distributions which is known to differ chemically from the remainder of the material and which almost always falls below that size. The sampler which most nearly met these specifications was the SoRI/EPA designed Five Series Cyclone. These cyclones are available commercially from a number of manufacturers both in and out of the United States.

SECTION 2

DESCRIPTION OF THE SAMPLER

The design goal for the SoRI/EPA Five-Stage Cyclone Sampler (Smith and Wilson, 1978) shown in Figure 1 was five equally spaced particle size cuts (D_{50}) on a logarithmic scale within the range of 0.1-10 μm. This in situ sampling system operates at a nominal sample flow rate of 28.3 L/min (1 ACFM), and is compact enough to fit through a 10 cm (4 inch) diameter port. The sampler consists of five cyclones and a backup filter connected in series. Since the backup filter is a separate unit, either a flat filter mat can be used or, in the case where there is a large percentage of fine particulate present, a thimble filter. The first of the five cyclones, Cyclone SRI-I (which separates the large fraction of particulate matter from the gas stream), accepts a range of nozzles to facilitate isokinetic sampling. The Sampler is available commercially from at least two U.S. vendors, Andersen Samplers Inc. and Intox.

The standard material of construction is 316 stainless steel. Other materials such as titanium (alloy 6AL-4V) or Hastelloy (X) may be used where either low weight or high temperature operation is required. Some special applications may require the use of flanges or some other device for connecting the parts rather than threads. For those applications, the outside dimensions can vary without affecting the collection characteristics provided that flow into the nozzle is not disturbed and critical interior dimensions are unchanged. To avoid flow disturbance, short nozzles should not be used.

The critical, internal dimensions of a cyclone are illustrated in Figure 2. These are critical because a change in any one of them may affect the operational characteristics of the cyclone (with the exception of H_{cup} and D_{cup} for some designs). The thickness of the gas exit tube wall is not expected to be critical as long as it is small compared to the diameter of the tube. Since there is no cyclone theory that analytically describes the performance of a small cyclone as a function of the critical dimensions, it is necessary to hold close tolerances during manufacture. Cyclones II through IV are all of conventional design; however, in Cyclone I the gas exits through a tube which extends up through the bottom of the catch cup and cyclone body into the normal exit tube. The normal exit tube is then blanked off flush with the top of the cyclone. Because the effect of a degraded surface finish on the performance of the cyclones is not known, the internal surfaces should be maintained to the smoothness of finish provided by the manufacturer.

Two versions of Cyclone IV have been made and calibrated. The original prototype (IV proto in Figure 2) is the version described by Smith and Wilson (1978). Problems with bridging and plugging of the hopper inlet led to a modified version with a shorter cone and large hopper opening being made. The latter, identified in Figure 2 as IV Comm., is the version which is produced by the commercial vendors.

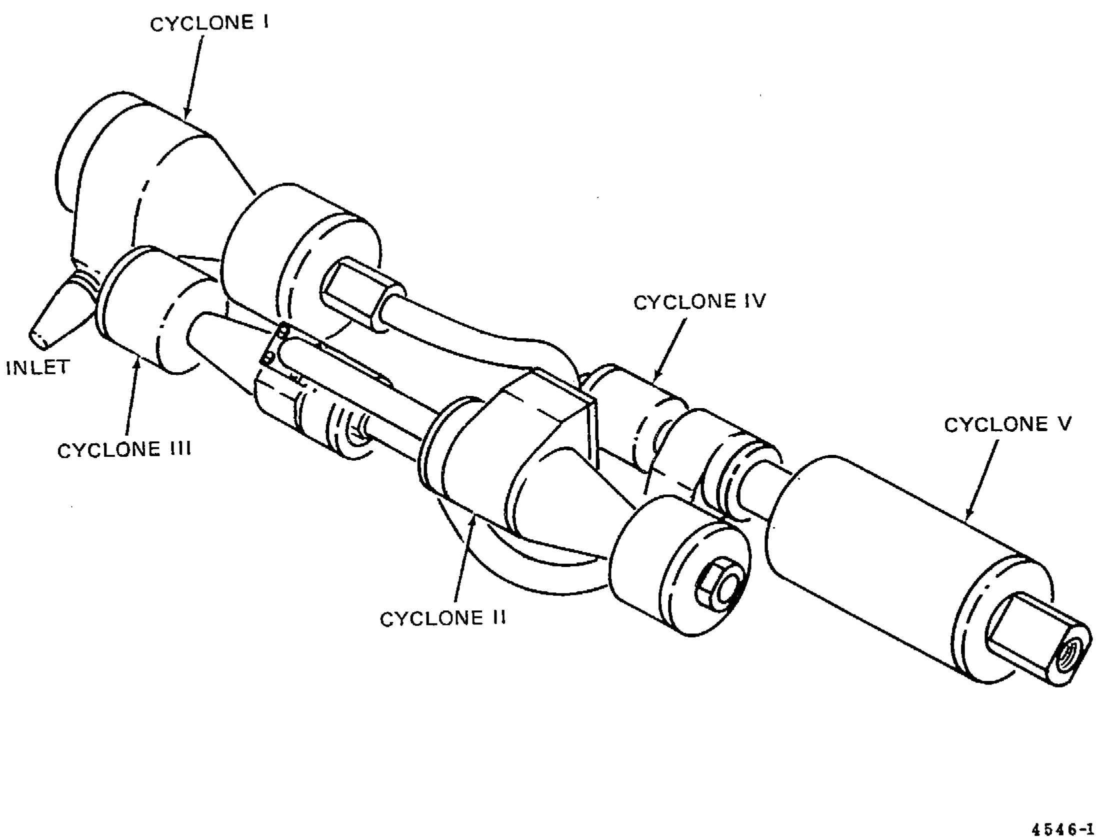
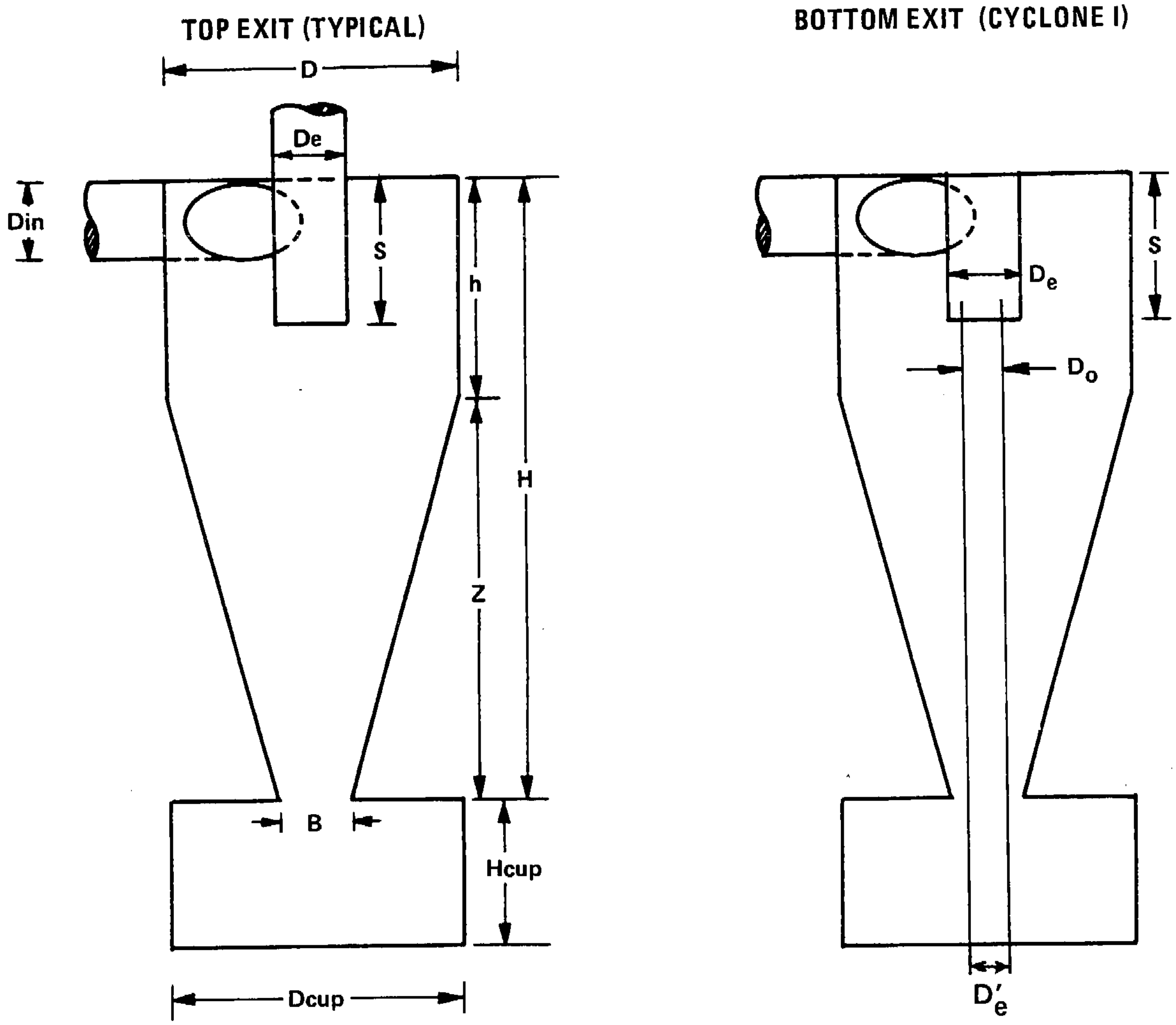


Figure 1. Environmental Protection Agency-Southern Research Institute Five-Stage Cyclone.

CYCLONE DIMENSIONS



CYCLONE DIMENSIONS

CYCLONE	Din (cm)	RELATIVE TO Din, dimensionless										
		D	De	B	H	h	Z	S	Hcup	Dcup	D'_e	D_o
I	1.27	3.52	1.4	1.48	5.47	1.76	3.71	1.24	1.77	3.50	0.80	0.98
II	1.01	3.62	1.04	1.28	6.75	2.09	4.66	1.55	2.20	3.69	–	–
III	.75	4.15	1.11	1.01	6.55	1.87	4.68	1.44	2.96	4.13	–	–
IV PROTO.	.51	4.98	1.16	1.00	6.51	2.02	4.49	1.14	4.35	5.14	–	–
IV COMM.	.51	4.98	1.16	2.14	5.15	2.02	3.57	1.14	4.35	5.14	–	–
V	.30	5.07	1.2	2.8	5.87	1.57	4.3	1.43	7.93	5.3		

Figure 2. The critical internal dimensions of the cyclones.

The cyclones are designed to provide a leak-free system when used with proper o-ring seals. Viton is preferred if the samples are to be analyzed for organic compounds. However, other materials such as silicone may be used. Metal o-rings composed of Inconel X-750 are recommended for very high temperature operation. Care should be taken when ordering o-rings to insure the dimensions are proper for good seal.

SECTION 3

OPERATING PRINCIPLES, CALIBRATION, AND EMPIRICAL MODELS

Cyclones are forms of centrifugal particle collectors in which the circulation of a particle laden gas stream about a central axis is induced by conversion of forward motion through the cyclone inlet. The gas enters through the inlet tube from whence it passes into the cylindrical body of the device. Here it acquires a spiral motion, descending along an outer spiral toward the base of the cyclone for some distance; it then undergoes an abrupt change of direction and continues upward to and through the exit tube. The length of the exit tube is made great enough that the gas does not simply "short-circuit" the intended flow path and flow directly from the inlet to the outlet tube. The flow in the central core of the cyclone, after the gas has turned upward, may proceed in a tighter inner spiral, or may flow in a rectilinear path to the outlet tube. The latter is believed to be the case when the Reynolds number of the flow in the outlet tube is low (Ayer and Hochstrasser, 1979). Large particles, because of their inertia, will tend to cross the curving flow streamlines and thus drift towards the wall of the cyclone body where they become disentrained upon contact. Additional separation may take place by impaction on the wall opposite the inlet and at the bottom of the outer spiral where the reversal in flow direction occurs (Fuchs, 1964).

The flow field within a cyclone is highly complex and cannot be modeled in two dimensions as has been done for impactors. Generally, the flow consists of a double spiral with the outer spiral moving down and the inner moving up to the exit tube. The flow pattern within a cyclone can, under some conditions, be unstable; resulting in two possible operating pressure drops and efficiency curves for a given flow rate (Hochstrasser, 1976). This may be indicative of transitions from operation with the core flow forming an inner spiral to a mode in which the core flow becomes laminar and rectilinear (Ayer and Hochstrasser, 1979). There is also evidence that the particle collection characteristics can be significantly influenced by flow perturbations located downstream of the exit tube (Knight, 1976). The lack of a complete understanding of the flow fields within cyclones makes it very difficult to accurately predict their performance on the sole basis of information concerning geometry, flow rate, and gas properties. A number of theories have been developed based upon simplified models (Rosin et al., 1932; Davies, 1952; Lapple, 1951; Leith and Licht, 1972; Soo, 1973; Dietz, 1981). Some of these models could be made to reproduce the shape of measured cyclone efficiency curves reasonably well, but these all relied upon the adjustment of empirical constants to make the calculated curves match the measured data. For small sampling cyclones the agreement between predicted and measured performance was never very good for theoretical models which did not use adjustable constants.

Typically the theories are based on the classical equations for centripetal force and include additional terms to account for viscous drag on the particles, turbulence, and particle exchange between the outer and inner vortices. The models then usually attempt to relate the cyclone efficiency to cyclone dimensions, flow rate and aerosol properties. The behavior is normally expressed in terms of the D_{50}, the diameter for which the collection efficiency is 50%. One of the more widely used equations, that of Lapple, is

$$D_{50} = \left(\frac{9 H_c B_c^2 \mu}{2\pi N e \rho Q} \right)^{1/2}$$

where

H_c = height of the cyclone inlet,
B_c = width of the cyclone inlet,
D_{50} = the particle diameter at which the efficiency is 50%,
μ = the gas viscosity,
Ne = the number of turns made by the gas stream in the outer spiral,
ρ = the particle density,
and Q = the volumetric flow rate.

The gas viscosity is a function of the gas composition and temperature so that, with the exception of Ne, the D_{50} is given in terms of easily measured variables: gas composition, gas temperature, flow rate, particle density, and cyclone dimensions. Unfortunately, the number of turns made by the gas stream within the cyclone is difficult to measure, may not be a constant for a given cyclone, and, at present, is impossible to predict (with sufficient accuracy to be useful), from the cyclone geometry and flow.

Leith and Licht's theory results in the following equation for cyclone D_{50}s:

$$D_{50} = \left[\left(\frac{18 D B_c H_c}{E\ (1+n)}\right) \left(\frac{\mu}{\rho Q}\right) (\ln\sqrt{2})^{2n+2} \right]^{1/2}$$

where

D = the cyclone diameter,
E = a coefficient which depends solely on the cyclone geometry, and

$$n = 1 - \left(1 - \frac{(0.394 D_c)^{0.14}}{2.5} \right) \left(\frac{T}{283}\right)^{0.3}$$

where

T = the gas temperature in degrees Kelvin.

This equation includes the same $\sqrt{\mu/\rho Q}$ term as did Lapple's equation, but has another temperature dependent term, n, in addition to the gas viscosity. The $\sqrt{\mu/\rho Q}$ term results in the predicted D_{50} increasing as the square-root of viscosity, which itself increases with temperature. The effect of n is to cause a further increase in the D_{50} with increasing temperature above that which would result from the increased viscosity alone. For cyclones of the sizes of interest here, the effect of n is to cause an additional increase in the calculated D_{50}s by amounts ranging from zero to about twenty percent as the temperature is increased from 10 to 250 degrees Celsius.

All of the theoretical models developed to date result in the term $\sqrt{\mu/\rho Q}$ being the dominant factor in calculating the cyclone performance. Thus all models result in the D_{50} having an inverse square-root of flow rate dependency. Chan and Lippmann (1977) showed that this flow rate dependency did not hold for many small sampling cyclones. In fitting an equation of the form $D_{50}=kQ^n$ to experimental data, they found n to lie between -.636 and -2.13 for several cyclones. Similarly Smith and Wilson (1977) reported values of ranging from -.63 to -1.11 for the SoRI/EPA Five-Stage Cyclone set. Figure 3 illustrates the D_{50}-flow rate relationships reported by Chan and Lippmann and Smith and Wilson. Based on data taken with air in the temperature range from 20 to 200 degrees Celsius, the latter authors found the cyclone D_{50} exhibited a more nearly linear than square-root dependence on viscosity. Thus the theoretical models are found to be deficient in predicting the forms of the dependencies on the gas conditions and flow rates.

As a consequence of the inadequacies of current theories, empirical models based on fits to measured behavior have become the basis for calculation of cyclone performance. Beeckmans (1979) concluded that the collection efficiency (by particle size) of a cyclone is related to the particle Stokes number, Stk, and the Reynolds number, Re, of the flow. For the cyclones which he studied, he found that the collection efficiency, expressed in transfer units, could be well represented by an equation of the form

$$N_t = a_o + a_1 \ln Re + a_2 \ln Stk$$

where

N_t = the number of transfer units,

= -ln (penetration)

and

a_o, a_1, and a_2, are regression constants and the penetration is the fraction of the particles passed by the cyclone.

Stk and Re in the equation are given by:

$$Stk = \frac{\rho_p C \upsilon d^2}{9 \mu D}$$

and

$$Re = \frac{4 \rho_g Q}{\pi \mu D}$$

where

ρ_p = the density of the particle,

C = the Cunningham slip correction (C is dependent of the size of the particle relative to the mean free path of the gas molecules and is described in Section 7),

υ = the gas velocity at the cyclone inlet,
d = the particle diameter,
D = the cyclone inlet diameter,
μ = the gas viscosity,

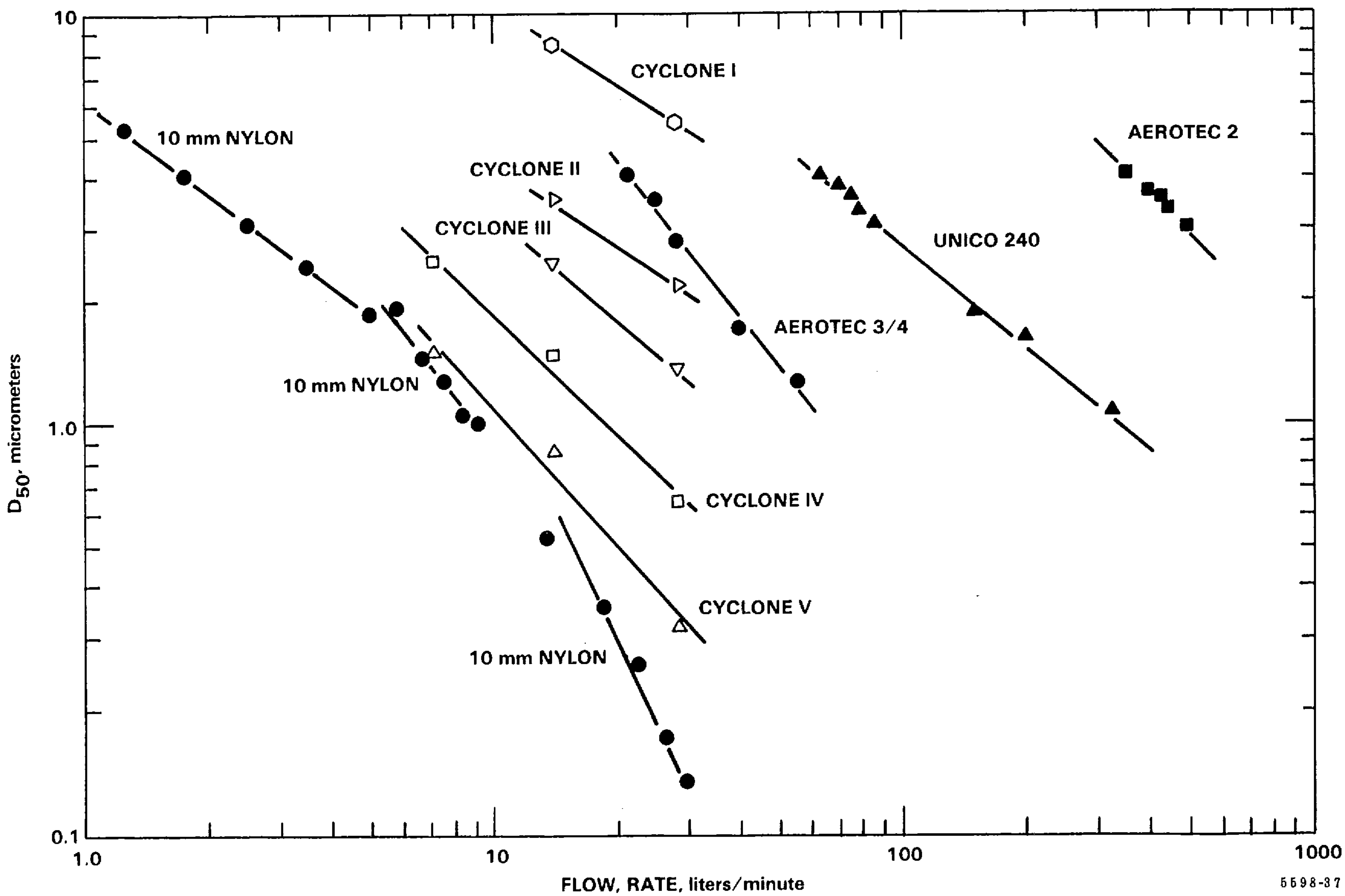


Figure 3. D_{50} vs. flow rate for Cyclones I through V at flow rates of 7.1, 14.2, and 28.3 L/min, a temperature of 25 °C, and for a particle density of 1.00 g/cm^3 (Smith and Wilson, 1979). Other cyclone data from Chan and Lippman (1977).

ρ_g = the gas density,

and

Q = the total volumetric flow rate.

Thus the value of Stk for a collection efficiency of 50% becomes a function of Re. Note, Stk and Re can also be defined in terms of the exit tube diameter and in some contexts it may be more appropriate to do so.

Similarly, Saltzman and Hochstrasser (1983) found that the D_{50}s of eighteen small cyclones could be calculated from an equation of the form

$$\log (D_{50}/D_e) = \log K_d + m \log (\frac{R_e}{1000})$$

where

D_e = the diameter of the cyclone exit tube,

K_d = a dimensionless constant characterizing each cyclone

and

m = an empirical constant.

In their study, the performance measurements were made using air at laboratory conditions. Saltzman and Hochstrasser concluded that a single value of m, -0.713, could be used to describe the behavior of all eighteen cyclones studied. The values of K_d for seventeen of the eighteen cyclones were quite close to one another, falling in the range 0.0002 to 0.00026.

A laboratory study conducted by Lee et al. (1985) revealed that the D_{50}s of four other small sampling cyclones were highly correlated with Re. On the other hand, they found that with Argon as the carrier gas, the D_{50}s of the cyclones decreased as compared to D_{50}s for air in spite of the higher viscosity of Argon, as shown in Figure 4. This behavior was contrary to the increase in D_{50} attributed by Smith and Wilson to increased viscosity in air at elevated temperature. Three of these cyclones were from the SoRI/EPA Five-Stage Cyclone set. In the study by Lee et al., the D_{50}s of the cyclones were measured over a range of flow rates using both air and argon as carrier gases. By using different gases, variations in viscosity and Reynolds numbers could be achieved independently of variations in flow rate. The results of the study indicated that gas density as well as viscosity has a strong influence on cyclone D_{50}s.

Additional calibrations of the Five-Stage Cyclone Sampler have been carried out at Southern Research Institute (Farthing, 1985). These calibrations were carried out over a wide range of flow rates with air, helium, carbon dioxide, and argon as carrier gases. Again, the use of gases other than air permitted independent variation of flow rate and Reynolds number. The results of these calibrations are shown in Figures 5 through 10. The earlier calibrations reported by Smith and Wilson (1979) have also been incorporated in these figures. From these figures one can see that the particle Stokes number for 50% collection can be determined for each cyclone from the Reynolds number

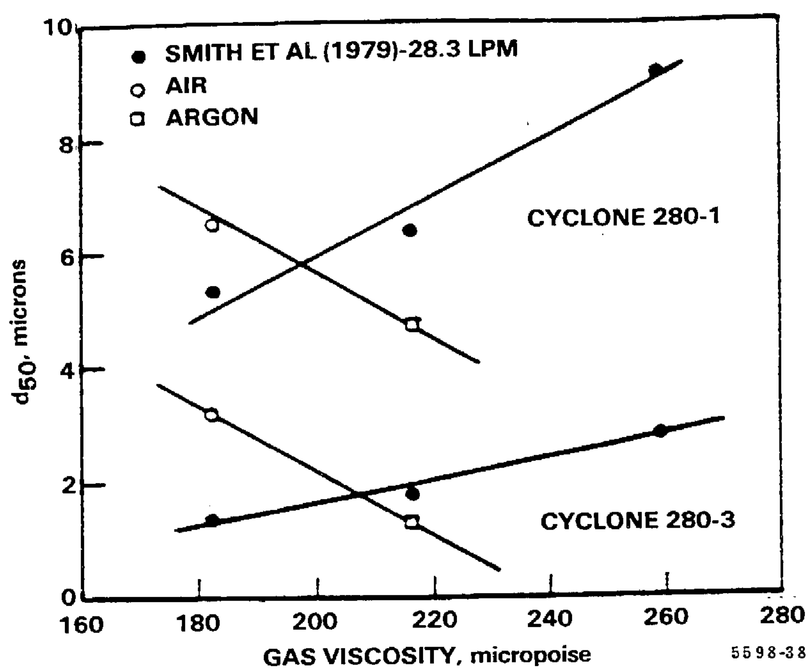


Figure 4. Particle cut diameter vs gas viscosity. (Lee, et al., 1985)

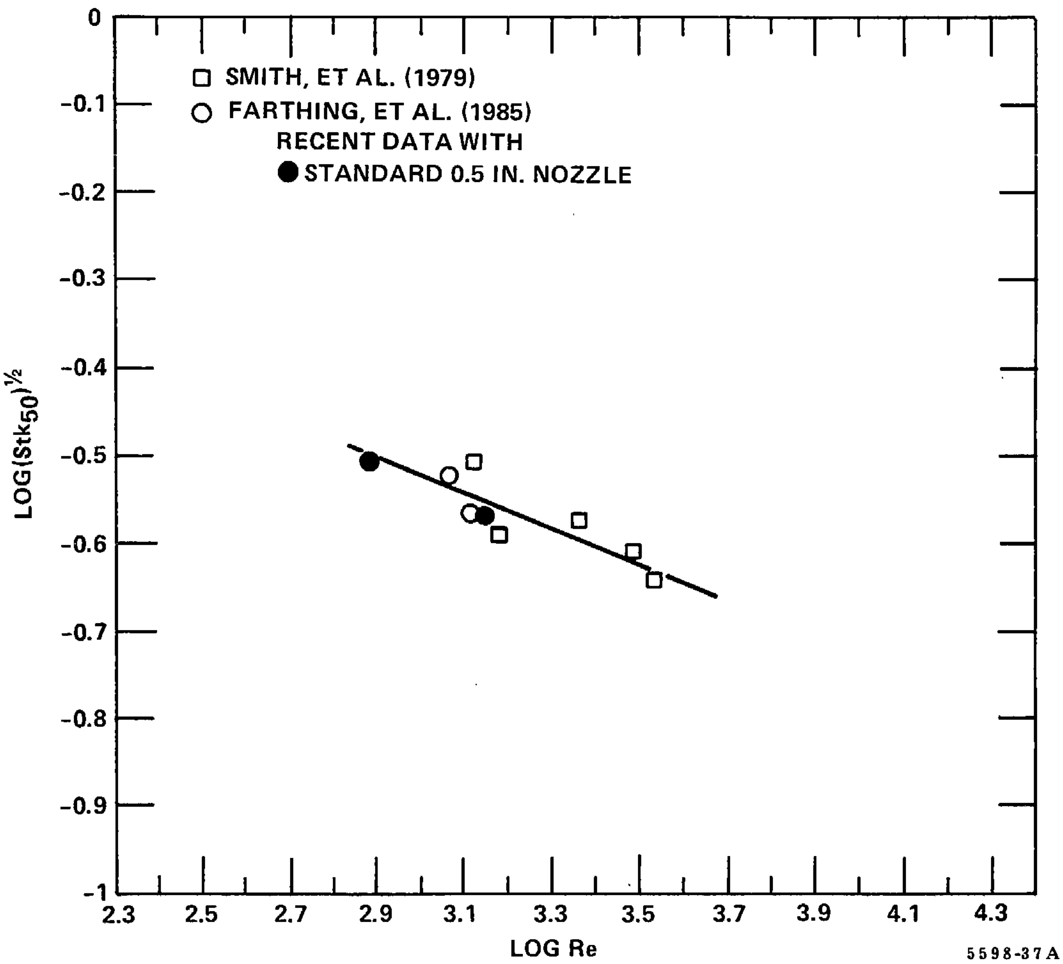


Figure 5. Calibration data for Cyclone I of the five-stage cyclone sampler. Data from Smith and Wilson (1979), Farthing, et al. (1985) and unpublished data from this contract. (Air only, variable temperature and flow rate).

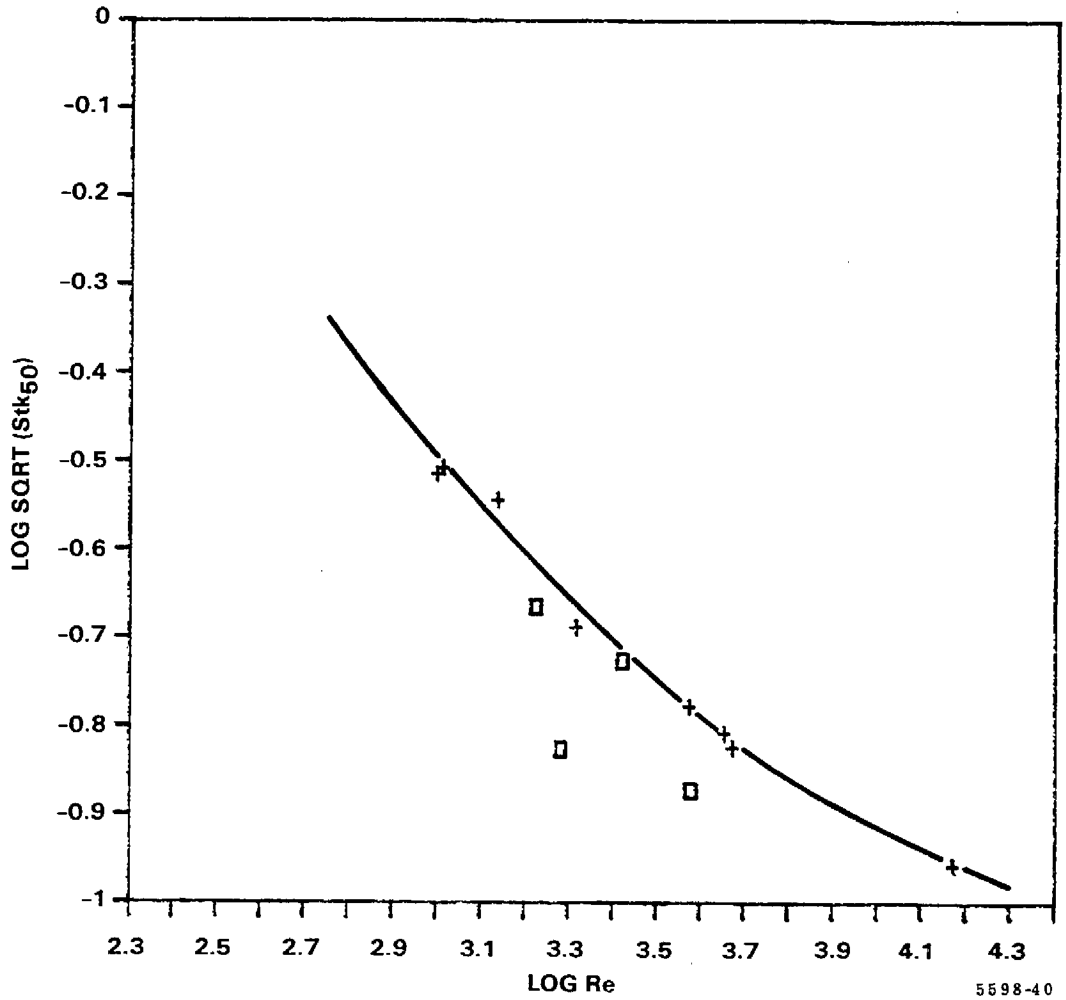


Figure 6. Calibration data for Cyclone II of the five-stage cyclone sampler. □—data from Smith and Wilson (1979), air only, variable temperature and flow rate. +—data from Farthing (1985), air, CO_2, Argon, and Helium, laboratory conditions, variable flowrate.

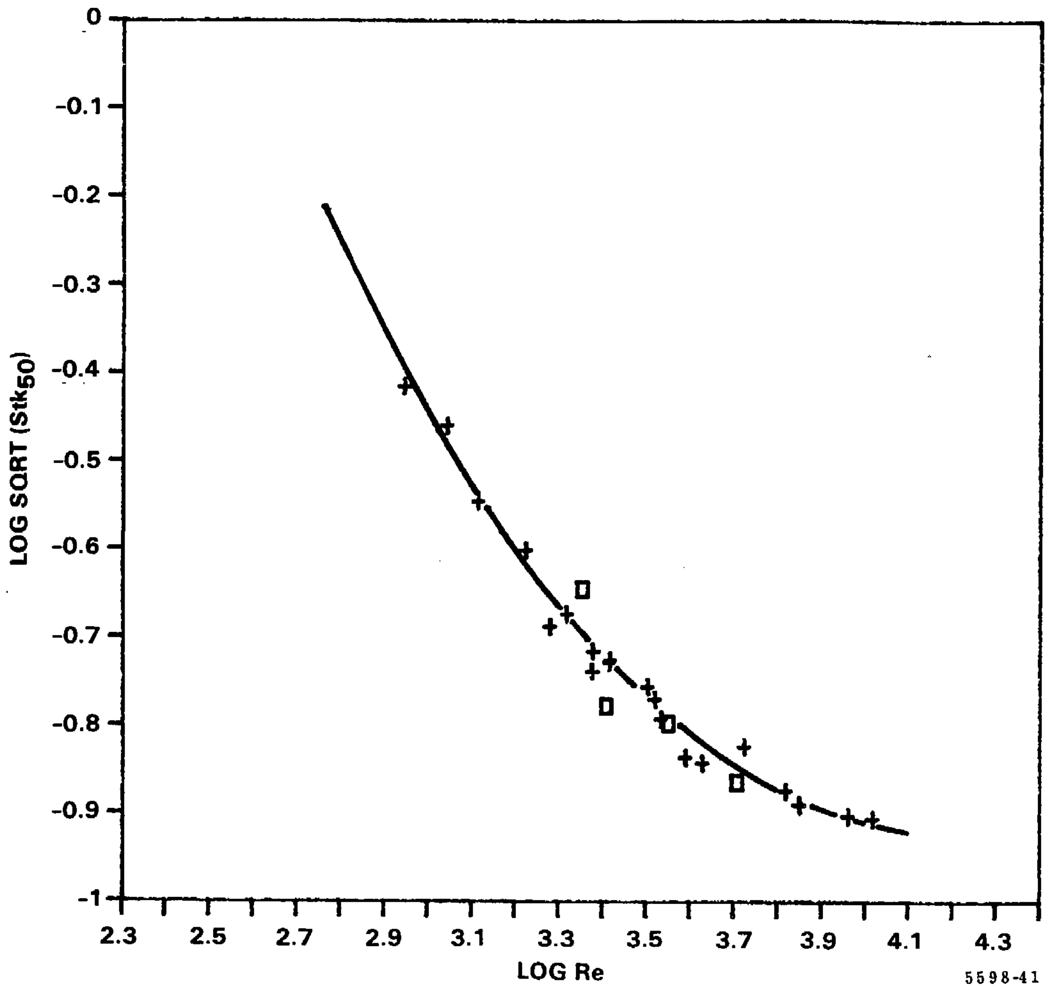


Figure 7. Calibration data for Cyclone III of the five-stage cyclone sampler. □ —data from Smith and Wilson (1979), air only, variable temperature and flow rate. + —data from Farthing (1985), air, CO_2, Argon, and Helium, laboratory conditions, variable flowrate.

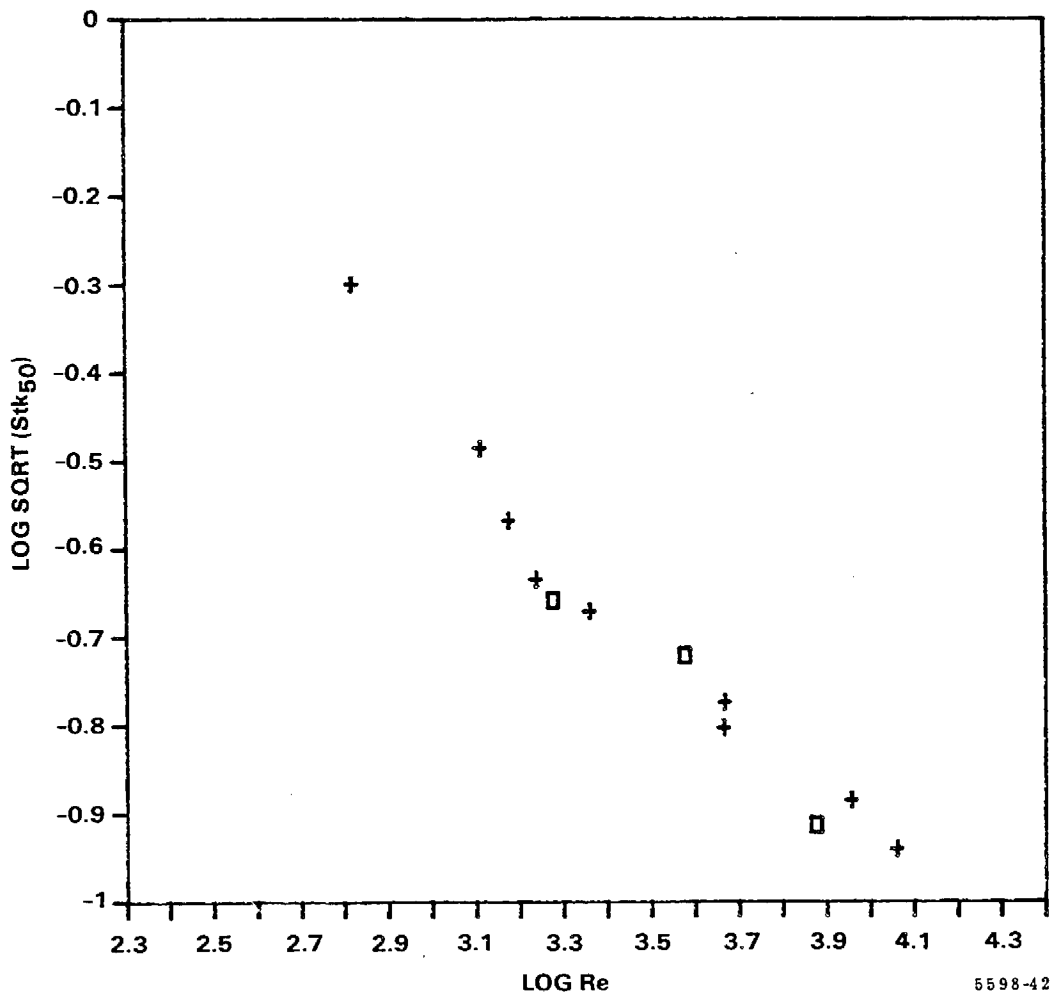


Figure 8. Calibration data for prototype Cyclone IV (IV proto.) of the five-stage cyclone sampler. □ - *data from Smith and Wilson (1979), air only, variable temperature flow rate.* + - *data from Farthing (1985), air, CO_2, Argon, and Helium, laboratory conditions, variable flowrate.*

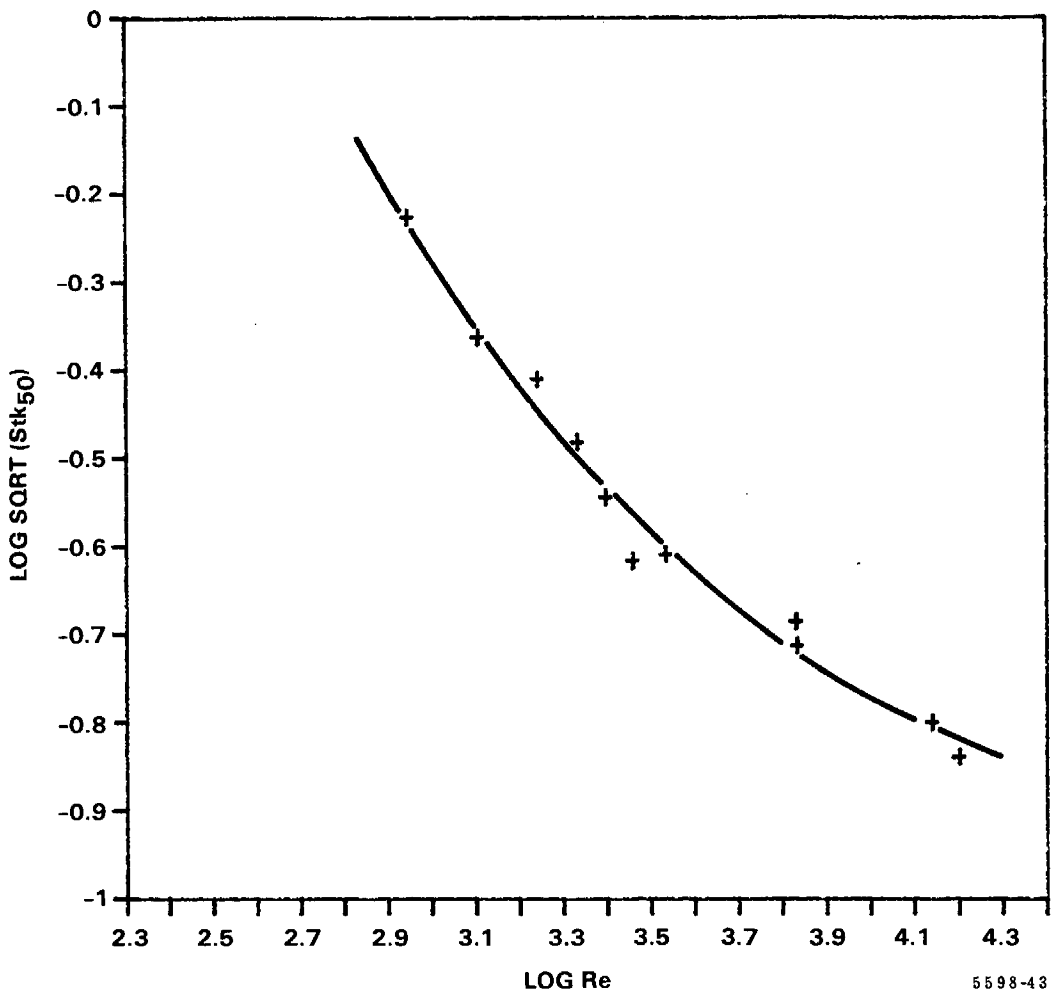


Figure 9. Calibration data for commercial Cyclone IV (IV comm.) of the five-stage cyclone sampler. □ - data from Smith and Wilson (1979), air only, variable temperature and flow rate. +- data from Farthing (1985), air, CO_2, Argon, and Helium, laboratory conditions, variable flowrate.

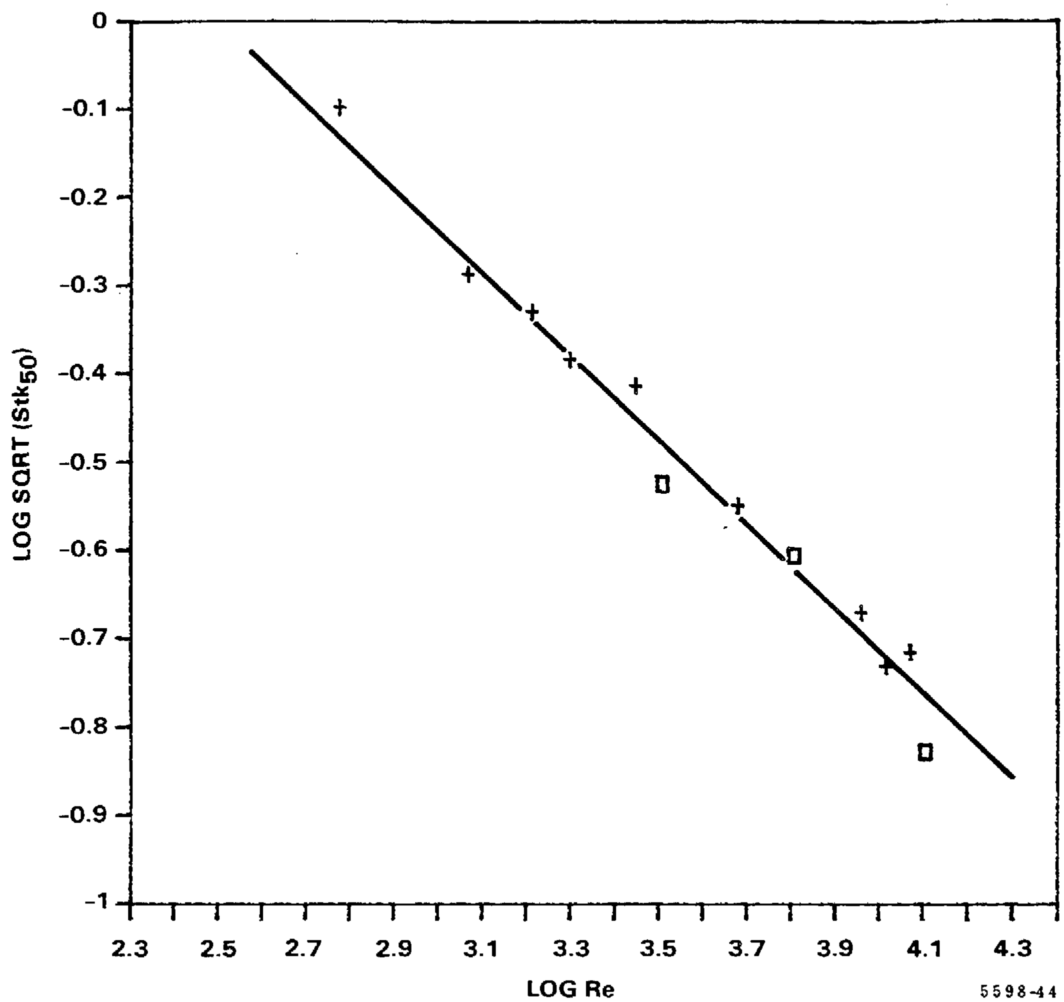


Figure 10. Calibration data for Cyclone V of the five-stage cyclone sampler. □—data from Smith and Wilson (1979), air only, variable temperature and flow rate. +—data from Farthing (1985), air, CO_2, Argon, and Helium, laboratory conditions, variable flowrate.

of the inlet flow. A similar set of curves would have been obtained had the outlet Reynolds number been used instead of that for the inlet. The exit tubes of these cyclones are only slightly larger in diameter than the corresponding inlet tubes (4 to 18 percent), so the outlet Reynolds numbers would only be slightly lower than those calculated for the inlet. It is worth noting that the data for each cyclone can be represented by a smooth continuous curve or, almost equally well, by two straight line segments. If two line segments are used, the transition point between the two would be located at a Reynolds number near 2000. The location of the break point is thus consistent with the change in the behavior of the core flow postulated by Hochstrasser.

In order to make use of the calibration data in the analysis of field samples, a mathematical relationship must be established between Stk_{50} and Re. A satisfactory fit to the calibration data was obtained for each cyclone using an equation of the form:

$$\ln \sqrt{Stk_{50}} = C + A\ (\ln Re) + B(\ln Re)^{1/2}$$

where A, B, and C are regression constants based on a least squares fitting procedure. Values of A, B, and C and their standard errors (SE) are given below:

Cyclone	A	SE	B	SE	C	SE
I	-0.197	0.054	-	-	.156	0.408
II	1.982	0.665	-13.596	3.786	20.894	5.372
III	4.732	0.604	-29.370	3.422	43.462	4.841
IV	2.841	0.820	-18.929	4.719	29.494	6.768
V	-0.472	0.016	-	-	2.707	0.135

The fits result in the following error ranges in reproducing the calibration results.

	Error	
Cyclone	Minimum	Maximum
I	-7	+10
II	-4	+8
III	-7	+7
IV	-12	+9
V	-6	+6

These fitting equations have no known underlying physical basis and simply represent a means of using the calibration data for performance prediction. Caution should be exercised in using the fits to extrapolate beyond the range of the Reynolds numbers in calibration data for each cyclone. The lines drawn in Figures 5 through 10 show the values obtained from the curve fitting equations.

SECTION 4

PRETEST OPERATIONS

4.1 CLEANING, INSPECTION, AND ASSEMBLY

The interior surfaces of each cyclone should be inspected for quality of finish and for defects due to corrosion, scouring, or deformation. The o-ring grooves and mating surfaces should be flat and smooth and have no transverse scratches. Certain concentric scratches from machining tools are allowable if they do not affect the leak-seal integrity of the cyclone. The o-rings should also be inspected for dents, cracks, scratches, and deformation. Nicked or bent o-rings should be replaced. Metal o-rings should last several tests, depending on the test conditions, but the pliable silicone or viton o-rings, especially those in the back-up filter or thimble holder may need to be replaced after each run. The filter holder should be cleaned between each run. The nozzles should be cleaned and inspected for dents on the rim of the nozzle. Large dents that cannot be straightened by hand tools may require the nozzle rim to be re-machined.

Before using the sampler, it should be cleaned with a mild detergent in an ultrasonic bath, rinsed with distilled or dionized water, and dried. All the internal surfaces must be cleaned. Any surface which comes in contact with the sample gas is considered an internal surface. If analysis for organic compounds is to be done, additional rinses of all the internal surfaces with an organic solvent such as methylene chloride should be made. Teflon wash bottles should be used to hold the solvent during the wash procedure. All glassware to be used during the wash should be thoroughly cleaned and rinsed with the solvent.

A complete second rinse of each cyclone with the chosen solvent is recommended prior to taking the cyclone set into the field. An analysis of this rinse should be made to insure the absence of contaminants in the cyclones. At the same time, this preliminary rinse analysis serves as a check that appropriate cyclone cleaning procedures were used. This rinse should be performed long enough in advance of the field test that any action dictated by the results of the analysis may be carried out.

The internal surfaces of each cyclone (i.e., the body underneath the cap, the outside of the gas exit tube, the inside walls, and the underside of the body) should be rinsed with the solvent and the wash collected in a clean glass beaker. For each cyclone the inside of the gas exit tube and the connecting tubing should be rinsed together with the downstream cyclone. Metal or viton o-rings should be washed and rinsed as described above but their solvent rinse should not be included with the cyclone rinse. The collected rinse should be stored in glass bottles with Teflon caps and labeled with the appropriate cyclone I.D. After completion of the rinse procedure, the cyclone set should be assembled and sealed with Saran wrap or aluminum foil to prevent contamination during transport to the field site.

The sampler should be assembled as shown in the assembly drawing, Figure 1. The proper nozzle and filter holder should be selected and attached to the sampler at the appropriate places. Threads should not be coated with anything (such as thread lubricant) which could contaminate the sample. Before the sampler is used in the field, the threads can be silver or chromium plated to plated to prevent galling. Sealant is not needed for the threads on the nozzle; the metal-to-metal seal is sufficient. Teflon tape may be used, if temperatures permit, as a sealant and thread lubricant on any tapered pipe threads and screw-together parts.

Once the cyclone set has arrived at the field test site, a blank wash of the set should be performed using the desired solvent prior to any test runs. This blank wash should be performed in the same manner as the wash procedure described previously.

4.2 GAS VELOCITY AND ANALYSIS

The results of a velocity traverse, stack gas temperature measurement, and gas analysis are used to determine testing parameters such as flow rate and nozzle size.

The velocities and temperature in the flue, as well as the static pressure in the flue, should be measured. An extra effort should be made to obtain the point velocities at the proposed sampling points if those suggested in Section 5 are to be used. If possible, velocity fluctuations at those points should also be noted. If the velocity fluctuations are so large that ±20% isokineticity cannot be maintained, alternate sampling positions should be selected, if possible, where the velocity is more stable. It should be noted that the flow rate through the sampler must be constant.

A gas analysis should be performed to determine the composition (molecular weight) of the gas, including the amount of water vapor. The molecular weight of the gas can then be accurately determined for viscosity and flow rate calculations. Supplemental heating of the sampler may be needed if the gas temperature is near the dewpoint or if the gas is saturated. It may be acceptable to use an estimation of the flue gas composition based on previous tests. This is especially true if this particular source has been tested often. In such a situation, an estimate of the gas composition for the purpose of determining the gas viscosity is appropriate.

4.3 SAMPLING TIME

The length of time required to collect an adequate sample is dependent upon the mass loading of the aerosol, the size distribution of the particles, the flow rate of the sampler, and the amount of material needed for the analyses to be performed. If the results of a mass test are available, the mass loading can be obtained from them. If not, an estimate should be made based on the pre-test survey or other available information. Given the mass concentration, an estimate of the sampling time for initial tests can be obtained from Figure 11. Results from the initial tests can then be used to more accurately establish the optimum sampling time. The curves in the figure are based on collecting a one-gram sample. If more or less material is needed, the user should adjust the sampling time as appropriate.

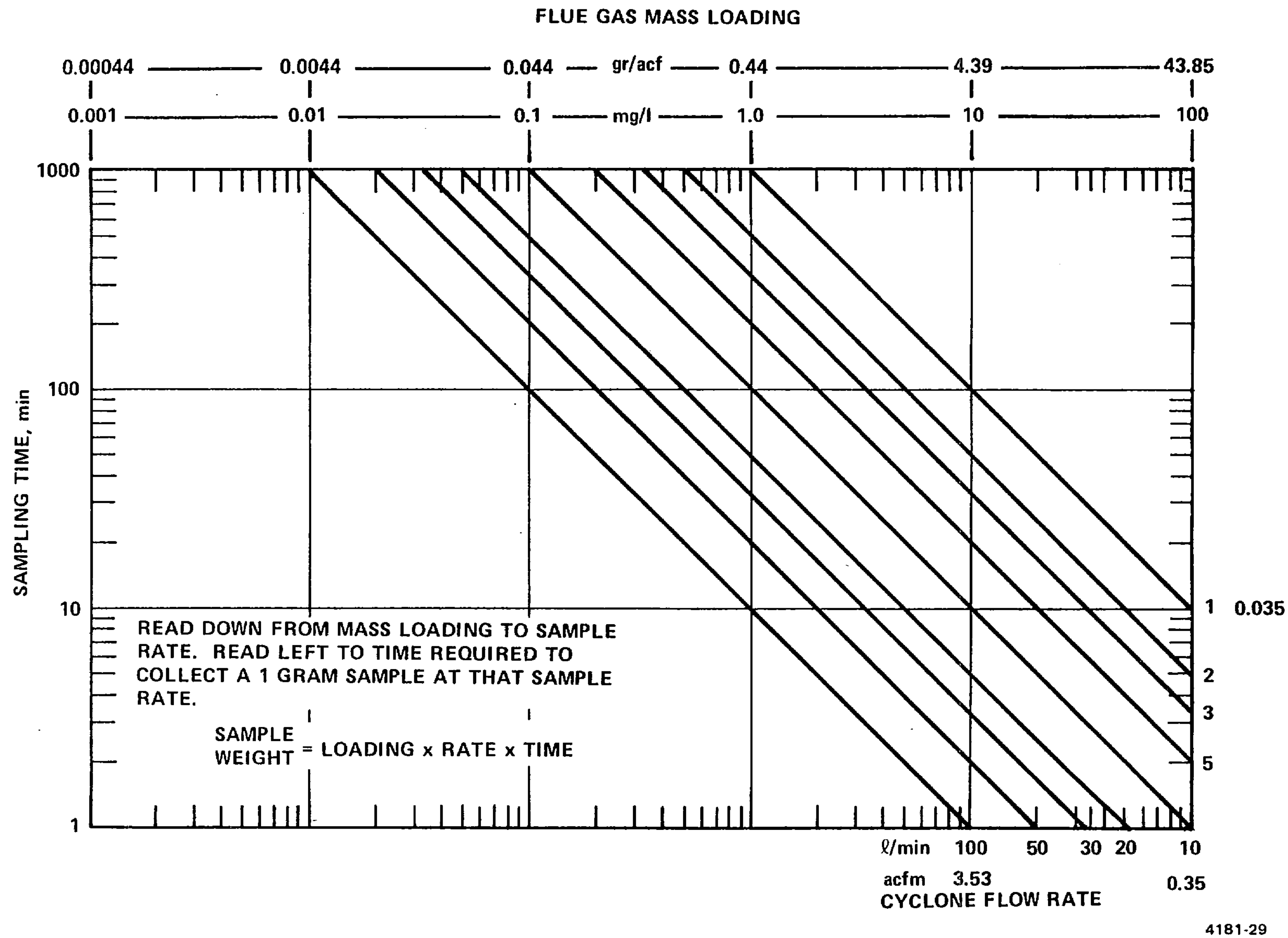


Figure 11. Nomograph for selecting proper sampling duration.

4.4 BACK-UP FILTER

The selection of the back-up filter should be made according to the size distribution of the aerosol, mass loading, flow rate, amount of sample required, and the type of analysis which will be performed. If a large fraction of the aerosol is fine particulate, a flat filter will blind before the cyclones have collected adequate samples. In such cases, a thimble should be used. Similarly, if the mass loading is high, a thimble should be used to allow longer run times so that well integrated samples can be obtained. If either the mass or the amount of fine particulate is low, a flat filter should be used so that weighing errors will be minimized. At times, it may be advantageous to use a final filter during only a portion of the total sampling time.

Glass filters may react with constituents in the gas stream (especially SO_x), and the filter could lose or gain weight (Felix, et al., 1977). This weight change due to flue gas exposure may be comparable to the weight change due to the collection of the aerosol. Consequently, glass filter materials should be avoided. If temperatures permit, Teflon filters should be used. Otherwise, pure quartz fiber filters are recommended.

SECTION 5

SAMPLING

Figure 12 shows the locations of the sampling points that are recommended. After a measurement of the velocity profile has been made and the nozzle has been selected, samples should be taken at the locations shown. In sampling the effluents from variable or cyclical processes, the test should extend through several process cycles to insure that a representative sample is obtained.

Regardless of the velocity distribution in the flue, the flow rate through the sampler must remain essentially constant. It is desirable to maintain sampling within ±20% of isokinetic throughout the sampling period, but the sampling rate should not be altered to accomplish this. If a zone of the duct has a velocity that would result in a large deviation from isokinetic, it simply should be avoided.

5.1 SELECTING THE SAMPLE FLOW RATE AND NOZZLE

The D_{50} of a cyclone is dependent on gas density, gas viscosity, and flow rate. Of these variables, only the flow rate can be set by the user. Therefore, if a specified size cut off must be obtained in a particular sampling application, the required sampler flow rate must be determined. Plots of the D_{50}s of the five cyclones versus flow rate are shown in Figures 13 through 17. In these figures, curves are shown for operation at 25, 100, 150, and 200 degrees celcius. A gas composition typical of many industrial flue gases was used in generating these curves (10% CO_2, 8% O_2, 82% N_2 on a dry basis and 10% moisture). Estimates of the required flow rate needed to obtain a particular D_{50} can be obtained from these curves for most cases. However, if the gas temperature is much higher than 200°C or if the composition is radically different from that used here, the required flow rate should be obtained by back calculation from the D_{50} equations. The data reduction computer program described in the Appendix may be used to facilitate these calculations. Note that flow rate selection can be used to obtain a specified cut with any one, but only one, of the five cyclones. After a flow rate is selected, the cuts of the remaining four cyclones are fixed. These cuts can be estimated from the figures.

Once the desired flow rate is known, the appropriate nozzle can be selected using Figure 18. Only straight nozzles should be used.

5.2 LEAK TESTING

Before use, the sampler should be leak tested. The first test should be made immediately after assembly. This test can be performed in the field lab with a minimum amount of equipment. A leak check should also be made after the cyclones have reached the sampling temperature. Some slight leakage is expected, especially if metallic o-rings are used, and the sampler should not be expected to meet the Method 5 leak check criterion. The probe and the remainder of the sampling system should, however, meet the Method 5 criterion.

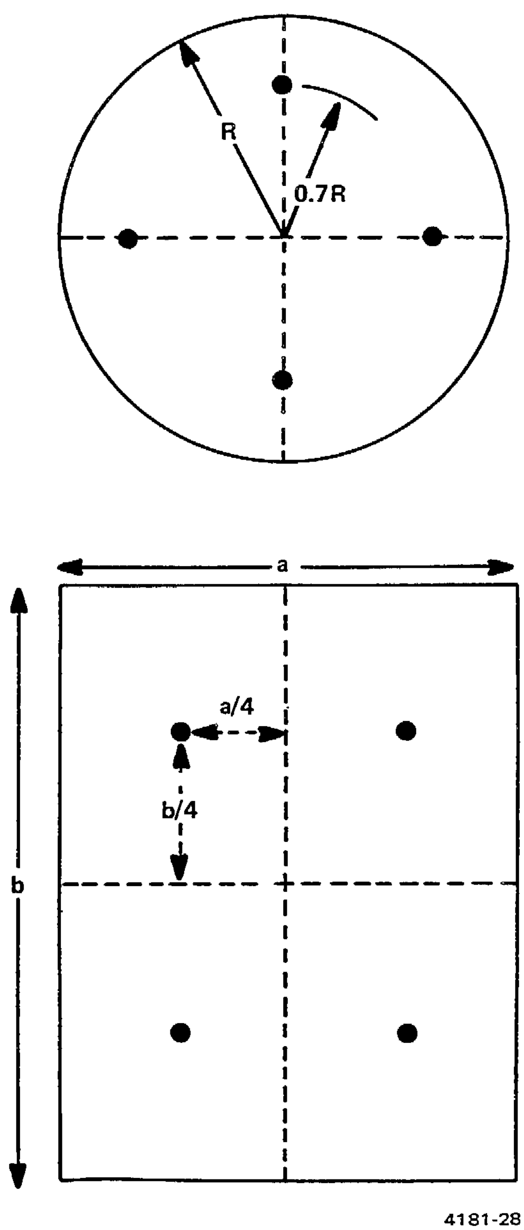


Figure 12. Recommended sampling points for circular and square or rectangular ducts.

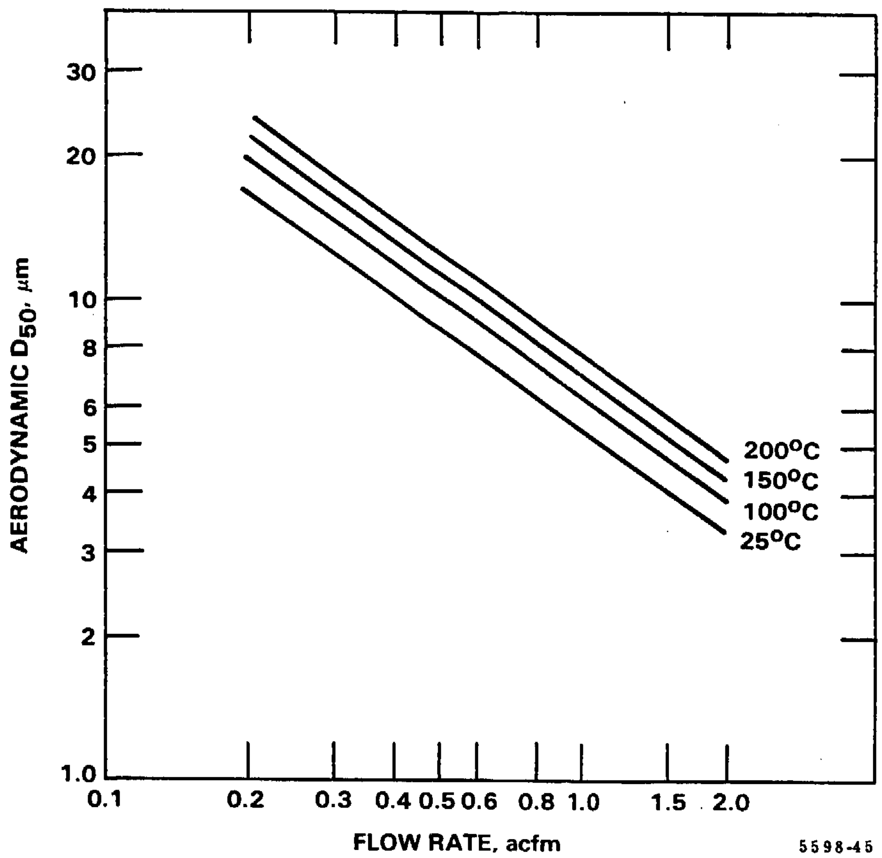


Figure 13. D_{50} versus flow rate for Cyclone I of the five stage cyclone sampler.

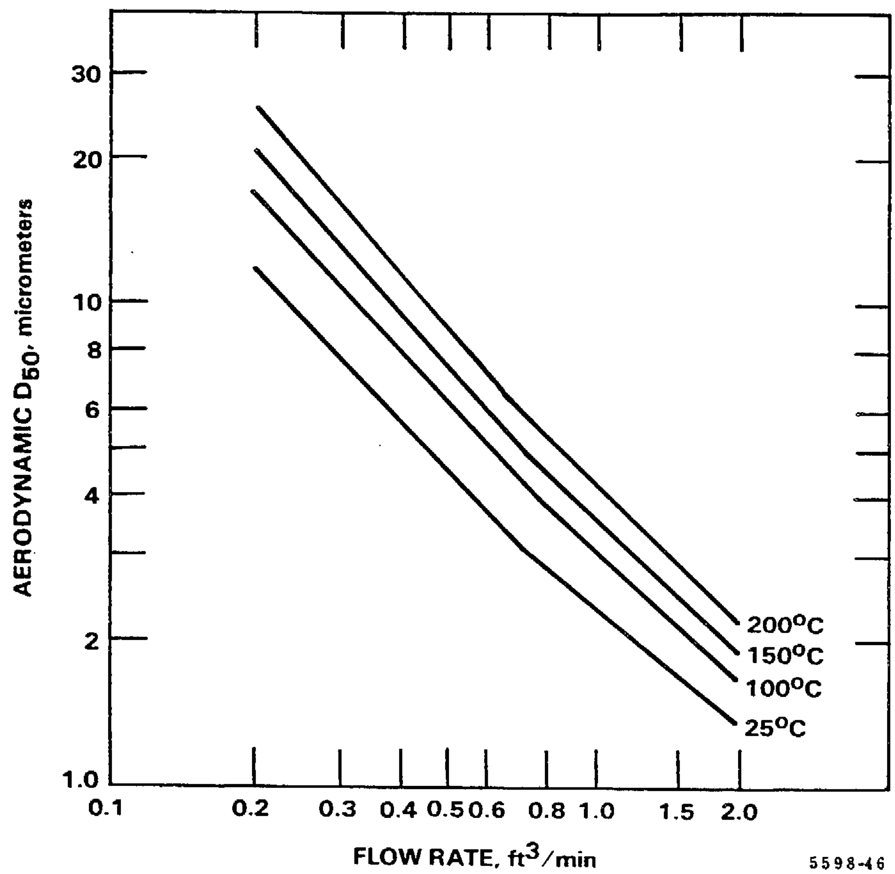


Figure 14. D_{50} versus flow rate for Cyclone II of the five stage cyclone sampler.

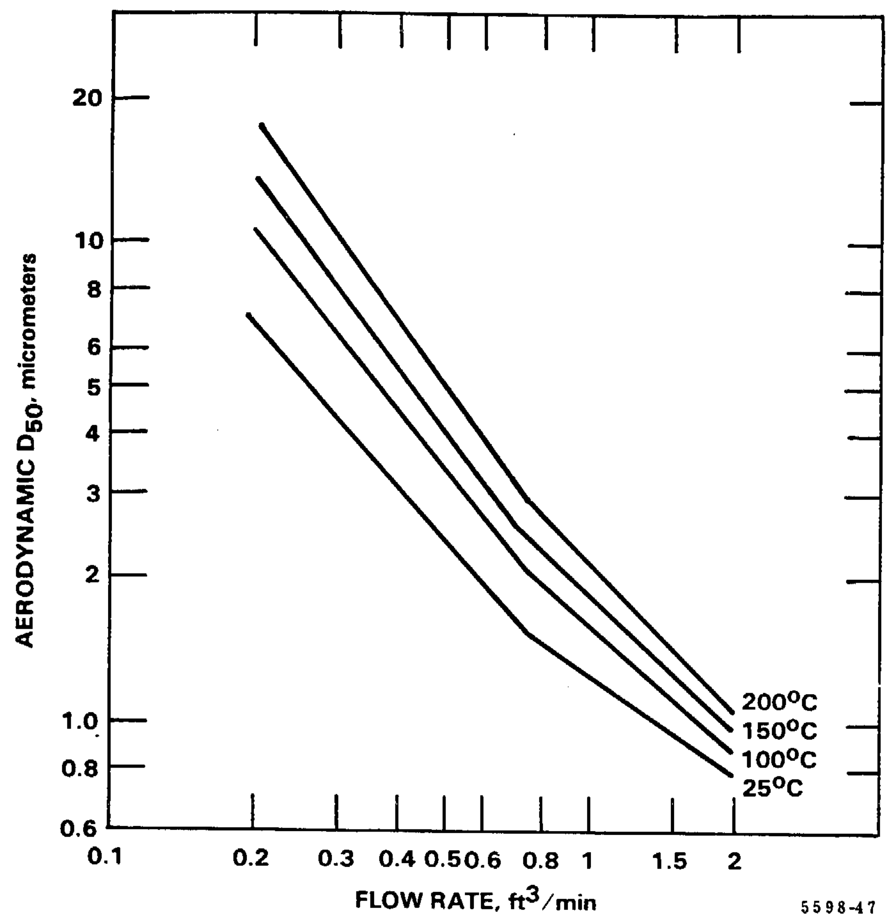


Figure 15. D_{50} versus flow rate for Cyclone III of the five stage cyclone sampler.

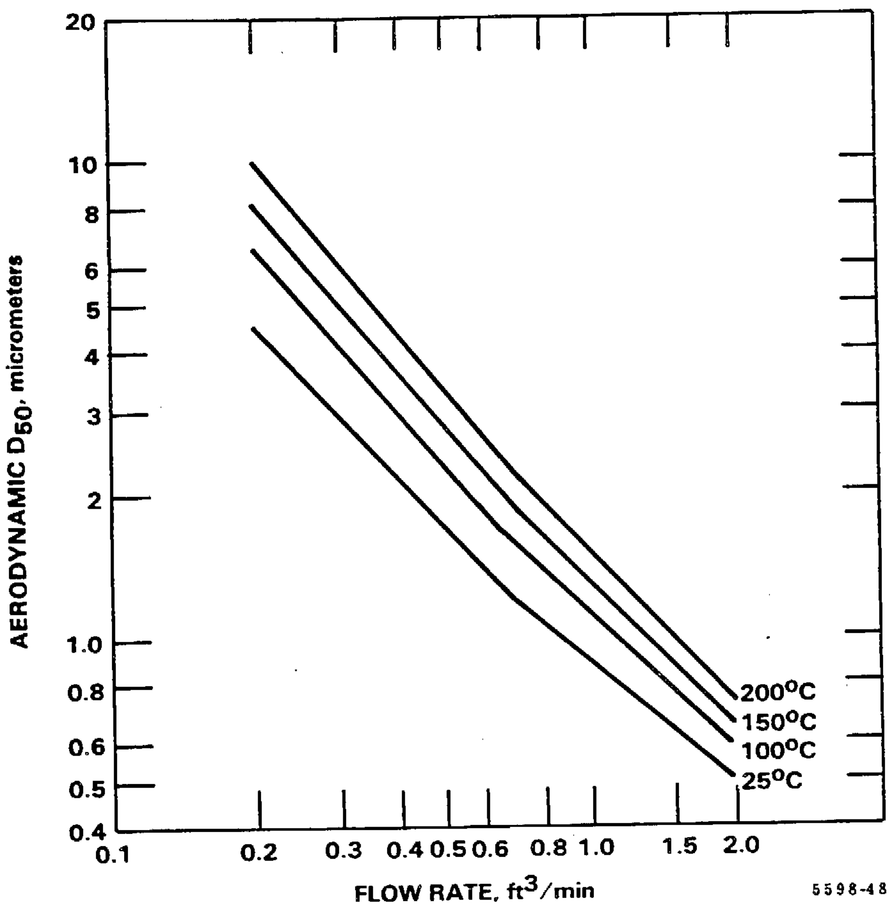


Figure 16. D_{50} versus flow rate for Cyclone IV of the five-stage cyclone sampler.

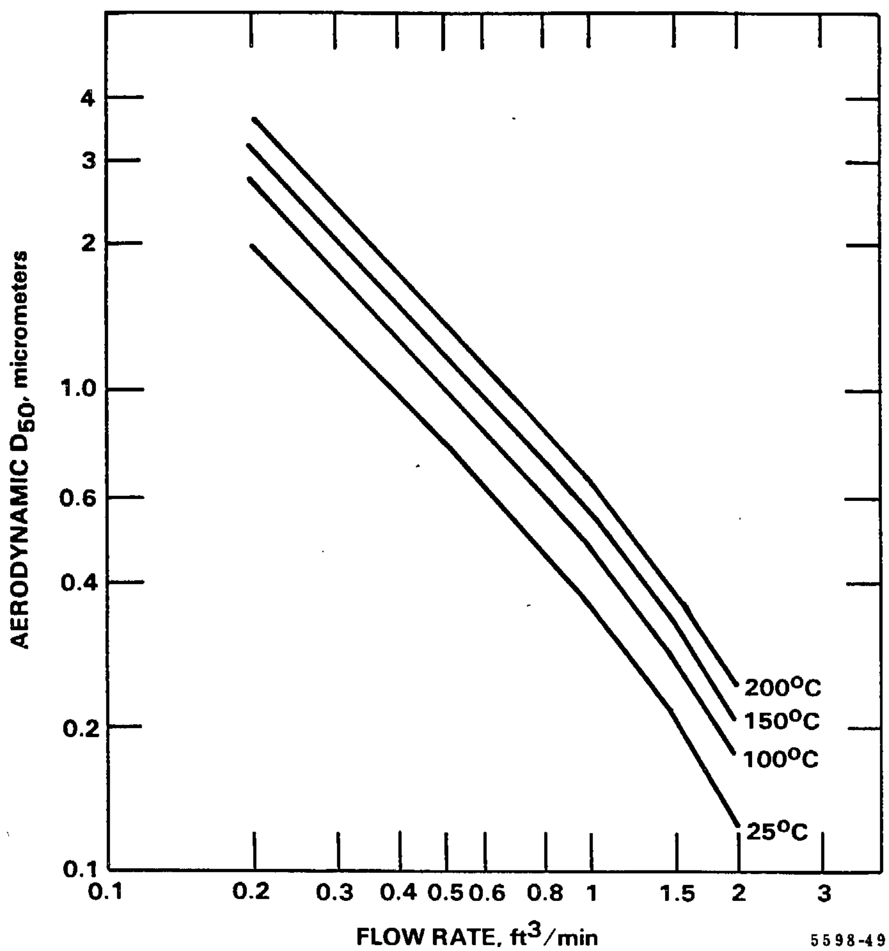


Figure 17. D_{50} versus flow rate for Cyclone V of the five-stage cyclone sampler.

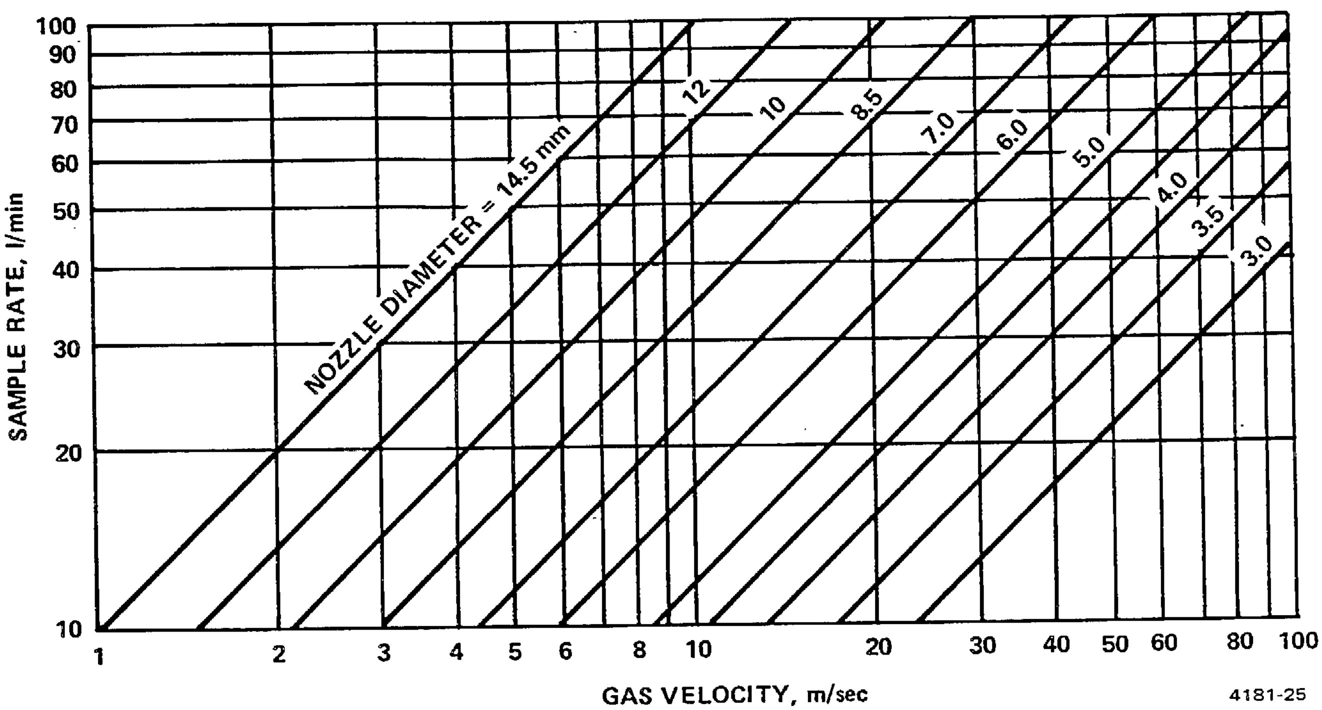


Figure 18. Nomograph for selecting nozzles for isokinetic sampling.

There can be no substitute for trained and experienced personnel to operate the Five-Stage Cyclone Sampler. Exceptional care should be taken throughout all phases of operation, from preparation to clean-up.

5.3 FLOW RATE

To ensure stable cut points the predetermined flow rate must be maintained throughout the run. Any attempt to modulate flow to provide isokinetic sampling will compromise the utility of the data by shifting the cut points of the cyclones.

As the final filter collects particulate, the pressure drop across it will increase, lowering the sample flow rate. The flow rate should be monitored and adjusted as necessary to compensate for this filter loading effect. Filter changes or removal may be necessary if the pressure drop becomes excessive.

5.4 TRAVERSING

During traversing (moving to a new point or new port), all motion should be smooth and brief to avoid bumping or vibrating the sampler. When removing or inserting the sampler, care must be taken not to scrape the nozzle on the port wall. Also, the sampler should not be allowed to bump against the far inside wall of the flue. Flow is maintained while moving from port to port as well as point to point. If flow is stopped and then restarted it is possible that particulate matter collected in one cyclone could be reentrained and accidently transferred to a lower cyclone, thus compromising the integrity of the samples.

5.5 ORIENTATION

The Five-Stage Cyclone Sampler is designed to operate in any orientation with equal results. However, the flow should not be terminated until the run is complete and the sampler is in a horizontal position. Otherwise, some material might fall from one stage of the sample to another and thus be measured where it is not collected. After the flow has been terminated, the sampler can be transported to the lab. It should be kept in a horizontal position with the nozzle plugged or covered to avoid contamination or loss of sample.

5.6 DATA LOGGING

In addition to the sampling parameters and process information normally recorded such as gas composition and temperatures, pressures, gas volumes, etc., the operator of the Five-Stage Cyclone Sampler should also record the sampler identification, orientation, filter identification, gas velocity, flow rate and the run time. A data sheet for manual setup data entry which might be used in the field is shown in Figure 19. An alternate form for use with a computer program for doing the setup calculations (velocity traverse, nozzle and flow rate selection, and orifice meter settings) is given in the Appendix.

RUN SHEET FOR CARB SIZE DISTRIBUTION METHOD USING A CASCADE IMPACTOR SAMPLING TRAIN

REAL BLANK

RUN CODE	DATE	DIFFERENTIAL STACK PRESSURE (IN. H_2O)
CONTROL BOX ID	START TIME	AMBIENT PRESSURE (LAB BAROMETER) (IN. Hg)
GAS METER ID	END TIME	AMBIENT TEMPERATURE (F)
THE CALCULATED TARGET ΔH VALUES REQUIRES THE OPERATOR TO USE ORIFICE ID ______	SAMPLING DURATION (MIN.)	—60 SEC LEAK TEST— PRE HOT A. 15 IN. Hg W/SAMPLER FT^3
SAMPLING ASSIGNMENT INLET, OUTLET, OTHER:	GAS METER-START (FT^3)	B. 5 IN. Hg W/SAMPLER FT^3
	GAS METER-FINISH (FT^3)	C. 15 IN. Hg W/O SAMPLER FT^3 POST HOT
TARGET ΔH	TOTAL VOLUME BY GAS METER (ACF)	NOTE: RELEASE VACUUM AT NOZZLE TO AVOID RUPTURING FILTER. PASS ≤0.02 FT^3 FOR A OR B OR C VISUAL CHECK OF NOZZLE ☐

	RUN TIME (MIN)	PORT NO. TRAVERSE POINT	GAS METER READING	GAS METER TEMP. (F)	FLUE GAS TEMP. (F)		ORIFICE ΔH IN. (H_2O)	PUMP VACUUM (IN. Hg)	PROBE TEMP. (F)
	Pre								
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									
21									
22									
23									
24									
25									
26									
27									
28									
29									
30									
	POST TEST CALCULATIONS:								
		TOTAL							
		AVG.							

—WATER—

CONDENSER ID NO.

CONDENSER H_2O CATCH (ml)

DRYING COLUMN WEIGHT CHANGE

ID NO. ______ INITIAL WT. ______ (gm)

FINAL WT. ______ (gm)

(1 gm = 1 ml) H_2O GAIN (ml)

TOTAL VOLUME H_2O (ml)

NOTES AND OBSERVATIONS

SAMPLING LOCATION

INLET OUTLET

IN THE SPACE BELOW GIVE THE UNIT, CHAMBER, DUCT PANTLEG, ETC. WHERE THE SAMPLER WAS RUN.

PORT NUMBER(S)

SAMPLER ORIENTATION (CIRCLE ONE)

HORIZONTAL
TOP ENTRY VERTICAL
W/ TURN AROUND
W/O TURN AROUND
BOTTOM ENTRY VERTICAL
OTHER

OPERATORS

(1) ______ (2) ______

5050-482A

Figure 19. Run sheet for manual setup data entry. This data form is also used for Cascade Impactors.

SECTION 6

SAMPLE RETRIEVAL AND WEIGHING

After the sampler has cooled to nearly ambient temperature and brought into the lab, it should be carefully "unloaded." Unloading consists of removing all of the particulate matter retained in the sampler. Great care is required in this procedure to insure that all of the particulate is recovered and placed in the proper sample containers.

The sample collected in cyclone SRI-I should be removed first, followed by the samples collected in cyclone SRI-II, SRI-III, SRI-IV, and SRI-V, respectively. The particles adhering to the internal surfaces of the cyclone, i.e., the body underneath the cap, the outside of the gas exit tube, inside the nozzle, the inside walls, and the underside of the body, should be brushed, scraped, or rinsed into a pre-weighed sample container along with the material from the collection cup. If the particulate matter is a dry powder, a No. 7 camel's hair brush is suggested for this operation. The dust deposited inside a gas exit tube and the connecting tubing to the next cyclone should be included in the sample for the downstream cyclone. The dust collected on the inside of the gas exit tube and connecting tubing to the filter should be brushed onto the filter. When all internal surfaces directly upstream of the filter have been brushed clean, remove the filter and place it in its proper sample container.

In some cases, it may also be necessary to wash the internal surfaces of the nozzle and cyclone with a solvent, such as methylene chloride, into preweighed bottles. If organic analyses are to be performed, glass bottles with Teflon caps should be used. If the material is hard and dry, the particles can be brushed off into the container; if the particles are sticky or wet, a washdown procedure should be followed as described previously in Section 4, PRETEST OPERATIONS. The solvent must be considerably more volatile than the particles (Methylene chloride is recommended, but other solvents may be needed for some compounds.) A teflon spatula or Teflon version of a "rubber policeman" may be useful in the recovery of sticky particulate matter or as an aid in recovery when solvent rinses are being made.

SECTION 7

DATA ANALYSIS

After obtaining a sample, the data must be reduced to obtain the desired size distribution from the stage weights, sampling information, and hardware specifics. Data taken in various studies of particulate emissions should be readily comparable, regardless of the sampling team. The data should therefore be presented in a uniform format. The data analysis method presented below is recommended for use in all studies of particulate matter performed with cyclone systems.

The data most often required from cyclone measurements are composition with respect to particle size. Other data needs may include particle-size distributions across emission control devices and perhaps fractional collection efficiencies of these devices. In all these cases it is necessary to determine the size range of the particles collected in each cyclone. The effective cutoff diameter, or lower limit to the size collected, is taken to be the cyclone's D_{50}. The D_{50} of a cyclone is the particle diameter for which the cyclone achieves a 50 percent collection efficiency; half of the particles of that size are retained by the cyclone and half are passed. This D_{50} analysis method simplifies the capture efficiency distribution by assuming that a given stage captures all of the particles with a diameter equal to or greater than the D_{50} of that cyclone and less than the D_{50} of the preceding cyclone. Thus, for the purpose of constructing a size distribution, particles collected by a specific cyclone are assumed to have diameters between the D_{50} of that cyclone and the D_{50} of the cyclone prior to it.

The simplification described above does not take into account the shape or slope of the calibration collection efficiency curves. It is assumed, rather, that the collection efficiency curve is a step function (see Figure 20). Since deconvolution techniques which use the entire calibration graph are not sufficiently advanced enough to yield reliable results, the D_{50} method is recommended and is the only method described herein.

7.1 CALCULATION OF CYCLONE D_{50} VALUES

The general form of the empirical equation used here to describe the behavior of a small cyclone is the same as that used for cascade impactors:

$$D_{50} = \left(\frac{18\ \mu\ D_j\ \psi_{50}}{C\rho_p v_j}\right)^{1/2} \qquad (1)$$

where D_{50} = diameter of a particle having 50% probability of collection by the cyclone, cm

μ = viscosity of gas passing through the cyclone, poise

D_j = diameter of cyclone inlet, cm,

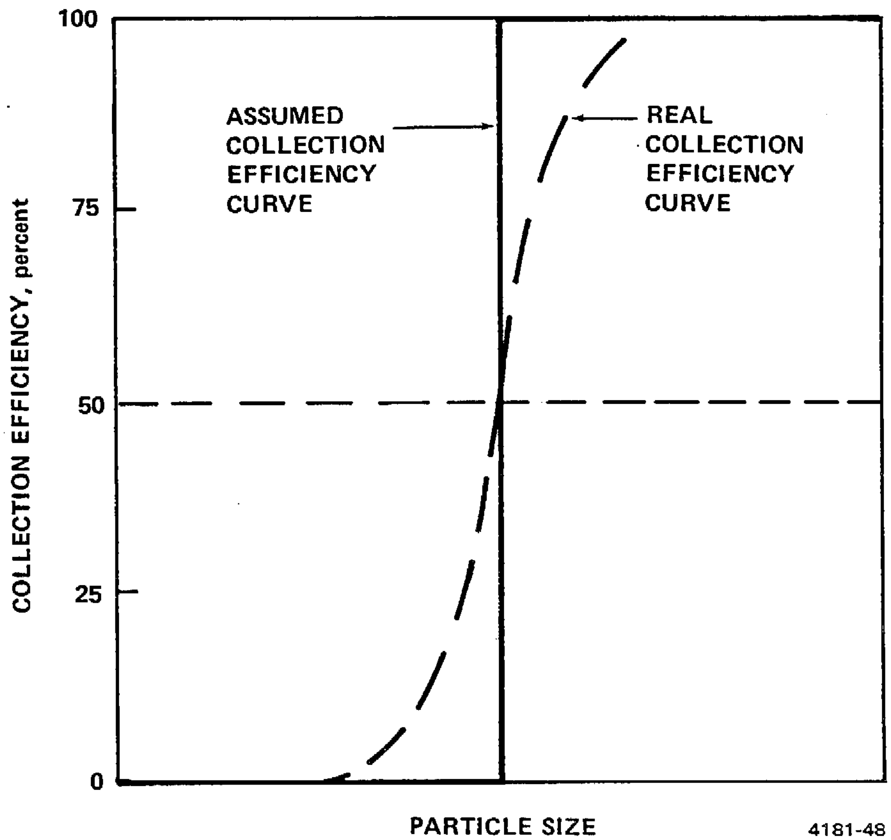


Figure 20. The assumed collection efficiency curve of the D_{50} method compared to the real collection efficiency curve of an impactor stage or cyclone.

ψ_{50} = inertial size parameter determined by calibration, dimensionless

= $Stk_{50}/2$

C = Cunningham slip correction factor, dimensionless

ρ_p = density of particle, g/c^3

v_j = mean velocity of gas through the cyclone inlet, cm/sec (calculated using upstream pressure)

The Cunningham correction, C, is given by:

$$C = 1 + \frac{2\,\ell}{D_{50}}\left[1.23 + 0.41 \exp\left(\frac{-0.44\ D_{50}}{\ell}\right)\right] \qquad (2)$$

where ℓ = mean free path of air molecules in the cyclone (at upstream conditions), cm

The mean free path, ℓ, in cm is given by:

$$\ell = \frac{0.7923\mu}{P}\ \sqrt{T/MW} \qquad (3)$$

where P = gas pressure, cm Hg,
T = gas temperature, °K,

and
MW = wet molecular weight of the gas.

Note that the cyclone inlet pressure conditions are used throughout these calculations. The pressure, in fact, drops continuously from the inlet to the outlet.

The Stokes diameter of a particle, as defined by equation 1, is of interest for most applications. However, at times, for example for PM_{10} purposes, data must be expressed in terms of the aerodynamic diameter, defined as the diameter of a sphere having unit density and the same settling velocity as the particle of interest. In order to calculate the D_{50} of a stage on an aerodynamic basis, ρ_p is set equal to 1.0 g/cm^3 and equation 1 becomes:

$$D_{50} = \left(\frac{18\psi_{50}\mu D_j}{C\ v_j}\right)^{1/2} \qquad (4)$$

The values of ψ_{50} for each stage must be found by calibration. Then, since C is dependent on particle size, the D_{50} can be calculated using an iterative solution of equations 2 and 1 or 3 as appropriate. Such an iterative approach is used in the computer data reduction system described in the Appendix.

Based on experimental data, the following equation has been derived for cyclones SRI-I through SRI-V. These equations relate $\sqrt{\psi_{50}}$ to the Reynolds number of the flow at the cyclone inlet.

$$\ln\left(\sqrt{\psi_{50}}\right) = A \ln(Re) + B\left(\ln(Re)\right)^{1/2} + C \qquad (5)$$

where A, B, and C are empirically determined constants. The values, obtained by least squares fits to calibration data, are as follows:

Cyclone	A	B	C
I	-0.197	0.0	-0.191
II	1.982	-13.596	20.547
III	4.732	-29.370	43.115
IV	2.841	-18.929	29.147
V	-0.472	0.0	2.360

These values are based on calibrations obtained over a wide range of flow rates (2 to 55 lpm) with air at temperatures from ambient to 200° C and carbon dioxide, helium, and argon at ambient conditions (Farthing, 1985). The equations generally reproduce the calibration values of $\sqrt{\psi_{50}}$ to an accuracy of 10% or better.

Although the equations may be solved by hand calculation, it is generally impractical to do so, and a system of computer programs has been provided for the purpose (see Appendix). The programs are modified versions of those used for reducing impactor data and generally follow the same conventions and provide the same outputs as the impactor versions described in Attachment No. 1 to this same project report.

7.2 PARTICLE SIZE DISTRIBUTIONS

The true particle size distribution of almost any particle-laden gas stream (outside the laboratory) is a smooth and continuous curve. As cyclone systems have a finite number of stages, they break this continuous particle-size distribution into a series of discrete steps in separate but overlapping size intervals. The object of the cyclone system data analysis is to transform these discrete steps into a good approximation of the real, continuous distribution.

It is assumed for the purpose of analysis that all of the material caught in a particular cyclone consists of particles having aerodynamic diameters equal to, or greater than, the D_{50} of that cyclone, and less than the D_{50} of the preceding cyclone. For the first cyclone, it is assumed that all of the particles caught have aerodynamic diameters greater than, or equal to the D_{50} for that cyclone, but less than the maximum particle size. When possible, the maximum particle size should be measured, for example, with an optical microscope. If this is not possible, an arbitrary value of 1000 μm or larger should be used for uncontrolled sources and a value of about 20 μm to 100 μm for controlled sources.

Particle size distribution data should be presented on both a differential basis and a cumulative basis as discussed below.

7.2.1 Differential Particle Size Distributions

Since the true particle size distribution is continuous, the amount of material with particle diameters between D and D+dD can be represented by dM. Then the integral

$$\int_{D_1}^{D_2} \frac{dM}{dD} dD \qquad (6)$$

yields the total amount made up of particles with diameters between D_1 and D_2.

The Five Stage Series Cyclone Sampler was designed so that the relationship between successive stage D_{50}s is logarithmic. For this reason, and to minimize graph scaling problems, the differential particle size distributions are plotted on log-log or semi-log paper with dM/d(log D) as the ordinate and log D as the abscissa. The mass of the material on stage "n" is designated by ΔM_n and is, in approximation, the mass of particulate matter with particle diameters between $(D_{50})_n$ and $(D_{50})_{n+1}$. The Δ (log D) associated with ΔM_n is $\log(D_{50})_{n+1} - \log(D_{50})_n$. Using these approximations, the derivative term associated with the stage "n" is:

$$dm/d(\log D)_n \simeq \frac{M_n}{\Delta(\log D_{50})_n} = \frac{\text{mass on stage "n"}}{\log (D_{50})_{n-1} - \log (D_{50})_n} \qquad (7)$$

Plotting this approximation of dM/d(log D) versus log D results in a histogram. From such a histogram, the total mass of particles with diameters between $(D_{50})_i$ and $(D_{50})_j$ can be calculated as the sum:

$$\text{Mass} = \sum_{k=i}^{j} \frac{\Delta M_k}{\Delta(\log D_{50})_k} (\Delta \log D_{50})_k \qquad (8)$$

where "k" takes on values corresponding to the discrete increments of the histogram.

If a cyclone system with an infinite number of stages were available, the histogram would approach a continuous function, the Δ(log D_{50}) terms would approach d(log D), and the mass between D_m and D_n could be calculated as

$$\text{Mass} = \int_{D_m}^{D_n} \frac{dM}{d(\log D)} d(\log D) \qquad (9)$$

Such a system does not exist, but the histogram can be plotted as a smooth curve by assigning some average of $(D_{50})_{n-1}$ and $(D_{50})_n$ to the $\Delta M/\Delta(\log D_{50})|_n$ term. The geometric mean of the D_{50}s is generally used. This curve is then a continuous function approximating the actual particle-size distribution. Note that the area under the curve in a given size range is equal to the mass of the particulate matter in that interval. Such a curve is needed to calculate fractional collection efficiencies of control devices if the D_{50}s differ for inlet and outlet measurements. To normalize the differences in the masses of samples collected by various instruments, the mass collected in each cyclone is usually divided by the volume of the sampled gas at standard temperature and pressure, yielding concentration units. The accuracy of the approximation described above is limited by the number of data points and by neglecting any non-ideal behavior. An example of such a distribution is shown in Figure 21.

7.2.2 Cumulative Particle Size Distributions

Two forms of cumulative distributions are commonly used - cumulative concentration and cumulative percentage. These are generated, respectively, by summing the concentrations of particles smaller than the D_{50}s of successive stages or by summing the percentages of the total concentration smaller than the successive D_{50}s. Distributions in this form are conventionally plotted commencing at the smallest diameter for which data was obtained and progressively summing to the larger sizes.

Cumulative distributions do have some disadvantages compared to differential distributions. An error in a stage weight is propagated forward throughout the remainder of the distribution in a cumulative analysis, but is isolated by the differential approach. Also the differential method need not involve the use of data for sizes outside of the range over which the sampler provides size resolution and so is useful in comparing results obtained using cyclones with those obtained from instruments which cover only restricted particle size intervals (e.g. optical particle counters). Cumulative distributions are also not amenable to making direct comparisons of concentrations at selected sizes as can be done with differential distributions.

Cumulative Concentration Format

A cumulative concentration particle-size distribution is shown in Figure 22. Distributions in the cumulative concentration format are formed by first calculating the concentrations for each size fraction provided by the sampler and successively summing these concentrations. In the conventional format, the summation begins at the smallest D_{50}. The small particle end of the size spectrum is selected for the beginning of the summation because in most instances the larger particles dominate the distribution and the addition of the smaller particles to the larger would be undetectable in the presentation. Note that it is possible to present data in a form of cumulative concentration format in the absence of information regarding concentrations at one extreme of the distribution.

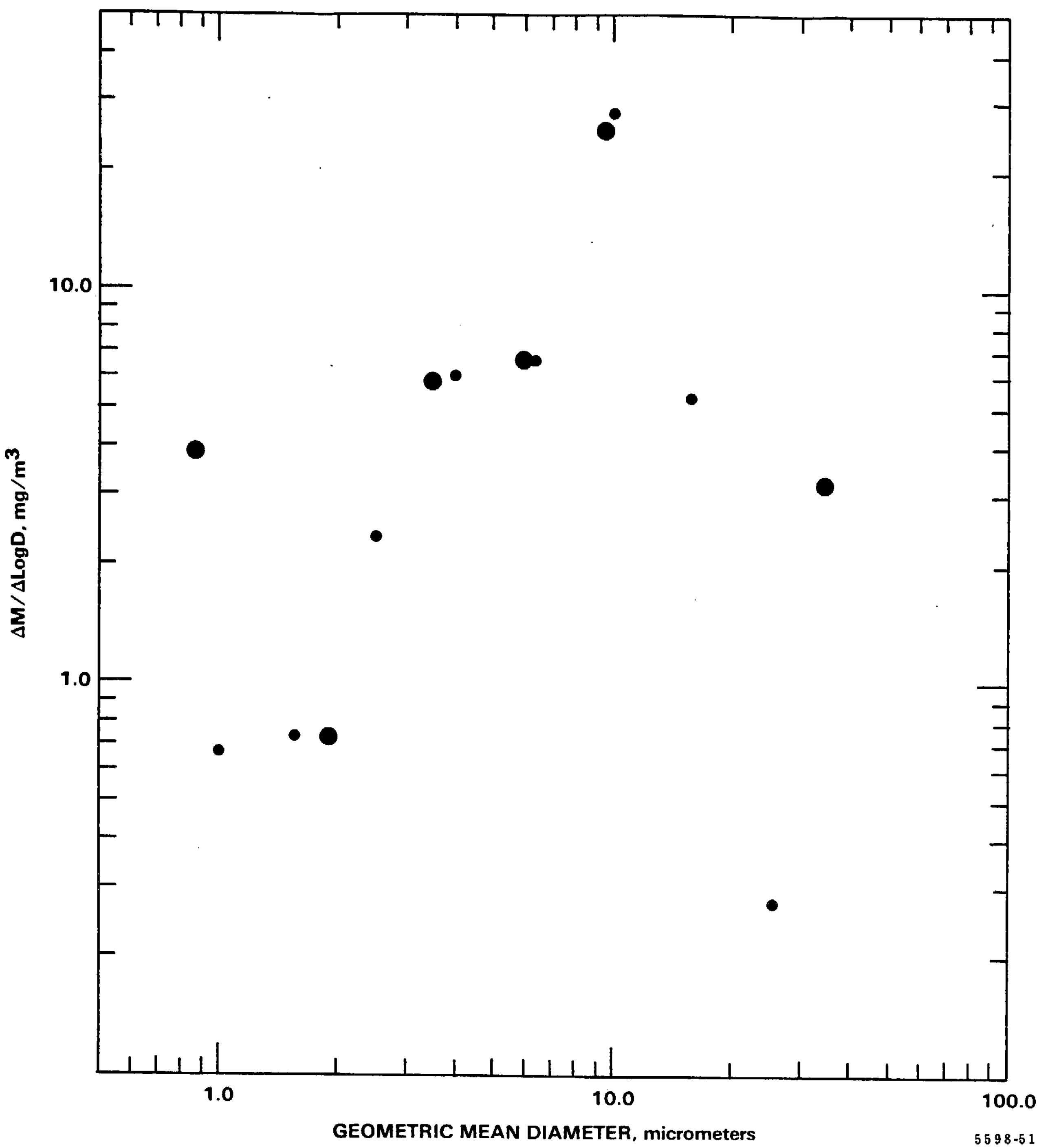


Figure 21. ΔM/ΔLogD versus geometric mean aerodynamic diameter. Large symbols represent results from manual data reduction, small symbols represent results from the computer program.

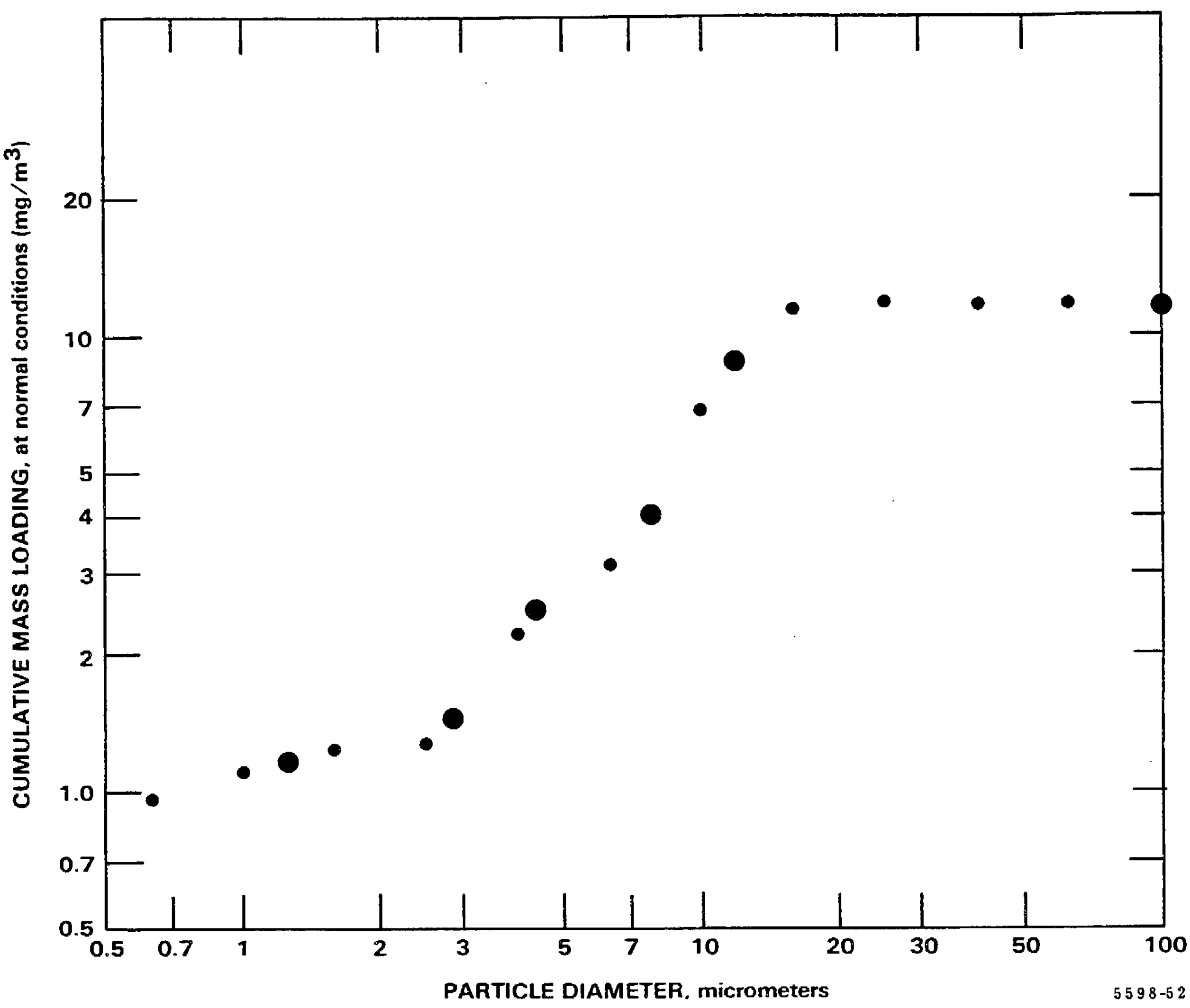


Figure 22. Cumulative mass loading versus Aerodynamc Diameter. The large symbols represent the results from manual data reduction and the computer program. The small symbols represent the results from a spline fit to the original distribution which is made by the computer program.

The value of the ordinate at a given D_{50} would be:

$$\text{Mass concentration smaller than } (D_{50})_k = \sum_{i=0}^{k-1} C_i \qquad (10)$$

where
- i = o corresponds to the filter,
- i = k corresponds to the selected stage,
- C_i = concentration determined from the stage i particulate catch,
- N = total number of stages (including the precollector).

This equation requires that the stages be counted upward from the final filter. There is no $(D_{50})_0$ since the "0" stage corresponds to the backup filter. $(D_{50})_1$ is the cut-point of the final stage.

Cumulative Percentage Format

Many aerosols have particle size distributions which follow, or can be approximated by, the "Normal" or Gaussian function if the logarithm of the particle diameter is used as the independent variable. Such distributions, called log-normal distributions, can be characterized or described by three parameters: a normalizing constant which defines the total concentration, and two constants which define the location and shape of the distribution. Generally, the mass median diameter and the geometric standard deviation are used for the latter two parameters. The mass median diameter, or MMD, locates the diameter about which the distribution is centered and is the diameter at which half the particulate mass is contained in particles having smaller diameters and half in those which are larger. The geometric standard deviation, or σ_g, defines the spread of the distribution and is defined by ratios of the median diameter and the plus and minus one sigma diameters in the log-normal function. It is approximately equal to D(84%)/MMD and/or MMD/D(16%), where D(84%) and D(16%) are the diameters below which sizes one finds respectively 84% and 16% of the particle mass.

Size distribution presentations on a cumulative percentage basis are formed as the sums of the percentages of the total catch collected by each stage of the sampler. When plotted, they are usually displayed on special log-probability paper as shown in Figure 23, with the logarithmic axis used for particle diameter, and the "probability", or percentage, axis for the cumulative percentage. True log-normal distributions form straight lines when plotted on this paper, making estimation of the mass median diameter and geometric standard deviation a simple task. Deviations of a distribution from the log-normal form will result in curvature or slope changes in this type of plot.

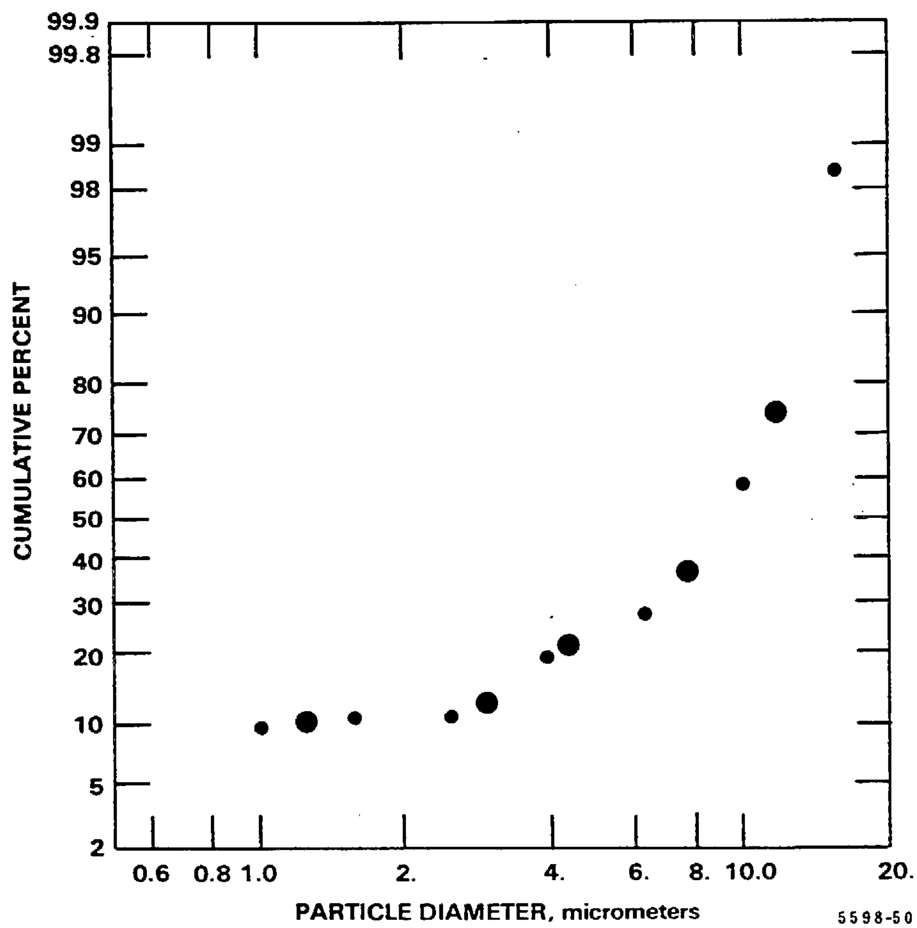


Figure 23. Cumulative percent versus Aerodynamic Diameter. The large symbols represent the results from manual data reduction and the computer program. The small symbols represent the results from a spline fit to the original distribution which is made by the computer program.

Disadvantages of the cumulative percentage format are that a knowledge of the complete size distribution is required in order to form it, and an error in the measured concentration in any size interval is propagated throughout the entire presentation. It should also be remembered that a distribution presented in a cumulative percentage format is incompletely specified, as it does not contain information with regard to absolute concentrations. In order to make full utilization of the data possible, the total concentration should be specified in the plot legend.

The value of the ordinate at a given D_{50} would be:

$$\text{Mass percent smaller than } (D_{50})_k = \frac{\sum_{i=0}^{k-1} m_i}{\sum_{i=0}^{N} m_i} \tag{11}$$

where
- i = 0 corresponds to the filter
- i = k corresponds to the stage under consideration
- m_i = mass collected on stage i, and
- N corresponds to the total number of stages.

Again, this equation requires that the stages be counted upward from the final filter.

An example of data analysis for a hypothetical sample is detailed in the following paragraphs. The illustrations shown in Figures 21, 22, and 23 are from that example. The large solid points in the figures represent the hand calculated results obtained as described the sample circulations which follow. The smaller points show the results for the same example as calculated by the data reduction program described in the Appendix.

7.3 SAMPLE CALCULATIONS FOR DATA ANALYSIS

The following is an example of the data analysis procedure recommended for a typical cyclone sampler test run. In the material below, the steps necessary to obtain particle size distributions from the run information are detailed. Values of important quantities are calculated for stage 3 of a hypothetical cyclone sampler run with the sampling parameters listed in Table 1. The values in Table 1 were generated from the data given by the sample field data log (Run Sheet) shown in Figure 24.

7.3.1 STAGE CUT DIAMETERS (D_{50})

The aerodynamic D_{50} cut points of the cyclone stages can be calculated using equations 1 through 5, and the equations shown below.

TABLE 1

SAMPLING PARAMETERS FOR A CYCLONE SAMPLER TEST

Cyclone Type	SoRI Five-Stage Sampler
Stack Temperature	148.9°C (300°F)
Cyclone Temperature	148.9°C (300°F)
Stack Pressure	75.3cm Hg (29.6 in.Hg)
Sampler Flow rate	14.5 ℓ/min (0.51 ft^3/min)
Sampling Duration	120 minutes
Gas Composition (wet)	0.21% CO_2, 0.03% CO, 76.08% N_2, 18.78% O_2, 4.90% H_2O
Assumed Particle Density	1.0 g/cm^3
Maximum Particle Diameter	100μm

	Mass*, mg
Stage 1	3.32
Stage 2	5.05
Stage 3	1.81
Stage 4	1.10
Stage 5	.30
Filter	1.28

* Masses represent the amounts of a particular compound found in the samples, not the total catches of the cyclones and filter.

RUN SHEET FOR CARB SIZE DISTRIBUTION METHOD USING A CASCADE IMPACTOR SAMPLING TRAIN

REAL (circled) BLANK

RUN CODE: TØR DEMO	DATE: 4/20/79	DIFFERENTIAL STACK PRESSURE: 0.0 (IN. H_2O)
CONTROL BOX ID: RAC #1	START TIME: 0900	AMBIENT PRESSURE (LAB BAROMETER): 29.6 (IN. Hg)
GAS METER ID: RAC #1	END TIME: 1110	AMBIENT TEMPERATURE: 74 (F)
THE CALCULATED TARGET ΔH VALUES REQUIRES THE OPERATOR TO USE ORIFICE ID: 0.120 S	SAMPLING DURATION: 120 (MIN.)	—60 SEC LEAK TEST— PRE HOT A. 15 IN. Hg W/SAMPLER: 0.160 FT^3
SAMPLING ASSIGNMENT INLET / OUTLET (circled) / OTHER:	GAS METER-START: 21.45 (FT^3)	B. 5 IN. Hg W/SAMPLER: 0.007 FT^3
	GAS METER-FINISH: 64.45 (FT^3)	C. 15 IN. Hg W/O SAMPLER FT^3 POST HOT: 0.005
TARGET ΔH: 0.44	TOTAL VOLUME BY GAS METER: 43.00 (ACF)	NOTE: RELEASE VACUUM AT NOZZLE TO AVOID RUPTURING FILTER. PASS ≤ 0.02 FT^3 FOR A OR B OR C. VISUAL CHECK OF NOZZLE ☑ O.K.

	RUN TIME (MIN)	PORT NO. TRAVERSE POINT	GAS METER READING	GAS METER TEMP. (F)	FLUE GAS TEMP. (F)		ORIFICE ΔH IN. (H_2O)	PUMP VACUUM (IN. Hg)	PROBE TEMP. (F)
	Pre	1	21.45	74	300				280
1	10	1	25.06	74	300		0.44	2	
2	20	1	28.6		301		0.44		
3	30	1	32.15		301		0.44		
4									
5	40	2	35.85	74	298		0.44	2.5	280
6	50	2	39.3		300		0.44		
7	60	2	43.0		302		0.44		
8									
9	70	3	46.6	74	300		0.44	3	
10	80	3	50.0		298		0.44		
11	90	3	53.8		300		0.44		
12									
13	100	4	57.4		299		0.44	4.7	275
14	110	4	61.0	74	300		0.44		
15	120	4	64.45	74	301		0.44	7.2	
16									
17									
18									
19									
20									
21									
22									
23									
24									
25									
26									
27									
28									
29									
30									
POST TEST CALCULATIONS:									
		TOTAL	43.0						
		AVG.		74	300		0.44		

—WATER—

CONDENSER ID NO.: NA

CONDENSER H_2O CATCH: 40 (ml)

DRYING COLUMN WEIGHT CHANGE

ID NO. 12 INITIAL WT. 478.0 (gm) FINAL WT. 481.7 (gm)

(1 gm = 1 ml) H_2O GAIN: 3.7 (ml)

TOTAL VOLUME H_2O: 43.7 (ml)

NOTES AND OBSERVATIONS

CO_2 = 0.22%

CO = 0.032%

O_2 = 19.75%

SAMPLING LOCATION

INLET / OUTLET (circled)

IN THE SPACE BELOW GIVE THE UNIT, CHAMBER, DUCT PANTLEG, ETC. WHERE THE SAMPLER WAS RUN.

STACK

PORT NUMBER(S)

1 THRU 4

SAMPLER ORIENTATION (CIRCLE ONE)

HORIZONTAL (circled)
TOP ENTRY VERTICAL
W/ TURN AROUND
W/O TURN AROUND
BOTTOM ENTRY VERTICAL
OTHER: 0.1875 INCH NOZZLE VELOCITY = 50 FPS

OPERATORS

(1) LGK (2) WBD

5050-482A

Figure 24. Sample field data log.

The gas viscosity, μ, is calculated (in poises) by equations 12 and 13 from the gas composition and the viscosities of the individual gas components (Wilke, 1950). The viscosities of the gas components are calculated from polynomial fits to published data.(Hodgmen, 1960) Equations 14 through 18 give these polynomial fits:

$$\mu = \sum_{i=1}^{5} \frac{\mu_i}{1 + \frac{1}{f_i} \sum_{\substack{j=1 \\ j \neq i}}^{5} (f_j \phi_{ij})} \times 10^{-6} \tag{12}$$

where

$$\phi_{ij} = \frac{\left[1 + (\mu_i/\mu_j)^{1/2} (w_j/w_i)^{1/4}\right]^2}{(4\sqrt{2}) \left[1 + (w_i/w_j)\right]^{1/2}} \tag{13}$$

μ_{1-5} = pure gas viscosity, micropoises

μ_1 = gas viscosity of CO_2

$$\mu_1 = 138.494 + 0.499\ T_{CI} - 0.267 \times 10^{-3}\ T_{CI}^2 + 0.972 \times 10^{-7}\ T_{CI} \tag{14}$$

μ_2 = gas viscosity of CO

$$\mu_2 = 165.763 + 0.442\ T_{CI} - 0.213 \times 10^{-3}\ T_{CI}^2 \tag{15}$$

μ_3 = gas viscosity of N_2

$$\mu_3 = 167.086 + 0.417\ T_{CI} - 0.139 \times 10^{-3}\ T_{CI}^2 \tag{16}$$

μ_4 = gas viscosity of O_2

$$\mu_4 = 190.187 + 0.558\ T_{CI} - 0.336 \times 10^{-3}\ T_{CI}^2 + 0.139 \times 10^{-6}\ T_{CI} \tag{17}$$

μ_5 = gas viscosity of H_2O

$$\mu_5 = 87.800 + 0.374\ T_{CI} + 0.238 \times 10^{-4}\ T_{CI}^2 \tag{18}$$

where T_{CI} = temperature, °C

f_{1-5} = wet gas fractions of CO_2, CO, N_2, O_2, and H_2O, respectively

w_{1-5} = molecular weights of CO_2, CO, N_2, O_2, and H_2O, respectively

For CO_2

$$\mu_1 = 138.494 + 0.499\ (148.9)\ -0.267 \times 10^{-3}\ (148.9)^2 + 0.972 \times 10^{-7}\ (148.9)^3$$

$$\mu_1 = 207.2 \text{ micropoises}$$

Likewise

$$\mu_2 = 226.9 \text{ micropoises}$$
$$\mu_3 = 226.1 \text{ micropoises}$$
$$\mu_4 = 266.3 \text{ micropoises}$$
$$\mu_5 = 144.4 \text{ micropoises}$$

The molecular weights are:

w_1 = 44.10 (CO_2)
w_2 = 28.01 (CO)
w_3 = 28.02 (N_2)
w_4 = 32.00 (O_2)
w_5 = 18.02 (H_2O)

With these values and the wet gas fractions, the viscosity can be calculated from equations 11 and 12 to be 230 micropoises.

For Cyclone 3:

The gas density is given by:

$$\rho = \rho_{std}\ \left(\frac{MW}{MA}\right)\left(\frac{P_3}{P_{std}}\right)\left(\frac{273}{273+T_I}\right) \qquad (19)$$

where

$$\rho_{std} = 1.29 \times 10^{-3}\ g/cm^3$$

MW = wet molecular weight of flue gas
= (0.0021 x 44) + (0.0003 + .7608) x 28 + (0.1878 x 32) + (0.049 x 18)
= 28.29

MA = 28.97

$$P = 75.3 - \Delta P_{cyc1} - \Delta P_{cyc2} = 75.3 \text{ cm Hg}$$

and P_{std} = 76.0 cm Hg

Thus for Cyclone 3:

$$\rho_3 = 1.29 \times 10^{-3}\ \left(\frac{28.29}{28.97}\right)\left(\frac{75.3}{76.0}\right)\left(\frac{273}{273+149}\right)$$

$$= 0.807 \times 10^{-3}\ g/cm^3$$

The pressure drop created by Cyclone III (needed to calculate the inlet flow rate for Cyclone IV) can be estimated by treating the cyclone inlet and outlet as orifice plates. The pressure drop for an orifice plate is given by:

$$\Delta P = \frac{1}{2}\ \rho_g\ \left(\frac{\upsilon}{c_d}\right)^2 \text{ dynes/cm}^2 = 3.75 \times 10^{-5}\ \rho_g\ \left(\frac{\upsilon}{c_d}\right)^2 \text{ cm Hg.} \qquad (20)$$

where

ρ_g = gas density at orifice inlet, g/cm^3

υ = plug flow gas velocity, cm/s

and c_d = coefficient of discharge, dimensionless

The coefficient of discharge can be taken to be 0.61 with suitable accuracy so the equation becomes:

$$\Delta P = 1.008 \times 10^{-4}\ \rho_g\ \upsilon^2 \text{ cm Hg.} \tag{21}$$

$$\text{and } \upsilon = \frac{4Q}{\pi D_{i,o}^2} \tag{22}$$

where Q_n is the volumetric flow rate in cm/s and $D_{i,o}$ is respectively the cyclone inlet and outlet diameter.

Q is given by:

$$Q = Q_{inlet} \times \frac{P_s}{P} \tag{23}$$

where Q_{inlet} = cyclone flow at stack conditions, cm^3/s

P_s = absolute gas pressure in the stack

and P = gas pressure at the inlet to the part of the cyclone being considered

= P_s - (sum of the ΔPs of the preceding cyclone inlets and outlets)

$$\text{Thus } \Delta P_{3i} = 1.008 \times 10^{-4} \times (0.807 \times 10^{-3}) \times \left(\frac{4 \times 241}{\pi \times 0.75 \times 0.75}\right)^2$$

$$= 0.024 \text{ cm Hg.}$$

$$\text{and } \Delta P_{3o} = 1.008 \times 10^{-4} \times (0.807 \times 10^{-3}) \times \left(\frac{4 \times 241 \times \frac{75.3}{75.28}}{\pi \times 0.8325 \times 0.8325}\right)^2$$

$$= 0.016 \text{ cm Hg.}$$

or ΔP_3 = 0.024 + 0.016 cm Hg. = 0.04 cm Hg.

The Reynolds number is given by:

$$Re = \frac{4\rho Q}{\pi \mu D} \tag{24}$$

where for Cyclone 3

Q = 0.51 acfm = 241 cm^3/s

D_3 = 0.75 cm

Therefore

$$Re_3 = \frac{4 \times 0.807 \times 10^{-3} \times 241}{\pi \times 230 \times 10^{-6} \times 0.75} = 1440$$

and

$$(\ln\sqrt{\psi_{50}})_3 = A_3(\ln Re_3) + B_3(\ln Re_3)^{1/2} + C_3$$

$$= 4.733\ (\ln 1410) - 29.374\ (\ln 1410)^{1/2} + 43.121$$
$$= -1.673$$

Thus for this run

$$(\sqrt{\psi_{50}})_3 = 0.1877$$

and $(\psi_{50})_3 = 0.0352$

Now $D_{50} = \left(\frac{18\mu D\psi_{50}}{C\rho_p \upsilon} \right)^{1/2}$

where $C = 1 + \frac{2\ell}{D_{50}} \left[1.23 + 0.41 \exp\left(\frac{-0.44 D_{50}}{\ell} \right)\right]$

When

$D_{50}/\ell > 2.7$ the exponential term can be neglected so

$$C = 1 + \frac{2.46\ell}{D_{50}} \quad (25)$$

The mean free path, ℓ, is given by the expression:

$$\ell = \frac{0.7923\mu}{P} \sqrt{T/MW} \quad (26)$$

where μ = viscosity in poise
T = temperature in °K
MW = wet molecular weight of the flue gas
and P = pressure in cm Hg.

The above approximation for C, neglecting the exponential term, will generally be applicable in reducing cyclone data and makes it unnecessary to use an iterative method of solving for the stage D_{50}s. This greatly facilitates hand calculation. The computer data reduction program which is provided in the appendix does not use the approximation and solves for the D_{50}s using the more generally applicable iterative technique.

Therefore

$$\ell_3 = \frac{0.7775 \times 230 \times 10^{-6}}{75.3} \sqrt{(273+150)/28.3}$$

$$= 9.36 \times 10^{-6} \text{cm} = 0.094 \mu\text{m}$$

$$D_{50}^2 = \frac{18\mu\ D_{in}\ \psi_{50}}{C\ \rho_p\ \upsilon} \quad (27)$$

$$= \frac{18\mu D_{in}\psi_{50}}{\left(1 + \frac{2.46\ell}{D_{50}}\right)\rho_p \upsilon_{in}} \qquad \text{for} \quad \frac{D_{50}}{\ell} > 2.7$$

or

$$D_{50}^2 + 2.46\ell D_{50} - \left(\frac{18\mu D_{in}\psi_{50}}{\rho_p\, \upsilon_{in}} \right) = 0$$

Therefore

$$D_{50} = [1/2]\left(-2.46\ell + \left[(.46\ell)^2 + 4(18\mu D_{in}\psi_{50})/(\rho_p \upsilon_{in})\right]\right)^{1/2}$$

$$= -1.23\ell + \left[1.513\ell^2 + (18\mu D_{in}\psi_{50})/(\rho_p \upsilon_{in})\right]^{1/2} \qquad (28)$$

The inlet velocity for a cyclone is given by

$$\upsilon_{in} = \left[\frac{4Q}{\pi (D_{in})_3^2} \right] \left(\frac{P}{P_3}\right) \qquad (29)$$

So for Cyclone 3

$$\upsilon_{in} = \frac{4x241}{\pi x (0.75)^2} = 545 \text{ cm/s}$$

Therefore for Cyclone 3

$$D_{50} = -1.15x10^{-5} + \left(1.513x8.76x10^{-11} + \frac{18x230x10^{-6}x0.75x0.0352}{1 \; x \; 545}\right)^{1/2}$$

$$= -1.15x10^{-5} + \left(1.325x10^{-10} + 2.005x10^{-7}\right)^{1/2}$$
$$= -1.15x10^{-5} + \left(2.006x10^{-7}\right)^{1/2}$$
$$= -1.15x10^{-5} + 4.47x10^{-4} \text{ cm}$$
$$= 4.35x10^{-4} \text{ cm} = 4.3 \; \mu m$$

The D_{50} for all five cyclones, calculated as above, will be found to be as follows:

Stage 1 D_{50} = 11.7 μm
Stage 2 D_{50} = 7.7 μm
Stage 3 D_{50} = 4.3 μm
Stage 4 D_{50} = 2.9 μm
Stage 5 D_{50} = 1.2 μm

7.3.2 MASS LOADING

After the D_{50} has been calculated the process of transforming the stage weights into particle size distributions can begin. Sample run data needed (other than those given above) are sampler flow rate, Q; stack temperature, T_s; stack pressure, P_s; sampling duration, t; and the mass collected each stage, MA_j. The mass loading, M_L, is calculated from the total gas volume sampled, Qt, and the total mass, M, of the particles collected:

$$M_L = \frac{M}{Qt} \qquad (30)$$

where

$$M = \sum_j MA_j \qquad (31)$$

where

j = stage 1, stage 2, stage 3,...stage n, backup filter,
N = number of stages in sampler.

It is convenient to let the first cyclone have a j value of 1 and the backup filter a j value of N+1.

Thus

$$M = \sum_{j=1}^{N+1} MA_j$$

The preferred units of M_L are milligrams per cubic meter of gas at dry normal conditions (mg/DNm^3). Normal conditions are defined as 20°C and 760mm Hg (Torr). In addition, the mass loading may be given in mg/am^3 (milligrams per actual cubic meter at stack conditions), gr/dscf (grains per dry standard cubic foot), and gr/acf (grains per actual cubic foot).

For this run,

$$M_L = \frac{12.86 \text{ mg}}{(14.5 \times 10^{-3} m^3/min)\ (120 \text{ min})} = 7.39 \text{ mg/am}^3$$

$$= 11.3 \text{ mg/DNm}^3$$

7.7.3 CUMULATIVE SIZE DISTRIBUTION

The percentage of the total mass sampled contained in particles with diameters smaller than a particular D_{50} is designated the cumulative percent of mass smaller than D_{50}. It is the mass accumulated to stage j divided by the total mass collected on all the stages, and converted to a percentage:

$$\text{CUM }\%_j = \frac{\sum_{i=j+1}^{N+1} MA_i}{M_t} \times 100\% \qquad (32)$$

For stage 3:

$$\text{CUM }\%_3 = \frac{(1.10 + 0.30 + 1.28)\text{ mg}}{12.86\text{ mg}} \times 100\%$$

$$= 20.8\%$$

The cumulative mass loading (at normal conditions) of particles smaller in diameter than the corresponding D_{50} for a particular stage j is given by:

$$\text{CUM (DN)}_j = \frac{\sum_{i=j+1}^{N+1} MA_i}{Qt} \times \frac{T_s\ (760\text{ mm Hg})}{P_s\ (293°\text{K})} \times \frac{1}{(1 - f_{H_2O})} \qquad (33)$$

where: T_s = stack temperature, °K,
P_s = stack pressure, mm Hg,
f_{H_2O} = fraction of water vapor in the gas sampled.

The cumulative mass loading (at actual conditions) of particles smaller in diameter than the corresponding D_{50} for a particular stage j is given by:

$$\text{CUM (A)}_j = \frac{\sum_{i=j+1}^{N+1} MA_i}{Qt} \qquad (34)$$

For stage 3:

$$\text{CUM (A)}_3 = \frac{2.68\text{ mg}}{(14.5\times10^{-3}\text{m}^3/\text{min})\ (120\text{ min})}$$

$$= 1.57\text{ mg/am}^3$$

The cumulative concentration for Stage 3 at dry normal conditions, CUM(DN), is then:

$$\text{CUM }(DN)_3 = 1.57\ mg/am^3 \times \frac{(148.9+273°K)(760mm\ Hg)}{(753mm\ Hg)(293°K)} \times \frac{1}{1-0.049}$$

$$\text{CUM }(DN)_3 = 2.40\ mg/DNm^3.$$

For graphical presentation, the cumulative mass loading is plotted as the ordinate and the corresponding aerodynamic D_{50} as the abscissa.

7.3.4 DIFFERENTIAL SIZE DISTRIBUTION

The mass concentration for each size range defined by the D_{50} cut points is labeled ΔM_j and is calculated by dividing the mass collected on each stage by the total volume of gas (at normal conditions) sampled.

$$\Delta M_j = \frac{MA_j}{Q\ t} \times \frac{T_s\ (760mm\ Hg)}{P_s\ (293°K)} \times \frac{1}{(1-f_{H_2O})} \qquad (35)$$

For stage 3:

$$\Delta M_3 = \frac{1.81\ mg}{(14.5x10^{-3}m^3/min) \times 120\ min} \times 1.53$$

$$\Delta M_3 = 1.59\ mg/DNm^3$$

Now $\Delta\log D$ is defined as:

$$(\Delta\log D)_j = \log_{10}(D_{50j-1}) - \log_{10}(D_{50j}) \qquad (36)$$

For stage 3:

$$(\Delta\log D)_3 = \log_{10}(7.7) - \log_{10}(4.3)$$

$$(\Delta\log D)_3 = .25$$

In the calculation of $\Delta\log D$ for the first cyclone, the maximum particle diameter is used. For a maximum particle diameter = 100.0 μm:

$$(\Delta\log D)_1 = \log_{10}(100) - \log_{10}(11.7) = 1.11$$

A pseudo D_{50} for the filter stage (N+1) is often obtained by arbitrarily making it to be half of the D_{50} of the last cyclone (stage N).

$$(\Delta\log D)_{N+1} = \log_{10}(D_{50N}) - \log_{10}\frac{D_{50N}}{2} = .30$$

The differential mass distribution is calculated from:

$$\frac{\Delta M}{\Delta\log D} = \frac{\Delta M_j}{(\Delta\log D)_j} = \frac{\Delta M_j}{\log_{10}(D_{50j-1}) - \log_{10}(D_{50j})} \qquad (37)$$

For stage 3:

$$\frac{\Delta M}{\Delta \log D_3} = \frac{\Delta M_3}{(\Delta \log D)_3} = \frac{1.59 \text{ mg/DNm}^3}{.25} = 6.36 \text{ mg/DNm}^3.$$

The differential size distribution is usually plotted as the ordinate on a graph where the abscissa is the geometric mean diameter, GMD_j, for the corresponding stage j.

$$GMD_j = \sqrt{D_{50j} \times D_{50j-1}} \qquad (38)$$

For stage 3:

$$GMD_3 = \sqrt{D_{50_3} \times D_{50_2}} = \sqrt{4.3 \times 7.7}$$

$$GMD_3 = 5.8 \ \mu m.$$

As in the $\Delta \log D$ calculation, the maximum particle diameter is again used for the first cyclone calculation and half the D_{50} of stage n for the filter stage calculation. For the first cyclone (assuming the maximum particle diameter = 100 μm):

$$GMD_1 = \sqrt{10.7 \times 100} = 34.2 \ \mu m$$

and for the backup filter:

$$GMD_{N+1} = \sqrt{(D_{50N} / 2) x D_{50N}} = (D_{50N} / \sqrt{2}) = 0.85$$

The finite-difference method used here results in values for $\Delta M/\Delta \log D$ for the first cyclone and the backup filter which can have little physical meaning because of the large size intervals covered by log D.

An alternative method of calculating the differential particle size distribution is to measure the slope of the cumulative mass loading curve at selected intervals and plot this slope versus the corresponding particle size.

A differential number distribution can also be derived. Since ΔM_j is the mass per unit volume for stage j then we can define ΔN_j as the number of particles per unit volume for stage j. Now ΔM_j and ΔN_j are related by the equation $\Delta M_j = \Delta N_j \times M_p$, where M_p is the average mass of the particles collected on one stage. Dividing both sides of the equation by $M_p \times \Delta \log D$ yields:

$$\frac{(\Delta M/\Delta \log D)_j}{M_p} = \frac{\Delta N}{\Delta \log D_j} \qquad (39)$$

Now $M_p = \rho_p V_p$ where ρ_p is the assumed density of the particle and V_p is the average volume of one particle on one stage:

$$M_p = \frac{\pi \rho_p \ (GMD)_j^3}{6} \qquad (40)$$

Therefore:

$$(\Delta N/\Delta \log D)_j = 6 \ (\Delta M/\Delta \log D)_j / \pi \rho_p (GMD)_j^3 \qquad (41)$$

For cyclone 3:

$$(\Delta N/\Delta \log D)_3 = 6(6.36 \text{ mg/DNm}^3)/(3.14 \ (10^3 \text{ mg/cm}^3)(5.8 \times 10^{-4} \text{cm}^3)$$

$$(\Delta N/\Delta \log D)_3 = 6.23 \times 10^7 \text{ particles/DNm}^3.$$

The results for all stages from the run, for each form of the distribution, are given in Table 2.

7.3.5 Combining Data from Multiple Runs

The previous parts of this section deal with the analysis and presentation of data from a single run (sample). However, in some cases a number of runs will be made at each source and condition tested, and the data from these several runs are to be combined or averaged to produce the desired final distribution. These runs may represent repeated samples taken at a common location, or they may be samples taken from a number of locations across a duct to insure that a representative result is obtained in circumstances where stratification may or does exist. Even under the best of circumstances, combining data from multiple samples can be difficult. Differences in sampling flow rates, temperatures, and perhaps in the hardware used from one run to another will result in variations in the cut diameters (D_{50}'s) for any one stage from one run to the next at any location. Because of these differences in stage D_{50}'s, it becomes improper to simply average the results for individual stages or to directly compare them for calculating control device efficiencies. The solution to the problem is to generate a continuous analytic function (or series of functions) which fit the measured results for each run. Interpolation using these functions permits one to express the results of all the runs at a common set of selected diameters. Once the data are adjusted to a common diameter basis, it becomes a simple matter to average and compare runs. Adjustment to a common set of selected diameters also facilitates comparison with data taken at other sources, or using other instruments.

Two approaches have been tried in generating analytic expressions fitted to measured data. In one approach, least squares or other optimizing procedures are used to fit any one of a number of common distribution functions to the data (e.g. the log-normal function). However, except in rare instances, these functions are only approximations and may be poor approximations at that. The more widely favored and used approach is to make a piecewise continuous spline fit to the data. Usually such a fit is made to one of the forms of the cumulative distribution because in the limit the stage cuts become true step functions and, fits to the cumulative distribution become exact. In any case, such techniques provide useful interpolation methods, and, by making use of some boundary conditions, can be used to make reasonable extrapolations beyond the size range spanned by the largest and smallest D_{50}'s of the sampler.

TABLE 2

CALCULATED PARTICLE SIZE DISTRIBUTION PARAMETERS FOR THE SAMPLING PARAMETERS LISTED IN TABLE 1

STAGE	D_{50} (micrometers)	CUM% (Percent)	CUM(A) (mg/m^3)	CUM(DN) (mg/m^3)	ΔM (mg/m^3)	$\Delta LogD$ ---	$\Delta M/\Delta LogD$ (mg/m^3)	GMD (micrometers)
1	11.4	74.2	5.60	8.56	2.98	.93	3.2	34.2
2	7.7	34.9	2.63	4.02	4.53	.18	25.2	9.5
3	4.3	20.8	1.57	2.40	1.59	.25	6.36	5.8
4	2.9	12.3	.93	1.42	.99	.17	5.8	3.5
5	1.2	9.9	.75	1.15	.27	.38	.71	1.9
Filter	---	---	---	---	1.15	.30	3.8	.85

A spline technique was recommended for use by the ARB and is implemented in the computer data reduction package detailed the Appendix. The technique is a modification of one proposed by Lawless (1978) in which a cubic spline fit is made to the cumulative percentage form of the measured distribution in log-probability space. Modifications have been made to Lawless's technique to insure that no negative slopes are generated and to force continuity in slope in the extrapolation regions beyond the span of the cyclone D_{50}'s. The results of the fit to the cumulative percentage data points are converted back to a concentration basis for the remaining steps. Once obtained, the analytic expression(s) for the fit can be used to generate values of the cumulative distribution at user selected particle sizes and can be differentiated to obtain values of dM/dLogD at any desired diameter. Results from the spline fit to the data from the sample run used in the previous paragraphs can be found as an example the Appendix and were shown in Figures 21 through 23.

An alternative spline fit procedure was developed by Johnson et.al. (1978) as a part of the development of CIDRS (Cascade Impactor Data Reduction System) for the US Environmental Protection Agency (EPA). In the EPA CIDRS the fit is made in log-log space to the cumulative concentration form of the distribution. Modeling of impactor performance in sampling unimodal and bimodal particle size distributions and comparisons of the resulting apparent distributions produced by the EPA CIDRS with the originals showed excellent agreement within the span of the impactor D_{50}'s and fair agreement in extrapolations to beyond a factor of two in diameter from the limits of the measurement range (McCain et.al., 1979). Similar tests of the EPA CIDRS by Smith et.al. (1982) showed that the maximum errors which might be expected in extrapolations of cumulative concentrations to diameters of about twice the D_{50} of the first impactor stage were about 15% and typical errors would be 5% or less. Because most aerosol size distributions are approximately log-normal, the curvatures of the distribution plots are much less radical in log-probability space and consequently easier to fit without generating artifacts; therefore, the cubic spline fit in log-probability space was selected for use by ARB. Experience in fitting the same data by both the Lawless and SoRI techniques has shown good agreement between the two when the data are well behaved and superior performance by the log-probability fit when the cumulative concentration curve showed extreme curvatures. Therefore, the errors associated with the extrapolations made using the Lawless method are expected to be comparable to, or smaller than, those from the EPA CIDRS technique.

Averages of size distribution data are generally desired in both differential and cumulative forms together with measures of the scatter in the data (e.g., variances and/or confidence limits). Having obtained the spline fits, it becomes a simple matter to obtain average values of dM/dLogD and associated variances for a standard set of user selected diameters. In addition, standard statistical tests for outliers can be used to flag and, if desired, remove values from the averaging process if they deviate too greatly from the rest of the data. Outliers are identified by comparing the deviation of the suspect data from the mean of the entire set relative to the standard deviation of the set to the critical value of Student's t-Distribution for the number of samples and desired confidence level. The value X_i is considered to be an outlier and may be excluded if the following condition is met:

$$\frac{[X_i - X_m]}{S} > C_n \tag{5-42}$$

where

X_i = individual value,

X_m = mean of all values,

S = standard deviation of the data set,

C_n = critical value from Student's t-Table.

The application of this test requires that there be three or more runs to be averaged. Care should also be taken by the user to not exclude values arbitrarily which might represent real states of the process being measured.

The situation becomes more complicated when averages for the cumulative forms of the distribution are sought. Direct averaging of data in the cumulative percentage form is quite inappropriate because all information regarding relative concentrations among the runs is lost in the cumulative percentage distribution form. The average cumulative percentage distribution must instead be generated from the average cumulative concentration. Because errors in values for single impactor stages are propogated forward from the D_{50} of the stage throughout the remainder of the distribution, valuable information from stages other than the one with the bad data will be lost if the cumulative distributions are averaged directly with removal of outliers. On the other hand if direct averaging is used without omitting erroneous values detected through outlier analysis, the errors are incorporated in the final results. In order to circumvent these problems, average cumulative distributions are better constructed by numerically integrating the averaged differential distribution. This results in the omission of data from the averaging process only for sizes in the immediate vicinity of the range covered by the stage(s) for which the values are suspect. Variances for the resulting points on the cumulative distribution curve are estimated by using the fact that the variance in the sum of two quantities is equal to the sum of their individual variances.

REFERENCES

Ayer, H.E., and J.M. Hochstrasser. Cyclone Discussion. In: Aerosol Measurement, D.A. Lundgren, et. al., eds. University Presses of Florida, Gainesville, Fl, 1979. pp 70-79.

Beckmans, J.M. Analysis of the Cyclone As a Size Selective Aerosol Sampler. In: Aerosol Measurement, D.A. Lundgren, et. al., eds. University Presses of Florida, Gainesville, FL, 1979. pp. 56-69

Chan, T., and M. Lippman. Particle Collection Efficiencies of Air Sampling Cyclones: An Empirical Theory. Environ Sci. Technol. 11(4): 377-382, 1977.

Davies, C.N. The Separation of Airborne Dust and Particles, Proc. Inst. Mech. Engng. 1(B): 185-198, 1952.

Dietz, P.W. Collection Efficiency of Cyclone Separators. AICHE, J., 27(6): 888-892, 1981.

Farthing, William E., and Ashley D. Williamson. A Unified View of Inertial Impactors and Cyclones. Presented at 1985 Annual Meeting of AAAR, Albuquerque, NM.

Felix, Larry G., George I. Clinard, George E. Lacey, and Joseph D. McCain. Inertial Cascade Impactor Substrate Media for Flue Gas Sampling. EPA-600/7-77-060 (NTIS PB 276583), U.S. Environmental Protection Agency, RTP, NC, 1977. 89pp.

Hochstrasser, J.M. The Investigation and Development of Cyclone Dust Collector Theories for Application to Miniature Cyclone Presamplers. Ph.D Dissertation, Univ. of Cincinnati, 1976.

Hodgman, C.D., Ed., Handbook of Chemistry and Physics. 41st ed., Chemical Rubber Publ. Co., Cleveland, Ohio, 1959. pp. 2188-2192.

Johnson, J.W., G.I. Clinard, L.G. Felix, and J.D. McCain. A Computer-Based Cascade Impactor Data Reduction System. EPA-600/7-78-042 (NTIS PB 285433),U.S. Environmental Protection Agency, RTP, NC, 1978. 601pp.

Knight, G. Tentative Specifications for Respirable Dust Sampling. In correspondence to ACGlH Aerosol Hazards Committee, January 28, 1976.

Lee, K.W., J.A. Greseke, and W.H. Piispanen. Evaluation of Cyclone Performance in Different Gases. Atmospheric Environment, 19(6): 847-852, 1985.

Leith, D., and W. Licht. The Collection Efficiency of Cyclone Type Particle Collection - A New Theoretical Approach. In AICHE Symp. Ser. 68, 1972. pp. 196-206.

Rosin, P., and E. Rammler, and W. Intelman. Priciples and Limits of Cyclone Dust Removal. Z. Ver. dt. Ing., 76:433-437, 1932.

Saltzman, B.E., and J.M. Hochstrasser. Design and Performance of Miniature Cyclones for Respirable Aerosol Sampling. Environ Sci. Technol, 17:418-424, 1983.

Smith, Wallace B., and R. R. Wilson, Jr. Development and Laboratory Evaluation of a Five Stage Cyclone System. EPA 600/7-78-008 (NTIS PB 279084), U.S. Environmental Protection Agency, RTP, NC, 1978. 66 pp.

Smith, Wallace B., D.B. Harris, and R.R. Wilson, Jr. A Five-Stage Cyclone System For In Situ Sampling. Environ. Sci. and Technol., 13(11):1387-1392, 1979.

Soo, S.L. Some Basic Aspects of Cyclone Separators. Proc. of 1st Intl. Conf. on Particle Technol., IIT Research Inst., 1973. pp 9-16.

Wilke, C.R. A Viscosity Equation for Gas Mixtures. J. Chem Phys., 18(4):517-519, 1950.

Williamson, A.D., D.L. Iozia, P.V. Bush, W.E. Farthing, J.D. McCain, W.B. Smith. Development, Appliction, and Support of Particulate Sampling Procedures. Third Annual Report (1982). SoRI-EAS-83-348. Southern Research Institute, Birmingham, AL, 1983.

Appendix

Cascade Cyclone Data Reduction System - Cyclone CIDRS
(Documentation for Computer Programs)

CONTENTS

Appendix

Cascade Cyclone Data Reduction System (Cyclone CIDRS)

Although it is possible to reduce data obtained from cascade cyclone by hand or with calculators, the number of calculations which must be done to treat the data from just one run make hand calculations impractically laborious. When the treatment of data from multiple runs is considered it becomes obvious that a computer is required. In March 1978 a system of programs known by the acronym "CIDRS" (for Cascade Impactor Data Reduction System) was published for this purpose for cascade impactor applications by the US EPA. CIDRS was written in Fortran for use on large "main-frame" computers and has been adapted since for use on some minicomputers. Denver Research Institute released an adaptation of CIDRS written in BASIC for the TRS-80 micro-computer in March 1980. The system described here, Cyclone CIDRS, is a modified version for cyclones of an updated and expanded adaptation of the TRS-80 CIDRS, written in BASIC for the Apple II micro-computer series. With some effort, the program could be adapted to any other micro-computer which is programmable in one of the variants of Microsoft BASIC.

The CIDRS package consists of a series of programs which together provide the capabilities to:

1) Calculate and store the values of needed ancillary data such as dry gas composition and moisture content of stack gases (Methods 3 and 4).

2) Reduce velocity (pitot) traverse data (Method 2) and aid in the selection of sampling flow rates and nozzle dimensions.

3) Generate files containing the hardware specifics on the cyclone configurations used in sampling for later use in calculating stage D50's.

4) Reduce the data from individual runs and generate size distribution information from that data at a set of standard conditions for a standardized array of particle sizes.

5) Combine and appropriately average the results from multiple sample runs obtained at a single source.

6) Plot the size distributions and fractional efficiencies obtained above.

In Addition, programs are also provided to facilitate program selection, for carrying out disk file "housekeeping" chores, and defining orifice constants for use in flow rate calculations.

Cyclone CIDRS is written to be used with a single disk drive Apple II system operating under Apple DOS 3.3. Printed output of tabular material should be possible with any combination of printer and compatible interface. The interface is expected to be located in Slot 1 of the Apple. Graphics dump capability is included for dot matrix printers with graphics capability when used with a Prometheus Graffiti interface, an Orange-Micro Grappler, or similar "smart" interface card. Otherwise the user must supply his own screen dump routines if graphics hardcopy is desired.

The programs making up Cyclone CIDRS are supplied on a single floppy disk. This contains the data reduction programs, several necessary data files and some sample data files. Also included is a configuration file for the SoRI/EPA Five-Stage Cyclone Sampler. The disk is copyable and it is recommended that the original be write protected and preserved as a master copy and duplicates be used as working versions.

Briefly, the programs on the CIDRS disk relating to single Cyclone run data analysis are:

CYCPROG - This is the main program of the system. It accepts and reduces the raw data from individual runs. The program calculates stage D50's, particle concentrations for each stage, calculates log-normal distribution parameters based on a least squares best fit to the measured size distribution, and generates size distribution information for a set of standardized particle sizes through a spline fit and interpolation/extrapolation procedure. The final results can be saved to disk for plotting or to be combined with data from other runs.

ORSAT - Accepts data from Orsat analyses, calculates excess air for combustion processes, and writes the gas composition data to disk for later use by CYCPROG.

METH4 - Reduces data from Method 4 moisture content sampling and writes the results to a disk file for later use by CYCPROG. The file value for moisture content becomes the default value used in reducing impactor data, but it can be altered in CYCPROG.

DEF/CYC - This program builds files containing specific hardware information on the cyclone configurations used in sampling. Information on the type of cyclone (round or rectangular inlets), number of stages, inlet and exit dimensions of the jets on each stage, and calibration constants for calculating values of $\sqrt{\psi_{50}}$ for each stage must be entered. The information in these files is used by CYCPROG for calculating the stage D50's.

DEF/ORI - CYCPROG permits the impactor flow rate and gas volume sampled to be calculated from data obtained with dry gas meters or from orifice meters at the users option. This program generates files of orifice calibration information for use by CYCPROG if the flow rate is to be calculated from orifice meter data. It also calculates values for $\Delta H@$ for use in setting flow rates during sampling.

Combining data from multiple runs is accomplished through STATIS, a program for averaging data from multiple runs made under similar conditions. Simple averages of the differential forms of distributions are made with tests for and rejection of outliers being made at the user's option. The average differential distribution is then integrated to obtain the average distribution in the cumulative forms. Standard deviations and 90% confidence limits are calculated for all forms of the distribution. Provision is also made for correcting the data for errors arising from anisokinetic sampling if the user so desires. The results can be written to disk for later plotting and for use in calculating fractional efficiencies of control devices.

Plotting - Only screen plotting capabilities are included in the system with provision for doing "screen dumps" to dot matrix printers that have graphics capability. The actual plotting is done via a commercial machine language program, Ampergraph. The programs on the disk related to plotting are:

AMPERGRAPH - The machine language plotting routines. The copyright to this program is owned by Madwest Software, Madison, WI and license fees for its use here have been paid to Madwest. Distribution of additional copies will require payment of additional fees ($18.00 each copy on a single copy distribution basis).

DATAPLOT - Program for loading AMPERGRAPH and selecting whether the data to be plotted is from single run analyses (files from CYCPROG) or from combined runs (files from STATIS.)

PLOT3 - Plots data from single runs in three forms: differential, cumulative mass concentration, and cumulative percent by mass. In the cumulative forms both the original distribution generated directly from the data and the results from the spline fit are plotted.

STATPLOT - Plots the results of combining data from multiple runs by STATIS. The results are plotted in the same three forms as used in the single run plotting. Error bars representing 90% confidence limits are also shown.

In addition to the primary data reduction and plotting programs described above, there are several utility programs on the impactor run analysis disk. These are:

MAIN MENU - Provides a way for linking the operation of the various programs described above. Menu selection of the programs can be made from MAIN MENU. All programs return to this one upon completion of use.

PURGE RUNFILE - If files of reduced run data are to be deleted, that should be done via this program as it also removes the deleted runs from an index file which is also maintained on the disk. It also provides a catalog of the reduced data files on the disk.

XPOINTS.DAT - A text file which contains the array of standardized particle diameters to be used in the data presentations.

Field setup for a run can be facilitated by program SETUP. This is a program for reducing velocity traverse data, selecting nozzle diameters and flow rates for isokinetic sampling, selecting metering orifices for impactor sampling, and generating orifice meter pressure drop settings for sampling.

Most of the programs in Cyclone CIDRS for the Apple use a commercial machine language program called "BUILD USING", which is appended to them, for formatting text output to the screen and printer. Apple Computer Inc. did not include any form of the common "Print Using" capability found on most microcomputers. "BUILD USING" adds this capability. For translations of the programs to other machines, the calls to "BUILD USING" are as follows:

Call BU, output string, format string, expression and/or variable list.

output string = formatted result for printing
format string = string expression of format to be used.
expression and/or variable list = list of values (separated by commas) to be printed.

The output string is then printed by a simple Print statement. The Copyright for this program is owned by Rod Stover and it is marketed by Sensible Software, Inc., West Bloomfield, MI. It is used in CIDRS, in an undocumented form, with the permission of Sensible Software, Inc.

The programs described above all use menu selection of all options, and provide interactive prompts for data input. More complete descriptions of each of the programs, lists of all variables used, and detailed operating instructions follow. In the variable lists, all variable names that end with "$" are strings, and all that end with a "(" are arrays. Samples of the results from each program follow the respective detailed descriptions. No commas or semicolons may be used in any inputs.

MAIN MENU

MAIN MENU is a program which provides simple selection of the programs on the CIDRS disk. It is run automatically when the disk is booted, and most of the programs in the system return to it upon their completion.

Program Operation

When run, the monitor screen will show MAIN MENU and lists both the primary program CYCPROG and the auxilliary programs, as shown below:

```
                 MAIN MENU

TO SELECT OPTION ENTER APPROPRIATE NUMBER

  1) ORSAT
  2) METHOD 4 (H20)
  3) CYCPROG
  4) DEFINE CYCLONE CONFIG.
  5) DATAPLOT
  6) STATIS (AVERAGE RUNS)
  7) DELETE RUNFILE
  8) DEFINE ORIFICE CONSTANTS
  9) RUN SETUP
  Q)UIT

YOUR CHOICE
```

MAIN MENU

The user should type a selection of a number 1 through 10 or the letter Q and then press the Return button. This will bring up the selected program.

Program Options

The auxilliary programs listed on the "MAIN MENU" shown in Figure 1 are briefly defined below:

1) ORSAT writes the gas composition file needed by the CYCPROG program.

2) METH 4 writes the percent water vapor in the stack gases file needed by the CYCPROG program.

3) CYCPROG is the primary program.

4) DEF/CYC write files on the cyclone inlet and exit diameters and calibration constants for the specific cyclone in the set. The program CYCPROG uses this file information to set the number of stages for the particle sample weight input data page (page 3 of 3 of input data to MPPROG) and for calculation of the stage D50s.

5) DATAPLOT loads the binary plotting routines and allows selection of data from CYCPROG or STATIS for plotting on monitor screen. Plots of cumulative percent of particles by weight, cumulative mass concentration, and DM/dLogD are made. The x-axis is logarithmetic and spans the range from 0.1 to 100 microns particle diameter. Plots of the CYCPROG output will show the actual original points (stage D50 on the x-axis and percent of particles less than stated diameter, etc. on the y-axis) and points at a set of standard diameters resulting from a mathematical spline fit. Plots of the output of STATIS will show mathematical averages of the spline fit values and 90% confidence limits. The graphical output is for the monitor screen only, with a provision for screen graphics "dump" to a dot matrix printer. A Prometheus "Graphitti", Orange Micro "Grappler", or other similar "smart" printer card with "screen dump" capabilities is required for the "dump" function to work.

6) STATIS averages the particle size data from two or more runs. It provides output on cumulative percent, cumulative concentration, and dM/dLogD bases with 90% confidence limits. Runs to average are selected by CYCPROG test and run numbers. Mixing of "inlet" and "outlet" impactor runs is not permitted. The dM/dLogD values at each particle diameter are averaged and these averaged dM/dLogD values are integrated to provide averages of the cumulative mass concentration and of the cumulative percent less than size distributions. Hardcopy output of the calculated results and disk storage for access by "DATAPLOT" are available as options. Provision is also made for correcting for anisokinetic sampling errors.

7) DELETE RUNFILE- This program deletes old impactor run files from the disk and an index catalog that is accessed by STATIS and CYCPROG. You should delete all old impactor run results via this "PURGE RUNFILE" program in order that the "RUN/NAM" index file will match what is actually on the disk.

8) DEF/ORI - This program accepts calibration data for flow metering orifices and calculates the value of the calibration constant, ΔH@, used in setting up for a sampling run. The data and results can be printed and/or saved to a disk file for later use.

9) SETUP - This program accepts data from a pitot traverse (pitot Δp and temperatures) and calculates point and average velocities from the traverse measurements. The flue gas composition, barometric pressure, and stack pressure are also required as input data. The program can then be used to provide flow rates for isokinetic sampling for each nozzle size which one has available, thereby facilitating nozzle and flowrate selection for isokinetic sampling. After a nozzle and flow rate are selected, the program will provide the required orifice meter setting needed to obtain the selected flowrate.

Q) Exit to BASIC.

If you plan to input cascade impactor data into the CYCPROG program, you will first need to input data into ORSAT and METH4 (and DEF/CYC if you are not using a cyclone set for which the specifications are already stored).

With the MAIN MENU program (Figure 1) showing on the screen monitor, you will need to select the number that corresponds to program you wish to run and type it in.

Description of Variables

A - option selected
A$ - input dummy
D$ - DOS command flag

ORSAT

ORSAT is a program for generating a disk file of the dry gas composition to be used in CYCPROG for calculating stage D50s. The program accepts data from conventional Orsat type analyses and provides output to a printer and/or disk at the user's option. Excess Air and Dry Molecular weight are also calculated per EPA Method 3.

Processing Orsat Data

To obtain the program "ORSAT" from the MAIN MENU program press "1" and then press the "Return" button. The monitor screen will show ORSAT V 1.0 as presented below:

```
              ORSAT V 1.0

TO ENTER/CHANGE AN ITEM PRESS NUMBER OF
ITEM THEN VALUE AND PRESS (RETURN)

 1) YES HARD COPY OPTION
 2) YES DISK FILE UPDATE
 3)  0.00 CARBON MONOXIDE %
 4)  0.00 CARBON DIOXIDE %
 5)  0.00 OXYGEN %
 6)  0.00 NITROGEN %

    00.000 DRY MOLECULAR WEIGHT
    00.000 EXCESS AIR %

SELECT S)AVE, OR ENTER NUMBER OF ITEM
TO BE CHANGED
```

Monitor Screen View of Program "ORSAT"

Note that the gas compositions shown above are all 0.00 whereas these will normally have values either from data you have entered or from old data from a prior test. The values currently on file are read into memory when the program is run.

To enter a new value for any of the 6 variables press the number of the item to be changed, then enter the new value. Note that these gas compositions are all in units of percent by gas volume on a dry (no water vapor) basis, as is provided by an Orsat Gas Analysis (EPA METH3).

After entering all the new Orsat data, press the letter "S" (for Save). The input data will be saved for use in CYCPROG, which performs the particle size data reduction calculations, and control will be passed back to the MAIN MENU program.

Program Description

Initialization is done in lines 6 through 100 and a subroutine from lines 1000 through 1190. The current values of the ORSAT file (ORSAT.DAT) are read into memory in lines 1125 through 1180. The data entry takes place in a subroutine from line 2000 to 2250. The excess air calculation takes place in in lines 2110 and 2115. The dry molecular weight of the flue gas is calculated in line 2100. Printed output, if selected, takes place in a subroutine from line 3000 through 3150 and the disk update takes place in a subroutine from line 4000 through 4040. A machine language subroutine for print formatting is appended to the program as line 63999. THIS LINE MAY NOT BE EDITED - doing so will result in an irrecoverable loss of the program. The subroutine is copyrighted and permission has been granted by the copyright owner for its use here.

Description of Variables

A - input selection dummy
A$ - input dummy
BU - print formatter address
CU - percent carbon dioxide
CM - percent carbon monoxide
D$ - DOS command flag
EX - percent excess air
F$(- print format statements
F1$ - hardcopy flag
F2$ - disk update flag
FM$ - print format
MW - molecular weight
MW$ - input error message
N2 - percent nitrogen
O2 - percent oxygen
R$ - input and print dummies
X - intermediate value in excess air calculation

METH4

METH4 is a program for generating a disk file of the flue gas moisture content to be used in CYCPROG for calculating stage D50s. The program accepts data from conventional Method 4 sampling analyses and provides output to a printer and/or disk at the user's option.

Processing EPA METH4 Data (Moisture Content)

After pressing "2" on the MAIN MENU program, the METH4 Program will appear on the monitor screen, as is shown below: (NOTE: the values will be filled in with data from the current METH4 data file).

```
                METH4   V 1.0

TO ENTER/CHANGE AN ITEM PRESS NUMBER OF
ITEM THEN NEW VALUE AND PRESS (RETURN)

 1) YES HARD COPY OPTION
 2) YES DISK FILE UPDATE
 3)  0.000 GAS METER VOL. (CU FT)
 4)  0.00 ML WATER COLLECTED
 5) 0      GAS METER TEMP (DEG.F)
 6)  0.00 GAS M. DP (IN.H20)
 7)  0.00 P BAROM.  (IN.HG)
 8)  1.000 GAS METER CORR. FACTOR
     0.000 MOISTURE CONTENT (%)

SELECT S)AVE, OR ENTER NUMBER OF ITEM TO
BE CHANGED
```

METH4 Program as Seen on Monitor Screen

If you wish to enter data obtained from an EPA METH4 test, type in the appropriate item number and then the value of the variable in the proper units.

After you have completed entering your data, press the key S (for Save), then press the "Return" key.

When you have finished with the METH4 Program, you will be returned to the MAIN MENU.

Program Description

Initialization is done in lines 6 through 100 and a subroutine from lines 1000 through 1160. The current values of the METH4 file (METH4.DAT) are read into memory in lines 1120 through 1190. The data entry takes place in a subroutine from line 2000 to 2260. The moisture content is recalculated in lines 2100 through 2115 each time an entry is changed. Printed output, if selected, takes place in a subroutine from line 3000 through 3150 and the disk update takes place in a subroutine from line 4000 through 4040. A machine language subroutine for print formatting is appended to the program as line 63999. THIS LINE MAY NOT BE EDITED - doing so will result in a irrecoverable loss of the program. The subroutine is copywrited and permission has been granted by the copywrite owner for its use here.

Description of Variables

A - menu selection dummy
A$ - input dummy
BU - print formatter address
BW - fraction moisture
D$ - DOS command flag
F$(- print format statements
F1$ - hardcopy flag
F2$ - disk update flag
FM$ - print format
MF - gas meter correction factor
PB - barometric pressure
PG - gas meter differential pressure to ambient
R$ - input and print dummies
TG - gas meter temperature
VG - gas meter volume
VH - volume of water vapor at normal conditions
VS - volume of dry gas at normal conditions
WA - volume of condensed water

DEF/CYC

DEF/CYC is used to generate files to use in data reduction by CYCPROG. These files contain the needed hardware information on the specific series cyclone configurations used in sampling. Because the same configuration tends to be used repeatedly, it is desirable to store the information in a permanent file which can be accessed simply whenever it is needed. The information to be input includes a unique name to be used in identifying the file, the number of stages which make up the set and the constants for calculating the value of $\sqrt{\psi_{50}}$ from the Reynolds numbers and the inlets and outlets diameters for each cyclone The files can be called up for review by simply entering the name of the set. The disk files can be updated and printed copies of a configuration file can be obtained at the user's option.

Data Input

Input takes place on two screen pages, the first of which is concerned primarily with general information, and the second for individual stage input and/or changes. The information needed on Page 1 is input by entering the selected menu item number, at which point a prompt for that item will be given. The Page 1 input display is shown on the next page. The items are:

1) Is hardcopy desired? Selecting this item will reverse the currently displayed answer.

2) Is a disk update of the file desired? Again selection of the item reverses the answer.

3) Cyclone set: The file name to be used is the set name with /IMP added. The /IMP is added by the program and should not be entered by the user. When a file name is entered, the disk is checked for the existence of a current file with that name. If such a file exists, it is read into memory and the current information in the file will be displayed on the data entry screens.

4) Description: Enter a brief description of the configuration to help identify its properties for use in CYCPROG. This description will be printed on the screen when the impactor is selected in CYCPROG. Be brief to avoid space problems in the CYCPROG display.

5) Select the type of jet geometry - Circular (round) or Slit. Selection of this option toggles between the two.

6) Enter the number of stages making up the set configuration. This does not include the backup filter. The program is dimensioned for a maximum of 15 stages.

```
   DEFIMP  V2.4-Page 1 of 2

1) HARD COPY OPTION:                   YES
2) DISK FILE UPDATE:                   YES
3) IMPACTOR NAME:
   FILE NAME:----------
4) DESCRIPTION:
5) SHAPE OF JETS (CIRC./SLIT):       CIRC.
6) NUMBER OF STAGES:                     0

P)AGE, Q)UIT, OR NUMBER OF ITEM
TO ENTER/CHANGE: ?
```

After completing the entries on Page 1, press "P" and "Return" to proceed to the second page of data entry which is illustrated below. This page is devoted entirely to the stage parameters. The program will set up one line for parameters for each stage, numbered sequentially from 1 to the total number of stages entered on the previous page. Entry of data is made by entering the stage number for which information is to be entered or changed. When a stage is selected, the cursor will be placed at the start of the leftmost entry in its line. Pressing "Return" will accept the current value of the entry and advance the cursor to the start of the next entry. Entering a number will change the current value to that number. When the cursor is advanced beyond the last field the program will revert to the stage select mode.

A, B, and C are the constants for calculating $\sqrt{\psi_{50}}$ from the Reynolds number.

DEFIMP V2.4-PAGE 2 of 2

STAGE NO.	A	B	C	INLET DIA.	EXIT DIA.
1	0	0.000	0.0000	0.000	0.00
2	0	0.000	0.0000	0.000	0.00
3	0	0.000	0.0000	0.000	0.00
4	0	0.000	0.0000	0.000	0.00
5	0	0.000	0.0000	0.000	0.00

TO ENTER/CHANGE DATA FOR A STAGE ENTER STAGE
NO. P)AGE

Upon completion of all data entry, press "Q" and "Return" to proceed. The information will be printed and/or saved to disk depending on the users selected options.

Description of Major Program Segments

Program initialization takes place in lines 6 through 100 and in a subroutine from line 1000 to line 1160. Page 1 of the primary data entry menu takes place in lines 2000 through 2490, with pre-existing files being checked and loaded in lines 2367 through 2450. Page 2 of the data entry is done in lines 2500 through 3350.

Printing of the information is done by a subroutine from line 4000 through 4500 and the disk update is done in lines 5000 through 5920. A machine language subroutine for print formatting is appended to the program as line 63999. THIS LINE MAY NOT BE EDITED - doing so will result in an irrecoverable loss of the program. The subroutine is copyrighted and permission has been granted by the copyright owner for its use here.

Identification of Variables

A - option selection dummy
A$ - input dummy
BU - address of print formatter
CP(- plot variable for relative cut spacing
CR - test value for closeness of cuts
CZ - index of number of stages selected in stage select routine
D$ - flag for DOS commands
DC - coefficient of discharge
EF - error flag
F$(- format statements for printing
F1$ - flag for hardcopy
F2$ - flag for disk update/save
HH - screen tab index
I - loop index
J - variable counter
JD(- inlet diameter
JK(- $\sqrt{\psi_{50}}$ constant, A
JL(- outlet diameter
JN(- $\sqrt{\psi_{50}}$ constant, B
JS(- $\sqrt{\psi_{50}}$ constant, C
N$(- names of sets on file
NI$ - set name
NM$ - set file name
NS - number of stages
OK - flag for pre-existing file
P - menu page number
PF - format selector
R$ - dummy for input and printing
RM$ - set description
SH - set type flag
SH$ - set type
TI - number of set on file
Y$ - input dummy

D E F CYCLONE V3.0

2) DISK FILE UPDATE: YES

3) CYCLONE SET NAME: SORI5

FILE NAME: SORI5/IMP

4) DESCRIPTION: SORI 5 CYC'S (NEW#4) WITH WEF'S CONSTANTS

5) INLET SHAPE (CIRC./SLOT) : CIRC.

6) NUMBER OF STAGES: 5

CYC NO.	A	B	C	IN DIA.	OUT DIA.
1	.304	-2.767	3.620	1.2700	1.5000
2	1.982	-13.60	20.550	1.0000	1.0500
3	4.733	-29.37	43.121	.7500	.8330
4	2.841	-18.93	29.150	.5100	.5940
5	-.033	-2.475	5.833	.3050	.3560

CYCPROG

This program is the heart of the entire system and is the longest and most complex program in Cyclone CIDRS. The required inputs are cyclone set configurations from DEF/CYC, stage weights from the cyclone run, blank corrections to be applied to the stage weights, sampling information regarding the gas volume sampled, the sample duration, pressures and temperatures at meter, flue gas, and cyclone conditions, the particle density to be used if D50's are to be calculated on a Stokes diameter basis, the flue gas composition and moisture content, the diameter of the sampling nozzle, and the flue gas velocity.

Options availble to the user include:

1) Choice of the diameter basis to be used in the data presentation --Stokes (physical), Classical Aerodynamic, and Impaction Aerodynamic.

2) Obtaining printed output of the input data and the results.

3) Saving either or both the input data and results to disk for later use.

PROGRAM OPERATION

The program operation proceeds through a number of subroutines which will be described in more detail later. These routines can be broken down into fundamental operations. The first is related to program initialization and requires no user input or intervention. The second is data input which takes place in three screen pages. The third deals with preliminary calculations of such items as gas flow rates, stage pressures, jet velocities, gas viscosity, and isokinetic ratio; this section requires little user intervention other than restarting at program halts for display of intermediate information. The fourth program block is the one in which the stage D50's are calculated. In the fifth block, the best log-normal fit is made and the spline fit and interpolation/extrapolation are performed to obtain results at a standard set of particle diameters. The final block provides screen and printed displays of the results and handles disk storage of the data and results as desired.

Data Input

To select the CYCPROG Program from the Main Menu, press 3 and then the Return key. Then the CYCPROG program will load and run. First the user will be prompted as to whether an old data set is to be loaded. If so, respond "Y" and a prompt for the File Name for that data set will be given. After either choice, the program will proceed to the data input/change routines. These consist of three menu pages as follows:

```
          CYCPROG V3.1 - Page 1 of 3

 1) Part. Diameter          Imp. Aero.
 2) Date of Test:
 3) Time of Test:
 4) Location of Test:
 5) Test Number
 6) Test Type
 7) Run Number:
 8) Run Remarks:
 9) Water Vapor              0.00%
     CO2 00.00%          CO  0.00%
     02   0.00%          N2 00.00%
10) Sampler Type:
11) Particle Density    0.00 GRAMS/CC
12) Orifice ID (optional):

ENTER: Q)UIT, P)AGE, OR NUMBER OF ITEM TO
 ENTER/CHANGE:
```

CYCPROG, Page 1 of 3, as shown on screen

If you wish to enter or change the test data on page 1 of 3, press the item number of the variable and then type in the information (in the appropriate units).

The explanation, units, and choices for the variables on Page 1 of 3 of MPPROG are as follows:

1) Select one of three types of particle diameters. The diameters are: P (physical or Stokes), C (classical aerodynamic), or I (impaction aerodynamic).
2) Enter date (ALPHA NUMERIC), such as July 18 1984 or 7/18/84.
3) Enter test time (NUMERIC) on a 24 hour basis, such as 1430 for 2:30pm.
4) Enter test location (ALPHA NUMERIC).
5) Enter field test number (NUMERIC). The test number is expected to be keyed to major projects.
6) Select test type, either INLET or OUTLET. (Inlet to or outlet from control equipment such as an electrostatic precipitator).

7) Enter run designation (ALPHA NUMERIC).
The program will generate the FILE NAME from the test number, the run designation, and the test type. If that file name already exists in the run index file, the file name and run designation will be rejected.

8) Enter remarks and comments about the sample run (ALPHA NUMERIC). If lengthy comments are made, some of the menu items may be pushed off the screen display.

9) The percent water vapor and dry gas composition will be obtained from the METH4 and ORSAT program files. These can be changed from the keyboard here. The percent water can also be calculated by entering a water volume on the next menu page if you wish.

Enter the name of the specific cyclone set that was used in DEF/CYC for specifying the hardware configuration. Data on the number of stages, stage geometry, and stage calibration constants will be obtained from the impactor file which was generated by the program "DEF/CYC". You must run "DEF/CYC" before CYCPROG to generate the cyclone file unless you select a configuration which is already on file. A hardware definition file for the SoRI/EPA Five-Stage Cyclone Sampler is stored on the disk under the name SORI5/IMP. Enter only the selected name (such as SORI5). Do not include the /IMP portion of the file name.

11) Enter the particle density to be used in calculating the particle Stokes (physical) diameter. Be very careful in what particle density you use here. Note that with a particle density of 1.0 grams/cc results in calculating the particle aerodynamic diameter (i.e. diameter of sphere of unit density which has aerodynamic properties equal to the actual real particle). If you select aerodynamic dia. (item 1), the program sets particle density = 1.0 when the calculations are done.

12) Enter the gas metering orifice identification diameter. Enter the ID designation as 3 digits/period/alpha set name. The program gets the orifice constants from the file written by the program DEF/ORI. This orifice ID is not required unless the stack gas sampling flow rate is to be calculated from an orifice meter rather than a dry gas meter. It is useful to enter the orifice ID for completeness in run documentation in any case.

Note that the numbers above correspond to the item numbers in Page 1 of 3 (Fig. 5). When the user has completed data entry into page 1 of 3, then press P and RETURN and page 2 of 3 will appear.

Input to Page 2 of 3 - page 2 of 3 will appear on the monitor screen as shown below:

```
 1) GAS METER VOL               .000 CUBIC FEET
 2) IMPACTOR DELTA P            .00  IN. HG.
 3) ORIFICE DELTA P             .00  INCHES H20
 4) STACK PRESSURE              .00  INCHES H20
 5) BAROMETRIC PRES             .00  INCHES HG
 6) STACK TEMP                 0     DEGREES F
 7) METER TEMP                 0     DEGREES F
 8) IMPACTOR TEMP              0     DEGREES F
 9) SAMPLE TIME                 .00  MINUTES
10) AVG GAS VEL                 .00  FEET/SEC
11) ORIFICE PRESS               .00  INCHES HG
12) NOZZLE DIA                  .000 INCHES
13) MAX PART DIA              60.00  MICRONS
14) VOL of CONDENSED WATER      .00  CC
15) METER CORR FACTOR          1.00

ENTER:  Q)UIT,  P)AGE, or NUMBER OF ITEM TO
ENTER/CHANGE:
```

CYCPROG, Page 2 of 3 as shown on screen

Now if you wish to enter the cyclone test data on page 2 of 3, press the item number of the variable you wish to enter or change and return. The explanation for the variables on page 2 of 3 of CYCPROG are as follows:

1) Enter dry gas meter volume in cubic feet. Set equal to zero (0) if the gas flow is to be calculated from the orifice meter.

2) Enter the sampler gas pressure drop. If left at 0, the program will calculate the stage pressure drop for each stage using standard orifice equations and the stage geometry, gas composition, temperature, pressure, and gas sampling flow rate. Normally it should be left at zero because the pressure drop will not be measured during the run.

3) Enter the gas flow rate metering orifice pressure drop. If the orifice meter is downstream of dry gas meter and vacuum pump as in a standard EPA METH5 type sampling train the orifice meter pressure drop should be entered as a negative value.

4) Enter the static pressure of stack gas (negative if stack is below ambient atmospheric pressure). This stack pressure is the pressure difference (inches water gauge) between the stack gas and the atmospheric barometric pressure.

5) Enter the atmospheric barometric pressure (inches mercury absolute) at the elevation of the stack sampling location.

6) Enter the stack gas temperature (degrees F).

7) Enter the dry gas meter temperature (degrees F).

8) Enter the sampler temp. (degrees F). May differ from stack gas temperature.

9) Enter the total time of gas sampling through cyclone (minutes).

10) Enter the stack gas velocity (ft/sec). This is optional but needed if the isokinetic ratio is to be calculated and if correction for non-isokinetic sampling is desired.

11) Enter the orifice meter differential pressure to ambient. This is negative if the orifice meter and dry gas meter were located upstream of the vacuum pump as is done on occasion. Leave the value as zero if the pump, orifice, and gas meter were in the standard Method 5 configuration.

12) Enter the sampling nozzle diameter (inches). Optional, but needed if the isokinetic ratio is to be calculated or correction for non-isokinetic sampling is desired.

13) Enter the maximum particle diameter (typically 60 microns for controlled sources, 1000 microns for uncontrolled).

14) Enter the volume of condensed water collected if a moisture content specific to this run is to be calculated. If left zero, the default or previous value will be used.

15) Enter the dry gas meter correction factor if different from 1.0.

When the entry of data into page 2 is complete, press P and Return and page 3 of 3 will appear.

Input to Page 3 of 3

The page 3 of 3 of CYCPROG data entry is shown in below:

```
Cyclone Version 3.1      Page 3 of 3

MASS GAIN OF STAGE 1          .00 MG
MASS GAIN OF STAGE 2          .00 MG
MASS GAIN OF STAGE 3          .00 MG
MASS GAIN OF STAGE 4          .00 MG
MASS GAIN OF STAGE 5          .00 MG
MASS GAIN ON FILTER 6         .00 MG


MASS GAIN OF 8 BLANK SUBST. .00 MG
MASS GAIN OF 9 BLANK FILTER .00 MG

ENTER: Q)UIT, P)AGE, or NUMBER OF
ITEM TO ENTER/CHANGE:
```

CYCPROG, Page 3 of 3, as shown on screen

Note that the number of stages shown on the monitor screen is dependent upon the sampler specified in item #10 on page 1 of 3 of CYCPROG. For example the SORI5 has 5 stage weights, 1 filter weight, 1 blank cyclone weight, and 1 blank filter weight (8 weights in total).

To enter the masses collected by the stages, the outlet filter, and the blanks, press the number of the stage or of the filter or blank you wish to enter or change and Return.

Note that the program will subtract the blank weights from the measured stage and outlet filter weights to correct for interferences. Negative or zero net stage weights are not allowed - they will cause fatal errors. Therefore, if a stage weight other than a blank is zero, give it an infinitesimally small positive value. At this point data entry for the run is complete.

Check Filename

The user should now check page 1 of 3 (press P) for the file name (Item #7 on page 1 of 3). This is an alpha numeric filename (name composed of letters and numbers). This filename is generated by CYCPROG from the test number, the run number, and the test type (inlet to control equipment or outlet from control equipment). An example of a filename is T1R2.OT (corresponds to test #1, run #2, outlet from control equipment).

Processing the Data

After completing the data entry, press "Q" and "Return" to begin processing. Several intermediate results will be shown on the screen, after which the program will pause and then proceed to calculate the D_{50}s.

After the stage D50's are calculated, the reduced size distribution will be printed on the screen in cumulative percent by mass form and the log-normal and spline fits will be made. The user will then be given prompts regarding whether hardcopy of the results is desired and if the results and/or raw data are to be saved to disk. Finally the choice of returning to the main menu or continuing with the reduction of more runs in this program will be made.

Description of Major Subroutines in CYCPROG.

Initialization

Partial initialization takes place in lines 9 through 99 at which point a jump to a subroutine from lines 1000 through 1399 takes place. The bulk of the Format statements used in setting up the displays are found in these lines and values of a number of important constants and flags are set up there. The default moisture content and the dry gas analysis are read in by routines at lines 1270 and 1300. The array of standard particle diameters for which results are calculated is read in from disk by a subroutine at line 5700.

Menu Selection

A short subroutine at line 1400 is used to enter the users selection of menu choices and check the choice for validity.

Data Entry

Data entry takes place in a series of three major blocks (screen pages) of a subroutine beginning at line 2000. Lines 2000 to 2999 make up the first page of data entry, which is primarily devoted to general information on the run and the hardware used in making it. Lines 3000 to 3390 make up the second page of data entry in which information is entered regarding sample volumes, flows, pressures, temperatures, etc. Finally, catch weights are entered at the third screen page which runs from line 3500 to 3690.

In the first data entry page, a subroutine at line 2800 is used to check for the validity of disk files from which input is requested. Cyclone configuration files are read from disk by a routine beginning at line 2350. File names for disk storage of raw data and results are formed when the run identification is entered by a subroutine at line 2420. The file name is constructed from the test number, run ID, and Inlet/Outlet designation. To insure that previous files are not overwritten, the file name is checked against an index file when it is formed. An existing file name cannot be used. If the flow is to be calculated from orifice meter data, the orifice meter calibration information is read in by a subroutine at line 2610. Entry of data on the remaining pages is straightforward and self-explanatory.

Calculation Sequence

Upon completion of data entry, the calculations take place in the following sequence:

1) The gas viscosity and wet and dry molecular weights are calculated in a subroutine at lines 4500 through 4810. The viscosity is calculated by a method in which the viscosity of a gas mixture is calculated from the viscosities of its constituents (Wilke, 1950). The individual component viscosities are calculated from polynomial curve fits to data contained in the CRC Handbook of Chemistry and Physics.

2) The flow rate at standard conditions and at impactor conditions (which will usually be stack conditions) and the isokinetic ratio are calculated from either the gas meter or orifice meter data as selected by the user in a subroutine located in lines 4000 through 4050.

3) Stage pressure drops, velocities, and Reynolds numbers are calculated in a subroutine from line 4900 through 4998. The pressure drops of individual stages are calculated by treating the inlets and outlets as orifice plates having coefficients of discharge as of 0.61.

4) Theoretical stage constants for D50 calculations are calculated, in lines 5051 and 5052. The stage constants are calculated from curve fits to calibration values of $\sqrt{\psi_{50}}$ versus Re (Farthing, 1985).

5) Stage D50's are calculated in an iterative loop from lines 5000 to 5160. In the loop an initial estimate of the value of the Cunningham correction factor, CU, is made and a value of the D50 is calculated using the estimate. A new value of CU is then calculated using the D50 and the process is repeated until successive estimates of CU differ by less than 0.02%, at which time the loop is terminated. The last pair of values of D50 and CU are retained as the final results.

6) The stage weights are used to form cumulative percentages smaller than consecutive D50s beginning at the final stage and proceeding toward the inlet in lines 5170 through 5350. Corrections for blank weight gains are made in the process. The total measured mass concentration in at dry normal conditions is calculated at line 5380.

7) Transformations to log-probability coordinates from linear diameters and cumulative percentages are made preparatory to the spline and best log-normal fits in lines 5500 through 5690 and 5775 through 5778. Any stages to be omitted in the fits are dropped in lines 5581 through 5583. The data to be fit are then reordered in lines 5780 to 5900 so that the stage index increases from the filter to the impactor inlet rather than the entry order from inlet to filter. If problems are encountered that would lead to a fatal error, an error flag is set and the program will return to the data input pages.

8) A least squares fit of the best log-normal approximation to the distribution is made by a subroutine from line 10000 to 10150.

9) A cubic spline is fit to the data for use in generating distribution parameters at a set standard diameters in lines 6000 through 6290 (Lawless, 1978). A modification of the cubic spline described by Lawless is used. The modification insures that no negative slopes will be generated. Interpolation along the spline curve is used to generate distribution values at the standard diameters which fall between the stage D50s and to extrapolate for those which fall below the smallest D50 or above the largest. The extrapolations are carried to diameters far removed from the range of the stage D50s for later use in averaging results from multiple runs. However, they should not be expected to be very good, quantitatively, much farther than a factor of two in diameter from the smallest and largest of the stage D50s. These interpolations and extrapolations are made between lines 6500 and 6848.

10) Printed output of the raw data and results are done, if desired, by a subroutine at lines 9000 through 9890.

11) If desired, results are saved to disk for later plotting and/or averaging by a subroutine from lines 7000 through 7700. The results are written to a text file and the text file name is added to an index file.

12) Raw data are saved, if desired, in two files by a subroutine in lines 30000, 30090. All numeric information needed to reproduce the results are placed in data arrays, if they are not already array variables, and a binary save of the memory locations in which array variables are stored in the machine is made. This makes the numeric storage fast and compact. String variables are simply written to a standard text file. Reloading of raw data from a previously stored run is done through the following subroutine (lines 31000 through 31090).

13) A machine language subroutine for print formatting is appended to the program as line 63999. THIS LINE MAY NOT BE EDITED - doing so will result in an irrecoverable loss of the program. The subroutine is copyrighted and permission has been granted by the copyright owner for its use here.

Description of Variables in CYCPROG

AV - average flue gas velocity
B(- intermediate value storage for spline fit
BS - first stage for which theoretical stage constant is to be generated
BU - address of the print formatting routine
BW - flue gas fraction moisture
C - dummy used in spline fit
C0-C3 - constants used in normal transform
CC - previous value of Cunningham correction in iteration
CC(- final values of Cunningham corrections
CD - flue gas percent CO2
CM - flue gas percent CO
CP - metering orifice calibration pressure
CQ - metering orifice calibration flow rate
CT - metering orifice calibration temperature
CU - new value of Cunningham correction in iteration
CU(- cumulative mass fraction smaller than D50
D$ - DOS command prefix
D0-D3 - constants for inverse normal transformation
D5 - new stage D50 estimate in iteration
D5(- final stage D50s
D6(- stage D50s on impaction aerodynamic basis
DA - start of array storage address - used in raw data save
DA(- dummy array into which non-subscripted variables are placed
for data save
DC - discharge coefficient & square of same
DG(- dM/dLogD's
DI - metering orifice diameter
DL - length of array space in memory - used in data save
DL(- estimate of slope in spline fit
DM - dry molecular weight of flue gas
DP - measured total pressure drop
DP(- stage pressure drops
DQ - dummy used in spline interpolation
DQ(- dummy used in spline fit
DT$ - date
ET - convergence test value in spline fit
F$ - format strings
F$(- format strings
F(- gas composition fractions as array
F1 - flag for diameter basis on which spline fit is made
FC - blank backup filter weight gain
FF - backup filter weight gain
FF$ - flag for substrate selection in theoretical stage constant calculation
FI - number of reduced data sets stored on disk
FI$ - file name for reduced data
FL - flag in normal and inverse normal transforms

FR - constant used in transforming form deg. F to deg. Rankine
FS - cyclone flowrate at dry normal conditions
GD - gas density
H(- lst differences for spline fit
Hl, H2 - scaling lengths for spline interpolations
H2(- 2nd differences for spline fit
HG - constant used in conversions from in. H20 to in. Hg
I - loop index
I$ - test type
IM$ - cyclone type
IN$ - cyclone comments
IS - percent isokinetic
J - loop index
JD(- inlet and outlet diameters
JK(- $\sqrt{\psi_{50}}$ constant, A
JN(- $\sqrt{\psi_{50}}$ constant, B
JS(- $\sqrt{\psi_{50}}$ constant, C
K - loop index & counter
L - mean free path
L$ - test location
L1-L9 - used in log-normal fit
LR - Log (Reynolds number) in base 10
LT - Ln(10)
LZ - used in log-normal fit
M(- stage weight gains
MA - molecular weight of standard air
MF - gas meter correction factor
MR - number of stages to omit in spline fit
MW - wet molecular weight
MW(- individual constituent molecular weights
MX - number of menu items per page
N2 - percent nitrogen
ND - nozzle diameter
NM$ - file name for data storage
NN - number of orifices in orifice set
NP - number of entries in array of standard diameters
NZ - number of data points to be used in spline fit
02 - percent oxygen in flue gas
OK - file validity flag
OM - relaxation parameter used in spline fit
OP - metering orifice pressure drop
P - menu selection variable
PB - barometric pressure
PC - pressure differential to ambient at metering orifice inlet (orifice upstream of pump)
PM - pressure conversion factor
PP - metering orifice calibration pressure
PR - used in spline interpolation
PS - stack pressure differential to ambient

QC - flow rate conversion factor cfm to cc/s
QI - sampler flow rate (acfm at impactor conditions)
QO - orifice flow rate
QS - sampler flow rate at dry standard conditions
R$ - dummy string for input and printing
RE(- stage Reynolds numbers
RH - particle density
RN$ - run designation
RO$ - orifice ID
RR$ - run remarks
S - number of cyclone stages in set, does not include the backup filter
S1 - used in spline interpolation
S2(, S3(- used in spline fit
SC - weight gain of blank stage
SH - sampler type flag
SI(- values of $\sqrt{\psi_{50}}$ for each stage
SP - standard barometric pressure
SU - used in viscosity calculation
T - gas temperature, deg. C
T$ - time at which run was made
TC - total mass concentration
TD - duration of sample
TI - sampler temperature
TK - temperature, deg. K
TM - gas meter temperature
TN - test number
TN$ - test remarks
TS - stack temperature
TX, TY - dummies for sorting
U - gas viscosity
U(- single constituent viscosity
VJ(- stage inlet velocities
VM - meter volume
VT - total pressure drop
W - goodness of fit estimater for spline fit
WA - volume of condensed water
X - dummy for file input
X$ - input dummy
X(- array of log(D50)'s
XO - maximum particle diameter
X1-X3 - used in spline interpolation and as dummies
XM - sum of stage weight gains
XP(- array of standard diameters
XX$ - dummy for printing
XX(- LOGs of standard diameters
XY$, XZ$ - dummies for printing
Y - test number
Y(- normal transforms of cumulative percents
Y1(- slope of spline fit

Y2(- used in spline fit
YY$ - dummy for file checks
YY(- cumulative percents in probability space
ZY - error flag
ZZ$ - dummy for file input
ZZ$(- names of files in index file

```
********************CYCPROG V 3.1 ********************

************* INPUT DATA ***********


 1)PART. DIAMETER    CLASSICAL AERODYAMIC
 2)DATE OF TEST:
 3)TIME OF TEST:
 4)LOCATION OF TEST:
 5)TEST NUMBER     0  REMARKS:
 6)TEST TYPE          OUTLET
 7)RUN NUMBER: DEMO-FILE NAME:T0RDEMO.OT
 8)RUN REMARKS: EXAMPLE FROM PROCEDURES MANUAL
10)SAMPLER  TYPE: SORI5  SORI 5 CYC'S (NEW#4) WITH WEF'S CONSTANTS
11) PARTICLE DENSITY  1.00 GRAMS/CC

 9)WATER VAPOR          4.90% (KEYBOARD)
   CO2    .22%        CO    .03%
   O2   19.75%        N2 80.00%
12) ORIFICE ID :


 1)GAS METER VOL     43.000 CUBIC FEET
 2)SAMPLER  DELTA P    .00 IN. HG.
 3)ORIFICE DELTA P     .00 INCHES H2O
 4)STACK PRESSURE      .00 INCHES H2O
 5)BAROMETRIC PRES   29.60 INCHES HG
 6)STACK TEMP       300    DEGREES F
 7)METER TEMP       100    DEGREES F
 8)SAMPLER  TEMP    300    DEGREES F
 9)SAMPLE TIME      120.00 MINUTES
10)AVG GAS VEL       50.00 FEET/SEC
11)ORIFICE PRES        .00 INCHES HG
12)NOZZLE DIA          .188 INCHES
13)MAX  PART  DIA   1000.0 MICRONS


MASS GAIN ON STAGE 1      3.32 MG
MASS GAIN ON STAGE 2      5.05 MG
MASS GAIN ON STAGE 3      1.81 MG
MASS GAIN ON STAGE 4      1.10 MG
MASS GAIN ON STAGE 5       .30 MG
MASS GAIN ON FILTER       1.28 MG

MASS GAIN OF BLANK SUBSTRATE     .00
MASS GAIN OF BLANK FILTER        .00
```

********* RESULTS **********

ACTUAL FLOW RATE .511 CFM

FLOW RATE AT STANDARD CONDITIONS .334 CFM

PERCENT ISOKINETIC 88.425 %

VISCOSITY 229.8E-06GM/CM SEC

CALCULATED SAMPLER DELTA P = .64 IN. HG

STAGE	CUNN. CORR.	DP DP(CLAS AERO)	DP (IMP AERO)	CUM. FREQ.	INLET RE	SQRT PSI50
1	1.022	11.401	11.524	74.1835	852	.220
2	1.032	7.680	7.803	34.9145	1082	.213
3	1.057	4.344	4.467	20.8398	1443	.187
4	1.086	2.910	3.032	12.2862	2122	.227
5	1.204	1.239	1.360	9.9533	3548	.220

TOTAL MASS CONCENTRATION = 1.13E+01 MG/DRY NORMAL CUBIC METER

SPLINE FIT ON CLASSICAL AERODYNAMIC DIAMETER BASIS

PARTICLE DIA. (MICRONS)	CUMFR (STDDEV)	CUMFR (PERCENT)	CUM.MASS (MG/DRY N.CU.METER)	DM/DLOGD
.100	- 1.6485	4.96	5.62E-01	3.87E-01
.159	- 1.5819	5.68	6.43E-01	4.30E-01
.251	- 1.5153	6.48	7.34E-01	4.77E-01
.398	- 1.4486	7.37	8.34E-01	5.27E-01
.631	- 1.3820	8.35	9.45E-01	5.79E-01
1.000	- 1.3154	9.42	1.07E+00	6.33E-01
1.585	- 1.2488	10.59	1.20E+00	6.90E-01
2.512	- 1.2514	10.54	1.19E+00	2.25E+00
3.981	- .8773	19.02	2.15E+00	5.95E+00
6.310	- .6224	26.69	3.02E+00	6.48E+00
10.000	.2538	60.02	6.79E+00	2.94E+01
15.850	2.3798	99.13	1.12E+01	3.22E+00
25.120	4.8022	100.00	1.13E+01	5.38E-04
39.810	7.2332	100.00	1.13E+01	2.40E-10
63.100	9.6839	100.00	1.13E+01	2.41E-19
100.00	12.1705	100.00	1.13E+01	3.89E-31
158.50	14.7302	100.00	1.13E+01	0.00E+00
251.20	17.4452	100.00	1.13E+01	0.00E+00
398.10	20.5657	100.00	1.13E+01	0.00E+00
631.00	25.3436	100.00	1.13E+01	0.00E+00

*** INHALABLE PARTICULATE MATTER ***

CUM MASS LESS THAN 1.000 MICRON: 1.07 MG/DNM3 (9.42 %)

CUM MASS LESS THAN 2.512 MICRON: 1.19 MG/DNM3 (10.54 %)

CUM MASS LESS THAN 10.000 MICRON: 6.79 MG/DNM3 (60.02 %)

CUM MASS LESS THAN 15.850 MICRON: 11.22 MG/DNM3 (99.13 %)

**** RESULTS CONTINUED ****

LOG-NORMAL SIZE DISTRIBUTION PARAMETERS

LEAST SQUARES LINE: Y=-1.76 + 1.86X
MASS MEDIAN DIAMETER: 8.912
GEOMETRIC STANDARD DEVIATION: 3.454
CORRELATION COEFFICIENT: .799

DATAPLOT

DATAPLOT performs two functions. First it loads the binary program "AMPERGRAPH" and then prompts the user to select the source of the information to be plotted. Upon selecting the source, the program loads the appropriate BASIC program to deal with the actual plotting. The selection of the source is made by entering one of the following:

R - plot data from CYCPROG (single run data, run PLOT3)

S - plot combined run data from STATIS

There are no user modifiable variables in the program.

PLOT3 and STATPLOT

PLOT 3 and STATPLOT are programs for plotting size distribution results. PLOT3 plots single run data from files generated by CYCPROG, while STATPLOT plots combined run results from STATIS. The programs produce plots of the size distribution in three forms as follows:

1) Cumulative percentage - Done in a Log-Probability format with particle diameters on a logrithmic scale as the abcissa and cumulative percentage on a probability scale as the ordinate. The probability axis is marked with ticks at identified percentages. Both the original distribution and the results of the spline fit will be plotted if the files were generated by CYCPROG.

2) Differential distribution - Done in a log-Log format with particle diameters as the abcissa and dM/dLogD as the ordinate. The range of the vertical axis is selectable by the user. Only the results of the spline fit are plotted if the data are from CYCPROG. Error bars representing 90% confidence limits are added if the data are from STATIS.

3) Cumulative mass concentration - Done in a Log-Log format with particle diameter as the abcissa and cumulative mass concentration as the ordinate. The range of the vertical axis is selectable by the user. Both the original distribution and the results of the spline fit will be plotted if the data are from MPPROG. Error bars representing 90% confidence limits will be added if the data are from STATIS.

The range of the particle size axis is fixed in the program as 0.1um to 100um but can be altered by editing the program ("0.1,100" in lines 100, 275, and 410 in PLOT3; lines 100, 275, and 405 in STATPLOT). The limits must be integral powers of ten. The actual plotting is done by "AMPERGRAPH", a set of machine language routines which must have been loaded before PLOT3 or STATPLOT is run. If these programs have been run from DATAPLOT, AMPERGRAPH will have been loaded.

Provision is made for obtaining hardcopies of the plots on compatible dot-matrix printers. The printer interface must be in Slot 1 of the Apple, and must be an Orange Micro "Grappler" card, a Prometheus "Grafitti" card, or a similar "smart" interface card that provides onboard graphics dump software and uses the same commands as do the "Grappler" and "Grafitti" cards. The program can also be modified by the user to make use of a user supplied graphics dump routine.

HIMEM is reset to protect the graphics display area and the AMPERGRAPH routines. When the user has completed all plotting HIMEM should be restored to its normal value or there may not be enough space for long programs or programs which require large variable space to run. Normally this is 38400 for Apple DOS 3.3, but it can be different if a variant of the standard DOS 3.3 is used. Entering "HIMEM:38400" from BASIC will do the reset. This is done by the program if it makes a normal exit, but must be done by the user if the program crashes or its operation is halted prematurely by the user. In the event of a crash due to an input error, etc. the program can be re-started by typing "TEXT", pressing Return, then typing "RUN" and pressing Return.

Program Operation

When run, the program first displays the contents of the reduced run index file on the screen if single run data is being plotted. A catalog of the disk will be displayed if the data is to come from STATPLOT files. The user is then prompted to enter the name of the file from which the data is to be plotted.

The following sequence is done if the data to be plotted are from CYCPROG:

After the file is read, the Cumulative Percentage plot will be drawn and held on the screen for a short period of time after which the user will be asked if hardcopy is desired. If so, the screen dump will be done.

Next, the minimum and maximum values of dM/dLogD will be printed on the screen and the user will be asked to enter the desired minimum and maximum values for the vertical axis. THESE VALUES MUST BE INTEGRAL POWERS OF TEN. The differential distribution will then be plotted and again the user will be asked if hardcopy is desired.

Upon completion of the differential distribution, the minimum and maximum values of the cumulative concentrations will be displayed and the user will be asked to enter the desired minimum and maximum values to be plotted. AGAIN, THESE VALUES MUST BE INTEGRAL POWERS OF TEN. And once more, the data will be plotted and the user will be asked about hardcopy.

The order in which the plots are done changes to the sequence: Cumulative Concentration, dM/dLogD, and Cumulative Percentage, if combined run results are being plotted.

The program exits to BASIC when the cumulative concentration curve is completed. If more runs are to be plotted, simply type "RUN" and press Return. If another program in the system is to be run, type "RUN MAIN MENU" and press Return.

Program Descriptions

PLOT3

Initialization takes place in lines 5 through 16. The run index file is read in line 17 and the file names in the index are displayed in line 10. The file name to be read is entered in line 19, and the file is read into memory in lines 20 through 80. The plotting grid for the cumulative percent plot is drawn in lines 100 through 140 and the vertical axis is labeled in lines 141 through 151. The file name is printed in the upper left portion of the plotting grid in line 154. The spline fit results for the cumulative percentage curve are plotted in lines 159 through 170. The raw data for cumulative fractions of the total concentration are converted by a subroutine in lines 5580 through 5700 at line 171, and the original size distribution is plotted in lines 172 through 177. A FOR/NEXT loop is used in line 178 to set the duration for which the screen display is held. Hardcopy is taken care of in lines 179 through 190.

The minimum and maximum values of dM/dLogD are found in lines 210 through 240 and displayed in lines 250 and 260. The user enters the vertical plot limits in line 270. The differential distribution is plotted in lines 271 through 340. Hardcopy is provided for in lines 341 through 346.

The minimum and maximum cumulative concentrations are found in lines 370 and 380, and the user enters the selected values for the plot limits at line 390. The plotting grid is drawn and labeled in lines 400 through 480. The results of the spline fit are plotted in lines 510 through 540, and the original data are plotted in lines 550 through 570. Hardcopy is provided for in lines 590 through 630. Lines 8988 through 9950 provide transforms from probability units to linear percent.

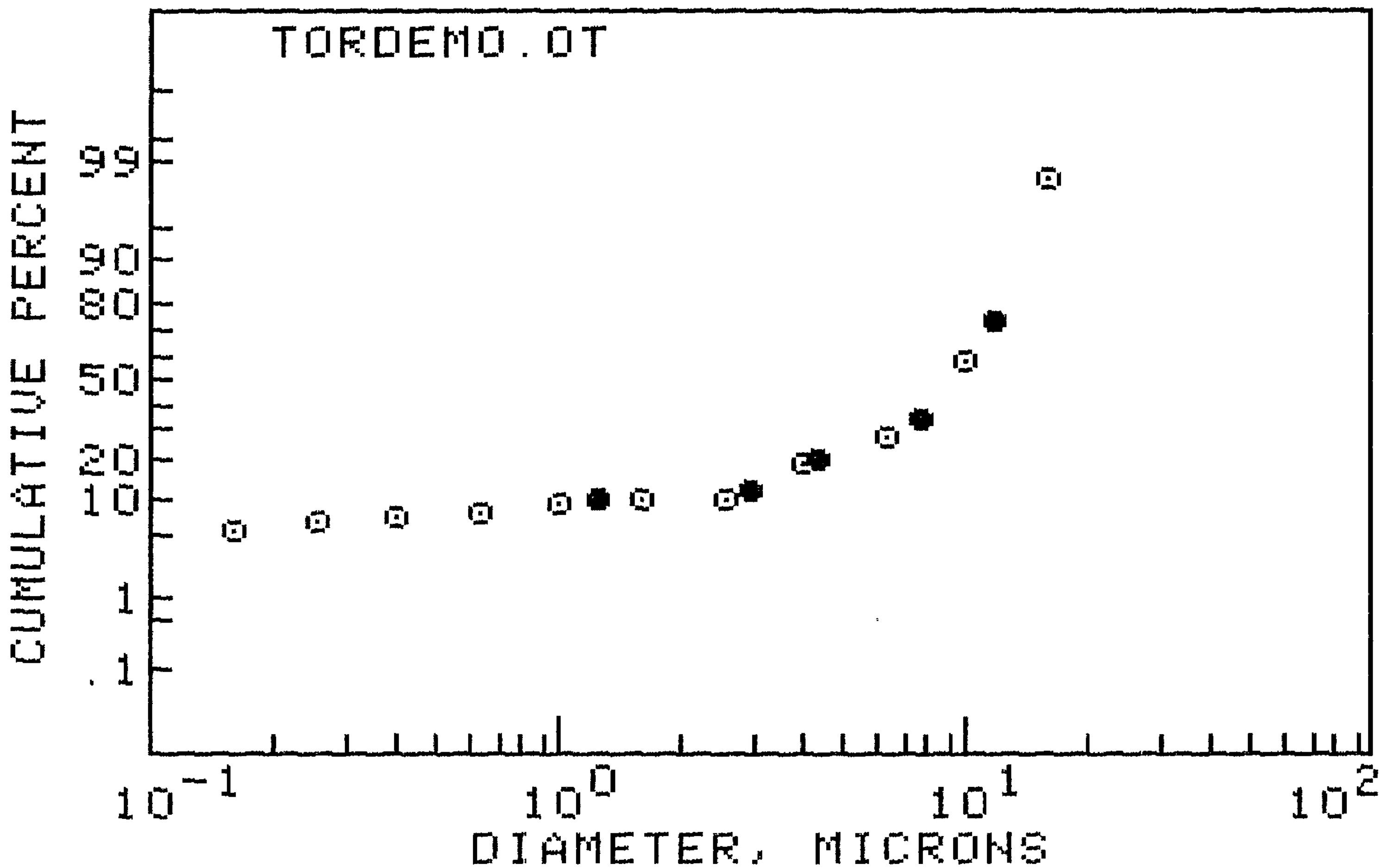
Description of Variables in PLOT3

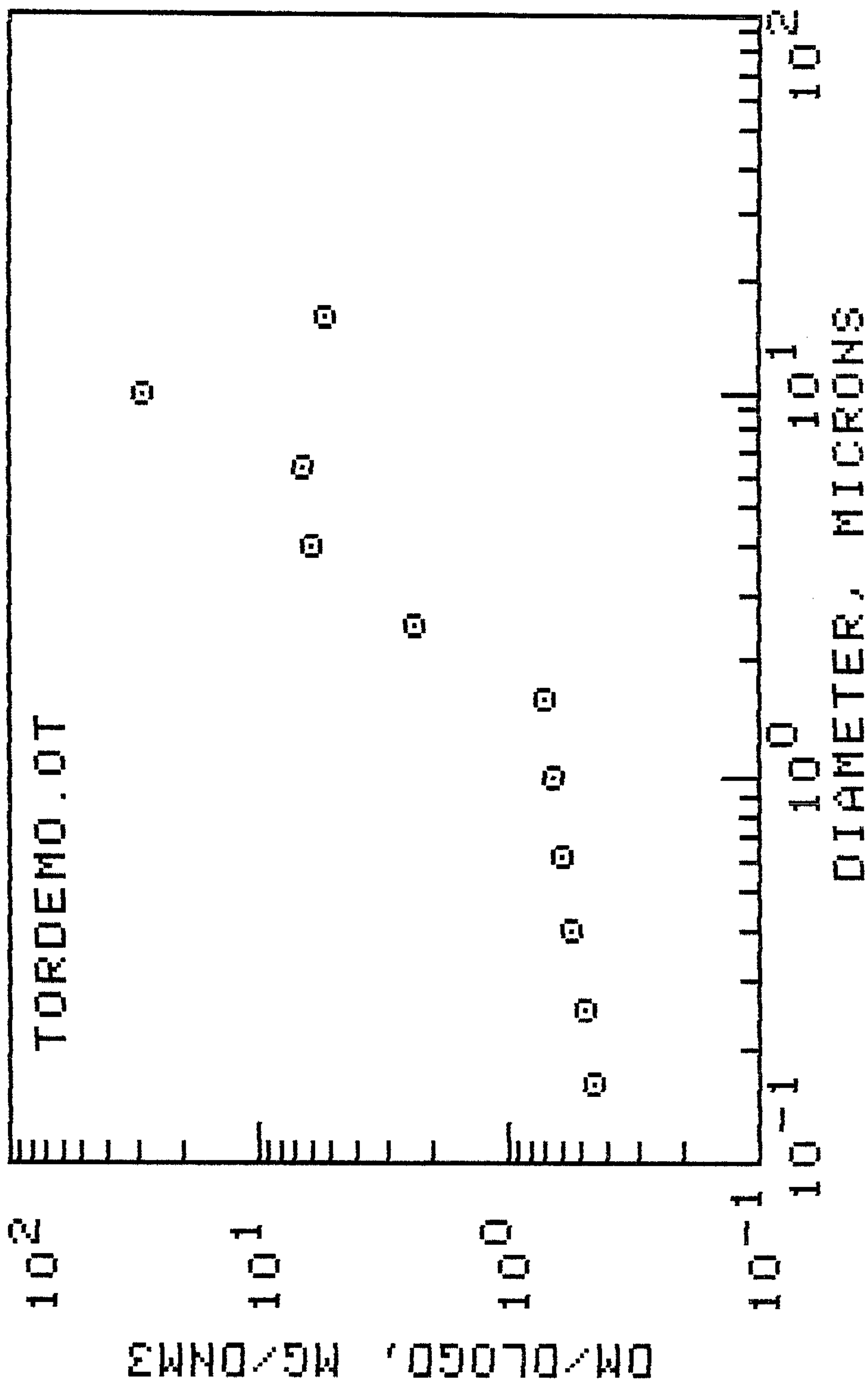
CO-C3 - constants used in normal transforms
CU - cumulative percent/100
CU(- cumulative percent/100 from raw data
D$ - DOS command flag
DO-D3 - used in normal transforms
D5(- stage D50s on selected diameter basis
D6(- stage D50s on Impaction Aerodynamic basis
DB - sorting dummy
DB$ - diameter basis
DG(- dM/dLogD
DL - sorting dummy
DT$ - date
FL - flag used in normal transforms
I - loop index
L$ - sampling location
LA$ - labels for tick marks
LX$ - label for X-axis
LY$ - label for Y-axis
NM$ - file name
NP - number of diameters in standardized diameter array
NR - number of runs in index file
P$ - screen dump command string
R$ - input dummy
RR$ - run remarks
S - number of impactor stages
T - intermediate value in normal transform
T$ - run time
TC - total concentration
X1 - dummy variable
X2 - dummy used in normal transform
X3 - linearized cumulative fraction
XP(- array of standard diameters
Y$ - contents of index file
Y(- cumulative fractions smaller than D50s in probability units
YL - maximum dM/dLogD
YM - minimum dM/dLogD
YY(- cumulative percents at standard diameters in probability units

Description of Variables in STATPLOT

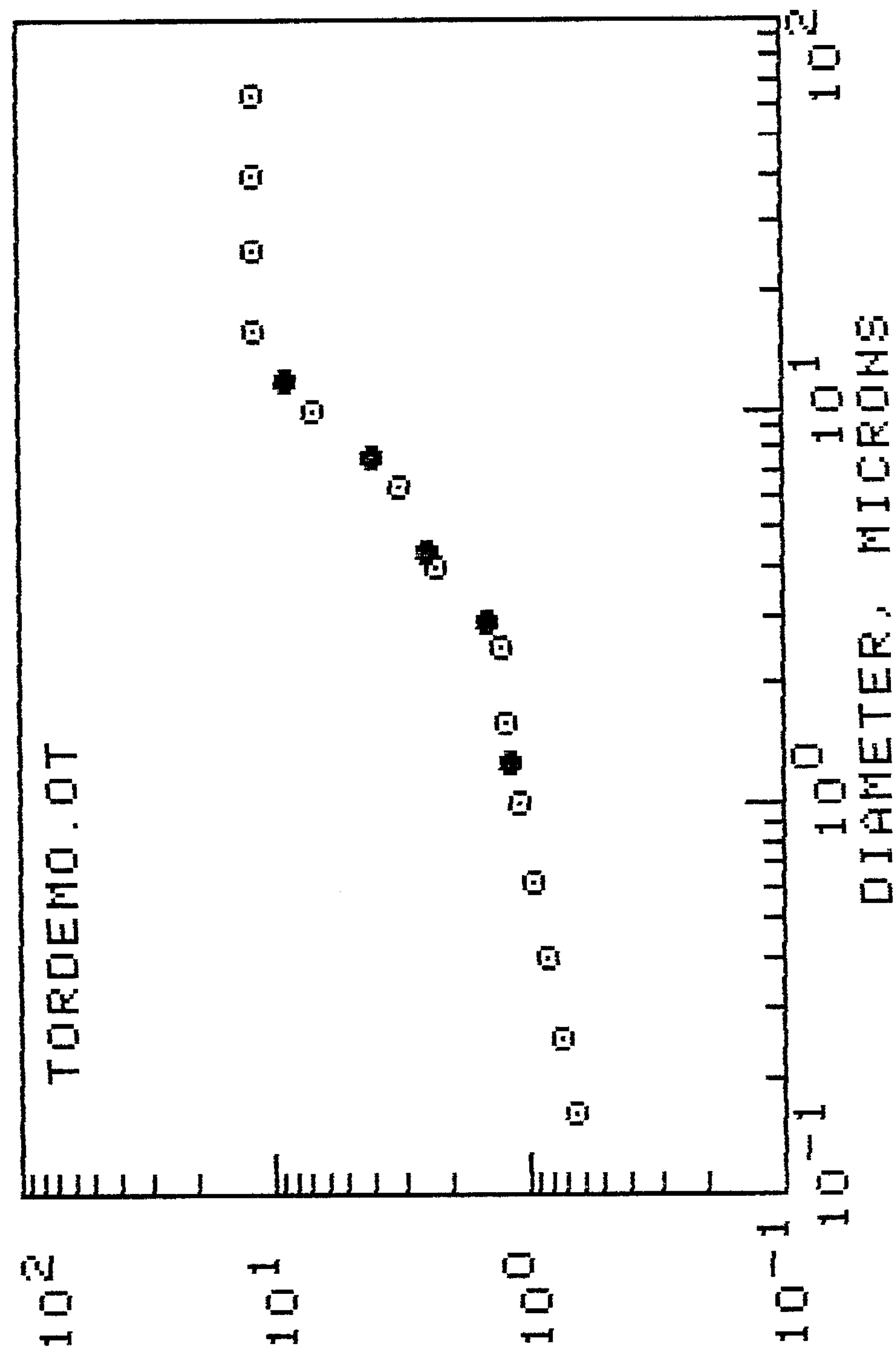
Most of the variables which appear in STATPLOT also appear in PLOT 3 and have the same meanings. The following are not shared with PLOT3:

CY(- confidence intervals for cumulative loading
M(- dM/dLogD
S(- standard deviation (not used, but read from file)


TORDEMO.OT
CUMULATIVE PERCENT
99
90
80
50
20
10
1
.1
10^{-1}
10^{0}
10^{1}
10^{2}
DIAMETER, MICRONS



TORDEMO.OT
DIAMETER, MICRONS
DM/DLOGD, MG/DNM3
10^{-1}
10^{0}
10^{1}
10^{2}
10^{-1}
10^{0}
10^{1}
10^{2}



TORDEMO.OT
CUM. CONC., MG/DNM3
DIAMETER, MICRONS
10^-1
10^0
10^1
10^2

PURGE RUNFILE and PURGE IMPACTOR FILE

These programs are used for purging obsolete reduced run data files and sampler configuration files, respectively, from the data disk. If old files are to be deleted, the deletions should be done through these programs so that the names of the deleted files will be removed from the index files. The operation of the programs is quite similar, consequently they are described here together.

Program Operation

A catalog of the disk will be displayed and the user will be prompted for entry of the file to be deleted. In the case of deleting run files, the test number, run ID, and test type will be requested and the file name will be constructed from these. In the case of impactor files, the name of the sampler (the file name less the /IMP ending) is to be entered. NOTE: The verification of the name of the file to be deleted requires only the single key "Y" or "N" as a response; do not press return after pressing the proper key. After receiving verification of the file name, the program will delete the file from the disk and rewrite the appropriate index file with the entry dropped from it. The user will then be asked ;if more files are to be deleted, and if so, will repeat the sequence. If not, the program will terminate. To return to the system menu, type "RUN MAIN MENU" and press Return.

Program Descriptions

The disk catalog is displayed in line 15 and the file name is input or constructed in lines 20 through 40. Verification of the file name is requested in line 50. The file is deleted in lines 62 through 65. The index file is read in lines 75 through 150, and rewritten in lines 160 through 220. The prompt for deleting more runs is given inline 230.

Description of Variables

D$ - DOS command flag
I - loop index
I$ - inlet/outlet flag
K(- flag for index of run/sampler to be dropped
M - number of names left in index file after deletion
MM$ - name of sampler file to be deleted
NM$ - name of sampler or of runfile to be deleted
NR - number of entries in the index file
R$ - input dummy
RN$ - run ID
RO - flag to avoid attempt to redimension arrays
TN - test number of run file to be deleted
Y$(- contents of index file

SETUP

SETUP is a program for reducing data from velocity traverses, selecting impactor nozzle diameters and flow rates for sampling, calculating orifice and gas meter settings to obtain the selected flow rates, and filling in pretest information on field data sheets for impactor and cyclone runs. Printing of the pretest information is formatted for use with the preprinted field data form (run sheet) shown following the program description. The program is intended primarily to assist in sampling stationary sources using cascade impactors and cyclones, but it can also be used in conjunction with the program MTOP for setting up to do Method 5 and Method 17 sampling.

Program Operation

The program operates in a series of three major blocks. The first block is devoted to the reduction of data from a velocity traverse, the second to the selection of sampling nozzles and flowrates, and the third to the selection of metering orifices and the generation of meter parameters for obtaining the selected sampling rate. If velocities and temperatures are known, one can skip the velocity traverse portion of the program and move directly to nozzle and flow rate selection by responding "N" to a prompt which is given when the program begins. If the latter is done, the required velocity and temperature must be entered manually; prompts for this will be given. Printed output is available from the first (velocity) and third (metering parameters) blocks.

Velocity Traverse

Data input to the velocity traverse portion takes place on two or more screen pages. The first page is devoted to general information regarding the measurement location and the circumstances of measurement. The remaining pages are for the input of the temperatures and velocity pressures at each of the measurement points for a single port. The first page for data input is shown on the following page. When selecting items for data entry from a "menu" for which only a single character entry is possible, only the key which designates the item should be pressed. Do not press return after pressing the key for your selection. A prompt for the required input will then appear at the bottom of the screen.

```
        IMPACTOR OP & VELOCITY PROGRAM

1) TEST CODE (xxxxI)
2) NUMBER OF PORTS                   0
3) NUMBER OF POINTS PER PORT         0
4) DATE
5) % O2                             0.0
6) % CO2                            0.0
7) % H2O                            0.0
8) AMBIENT PRESSURE                30.00 in. Hg
9) DELTA P STACK                    0.00 in. H2O
A) AMBIENT TEMP                     0.   deg F
B) STACK TYPE                       RECT/
D) DUCT LENGTH                      0.00 feet
E) DUCT DEPTH                       0.00 feet

ENTER ITEM NO. TO CHANGE, C TO CONTINUE,
R TO RETURN TO MENU, OR V FOR NEW
VELOCITY TRAVERSE.
```

The information needed for page 1 is entered as follows:

1) Enter a five character code for the velocity traverse. A code based on the Test Number to be ;used as the major project designation in CYCPROG followed by "I" or "O" for inlet or outlet is suggested. This code can consist of any alpha-numeric string without commas or semicolons.

2) Enter the number of ports used in making the traverse.

3) Enter the number of points at which measurements were made along each traverse line.

4) Enter the date in a form which suits the user. (NO commas or semicolons).

5) Enter the oxygen content of the flue gas as a percentage on a dry basis.

6) Enter the CO2 content of the flue gas as a percentage on a dry basis.

7) Enter the flue gas moisture content as a percentage (wet basis).

8) Enter the barometric pressure at the sampling location in inches of mercury.

9) Enter the pressure differential between the stack and ambient in inches of water (negative if stack is at lower pressure than ambient).

A) Enter the expected gas/orifice meter temperature in "°F".

B) Toggles the stack type between rectangular and round. This will also toggle entry "D" between "DUCT LENGTH" and "DUCT DIAMETER". At the same time, entry "E" will appear or disappear as appropriate.

D) Enter the stack length (the dimension along the face in which the ports are installed) for a rectangular duct or the diameter if the duct is round.

E) Enter the depth of the port (dimension of the face parallel to a traverse line) if the duct is rectangular.

The duct dimensions are not necessary, but if given, the total volumetric gas flow will be calculated.

When the entry to this page is completed, press "C" to move on to the actual entry of the traverse measurements. Pressing "R" will permit the user to exit this program and return to the disk menu (all data will be lost). Pressing "V" simply restarts the program but preserves the data.

A sample screen for the remaining pages of velocity traverse data entry is shown below. The number of traverse points per port entered on page 1 sets the number of line entries for this page. This page will be repeated once for ech of the number of ports entered on page 1. Entering "N" will advance to the page for the next port in the sequence. The program "wraps" back around to Port 1 if "N" is entered when on the page for the final port. Entering "K" enables entry of the pitot calibration constant. Entering "P" permits one to select a particular port number for data entry. Entering "V" restarts the program but preserves all current data. Entry of a point number results in successive prompts for the entry of the velocity pressure and flue gas temperature at that point. Pressing only "Return" for either entry retains the current value for that entry.

```
          VELOCITY TRAVERSE

P) PORT NO          1
K) PITOT CONSTANT   0.830

POINT #    Vp(H2O)  T(degF)  VEL(ft/s)
  1         0.000      0        0.00
  2         0.000      0        0.00
  3         0.000      0        0.00
AVG DUCT VELOCITY = 0.0 ft/sec
AVG DUCT TEMP     = 0   deg F
AVG SQRT DELTA P  = 0.000 in H2O

ENTER POINT NO. OR ITEM NO.,
N FOR NEXT PORT, C TO CONTINUE,
V TO RESTART
```

If the duct is round, the program will provide a line in the field for Port 1 for entry of data for the center of the duct. This information is not used for any of the calculations of average velocities or flow rates and entry is optional. It is needed if a contour map of the velocity field is to be plotted later. The entry sequence for a round stack is from the center outward.

After entering all the data for the complete traverse, enter "C" and the program will calculate and display the average velocity and temperature for the entire duct (and the total volumetric flow rate if the duct ;dimensions were entered). A printed copy of the raw and reduced data can be obtained at the user's option by pressing "P". Pressing "S" will save the data to disk under the file name "VEL DATA", with the Test Code appended (eg VEL DATA.221 if the Test Code were 221). Pressing "V" restarts the program with all data intact. Pressing "D" will advance to the next major program block-selection of nozzle size and flow rate.

This portion of the program operates through three screen pages of entry and selection. The first page, shown below, repeats a large portion of Page 1 from the velocity traverse section but adds lines for entering a Run Number, Substrate Set Number, and Sampler ID information. The entries which duplicate those of the velocity traverse section will already be filled if the velocity section was not skipped. The Run Number can be any alpha-numeric sequence that contains no commas or semicolons. A suggested sequence is the Test Number designating a major test series, followed by I or O to designate that the sample was an inlet or outlet sample, followed by a number representing the inlet or outlet sample sequence number for that test. The Substrate Set identifier for impactor runs can only be numeric.

```
        IMPACTOR OP & VELOCITY PROGRAM

1) RUN NUMBER  (xxxxI-n)
2) SUBSTRATE SET NO.       0
3) IMP TYPE/SHELL NO/PLATE NO
4) DATE
5) % O2                    0.0
6) % CO2                   0.0
7) % H2O                   0.0
8) AMBIENT PRESSURE       30.00 in Hg
9) DELTA P STACK           0.00 in H20
A) AMBIENT TEMP            0.   deg F
B) STACK TYPE              RECT.
D) DUCT LENGTH             0.00 ft
E) DUCT DEPTH              0.00 ft

ENTER ITEM NO. TO CHANGE, C TO CONTINUE,
R TO RETURN TO MENU, OR V FOR NEW VELOCITY
```

When entry to Page 1 is complete, press "C" to continue. (Pressing "V" will restart the program with all data intact; pressing "R" will offer an opportunity to exit the program and return to the disk menu.) At this point the program will offer selection of doing the sampling calculations for the average velocity and temperature for a particular port from the velocity traverse, for the duct as a whole, or for a velocity and temperature which the user will enter directly. After "C" has been pressed, the values of velocity and temperature to be used in the remaining calculations will be displayed. These may be changed at the user's option. They must be entered if the velocity trverse section of the program was skipped. Pressing "C" once more results in the display of a menu for selecting the type of sampler to be used. Selecting one of the samplers shown will result in the program stepping through an array of nozzle sizes, calculating the flow rate required for isokinetic sampling for each size. Once the calculated flow drops below a maximum for the particular sampler, the program will display the nozzle diameter (in mm) and flow rate (in acfm) and ask if the combination is acceptable. If it is not, the program will continue stepping downward through the available nozzles until an acceptable combination is reached. The maximum flow rates for display are:

Andersen - 1.25 acfm - set in line 1700

Brink - .04 acfm for the 5 stage - set in line 1770
      - .025 acfm for the 6 stage - set in line 1760

Pilat (UW) - 2.0 acfm - set in line 1710

Series Cyclone - 2.0 acfm - set in line 1729

These limits should not be taken as usable upper limits for the sampler flow rates; they are probably too high in most cases. They are used here merely to start the displayed combinations at the first set which approaches a usable value. When an acceptable combination is found, pressing "Y" will result in the program advancing to the next major block - selection of a metering orifice and calculation of metering parameters.

The nozzle sizes for the Andersen and Pilat impactors start at 5/8 inch and decrease in size by increments of 1/16 inch to a minimum of 1/8 inch. All of these sizes may not be available to the user. These sizes are set in lines 1650 through 1680. The Brink nozzles start at a size of 5mm and decrease in steps of .5mm to 2mm and then in steps of .1mm to 1mm. These sizes are set in lines 1750 through 1830. The series cyclone nozzles sizes are set in a twelve (12) element array at line 11497 with dimensions ranging from 3.5 to 12mm.

Metering Parameters

Once the sampling flow rate to be used has been found, meter rates and orifice meter settings must be calculated. Because impactors typically operate at much lower flow rates than used with conventional Method 5 sampling systems, smaller orifice meters are needed than are used with Method 5 systems. Method 5 nomographs cannot be used with the smaller orifices so the required settings are calculated here. The very wide range of possible flow rates that can be used with impactors make it impossible to standardize on one or even two orifice meter configurations as done in Method 5, therefore the program requires entry of an orifice ID and calibration constant, $\Delta H@$, for the selected orifice.

After the orifice constant is entered, the program will display a table of orifice meter settings and corresponding times, in seconds, per gas meter revolution. The gas meter is assumed to produce 1 revolution per 0.1cf. The settings are based on the absolute pressure at the orifice inlet being atmospheric less the value quoted as Psys. The absolute pressure in the gas meter is taken as being equal to the pressure at the orifice meter inlet less the orifice meter pressure differential. The system is set up as it is to enable sampling with the orifice and gas meter located upstream of the pump to avoid requiring a leakless pump. The latter are difficult to obtain for use at the low flow rates at which some impactors operate. The actual pressure at the orifice meter in this system configuration will depend on the impactor used, the flow rate, losses through the backup filter, probe, hoses and moisture traps. Thus the table is generated for wide range of possible orifice inlet pressures. It is desirable to us an orifice meter which produces a pressure differential in the range of two (2) to five (5) inches of water for good readability without undue flow restriction. If a Method 5 type pump and meter configuration is used, the orifice meter should be set to the value corresponding to the entries for Psys of 0 or -0.5.

Gas meter accuracy becomes problematical at the very low flow rates at which the Brink impactor is operated. However, it is not a good practice to rely solely on a single meter for setting the flow and calculating the total volume sampled; a cross check is desirable. One simple way to obtain a cross check is to employ two orifice meters in series. It is unlikely that both will have problems at any one time, thus the flow can be set with one and verified with the other. Provision for such a douple orifice meter setup is made if the Brink impactor is selected.

After the orifice has been selected, an option to obtain a printed copy of the table and other information can be obtained by pressing "C". The printout is formatted to be done on a preprinted field sampling form. Examples of a blank form and one on which the information has been printed are provided at the end of the program description. The program then returns to the start of the velocity traverse section.

Program Description

Initialization is done in lines 110 through 140 and a subroutine from line 11000 through 11500.

Page 1 data input for both the velocity traverse and flow rate selection segments is handled in lines 165 through 580. Pressure and molecular weight calculations are done in lines 600 through 640. Flags are checked in lines 645 and 650 to jump to either the average velocitiy output, the flow rate selection segment, or to fall through to the velocity traverse data input as appropriate. Input of the velocity traverse data is done in lines 660 through 900. Velocities are calculated and the velocity pressures and temperatures are summed for averaging in lines 910 through 990. The average velocity and temperature for each port is calculated in lines 1000 and 1010. The average square root of the velocity pressure for the port calculated in line 1015. Grand averages for the duct as a whole are calculated in lines 1030 through 1115. The display of the grand averages is done in lines 1110 through 1190 and the options at that point are handled in lines 1190 through 1240. The disk save of the point velocities is done via a subroutine in lines 20000 through 20180. Printing of the velocity traverse data and results is done by a subroutine in lines 8000 through 8460.

Selection of the portion of the duct for which the sampling flow rate calculations are to be made takes place in lines 1300 through 1560. The sampler type to be used is selected in lines 1570 through 1640. The nozzle and flow rate calculations and selection are done in lines 1650 through 1995. Metering orifice selection is done in lines 2000 through 2580. Printing of the Run Sheet (orifice DP table) is done in lines 2600 through 2970.

Description of Variables

A - dummy for menu selections
A$ - dummy for menu selections
A2 - substrate set number
B1 - number of ports
B2 - number of traverse points per port
BU - print formatter address
C - pitot constant
CJ - number of points for averaging
CN(- cyclone nozzle diameters
D$ - DOS command flag
D1 - nozzle diameter in 16ths of an inch
D2 - duct area
D4 - nozzle diameter in mm
DB - duct depth
DL - duct length or diameter
F - gas meter temperature
F$(- format statements
F1 - internal flag for jumps
F9 - internal flag for jumps
F1$ - part of file name for velocity traverse save to disk
FK - temperature in deg. Rankine
FO$ - format statement
G - sampler type selector
G$ - date
G1 - % O2
G2 - % CO2
G4 - % N2
G5 - % H2O
H1 - orifice calibration constant (H)
H2 - orifice calibration constant (H)

I - loop index
I$ - sampler ID
11, 12, & 13 - indices for print formatting
J - loop index
J(- time per meter revolution
K - loop index
M - number of orifice meters
M1 - dry mol. weight
M2 - wet mol. weight
M3 - number of Brink stages
N - port number selected manually
N$ - run designation
O$ - flag for selected port(s) for traverse
O(- velocity pressures
O1 - orifice ID
O2 - orifice ID of second orifice
(A(- point velocity
P1 - local barometric pressure
P2 - stack pressure differential
P3 - absolute pressure of flue gas
Q$ - flag for new traverse
Q1 - sampling flow rate
Q2 - stack flow rate, acfm
Q3 - stack flow rate, dscfm
R - metering orifice inlet pressure differential to ambient
R$ - input and printing ;dummy
RR - same as R
S(- intermediate pressure calculation results
SP - flag for round duct velocity traverse
ST$ - duct type
T - temperature for orifice/gas meter calculations
T(- temperature at traverse point
V - velocity for flow rate calculations
V(- velocity at traverse point
X - orifice meter intermediate calculation results
X(- average temperature for port
Y(- average velocity for port
Z$ - input dummy
Z1 - average velocity in duct
Z2 - average temperature in duct
Z3 - average square root of velocity pressure for duct

REAL BLANK

START TIME	SAMPLING TIME (min.) / Traverse point	VOLUME COND. H_2O (ml)
END TIME	OPERATORS: 1) 2)	SAMPLING LOCATION

RUN EVALUATION

UNLOADED BY

	TIME (MIN)	Port No. / Traverse point	GAS METER VOLUME	GAS METER TEMP. (F)	PRESS. DROP (in. Hg)	METER ORIFICE ΔP_1 (in. H_2O)	ΔP_2 (in. H_2O) or Gas Meter S/Rev	IMPACTOR TEMP. (F)	FLUE GAS TEMP. (F)
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									
21									
22									
23									
24									
25									
26									
27									
28									
29									
30									
31									
32									
33									
34									
35									

SAMPLING NOTES

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NOTES AND OBSERVATIONS	Note Your Observations on the APPEARANCE of EACH Stage, Substrate, or Cyclone Upon Disassembly
	PRECUTTER CYCLONE
	STAGE ZERO
	STAGE ONE
	STAGE TWO
	STAGE THREE
	STAGE FOUR
	STAGE FIVE
	STAGE SIX
	STAGE SEVEN
	STAGE EIGHT
	BACK UP FILTER(S)

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DEMO 1/2/86

% O2:	9.7	% N2:	81.3	AMB P:	30.00	Cp:	.83	DUCT AREA:	144
%CO2:	9.0	%H2O:	14.6	<>Pstk:	-5.0	AMB T:	90		

	PORT 1			PORT 2			PORT 3		
PT #	PV H2O	T F	VEL ft/s	PV H2O	T F	VEL ft/s	PV H2O	T F	VEL ft/s
1	.30	300	37.1	.28	295	35.7	.29	301	36.5
2	.32	305	38.5	.31	303	37.8	.31	310	38.0
3	.33	310	39.2	.33	312	39.2	.33	320	39.4
AVG	.56	305	38.3	.55	303	37.6	.56	310	38.0

AVG DUCT VEL = 37.9 ft/s
AVG DUCT TEMP = 306 deg F
AVG SQRT DELTA P = 0.558 IN. H2O

VOLUME FLOW = 327,884 acfm
= 191,825 scfm

REAL BLANK

DEMO

IMP ID: 5CYCS	% O2: 9.7	AMB P: 30.00	PORT : A
DATE: 1/2/86	% CO2: 9.0	AMB T: 90	GAS VEL: 37.95
SUB SET : 0	% N2: 81.3	<>Pstack: -5.0	GAS TEMP: 306
	% H20: 14.60	Pstack: 29.63	IMP FLOW: .943

START TIME	SAMPLING TIME (min.) / Traverse point	VOLUME COND. H_2O (ml)
END TIME	OPERATORS: 1) 2)	SAMPLING LOCATION
RUN EVALUATION		UNLOADED BY

	TIME (MIN)	Port No. / Traverse point	GAS METER VOLUME	GAS METER TEMP. (F)	PRESS. DROP (in. Hg)	METER ORIFICE ΔP_1 (in. H_2O)	ΔP_2 (in. H_2O) or Gas Meter S/Rev	IMPACTOR TEMP. (F)	FLUE GAS TEMP. (F)
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									
21									
22									
23									
24									
25									
26									
27									
28									
29									
30									
31									
32									
33									
34									
35									

NOZ DIA: 7.000

ORI ID: .120S
<>H@: 3.05
GAS METER #:

Psys Hg	<>P H20	TIME sec
-1.0	1.7	7.8
-.5	1.7	7.6
.0	1.8	7.5
.5	1.8	7.4
1.0	1.8	7.3
1.5	1.8	7.1
2.0	1.9	7.0
2.5	1.9	6.9
3.0	1.9	6.8
3.5	2.0	6.6
4.0	2.0	6.5
4.5	2.1	6.4
5.0	2.1	6.2
5.5	2.1	6.1
6.0	2.2	6.0
6.5	2.2	5.9
7.0	2.3	5.7
7.5	2.3	5.6
8.0	2.4	5.5
8.5	2.4	5.4
9.0	2.5	5.2
9.5	2.6	5.1
10.0	2.6	5.0
10.5	2.7	4.9

SAMPLING NOTES

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DEF/ORI

DEF/ORI is used to generate files to be used in data reduction by CYCPROG which contain the needed information on metering orifices for flow rate calculations. Because the same orifices tend to be used repetitively, it is desirable to store the information in a permanent file which can be accessed simply whenever it is needed. The information to be input includes a unique letter to be used in identifying a file which contains data on a set of orifices, a nominal hole diameter for each orifice, and calibration pressures, temperatures, and flowrates. The program also calculates values of ΔH@ for each orifice for use in setting flow rates when sampling. The files can be called up for review by simply entering the letter designation for the set to be reviewed. The disk files can be updated and printed copies can be obtained at the user's option.

Data Input

Input takes place on two screen pages, the first of which is concerned primarily with general information, and the second for individual orifice input and/or changes. The information needed on Page 1 is input by entering the selected menu item number, at which point a prompt for that item will be given. the Page 1 input display is shown below.

```
DEFORI V1.2 - PAGE 1 OF 2

1) HARD COPY OPTION: YES
2) DISK FILE UPDATE: YES
3) ORIFICE SET NAME:
   FILE NAME: ________
4) DESCRIPTION:
5) NUMBER IN SET:  0

P)AGE, Q)UIT, OR NUMBER OF ITEM
TO ENTER/CHANGE: ?
```

The items entered on page 1 are:

1) Is hardcopy desired?. Selecting this item will reverse the currently displayed answer.

2) Is a disk update of the file desired? Again selection of the item reverses the answer.

3) Orifice set designation: The file name used is the set designation with /ORI added. The /ORI is added by the program and should not be entered by the user. When a new set designation is entered, the disk is checked for the existence of a current file with that designation. If such a file exists, it is read into memory and the current information in the file will be displayed on the data entry screens.

4) Description: Enter a brief description of the configuration to help identify it later.

5) Enter the number of orifices in the set. If the set already existed, this will have been filled in when the file was read. It can be altered if additional orifices are to be added to the set.

After completing the entries on Page 1, press "P" and "Return" to proceed to the second page of data entry which is illustrated below.

```
                DEFORI V1.2 - PAGE 2 OF 2

ORI.     DIA.     QCAL      PCAL      TCAL      DPCAL
NO.      (IN)     (CFM)    (IN HG)   (DEG F)    (H20)
 1       .000     .0000      .00        0         .00
 2       .000     .0000      .00        0         .00
 3       .000     .0000      .00        0         .00

TO ENTER/CHANGE DATA FOR AN ORI.
ENTER ORI. NO. OR Q)UIT OR P)AGE
```

This page is devoted entirely to orifice calibration information. The program will set up one line for parameters for each orifice in the set, numbered sequentially from 1 to the number entered on the previous page. Entry of data is made by entering the number for which information is to be entered or changed. When an orifice is selected, the cursor will be placed at the start of the leftmost entry in its line. Pressing "Return" will accept the current value and advance the cursor to the start of the next entry. Entering a value will replace the current entry. When the cursor is advances beyond the last field the program will revert to the orifice select mode. Single point calibrations are used here. The data required for each orifice are:

The nominal diameter of the orifice.

The flow rate, in acfm, at the orifice inlet conditions at which the orifice was calibrated.

The absolute pressure, in inches of mercury, at the orifice inlet during calibration.

The gas temperature, in degrees Fahrenheit during calibration.

The pressure differential across the orifice, in inches of water, at the calibration flow rate.

Upon completion of all data entry, press "Q" and "Return" to proceed. The information will be printed and/or saved to disk depending on the users selected options.

Description of Major Program Segments

Program initialization takes place in lines 6 through 100 and in a subroutine from line 1000 to line 1160. Page 1 of the primary data entry menu takes place in lines 2000 through 2475 with pre-existing files being checked and loaded in lines 2367 through 2460. Page 2 of the data entry is done in lines 2500 through 3350.

Printing of the information is done by a subroutine from line 4000 through 4500 and the disk update is done in lines 5000 through 5920. A machine language subroutine for print formatting is appended to the program as line 63999. THIS LINE MAY NOT BE EDITED - doing so will result in an irrecoverable loss of the program. The subroutine is copyrighted and permission has been granted by the copyright owner for its use here.

Identification of Variables

A - option selection dummy
A$ - input dummy
BU - address of print formatter
D$ - DOS command flag
EF - error flag
F$(- format statements for printing
F1$ - flag for hardcopy
F2$ - flag for disk update/save
HH - screen tab index
I - loop index
J - variable counter
JA(- pressure differential
JD(- pressure
JL(- temperature
JN(- orifice diameter
JS(- flow rate
N$(- designations of orifice sets on file
NI$ - set designation
NM$ - orifice file name
NS - number of orifices in set
OK - flag for pre-existing file
P - menu page number
PF - format selector
R$ - dummy for input and printing
RM$ - set description
TI - number of sets on file
Y$ - input dummy

STATIS

STATIS is a program for combining data from multiple runs. STATIS provides results by forming simple averages of the data from the selected runs. The program will provide corrections for errors resulting from anisokinetic sampling to be made by particle size if the user so desires. A maximum of 20 runs can be averaged by the program as it is currently dimensioned.

The program actually averages only the differential form of the distribution. The values of dM/dLogD for the standardized set of diameters generated and stored on disk by CYCPROG are picked up from the data disk for averaging as the runs are selected. If three or more runs are being averaged, outliers can be identified and removed from the averaging process at the user's option. Average cumulative forms of the distribution are generated by integrating the average differential distribution. The average distribution in the cumulative concentration form is obtained directly by the integration. The average distribution in the cumulative percent by mass form is obtained by normalizing the average cumulative concentration form. By constructing the averaged cumulative forms of the distribution in this way the effect of errors in the original data for single stages can be removed from the results if outliers are removed without discarding data from other valid stages. If the cumulative distributions were averaged directly, an error at any one stage of a run would propagate forward through the remainder of the distribution if the erroneous data were not dropped; but if outlier analysis were used, it might then result in the loss of valid data from other stages. If three or more runs are averaged, the program also provides 90% confidence limits for the results.

Program Operation

At startup, the user is asked if correction for anisokinetic sampling is desired. If so, the values of dM/dLogD will be corrected for each selected run as it is read into memory.

The runs to be averaged are selected by specifying the test type (Inlet or Outlet), the test number, and the run designations. Mixing of test types is not permitted. It is anticipated that a single test number will be used to identify a major test program or series of tests, consequently all the runs to be averaged will probably share a common test number and only the run identifiers will be different. If this is the case, once the test number is entered and the type is specified, only the run identifier must be specified to read it into memory. Runs with different test numbers can be averaged however.

The data entry options and program operation are controlled by entering a number, 1, 2, or 3, the letter "C", or the letter "Q". These result in the following actions:

1) Toggle the test type between Inlet and Outlet

2) Selects entry of the Test Number

3) Select entry of the next run to be used by entry of the run identifier (the characters between the "R" and the ".IT" or ".OT" in the run file name).

C) Display the contents of the index file for the reduced runs stored on the disk.

Q) Quit the selection process and proceed with the averaging.

Each time a run is selected the Test Number, Run identifier, and Test Type are combined to form the run (result) file name. This name is checked against the index file and if the name is valid, the file is read. As the file is read, the diameters at which the spline interpolations were made in CYCPROG are checked to be certain that they are consistent from run to run, and the diameter basis on which the fits were made are checked for consistency. If a run is selected for which either the diameters or diameter basis is not the same as that of the first run entered, it is rejected for inclusion in the average and a message to that effect is written on the screen. If corrections for anisokinetic sampling is desired, a run will be rejected for which the gas velocity and/or nozzle diameter was omitted in the CYCPROG data entry. A message to this effect will be given in such a case. Once a run is read into memory and accepted, a counter for the sequence number of the next run to entered, if any, will be advanced and a new prompt line for input option "3" will be added.

After all runs to be averaged have been selected and "Q" is entered, the user will be asked if outliers are to be dropped. Once this question is answered the calculations will proceed. Upon completion of the calculations the results will be displayed on the screen. A value of 3.0 E+33 is used for the confidence interval as a flag if insufficient runs were averaged for a meaningful confidence interval to be calculated. Following the screen display the user will be given prompts regarding whether printed copy and saving the results to disk are desired. If the results are to be saved to disk, a prompt for a file name will be given. No index file is maintained for these file names. If plots of the averaged results are desired or if they are too used for calculating fractional efficiencies, they must be saved on the disk.

Program Description

Initialization is done in lines 6 through 35 and in a subroutine from line 1000 through 1399. The index file of the reduced data stored on the disk is read during this initialization.

Selection of the input options is made through a subroutine from line 1400 through 1450 from the major input routine 2000 through 2179. The index file is displayed by a subroutine from line 1460 through 1510. The run file name is constructed and checked in lines 2175 through 2180. Data files are read in lines 3000 through 3048. Checks for file consistency are done in lines 3049 through 3078.

The values of dM/dLogD are reconstructed from the file information and corrections for anisokinetic sampling are made in lines 3125 through 3150. The Corrections for anisokinetic sampling are made using an equation developed by Beleyev and Levin (1972).

The actual averaging process takes place in a subroutine which begins at line 4000 and ends at line 4400. Values for Students t-table at the 90% confidence limit are set up for 2 through 9 samples in lines 4040 through 4110. These are used in the outlier tests and in calculating the 90% confidence limits for the results. The t-table value for an infinite number of samples is used if 10 or more runs are being averaged. The averaging takes place in lines 4130 through 4235. Outlier tests are performed in lines 4240 through 4275. The outlier tests are performed as described in Appendix F of EPA Publication 600/9-76-005 (Quality Assurance Handbook for Air Pollution Measurement Systems. Volume I - Principles). The integration for calculation of the average cumulative concentration is done in lines 4381 through 4388. The values of the cumulative concentrations smaller than the first standard particle diameter from the MPPROG data files are averaged and used as a constant of integration.

The screen display of the results is done by a subroutine from line 5000 through line 5110. Printed output is done in lines 6000 through 6400, and the disk save is done in lines 7000 through 7100.

A machine language subroutine for print formatting is appended to the program as line 63999. THIS LINE MAY NOT BE EDITED - doing so will result in an irrecoverable loss of the program. The subroutine is copyrighted and permission has been granted by the copyright owner for its use here.

Description of Variables

A - menu selection dummy
AV - duct velocity for last run read from disk
B - intermediate value in anisokinetic correction
BA - constant in anisokinetic error correction
BB - constant in anisokinetic error correction
BU - print formatter address
C(- confidence intervals
C1-C3 - constants used in conversions from probabiliby scale
CI(- confidence intervals

CK - error flag
CP(- average cumulative percent
D$ - DOS command flag
DO - intermediate value used in probability scale conversion
DB$ - diameter basis for spline fit
DG(- dM/dLogD
DT$ - run date
F$(- print format statements
F0$-F3$ - print format statements
FA$ - print format statement
FB$ - print format statement
FL - flag used in probability scale conversion
FM$ - print format statement
FM$(- print format statements
FP$ - print format statement
I - loop index
I$ - input file type designation
IC$ - flag for anisokinetic correction
IO$ - run type
IS - percent isokinetic
J - loop index
K - loop index
KF - constant in anisokinetic correction
L$ - sampling location
M(- average dM/dLogD's
MX - index counter for run input
N - number of runs selected
ND - nozzle diameter
NI - index number of next run to be input
NM$ - run data file name
NN - Number of points retained in average
NP - number of particle diameters in standard set
NR - number of run data files on disk
OK - error flag
OL$ - do outlier flag
R - isokinetic ratio
R$ - dummy for printing
RH - particle density
RN$ - run designation
RR$ - run remarks
RT - intermediate value in anisokinetic correction
S - number of stages in impactor
S(- standard deviations
SS - sum of squares of deviations
SX - sum of dM/dLogD's
T$ - run time
TC - total concentration
TC(- t-table values at 90% confidence level
TN - test number
U - gas viscosity
VE(- flue gas velocity
VS - dummy used in averaging

X - input dummy
X(- standardized diameter array
X1-X3 - used in conversion from probability scale
XP(- particle diameters
Y(- particle concentrations
YY(- cumulative percent in probability units
Z - dummy for outlier test
ZZ - dummy for outlier test
ZZ$ - diameter basis

MAIN MENU

```
1  REM    ¤¤¤¤ MAIN MENU ¤¤¤
7 D$ =  CHR$ (4)
9  HOME : PRINT "        MAIN  MENU": PRINT : PRINT
10  PRINT "TO SELECT OPTION ENTER APPROPIATE NUMBER"
11  PRINT " 1) RUN ORSAT"
12  PRINT " 2) RUN METHOD 4 (H2O)"
13  PRINT " 3) RUN 'CYCPROG'"
14  PRINT " 4) RUN DEFINE CYCLONE CONFIG."
15  PRINT " 5) RUN DATAPLOT"
16  PRINT " 6) RUN STATIS"
18  PRINT " 7) RUN DELETE RUNFILE"
19  PRINT " 8) RUN DEFINE ORIFICE CONSTANTS"
20  PRINT " 9) RUN SETUP"
80  PRINT " Q)UIT"
90  PRINT : INPUT "YOUR CHOICE";A$
95  IF A$ = "Q" THEN  PRINT : HOME : END
97 A =  VAL (A$)
98  IF A < 1 OR A > 9 GOTO 90
110  IF A = 1 THEN  PRINT D$;"RUN ORSAT"
120  IF A = 2 THEN  PRINT D$;"RUN METH4"
130  IF A = 3 THEN  PRINT D$;"RUN CYCPROG"
140  IF A = 4 THEN  PRINT D$;"RUN DEF/CYC"
150  IF A = 5 THEN  PRINT D$;"RUN DATAPLOT"
160  IF A = 6 THEN  PRINT D$;"RUN STATIS"
180  IF A = 7 THEN  PRINT D$;"RUN  PURGE RUNFILE"
185  IF A = 8 THEN  PRINT D$;"RUN DEF/ORI"
187  IF A = 9 THEN  PRINT D$;"RUN SETUP"
190  GOTO 90
200  IF A > 1 THEN  PRINT " PROGRAM NOT READY YET": END

]
```

```
1  REM    ** ORSAT PROGRAM V 1.0"
2  REM  **CREATES/UPDATES/LISTS ORSAT.DAT
3  REM  ***DRI VERS.26-NOV-79
4  REM  ** SRI VERS.2/1/83
5  REM
6  GOSUB 63999
7 D$ =  CHR$ (4)
10 F1$ = "YES":F2$ = "YES"
100  REM  ** MAIN PROGRAM **
110  GOSUB 1000
120  GOSUB 2000
130  IF F1$ = "YES" THEN  GOSUB 3000
140  IF F2$ = "YES" THEN  GOSUB 4000
145  PRINT
997  PRINT D$;"RUN MAIN MENU"
998  GOTO 110
999  END
1000  REM     ** FORMAT DEFINITION
1010  HOME
1020 P = 1
1030 F$(0) = "     ORSAT V 1.0"
1040 F$(1) = " 1) & HARD COPY OPTION  "
1050 F$(2) = " 2) & DISK FILE UPDATE  "
1060 F$(3) = " 3) #<0#.##  CARBON MONOXIDE %"
1070 F$(4) = " 4) #<0#.##  CARBON DIOXIDE %"
1080 F$(5) = " 5) #<0#.##  OXYGEN %"
1090 F$(6) = " 6) #<0#.##  NITROGEN %"
1100 F$(7) = "    #<0#.### DRY MOLECULAR WEIGHT"
1110 F$(8) = "    #<0#.### EXCESS AIR %"
1120  ONERR  GOTO 1170
1125  PRINT D$;"OPEN ORSAT.DAT"
1130  PRINT D$;"READ ORSAT.DAT"
1140  INPUT CM,CD,O2,N2,MW,EX
1150  PRINT D$;"CLOSE ORSAT.DAT"
1160  RETURN
1170  PRINT "ERROR; TO CONTINUE PRESS ANY KEY; ERROR CODE =
"; PEEK (222): INPUT A$: GOTO 120
1180  PRINT D$;"CLOSE"
1190  RETURN
1400  REM  ** MENU INSTRUCTIONS
2000  REM   ** MASTER MENU AND COMPUTATIONS
2005  HOME : PRINT F$(0): PRINT
2010  PRINT "TO ENTER/CHANGE AN ITEM PRESS NUMBER OF ITEM TH
EN NEW VALUE AND PRESS <RETURN>"
2020  GOTO 2030
2030  VTAB 6: CALL BU,R$,F$(1),F1$: PRINT R$
2040  CALL BU,R$,F$(2),F2$: PRINT R$
2050  CALL BU,R$,F$(3),CM: PRINT R$
2060  CALL BU,R$,F$(4),CD: PRINT R$
2070  CALL BU,R$,F$(5),O2: PRINT R$
2080  CALL BU,R$,F$(6),N2: PRINT R$
2090  PRINT
```

```
2100 MW = .44 * CD + .32 * O2 + .28 * (CM + N2)
2110 X = .264 * N2 - (O2 - .5 * CM): IF X = 0 THEN EX = 0: GOTO
2120
2115 EX = (O2 - .5 * CM) * 100 / X
2120  CALL BU,R$,F$(7),MW: PRINT R$
2130  CALL BU,R$,F$(8),EX: PRINT R$: PRINT
2140 X = CM + CD + O2 + N2
2145 MW$ = "WARNING: TOTAL ADDS TO ##<0#.#%, NOT 100%"
2150  IF X <  > 100 THEN  CALL BU,R$,MW$,X: PRINT R$
2160  IF X < 2 AND N2 > 0 THEN  PRINT "WARNING: ENTER % RATH
ER THAN FRACTIONAL VALUES"
2165  PRINT "
       "
2170  VTAB 21: PRINT : PRINT "SELECT S)AVE, OR ENTER NUMBER
OF ITEM TO BE CHANGED"
2175  VTAB 23: HTAB 13: GET A$
2180  IF A$ = "S" THEN  RETURN
2190 A =  VAL (A$)
2195  IF A < 1 OR A > 6 GOTO 2170
2200  IF A = 1 THEN F1$ = "NO": PRINT : GOTO 2020
2210  IF A = 2 THEN F2$ = "NO": PRINT : GOTO 2020
2215  HTAB 15: PRINT "        ": VTAB 23: HTAB 15
2220  IF A = 3 THEN  INPUT "CM= ";CM: GOTO 2020
2230  IF A = 4 THEN  INPUT "CD= ";CD: GOTO 2020
2240  IF A = 5 THEN  INPUT "O2= ";O2: GOTO 2020
2250  IF A = 6 THEN  INPUT "N2= ";N2: GOTO 2020
3000  REM  ** HARDCOPY OPTION
3010  PRINT "PRINTED COPY OPTION NOW BEING EXECUTED-TURN PRI
NTER ON AND PRESS ANY KEY": GET A$
3012  PRINT
3015  PRINT D$;"PR#1"
3020  PRINT "        ORSAT DATA": PRINT
3050  CALL BU,R$,F$(3),CM: PRINT R$
3060  CALL BU,R$,F$(4),CD: PRINT R$
3070  CALL BU,R$,F$(5),O2: PRINT R$
3080  CALL BU,R$,F$(6),N2: PRINT R$
3120  CALL BU,R$,F$(7),MW: PRINT R$
3130  CALL BU,R$,F$(8),EX: PRINT R$
3140  PRINT D$;"PR#0"
3150  RETURN
4000  PRINT
4001  PRINT D$;"OPEN ORSAT.DAT": PRINT D$;"CLOSE ORSAT.DAT":
 PRINT D$;"DELETE ORSAT.DAT"
4005 FM$ = "###.###^^^^"
4007  PRINT D$;"OPEN ORSAT.DAT"
4010  PRINT D$;"WRITE ORSAT.DAT"
4020  PRINT CM: PRINT CD: PRINT O2: PRINT N2: PRINT MW: PRINT
EX
4030  PRINT D$;"CLOSE ORSAT.DAT"
4040  RETURN
63999 BU =  PEEK (121) + 256 *  PEEK (122) + 286: CALL BU:BU
 =  PEEK (6) + 256 *  PEEK (7): CALL BU + 3: RETURN : REM


==> DO NOT EDIT 63999.
```

```
65535  REM
  BUILDUSING (2.0)   APPENDED.

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==> TO REMOVE 'APPENDAGE', ENTER:
]EXEC BU.STRIP

]
```

METH4

```
1  REM    ** METH4 PROGRAM V 1.0"
2  REM   **CREATES/UPDATES/LISTS METH4.DAT
3  REM   ***DRI VERS.26-NOV-79
4  REM   ** SRI VERS.2/2/83
5  REM
6  GOSUB 63999
7 D$ =  CHR$ (4)
10 F1$ = "YES":F2$ = "YES"
100  REM   ** MAIN PROGRAM **
110  GOSUB 1000
120  GOSUB 2000
130  IF F1$ = "YES" THEN  GOSUB 3000
140  IF F2$ = "YES" THEN  GOSUB 4000
145  PRINT
997  PRINT D$;"RUN MAIN MENU"
998  GOTO 110
999  END
1000  REM      ** FORMAT DEFINITION
1010  HOME
1020 P = 1
1030 F$(0) = "     METH4 V 1.0"
1040 F$(1) = " 1) & HARD COPY OPTION  "
1050 F$(2) = " 2) & DISK FILE UPDATE  "
1060 F$(3) = " 3) ##<0#.### GAS METER VOL.(CU.FT)"
1070 F$(4) = " 4) ###<0#.## ML WATER COLLECTED"
1080 F$(5) = " 5)  ###     GAS METER TEMP(DEG.F)"
1090 F$(6) = " 6)  ##<0#.## GAS M. DP(IN.H20)"
1100 F$(7) = " 7)   ##.## P BAROM.(IN.HG)"
1110 F$(8) = "     ##<0#.### MOISTURE CONTENT (%)"
1120  ONERR  GOTO 1170
1125  PRINT D$;"OPEN METH4.DAT"
1130  PRINT D$;"READ METH4.DAT"
1140  INPUT VG,WA,TG,PG,PB,BW
1150  PRINT D$;"CLOSE METH4.DAT"
1160  RETURN
1170  PRINT "ERROR; TO CONTINUE PRESS ANY KEY; ERROR CODE =
"; PEEK (222): INPUT A$: GOTO 120
1180  PRINT D$;"CLOSE"
1190  RETURN
1400  REM  ** MENU INSTRUCTIONS
2000  REM       ** MASTER MENU AND COMPUTATIONS
2005  HOME : PRINT F$(0): PRINT
2010  PRINT "TO ENTER/CHANGE AN ITEM PRESS NUMBER OF ITEM TH
EN NEW VALUE AND PRESS <RETURN>"
2020  GOTO 2030
2030  VTAB 6: CALL BU,R$,F$(1),F1$: PRINT R$
2040  CALL BU,R$,F$(2),F2$: PRINT R$
2050  CALL BU,R$,F$(3),VG: PRINT R$
2060  CALL BU,R$,F$(4),WA: PRINT R$
2070  CALL BU,R$,F$(5),TG: PRINT R$
2080  CALL BU,R$,F$(6),PG: PRINT R$
```

```
2085  CALL BU,R$,F$(7),PB: PRINT R$
2090  PRINT
2100 VH = .0472 * WA
2105 VS = 17.65 * VG * (PB - PG / 13.6) / (TG + 460)
2110  IF (VH + VS) = 0 THEN BW = 0: GOTO 2120
2115 BW = VH / (VH + VS)
2120  CALL BU,R$,F$(8),BW * 100: PRINT R$
2170  VTAB 21: PRINT : PRINT "SELECT S)AVE, OR ENTER NUMBER
OF ITEM TO BE CHANGED"
2175  VTAB 23: HTAB 13: GET A$
2180  IF A$ = "S" THEN  RETURN
2190 A =  VAL (A$)
2195  IF A < 1 OR A > 7 GOTO 2170
2200  IF A = 1 THEN F1$ = "NO": PRINT : GOTO 2020
2210  IF A = 2 THEN F2$ = "NO": PRINT : GOTO 2020
2215  HTAB 15: PRINT "                  ": VTAB 23: HTAB 15
2220  IF A = 3 THEN  INPUT "VG= ";VG: GOTO 2020
2230  IF A = 4 THEN  INPUT "WA= ";WA: GOTO 2020
2240  IF A = 5 THEN  INPUT "TG= ";TG: GOTO 2020
2250  IF A = 6 THEN  INPUT "PG= ";PG: GOTO 2020
2260  IF A = 7 THEN  INPUT "PB= ";PB: GOTO 2020
3000  REM     ** HARDCOPY OPTION
3010  PRINT "PRINTED COPY OPTION NOW BEING EXECUTED-TURN PRI
NTER ON AND PRESS ANY KEY": GET A$
3012  PRINT
3015  PRINT D$;"PR#1"
3020  PRINT "          METH4 DATA": PRINT
3050  CALL BU,R$,F$(3),VG: PRINT R$
3060  CALL BU,R$,F$(4),WA: PRINT R$
3070  CALL BU,R$,F$(5),TG: PRINT R$
3080  CALL BU,R$,F$(6),PG: PRINT R$
3120  CALL BU,R$,F$(7),PB: PRINT R$
3125  PRINT " "
3130  CALL BU,R$,F$(8),BW * 100: PRINT R$
3140  PRINT D$;"PR#0"
3150  RETURN
4000  PRINT
4001  PRINT D$;"OPEN METH4.DAT": PRINT D$;"CLOSE METH4.DAT":
 PRINT D$;"DELETE METH4.DAT"
4005 FM$ = "###.###^^^^"
4007  PRINT D$;"OPEN METH4.DAT"
4010  PRINT D$;"WRITE METH4.DAT"
4020  PRINT VG: PRINT WA: PRINT TG: PRINT PG: PRINT PB: PRINT
BW
4030  PRINT D$;"CLOSE METH4.DAT"
4040  RETURN
63999 BU =  PEEK (121) + 256 *  PEEK (122) + 286: CALL BU:BU
 =  PEEK (6) + 256 *  PEEK (7): CALL BU + 3: RETURN : REM


==> DO NOT EDIT 63999.

65535  REM
  BUILDUSING (2.0)   APPENDED.
```

```
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==> TO REMOVE 'APPENDAGE', ENTER:
]EXEC BU.STRIP

]
```

```
1  REM    *** DEFINE CYCLONE PROGRAM V 3.0 ***
2  REM       **CREATES/UPDATES/LISTS CYCLONE INFORMATION IN
&&&.IMP FILE
4  REM       ** VERS.1.1 3/29/83
5  REM  VERS. 3.0 1/9/86 JDM - WEF PSI50 CAL CURVES
6  GOSUB 63999
7 D$ =  CHR$ (4)
10 F1$ = "YES":F2$ = "YES"
13  DIM JN(15),JS(15),JD(15),JL(15),MZ(15)
20  DIM F$(13),A$(30)
21  DIM N$(99)
30 NM$ = "-------":SH$ = "CIRC.":SH = 1:EF = 0
100  REM    ** MAIN PROGRAM **
110  GOSUB 1000
120  GOSUB 2000
121  IF R$ = "Q" THEN  GOTO 135
122  GOSUB 2500
123  IF R$ = "Q" THEN  GOTO 135
124  IF R$ = "P" GOTO 120
135  IF F1$ = "YES" THEN  GOSUB 4000
140  IF F2$ = "YES" THEN  GOSUB 5000
145  REM  PRINT "RUN MAIN MENU"
997  REM  PRINT D$;"RUN MAIN MENU"
998  REM  GOTO 110
999  END
1000  REM             ** FORMAT DEFINITION
1010  HOME
1020 P = 1
1030 F$(0) = "       D E F CYCLONE V3.0"
1040 F$(1) = " 1)  HARD COPY OPTION: &"
1050 F$(2) = " 2)  DISK FILE UPDATE: &"
1055 F$(4) = "     FILE NAME: &"
1060 F$(3) = " 3)  CYCLONE SET NAME: &"
1070 F$(5) = " 4)  DESCRIPTION: "
1080 F$(7) = " 6)  NUMBER OF STAGES: ##"
1090 F$(6) = " 5)  INLET SHAPE (CIRC./SLOT) : &"
1130 F$(11) = "CYC     A      B      C     IN      OUT"
1140 F$(12) = "NO.                         DIA.    DIA."
1150 F$(13) = "## ; ##.###; ##.###; ##.###; #.####; #.####"
1155  REM          ONERR  GOTO 1170
1160  RETURN
1170  PRINT "ERROR; TO CONTINUE PRESS ANY KEY; ERROR CODE =
"; PEEK (222): INPUT R$: GOTO 120
1400  VTAB 22: PRINT "P)AGE, Q)UIT, OR NUMBER OF ITEM TO ENT
ER/CHANGE: ";
1410  INPUT R$
1420  IF R$ = "Q" THEN  RETURN
1430  IF R$ = "P" THEN P = P + 1: IF P > 2 THEN P = 1: RETURN

1435  IF R$ = "P" THEN  RETURN
1440 A =  VAL (R$): IF A < 1 OR A > 9 THEN  GOTO 1400
```

```
1450  RETURN
2000  REM     ** MAIN MENU
2010 P = 1
2020  HOME : PRINT F$(0) + "-PAGE 1 OF 2"
2030  VTAB 3: CALL BU,R$,F$(1),F1$: PRINT R$
2040  CALL BU,R$,F$(2),F2$: PRINT R$
2050  CALL BU,R$,F$(3),NI$: PRINT R$
2055  CALL BU,R$,F$(4),NM$: PRINT R$
2060  PRINT F$(5) + RM$
2070  CALL BU,R$,F$(6),SH$: PRINT R$
2080  CALL BU,R$,F$(7),NS: PRINT R$
2090  GOSUB 1400
2100  IF (R$ = "Q") OR (P = 2) THEN  RETURN
2110  IF A > 6 THEN  GOSUB 1400
2115  IF A = 0 GOTO 2000
2120  ON A GOSUB 2320,2340,2360,2460,2480,2470
2130  GOTO 2020
2320 A = 0: IF F1$ = "YES" THEN F1$ = "NO": RETURN
2325 F1$ = "YES": RETURN
2340 A = 0: IF F2$ = "YES" THEN F2$ = "NO": RETURN
2345 F2$ = "YES": RETURN
2360 A = 0: HOME : PRINT F$(0) + " PAGE 1 OF 2"
2365  VTAB 3: INPUT "KEY IN CYC. SET NAME: ";Y$
2366  IF Y$ = NI$ THEN  RETURN
2367 NI$ = Y$:NF = 1:NM$ = Y$ + "/IMP": REM  ONERR  GOTO 244
0
2368  PRINT Y$: PRINT D$;"OPEN IMP/NAM"
2370  PRINT D$;"READ IMP/NAM"
2371 OK = 0
2372  INPUT TI: IF TI = 0 THEN  PRINT D$;"CLOSE IMP/NAM": PRINT
"TI=0": FOR I = 1 TO 2000: NEXT I: RETURN
2374  FOR I = 1 TO TI
2376  INPUT N$(I)
2378  IF N$(I) = NI$ THEN OK = 1
2380  NEXT I
2381  PRINT D$;"CLOSE IMP/NAM"
2382  IF OK = 0 THEN  PRINT "OK=0 TI="TI: FOR I = 1 TO 2000:
 NEXT I: RETURN
2385  PRINT "OK=1 TI=";TI: FOR I = 1 TO 2000: NEXT I
2386  REM  RETURN
2388  PRINT D$;"OPEN" + NM$
2389  PRINT D$;"READ" + NM$
2390  INPUT NS
2391  IF NS = 0 GOTO 2450
2395  FOR I = 1 TO NS
2400  INPUT JN(I),JD(I),JA(I),JS(I),JL(I),JK(I),MZ(I)
2420  NEXT I
2430  INPUT RM$,MR,SH: IF SH = 0 THEN SH$ = "SLOT.": GOTO 24
50
2435  IF SH = 1 THEN SH$ = "CIRC.": GOTO 2450
2440 NF = 0: PRINT "FILE ERROR "; PEEK (222):EF = 1: STOP
2450  PRINT D$;"CLOSE" + NM$: RETURN
2460  IF A = 0 THEN  RETURN
2461 A = 0: HOME : PRINT F$(0)
```

```
2465  VTAB 3: INPUT "ENTER REMARKS/DESCRIPTION: ";RM$: RETURN

2470 A = 0: HOME : PRINT F%(0)
2475  VTAB 3: INPUT "ENTER NUMBER OF STAGES: ";NS: RETURN
2480 A = 0: IF SH$ = "CIRC." THEN SH$ = "SLOT NOT INSTALLED"
:SH = 0: RETURN
2485 SH$ = "CIRC.":SH = 0: RETURN
2500  REM     *** MENU PAGE 2
3000  REM
3001 J = 0:HH = 6
3005 PF = 13
3010  POKE 216,0
3020  HOME : PRINT F$(0) + "-PAGE 2 OF 2"
3030  VTAB 3: PRINT F$(11): PRINT F$(12)
3050  FOR I = 1 TO NS
3070  CALL BU,R$,F$(13),I,JK(I),JN(I),JS(I),JD(I),JL(I): PRINT
R$
3080  NEXT I
3090  VTAB 21: HTAB 1: PRINT "TO ENTER/CHANGE DATA FOR A STA
GE ENTER  STAGE NO. OR Q)UIT OR P)AGE             ";: VTAB 2
2: HTAB 29: INPUT R$: IF R$ = "Q" OR R$ = "P" THEN  RETURN
3108 J = 0
3110 I =  VAL (R$): IF I < 1 OR I > NS GOTO 3090
3112  VTAB 21: PRINT "PRESS 'RETURN' TO ACCEPT CURRENT VALUE
  OR ENTER NEW VALUE.                      "
3115  VTAB I + 4: CALL BU,R$,F$(13),I,JK(I),JN(I),JS(I),JD(I
),JL(I): PRINT R$;: HTAB HH - 1: INPUT "";R$: IF R$ = "" GOTO
3300
3120 J = J + 1: ON J GOTO 3130,3140,3150,3160,3170
3130 JK(I) =  VAL (R$):HH = HH + 7: GOTO 3115
3140 JN(I) =  VAL (R$):HH = HH + 7: GOTO 3115
3150 JS(I) =  VAL (R$):HH = HH + 7: GOTO 3115
3160 JD(I) =  VAL (R$):HH = HH + 7: GOTO 3115
3170 JL(I) =  VAL (R$):HH = 0: GOTO 3000
3171  GOTO 3000
3300 J = J + 1: ON J GOTO 3310,3320,3330,3340,3350
3310 HH = HH + 7: GOTO 3115
3320 HH = HH + 7: GOTO 3115
3330 HH = HH + 7: GOTO 3115
3340 HH = HH + 7: GOTO 3115
3350 HH = 6: GOTO 3000
3499  STOP
4000  REM    ** HARDCOPY OPTION
4010  PRINT "PRINTED COPY OPTION NOW BEING EXECUTED-TURN PRI
NTER ON AND PRESS ANY KEY": GET R$
4012  PRINT
4015  PRINT D$;"PR#1"
4020  PRINT F$(0)
4040  CALL BU,R$,F$(2),F2$: PRINT R$
4050  CALL BU,R$,F$(3),NI$: PRINT R$
4055  CALL BU,R$,F$(4),NM$: PRINT R$
4060  PRINT F$(5) + RM$
4070  CALL BU,R$,F$(6),SH$: PRINT R$
4080  CALL BU,R$,F$(7),NS: PRINT R$
```

```
4090  PRINT : PRINT : PRINT
4110  PRINT F$(11): PRINT F$(12)
4120  FOR I = 1 TO NS
4140  CALL BU,R$,F$(13),I,JK(I),JN(I),JS(I),JD(I),JL(I): PRINT
R$
4150  NEXT I
4160  IF MR = 0 THEN  PRINT D$;"PR#0": RETURN
4200  PRINT : PRINT : PRINT
4300  FOR I = 1 TO MR
4310  PRINT " THE MASS ON STAGE ";MZ(I);" AND ";MZ(I) + 1;"
WILL BE ASSIGNED TO THE CUTPOINT OF STAGE ";MZ(I) + 1;" FOR
THE SPLINE FITS, AND STAGE ";MZ(I);" WILL BE OMITTED IN SPLI
NE FITS": PRINT
4320  NEXT I
4490  PRINT D$;"PR#0"
4500  RETURN
5000  REM        ** DISK UPDATE
5001  PRINT "": PRINT D$;"OPEN" + NM$: PRINT D$;"CLOSE" + NM
$: PRINT D$;"DELETE" + NM$
5005  REM    ONERR  GOTO 5900
5007  PRINT D$;"OPEN" + NM$
5010  PRINT D$;"WRITE" + NM$
5020  PRINT NS
5030  FOR I = 1 TO NS
5040  PRINT JN(I): PRINT JD(I): PRINT JA(I): PRINT JS(I): PRINT
JL(I): PRINT JK(I): PRINT MZ(I)
5045  NEXT I
5050  PRINT RM$: PRINT MR: PRINT SH
5090  PRINT D$;"CLOSE" + NM$
5095  PRINT "OK=";OK: INPUT "TO CONT.ENTER Y";R$
5100  IF OK = 1 THEN  RETURN
5500  PRINT D$;"OPEN IMP/NAM"
5510  PRINT D$;"READ IMP/NAM"
5520  INPUT TI
5530 TI = TI + 1
5540  PRINT D$;"CLOSE IMP/NAM"
5550  PRINT D$;"OPEN IMP/NAM"
5560  PRINT D$;"WRITE IMP/NAM"
5570  PRINT TI
5580  PRINT D$;"CLOSE IMP/NAM"
5590  PRINT D$;"APPEND IMP/NAM"
5600  PRINT D$;"WRITE IMP/NAM"
5610  PRINT NI$
5620  PRINT D$;"CLOSE IMP/NAM"
5630  RETURN
5900  PRINT "DISK ERROR: "; PEEK (222)
5910  PRINT "CHECK DRIVE, ETC. IF NEEDED PRESS 'CONTROL C' A
ND THEN RESTART DISK SAVE WITH 'RUN 5000'
5920  GOTO 5000
63999 BU =  PEEK (121) + 256 *  PEEK (122) + 286: CALL BU:BU
 =  PEEK (6) + 256 *  PEEK (7): CALL BU + 3: RETURN : REM


==> DO NOT EDIT 63999.
```

```
65535  REM
  BUILDUSING (2.0)   APPENDED.

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==> TO REMOVE 'APPENDAGE', ENTER:
]EXEC BU.STRIP

]
```

```
1  REM  **** CYCLONE  PROGRAM VERSION 3.1  ****
2  REM           ***** MAIN CYC. DATA REDUCTION
3  REM           **** BASED ON SORI APPLE CIDRS *****
4  REM           **** APPLE VERSION BY J D MCCAIN
5  REM **** VERSION 1.0 CREATED 3/28/83 ****
6  REM    V1.1 5/18/83  V2.3 10/25/83  V3.0 1/8/86 (SWITCH
TO WEF'S PSI50 VS RE METHOD)
7  REM  V3.1 2/19/86 ADD DRY GAS INPUT AND BW FROM CONDENSER
 CATCH
9  GOSUB 63999
15 D$ =  CHR$ (13) +  CHR$ (4)
16 WG = 0:RH = 2.5:DA = 0:DL = 0
20  DIM M(23),JN(20),JD(20),JA(20),JS(20),JL(20),JK(20),DA(4
0),U(5),F(5),MW(5),MZ(20),RE(20)
30 I$ = "INLET"
50  DIM DI$(50)
60  DIM F$(32),ZZ$(100)
100  HOME : GOSUB 1000
105  POKE 216,0: PRINT "DO YOU WANT TO RETRIEVE AN OLD": PRINT
"DATA SET? (Y/N)": GET R$: IF R$ = "Y" THEN  GOSUB 31000
110  POKE 216,0: GOSUB 2000
115 ZY = 0
120  HOME : PRINT "CALCULATIONS"
140  PRINT : PRINT "FLOW RATES": GOSUB 4000
155  PRINT "DELTA P": GOSUB 4900
160  POKE 216,0: PRINT "CUTPOINTS": GOSUB 5000
170  HOME : PRINT "CALCULATIONS"
180  PRINT "FIT - INIT": GOSUB 5500
182  IF ZY = 1 THEN  GOTO 110
185  PRINT "LOG-NORMAL SIZE DISTRIBUTION": GOSUB 10000
190  PRINT "SPLINE FIT": GOSUB 6000
200  GOSUB 7000
220  POKE 216,0: GOSUB 9000
230  PRINT D$;"PR#0"
235  PRINT "DO YOU WANT TO SAVE RAW DATA? (Y/N)": GET R$: IF
R$ = "Y" THEN  GOSUB 30000
240  HOME : VTAB 5: PRINT "R)ETURN TO MAIN MENU OR": INPUT "
C)ONTINUE WITH MORE RUNS";R$
250  IF R$ = "R" THEN 997
260  IF R$ <  > "C" THEN 240
270  GOTO 110
997  PRINT D$;"RUN MAIN MENU"
999  END
1000  REM    <<< *** INITIALIZATION ***>>>
1002  DIM XX(20),YY(20),Y1(20),Y2(20),DG(20),XP(20),SI(20)
1004  DIM H(15),DL(15),H2(15),B(15),DQ(15),S2(15),C(15),S3(1
5)
1005  DIM CU(15),CC(15),PS(15),DP(15),VJ(15),D5(15),D6(15)
1006 F$(29) = " 1)PART. DIAMETER     "
1008 F$(30) = "12) ORIFICE ID : &"
1010 F$(32) = "14)WATER VOLUME    ####.#  CC"
```

```
1012 F$(31) = "15)METER FACTOR       #.####"
1015 F$(0) = "CYCPROG V 3.1 "
1020 F$(1) = " 2)DATE OF TEST: "
1030 F$(2) = " 3)TIME OF TEST: "
1040 F$(3) = " 4)LOCATION OF TEST: "
1050 F$(4) = " 5)TEST NUMBER ####  REMARKS: "
1060 F$(5) = " 7)RUN NUMBER: "
1070 F$(6) = " 8)RUN REMARKS: "
1080 F$(7) = "10)SAMPLER  TYPE: "
1090 F$(8) = " 1)GAS METER VOL    ###.### CUBIC FEET"
1100 F$(9) = " 2)SAMPLER  DELTA P ##.## IN. HG."
1110 F$(10) = " 3)ORIFICE DELTA P    #.## INCHES H2O"
1120 F$(11) = " 4)STACK PRESSURE    ##.## INCHES H2O"
1130 F$(12) = " 5)BAROMETRIC PRES   ##.## INCHES HG"
1140 F$(13) = " 6)STACK TEMP       ####     DEGREES F"
1150 F$(14) = " 7)METER TEMP        ###     DEGREES F"
1160 F$(15) = " 8)SAMPLER  TEMP    ####     DEGREES F"
1170 F$(16) = " 9)SAMPLE TIME      ####.## MINUTES"
1180 F$(17) = "10)AVG GAS VEL       ###.## FEET/SEC"
1190 F$(18) = "11)ORIFICE PRES       ##.## INCHES HG"
1200 F$(19) = "12)NOZZLE DIA         #.### INCHES"
1205 F$(21) = "13)MAX  PART  DIA   ###.## MICRONS"
1210 F$(20) = "     CO2 ##.##%;          CO ##.##%"
1220 F$(22) = "     O2   ##.##%;         N2 ##.##%"
1230 F$(24) = " 9)WATER VAPOR           ##.##%"
1240 F$(25) = "11) PARTICLE DENSITY ##.## GRAMS/CC"
1250 F$(26) = "MASS GAIN ON &;  ####.## MG"
1260 F$(27) = " 6)TEST TYPE             "
1265 F$(28) = "CUM MASS LESS THAN ##.###; MICRON: ###.##; MG
/DNM3 (###.## %)"
1270  PRINT D$;"OPEN METH4.DAT": PRINT D$;"READ METH4.DAT"
1280  INPUT X,X,X,X,X,BW
1290  PRINT D$;"CLOSE"
1300  PRINT D$;"OPEN ORSAT.DAT": PRINT D$;"READ ORSAT.DAT"
1310  INPUT CM,CD,O2,N2
1320  PRINT D$;"CLOSE"
1330 GD = 1.293E - 03:PM = 1.4764E - 05:MA = 28.97:DC2 = .61
 * .61:HG = 13.6:QC = 471.95:FR = 460:FS = 492:SP = 29.92:X0
 = 1000:F1 = 10:MF = 1
1340  RETURN
1400  REM          **** MENU INSTRUCTIONS
1410  VTAB 21: PRINT "ENTER: Q)UIT, P)AGE, OR NUMBER OF ITEM
  TO ENTER/CHANGE:"
1420  VTAB 22: HTAB 20: INPUT R$: IF R$ = "Q" THEN  RETURN
1430  IF R$ = "P" THEN  RETURN
1440 P =  VAL (R$): IF P < 1 OR P > MX THEN  GOTO 1410
1450  RETURN
2000  REM    ***<<< MENU, PAGE 1 >>>***
2010 MX = 12
2020  HOME : PRINT F$(0);"  - PAGE 1 OF 3": PRINT
2025  PRINT F$(29);: IF F1 = 1 THEN  PRINT "PHYSICAL": GOTO
2030
2026  IF F1 = 0 THEN  PRINT " IMP. AERO.": GOTO 2030
2027 F1 = 10: PRINT "CLASS. AERO."
```

```
2030  PRINT F$(1);DT$
2040  PRINT F$(2);T$
2050  PRINT F$(3);L$
2060  CALL BU,R$,F$(4),TN: PRINT R$;TR$
2070  PRINT F$(27);I$
2080  PRINT F$(5);RN$;" -FILE NAME: ";NM$
2090  PRINT F$(6);RR$
2100  CALL BU,R$,F$(24),BW * 100: PRINT R$
2104  CALL BU,R$,F$(20),CD,CM: PRINT R$
2106  CALL BU,R$,F$(22),O2,N2: PRINT R$: PRINT
2110  PRINT F$(7);IM$;"  ";IN$
2155  CALL BU,R$,F$(25),RH: PRINT R$
2157  CALL BU,R$,F$(30),RO$: PRINT R$
2160  GOSUB 1400
2200  IF R$ = "Q" THEN  RETURN
2210  IF R$ = "P" THEN  GOTO 3000
2230  ON P GOSUB 2252,2260,2270,2280,2290,2390,2420,2520,273
0,2530,2240,2610
2235  GOTO 2010
2240  VTAB 23: HTAB 15: INPUT " PART. DENS.= ";RH: RETURN
2252  VTAB 23: HTAB 15: PRINT "ENTER DIAM.BASIS I)MP.AERO, C
)LASS.AERO,OR P)HYSICAL": GET X$: IF X$ = "I" THEN F1 = 0: RETURN

2253  IF X$ = "C" THEN F1 = 10: RETURN
2254 F1 = 1: RETURN
2260  VTAB 23: HTAB 15: INPUT "ENTER TEST DATE ";DT$: RETURN

2270  VTAB 23: HTAB 15: INPUT "ENTER TEST TIME ";T$: RETURN

2280  VTAB 23: HTAB 15: INPUT "TEST LOCATION ";L$: RETURN
2290  VTAB 23: HTAB 15: INPUT "ENTER TEST NUMBER ";Y: IF TN =
Y THEN  RETURN
2295 TN = Y
2300 TN$ = "DEFT" +  STR$ (TN) + ".DAT"
2301 Y$ = "DEFT" +  STR$ (TN)
2302 ZZ$ = "TEST"
2304  GOSUB 2800
2305  IF OK = 0 THEN  RETURN
2310  PRINT D$;"OPEN" + TN$: PRINT D$;"READ" + TN$
2320  INPUT X,X,X,X,X,RH,TR$
2330  PRINT D$;"CLOSE"
2340 CLOSE1: IF RN$ = "" THEN  RETURN
2345  GOTO 2430
2350  RESUME 2360
2360  ONERR  GOTO 2999: VTAB 24: PRINT "THAT TEST IS NOT DEF
INED"
2380  FOR I = 1 TO 2000: NEXT I:TN = 0:NM$ = "":RN$ = "": RETURN

2390  VTAB 23: HTAB 15: INPUT "ENTER I)NLET OR O)UTLET ";X$:
 IF X$ = "I" THEN I$ = "INLET": RETURN
2400 X$ = "O":I$ = "OUTLET"
2410  IF RN$ = "" THEN  RETURN
2415  GOTO 2430
2420  VTAB 23: HTAB 15: INPUT "ENTER RUN NUMBER ";RN$
```

```
2430 NM$ = "T" +  STR$ (TN) + "R" + RN$ + "." +  LEFT$ (I$,1
) + "T"
2431 ZZ$ = "RUN":Y$ = NM$
2433  GOSUB 2800
2436  IF OK = 0 THEN  RETURN
2470  VTAB 24: PRINT "A FILE FOR THAT TEST/RUN ALREADY EXIST
S"
2480  FOR I = 1 TO 2000: NEXT I
2490 RN$ = "":NM$ = "": RETURN
2500  RESUME 2510
2510  ONERR  GOTO 2999: RETURN
2520  VTAB 23: HTAB 15: INPUT "ENTER RUN REMARKS ";RR$: RETURN

2530  VTAB 23: HTAB 15: INPUT "ENTER CYC. TYPE ";Y$: IF IM$ =
Y$ THEN  RETURN
2535 IM$ = Y$
2536 ZZ$ = "IMP"
2537  GOSUB 2800
2538  IF OK = 0 THEN  RETURN
2540  PRINT D$;"OPEN" + IM$ + "/IMP": PRINT D$;"READ" + IM$ +
"/IMP"
2550  INPUT S
2560  FOR I = 1 TO S
2570  INPUT JN(I),JD(I),JA(I),JS(I),JL(I),JK(I),MZ(I)
2580  NEXT I
2590  INPUT IN$,MR
2600  PRINT D$;"CLOSE": RETURN
2610  VTAB 23: HTAB 5: INPUT "ENTER ORIFICE ID (.DDDL) ";RO$
:Y$ =  RIGHT$ (RO$,1):ZZ$ = "ORI": GOSUB 2800
2620  IF OK = 0 THEN RO$ = RO$ + " NOT IN FILE": RETURN
2630  PRINT D$;"OPEN" + Y$ + "/ORI": PRINT D$;"READ" + Y$ +
"/ORI"
2640  INPUT NN
2650  FOR I = 1 TO NN
2660  INPUT DI,CQ,CP,CT,PP
2670  IF DI =  VAL (RO$) THEN  PRINT D$;"CLOSE": RETURN
2680  NEXT I
2690 RO$ = RO$ + " NOT IN FILE": PRINT D$;"CLOSE": RETURN
2730  VTAB 23: HTAB 20: INPUT "% H20= ";R$: IF R$ = "" THEN
 GOTO 2742
2735 BW =  VAL (R$):BW = BW / 100:WA = 0
2740 F$(24) =  LEFT$ (F$(24),28) + " (KEYBOARD)"
2742  VTAB 23: HTAB 20: PRINT "CHANGE OTHER GASES?";: GET R$
: PRINT R$: IF R$ <  > "Y" THEN  RETURN
2744  VTAB 23: HTAB 20: PRINT "                          ": VTAB 2
3: HTAB 20: INPUT "ENTER CO2: ";R$: IF R$ <  > "" THEN CD =
 VAL (R$)
2746  VTAB 23: HTAB 20: PRINT "                          ": VTAB 2
3: HTAB 20: INPUT "ENTER CO : ";R$: IF R$ <  > "" THEN CM =
 VAL (R$)
2748  VTAB 23: HTAB 20: PRINT "                          ": VTAB 2
3: HTAB 20: INPUT "ENTER  O2: ";R$: IF R$ <  > "" THEN O2 =
 VAL (R$)
2750 N2 = 100 - (O2 + CD + CM)
```

```
2760  RETURN
2800  PRINT D$;"OPEN" + ZZ$ + "/NAM": PRINT D$;"READ" + ZZ$ +
"/NAM"
2802 OK = 0
2805  INPUT N9: IF N9 = 0 THEN  PRINT D$;"CLOSE": PRINT "FIL
E FOR ";ZZ$;"/NAM EMPTY": FOR I = 1 TO 3000: NEXT I: RETURN

2810  FOR I = 1 TO N9
2815  INPUT YY$: IF YY$ = Y$ THEN OK = 1
2820  NEXT I
2830  PRINT D$;"CLOSE": IF N9 = 100 THEN  HOME : FLASH : PRINT
"FILE FOR ";ZZ$;"/NAM FULL": NORMAL : PRINT "PURGE FILE BEFO
RE CONTINUEING": FOR I = 1 TO 1000: NEXT I
2840  RETURN
3000  REM     <<<*** MENU, PAGE 2 ***>>>
3010 P = 1
3020  HOME : PRINT F$(0);" - PAGE 2 OF 3": PRINT
3030  CALL BU,R$,F$(8),VM: PRINT R$
3040  CALL BU,R$,F$(9),DP: PRINT R$
3050  CALL BU,R$,F$(10),OP: PRINT R$
3060  CALL BU,R$,F$(11),PS: PRINT R$
3070  CALL BU,R$,F$(12),PB: PRINT R$
3080  CALL BU,R$,F$(13),TS: PRINT R$
3090  CALL BU,R$,F$(14),TM: PRINT R$
3100  CALL BU,R$,F$(15),TI: PRINT R$
3110  CALL BU,R$,F$(16),TD: PRINT R$
3120  CALL BU,R$,F$(17),AV / 60: PRINT R$
3130  CALL BU,R$,F$(18),PC / 13.569: PRINT R$
3140  CALL BU,R$,F$(19),ND: PRINT R$
3150  CALL BU,R$,F$(21),X0: PRINT R$
3152  CALL BU,R$,F$(32),WA: PRINT R$
3154  CALL BU,R$,F$(31),MF: PRINT R$
3160 MX = 15: GOSUB 1400
3190  IF R$ = "Q" THEN  RETURN
3200  IF R$ = "P" THEN  GOTO 3500
3230  ON P GOSUB 3260,3270,3280,3290,3300,3310,3320,3330,334
0,3350,3360,3370,3380,3390,3400
3250  GOTO 3020
3260  VTAB 24: HTAB 5: INPUT "VM (0 FOR ORIFICE FLOW) = ";VM
: RETURN
3270  VTAB 24: INPUT "SAMPLER DP (CALC'S THEO.DP) DP= ";DP: RETURN

3280  VTAB 24: HTAB 15: INPUT "ORIFICE DP= ";OP: RETURN
3290  VTAB 24: HTAB 5: INPUT "STACK DP TO AMBIENT = ";PS: RETURN

3300  VTAB 24: HTAB 15: INPUT "PB= ";PB: RETURN
3310  VTAB 24: HTAB 15: INPUT "TS= ";TS: RETURN
3320  VTAB 24: HTAB 15: INPUT "TM= ";TM: RETURN
3330  VTAB 24: HTAB 15: INPUT "TI= ";TI: RETURN
3340  VTAB 24: HTAB 15: INPUT "SAMPLE DURATION= ";TD: RETURN

3350  VTAB 24: HTAB 15: INPUT "AV= ";AV:AV = AV * 60: RETURN

3360  VTAB 24: HTAB 15: INPUT "ORIFICE DP TO AMBIENT = ";PC:
```

```
PC = PC * 13.569: RETURN
3370  VTAB 24: HTAB 15: INPUT "ND= ";ND: RETURN
3380  VTAB 24: HTAB 15: INPUT "MAX DIA= ";X0: RETURN
3390  VTAB 24: HTAB 15: INPUT "WATER VOL.= ";WA: RETURN
3400  VTAB 24: HTAB 15: INPUT "METER FACTOR = ";MF: RETURN
3500  REM        <<< *** MENU, PAGE 3, CYCLONE STAGE WEIGHT
S ***>>>
3510 P = 1:WG = 1
3520  HOME : PRINT F$(0);" - PAGE 3 OF 3 (STAGE WEIGHTS)"
3540 NZ = S - MR:MX = S + 3: FOR I = 1 TO S + 3
3550  IF I <  = S THEN X$ = "STAGE " +  STR$ (I)
3570  IF I = S + 1 THEN X$ = "FILTER " +  STR$ (I)
3575  IF I = S + 2 THEN  PRINT :X$ =  STR$ (I) + " BLANK SUB
ST."
3578  IF I = S + 3 THEN X$ =  STR$ (I) + " BLANK FIL."
3580  CALL BU,R$,F$(26),X$,M(I): PRINT R$
3590  NEXT I
3600  GOSUB 1400
3640  IF R$ = "Q" THEN  RETURN
3650  IF R$ = "P" THEN  GOTO 2000
3670  VTAB 23: HTAB 10: PRINT "ENTER MASS ";P: VTAB 23: HTAB
23: INPUT ":";M(P)
3690 FF = M(S + 1):FC = M(S + 3):SC = M(S + 2): GOTO 3520
4000  REM    <<< *** SUBROUTINE FLOW ***>>>
4002  IF WA > 0 AND VM > 0 THEN VH = .0472 * WA:VS = 17.65 *
VM * MF * (PB - (OP - PC) / 13.6) / (TM + FR):BW = VH / (VH +
VS)
4003  PRINT "VISCOSITY": GOSUB 4500
4005  IF VM = 0 THEN QO = CQ *  SQR (OP * CP * MA * (TM + FR
) / PP / (CT + FR) / DM / (PB + PC / HG)):QS = QO * (PB + PC
 / HG) * FS / SP / (TM + FR):QI = QS * (TI + FR) * SP / FS /
(PB + PS / HG) / (1 - BW)
4020  IF VM <  > 0 THEN QI = VM / TD * (PB - (OP - PC) / HG)
 / (PB + PS / HG) * (TI + FR) / ((TM + FR) * (1 - BW))
4030  IF VM <  > 0 THEN QS = VM / TD * 17.65 * (PB - (OP - P
C) / HG) / (TM + FR)
4040  IF AV <  > 0 AND ND <  > 0 THEN IS = 183.35 * QI / (ND
 * ND * AV) * 100 * (TS + FR) / (TI + FR)
4045  PRINT "QI = ";QI;" QS= ";QS;" IS= ";IS
4050  RETURN
4200  REM   <<< *** SUBROUTINE JET ***>>>
4210 VU = 0
4220  FOR I = 1 TO S
4230 VJ(I) = QC * QI / (JA(I) * JN(I))
4240 VU = VU + VJ(I) * VJ(I)
4250  NEXT I
4260 VT = 0
4270  FOR I = 1 TO S
4280 DP(I) = VJ(I) * VJ(I) / VU * DP
4290 VT = VT + DP(I)
4300 PS(I) = PB + PS / 13.6 - VT
4310 VJ(I) = VJ(I) * (PB + PS / HG) / PS(I)
4320  NEXT I
4330  RETURN
```

```
4500  REM  <<<*** SUBROUTINE VISCOSITY ***>>>
4510 MW(1) = 44.1
4520 MW(2) = 28.01
4530 MW(3) = 28.02
4540 MW(4) = 32
4550 MW(5) = 18.02
4560 F(1) = CD / 100
4570 F(2) = CM / 100
4580 F(3) = N2 / 100
4590 F(4) = O2 / 100
4600 F(5) = BW
4610 MW = 0: FOR I = 1 TO 4:MW = MW + F(I) * MW(I): NEXT I:D
M = MW:MW = MW * (1 - BW) + BW * MW(5)
4620 T = (TI - 32) * 5 / 9
4630 U(1) = 138.494 + T * (.499 + T * ( - .286E - 3 + T * .9
72E - 7))
4640 U(2) = 165.763 + T * (.442 + T * ( - .213E - 3))
4650 U(3) = 167.086 + T * (.417 + T * ( - .139E - 3))
4660 U(4) = 190.187 + T * (.558 + T * ( - .336E - 3 + T * .1
39E - 6))
4670 U(5) = 87.8 + T * (.374 + T * ( - .283E - 4))
4680 U = 0
4690  FOR I = 1 TO 5
4700  IF F(I) = 0 GOTO 4790
4710 SU = 0
4720  FOR J = 1 TO 5
4730  IF F(I) = 0 GOTO 4770
4740  IF I = J GOTO 4770
4750 VT = 1 +  SQR (U(I) / U(J) *  SQR (MW(J) / MW(I)))
4760 SU = SU + VT * VT / (4 *  SQR ((1 + MW(I) / MW(J)) / 2)
) * F(J)
4770  NEXT J
4780 U = U + U(I) / (1 + SU / F(I))
4790  NEXT I
4795  PRINT "VIS = ";U;" UP"
4800 U = U * 1E - 6
4810  RETURN
4900  REM  **** THEO. PRES. DROP CALC. ****
4910 DP(0) = 0:AK = 3.14159 / 4
4920  FOR I = 1 TO 2 * S
4930  IF ( INT (I / 2) * 2 - I) <  > 0 THEN VJ(I) = QC * QI *
(PB + PS / HG) / (AK * JD(1 +  INT (I / 2)) * JD(1 +  INT (I
 / 2))) / (PB + PS / HG - DP(I - 1))
4935  IF ( INT (I / 2) * 2 - I) = 0 THEN VJ(I) = QC * QI * (
PB + PS / HG) / (AK * JL(I / 2) * JL(I / 2)) / (PB + PS / HG
 - DP(I - 1))
4940 DP(I) = DP(I - 1) + PM * GD * (PB + PS / HG - DP(I - 1)
) * MW * FS * VJ(I) * VJ(I) / SP / (TI + FR) / MA / DC2
4950 PS(I) = PB + PS / HG - DP(I - 1)
4960  NEXT I
4965 PS(2 * S + 1) = PB + PS / HG - DP(2 * S)
4970  RETURN
5000  REM  <<<*** SUBROUTINE CUT ***>>>
5001 F$ = "##;  #####;  ###.##;  #.#^^^^;  ##.###"
```

```
5005  IF F1 = 10 THEN RH = 1
5010 TK = 5 / 9 * (TI - 32) + 273
5015  PRINT "CYC    RE       V       GD      SQRT(PSI50)"
5020  FOR I = 1 TO S
5030 L = .337 * U *  SQR (TK / MW) / PS(2 * I)
5040 CU = 1.05
5050 X = 1
5051 GD(I) = GD * PS(2 * I - 1) * MW * FS / SP / (TI + FR) /
MA:RE(I) = GD(I) * VJ(2 * I - 1) * JD(I) / U: REM   GAS DENS
ITY AND REYNOLDS NO. AT CYCLONE INLET
5052 SI(I) =  EXP (JS(I) + JK(I) *  LOG (RE(I)) + JN(I) *  SQR
( LOG (RE(I)))): REM       SQUARE ROOT OF PSI50 FOR CYCLONE
= FCN OF RE
5053  CALL BU,R$,F$,I,RE(I),VJ(2 * I - 1),GD(I),SI(I): PRINT
R$
5060 D5 =  SQR (18 * U * JD(I) / (RH * VJ(2 * I - 1) * CU)) *
SI(I)
5070 CC = CU
5080 CU = 1 + 2 * L / D5 * (1.23 + .41 *  EXP ( - .44 * D5 /
L))
5090 X = X + 1
5095  REM  **LIMIT TO NO. OF ITERATIONS SET IN LINE 5100**
5100  IF X > 10 THEN  PRINT "STAGE ";I;"FAILED TO CONVERGE":
 GOTO 5120
5105  REM  **CONVERGENCE CRITERIUM SET IN LINE 5110**
5110  IF  ABS (1 - CC / CU) > .001 GOTO 5060
5120 D5(I) = D5 * 10000
5130 CC(I) = CU
5140 D6(I) = D5(I) *  SQR (CC(I) * RH)
5160  NEXT I
5170 XM = 0:M(S + 1) = FF
5180  FOR I = 1 TO S + 1
5190 XM = XM + M(I)
5200  NEXT I
5205 XM = XM - (S * SC) - FC
5210  FOR I = 1 TO S
5220 CU(I) = 0
5230  FOR J = I + 1 TO S + 1
5240 CU(I) = CU(I) + M(J)
5245  IF J < S + 1 THEN CU(I) = CU(I) - SC
5247  IF J = S + 1 THEN CU(I) = CU(I) - FC
5250  NEXT J
5260 CU(I) = CU(I) / XM
5270  NEXT I
5275  PRINT "PRESS ANY KEY TO CONTINUE": GET R$
5280  HOME
5290  IF F1 <  > 10 THEN  PRINT "STAGE C.CORR.   CUMFR  DP(P
HY) DP(I.AERO": GOTO 5297
5295  PRINT "STAGE C.CORR   CUMFR  DP(CL.A) DP(I.A)"
5297 F$ = "  ##; ###.###;  ##.###;  ##.###;  ##.###"
5300  FOR I = 1 TO S
5310  CALL BU,R$,F$,I,CC(I),CU(I) * 100,D5(I),D6(I): PRINT R
$
5320  NEXT I
```

```
5330  PRINT
5340  PRINT "PRESS ANY KEY TO CONTINUE": GET R$
5350  HOME
5380 TC = XM / (QS * TD * .02832): REM    MASS PER DNM3
5390  RETURN
5500  REM  <<<*** SUBROUTINE FIT ***>>>
5510 C0 = 2.515517
5520 C1 = 0.802853
5530 C2 = 0.010328
5540 D1 = 1.432788
5550 D2 = 0.189269
5560 D3 = 0.001308
5570 LT =  LOG (10)
5578 K = 0
5580  FOR I = 1 TO S
5581  FOR J = 1 TO MR
5582  IF MZ(J) = I THEN I = I + 1
5583  NEXT J
5585 K = K + 1
5590  IF F1 > 0 THEN X(K) =  LOG (D5(I)) / LT: GOTO 5600
5591 X(K) =  LOG (D6(I)) / LT
5600 FL = 1
5610 CU = CU(I)
5620  IF CU <  = .5 GOTO 5650
5630 FL =  - 1
5640 CU = 1 - CU
5650  IF CU <  = 0 THEN  PRINT "**** !!!! PUNT !!!! ****": PRINT
"STAGE WEIGHTS PRODUCE NEGATIVE OR ZERO CUMULATIVE. RECHECK
WEIGHTS.": GET R$:ZY = 1: RETURN
5660 T =  SQR ( - 2 *  LOG (CU))
5670 Y(K) = ( - T + (C0 + C1 * T + C2 * T * T) / (1 + T * (D
1 + T * (D2 + T * D3)))) * FL
5680  NEXT I
5690  GOTO 5700
5700  PRINT D$;"OPEN XPOINTS.DAT"
5705  PRINT D$;"READ XPOINTS.DAT"
5710  INPUT NP
5730  FOR I = 1 TO NP
5740  INPUT XP(I)
5750 XX(I) =  LOG (XP(I)) / LT
5760  NEXT I
5770  PRINT D$;"CLOSE"
5775 S = S - MR
5780  FOR I = 1 TO S / 2
5790 TX = X(I):TY = Y(I)
5800 X(I) = X(S + 1 - I):Y(I) = Y(S + 1 - I)
5810 X(S + 1 - I) = TX:Y(S + 1 - I) = TY
5820  NEXT I
5830  FOR I = 1 TO S - 1
5840  FOR J = I + 1 TO S
5850  IF X(J) >  = X(I) GOTO 5890
5860 TX = X(I):TY = Y(I)
5870 X(I) = X(J):Y(I) = Y(J)
5880 X(J) = TX:Y(J) = TY
```

```
5890  NEXT J
5900  NEXT I
5910  IF F1 = 1 THEN XX(0) =  LOG (X0 /  SQR (RH)) / LT: GOTO
5920
5915 XX(0) =  LOG (X0) / LT
5920  RETURN
6000  REM  <<<*** SPLINE FIT ***>>>
6005 YY(0) =  - 100
6010 OM = 1.0717968: REM  'RELAXATION PARAMETER'
6020 VT =  SQR (6.2832)
6030  REM  - FIRST DIFFERENCES
6040  FOR I = 1 TO S - 1
6050 H(I) = X(I + 1) - X(I)
6060 DL(I) = (Y(I + 1) - Y(I)) / H(I)
6070  NEXT I
6080  REM  - SECOND DIFF'S
6090  FOR I = 2 TO S - 1
6100 H2(I) = H(I - 1) + H(I)
6110 B(I) = .5 * H(I - 1) / H2(I)
6120 DQ(I) = (DL(I) - DL(I - 1)) / H2(I)
6130 S2(I) = 2 * DQ(I)
6140 C(I) = 3 * DQ(I)
6150  NEXT I
6160 S2(1) = 0
6170 S2(S) = 0
6180  REM   - SUCCESIVE OVER RELAXATION SOL'N
6190 ET = 0
6200  FOR I = 2 TO S - 1
6210 W = (C(I) - B(I) * S2(I - 1) - (.5 - B(I)) * S2(I + 1) -
S2(I)) * OM
6220  IF  ABS (W) > ET THEN ET =  ABS (W)
6230 S2(I) = S2(I) + W
6240  NEXT I
6250  IF ET > 1E - 5 GOTO 6190
6260  REM  - THIRD DIFF'S
6270  FOR I = 1 TO S - 1
6280 S3(I) = (S2(I + 1) - S2(I)) / H(I)
6290  NEXT I
6500  REM  *** NOW INTERPOLATE ***
6520  FOR J = 1 TO NP
6525  PRINT ".";
6530 I = 1
6540  IF XX(J) = X(1) GOTO 6750
6550  IF XX(J) < X(1) GOTO 6630
6560  IF XX(J) = X(S) GOTO 6730
6570  IF XX(J) > X(S) GOTO 6680
6580 I = I + 1
6590  IF XX(J) = X(I) GOTO 6750
6600  IF XX(J) > X(I) GOTO 6580
6610  GOTO 6740
6620  REM  EXTRAPOLATE BELOW X(1)
6630 S1 = DL(1) - H(1) / (H(1) + H(2)) * 2 * (DL(2) - DL(1))

6635  IF S1 < 0 THEN S1 = DL(1)
```

```
6640 YY(J) = Y(1) + (XX(J) - X(1)) * S1
6645  IF YY(J) < YY(J - 1) THEN S1 = DL(1):YY(J) = Y(1) + (X
X(J) - X(1)) * S1
6650 Y1(J) = S1
6660  GOTO 6820
6670  REM  - EXTRAPOLATE ABOVE X(S)
6680 S1 = DL(S - 1) + H(S - 1) * S2(S - 1)
6685  IF S1 < 0 THEN S1 = DL(S - 1)
6690 YY(J) = Y(S) + (XX(J) - X(S)) * S1
6694  IF XX(J) >  = XX(0) THEN YY(J) = 1E6:Y1(J) = 0: GOTO 6
710
6696 X3 = XX(J) - XX(0):X1 = X(S) - XX(0):X2 = XX(J) - X(S)
6698 YY(J) = YY(J) + ((X2 * X2 / X1 - X2) / X1 + 1) / X1 - 1
 / X3
6704 Y1(J) = S1 + (2 * X2 / X1 - 1) / X1 / X1 + 1 / X3 / X3
6710  GOTO 6820
6720  REM  -INTERPOLATE BETWEEN X(*)
6730 I = S
6740 I = I - 1
6750 H1 = XX(J) - X(I)
6760 H2 = XX(J) - X(I + 1)
6770 PR = H1 * H2
6780 Y2(J) = S2(I) + H1 * S3(I)
6790 DQ = (S2(I) + S2(I + 1) + Y2(J)) / 6
6800 YY(J) = Y(I) + H1 * DL(I) + PR * DQ
6805  IF YY(J) < Y(I) THEN YY(J) = Y(I) + H1 * DL(I)
6810 Y1(J) = DL(I) + (H1 + H2) * DQ + PR * S3(I) / 6
6815  IF Y1(J) < 0 THEN Y1(J) = DL(I)
6820 DG(J) =  EXP ( - YY(J) * YY(J) / 2) * Y1(J) * TC / VT
6830  NEXT J
6831  PRINT
6835 S = S + MR
6840  RETURN
7000  REM   <<<*** DISPLAY RESULTS ***>>>
7005 XZ$ = "PHYS DIA.":XY$ = "IMP. AERO DIA.":XX$ = "CLASS.
AERO DIA."
7006 F$ = "  ##.###; ###.####;  -#.##^^^^;  -#.##^^^^"
7007  IF F1 = 0 THEN ZZ$ = XY$
7008  IF F1 = 1 THEN ZZ$ = XZ$
7009  IF F1 = 10 THEN ZZ$ = XX$
7010  HOME : PRINT ZZ$ + " CUMFR SLOPE DM/DLOGD"
7020  FOR I = 1 TO NP STEP 2
7030  CALL BU,R$,F$,XP(I),YY(I),Y1(I),DG(I): PRINT R$
7040  NEXT I
7050  INPUT "DO YOU WANT TO SAVE THE RESULTS";Y$
7060  IF  LEFT$ (Y$,1) = "N" THEN  RETURN
7070  IF  LEFT$ (Y$,1) <  > "Y" THEN 7050
7080  PRINT D$;"OPEN" + NM$: PRINT D$;"WRITE" + NM$
7090  PRINT DT$: PRINT T$
7110  PRINT L$: PRINT RR$: PRINT ZZ$
7120  PRINT TC
7130  FOR I = 1 TO NP
7140  PRINT XP(I): PRINT YY(I): PRINT DG(I)
7150  NEXT I
```

```
7151  PRINT S
7152  FOR I = 1 TO S
7153  PRINT D5(I): PRINT D6(I): PRINT CU(I): PRINT Y(I)
7154  NEXT I
7156  PRINT AV: PRINT ND: PRINT IS: PRINT U: PRINT RH
7160  PRINT D$;"CLOSE"
7165  ONERR  GOTO 7700: PRINT D$;"VERIFY RUN/NAM": POKE 216,
0
7170  PRINT D$;"OPEN RUN/NAM": PRINT D$;"READ RUN/NAM"
7180  INPUT FI: FOR I = 1 TO FI: INPUT ZZ$(I): NEXT I:FI = F
I + 1: PRINT D$;"CLOSE"
7185 ZZ$(FI) = NM$
7190  PRINT D$;"OPEN RUN/NAM": PRINT D$;"WRITE RUN/NAM"
7200  PRINT FI: FOR I = 1 TO FI: PRINT ZZ$(I): NEXT I: PRINT
D$;"CLOSE"
7240  RETURN
7700 FI = 2:ZZ$(1) = "99999": POKE 216,0: GOTO 7185
9000  REM   <<<***HARDCOPY***>>>
9010  HOME : INPUT "DO YOU WANT HARDCOPY (Y/N) ?";R$: IF R$ =
"N" THEN  HOME : GOTO 9040
9015  IF R$ <  > "Y" THEN  GOTO 9010
9020  HOME : PRINT "TURN PRINTER ON"
9030  PRINT D$;"PR#1": PRINT  CHR$ (9) + "80 N" +  CHR$ (24)

9040  PRINT "     ********************";F$(0);"**************
******": PRINT
9050  PRINT "     ************* INPUT DATA ***********": PRINT
: PRINT
9060  PRINT F$(29);: IF F1 = 1 THEN  PRINT "PHYSICAL"
9065  IF F1 = 0 THEN  PRINT "IMPACTION AERODYNAMIC"
9070  IF F1 = 10 THEN  PRINT "CLASSICAL AERODYAMIC"
9080  PRINT F$(1);DT$
9090  PRINT F$(2);T$
9100  PRINT F$(3);L$
9110  CALL BU,R$,F$(4),TN: PRINT R$;TR$
9120  PRINT F$(27);I$
9130  PRINT F$(5);RN$;"-FILE NAME:";NM$
9140  PRINT F$(6);RR$
9180  PRINT F$(7);IM$;"  ";IN$
9185  CALL BU,R$,F$(25),RH: PRINT R$
9190  PRINT
9200  CALL BU,R$,F$(24),BW * 100: PRINT R$
9210  CALL BU,R$,F$(20),CD,CM: PRINT R$
9220  CALL BU,R$,F$(22),O2,N2: PRINT R$
9225  CALL BU,R$,F$(30),RO$: PRINT R$
9230  PRINT : PRINT
9240  CALL BU,R$,F$(8),VM: PRINT R$
9250  CALL BU,R$,F$(9),DP: PRINT R$
9260  CALL BU,R$,F$(10),OP: PRINT R$
9270  CALL BU,R$,F$(11),PS: PRINT R$
9280  CALL BU,R$,F$(12),PB: PRINT R$
9285  CALL BU,R$,F$(13),TS: PRINT R$
9290  CALL BU,R$,F$(14),TM: PRINT R$
9300  CALL BU,R$,F$(15),TI: PRINT R$
```

```
9310  CALL BU,R$,F$(16),TD: PRINT R$
9320  CALL BU,R$,F$(17),AV / 60: PRINT R$
9330  CALL BU,R$,F$(18),PC / 13.569: PRINT R$
9340  CALL BU,R$,F$(19),ND: PRINT R$
9350  CALL BU,R$,F$(21),X0: PRINT R$
9360  PRINT : PRINT
9370  FOR I = 1 TO S + 1
9380 X$ = "STAGE " +  STR$ (I)
9390  IF I = S + 1 THEN X$ = "FILTER "
9400  CALL BU,R$,F$(26),X$,M(I): PRINT R$
9410  NEXT I
9412  PRINT :X$ = "MASS GAIN OF BLANK SUBSTRATE   ##.##": CALL
BU,R$,X$,SC: PRINT R$
9414 X$ = "MASS GAIN OF BLANK FILTER       ##.##": CALL BU,R$
,X$,FC: PRINT R$
9420  PRINT  CHR$ (12)
9500  PRINT "*********        RESULTS      **********"
9510 F$ = "ACTUAL FLOW RATE            ##.### CFM": CALL BU,R$,F
$,QI: PRINT R$
9520 F$ = "FLOW RATE AT STANDARD CONDITIONS   ##.### CFM": CALL
BU,R$,F$,QS: PRINT R$
9530 F$ = "PERCENT ISOKINETIC         ###.### %": CALL BU,R$,F$
,IS: PRINT R$
9550 F$ = "VISCOSITY                 ###.#^^^^GM/CM-SEC": CALL
BU,R$,F$,U: PRINT R$
9555  IF DP = 0 THEN F$ = "CALCULATED SAMPLER DELTA P = ##.#
# IN. HG": CALL BU,R$,F$,DP(S * 2): PRINT R$
9558  PRINT : PRINT
9560  IF F1 = 10 THEN XZ$ = "DP(CLAS AERO)"
9565  IF F1 <  > 10 THEN XZ$ = "DP(PHYSICAL)"
9570  PRINT "STAGE   CUNN.      DP        DP          CUM.
INLET    SQRT"
9575  PRINT "         CORR. ";XZ$;"(IMP AERO)   FREQ.    RE
  PSI50"
9580 F$ = "  ##;    #.###;    ##.###;    ##.###;    ##.####;
   #####;   #.###"
9590  FOR I = 1 TO S
9600  CALL BU,R$,F$,I,CC(I),D5(I),D6(I),CU(I) * 100,RE(I),SI
(I): PRINT R$
9610  NEXT I
9620  IF MR = 0 GOTO 9650
9625  FOR I = 1 TO MR
9630  PRINT "NOTE: THE MASSES ON STAGES ";MZ(I);" AND ";MZ(I
) + 1;" HAVE BEEN COMBINED FOR THE SPLINE FIT BECAUSE OF CUT
S BEING TOO CLOSE TOGETHER"
9631  PRINT : PRINT
9650 F$ = "TOTAL MASS CONCENTRATION =  #.##^^^^ MG/DRY NORMA
L CUBIC METER": CALL BU,R$,F$,TC: PRINT R$
9651  PRINT
9655  IF F1 = 1 THEN  PRINT "SPLINE FIT ON PHYSICAL DIAMETER
 BASIS": PRINT
9660  IF F1 = 0 THEN  PRINT "SPLINE FIT ON IMPACTION AERODYN
AMIC DIAMETER BASIS": PRINT
9665  IF F1 = 10 THEN  PRINT "SPLINE FIT ON CLASSICAL AERODY
```

```
NAMIC DIAMETER BASIS": PRINT
9670  PRINT "PARTICLE DIA.  CUMFR  CUMFR   CUM.MASS   DM/DLO
GD"
9680  PRINT "  (MICRONS)  (STDDEV)(PERCENT)(MG/DRY N.CU.METE
R) "
9690  PRINT :D0 = .47047 /  SQR (2):C1 = .34802:C2 =  - .095
8798:C3 = .7478556
9695 F$ = " ##.###;  -##.####;    ###.##;   #.##^^^^;   #.##
^^^^"
9700  FOR I = 1 TO NP
9706 X1 = YY(I): GOSUB 9900
9710  CALL BU,R$,F$,XP(I),YY(I),X3 * 100,X3 * TC,DG(I): PRINT
R$
9720  NEXT I
9725  PRINT
9730  IF F1 <  > 10 THEN  GOTO 9790
9735  PRINT : PRINT
9740  PRINT "***  INHALABLE PARTICULATE MATTER ***"
9745  PRINT
9750 I = 6: GOSUB 9800
9760 I = 8: GOSUB 9800
9770 I = 11: GOSUB 9800
9780 I = 12: GOSUB 9800
9785  PRINT "NOTE: DIAMETERS FOR INHALABLE PARTICULATE MATTE
R ARE CLASSICAL AERODYNAMIC DIAMETERS"
9790  GOSUB 9840: PRINT  CHR$ (11): RETURN
9800 X1 = YY(I): GOSUB 9900
9810  CALL BU,R$,F$(28),XP(I),X3 * TC,X3 * 100: PRINT R$
9820  RETURN
9840  REM   *** PRINT SIZE DIST. PARAMETERS
9842  IF MR > 1 OR F1 = 10 THEN  PRINT  CHR$ (12)
9843  IF MR > 1 OR F1 = 10 THEN  PRINT " ****  RESULTS CONTI
NUED ****"
9845  PRINT
9850  PRINT "LOG-NORMAL SIZE DISTRIBUTION PARAMETERS": PRINT

9855 F$ = "LEAST SQUARES LINE:  Y=##.##; + ##.##X"
9860  CALL BU,R$,F$,L6,L5: PRINT R$
9865 F$ = "MASS MEDIAN DIAMETER: ###.###": CALL BU,R$,F$,L7:
 PRINT R$
9870 F$ = "GEOMETRIC STANDARD DEVIATION:  ###.###": CALL BU,
R$,F$,L8: PRINT R$
9880 F$ = "CORRELATION COEFFICIENT:  ###.###": CALL BU,R$,F$
,L9: PRINT R$
9890  RETURN
9900  REM   *** CALC. N(X)-THE NORMAL FCN ***
9905  IF X1 >  = 0 THEN FL = 1
9910  IF X1 < 0 THEN X1 =  - X1:FL =  - 1
9920 X2 = 1 / (1 + D0 * X1)
9930 X3 = 1 - ((C3 * X2 + C2) * X2 + C1) * X2 *  EXP ( - X1 *
X1 / 2)
9940 X3 = (1 + FL * X3) / 2
9950  RETURN
9960  REM   ***INSERT COEFF'S.
```

```
9970 D0 = .47047 /  SQR (2)
9980 C1 = .34802:C2 =  - .0958798:C3 = .7478556
9990  RETURN
10000  REM  *** CALCULATE LOG-NORMAL LEAST SQUARES FIT TO DA
TA ***
10020 LZ = 0:L1 = 0:L2 = 0:L3 = 0:L4 = 0:L5 = 0:L6 = 0:L7 =
0:L8 = 0:L9 = 0
10030  FOR I = 1 TO NZ
10040 LZ = LZ + X(I): REM  X(I) IS LOG OF STAGE D50
10050 L1 = L1 + Y(I): REM  Y(I) IS LOGNORM TRANSFORM OF CUM
FRACTION
10055 L2 = L2 + Y(I) * X(I)
10060 L3 = L3 + X(I) * X(I)
10070 L4 = L4 + Y(I) * Y(I)
10080  NEXT I
10090 L5 = (L2 - L1 * LZ / NZ) / (L3 - LZ * LZ / NZ)
10100 L6 = L1 / NZ - L5 * LZ / NZ
10110 L7 = 10 ^ ( - L6 / L5)
10120 L8 = 10 ^ (1 / L5)
10130 L9 = L5 *  SQR ((L3 - LZ * LZ / NZ) / (L4 - L1 * L1 /
NZ))
10140 L9 = L9 * L9
10145  PRINT "MMD= ";L7;" SIGG= ";L8;" R2= ";L9: PRINT : PRINT
"TO CONTINUE PRESS ANY KEY ": GET R$
10150  PRINT R$: RETURN
30000 DA(0) = F1:DA(1) = VM:DA(2) = DP:DA(3) = OP:DA(4) = PS
:DA(5) = PB:DA(6) = TS:DA(7) = TM:DA(8) = TI:DA(9) = TD:DA(1
0) = AV:DA(31) = WA:DA(32) = MF
30010 DA(11) = PC:DA(12) = ND:DA(13) = X0:DA(14) = TN:DA(15)
 = RH:DA(16) = S:DA(17) = MR:DA(18) = DC2:DA(19) = NN:DA(20)
 = DI:DA(21) = CQ:DA(22) = CP:DA(23) = CT:DA(24) = PP:DA(25)
 = BW:DA(26) = N9
30020 DA(27) = CD:DA(28) = CM:DA(29) = O2:DA(30) = N2
30040 DA =  PEEK (107) + 256 *  PEEK (108):DL =  PEEK (109) +
256 *  PEEK (110) - DA: REM  START AND LENGTH OF ARRAY STOR
AGE
30045 DL = 1000
30050  PRINT : PRINT D$;"BSAVE" + NM$ + ".DATA" + ",A";DA;",
L";DL
30060  PRINT D$;"OPEN" + NM$ + ".TEXT"
30070  PRINT D$;"WRITE" + NM$ + ".TEXT"
30080  PRINT DT$: PRINT T$: PRINT L$: PRINT I$: PRINT RN$: PRINT
NM$: PRINT RR$: PRINT IM$: PRINT IN$: PRINT RO$: PRINT SM$
30090  PRINT D$;"CLOSE": RETURN
30999  REM  RELOAD OLD RUN DATA
31000  PRINT "ENTER FILE NAME OF RUN TO BE RETRIEVED:": INPUT
FI$
31010 DA =  PEEK (107) + 256 *  PEEK (108)
31020  PRINT D$;"BLOAD" + FI$ + ".DATA,A";DA
31030 F1 = DA(0):VM = DA(1):DP = DA(2):OP = DA(3):PS = DA(4)
:PB = DA(5):TS = DA(6):TM = DA(7):TI = DA(8):TD = DA(9):AV =
DA(10)
31040 PC = DA(11):ND = DA(12):X0 = DA(13):TN = DA(14):RH = D
A(15):S = DA(16):MR = DA(17):DC2 = DA(18):NN = DA(19):DI = D
```

```
A(20):CQ = DA(21):CP = DA(22):CT = DA(23):PP = DA(24):BW = D
A(25):N9 = DA(26)
31050 CD = DA(27):CM = DA(28):O2 = DA(29):N2 = DA(30):WA = D
A(31):MF = DA(32)
31055 FF = M(S + 1):FC = M(S + 3):SC = M(S + 2)
31060  PRINT D$;"OPEN" + FI$ + ".TEXT"
31070  PRINT D$;"READ" + FI$ + ".TEXT"
31080  INPUT DT$: INPUT T$: INPUT L$: INPUT I$: INPUT RN$: INPUT
NM$: INPUT RR$: INPUT IM$: INPUT IN$: INPUT RO$: INPUT SM$
31085 F$(24) = " 9)WATER VAPOR         ##.##%"
31090  PRINT D$;"CLOSE": RETURN
63999 BU =  PEEK (121) + 256 *  PEEK (122) + 286: CALL BU:BU
 =  PEEK (6) + 256 *  PEEK (7): CALL BU + 3: RETURN : REM


==> DO NOT EDIT 63999.

65535  REM
  BUILDUSING (2.0)   APPENDED.

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==> TO REMOVE 'APPENDAGE', ENTER:
]EXEC BU.STRIP

]
```

```
0  REM  WRITTEN BY J.D.MCCAIN, SOUTHERN RESEARCH INSTITUTE -
 REVISION 8/1/84
1  TEXT : HOME : PRINT : PRINT "A CATALOG OF RUNS ON FILE WI
LL BE LISTED NEXT. SELECTTHE RUN TO BE PLOTTED AND TYPE IN F
ILE NAME WHEN REQUESTED. NOTE AMPERGRAPH LOADER MUST HAVE BE
EN RUN PRIOR TO THIS PROGRAM."
2  PRINT " THE RUN WILL THEN BE PLOTTED FIRST AS CUM. % VS.
DIA., THEN AS DM/DLOGD VS DIA., AND FINALLY AS CUM. CONC. VS
 DIA. TO PLOT ANOTHER RUN SIMPLY TYPE 'RUN' AFTER THE LAST H
AS BEEN COMPLETED. TO HALT CATALOG SCROLLING USE 'CTRL-S' "
3  PRINT "TO CONTINUE PRESS ANY KEY": GET R$: PRINT R$: PRINT

4  REM :PRINT : INPUT "ENTER FILE NAME OF RUN TO BE PLOTTED
    ";NM$
5  HIMEM: 16383
6  REM  **** PLOT SQUARE ****
10 D$ =  CHR$ (4)
12  DIM XP(20),YY(20),DG(20)
16 NP = 20
17  PRINT D$;"OPEN RUN/NAM" + ",D2": PRINT D$;"READ RUN/NAM"
: INPUT NR: DIM Y$(NR): FOR I = 1 TO NR: INPUT Y$(I): NEXT I
: PRINT D$;"CLOSE"
18  FOR I = 2 TO NR: PRINT Y$(I): NEXT I: PRINT
19  PRINT : INPUT "ENTER FILE NAME OF RUN TO BE PLOTTED
";NM$
20  PRINT D$;"OPEN" + NM$ + ",D2"
30  PRINT D$;"READ" + NM$
40  INPUT DT$: INPUT T$: INPUT L$: INPUT RR$: INPUT DB$: INPUT
TC
50  FOR I = 1 TO NP
60  INPUT XP(I): INPUT YY(I): INPUT DG(I)
70  NEXT I
71  INPUT S
72  DIM D5(S),D6(S),CU(S),Y(S)
73  FOR I = 1 TO S
74  INPUT D5(I): INPUT D6(I): INPUT CU(I): INPUT Y(I)
75  NEXT I
80  PRINT D$;"CLOSE"
85 C0 = 2.515517:C1 = .802853:C2 = .010328
86 D1 = 1.432788:D2 = .189269:D3 = .001308
90  PRINT XP(1),XP(20)
95  HGR2
100  & SCALE,.1,100, - 4,4
110  &  LOG X
120 LX$ = "DIAMETER, MICRONS"
130 LY$ = "CUMULATIVE PERCENT"
140  & LABELAXES,1,8
141 LABEL$ = ".1-": & LABEL,.068, - 3.22
142 LABEL$ = " 1-": & LABEL,.068, - 2.46
143 LABEL$ = "10-": & LABEL,.068, - 1.42
144 LABEL$ = "20-": & LABEL,.068, - .97
```

```
145 LABEL$ = "50-": & LABEL,.068, - .13
146 LABEL$ = "80-": & LABEL,.068,.71
147 LABEL$ = "90-": & LABEL,.068,1.16
148 LABEL$ = "99-": & LABEL,.068,2.2
149 LABEL$ = "  -": & LABEL,.068,2.96
150  & LABEL,.068, - 2.705: & LABEL,.068, - 1.775: & LABEL,.
068, - .655: & LABEL,.068, - .385
151  & LABEL,.068,.125: & LABEL,.068,.395: & LABEL,.068,1.51
5: & LABEL,.068,2.445
154 LABEL$ = NM$: & LABEL,.2,3.5
159  FOR I = 1 TO NP
160  & OPENCIRCLE,XP(I),YY(I)
170  NEXT I
171  GOSUB 5580
172  FOR I = 1 TO S
173  IF DB$ <  > "PHYS DIA." AND DB$ <  > "CLASS. AERO DIA."
 THEN  & CLOSEDCIRCLE,D6(I),Y(I): GOTO 177
174  & CLOSEDCIRCLE,D5(I),Y(I)
177  NEXT I
178  FOR I = 1 TO 5000: NEXT I
179  TEXT : HOME : INPUT "HARDCOPY? (REQUIRES GRAPHITTI CARD
) Y/N ";R$: IF R$ <  > "Y" THEN 200
180  PRINT : PRINT : INPUT "S)MALL (3X4) OR L)ARGE (6X8) SIZ
E FOR PLOT ";R$: IF R$ <  > "S" AND R$ <  > "L" GOTO 180
185  IF R$ = "S" THEN P$ = "G2R"
186  IF R$ = "L" THEN P$ = "G2RD"
187  PRINT D$;"PR#1"
190  PRINT  CHR$ (9) + P$: PRINT  CHR$ (12): PRINT D$;"PR#0"

200 DB = 0:DL = 1.0E32
210  FOR I = 1 TO 15
215  IF DG(I) <  = 0 THEN DG(I) = 1.0E - 15: GOTO 240
220  IF DG(I) > DB THEN DB = DG(I)
230  IF DG(I) < DL THEN DL = DG(I)
240  NEXT I
250  TEXT : HOME : PRINT "MIN DM/DLOGD=";DL
260  PRINT : PRINT "MAX DM/DLOGD=";DB
270  PRINT : PRINT : INPUT "SELECT RANGE FOR DM/DLOGD PLOT -
 MIN,MAX. MUST BE INTEGRAL POWERS OF TEN ";YL,YM
271  HGR2
275  & SCALE,.1,100,YL,YM
280  &  LOG X: &  LOG Y
290 LY$ = "DM/DLOGD, MG/DNM3"
300  & LABELAXES,1,YL
310 LABEL$ = NM$: & LABEL,.2,.6 * YM
320  FOR I = 1 TO 15
325  IF DG(I) <  = 0 THEN  GOTO 340
330  & OPENCIRCLE,XP(I),DG(I)
340  NEXT I
341  FOR I = 1 TO 5000: NEXT I: TEXT : HOME : INPUT "HARDCOP
Y? (REQUIRES GRAPHITTI CARD) Y/N";R$: IF R$ <  > "Y" THEN 35
0
342  PRINT : PRINT : INPUT "S)MALL (3X4) OR L)ARGE (6X8) SIZ
E FOR PLOT ";R$: IF R$ <  > "S" AND R$ <  > "L" GOTO 342
```

```
343  IF R$ = "S" THEN P$ = "G2R"
344  IF R$ = "L" THEN P$ = "G2RD"
345  PRINT D$;"PR#1"
346  PRINT  CHR$ (9) + P$: PRINT  CHR$ (12): PRINT D$;"PR#0"

350  REM    CUM CONC PLOT
360 D0 = .47047 /  SQR (2):C1 = .34802:C2 =  - .0958798:C3 =
.7478556
370  TEXT : HOME : PRINT "MIN CONC.=";:X1 = YY(1): GOSUB 990
0: PRINT X3 * TC
380  PRINT : PRINT "MAX CONC.=";:X1 = YY(15): GOSUB 9900: PRINT
X3 * TC
390  PRINT : PRINT : INPUT "SELECT RANGE FOR CUM. CONC. PLOT
 - MIN,MAX. MUST BE INTEGRAL POWERS OF TEN ";YL,YM
400  HGR2
410  & SCALE,.1,100,YL,YM
430  &  LOG X: &  LOG Y
440 LY$ = "CUM. CONC., MG/DNM3"
450  & LABELAXES,1,YL
480 LABEL$ = NM$: & LABEL,.2,.6 * YM
510  FOR I = 1 TO NP
520 X1 = YY(I): GOSUB 9900
525  IF X3 <  = 0 THEN 570
530  & OPENCIRCLE,XP(I),X3 * TC
540  NEXT I
550  FOR I = 1 TO S
555  IF DB$ <  > "PHYS DIA." AND DB$ <  > "CLASS. AERO DIA."
 THEN  & CLOSEDCIRCLE,D6(I),CU(I): GOTO 570
560  & CLOSEDCIRCLE,D5(I),CU(I) * TC
570  NEXT I
580  FOR I = 1 TO 5000: NEXT I: TEXT : HOME : INPUT "HARDCOP
Y? (REQUIRES GRAPHITTI CARD) Y/N";R$: IF R$ <  > "Y" THEN 70
0
590  PRINT : PRINT : INPUT "S)MALL (3X4) OR L)ARGE (6X8) SIZ
E FOR PLOT ";R$: IF R$ <  > "S" AND R$ <  > "L" GOTO 590
600  IF R$ = "S" THEN P$ = "G2R"
610  IF R$ = "L" THEN P$ = "G2RD"
620  PRINT D$;"PR#1"
630  PRINT  CHR$ (9) + P$: PRINT  CHR$ (12): PRINT D$;"PR#0"

700  HIMEM: 38400
999  END
5580  FOR I = 1 TO S
5600 FL = 1
5610 CU = CU(I)
5620  IF CU <  = .5 GOTO 5650
5630 FL =  - 1
5640 CU = 1 - CU
5650  REM
5660 T =  SQR ( - 2 *  LOG (CU))
5670 Y(I) = ( - T + (C0 + C1 * T + C2 * T * T) / (1 + T * (D
1 + T * (D2 + T * D3)))) * FL
5680  NEXT I
5700  RETURN
```

```
9899  REM  TRANSFORM FROM STD DEV TO LINEAR %
9900  IF X1 >  = 0 THEN FL = 1
9910  IF X1 < 0 THEN FL =  - 1:X1 =  - X1
9920 X2 = 1 / (1 + D0 * X1)
9930 X3 = 1 - ((C3 * X2 + C2) * X2 + C1) * X2 *  EXP ( - X1 *
X1 / 2)
9940 X3 = (1 + FL * X3) / 2
9950  RETURN
10000  END

]
```

STATPLOT

```
1  TEXT : HOME : PRINT : PRINT "A CATALOG WILL BE LISTED NEX
T. SELECT THE STATIS FILE TO BE PLOTTED AND TYPE IN FILE NAM
E WHEN REQUESTED. NOTE AMPERGRAPH LOADER MUST HAVE BEEN RUN
PRIOR TO THIS PROGRAM."
2  PRINT " THE RUN WILL THEN BE PLOTTED FIRST AS CUM.LOADING
 VS. DIA. AND THEN AS DM/DLOGD VS DIA. TO PLOT ANOTHER RUN S
IMPLY TYPE 'RUN' AFTER THE LAST HAS BEEN COMPLETED. TO HALT
CATALOG SCROLLING USE 'CTRL-S' "
3  PRINT "TO CONTINUE PRESS ANY KEY": GET R$: PRINT R$: PRINT

5  HIMEM: 16383
6  REM  **** PLOT SQUARE ****
10 D$ =  CHR$ (4)
12  DIM XP(21),M(21),S(21),CI(21),YY(21),CY(21)
16 NP = 20
17  PRINT D$;"CATALOG"
19  PRINT : INPUT "ENTER FILE NAME OF RUN TO BE PLOTTED
";NM$
20  PRINT D$;"OPEN" + NM$
30  PRINT D$;"READ" + NM$
40  INPUT DB$
50  FOR I = 0 TO NP + 1
55  IF I = NP + 1 THEN  INPUT XP(I): INPUT M(I): INPUT S(I):
 INPUT CI(I): GOTO 70
60  INPUT XP(I): INPUT M(I): INPUT S(I): INPUT CI(I): INPUT
YY(I): INPUT CY(I)
70  NEXT I
80  PRINT D$;"CLOSE"
85 C0 = 2.515517:C1 = .802853:C2 = .010328
86 D1 = 1.432788:D2 = .189269:D3 = .001308
90  PRINT "MIN CUM = ";YY(1);" MAX CUM = ";YY(20)
92  INPUT "ENTER YMIN,YMAX FOR CUM LOADING PLOT (MUST BE INT
EGRAL POWERS OF TEN) ";YL,YM
95  HGR2
100  & SCALE,.1,100,YL,YM
101  & LIMIT,.2,.7,0,1
110  &  LOG X: &  LOG Y
120 LX$ = "DIAMETER, MICRONS"
130 LY$ = "CUMULATIVE LOADING, MG/DNM3"
139  & AXES,.1,YL,1,YM / 2
140  REM   & LABELAXES,1,8
152  & FRAME
153 LABEL$ = "CUM. LOADING, MG/DNM3": & CENTERVLABEL,.02, SQR
(YL * YM)
154 LABEL$ = NM$: & LABEL,.2,.6 * YM
159  FOR I = 1 TO NP
160  & OPENCIRCLE,XP(I),YY(I)
165  & ERR OR BARS,0,CY(I)
170  NEXT I
176  FOR I = 1 TO 5000: NEXT I
179  TEXT : HOME : INPUT "HARDCOPY? (REQUIRES GRAPHITTI CARD
```

```
) Y/N ";R$: IF R$ <  > "Y" THEN 200
180  PRINT : PRINT : INPUT "S)MALL (3X4) OR L)ARGE (6X8) SIZ
E FOR PLOT ";R$: IF R$ <  > "S" AND R$ <  > "L" GOTO 180
185  IF R$ = "S" THEN P$ = "G2R"
186  IF R$ = "L" THEN P$ = "G2RD"
187  PRINT D$;"PR#1"
190  PRINT  CHR$ (9) + P$: PRINT D$;"PR#0"
200 DB = 0:DL = 1.0E32
210  FOR I = 1 TO 20
215  IF M(I) <  = 0 THEN M(I) = 1.0E - 15: GOTO 240
220  IF M(I) > DB THEN DB = M(I)
230  IF M(I) < DL THEN DL = M(I)
240  NEXT I
250  TEXT : HOME : PRINT "MIN DM/DLOGD=";DL
260  PRINT : PRINT "MAX DM/DLOGD=";DB
270  PRINT : PRINT : INPUT "SELECT RANGE FOR DM/DLOGD PLOT -
 MIN,MAX. MUST BE INTEGRAL POWERS OF TEN ";YL,YM
271  HGR2
275  & SCALE,.1,100,YL,YM
276  & LIMIT,.20,.7,0,1
280  &  LOG X: &  LOG Y
290 LABEL$ = "DM/DLOGD, MG/DNM3"
299  & AXES,.1,YL,1,YM / 2
300  & FRAME
305  & CENTERVLABEL,.02, SQR (YL * YM)
310 LABEL$ = NM$: & LABEL,.2,.6 * YM
320  FOR I = 1 TO 20
330  & OPENCIRCLE,XP(I),M(I)
335  & ERR OR BARS,0,CI(I)
340  NEXT I
341  FOR I = 1 TO 5000: NEXT I: TEXT : HOME : INPUT "HARDCOP
Y? (REQUIRES GRAPHITTI CARD) Y/N";R$: IF R$ <  > "Y" THEN 35
0
342  PRINT : PRINT : INPUT "S)MALL (3X4) OR L)ARGE (6X8) SIZ
E FOR PLOT ";R$: IF R$ <  > "S" AND R$ <  > "L" GOTO 342
343  IF R$ = "S" THEN P$ = "G2R"
344  IF R$ = "L" THEN P$ = "G2RD"
345  PRINT D$;"PR#1"
346  PRINT  CHR$ (9) + P$: PRINT D$;"PR#0"
348  HIMEM: 38400
350  END
5580  FOR I = 1 TO S
5600 FL = 1
5610 CU = CU(I)
5620  IF CU <  = .5 GOTO 5650
5630 FL =  - 1
5640 CU = 1 - CU
5650  REM
5660 T =  SQR ( - 2 *  LOG (CU))
5670 Y(I) = ( - T + (C0 + C1 * T + C2 * T * T) / (1 + T * (D
1 + T * (D2 + T * D3)))) * FL
5680  NEXT I
5700  RETURN
10000  END
```

PURGE RUNFILE

```
5 RO = 0
10 D$ =  CHR$ (4)
15  PRINT D$ + "CATALOG": FOR I = 1 TO 5000: NEXT I
20  HOME : PRINT : INPUT "ENTER TEST NUMBER OF RUN TO BE DEL
ETED ";TN
30  PRINT : INPUT "ENTER RUN ID OF RUN TO BE DELETED ";RN$
35  PRINT : INPUT "ENTER I)NLET OR O)UTLET RUN? ";I$
40 NM$ = "T" +  STR$ (TN) + "R" + RN$ + "." + I$ + "T"
50  PRINT "CHECK FILE NAME AND VERIFY THAT '";NM$;"' IS THE
FILE TO BE DELETED -Y/N ": GET R$: PRINT R$: PRINT
60  IF R$ <  > "Y" THEN  HOME : GOTO 20
62  PRINT D$;"OPEN" + NM$: PRINT D$;"CLOSE" + NM$
65  PRINT D$ + "DELETE" + NM$
70 K = 0:M = 0
72 D$ =  CHR$ (4)
75  PRINT D$ + "OPEN RUN/NAM"
80  PRINT D$ + "READ RUN/NAM"
90  INPUT NR
100  IF RO = 0 THEN  DIM Y$(NR),K(NR)
110  FOR I = 1 TO NR
120  INPUT Y$(I)
130  IF NM$ = Y$(I) THEN M = M + 1:K(M) = I
140  NEXT I
150  PRINT D$ + "CLOSE"
155  IF M = 0 THEN  END
160  PRINT D$ + "OPEN RUN/NAM"
170  PRINT D$ + "WRITE RUN/NAM"
175  PRINT NR - M
180  FOR I = 1 TO NR
190  IF NM$ = Y$(I) THEN  GOTO 210
200  PRINT Y$(I)
210  NEXT I
220  PRINT D$ + "CLOSE"
230  INPUT "MORE TO DELETE? (Y/N) ";R$: IF R$ <  > "Y" THEN
 END
240 RO = 1
250  GOTO 15

]
```

PURGE CYCLONE FILE

```
5 RO = 0
10 D$ =  CHR$ (4)
15  PRINT D$ + "CATALOG": FOR I = 1 TO 5000: NEXT I
20  HOME : PRINT : INPUT "ENTER IMPACTOR NAME TO BE DELETED
";NM$
40 MM$ = NM$ + "/IMP"
50  PRINT "CHECK FILE NAME AND VERIFY THAT": PRINT MM$: PRINT
" IS THE FILE TO BE DELETED -Y/N ": GET R$: PRINT R$: PRINT

60  IF R$ <  > "Y" THEN  HOME : GOTO 20
62  PRINT D$;"OPEN" + MM$: PRINT D$;"CLOSE" + MM$
65  PRINT D$ + "DELETE" + MM$
70 K = 0:M = 0
72 D$ =  CHR$ (4)
75  PRINT D$ + "OPEN IMP/NAM"
80  PRINT D$ + "READ IMP/NAM"
90  INPUT NR
100  IF RO = 0 THEN  DIM Y$(NR),K(NR)
110  FOR I = 1 TO NR
120  INPUT Y$(I)
130  IF NM$ = Y$(I) THEN M = M + 1:K(M) = I
140  NEXT I
150  PRINT D$ + "CLOSE"
155  IF M = 0 THEN  END
160  PRINT D$ + "OPEN IMP/NAM"
170  PRINT D$ + "WRITE IMP/NAM"
175  PRINT NR - M
180  FOR I = 1 TO NR
190  IF NM$ = Y$(I) THEN  GOTO 210
200  PRINT Y$(I)
210  NEXT I
220  PRINT D$ + "CLOSE"
230  INPUT "MORE TO DELETE? (Y/N) ";R$: IF R$ <  > "Y" THEN
 END
240 RO = 1
250  GOTO 15

]
```

```
1  REM   UPDATE TO SAVE VELOCITY TABLES 11/15/84 JDM
2  REM  CLEAN UP PROMPTS & CONVERT FROM KCAL TO <>H@ 12/27/8
5 JDM
100  REM   ** IMP OP & VEL TRAV PROG **
110  DIM X(20),Y(20),C(20),T(20,20),V(20,20),O(20,20),S(52),
J(52),F$(60)
120  GOSUB 63999
130 D$ =  CHR$ (4)
140  GOSUB 11000
150  HOME : PRINT F$(0): PRINT
160  PRINT "NEW VELOCITY TRAVERSE (Y OR N)?  ";: GET Q$: PRINT
Q$: PRINT : IF Q$ = "N" THEN F1 = 1
161  GOTO 170
165  HOME : PRINT F$(0): PRINT
170  IF Q$ = "Y" THEN  HOME : GOTO 270
180  IF Q$ >  < "N" THEN 150
190  REM   **  START
200  HOME : PRINT F$(0): PRINT
210  CALL BU,R$,F$(1),N$: PRINT R$
220  REM  GOSUB RUN CODE CHECK
230  CALL BU,R$,F$(2),A2: PRINT R$
240  CALL BU,R$,F$(3),I$: PRINT R$
250  GOTO 330
270  REM   **  VEL START
280  CALL BU,R$,F$(4),M$: PRINT R$
290 F3 = 0
300  IF  RIGHT$ (M$,1) = "O" THEN F3 = 1
310  CALL BU,R$,F$(5),B1: PRINT R$
320  CALL BU,R$,F$(6),B2: PRINT R$
330  CALL BU,R$,F$(7),G$: PRINT R$
340  CALL BU,R$,F$(8),G1: PRINT R$
350  CALL BU,R$,F$(9),G2: PRINT R$
360  CALL BU,R$,F$(10),G5: PRINT R$
370  CALL BU,R$,F$(11),P1: PRINT R$
380  CALL BU,R$,F$(12),P2: PRINT R$
390  CALL BU,R$,F$(13),F: PRINT R$
395  PRINT "B)  STACK TYPE               ";ST$
396  IF ST$ = "ROUND" THEN  CALL BU,R$,F$(52),DL: PRINT R$
397  IF ST$ = "RECT." THEN  CALL BU,R$,F$(50),DL: PRINT R$: CALL
BU,R$,F$(51),DB: PRINT R$
400  VTAB 20: PRINT "PRESS ITEM NO. TO CHANGE, C TO CONTINUE
,R TO RETURN TO MENU, OR V FOR NEW       VELOCITY"
410  VTAB 22: HTAB 13: GET A$
420  IF A$ = "R" THEN  PRINT "ARE YOU SURE YOU WANT TO EXIT
PROGRAM?";: GET R$: PRINT R$: PRINT : IF R$ = "Y" THEN  PRINT
D$;" RUN MENU"
425  IF A$ = "R" THEN  GOTO 165
430  IF A$ = "C" THEN 600
432  IF A$ = "V" THEN F9 = 0:F1 = 0:F4 = 0: GOTO 150
435  HTAB 15: PRINT "                         ": VTAB 22: HTAB
15
```

```
440  IF A$ = "A" THEN  INPUT "AMB TEMP = ";F: GOTO 165
445  IF A$ = "B" THEN  IF ST$ = "ROUND" THEN ST$ = "RECT.": GOTO
165
446  IF A$ = "B" THEN ST$ = "ROUND":B1 = 4: GOTO 165
447  IF A$ = "D" AND ST$ = "RECT." THEN  INPUT "ENTER DUCT L
ENGTH: ";DL:D2 = DL * DB: GOTO 165
448  IF A$ = "E" AND ST$ = "RECT." THEN  INPUT "ENTER DUCT D
EPTH : ";DB:D2 = DL * DB: GOTO 165
449  IF A$ = "D" AND ST$ = "ROUND" THEN  INPUT "ENTER DUCT D
IA. : ";DL:D2 = 3.14159 * (DL ^ 2) / 4: GOTO 165
450 A =  VAL (A$)
460  IF A = 1 AND Q$ = "N" THEN  INPUT "RUN NO. = ";N$: GOTO
165
470  IF A = 2 AND Q$ = "N" THEN  INPUT "SUBSTRATE SET = ";A2
: GOTO 165
480  IF A = 3 AND Q$ = "N" THEN  INPUT "TYPE/SHELL/PLATE = "
;I$: GOTO 165
490  IF A = 1 AND Q$ = "Y" THEN  INPUT "TEST CODE = ";M$: GOTO
165
500  IF A = 2 AND Q$ = "Y" THEN  INPUT "NO. PORTS = ";B1: GOTO
165
510  IF A = 3 AND Q$ = "Y" THEN  INPUT "NO. POINTS/PORT = ";
B2: GOTO 165
520  IF A = 4 THEN  INPUT "DATE = ";G$: GOTO 165
530  IF A = 5 THEN  INPUT "% O2 = ";G1: GOTO 165
540  IF A = 6 THEN  INPUT "% CO2 = ";G2: GOTO 165
550  IF A = 7 THEN  INPUT "% H2O = ";G5: GOTO 165
560  IF A = 8 THEN  INPUT "AMB PRES = ";P1: GOTO 165
570  IF A = 9 THEN  INPUT "DEL P STACK = ";P2: GOTO 165
580  GOTO 165
600 G4 = 100 - G1 - G2
610 P3 = P1 + P2 / 13.6
620 M1 = .32 * G1 + .44 * G2 + .28 * G4
630 M2 = (100 - G5) * M1 / 100 + .18 * G5
640 FK = F + 460
645  IF F1 = 1 THEN 1110
650  IF F4 = 1 OR F9 = 1 THEN 1300 REM        GOTO PORT #
660  REM   **  VEL TRAVERSE
670 I = 0
680 I = I + 1
685  IF I > B1 THEN I = 1
690  HOME : PRINT "VELOCITY TRAVERSE": PRINT
700  CALL BU,R$,F$(14),I: PRINT R$
710  CALL BU,R$,F$(15),C: PRINT R$
720  PRINT : PRINT "POINT #   Vp(H20)   T(degF)   VEL(ft/s)"

760 SP = 1: IF ST$ = "ROUND" AND I = 1 THEN SP = 0
765  FOR K = SP TO B2
770  CALL BU,R$,F$(16),K,O(I,K),T(I,K),V(I,K): PRINT R$
780  NEXT K
790  CALL BU,R$,F$(17),Y(I): PRINT R$
800  CALL BU,R$,F$(18),X(I): PRINT R$
805  CALL BU,R$,FO$,OA(I): PRINT R$
807  IF SP = 0 THEN  PRINT : PRINT "NOTE: POINT '0' IS CENTE
```

```
R (FOR CONTOURS"
810  VTAB 22: INPUT "ENTER POINT NO. OR ITEM NO., N FOR NEXT
 PORT, C TO CONTINUE, V TO RESTART ";A$
815  IF A$ = "V" THEN 165
820  IF A$ = "N" THEN 680
830  IF A$ = "P" THEN  HTAB 13: INPUT "PORT NO.= ";I: GOTO 6
90
840  IF A$ = "K" THEN  HTAB 13: INPUT "PITOT CONST. = ";C: GOTO
910
850  IF A$ = "C" THEN 1030
860 A =  VAL (A$)
870  IF A < 0 OR A > B2 THEN 690
880  HTAB 13: PRINT "FOR POINT NO. ";A
890  HTAB 13: INPUT "Vp = ";R$: IF R$ <  > "" THEN O(I,A) =
 VAL (R$)
900  HTAB 13: INPUT "T  = ";R$: IF R$ <  > "" THEN T(I,A) =
 VAL (R$)
910 CJ = 0
915 X(I) = 0
916 Y(I) = 0
918  IF SP = 0 AND A = 0 THEN V(1,0) = 85.48 * C /  SQR (P3 *
M2) *  SQR (O(1,0) * (T(1,0) + 460))
920  FOR J = 1 TO B2
940 V(I,J) = 85.48 * C /  SQR (P3 * M2) *  SQR (O(I,J) * (T(
I,J) + 460))
950 X(I) = X(I) + T(I,J)
960 Y(I) = Y(I) + V(I,J)
970 CJ = CJ + 1
980  NEXT J
990  IF CJ = 0 THEN 1020
1000 X(I) = X(I) / CJ
1010 Y(I) = Y(I) / CJ
1015 OA(I) = Y(I) / (( SQR (X(I) + 460)) * 85.48 * C) *  SQR
(P3 * M2)
1020  GOTO 690
1030 Z1 = 0
1040 Z2 = 0
1045 Z3 = 0
1050  FOR I = 1 TO B1
1060 Z1 = Z1 + Y(I)
1070 Z2 = Z2 + X(I)
1075 Z3 = Z3 + OA(I)
1080  NEXT I
1090 Z1 = Z1 / B1
1100 Z2 = Z2 / B1
1105 Z3 = Z3 / B1
1110  HOME : PRINT "VELOCITY TRAVERSE": PRINT :F1 = 0
1120  CALL BU,R$,F$(48),Z1: PRINT R$
1130  CALL BU,R$,F$(49),Z2: PRINT R$
1135  CALL BU,R$,FO$,Z3: PRINT R$
1140  PRINT : CALL BU,R$,F$(19),D2: PRINT R$: PRINT
1150 Q2 = Z1 * D2 * 60
1160 Q3 = Q2 * 530 / (460 + Z2) * P3 / 29.92 * (100 - G5) /
100
```

```
1170  CALL BU,R$,F$(20),Q2: PRINT R$
1180  CALL BU,R$,F$(21),Q3: PRINT R$
1190  VTAB 20: PRINT "PRESS ITEM NO TO CHANGE,P TO PRINT DAT
A,D FOR DELTA P PROGRAM,V FOR NEW VELOCITYPROGRAM, S FOR DIS
K SAVE"
1192  VTAB 23: HTAB 13: GET A$
1193  IF A$ = "S" THEN  GOSUB 20000: REM   SAVE TRAVERSE TO
DISK
1194  IF A$ = "3" THEN  INPUT "DUCT AREA = ";D2: GOTO 1110
1200  IF A$ = "P" THEN  GOSUB 8000: GOTO 1110 REM  VEL OUTPU
T
1210  IF A$ = "V" THEN F9 = 0: GOTO 150
1220  IF A$ = "D" THEN Q$ = "N":F9 = 1: GOTO 190
1225  IF A$ = "1" THEN  INPUT "DUCT VEL = ";Z1: GOTO 1110
1230  IF A$ = "2" THEN  INPUT "DUCT TEMP = ";Z2: GOTO 1110
1240  GOTO 1110
1300  REM   ** PORT NO.
1310  PRINT : PRINT "SELECT:": INPUT "PORT NO., M(=MANUAL),
OR A(=ALL) ";O$
1320  IF O$ = "A" THEN 1400
1330  IF O$ = "M" THEN  INPUT "MANUAL CALCULATION ON PORT NO
. ";O$: GOTO 1450
1340 N =  VAL (O$)
1350 V = Y(N)
1360 T = X(N)
1370  PRINT : CALL BU,R$,F$(24),V: PRINT R$
1380  CALL BU,R$,F$(25),T: PRINT R$
1390  GOTO 1570
1400 V = Z1
1410 T = Z2
1420  PRINT : CALL BU,R$,F$(17),V: PRINT R$
1430  CALL BU,R$,F$(18),T: PRINT R$
1440  GOTO 1570
1450  HOME : PRINT "MANUAL VELOCITY ": PRINT
1460  CALL BU,R$,F$(26),V: PRINT R$
1470  CALL BU,R$,F$(27),T: PRINT R$
1480  PRINT : PRINT "PRESS 1 OR 2 TO CHANGE,C TO CONTINUE,
 V TO RESTART ";: GET A$: PRINT A$
1500  IF A$ = "V" THEN 190
1510  IF A$ = "C" THEN 1580
1520 A =  VAL (A$)
1530  VTAB 8: PRINT "                                ": VTAB 8: HTAB
13
1540  IF A = 1 THEN  INPUT "GAS VEL = ";V: GOTO 1450
1550  IF A = 2 THEN  INPUT "GAS TEMP = ";T: GOTO 1450
1560  GOTO 1450
1570  REM   ** IMP FLOW RATE
1575  PRINT : PRINT "C TO CONTINUE";: GET Z$: PRINT
1580  HOME : PRINT "IMPACTOR FLOW RATE CALCULATION": PRINT
1590  PRINT "IMPACTOR TYPE     1)  ANDERSEN"
1600  PRINT "                  2)  BRINK"
1610  PRINT "                  3)  PILAT"
1615  PRINT "                  4)  SERIES CYCLONE"
1620  PRINT "                  5)  MANUAL SEARCH"
```

```
1630  PRINT : INPUT "YOUR CHOICE ";G: PRINT
1635  IF G < 1 OR G > 5 THEN 1580
1640  ON G GOTO 1650,1740,1650,1725,1860
1650 D1 = 11:I = 0
1660 I = I + 1
1670 D1 = D1 - 1
1675  IF D1 = 0 THEN  PRINT "NO MORE!!! - WILL RESTART": GOTO
1650
1680 D4 = D1 / 16 * 25.4
1690 Q1 = 5.072E - 04 * V * D4 ^ 2
1700  IF G = 1 AND Q1 > 1.25 THEN 1660
1710  IF G = 3 AND Q1 > 2 THEN 1660
1715  PRINT : PRINT "NOZ.DIA. = ";D4;"MM    Q = ";Q1;" ACFM":
 PRINT "ARE THESE OK? (Y/N)";: GET R$: PRINT R$: IF R$ = "N"
 THEN 1660
1716  IF R$ <  > "Y" THEN 1715
1720 D1 = D1 / 16: GOTO 2000
1725 I = 13: REM   NO. OF CYC. NOZZLES+1
1726 I = I - 1: IF I <  = 0 THEN  PRINT "NO MORE - WILL REST
ART": GOTO 1725
1728 D1 = CN(I):Q1 = 5.072E - 4 * V * D1 ^ 2
1729  IF Q1 > 2 AND I > 1 THEN 1726
1730  PRINT : PRINT "NOZ.DIA. = ";D1;"MM     Q= ";Q1;" ACFM":
 PRINT "ARE THESE OK? (Y/N)";: GET R$: PRINT R$: IF R$ = "N"
 THEN 1726
1732  IF R$ <  > "Y" THEN 1730
1735  GOTO 2000
1740  PRINT : INPUT "5 OR 6 STAGE BRINK ";M3
1745  IF M3 < 5 OR M3 > 6 THEN 1740
1750 D1 = 5
1760 Q2 = .025
1770  IF M3 = 5 THEN Q2 = .04
1775 I = 0
1780 I = I + 1
1790 Q1 = 5.072E - 04 * V * D1 ^ 2
1800  IF Q1 < Q2 THEN 1940
1810  IF D1 = 1.4 THEN 1940
1820  IF D1 < 2.5 THEN D1 = D1 - .1: GOTO 1840
1830 D1 = D1 - .5
1840  IF I < 20 GOTO 1780
1850  GOTO 1940
1860  VTAB 10
1870  CALL BU,R$,F$(28),D1: PRINT R$
1880 Q1 = 5.072E - 04 * V * D1 ^ 2
1890  PRINT : CALL BU,R$,F$(29),Q1: PRINT R$
1900  PRINT : PRINT "IS THE FLOW RATE OK (Y OR N)? ";: GET A
$: PRINT A$: PRINT
1910  IF A$ = "N" THEN  INPUT "NOZ DIA = ";D1: VTAB 14: PRINT
: PRINT : PRINT : GOTO 1860
1920  IF A$ = "Y" THEN 2000
1930  GOTO 1860
1940  IF G = 2 THEN  PRINT : CALL BU,R$,F$(28),D1: PRINT R$:
 GOTO 1970
1950 D1 = D1 / 16
```

```
1960  CALL BU,R$,F$(30),D1: PRINT R$
1970  CALL BU,R$,F$(29),Q1: PRINT R$
1980  PRINT : PRINT "ARE THESE NUMBERS OK (Y OR N)?";: GET A
$: PRINT A$: PRINT
1990  IF A$ = "N" THEN 1820
1995  IF A$ <  > "Y" THEN 1980
2000 X = (Q1 * (100 - G5) / 100 * P3 / (T + 460)) ^ 2 * FK *
M1 / .9234
2010  REM   **  ORIFICE SELECTION
2020 M = 1: IF G = 2 OR G = 5 THEN  PRINT : PRINT "1 ORIFICE
 OR 2?  ";: GET M: PRINT M: IF M < 1 OR M > 2 THEN 2020
2050  IF M = 2 THEN 2300
2060  HOME : PRINT "ONE ORIFICE": PRINT
2070  CALL BU,R$,F$(31),1,1,O1$: PRINT R$
2080  CALL BU,R$,F$(32),2,1,H1: PRINT R$
2090 R =  - 1.5
2100  FOR I = 1 TO 24
2110 R = R + .5
2120 S(I) = X * H1 / (P1 - R)
2130 J(I) = 6 * FK * (P1 - R - S(I) / 13.6) / (Q1 * FK * P3 *
(100 - G5) / 100)
2140  NEXT I
2150  PRINT : PRINT "Psys   <>P  Tsec    Psys   <>P  Tsec"
2160 R =  - 1.5
2170 RR = 0
2180  FOR I = 1 TO 12
2190 K = I + 12
2200 R = R + .5
2210 RR = R + 6
2220  CALL BU,R$,F$(33),R,S(I),J(I),RR,S(K),J(K): PRINT R$
2230  NEXT I
2240  PRINT : PRINT "PRESS C TO CONTINUE,1 TO CHANGE ORIFICE
 ID,2 TO CHANGE <>H@,F TO REPEAT FLOW    RATE CALCULATION,S
TO SKIP THIS CALC  ";: GET A$: PRINT A$
2250  IF A$ = "F" THEN 1570
2255  IF A$ = "S" THEN 190
2260  IF A$ = "1" THEN  VTAB 23: HTAB 13: INPUT "ORIFICE ID
= ";O1$: GOTO 2060
2270  IF A$ = "2" THEN  VTAB 23: HTAB 13: INPUT "<>H@ = ";H1
: GOTO 2060
2280  IF A$ = "C" THEN 2600
2290  GOTO 2060
2300  HOME : PRINT "2 ORIFICES": PRINT
2310  CALL BU,R$,F$(31),1,1,O1$: PRINT R$
2320  CALL BU,R$,F$(32),2,1,H1: PRINT R$
2330  CALL BU,R$,F$(31),3,2,O2$: PRINT R$
2340  CALL BU,R$,F$(32),4,2,H2: PRINT R$
2350 R =  - 1.5
2360  FOR I = 1 TO 24
2370 R = R + .5
2380 S(I) = X * H1 / (P1 - R)
2390 J(I) = X * H2 / (P1 - R - S(I))
2400  NEXT I
2410  PRINT : PRINT "Psys  <>P1  <>P2    Psys  <>P1  <>P2"
```

```
2420 R = 0
2430 RR = 0
2440  FOR I = 1 TO 12
2450 K = I + 12
2460 R = R + .5
2470 RR = R + 6
2480  CALL BU,R$,F$(33),R,S(I),J(I),RR,S(K),J(K): PRINT R$
2490  NEXT I
2500  PRINT : PRINT "C TO CONTINUE,1-4 TO CHANGE DATA,F FOR
 NEW FLOW RATE CALC,R TO REPEAT ";: GET A$: PRINT A$
2510  IF A$ = "R" THEN 190
2515  IF A$ = "F" THEN 1570
2520  IF A$ = "C" THEN 2600
2530 A =  VAL (A$)
2540  IF A = 1 THEN  HTAB 13: INPUT "ORIFICE #1 ID = ";O1$: GOTO
2300
2550  IF A = 2 THEN  HTAB 13: INPUT "Kcal #1 = ";H1: GOTO 23
00
2560  IF A = 3 THEN  INPUT "ORIFICE #2 ID = ";O2$: GOTO 2300

2570  IF A = 4 THEN  INPUT "Kcal #2 = ";H2
2580  GOTO 2300
2600  REM   ** FULL OUTPUT
2610  PRINT : PRINT "INSERT RUN SHEET": PRINT "C TO CONTINUE
, S TO SKIP ";: GET Z$: PRINT Z$
2612  IF Z$ <  > "C" AND Z$ <  > "S" THEN 2610
2615  IF Z$ = "S" THEN 190
2620  PRINT D$;"PR#1"
2630  PRINT "                              ";N$
2640  PRINT : CALL BU,R$,F$(36),I$,G1,P1,O$: PRINT R$
2650  PRINT : CALL BU,R$,F$(37),G$,G2,F,V: PRINT R$
2660  PRINT : CALL BU,R$,F$(38),A2,G4,P2,T: PRINT R$
2670  PRINT : CALL BU,R$,F$(34),G5,P3,Q1: PRINT R$
2700  PRINT : PRINT : PRINT : PRINT : PRINT : PRINT : PRINT

2705  CALL BU,R$,F$(39),D1: PRINT R$: PRINT
2707  IF M = 2 THEN 2840
2710  PRINT "
   ORI ID: ";O1$
2720  PRINT "
   <>H@:   ";H1
2730  PRINT "
   GAS METER #:"
2740 R =  - 1.5: PRINT
2750  PRINT "
   Psys   <>P   TIME"
2760  PRINT "
    Hg     H2O    sec"
2770  PRINT "
   ----   ---   ----"
2780  FOR I = 1 TO 24
2790 R = R + .5
2800  CALL BU,R$,F$(35),R,S(I),J(I): PRINT R$
2810  NEXT I
```

```
2820  PRINT : PRINT D$;"PR#0"
2830  GOTO 190
2840  PRINT "
   ORI #1 ID: ";O1$
2850  PRINT "
   <>H@ #1  : ";H1
2860  PRINT "
   ORI #2 ID: ";O2$
2870  PRINT "
   <>H@ #2  : ";H2
2880 R = 0: PRINT
2890  PRINT "
   Psys   <>P     <>P"
2900  PRINT "
    Hg    H2O     H2O"
2910  PRINT "
   ----   ---     ---"
2920  FOR I = 1 TO 24
2930 R = R + .5
2940  CALL BU,R$,F$(35),R,S(I),J(I): PRINT R$
2950  NEXT I
2960  PRINT : PRINT D$;"PR#0"
2970  GOTO 190
8000  REM    ** VEL OUTPUT
8010  PRINT : PRINT "LOAD TRAVERSE FORM INTO PRINTER, C TO
 CONTINUE ": GET Z$: PRINT Z$
8015  PRINT D$;"PR#1"
8020  CALL BU,R$,F$(40),M$,G$: PRINT R$: PRINT
8030  CALL BU,R$,F$(41),G1,G4,P1,C,D2: PRINT R$: PRINT
8040  CALL BU,R$,F$(42),G2,G5,P2,F: PRINT R$: PRINT : PRINT

8050 I = 1
8060 I1 = I + 1:I2 = I + 2:I3 = I + 3
8070  IF B1 < I3 THEN 8160
8080  CALL BU,R$,F$(43),I,I1,I2,I3: PRINT R$: PRINT
8090  PRINT "PT     PV    T    VEL     PV    T    VEL     PV    T
VEL     PV    T    VEL"
8100  PRINT " #     H2O   F   ft/s     H20   F   ft/s     H2O   F   f
t/s     H20   F   ft/s": PRINT
8110  FOR K = 1 TO B2
8120  CALL BU,R$,F$(44),K,O(I,K),T(I,K),V(I,K),O(I1,K),T(I1,
K),V(I1,K),O(I2,K),T(I2,K),V(I2,K),O(I3,K),T(I3,K),V(I3,K): PRINT
R$
8130  NEXT K
8140  PRINT : CALL BU,R$,F$(45),OA(I),X(I),Y(I),OA(I1),X(I1)
,Y(I1),OA(I2),X(I2),Y(I2),OA(I3),X(I3),Y(I3): PRINT R$: PRINT
: PRINT
8150  GOTO 8410
8160  IF B1 < I2 THEN 8250
8170  CALL BU,R$,F$(43),I,I1,I2: PRINT R$: PRINT
8180  PRINT "PT     PV    T    VEL     PV    T    VEL     PV    T
VEL"
8190  PRINT " #     H2O   F   ft/s     H20   F   ft/s     H2O   F   f
t/s": PRINT
```

```
8200  FOR K = 1 TO B2
8210  CALL BU,R$,F$(44),K,O(I,K),T(I,K),V(I,K),O(I1,K),T(I1,
K),V(I1,K),O(I2,K),T(I2,K),V(I2,K): PRINT R$
8220  NEXT K
8230  PRINT : CALL BU,R$,F$(45),OA(I),X(I),Y(I),OA(I1),X(I1)
,Y(I1),OA(I2),X(I2),Y(I2): PRINT R$: PRINT : PRINT
8240  GOTO 8410
8250  IF B1 < I1 THEN 8340
8260  CALL BU,R$,F$(43),I,I1: PRINT R$: PRINT
8270  PRINT "PT     PV    T    VEL      PV    T    VEL"
8280  PRINT " #     H20   F   ft/s     H20   F   ft/s": PRINT
8290  FOR K = 1 TO B2
8300  CALL BU,R$,F$(44),K,O(I,K),T(I,K),V(I,K),O(I1,K),T(I1,
K),V(I1,K): PRINT R$
8310  NEXT K
8320  PRINT : CALL BU,R$,F$(45),OA(I),X(I),Y(I),OA(I1),X(I1)
,Y(I1): PRINT R$: PRINT : PRINT
8330  GOTO 8410
8340  CALL BU,R$,F$(43),I: PRINT R$: PRINT
8350  PRINT "PT     PV    T    VEL"
8360  PRINT " #     H20   F   ft/s": PRINT
8370  FOR K = 1 TO B2
8380  CALL BU,R$,F$(44),K,O(I,K),T(I,K),V(I,K): PRINT R$
8390  NEXT K
8400  PRINT : CALL BU,R$,F$(45),OA(I),X(I),Y(I): PRINT R$: PRINT
: PRINT
8410 I = I + 4
8420  IF I <  = B1 THEN 8060
8430  CALL BU,R$,F$(46),Z1,Q2: PRINT R$
8440  CALL BU,R$,F$(47),Z2,Q3: PRINT R$
8445  CALL BU,R$,FO$,Z3: PRINT R$
8450  PRINT : PRINT D$;"PR#0"
8460  RETURN
11000  REM  **  FORMATS  **
11005 C = .83:P1 = 30: DIM CN(12):ST$ = "RECT."
11010 F$(0) = "IMPACTOR OP & VELOCITY PROGRAM"
11020 F$(1) = "1)  RUN NUMBER  (xxxxI-n)     #######"
11030 F$(2) = "2)  SUBSTRATE SET             #######"
11040 F$(3) = "3)  IMP TYPE/SHELL NO/PLATE NO #######"
11050 F$(4) = "1)  TEST CODE  (xxxxI)        #####"
11060 F$(5) = "2)  NUMBER OF PORTS             ##<0#"
11070 F$(6) = "3)  NUMBER OF POINTS PER PORT ##<0#"
11080 F$(7) = "4)  DATE                     ########"
11090 F$(8) = "5)  % O2                      #<0#.#"
11100 F$(9) = "6)  % CO2                     #<0#.#"
11110 F$(10) = "7)  % H20                     #<0#.#"
11120 F$(11) = "8)  AMBIENT PRESSURE     ##<0#.## in. Hg"
11130 F$(12) = "9)  DELTA P STACK       ###<0#.## in. H20"
11140 F$(13) = "A)  AMBIENT TEMP        ###<0#.   deg F"
11150 F$(14) = "P)  PORT NO             ###"
11160 F$(15) = "K)  PITOT CONSTANT      ##<0#.###"
11170 F$(16) = "   ##;      #<0#.###     ;###<0#;       ##<0
#.##"
11180 F$(17) = "AVG DUCT VELOCITY = ##<0#.# ft/sec"
```

```
11190 F$(18) = "AVG DUCT TEMP      = ####  deg F"
11200 F$(19) = "3) DUCT AREA =       ##<0#.# ft2"
11210 F$(20) = "FLOW RATE     = ##,###,##<0#.# acfm"
11220 F$(21) = "              = ##,###,##<0#.# scfm"
11230 F$(22) = "    % N2             ###.#"
11240 F$(23) = "    STACK PRES       ###.## in. Hg"
11250 F$(24) = "AVG PORT VELOCITY = ###.# ft sec"
11260 F$(25) = "AVG PORT TEMP      = ####  deg F"
11270 F$(26) = "1)  GAS VELOCITY     ##<0#.# ft/sec"
11280 F$(27) = "2)  GAS TEMP         ###<0#   deg F"
11290 F$(28) = "NOZZLE DIAMETER = ###.##  mm"
11300 F$(29) = "FLOW RATE       = ###.### ACFM"
11310 F$(30) = "NOZZLE DIAMETER = ###.##  in."
11320 F$(31) = "#;) ORIFICE NO ##; ID  #####"
11330 F$(32) = "#;) ORIFICE NO ##; ?<?>H@ ###<0#.###"
11340 F$(33) = "##.#; ###.#; ###.#;     ##.#; ###.#; ###.#"
11350 F$(34) = "                        % H20: ##.##;    Pstack
:  ##.##;     IMP FLOW: #.###"
11360 F$(35) = "
      ##.#; ###.#;   ###.#"
11370 F$(36) = " IMP ID:   ######;    % O2:  ##.#;     AMB P
: ##.##;       PORT #: ####"
11380 F$(37) = " DATE:   ########;    % CO2: ##.#;     AMB T
: #####;       GAS VEL: ##.##"
11390 F$(38) = " SUB SET #: ####;     % N2:  ##.#;     ?<?>P
stack: ###.#;   GAS TEMP:  ####"
11400 F$(39) = "
      NOZ DIA: ##.###"
11410 F$(40) = "                  ########;               #####
###"
11420 F$(41) = "% O2: ##.#;      % N2: ###.#;      AMB P: ##.#
#;      Cp: ####.##;      DUCT AREA: ###"
11430 F$(42) = "%CO2: ##.#;      %H20: ###.#;      ?<?>Pstk: #
##.#;     AMB T: ###"
11440 F$(43) = "         PORT ##;          PORT ##;          PO
RT ##;          PORT ##"
11450 F$(44) = "##;  #.## ;####; ##.#;  #.## ;####; ##.#;  #
.## ;####; ##.#;  #.## ;####; ##.#"
11460 F$(45) = "AVG #.##; ####; ##.#;  #.##; ####; ##.#;  #.
##; ####; ##.#;  #.##; ####; ##.#"
11470 F$(46) = "        AVG DUCT VEL  = ###.# ft/s;
VOLUME FLOW = ##,###,### acfm"
11480 F$(47) = "        AVG DUCT TEMP = ####  deg F;
          = ##,###,### scfm"
11490 F$(48) = "1) AVG DUCT VEL   = ##<0#.# ft/sec"
11491 F$(50) = "D)  DUCT LENGTH           #<0#.## FEET"
11492 F$(52) = "D)  DUCT DIAMETER         #<0#.## FEET"
11493 F$(51) = "E)  DUCT DEPTH            #<0#.## FEET"
11495 F$(49) = "2) AVG DUCT TEMP  = ####  deg F"
11496 FO$ = "AVG SQRT DELTA P  = #<0#.### IN. H2O"
11497 CN(1) = 3.5:CN(2) = 4:CN(3) = 4.5:CN(4) = 5:CN(5) = 5.
4:CN(6) = 6:CN(7) = 7:CN(8) = 8:CN(9) = 9:CN(10) = 10:CN(11)
 = 11:CN(12) = 12: REM    CYC NOZZLE SET
11500  RETURN
```

```
19999  REM  TRAVERSE SAVE
20000  PRINT :D$ =  CHR$ (4):FI$ = "VEL DATA." + M$
20100  PRINT D$;"OPEN" + FI$
20110  PRINT D$;"WRITE" + FI$
20120  PRINT ST$: PRINT B1: PRINT B2: PRINT DL: PRINT DB: PRINT
 INT (Z1 * 100 + .5) / 100: PRINT  INT (V(1,0) * 100 + .5) /
100
20130  FOR I = 1 TO B1
20140  FOR J = 1 TO B2
20150  PRINT  INT (V(I,J) * 100 + .5) / 100
20160  NEXT J
20170  NEXT I
20180  PRINT D$;"CLOSE": RETURN
63999 BU =  PEEK (121) + 256 *  PEEK (122) + 286: CALL BU:BU
 =  PEEK (6) + 256 *  PEEK (7): CALL BU + 3: RETURN : REM


==> DO NOT EDIT 63999.

65535  REM
  BUILDUSING (2.0)   APPENDED.

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==> TO REMOVE 'APPENDAGE', ENTER:
]EXEC BU.STRIP

]
```

```
1  REM   *** DEF/ORI PROGRAM V1.1 ***"
2  REM        **CREATES/UPDATES/LISTS INFORMATION IN &.ORI FI
LE
4  REM  *** VERSION 1.1  2/2/83 ***
5  REM
6  GOSUB 63999
7 D$ =  CHR$ (4)
10 F1$ = "YES":F2$ = "YES"
13  DIM JN(15),JS(15),JD(15),JL(15),MZ(15)
20  DIM F$(13),A$(30)
30 NM$ = "--------":SH$ = "CIRC.":SH = 0:EF = 0
100  REM    ** MAIN PROGRAM **
110  GOSUB 1000
120  GOSUB 2000
121  IF R$ = "Q" THEN  GOTO 130
122  GOSUB 2500
123  IF R$ = "Q" THEN  GOTO 135
124  IF R$ = "P" GOTO 120
135  IF F1$ = "YES" THEN  GOSUB 4000
140  IF F2$ = "YES" THEN  GOSUB 5000
145  PRINT "RUN MAIN MENU"
997  REM  PRINT D$;"RUN MAIN MENU"
998  REM  GOTO 110
999  END
1000  REM           ** FORMAT DEFINITION
1010  HOME
1020 P = 1
1030 F$(0) = "       D E F O R I   V1.0"
1040 F$(1) = " 1)  HARD COPY OPTION: &"
1050 F$(2) = " 2)  DISK FILE UPDATE: &"
1055 F$(4) = "     FILE NAME: &"
1060 F$(3) = " 3)  ORIFICE SET NAME : &"
1070 F$(5) = " 4)  DESCRIPTION: "
1080 F$(7) = " 5)  NUMBER IN SET: ##"
1100 F$(8) = "ORIFICE  DIA.(IN) QCAL   JET"
1130 F$(11) = "ORI. DIA.  QCAL   PCAL    TCAL   DPCAL"
1140 F$(12) = "NO.  (IN)  (CFM) (IN HG) (DEG F) (H2O)"
1150 F$(13) = "## ; #.###;  #.####;  ##.##;  ###;  ##.##"
1155  REM        ONERR  GOTO 1170
1160  RETURN
1170  PRINT "ERROR; TO CONTINUE PRESS ANY KEY; ERROR CODE =
"; PEEK (222): INPUT R$: GOTO 120
1400  VTAB 22: PRINT "P)AGE, Q)UIT, OR NUMBER OF ITEM TO ENT
ER/CHANGE: ";
1410  INPUT R$
1420  IF R$ = "Q" THEN  RETURN
1430  IF R$ = "P" THEN P = P + 1: IF P > 2 THEN P = 1: RETURN

1435  IF R$ = "P" THEN  RETURN
1440 A =  VAL (R$): IF A < 1 OR A > 9 THEN  GOTO 1400
1450  RETURN
```

```
2000  REM      ** MAIN MENU
2010 P = 1
2020  HOME : PRINT F$(0) + "-PAGE 1 OF 2"
2030  VTAB 3: CALL BU,R$,F$(1),F1$: PRINT R$
2040  CALL BU,R$,F$(2),F2$: PRINT R$
2050  CALL BU,R$,F$(3),NI$: PRINT R$
2055  CALL BU,R$,F$(4),NM$: PRINT R$
2060  PRINT F$(5) + RM$
2080  CALL BU,R$,F$(7),NS: PRINT R$
2090  GOSUB 1400
2100  IF (R$ = "Q") OR (P = 2) THEN  RETURN
2110  IF A > 5 THEN  GOSUB 1400
2115  IF A = 0 GOTO 2000
2120  ON A GOSUB 2320,2340,2360,2460,2470
2130  GOTO 2020
2320 A = 0: IF F1$ = "YES" THEN F1$ = "NO": RETURN
2325 F1$ = "YES": RETURN
2340 A = 0: IF F2$ = "YES" THEN F2$ = "NO": RETURN
2345 F2$ = "YES": RETURN
2360 A = 0: HOME : PRINT F$(0) + " PAGE 1 OF 2"
2365  VTAB 3: INPUT "KEY IN ORIFICE SET LETTER DESIG: ";Y$
2366  IF Y$ = NI$ THEN  RETURN
2367 NI$ = Y$:NF = 1:NM$ = Y$ + "/ORI": ONERR  GOTO 2440
2368  PRINT Y$: PRINT D$;"OPEN ORI/NAM"
2370  PRINT D$;"READ ORI/NAM"
2371 OK = 0
2372  INPUT TI: IF TI = 0 THEN  PRINT D$;"CLOSE ORI/NAM": PRINT
"TI=0": FOR I = 1 TO 2000: NEXT I: RETURN
2373  DIM N$(TI)
2374  FOR I = 1 TO TI
2376  INPUT N$(I)
2378  IF N$(I) = NI$ THEN OK = 1
2380  NEXT I
2381  PRINT D$;"CLOSE ORI/NAM"
2382  IF OK = 0 THEN  PRINT "OK=0 TI="TI: FOR I = 1 TO 2000:
 NEXT I: RETURN
2385  PRINT "OK=1 TI=";TI: FOR I = 1 TO 2000: NEXT I
2386  REM  RETURN
2388  PRINT D$;"OPEN" + NM$
2389  PRINT D$;"READ" + NM$
2390  INPUT NS
2391  IF NS = 0 GOTO 2450
2395  FOR I = 1 TO NS
2400  INPUT JN(I),JS(I),JD(I),JL(I),JA(I)
2420  NEXT I
2430  GOTO 2450
2440 NF = 0: PRINT "FILE ERROR "; PEEK (222):EF = 1: STOP
2450  PRINT D$;"CLOSE" + NM$: ONERR  GOTO 1170: RETURN
2460  IF A = 0 THEN  RETURN
2461 A = 0: HOME : PRINT F$(0)
2465  VTAB 3: INPUT "ENTER REMARKS/DESCRIPTION: ";RM$: RETURN

2470 A = 0: HOME : PRINT F%(0)
2475  VTAB 3: INPUT "ENTER NO. OF ORIFICES IN SET :";NS: RETURN
```

```
2500  REM     *** MENU PAGE 2
3000  REM
3001 J = 0:HH = 5:SH = 1
3020  HOME : PRINT F$(0) + "-PAGE 2 OF 2"
3030  VTAB 3: PRINT F$(11)
3040  PRINT F$(12)
3050  FOR I = 1 TO NS
3070  CALL BU,R$,F$(13),I,JN(I),JS(I),JD(I),JL(I),JA(I): PRINT
R$
3080  NEXT I
3090  VTAB 21: HTAB 1: PRINT "TO ENTER/CHANGE DATA FOR AN OR
I. ENTER ORI. NO. OR Q)UIT OR P)AGE                ";: VTAB 22:
 HTAB 29: INPUT R$: IF R$ = "Q" OR R$ = "P" THEN  RETURN
3108 J = 0
3110 I =  VAL (R$): IF I < 1 OR I > NS GOTO 3090
3112  VTAB 21: PRINT "TO CHANGE ENTRY AT CURSOR PRESS 'C' -
TO MOVE TO NEXT ENTRY PRESS ANY OTHER KEY     ": HTAB 9
3115  VTAB I + 4: HTAB HH - 1: GET R$: IF R$ <  > "C" GOTO 3
300
3120  VTAB I + 4: HTAB HH - 1:J = J + 1: ON J GOTO 3130,3140
,3150,3160,3170
3130  VTAB I + 4: HTAB HH - 1: INPUT JN(I): VTAB I + 4: CALL
BU,R$,F$(13),I,JN(I),JS(I),JD(I),JL(I),JA(I): PRINT R$;:HH =
HH + 7: GOTO 3115
3140  VTAB I + 4: HTAB HH + 0: INPUT JS(I): VTAB I + 4: CALL
BU,R$,F$(13),I,JN(I),JS(I),JD(I),JL(I),JA(I): PRINT R$;:HH =
HH + 8: GOTO 3115
3150  VTAB I + 4: HTAB HH - 1: INPUT JD(I): VTAB I + 4: CALL
BU,R$,F$(13),I,JN(I),JS(I),JD(I),JL(I),JA(I): PRINT R$;:HH =
HH + 7: GOTO 3115
3152 HH = 9: GOTO 3000
3155  GOTO 3115
3160  VTAB I + 4: HTAB HH - 1: INPUT JL(I): VTAB I + 4: CALL
BU,R$,F$(13),I,JN(I),JS(I),JD(I),JL(I),JA(I): PRINT R$;:HH =
HH + 5: GOTO 3115
3170  VTAB I + 4: HTAB HH - 1: INPUT JA(I): VTAB I + 4: CALL
BU,R$,F$(13),I,JN(I),JS(I),JD(I),JL(I),JA(I): PRINT R$;:HH =
5: GOTO 3000
3300 J = J + 1: ON J GOTO 3310,3320,3330,3340,3350
3310 HH = HH + 7: GOTO 3115
3320 HH = HH + 8: GOTO 3115
3330 HH = HH + 7: GOTO 3115
3340 HH = HH + 5: GOTO 3115
3350 HH = 5: GOTO 3090
3499  STOP
4000  REM    ** HARDCOPY OPTION
4010  PRINT "PRINTED COPY OPTION NOW BEING EXECUTED-TURN PRI
NTER ON AND PRESS ANY KEY": GET R$
4012  PRINT
4015  PRINT D$;"PR#1"
4020  PRINT F$(0)
4040  CALL BU,R$,F$(2),F2$: PRINT R$
4050  CALL BU,R$,F$(3),NI$: PRINT R$
```

```
4055  CALL BU,R$,F$(4),NM$: PRINT R$
4060  PRINT F$(5) + RM$
4080  CALL BU,R$,F$(7),NS: PRINT R$
4090  PRINT : PRINT : PRINT
4110  PRINT F$(11): PRINT F$(12)
4120  FOR I = 1 TO NS
4140  CALL BU,R$,F$(13),I,JN(I),JS(I),JD(I),JL(I),JA(I): PRINT
R$
4150  NEXT I
4160  PRINT D$;"PR#0": RETURN
5000  REM          ** DISK UPDATE
5001  PRINT "": PRINT D$;"OPEN" + NM$: PRINT D$;"CLOSE" + NM
$: PRINT D$;"DELETE" + NM$
5005  REM      ONERR  GOTO 5900
5007  PRINT D$;"OPEN" + NM$
5010  PRINT D$;"WRITE" + NM$
5020  PRINT NS
5030  FOR I = 1 TO NS
5040  PRINT JN(I): PRINT JS(I): PRINT JD(I): PRINT JL(I): PRINT
JA(I)
5045  NEXT I
5090  PRINT D$;"CLOSE" + NM$
5095  PRINT "OK=";OK: INPUT "TO CONT.ENTER Y";R$
5100  IF OK = 1 THEN  RETURN
5105  IF TI = 0 GOTO 5550
5500  PRINT D$;"OPEN ORI/NAM"
5510  PRINT D$;"READ ORI/NAM"
5520  INPUT TI: DIM NI$(TI + 1)
5530  FOR I = 1 TO TI: INPUT NI$(I): NEXT I
5540  PRINT D$;"CLOSE ORI/NAM"
5550 TI = TI + 1:NI$(TI) = NI$
5560  PRINT D$;"OPEN ORI/NAM": PRINT D$;"WRITE ORI/NAM"
5570  PRINT TI
5580  FOR I = 1 TO TI: PRINT NI$(I): NEXT I
5590  PRINT D$;"CLOSE"
5630  RETURN
5900  PRINT "DISK ERROR: "; PEEK (222)
5910  PRINT "CHECK DRIVE, ETC. IF NEEDED PRESS 'CONTROL C' A
ND THEN RESTART DISK SAVE WITH 'RUN 5000'
5920  GOTO 5000
63999 BU =  PEEK (121) + 256 *  PEEK (122) + 286: CALL BU:BU
 =  PEEK (6) + 256 *  PEEK (7): CALL BU + 3: RETURN : REM

==> DO NOT EDIT 63999.

65535  REM
  BUILDUSING (2.0)   APPENDED.

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 SENSIBLE SOFTWARE
==> TO REMOVE 'APPENDAGE', ENTER:
]EXEC BU.STRIP
```

```
1  REM  ISOCORR V 1.0 - AVERAGES DATA AFTER MAKING CORRECTIO
N FOR ISOKINETIC SAMPLING ERROR - USES BELAYEV & LEVIN ALGLR
ITHM - 8/16/84
2  REM     COMPUTES AVERAGES AND CONFIDENCE INTERVALS FOR DM
/DLOGD AND CUM. LOADING. CUM. LOADING OBTAINED BY INTEGRATIO
N OF AVG DMDLOGD AFTER OUTLIER REMOVAL.
3  REM     ORG 2/25/83 JDM - V1.3 4/2/83 - V1.4 2/22/84 - V
2.0 8/17/84
6 D$ =  CHR$ (4):KF = 1800000000:BA = 2:BB = .617
10  HOME
20  DIM X(21),Y(21,20),XP(20),YY(20),DG(20),CP(20)
30  GOSUB 63999
35  GOSUB 1000
40  HOME : PRINT F0$: PRINT : PRINT
50  PRINT "DO YOU WANT THE DATA CORRECTED FOR": INPUT "ISOKI
NETIC SAMPLING ERRORS (Y/N)? ";IC$: IF IC$ <  > "Y" AND IC$ <
 > "N" THEN 40
100  HOME : PRINT "IMPACTOR DATA STATISTICS PROGRAM"
110  GOSUB 2000
115  IF OK = 0 GOTO 140
120  GOSUB 3000
130  GOTO 110
140  GOSUB 4000
150  GOSUB 5000
160  GOSUB 6000
170  GOSUB 7000
180  REM   PRINT D$;"RUN MAIN-MENU"
999  END
1000  REM   ** INITIALIZE"
1001 NP = 20
1005 C1 = .34802:C2 =  - .0958798:C3 = .7478556:D0 = .47047 /
 SQR (2)
1010 N = 0:IO$ = "INLET":I$ = ".IT"
1020 F0$ = " STAT. VER 2.0"
1030 F1$ = "##.#    "
1040 F2$ = "###.##; #.##^^^^;  #.##^^^^;  #.##^^^^"
1050 F3$ = "####.###"
1070  PRINT D$;"OPEN RUN/NAM" + ",D2"
1080  PRINT D$;"READ RUN/NAM"
1090  INPUT NR
1100  DIM RN$(NR)
1110  FOR I = 1 TO NR
1120  INPUT RN$(I)
1130  NEXT I
1140  PRINT D$;"CLOSE RUN/NAM"
1150  DIM F$(20),FM$(10)
1170 FM$(2) = "1) TEST TYPE &; 2) TEST NUMBER ###"
1180 FM$(3) = "3)RUN ## ; &"
1399  RETURN
1400  REM    MENU INSTRUCTIONS
1410  VTAB 23: PRINT "C)AT. OF RUNS, Q)UIT, OR NUMBER OF ITE
```

```
M TO ENTER/CHANGE: ";
1420  INPUT R$
1425  IF R$ = "C" THEN  GOTO 1460
1430  IF R$ = "Q" THEN CK = 0: RETURN
1440 A =  VAL (R$): IF A < 1 OR A > 3 THEN  GOTO 1400
1450  RETURN
1460  HOME : VTAB 3
1465  SPEED= 100
1470  FOR I = 1 TO NR
1480  PRINT RN$(I)
1490  NEXT I
1495  SPEED= 255
1500  VTAB 1: PRINT "THE AVAILABLE RUNS ARE :"
1510  VTAB 23: PRINT "TO CONTINUE PRESS SPACE BAR.": GET R$:
A = 4: RETURN
2000  REM   MENU
2010 P = 1
2020  HOME : PRINT F0$;" - PAGE 1 OF 1"
2030  CALL BU,R$,FM$(2),IO$,TN: PRINT R$
2050  IF N = 20 THEN MX = 20
2060  IF N < 20 THEN MX = N + 1
2065  IF P > 12 THEN P = 12
2070  FOR I = 1 TO MX
2080  CALL BU,R$,FM$(3),I,F$(I): PRINT R$
2100  NEXT I
2105 NI = MX
2110  GOSUB 1400
2115  IF R$ = "Q" THEN OK = 0: RETURN
2120  ON A GOTO 2130,2150,2170,2020
2130  IF IO$ = "INLET" THEN IO$ = "OUTLET":I$ = ".OT": GOTO
2020
2135 IO$ = "INLET":I$ = ".IT": GOTO 2020
2150  VTAB 24: HTAB 19: PRINT "                    ": VTAB 24: HTAB
19: INPUT "TN= ";TN: GOTO 2020
2170  VTAB 24: HTAB 19: PRINT "                 ": VTAB 24: HTAB
19: INPUT "RUN = ";RN$
2175 NM$ = "T" +  STR$ (TN) + "R" + RN$ + I$:OK = 0
2176  FOR I = 1 TO NR
2177  IF NM$ = RN$(I) THEN OK = 1
2178  NEXT I
2179  IF OK = 1 THEN  RETURN
2180  VTAB 24: INVERSE : PRINT " RUN NOT IN CATALOG - TRY AG
AIN ": NORMAL : FOR I = 1 TO 2000: NEXT I: GOTO 2020
3000  REM   READ RUN FILES
3010 CK = 0
3020  PRINT D$;"OPEN" + NM$ + ",D2": PRINT D$;"READ" + NM$
3030  INPUT DT$: INPUT T$: INPUT L$: INPUT RR$: INPUT DB$: INPUT
TC
3040  FOR I = 1 TO NP: INPUT XP(I): INPUT YY(I): INPUT DG(I)
: NEXT I
3041  IF IC$ = "N" THEN 3048
3042  INPUT S
3044  FOR I = 1 TO S: INPUT X: INPUT X: INPUT X: INPUT X: NEXT
I
```

```
3046  INPUT AV: INPUT ND: INPUT IS: INPUT U: INPUT RH
3048  PRINT D$;"CLOSE": IF IC$ = "N" THEN 3050
3049  IF AV <  = 0 OR ND <  = 0 OR IS <  = 0 THEN  PRINT "NO
 VELOCITY OR NOZZLE DIAMETER FOR RUN": PRINT "SPECIFIED - CA
NNOT DO ISOKINETIC ERROR": PRINT "CORRECTION - RUN REJECTED"
: RETURN
3050  IF NI = 1 THEN ZZ$ = DB$: FOR I = 1 TO NP:X(I) = XP(I)
: NEXT I
3060  FOR I = 1 TO NP: IF XP(I) <  > X(I) THEN CK = 1: NEXT
I
3065  IF DB$ <  > ZZ$ THEN CK = 1
3070  IF CK = 1 THEN  VTAB 24: INVERSE : PRINT "LAST RUN WAS
 INCOMPATIBLE IN DIAMETERS": NORMAL : FOR I = 1 TO 2000: NEXT
I: RETURN
3080 X1 = YY(1): IF X1 >  = 0 THEN FL = 1
3090  IF X1 < 0 THEN X1 =  - X1:FL =  - 1
3100 X2 = 1 / (1 + D0 * X1)
3110 X3 = 1 - ((C3 * X2 + C2) * X2 + C1) * X2 *  EXP ( - X1 *
X1 / 2)
3120 Y(0,NI) = TC * (1 + FL * X3) / 2:Y(NP + 1,NI) = TC
3125  IF IC$ = "Y" THEN R = 100 / IS:AV = AV * .508:ND = ND *
2.54
3130  FOR I = 1 TO NP
3132  IF IC$ = "N" THEN Y(I,NI) = DG(I): GOTO 3150
3135 RT = RH * XP(I) * XP(I) / (KF * U)
3140 B = (BA + BB / R) * RT * AV / ND
3145 Y(I,NI) = DG(I) / (1 + (R - 1) * B / (B + 1))
3150  NEXT I
3170  REM   HOME : PRINT NI,Y(0,NI),Y(1,NI),Y(20,NI),TC
3180  REM   FOR I = 1 TO 5000: NEXT I
3190 N = N + 1:CK = 1:F$(NI) = NM$: RETURN
4000  REM   *** NOW DO AVERAGES,STATS ETC.
4004  HOME : PRINT : PRINT "COMPUTING STATISTICS"
4020  DIM TC(10),CI(NP + 1)
4040 TC(2) = 6.314
4050 TC(3) = 2.920
4060 TC(4) = 3.353
4070 TC(5) = 2.132
4080 TC(6) = 2.015
4090 TC(7) = 1.943
4100 TC(8) = 1.895
4110 TC(9) = 1.86
4120  DIM M(NP + 1),S(NP + 1),C(NP + 1)
4125  INPUT "REMOVE OUTLIERS ? (Y/N)";OL$: IF OL$ <  > "Y" AND
OL$ <  > "N" THEN 4125
4130  FOR I = 0 TO NP + 1
4135  PRINT "C";
4140 SX = 0
4150 SS = 0
4160  FOR J = 1 TO N
4170 Z = Y(I,J)
4180 SX = SX + Z
4190 SS = SS + Z * Z
4200  NEXT J
```

```
4210 M(I) = SX / N
4215  IF N = 1 THEN 4230
4220 S(I) =  SQR ( ABS ((SS - SX * SX / N) / (N - 1)))
4230  IF N < 2 THEN C(I) = 3E33: GOTO 4380
4235  IF N = 2 THEN CI(I) = TC(2) * S(I) /  SQR (2): GOTO 43
80
4237  IF OL$ = "N" THEN NN = N: GOTO 4370
4240 SX = 0
4250 SS = 0
4260 NN = 0
4270  IF N < 3 THEN ZZ = 3E33
4274  IF N >  = 3 AND N < 10 THEN ZZ = S(I) * TC(N)
4276  IF N >  = 10 THEN ZZ = S(I) * 1.645
4280  FOR J = 1 TO N
4290 Z = Y(I,J)
4300  IF  ABS (Z - M(I)) > ZZ GOTO 4340
4310 SX = SX + Z
4320 SS = SS + Z * Z
4330 NN = NN + 1
4340  NEXT J
4350 M(I) = SX / NN
4355  IF NN <  = 1 THEN S(I) = O:C(I) = 3E33
4360 S(I) =  SQR ( ABS ((SS - SX * SX / NN) / (NN - 1)))
4370  IF NN >  = 2 AND NN < 10 THEN CI(I) = S(I) * TC(NN) /
 SQR (NN)
4375  IF NN > 10 THEN CI(I) = 1.645 * S(I) /  SQR (NN)
4380  NEXT I
4381  REM      INTEGRATE FOR AVERAGE CUM. USING MODIFIED SIMP
SONS'S RULE - MOD. GIVES VALUES AT EVERY X RATHER THAN ONLY
FOR ALTERNATE X'S
4382 YY(1) = M(0):DG(1) = CI(0) * CI(0)
4384  FOR I = 2 TO NP
4386 YY(I) = YY(I - 1) + 0.2 * (((I -  INT (I / 2) * 2) = 0)
 * (2 * M(I) + M(I - 1)) + ((I -  INT (I / 2) * 2) = 1) * (2
 * M(I - 1) + M(I))) / 3:DG(I) = DG(I - 1) + (CI(I) * CI(I) +
CI(I - 1) * CI(I - 1)) * .01
4388  NEXT I
4389  PRINT
4400  RETURN
5000  REM  *** DISPLAY RESULTS ***
5010  HOME
5012  PRINT ZZ$: PRINT
5015  PRINT "DIA.  MEAN   STD DEV    90%CON.INT."
5020  FOR I = 0 TO NP + 1
5030 K = I - 1
5040  IF K / 10 <  >  INT (K / 10) THEN 5060
5050  PRINT " DIA.   MEAN      STD DEV   90%CON.INT."
5060  REM  IF I <  = NP THEN  CALL BU,R$,F1$,X(I): PRINT R$;

5070  CALL BU,R$,F2$,X(I),M(I),S(I),CI(I): PRINT R$
5071  REM  FIX SO THAT NA IS PRINTED IF CI=3E33
5090  IF I <  > NP AND I / 10 =  INT (I / 10) THEN  PRINT "<
PRESS SPACE BAR FOR MORE>": GET R$
5100  NEXT I
```

```
5105  PRINT "<PRESS SPACE BAR TO CONTINUE>:GET R$
5110  RETURN
6000  REM  *** HARDCOPY ***
6005  PRINT
6010  PRINT "DO YOU WANT HARDCOPY ? (Y / N)": GET R$: IF R$ <
 > "Y" AND R$ <  > "N" THEN  GOTO 6010
6020  IF R$ = "N" THEN  RETURN
6030  PRINT : PRINT "TURN PRINTER ON"
6035  PRINT D$;"PR#1"
6040  PRINT  CHR$ (1) + "80N" +  CHR$ (24)
6045  PRINT  CHR$ (9) + "6L" +  CHR$ (24)
6050 FA$ = "  DIA.   DM/DLOGD  STD DEV   90% CON        CUM L
OAD.  90% CON  CUM%"
6055 FB$ = " MICRON   MG/DNM3                  INT           MG/D
NM3      INT  "
6060 FM$ = " ###.##;  #.##^^^^;  #.##^^^^;  #.##^^^^;        #
.##^^^^;  #.##^^^^  ;##.##"
6065 FP$ = " ###.##;  #.##^^^^;  #.##^^^^;    NA           #.
##^^^^;     NA       ;##.##"
6070  IF IC$ = "Y" THEN  PRINT "****** RESULTS OF STATIS(TIC
S) WITH ISOKINETIC CORRECTIONS ******": GOTO 6075
6072  PRINT "******* RESULTS OF STATIS(TICS) *******"
6075  PRINT
6080  PRINT " RESULTS OF AVERAGES FOR RUNS :": PRINT
6090  FOR I = 1 TO N
6100  PRINT F$(I)
6110  NEXT I
6120  PRINT : PRINT ZZ$: PRINT : PRINT
6130  PRINT FA$: PRINT FB$: PRINT
6140  FOR I = 1 TO NP
6142 CP(I) = 100 * YY(I) / YY(NP): IF CP(I) <  = .005 THEN C
P(I) = 0
6145  IF CI(I) > 1E32 THEN  CALL BU,R$,FP$,X(I),M(I),S(I),YY
(I),CP(I): PRINT R$: GOTO 6160
6150  CALL BU,R$,FM$,X(I),M(I),S(I),CI(I),YY(I), SQR (DG(I))
,CP(I): PRINT R$
6160  NEXT I
6170  PRINT
6180  PRINT "FOR TOTAL MASS: (UNCORRECTED)"
6190  CALL BU,R$,FM$,9999,M(NP + 1),S(I),CI(NP + 1): PRINT R
$
6200  PRINT  CHR$ (12)
6300  PRINT D$;"PR#0"
6400  RETURN
7000  REM  *** DISK SAVE ***
7010  HOME : INPUT " DO YOU WANT TO SAVE THE RESULTS ON DISK
? (Y/N)";R$
7020  IF R$ = "N" THEN  RETURN
7030  IF R$ <  > "Y" GOTO 7010
7040  INPUT "ENTER A FILENAME FOR THE RESULTS :";NM$
7050  PRINT D$;"OPEN" + NM$ + ",D2": PRINT D$;"WRITE" + NM$
7055  PRINT ZZ$
7060  FOR I = 0 TO NP + 1
7065  IF I = NP + 1 THEN  PRINT X(I): PRINT M(I): PRINT S(I)
```

```
: PRINT CI(I): GOTO 7080
7070  PRINT X(I): PRINT M(I): PRINT S(I): PRINT CI(I): PRINT
YY(I): PRINT  SQR (DG(I))
7080  NEXT I
7085  PRINT IO$
7090  PRINT D$;"CLOSE"
7100  RETURN
63999 BU =  PEEK (121) + 256 *  PEEK (122) + 286: CALL BU:BU
 =  PEEK (6) + 256 *  PEEK (7): CALL BU + 3: RETURN : REM


==> DO NOT EDIT 63999.

65535  REM
  BUILDUSING (2.0)   APPENDED.

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==> TO REMOVE 'APPENDAGE', ENTER:
]EXEC BU.STRIP

]
```

UNIT CONVERSION TABLE

English to Metric

1 in	=	25.40 mm = 2.540 cm
1 ft	=	0.3048 m
1 ft^3	=	0.02832 m^3 = 28.32 liters
1 lb	=	453.6 gm
1 grain	=	0.06480 gm
1 lb/ft^3	=	1.602×10^4 gm/m^3
1 gr/ft^3	=	2.288 gm/m^3

Metric to English

1 cm	=	0.3937 in.
1 m	=	3.281 ft
1 m^3	=	35.31 ft^3
1 gm	=	0.002205 lb
1 gm	=	15.43 grains
1 gm/m^3	=	6.243×10^{-5} lb/ft^3
1 gm/m^3	=	0.4370 gr/ft^3

Others

1 m^3	=	10^3 liters = $10^6 cm^3$
1 cm^3	=	1 cc = 10^{-3} liters
1 μm	=	10^{-6}m = 10^4Å
1 lb	=	7,000 grains
1 in. Hg	=	13.6 in. H_2O
R	=	0.08205 liter-atm/mole-K
1 gm/gm-mole	=	1 lb/lb-mole = 1 amu
°R	=	°F + 460
°K	=	°C + 273.2
°C	=	(5/9) (°F − 32)
°F	=	(9/5) °C + 32
1 ft/sec	=	0.6818 miles/hr

Nozzle Sizes

Fractional Inches		Decimal Inches		Decimal mm
1/8	=	.125	=	3.18
3/16	=	.1875	=	4.76
1/4	=	.250	=	6.35
5/16	=	.3125	=	7.94
3/8	=	.375	=	9.53
1/2	=	.500	=	12.70

Normal conditions are 20.0°C, 760 Torr, (68°F, 29.92 in. Hg) on a dry basis.
MMW of Standard Air, dry is 28.95 amu.
The Pitot/coefficient, C_p, for a isolated Type S Pitot Tube may be assigned a baseline value of 0.84 if the geometry of the Pitot meets the dimensional critera given in Method 2.
ΔH@ is defined as the Method 5 orifice pressure differential (in. H_2O) that correlates to 0.75 cfm of dry air at 528°R and 29.92 in. Hg.
$V_A = (P_N/P_A)\ (T_A/T_N)\ V_N$, for absolute temperature.