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

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

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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 \text{ \mu m}) 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 \text{ \mu m}. 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 \text{ \mu m} to 20 \text{ \mu m}. 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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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 \(\mu\)m. 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 \(H_{\text{cup}}\) and \(D_{\text{cup}}\) 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.
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

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

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%,
- $\mu$ = the gas viscosity,
- $N e$ = the number of turns made by the gas stream in the outer spiral,
- $\rho$ = 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 $N e$, 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 $D_{50}'s$:

$$D_{50} = \left[ \frac{18DB_c H_c}{E (1+n)} \left( \frac{\mu}{\rho Q} \right) (1n7) 2n+2 \right]^{1/2}$$

where

- $D$ = the cyclone diameter,
- $E$ = a coefficient which depends solely on the cyclone geometry, and
- $n = 1 - \left[ 1 - \left( \frac{0.394D}{2.5} \left( \frac{T}{283} \right)^{0.3} \right) \right]^{0.14}$

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 $\sqrt{u/\rho}$ 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 -0.63 and -2.13 for several cyclones. Similarly Smith and Wilson (1977) reported values of ranging from -0.63 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

$$N_t = a_0 + a_1 \ln(Re) + a_2 \ln(Stk)$$

where

$N_t$ = the number of transfer units,

$= -\ln$ (penetration)

and

$a_0$, $a_1$, 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:

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

and

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

where

$\rho_p$ = 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),

$u$ = the gas velocity at the cyclone inlet,

$d$ = the particle diameter,

$D$ = the cyclone inlet diameter,

$\mu$ = 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).
\[ \rho_g = \text{the gas density}, \]

\[ Q = \text{the total volumetric flow rate}. \]

Thus the value of \( \text{Stk} \) for a collection efficiency of 50% becomes a function of \( \text{Re} \). Note, \( \text{Stk} \) and \( \text{Re} \) 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

\[ \log \left( \frac{D_{50}}{D_e} \right) = \log K_d + m \log \left( \frac{\text{Re}}{1000} \right) \]

where

\[ D_e = \text{the diameter of the cyclone exit tube}, \]

\[ K_d = \text{a dimensionless constant characterizing each cyclone} \]

and

\[ m = \text{an empirical constant}. \]

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 \( \text{Re} \). 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, CO₂, 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, CO₂, 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, CO₂, 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, CO₂, 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, CO₂, 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:

\[ \ln \sqrt{\text{SEk}_{50}} = C + A \ln(\text{Re}) + B(\ln(\text{Re}))^{1/2} \]

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:

<table>
<thead>
<tr>
<th>Cyclone</th>
<th>A</th>
<th>SE</th>
<th>B</th>
<th>SE</th>
<th>C</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>-0.197</td>
<td>0.054</td>
<td>-</td>
<td>-</td>
<td>0.156</td>
<td>0.408</td>
</tr>
<tr>
<td>II</td>
<td>1.982</td>
<td>0.665</td>
<td>-13.596</td>
<td>3.786</td>
<td>20.894</td>
<td>5.372</td>
</tr>
<tr>
<td>III</td>
<td>4.732</td>
<td>0.604</td>
<td>-29.370</td>
<td>3.422</td>
<td>43.462</td>
<td>4.841</td>
</tr>
<tr>
<td>IV</td>
<td>2.841</td>
<td>0.820</td>
<td>-18.929</td>
<td>4.719</td>
<td>29.494</td>
<td>6.768</td>
</tr>
<tr>
<td>V</td>
<td>-0.472</td>
<td>0.016</td>
<td>-</td>
<td>-</td>
<td>2.707</td>
<td>0.135</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Cyclone</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>-7</td>
<td>+10</td>
</tr>
<tr>
<td>II</td>
<td>-4</td>
<td>+8</td>
</tr>
<tr>
<td>III</td>
<td>-7</td>
<td>+7</td>
</tr>
<tr>
<td>IV</td>
<td>-12</td>
<td>+9</td>
</tr>
<tr>
<td>V</td>
<td>-6</td>
<td>+6</td>
</tr>
</tbody>
</table>

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% isokinetic 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.

4-2
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 frac-
tion 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% CO2, 8% O2, 82% N2 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.
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:

$$D_{50} = \left(\frac{18 \mu D_j \psi_{50}}{Cp_P V_j}\right)^{1/2}$$

(1)

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

$\mu$ = 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.
\[ \psi_{50} = \text{inertial size parameter determined by calibration, dimensionless} \]
\[ = \text{Stk}_{50}/2 \]

\[ C = \text{Cunningham slip correction factor, dimensionless} \]

\[ \rho_p = \text{density of particle, g/c}^3 \]

\[ v_j = \text{mean velocity of gas through the cyclone inlet, cm/sec (calculated using upstream pressure)} \]

The Cunningham correction, \( C \), is given by:
\[ C = 1 + \frac{2 \ell}{D_{50}} \left[ 1.23 + 0.41 \exp \left( \frac{-0.44 D_{50}}{\ell} \right) \right] \tag{2} \]

where \( \ell = \text{mean free path of air molecules in the cyclone (at upstream conditions), cm} \)

The mean free path, \( \ell \), in cm is given by:
\[ \ell = \frac{0.7923H}{P} \sqrt{\frac{T}{M_W}} \tag{3} \]

where \( P = \text{gas pressure, cm Hg,} \)

\( T = \text{gas temperature, °K,} \)

and

\( M_W = \text{wet molecular weight of the gas.} \)

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 \( \text{PM}_{10} \) 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, \( \rho_p \) is set equal to 1.0 g/cm\(^3\) and equation 1 becomes:
\[ D_{50} = \left( \frac{18 \psi_{50} D_i}{C v_j} \right)^{1/2} \tag{4} \]

The values of \( \psi_{50} \) 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.
\[ \ln \left( \sqrt{\frac{\psi}{S_{50}}} \right) = A \ln(\text{Re}) + B \left( \ln(\text{Re}) \right)^{1/2} + C \]  

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

<table>
<thead>
<tr>
<th>Cyclone</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>-0.197</td>
<td>0.0</td>
<td>-0.191</td>
</tr>
<tr>
<td>II</td>
<td>1.982</td>
<td>-13.596</td>
<td>20.547</td>
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<td>III</td>
<td>4.732</td>
<td>-29.370</td>
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<tr>
<td>IV</td>
<td>2.841</td>
<td>-18.929</td>
<td>29.147</td>
</tr>
<tr>
<td>V</td>
<td>-0.472</td>
<td>0.0</td>
<td>2.360</td>
</tr>
</tbody>
</table>

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 \( \mu \text{m} \) or larger should be used for uncontrolled sources and a value of about 20 \( \mu \text{m} \) to 100 \( \mu \text{m} \) 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 \( D + \Delta D \) can be represented by \( dM \). Then the integral

\[
\int_{D_1}^{D_2} \frac{dM}{dD} \, dD
\]

(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 \( \Delta M_n \) and is, in approximation, the mass of particulate matter with particle diameters between \( (D_{50})_n \) and \( (D_{50})_{n+1} \). The \( \Delta (\log D) \) associated with \( \Delta M_n \) is \( \Delta(\log D_{50})_n - \Delta(\log D_{50})_{n+1} \). Using these approximations, the derivative term associated with the stage "n" is:

\[
\frac{dM}{d(\log D)_n} = \frac{\Delta M_n}{\Delta(\log D_{50})_n} = \frac{\text{mass on stage "n"}}{\log (D_{50})_{n-1} - \log (D_{50})_n}
\]

(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:

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

(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 \( \Delta(\log D_{50}) \) terms would approach \( d(\log D) \), and the mass between \( D_m \) and \( D_n \) could be calculated as

\[
\text{Mass} = \int_{D_m}^{D_n} \frac{dM}{d(\log D)} \, d(\log D)
\]

(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.

7-6
Figure 21. $\Delta M / \Delta \log D$ 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 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.
The value of the ordinate at a given $D_{50}$ would be:

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

where

- $i = 0$ 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 $\sigma_g$, 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:

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

(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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cyclone Type</td>
<td>SoRI Five-Stage Sampler</td>
</tr>
<tr>
<td>Stack Temperature</td>
<td>148.9°C (300°F)</td>
</tr>
<tr>
<td>Cyclone Temperature</td>
<td>148.9°C (300°F)</td>
</tr>
<tr>
<td>Stack Pressure</td>
<td>75.3cm Hg (29.6 in.Hg)</td>
</tr>
<tr>
<td>Sampler Flow rate</td>
<td>14.5 l/min (0.51 ft³/min)</td>
</tr>
<tr>
<td>Sampling Duration</td>
<td>120 minutes</td>
</tr>
<tr>
<td>Gas Composition (wet)</td>
<td>0.21% CO₂, 0.03% CO, 76.08% N₂, 18.78% O₂, 4.90% H₂O</td>
</tr>
<tr>
<td>Assumed Particle Density</td>
<td>1.0 g/cm³</td>
</tr>
<tr>
<td>Maximum Particle Diameter</td>
<td>100μm</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Stage</th>
<th>Mass*, mg</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3.32</td>
</tr>
<tr>
<td>2</td>
<td>5.05</td>
</tr>
<tr>
<td>3</td>
<td>1.81</td>
</tr>
<tr>
<td>4</td>
<td>1.10</td>
</tr>
<tr>
<td>5</td>
<td>0.30</td>
</tr>
<tr>
<td>Filter</td>
<td>1.28</td>
</tr>
</tbody>
</table>

* 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

<table>
<thead>
<tr>
<th>RUN CODE</th>
<th>TGR DEMO</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONTROL BOX ID</td>
<td>RAC #1</td>
</tr>
<tr>
<td>GAS METER ID</td>
<td>RAC #1</td>
</tr>
<tr>
<td>GAS METER START</td>
<td>21.45 ft³</td>
</tr>
<tr>
<td>GAS METER FINISH</td>
<td>64.45 ft³</td>
</tr>
<tr>
<td>Orifice ID</td>
<td>0.01200 s</td>
</tr>
<tr>
<td>Date</td>
<td>4/20/79</td>
</tr>
<tr>
<td>Start Time</td>
<td>0900</td>
</tr>
<tr>
<td>End Time</td>
<td>110</td>
</tr>
<tr>
<td>Differential Stack Pressure</td>
<td>0.0 (in. H₂O)</td>
</tr>
<tr>
<td>Ambient Pressure (Barometer)</td>
<td>29.6 (in. Hg)</td>
</tr>
<tr>
<td>Ambient Temperature</td>
<td>74 (°F)</td>
</tr>
<tr>
<td>Sampling Duration</td>
<td>120 (min)</td>
</tr>
<tr>
<td>Inlet/Outlet</td>
<td>Other</td>
</tr>
<tr>
<td>Note: Release Vacuum at Nozzle To Avoid Rupturing Filter. Pass ≤ 0.02 ft³ For A or B or C Visual Check of Nozzle √ O.K.</td>
<td></td>
</tr>
</tbody>
</table>

### TARGET CH

<table>
<thead>
<tr>
<th>RUN TIME (MIN)</th>
<th>PORT NO.</th>
<th>TRAVEL POINT</th>
<th>GAS METER READING</th>
<th>GAS METER TEMP</th>
<th>FLUE GAS TEMP</th>
<th>ORIFICE CH</th>
<th>PUMP VACUUM</th>
<th>PROBE TEMP</th>
<th>TOTAL VOLUME</th>
<th>H₂O</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre 1</td>
<td>1</td>
<td>21.45</td>
<td>74</td>
<td>300</td>
<td>280 ft³</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>25.06</td>
<td>74</td>
<td>300</td>
<td>0.44</td>
<td>2</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>28.6</td>
<td>74</td>
<td>301</td>
<td>0.44</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>32.15</td>
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<td>301</td>
<td>0.44</td>
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<td></td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>35.86</td>
<td>74</td>
<td>298</td>
<td>0.44</td>
<td>2.5</td>
<td>280 ft³</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>39.3</td>
<td>74</td>
<td>300</td>
<td>0.44</td>
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</tr>
<tr>
<td>6</td>
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<td>43.0</td>
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<td>302</td>
<td>0.44</td>
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<td></td>
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<td>7</td>
<td>3</td>
<td>46.0</td>
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<td>300</td>
<td>0.44</td>
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<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>8</td>
<td>3</td>
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<td>298</td>
<td>0.44</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
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<td>53.8</td>
<td>74</td>
<td>300</td>
<td>0.44</td>
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<td></td>
<td></td>
<td>4.7</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>4</td>
<td>57.4</td>
<td>74</td>
<td>299</td>
<td>0.44</td>
<td>4.7</td>
<td>2.75 ft³</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>4</td>
<td>61.0</td>
<td>74</td>
<td>300</td>
<td>0.44</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>4</td>
<td>64.45</td>
<td>74</td>
<td>301</td>
<td>0.44</td>
<td>7.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Notes and Observations:**
- **CO₂ = 0.22 %**
- **CO = 0.032 %**
- **O₂ = 19.75 %**

**Sampling Location:** inlet / outlet

**In the space below give the unit, chamber, duct pantleg, etc. where the sampler was run.**

### STACK

**Port Numbers:** 1 thru 4

**Sampler Orientation (Circle One):** horizontal

**Top Entry Vertical, W/ Turn Around, etc.**

**Bottom Entry Vertical, O: 0.1875 Inch Nozzle, Velocity = 50 FPS**

### Operators

<table>
<thead>
<tr>
<th>Operator</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
<td>L.G.K</td>
<td>W.B.D</td>
</tr>
</tbody>
</table>
The gas viscosity, \( \mu \), 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:

\[
\mu = \sum_{i=1}^{5} \frac{\mu_i}{1 + \frac{1}{f_{i,j}} \sum_{j=1}^{5} (f_{j} \phi_{ij})} \times 10^{-6} \tag{12}
\]

where

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

\( \mu_{1-5} \) = pure gas viscosity, micropoises

\( \mu_1 \) = gas viscosity of \( \text{CO}_2 \)

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

\( \mu_2 \) = gas viscosity of \( \text{CO} \)

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

\( \mu_3 \) = gas viscosity of \( \text{N}_2 \)

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

\( \mu_4 \) = gas viscosity of \( \text{O}_2 \)

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

\( \mu_5 \) = gas viscosity of \( \text{H}_2\text{O} \)

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

where

\( T_{\text{CI}} \) = temperature, °C

\( f_{1-5} \) = wet gas fractions of \( \text{CO}_2, \text{CO}, \text{N}_2, \text{O}_2, \) and \( \text{H}_2\text{O} \), respectively

\( w_{1-5} \) = molecular weights of \( \text{CO}_2, \text{CO}, \text{N}_2, \text{O}_2, \) and \( \text{H}_2\text{O} \), respectively
For CO₂

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

\[ \mu_1 = 207.2 \text{ micropoises} \]

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:

\[ w_1 = 44.10 \text{ (CO₂)} \]
\[ w_2 = 28.01 \text{ (CO)} \]
\[ w_3 = 28.02 \text{ (N₂)} \]
\[ w_4 = 32.00 \text{ (O₂)} \]
\[ w_5 = 18.02 \text{ (H₂O)} \]

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:

\[ \rho = \rho_{\text{std}} \left( \frac{\text{MW}}{\text{MA}} \right) \left( \frac{P_3}{P_{\text{std}}} \right) \left( \frac{273}{273+T_{\text{I}}} \right) \]

(19)

where

\[ \rho_{\text{std}} = 1.29 \times 10^{-3} \text{ g/cm}^3 \]

\[ \text{MW} = \text{wet molecular weight of flue gas} \]
\[ = (0.0021 \times 44) + (0.0003 + .7608) \times 28 \]
\[ + (0.1878 \times 32) + (0.049 \times 18) \]
\[ = 28.29 \]

\[ \text{MA} = 28.97 \]

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

and \[ P_{\text{std}} = 76.0 \text{ cm Hg} \]

Thus for Cyclone 3:

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

\[ = 0.807 \times 10^{-3} \text{ g/cm}^3 \]

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:

\[ \Delta P = \frac{1}{2} \rho_g \left( \frac{v}{c_d} \right)^2 \text{ dynes/cm}^2 = 3.75 \times 10^{-5} \rho_g \left( \frac{v}{c_d} \right)^2 \text{ cm Hg.} \]

(20)
where
\[ \rho_g = \text{gas density at orifice inlet, g/cm}^3 \]
\[ u_i = \text{plug flow gas velocity, cm/s} \]
and \[ c_d = \text{coefficient of discharge, dimensionless} \]

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

\[ \Delta P = 1.008 \times 10^{-4} \rho_g u^2 \text{ cm Hg.} \]

\[ \quad \text{and} \ u = \frac{4Q}{\pi D_{i,o}^2} \]

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:

\[ Q = Q_{\text{inlet}} \times \frac{P_s}{P} \]

where \( Q_{\text{inlet}} \) = cyclone flow at stack conditions, cm\(^3\)/s
\( P_s \) = absolute gas pressure in the stack
\( P \) = gas pressure at the inlet to the part of the cyclone being considered
\[ = P_s - (\text{sum of the } \Delta P_s \text{ of the preceding cyclone inlets and outlets}) \]

Thus \( \Delta P_{31} = 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 \]
\[ = 0.024 \text{ cm Hg.} \]

and \( \Delta P_{30} = 1.008 \times 10^{-4} \times (0.807 \times 10^{-3}) \times \left( \frac{4 \times 241 \times 75.3}{\pi \times 0.8325 \times 0.8325} \right)^2 \]
\[ = 0.016 \text{ cm Hg.} \]

or \( \Delta P_3 = 0.024 + 0.016 \text{ cm Hg.} = 0.04 \text{ cm Hg.} \)

The Reynolds number is given by:

\[ Re = \frac{4\rho Q}{\pi \mu D} \]

where for Cyclone 3
\[ Q = 0.51 \text{ acfm} = 241 \text{ cm}^3/s \]
\[ D_3 = 0.75 \text{ cm} \]

Therefore
\[ Re_3 = \frac{4\times0.807\times10^{-3}\times241}{\pi\times230\times10^{-6}\times0.75} = 1440 \]
and
\[
(\ln \sqrt{\psi_5})_3 = A_3 (\ln \text{Re}_3) + B_3 (\ln \text{Re}_3)^{1/2} + C_3 \\
= 4.733 (\ln 1410) - 29.374 (\ln 1410)^{1/2} + 43.121 \\
= -1.673
\]

Thus for this run
\[
(\sqrt{\psi_5})_3 = 0.1877
\]

and
\[
(\psi_5)_3 = 0.0352
\]

Now
\[
D_{50}^2 = \left( \frac{18 \mu \psi_5}{C \rho \nu} \right)^{1/2}
\]

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

When
\[
D_{50}/\lambda > 2.7 \text{ the exponential term can be neglected so }
\]

\[
C = 1 + \frac{2.46 \lambda}{D_{50}}
\]

The mean free path, \( \lambda \), is given by the expression:
\[
\lambda = \frac{0.7923 \mu}{\sqrt{T/MW}}
\]

where
\[
\mu = \text{viscosity in poise} \\
T = \text{temperature in } ^\circ \text{K} \\
MW = \text{wet molecular weight of the flue gas} \\
\rho = \text{pressure in cm Hg.}
\]

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
\[
\lambda_3 = \frac{0.7775 \times 230 \times 10^{-6}}{75.3} \sqrt{(273+150)/28.3} \\
= 9.36 \times 10^{-6} \text{ cm} = 0.094 \mu \text{m}
\]

\[
D_{50}^2 = \frac{18 \mu D_{in} \psi_5}{C \rho \nu} \\
= \frac{18 \mu D_{in} \psi_5}{(1 + \frac{2.46 \lambda}{D_{50}}) \rho \nu} \text{ for } \frac{D_{50}}{\lambda} > 2.7
\]

7-17
or
\[ D_{50}^2 + 2.46\xi D_{50} - \left( \frac{18\mu D_{in}\psi_{50}}{\rho_p v_{in}} \right) = 0 \]

Therefore
\[ D_{50} = \left[ \frac{1}{2} \right] \left( -2.46\xi + \left[ (0.46\xi)^2 + 4\left( 18\mu D_{in} \psi_{50} / (\rho_p v_{in}) \right) \right]^{1/2} \right) \]
\[ = -1.23\xi + \left[ 1.513\xi^2 + (18\mu D_{in} \psi_{50}) / (\rho_p v_{in}) \right]^{1/2} \quad (28) \]

The inlet velocity for a cyclone is given by
\[ v_{in} = \left[ \frac{4Q}{\pi(D_{in})^2} \right] \left( \frac{\rho}{\rho_3} \right) \quad (29) \]

So for Cyclone 3
\[ v_{in} = \frac{4 \times 241}{\pi (0.75)^2} = 545 \text{ cm/s} \]

Therefore for Cyclone 3
\[ D_{50} = -1.15 \times 10^{-5} + \left( 1.513 \times 8.76 \times 10^{-11} + \frac{18 \times 230 \times 10^{-6} \times 0.75 \times 0.0352}{1 \times 545} \right)^{1/2} \]
\[ = -1.15 \times 10^{-5} + \left( 1.325 \times 10^{-10} + 2.005 \times 10^{-7} \right)^{1/2} \]
\[ = -1.15 \times 10^{-5} + (2.006 \times 10^{-7})^{1/2} \]
\[ = -1.15 \times 10^{-5} + 4.47 \times 10^{-4} \text{ cm} \]
\[ = 4.35 \times 10^{-4} \text{ cm} = 4.3 \mu m \]

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

| Stage 1 | \( D_{50} = 11.7 \mu m \) |
| Stage 2 | \( D_{50} = 7.7 \mu m \) |
| Stage 3 | \( D_{50} = 4.3 \mu m \) |
| Stage 4 | \( D_{50} = 2.9 \mu m \) |
| Stage 5 | \( D_{50} = 1.2 \mu m \) |
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, $M_{A_j}$. The mass loading, $M_L$, is calculated from the total gas volume sampled, $Q_t$, and the total mass, $M$, of the particles collected:

$$M_L = \frac{M}{Q_t} \quad (30)$$

where

$$M = \sum_{j} M_{A_j} \quad (31)$$

where

- $j = \text{stage 1, stage 2, stage 3, ... stage n, backup filter}$,
- $N = \text{number of stages in sampler}$.

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

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

The preferred units of $M_L$ are milligrams per cubic meter of gas at dry normal conditions (mg/DNm³). Normal conditions are defined as 20°C and 760mm Hg (Torr). In addition, the mass loading may be given in mg/am³ (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,

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

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

\[
\text{CUM} \ %_j = \frac{\sum_{i=j+1}^{N+1} \text{MA}_i}{M_t} \times 100\%
\]

(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:

\[
\text{CUM} \ (\text{DN})_j = \frac{\sum_{i=j+1}^{N+1} \text{MA}_i}{Q_t} \times \frac{T_S}{P_S} \frac{(760 \text{ mm Hg})}{(293^\circ \text{K})} \times \frac{1}{(1 - f_{H_2O})}
\]

(33)

where:

- \( T_S \) = stack temperature, \(^\circ\)K,
- \( P_S \) = stack pressure, \( \text{mm Hg} \),
- \( f_{H_2O} \) = 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:

\[
\text{CUM} \ (\text{A})_j = \frac{\sum_{i=j+1}^{N+1} \text{MA}_i}{Q_t}
\]

(34)

For stage 3:

\[
\text{CUM} \ (\text{A})_3 = \frac{2.68 \text{ mg}}{(14.5 \times 10^{-3} \text{ m}^3/\text{min}) \times (120 \text{ min})} = 1.57 \text{ mg/am}^3
\]

The cumulative concentration for Stage 3 at dry normal conditions, \( \text{CUM(DN)} \), is then:
\[ CUM (DN)_3 = 1.57 \text{ mg/am}^3 \times \frac{(148.9+273^*K)(760\text{ mm Hg})}{(753\text{ mm Hg})(293^*K)} \times \frac{1}{1-0.049} \]

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

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 \(\Delta M_j\) and is calculated by dividing the mass collected on each stage by the total volume of gas (at normal conditions) sampled.

\[ \Delta M_j = \frac{M_{A_j}}{Q t} \times \frac{T_s (760\text{ mm Hg})}{P_s (293^*K)} \times \frac{1}{(1-f_{H_2O})} \] (35)

For stage 3:

\[ \Delta M_3 = \frac{1.81 \text{ mg}}{(14.5\times10^{-3}\text{ m}^3/\text{min}) \times 120 \text{ min}} \times 1.53 \]

\[ \Delta M_3 = 1.59 \text{ mg/DNm}^3 \]

Now \(\Delta \log D\) is defined as:

\[ (\Delta \log D)_j = \log_{10} (D_{50j-1}) - \log_{10} (D_{50j}) \] (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 \(\mu m:\)

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

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:

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

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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\textsubscript{j}, for the corresponding stage \text{j}.

\[
\text{GMD}_j = \sqrt{D_{50j} \times D_{50j-1}}
\]

For stage 3:

\[
\text{GMD}_3 = \sqrt{D_{503} \times D_{502}} = \sqrt{4.3 \times 7.7} = 5.8 \ \mu m.
\]

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 \(\mu m\)):

\[
\text{GMD}_1 = \sqrt{100 \times 100} = 34.2 \ \mu m
\]

and for the backup filter:

\[
\text{GMD}_{N+1} = \sqrt{\left(\frac{D_{50N}}{2}\right) \times D_{50N}} = \left(\frac{D_{50N}}{\sqrt{2}}\right) = 0.85
\]

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 \(\Delta M_j\) is the mass per unit volume for stage \(j\) then we can define \(\Delta N_j\) as the number of particles per unit volume for stage \(j\). Now \(\Delta M_j\) and \(\Delta N_j\) 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:

\[
\frac{(\Delta M/\Delta \log D)_j}{M_p} = \frac{\Delta N}{\Delta \log D_j}
\]

Now \(M_p = \rho_p V_p\) where \(\rho_p\) is the assumed density of the particle and \(V_p\) is the average volume of one particle on one stage.
\[ M_p = \frac{\pi \rho_p (GMD)_j^3}{6} \]  

Therefore:

\[ (\Delta N/\Delta \log D)_j = 6 (\Delta M/\Delta \log D)_j/\pi \rho_p (GMD)_j^3 \]  

For cyclone 3:

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

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

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>
<thead>
<tr>
<th>STAGE</th>
<th>$D_{50}$ (micrometers)</th>
<th>CUM% (Percent)</th>
<th>CUM(A) (mg/m³)</th>
<th>CUM(DN) (mg/m³)</th>
<th>ΔM (mg/m³)</th>
<th>ΔLogD</th>
<th>ΔM/ΔLogD (mg/m³)</th>
<th>GMD (micrometers)</th>
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<tr>
<td>1</td>
<td>11.4</td>
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<td>8.56</td>
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<td>2</td>
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<td>34.9</td>
<td>2.63</td>
<td>4.02</td>
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<td>25.2</td>
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<td>.25</td>
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<td>3.8</td>
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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 D₅₀'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 D₅₀'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 D₅₀ 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 SoRT 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:
\[ \frac{[X_i - X_m]}{S} > C_n \]  \hspace{1cm} (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 propagated 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


Appendix

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

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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 \( \sqrt[50]{S} \) 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 auxiliary programs, as shown below:

```
MAIN MENU

TO SELECT OPTION ENTER APPROPRIATE NUMBER

1) ORSAT
2) METHOD 4 (H2O)
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 auxiliary 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 logarithmic 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, ΔH0, 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 CYCPREG 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 METH 3).

After entering all the new Orsat data, press the letter "S" (for Save). The input data will be saved for use in CYCPREG, 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 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
DS$ - DOS command flag
EX - percent excess air
F$( - print format statements
FL$ - hardcopy flag
F2$ - disk update flag
FM$ - print format
MW - molecular weight
MW$ - input error message
N2 - percent nitrogen
O2 - percent oxygen
RS$ - 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 CYCROG 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.H2O)
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 an irrecoverable loss of the program. The subroutine is copywritten and permission has been granted by the copywrite owner for its use here.

Description of Variables

A  - menu selection dummy
A$  - input dummy
EU  - print formatter address
BW  - fraction moisture
D$  - DOS command flag
FS($ - print format statements
FL$  - hardcopy flag
F2$  - disk update flag
FM$  - print format
MP  - 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 \( \sqrt{V_{50}} \) 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 $\sqrt{\nu_{50}}$ from the Reynolds number.

<table>
<thead>
<tr>
<th>STAGE NO.</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>INLET DIA.</th>
<th>EXIT DIA.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.000</td>
<td>0.00</td>
</tr>
<tr>
<td>2</td>
<td>0.000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.000</td>
<td>0.00</td>
</tr>
<tr>
<td>3</td>
<td>0.000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.000</td>
<td>0.00</td>
</tr>
<tr>
<td>4</td>
<td>0.000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.000</td>
<td>0.00</td>
</tr>
<tr>
<td>5</td>
<td>0.000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.000</td>
<td>0.00</td>
</tr>
</tbody>
</table>

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 user's 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
DS - 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( - $\sqrt[3]{u_{50}}$ constant, A
JL( - outlet diameter
JN( - $\sqrt{u_{50}}$ constant, B
JS( - $\sqrt[3]{u_{50}}$ constant, C
N$( - names of sets on file
N1$ - 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
RS$ - set description
SH - set type flag
S# - 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

<table>
<thead>
<tr>
<th>CYC NO.</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>IN DIA.</th>
<th>OUT DIA.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>.304</td>
<td>-2.767</td>
<td>3.620</td>
<td>1.2700</td>
<td>1.5000</td>
</tr>
<tr>
<td>2</td>
<td>1.982</td>
<td>-13.60</td>
<td>20.550</td>
<td>1.0000</td>
<td>1.0500</td>
</tr>
<tr>
<td>3</td>
<td>4.733</td>
<td>-29.37</td>
<td>43.121</td>
<td>.7500</td>
<td>.8330</td>
</tr>
<tr>
<td>4</td>
<td>2.841</td>
<td>-18.93</td>
<td>29.150</td>
<td>.5100</td>
<td>.5940</td>
</tr>
<tr>
<td>5</td>
<td>-.033</td>
<td>-2.475</td>
<td>5.833</td>
<td>.3050</td>
<td>.3560</td>
</tr>
</tbody>
</table>
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 available 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:

<table>
<thead>
<tr>
<th>CYCPROG V3.1 - Page 1 of 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>2) Date of Test:</td>
</tr>
<tr>
<td>3) Time of Test:</td>
</tr>
<tr>
<td>4) Location of Test:</td>
</tr>
<tr>
<td>5) Test Number</td>
</tr>
<tr>
<td>6) Test Type</td>
</tr>
<tr>
<td>7) Run Number:</td>
</tr>
<tr>
<td>8) Run Remarks:</td>
</tr>
<tr>
<td>9) Water Vapor</td>
</tr>
<tr>
<td>CO2 00.00%</td>
</tr>
<tr>
<td>O2 0.00%</td>
</tr>
<tr>
<td>10) Sampler Type:</td>
</tr>
<tr>
<td>11) Particle Density</td>
</tr>
<tr>
<td>12) Orifice ID (optional):</td>
</tr>
</tbody>
</table>

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:

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>GAS METER VOL</td>
<td>.000 CUBIC FEET</td>
</tr>
<tr>
<td>2</td>
<td>IMPACTOR DELTA P</td>
<td>.00 IN. HG.</td>
</tr>
<tr>
<td>3</td>
<td>ORIFICE DELTA P</td>
<td>.00 INCHES H2O</td>
</tr>
<tr>
<td>4</td>
<td>STACK PRESSURE</td>
<td>.00 INCHES H2O</td>
</tr>
<tr>
<td>5</td>
<td>BAROMETRIC PRES</td>
<td>.00 INCHES HG</td>
</tr>
<tr>
<td>6</td>
<td>STACK TEMP</td>
<td>0 DEGREES F</td>
</tr>
<tr>
<td>7</td>
<td>METER TEMP</td>
<td>0 DEGREES F</td>
</tr>
<tr>
<td>8</td>
<td>IMPACTOR TEMP</td>
<td>0 DEGREES F</td>
</tr>
<tr>
<td>9</td>
<td>SAMPLE TIME</td>
<td>.00 MINUTES</td>
</tr>
<tr>
<td>10</td>
<td>AVG GAS VEL</td>
<td>.00 FEET/SEC</td>
</tr>
<tr>
<td>11</td>
<td>ORIFICE PRESS</td>
<td>.00 INCHES HG</td>
</tr>
<tr>
<td>12</td>
<td>NOZZLE DIA</td>
<td>.000 INCHES</td>
</tr>
<tr>
<td>13</td>
<td>MAX PART DIA</td>
<td>60.00 MICRONS</td>
</tr>
<tr>
<td>14</td>
<td>VOL of CONDENSED WATER</td>
<td>.00 CC</td>
</tr>
<tr>
<td>15</td>
<td>METER CORR FACTOR</td>
<td>1.00</td>
</tr>
</tbody>
</table>

ENTER: QUIT, PAGE, 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:

<table>
<thead>
<tr>
<th>Cyclone Version 3.1</th>
<th>Page 3 of 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>MASS GAIN OF STAGE 1</td>
<td>.00 MG</td>
</tr>
<tr>
<td>MASS GAIN OF STAGE 2</td>
<td>.00 MG</td>
</tr>
<tr>
<td>MASS GAIN OF STAGE 3</td>
<td>.00 MG</td>
</tr>
<tr>
<td>MASS GAIN OF STAGE 4</td>
<td>.00 MG</td>
</tr>
<tr>
<td>MASS GAIN OF STAGE 5</td>
<td>.00 MG</td>
</tr>
<tr>
<td>MASS GAIN ON FILTER 6</td>
<td>.00 MG</td>
</tr>
<tr>
<td>MASS GAIN OF 8 BLANK SUBST.</td>
<td>.00 MG</td>
</tr>
<tr>
<td>MASS GAIN OF 9 BLANK FILTER</td>
<td>.00 MG</td>
</tr>
</tbody>
</table>

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
CO-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
CN - 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
FS - format strings
FS( - format strings
F1 - 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
F1 - number of reduced data sets stored on disk
F1$ - 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( - 1st differences for spline fit
H1, 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
IS - test type
IM$ - cyclone type
IN$ - cyclone comments
IS - percent isokinetic
J - loop index
JD( - inlet and outlet diameters
JK(- - $\sqrt[8]{\psi_{10}}$ constant, A
JN( - $\sqrt[8]{\psi_{10}}$ constant, B
JS(- - $\sqrt[8]{\psi_{50}}$ constant, C
K - loop index & counter
L - mean free path
LS - 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
O2 - 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)
QQ - 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
RNS - run designation
RO$ - orifice ID
RR$ - run remarks
S - number of cyclone stages in set, does not include the backup filter
SL - used in spline interpolation
S2(, S3( - used in spline fit
SC - weight gain of blank stage
SH - sampler type flag
S/( - values of $\sqrt{50}$ for each stage
SP - standard barometric pressure
SU - used in viscosity calculation
T - gas temperature, deg. C
TS$ - time at which run was made
TC - total mass concentration
TD - duration of sample
TI - sampler temperature
TJ - 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 estimator for spline fit
WA - volume of condensed water
X - dummy for file input
XS$ - input dummy
X( - array of log(D50)'s
X0 - maximum particle diameter
XL-X3 - used in spline interpolation and as dummies
X4 - sum of stage weight gains
XP( - array of standard diameters
XXS$ - 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
1) PART. DIAMETER: CLASSICAL AERODYNAMIC
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
9) SAMPLER TYPE: SORI5 SORI 5 CYC'S (NEW #4) WITH WEF'S CONSTANTS
10) PARTICLE DENSITY: 1.00 GRAMS/CC

9a) 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: .100 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 %
VISCOITY 229.8E-06G/CM SEC
CALCULATED SAMPLER DELTA P = .64 IN. HG

<table>
<thead>
<tr>
<th>STAGE</th>
<th>CUNN.</th>
<th>DP</th>
<th>DP</th>
<th>CUM.</th>
<th>INLET</th>
<th>SQRT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CORR. DP&lt;CLAS AERO&gt;(IMP AERO)</td>
<td>FREQ.</td>
<td>RE</td>
<td>PSI50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1.822</td>
<td>11.401</td>
<td>11.524</td>
<td>74.1835</td>
<td>852</td>
<td>.220</td>
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<tr>
<td>2</td>
<td>1.832</td>
<td>7.688</td>
<td>7.803</td>
<td>34.9145</td>
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<td>.213</td>
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<tr>
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</tr>
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<td>4</td>
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<td>12.2862</td>
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<td>.227</td>
</tr>
<tr>
<td>5</td>
<td>1.204</td>
<td>1.239</td>
<td>1.360</td>
<td>9.9533</td>
<td>3548</td>
<td>.220</td>
</tr>
</tbody>
</table>

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

SPLINE FIT ON CLASSICAL AERODYNAMIC DIAMETER BASIS

PARTICLE DIA. CUMFR CUMFR CUM.MASS DM/DLOGD (MICRONS) (STDDEV) (PERCENT) (MG/DRY N.CU.METER)

| .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 | 1.29E+00 | 6.90E-01 |
| 2.512 | - 1.2534 | 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-15 |
| 63.100| 9.4839   | 100.00| 1.13E+01 | 2.41E+19 |
| 100.00| 12.1785  | 100.00| 1.13E+01 | 3.09E-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

PLOT3 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 logarithmic scale as the abscissa 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 abscissa 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 "Graffiti" card, or a similar "smart" interface card that provides onboard graphics dump software and uses the same commands as do the "Grappler" and "Graffiti" 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 \( \frac{dM}{d\log D} \) 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( - \( \frac{dM}{d\log D} \)
- DL - sorting dummy
- DTP$ - date
- FL - flag used in normal transforms
- I - loop index
- LS - 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
- PS - screen dump command string
- RS - 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 \( \frac{dM}{d\log D} \)
- YM - minimum \( \frac{dM}{d\log D} \)
- YY( - cumulative percents at standard diameters in probability units

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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)
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
MMS$ - 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
RNS$ - 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.
<table>
<thead>
<tr>
<th>IMPACTOR OP &amp; VELOCITY PROGRAM</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) TEST CODE (xxxxi)</td>
</tr>
<tr>
<td>2) NUMBER OF PORTS</td>
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<tr>
<td>3) NUMBER OF POINTS PER PORT</td>
</tr>
<tr>
<td>4) DATE</td>
</tr>
<tr>
<td>5) % O2</td>
</tr>
<tr>
<td>6) % CO2</td>
</tr>
<tr>
<td>7) % H2O</td>
</tr>
<tr>
<td>8) AMBIENT PRESSURE</td>
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<tr>
<td>9) DELTA P STACK</td>
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<tr>
<td>A) AMBIENT TEMP</td>
</tr>
<tr>
<td>B) STACK TYPE</td>
</tr>
<tr>
<td>D) DUCT LENGTH</td>
</tr>
<tr>
<td>E) DUCT DEPTH</td>
</tr>
</tbody>
</table>

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 each 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.

<table>
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<tr>
<th>POINT #</th>
<th>Vp(H2O)</th>
<th>T(degF)</th>
<th>VEL(ft/s)</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>0.000</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td>2</td>
<td>0.000</td>
<td>0</td>
<td>0.00</td>
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<tr>
<td>3</td>
<td>0.000</td>
<td>0</td>
<td>0.00</td>
</tr>
</tbody>
</table>

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

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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.

<table>
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<tr>
<th>IMPACTOR OP &amp; VELOCITY PROGRAM</th>
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<tbody>
<tr>
<td>1) RUN NUMBER (xxxxxI-n)</td>
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<tr>
<td>2) SUBSTRATE SET NO. 0</td>
</tr>
<tr>
<td>3) IMP TYPE/ SHELL NO/ PLATE NO</td>
</tr>
<tr>
<td>4) DATE</td>
</tr>
<tr>
<td>5) % O2 0.0</td>
</tr>
<tr>
<td>6) % CO2 0.0</td>
</tr>
<tr>
<td>7) % H2O 0.0</td>
</tr>
<tr>
<td>8) AMBIENT PRESSURE 30.00 in Hg</td>
</tr>
<tr>
<td>9) DELTA P STACK 0.00 in H2O</td>
</tr>
<tr>
<td>A) AMBIENT TEMP 0.0 deg F</td>
</tr>
<tr>
<td>B) STACK TYPE RECT.</td>
</tr>
<tr>
<td>D) DUCT LENGTH 0.00 ft</td>
</tr>
<tr>
<td>E) DUCT DEPTH 0.00 ft</td>
</tr>
</tbody>
</table>

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

A-47
When entry to Page 1 is complete, press "C" to continue. (Pressing "Y" 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 traverse 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 nozzle 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, ΔH®, 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 use 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 double 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 velocity 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
<table>
<thead>
<tr>
<th>TIME (MIN)</th>
<th>GAS METER VOLUME</th>
<th>GAS METER TEMP (F)</th>
<th>PRESS. DROP (in. Hg)</th>
<th>METER ORIFICE ( \Delta P ) (in. Hg(\cdot)O)</th>
<th>IMPACTOR TEMP. (F)</th>
<th>FLUE GAS TEMP. (F)</th>
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<tbody>
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**END TIME**

**OPERATORS:** 1) 2)

**RUN LOCATION**

**EVALUATION**

**TIME**

**VOLUME COND. H₂O**

**SAMPLING LOCATION**

**UNLOADED BY**

**SAMPLING NOTES**
<table>
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<tr>
<td>STAGE EIGHT</td>
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<tr>
<td>BACK UP FILTER(S)</td>
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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

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<tr>
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<td>AVG</td>
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AVG DUCT VEL = 37.9 ft/s  VOLUME FLOW = 327,884 acfm
AVG DUCT TEMP = 306 deg F  = 191,825 scfm
AVG SORT DELTA P = 0.558 IN. H20
### DEMO

**IMP ID:** 5CYCS  
**% O2:** 9.7  
**AMB P:** 30.00  
**FORT:** A  
**DATE:** 1/2/86  
**% CO2:** 9.0  
**AMB T:** 90  
**GAS VEL:** 37.95  
**SUBSET:** 0  
**% N2:** 81.3  
**Pstack:** -5.0  
**% H2O:** 14.60  
**Pstack:** 29.63  
**IMP FLOW:** 0.943

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<th>PRESS. DROP (in. Hg)</th>
<th>METER ORIFICE ∆P (in. H2O)</th>
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<th>FLUE GAS TEMP. (F)</th>
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**NOZ DIA:** 7.000  
**ORI ID:** .120S  
**°<P:** 3.05  
**GAS METER #:**

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**SAMPLING NOTES**
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 ΔH₀ 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.

<table>
<thead>
<tr>
<th>ORI. NO.</th>
<th>DIA. (IN)</th>
<th>QCAL (CFM)</th>
<th>PCAL (IN Hg)</th>
<th>TCAL (DEG F)</th>
<th>DPCAL (H20)</th>
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</table>

TO ENTER/CHANGE DATA FOR AN ORI.
ENTER ORI. NO. OR QUIT OR PAGE

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
NS( - designations of orifice sets on file
NIS - set designation
NMS$ - 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
RMS$ - 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 \(\frac{dM}{d\log D}\) 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 \(\frac{dM}{d\log D}\) 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
P$( - print format statements
PO$-PO$ - print format statements
PAS - print format statement
PBS - print format statement
PL - flag used in probability scale conversion
PM$ - print format statement
PMS( - print format statements
PP$ - 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
KP - constant in anisokinetic correction
LS$ - 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
OLS - do outlier flag
R - isokinetic ratio
RS$ - dummy for printing
RH - particle density
RNS$ - run designation
RRS$ - 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
XL-X3 - used in conversion from probability scale
XP( - particle diameters
Y( - particle concentrations
XY( - cumulative percent in probability units
Z - dummy for outlier test
ZZ - dummy for outlier test
ZZ$ - diameter basis
MAIN MENU

1 REM XXXX MAIN MENU XXX
7 D$ = CHR$ (4)
9 HOME : PRINT " MAIN MENU": PRINT ; PRINT
10 PRINT "TO SELECT OPTION ENTER APPROPRIATE 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 " QUIT"
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$(4)
8 IF F1$ = "YES" THEN GOSUB 3000
9 IF F2$ = "YES" THEN GOSUB 4000
10 PRINT
11 PRINT D$: "RUN MAIN MENU"
12 GOTO 110
13 END
14 REM ** FORMAT DEFINITION
15 Hому
16 P = 1
17 F$(0) = " ORSAT V 1.0"
18 F$(1) = " 1) & HARD COPY OPTION "
19 F$(2) = " 2) & DISK FILE UPDATE "
20 F$(3) = " 3) #O## CARBON MONOXIDE %"
21 F$(4) = " 4) #O## CARBON DIOXIDE %"
22 F$(5) = " 5) #O## OXYGEN %"
23 F$(6) = " 6) #O## NITROGEN %"
24 F$(7) = " #O## DRY MOLECULAR WEIGHT"
25 F$(8) = " #O## EXCESS AIR %"
26 ONERR 605170
27 PRINT D$: "OPEN ORSAT.DAT"
28 PRINT D$: "READ ORSAT.DAT"
29 INPUT CM, CD, O2, N2, MW, EX
30 PRINT D$: "CLOSE ORSAT.DAT"
31 RETURN
32 PRINT "ERROR: TO CONTINUE PRESS ANY KEY; ERROR CODE = ", PEEK (222): INPUT A$: GOTO 120
33 PRINT D$: "CLOSE"
34 RETURN
35 REM ** MENU INSTRUCTIONS
36 REM ** MASTER MENU AND COMPUTATIONS
37 REM HOME: PRINT F$(0): PRINT
38 REM 'TO ENTER/CHANGE AN ITEM PRESS NUMBER OF ITEM THEN NEW VALUE AND PRESS <RETURN>"'
39 GOTO 2030
40 VTAB 6: CALL BU, R$, F$(1), F1$: PRINT R$
41 CALL BU, R$, F$(2), F2$: PRINT R$
42 CALL BU, R$, F$(3), CM: PRINT R$
43 CALL BU, R$, F$(4), CD: PRINT R$
44 CALL BU, R$, F$(5), O2: PRINT R$
45 CALL BU, R$, F$(6), N2: PRINT R$
46 PRINT
2100 MW = .44 \times CD + .32 \times 02 + .28 \times (CM + N2)
2110 X = .264 \times N2 - (02 - .5 \times CM): IF X = 0 THEN EX = 0: GOTO 2120
2120 CALL BU, R\$, F\$(7), MW: PRINT R\$
2130 CALL BU, R\$, F\$(8), EX: PRINT R\$: PRINT
2140 X = CM + CD + 02 + N2
2145 MW\$ = "WARNING: TOTAL ADDS TO \#\#\#\#\#\#\$, NOT 100\%"
2150 IF X \(\neq\) 100 THEN CALL BU, R\$, MW\$, X: PRINT R\$
2160 IF X < 2 AND N2 > 0 THEN PRINT "WARNING: ENTER \% RATHER THAN FRACTIONAL VALUES"
2165 PRINT ""
2170 VTAB 21: PRINT: PRINT "SELECT SAVE, OR ENTER NUMBER OF ITEM TO BE CHANGED"
2175 VTAB 23: HTABLE 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 HTABLE 15: PRINT "": VTAB 23: HTABLE 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 "02= "; 02: 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 PRINTER ON AND PRESS ANY KEY": GET A\$
3012 PRINT
3015 PRINT D\$; "PR#1"
3020 PRINT " ORSAT DATA": PRINT
3025 CALL BU, R\$, F\$(3), CM: PRINT R\$
3030 CALL BU, R\$, F\$(4), CD: PRINT R\$
3035 CALL BU, R\$, F\$(5), 02: PRINT R\$
3040 CALL BU, R\$, F\$(6), N2: PRINT R\$
3110 CALL BU, R\$, F\$(7), MW: PRINT R\$
3115 CALL BU, R\$, F\$(8), EX: PRINT R\$
3120 PRINT D\$; "PR#0"
3125 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 02: PRINT N2: PRINT MW: PRINT EX
4030 PRINT D\$; "CLOSE ORSAT.DAT"
4040 RETURN
63999 BU = PEEK (121) + 256 \times PEEK (122) + 286: CALL BU: BU = PEEK (6) + 256 \times PEEK (7): CALL BU + 3: RETURN : REM

=> DO NOT EDIT 63999.
```plaintext
65535 REM
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==> TO REMOVE 'APPENDAGE', ENTER:
   JEXEC BU.STRIp
```

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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)
8 F1$ = "YES":F2$ = "YES"
9 REM  ** MAIN PROGRAM **
10 GOSUB 1800
11 GOSUB 2000
12 IF F1$ = "YES" THEN GOSUB 3000
13 IF F2$ = "YES" THEN GOSUB 4000
14 PRINT
15 PRINT D$; "RUN MAIN MENU"
16 GOTO 110
17 END
100 REM  ** FORMAT DEFINITION**
101 HOME
102 P = 1
103 F$(0) = " METH4 V 1.0"
104 F$(1) = " 1) & HARD COPY OPTION "
105 F$(2) = " 2) & DISK FILE UPDATE "
106 F$(3) = " 3) ##<0##.### GAS METER VOL.(CU,FT)"
107 F$(4) = " 4) ##<0##.### ML WATER COLLECTED"
108 F$(5) = " 5) ### : GAS METER TEMP.(DEG.F)"
109 F$(6) = " 6) ##<0##.### GAS M, DP(IN,H20)"
110 F$(7) = " 7) ### P BAROM.(IN, HG)"
111 F$(8) = "##<0##.### MOISTURE CONTENT (%)"
112 ONERR GOTO 1170
113 PRINT D$; "OPEN METH4.DAT"
114 PRINT D$; "READ METH4.DAT"
115 INPUT VG,WA,TG,PG,PB,BW
116 PRINT D$; "CLOSE METH4.DAT"
117 RETURN
118 PRINT "ERROR: TO CONTINUE PRESS ANY KEY; ERROR CODE = ";
119 PRINT (222): INPUT A$: GOTO 120
120 PRINT D$; "CLOSE"
121 RETURN
122 REM  ** MENU INSTRUCTIONS**
123 REM  ** MASTER MENU AND COMPUTATIONS**
124 HOME : PRINT F$(0): PRINT
125 PRINT "TO ENTER/CHANGE AN ITEM PRESS NUMBER OF ITEM THEN NEW VALUE AND PRESS <RETURN>"
126 GOTO 2030
127 UTAB 6: CALL BU,R$,F$(1),F1$: PRINT R$
128 CALL BU,R$,F$(2),F2$: PRINT R$
129 CALL BU,R$,F$(3),VG: PRINT R$
130 CALL BU,R$,F$(4),WA: PRINT R$
131 CALL BU,R$,F$(5),TG: PRINT R$
132 CALL BU,R$,F$(6),PG: PRINT R$
133 A-67
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 "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$)
2195 IF A < 1 OR A > 7 GOTO 2120
2200 IF A = 1 THEN F1$ = "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 PRINTER 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.

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==> TO REMOVE 'APPENDAGE', ENTER:
JEXEC BU.STRIPI

}
DEF/CYC

1 REM   *** DEFINE CYCLONE PROGRAM V 3.0 ***
2 REM   **CREATES/UPDATES/LISTS CYCLONE INFORMATION IN
&;&.IMP FILE
3 REM   ** VERS.1.1 3/29/83
4 REM   VERS. 3.0 1/9/86 JDM - WEF PS150 CAL CURVES
5 GOSUB 63999
6 D$ = CHR$(4)
7 F1$ = "YES";F2$ = "YES"
8 DIM JN(15),JS(15),JD(15),JL(15),M2(15)
9  DIM F$(13),A$(30)
10 DIM N$(99)
11 N$(1) = "--------";SH$ = "CIRC.";SH = 1;EF = 0
12 REM   ** MAIN PROGRAM **
13 GOSUB 1000
14 GOSUB 2000
15 IF R$ = "Q" THEN GOTO 135
16 GOSUB 2500
17 IF R$ = "Q" THEN GOTO 135
18 IF R$ = "P" GOTO 120
19 IF F1$ = "YES" THEN GOSUB 4000
20 IF F2$ = "YES" THEN GOSUB 5000
21 REM PRINT "RUN MAIN MENU"
22 REM PRINT D$;"RUN MAIN MENU"
23 REM GOTO 110
24 END
25 REM   ** FORMAT DEFINITION
26 HOME
27 P = 1
28 F$(0) = "D E F CYCLONE V3.0"
29 F$(1) = "1) HARD COPY OPTION: &"
30 F$(2) = "2) DISK FILE UPDATE: &"
31 F$(3) = "3) FILE NAME: &"
32 F$(4) = "4) CYCLONE SET NAME: &"
33 F$(5) = "5) DESCRIPTION:"
34 F$(7) = "6) NUMBER OF STAGES: ##"
35 F$(6) = "7) INLET SHAPE (CIRC./SLOT) : &"
36 F$(11) = "CYC A B C IN OUT"
37 F$(12) = "NO. DIA. DIA."
38 F$(13) = "## ; ## ; ## ; ## ; ## ; ## ; ## ; ##"
39 REM ONERR GOTO 1170
40 RETURN
41 PRINT "ERROR; TO CONTINUE PRESS ANY KEY; ERROR CODE = "; PEEK (222); INPUT R$; GOTO 120
42 VTAB 22: PRINT "P)AGE, Q)UIT, OR NUMBER OF ITEM TO EN
43 TER/CHANGE: ";
44 INPUT R$
45 IF R$ = "Q" THEN RETURN
46 IF R$ = "P" THEN P = P + 1: IF P > 2 THEN P = 1: RETURN
47 IF R$ = "P" THEN RETURN
48 A = VAL (R$): IF A < 1 OR A > 9 THEN GOTO 1400

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RETURN
2000 REM XX MAIN MENU
2010 P = 1
2020 HOME : PRINT F$(0) + "-PAGE 1 OF 2"
2030 UTAB 3: CALL BU,R$,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
2132 A = 0: IF F1$ = "YES" THEN F1$ = "NO": RETURN
2135 F1$ = "YES": RETURN
2136 A = 0: IF F2$ = "YES" THEN F2$ = "NO": RETURN
2137 F2$ = "YES": RETURN
2138 A = 0: HOME : PRINT F$(0) + " PAGE 1 OF 2"
2139 UTAB 3: INPUT "KEY IN CYC. SET NAME: ";Y$
2140 IF Y$ = NI$ THEN RETURN
2143 NI$ = Y$: NF = 1: NM$ = Y$ + "/IMP": REM ONERR GOTO 2440
2145 PRINT Y$: PRINT D$;"OPEN IMP/NAM"
2146 PRINT D$;"READ IMP/NAM"
2147 OK = 0
2149 INPUT TI: IF TI = 0 THEN PRINT D$;"CLOSE IMP/NAM": PRINT "TI=0": FOR I = 1 TO 2000: NEXT I: RETURN
2151 FOR I = 1 TO TI
2152 INPUT N$(I)
2153 IF N$(I) = NI$ THEN OK = 1
2155 NEXT I
2156 PRINT D$;"CLOSE IMP/NAM"
2157 IF OK = 0 THEN PRINT "OK=0 TI="TI: FOR I = 1 TO 2000: NEXT I: RETURN
2159 PRINT "OK=1 TI=";TI: FOR I = 1 TO 2000: NEXT I
2161 REM RETURN
2162 PRINT D$;"OPEN" + NM$
2163 PRINT D$;"READ" + NM$
2165 INPUT NS
2167 IF NS = 0 GOTO 2450
2169 FOR I = 1 TO NS
2171 INPUT JN$(I),JD$(I),JA$(I),JS$(I),JL$(I),JK$(I),MZ$(I)
2173 NEXT I
2175 INPUT RM$,MR,SH: IF SH = 0 THEN SH$ = "SLOT.": GOTO 2450
2177 IF SH = 1 THEN SH$ = "CIRC.": GOTO 2450
2180 NF = 0: PRINT "FILE ERROR "; PEEK (222):EF = 1: STOP
2182 PRINT D$;"CLOSE" + NM$: RETURN
2184 IF A = 0 THEN RETURN
2186 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"
2485 SH$ = "CIRC." : SH$ = 0 : RETURN
2500 REM XXX 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 STAGE ENTER STAGE NO. OR QUIT OR PAGE " ; VTAB 2
3099 VTAB 21: PRINT "RETURN" TO ACCEPT CURRENT VALUE OR ENTER NEW VALUE.
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 3000
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$): HH = 0: GOTO 3000
3171 GOTO 3000
3300 J = J + 1: ON J GOTO 3310, 3320, 3330, 3340, 3350
3310 HH = HH + 7: GOTO 3115
3320 HH = HH + 7: GOTO 3115
3330 HH = HH + 7: GOTO 3115
3340 HH = HH + 7: GOTO 3115
3350 HH = 6: GOTO 3000
3499 STOP
4000 REM XXX HARDCOPY OPTION
4010 PRINT "PRINTED COPY OPTION NOW BEING EXECUTED-TURN PRINT ON AND PRESS ANY KEY": GET R$
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$(3),N1$: 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$(7),NS: PRINT R$

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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$;"PR#0": RETURN
4200 PRINT: PRINT: PRINT
4300 FOR I = 1 TO MR
4310 PRINT " THE MASS ON STAGE ":M2(I):" AND ":M2(I) + 1:" WIL BE ASSIGNED TO THE CUTPOINT OF STAGE ":M2(I) + 1:" FOR THE SPLINE FITS, AND STAGE ":M2(I):" WIL BE OMITTED IN SPlI NE FITS": PRINT
4320 NEXT I
4490 PRINT D$;"PR#0"
4500 RETURN
5000 REM XX DISK UPDATE
5001 PRINT ": PRINT D$;"OPEN" + NM$: PRINT D$;"CLOSE" + NM$
5005 REM ONERR GOTO 5900
5007 PRINT D$;"OPEN" + NM$
5010 PRINT D$;"WRITE" + NM$
5020 PRINT NS
5030 FOR I = 1 TO NS
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' AND 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.
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==> TO REMOVE 'APPENDAGE', ENTER:
JEXEC BU_STRIP
CYCProg

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 3/26/83 *****
6 REM V1.1 5/18/83 V2.3 10/25/83 V3.0 1/8/86 (SWITCH TO WEF'S PS150 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(40), U(5), F(5), MN(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$; "PRH0". 
235 PRINT "DO YOU WANT TO SAVE RAW DATA? (Y/N)": GET R$; 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$; "RUN MAIN MENU" 
999 END 
1000 REM "<<<< XXX INITIALIZATION >>>>"
1002 DIM XX(20), YY(20), Y1(20), Y2(20), DG(20), XP(20), SI(20)
1004 DIM H(15), DL(15), HZ(15), E(15), DQ(15), S2(15), C(15), S3(15)
1005 DIM CU(15), CC(15), PS(15), DP(15), VJ(15), DS(15), D6(15)
1008 F$(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) = "CYC PROG 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 H20"
1120 F$(11) = " 4") STACK PRESSURE ### INCHES H20"
1130 F$(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$(20) = " " CO2 ###%; CO ###%""HN"
1220 F$(22) = " " O2 ###%; N2 ###%;"HN"
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$:"READ METH4.DAT"
1280 INPUT X,X,X,X,X,X,BW
1290 PRINT D$:"CLOSE"
1300 PRINT D$:"OPEN ORSAT.DAT": PRINT D$:"READ ORSAT.DAT"
1310 INPUT CM,CD,02,N2
1320 PRINT D$:"CLOSE"
1330 GD = 1.293E - 03; PM = 1.4764E - 05; MA = 28.97; DC2 = .61
* 61; HG = 13.610C = 471.95; FR = 460; FS = 492; SP = 29.92; X0
= 1000; F1 = 10; MF = 1
1340 RETURN
1400 REM **** MENU INSTRUCTIONS
1410 VTAB 21: PRINT "ENTER: 0)UIT, P)AGE, OR NUMBER OF ITEM TO ENTER/CHANGE:" 
1420 VTAB 22: HTAB 20: INPUT R$: IF R$ = "Q" THEN RETURN
1430 IF R$ = "P" THEN RETURN
1440 P = VAL (R$): IF P < 1 OR P > MX THEN GOTO 1410
1450 RETURN
2000 REM xxxxxxx MENU, PAGE 1 >>>>>> 
2010 MX = 12 
2020 HOME: PRINT F$(0):" - PAGE 1 OF 3": PRINT
2025 PRINT F$(29): IF F1 = 1 THEN PRINT "PHYSICAL": GOTO
2030 2030 IF F1 = 0 THEN PRINT "IMP. AERO."": GOTO 2030
2027 F1 = 10: PRINT "CLASS. AERO."
2030 PRINT F$(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
2233 GOTO 2910
2240 VTAB 23: HTAB 15: INPUT " PART. DEN$,= " ;RH$; RETURN
2252 VTAB 23: HTAB 15: PRINT "ENTER DIAM.BASIS IMP.AERO, C
> LASS.AERO, OR P>PHYSICAL": 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$; RETURN
2290 VTAB 23: HTAB 15: INPUT "ENTER TEST NUMBER "; Y; IF TN = 
2295 TN = Y
2300 TN$ = "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 ON ERR GOTO 2999: VTAB 24: PRINT "THAT TEST IS NOT DE
2360 FINED"
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$:
2400 IF X$ = "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 QNERR GOTO 29999
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$; "READ" + Y$ + "/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 (.DDD) "; RO$
2620 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, CO, CP, CT, PP
2670 IF DI = VAL (RO$) THEN PRINT D$; "CLOSE": RETURN
2680 NEXT I
2690 RO$ = RO$ + " NOT IN FILE"; PRINT D$; "CLOSE": RETURN
2700 VTAB 23: HTAB 20: INPUT "/ H20= "; R$: IF R$ = "" THEN GOTO 2742
2735 BW = VAL (R$); BW = BW / 100; WA = 0
2740 R$(24) = LEFT$ (F$(24), 28) + " (KEYBOARD)"
2742 VTAB 23: HTAB 20: PRINT "CHANGE OTHER GASES?"; GET R$
2743 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$;"CLOSE": PRINT "FILE FOR ":ZZ$;"/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$;"/NAM FULL": NORMAL: PRINT "PURGE FILE BEFORE CONTINUEING": FOR I = 1 TO 1000: NEXT I
2840 RETURN
3000 REM <<<<< MENU, PAGE 2 >>>>>
3010 P = 1
3020 HOME: PRINT F$(0);" - PAGE 2 OF 3": PRINT
3030 CALL BU,R$,F$(9),VM: PRINT R$
3040 CALL BU,R$,F$(9),DP: PRINT R$
3050 CALL BU,R$,F$(10),DP: 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
3170 IF R$ = "O" THEN RETURN
3200 IF R$ = "P" THEN GOTO 3500
3230 ON P GOSUB 3260,3270,3280,3290,3300,3310,3320,3330,3340,3350,3360,3370,3380,3390,3400
3250 GOTO 3620
3260 VTAB 24: HTAB 5: INPUT "VM (0 FOR ORIFICE FLOW) = ";VM: RETURN
3270 VTAB 24: INPUT "SAMPLE 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
3560 REM <<<< *** MENU, PAGE 3, CYCLONE STAGE WEIGHT S %>%>
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$(I)
3575 IF I = S + 2 THEN PRINT iX$ = STR$(I) + " BLANK SUBST."
3578 IF I = S + 3 THEN X$ = STR$(I) + " BLANK FIL."
3580 CALL BU,R$,F$(26),X$,M(I): PRINT R$
3590 NEXT I
3600 GOSUB 1490
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 "VISCOSETY": GOSUB 4500
4005 IF VM = 0 THEN QO = CQ × (QP × 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 - PC) / 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) = 02 / 100
4600 F(5) = BW
4610 MW = 0: FOR I = 1 TO 4:MW = MW + F(I) * MW(I): NEXT I:D
4620 M = MW:MW = MW * (1 - BW) + BW * MW(5)
4630 T = (TI - 32) * 5 / 9
4640 U(1) = 138.494 + T * (.499 + T * (- .286E - 3 + T * .972E - 7))
4650 U(2) = 165.763 + T * (.442 + T * (- .213E - 3))
4660 U(3) = 167.088 + T * (.417 + T * (- .139E - 3))
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 NEXT I
4790 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 - 1) < 0 THEN UJ(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 - 1) = 0 THEN UJ(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 * UJ(I) / SP / (TI + FR) / MA / DC2
4950 PS(I) = PB + PS / HG - DP(I - 1)
4960 NEXT I
4970 RETURN
5000 REM <<<*** SUBROUTINE CUT ***>>>
5001 Fs = "###; #######; #######; ###.###; .###^###; ###.###"
5005 IF F1 = 10 THEN RH = 1
5100 TK = 5 / 9 * (TI - 32) + 273
5115 PRINT "CYC RE V GD SQRT(PSI50)"
5200 FOR I = 1 TO S
5300 L = .337 * U * SQR(TK / MW) / PS(2 * I)
5400 CU = 1.05
5500 X = 1
5600 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
5800 SI(I) = EXP(JS(I) + JK(I) * LOG(RE(I)) + JN(I) * SQR
< LOG(RE(I))>): REM SQUARE ROOT OF PSI50 FOR CYCLONE
5900 = FCN OF RE
6000 CALL BU,R$,F$,I,RE(I),VJ(2 * I - 1),GD(I),SI(I): PRINT
6100 R$
6200 D5 = SQR((18 * U * JD(I) / (RH * VJ(2 * I - 1) * CU)) * SI(I)
6300 CC = CU
6400 CU = 1 + 2 * L / D5 * (1.23 + .41 * EXP(-.44 * D5 / L))
6500 X = X + 1
6600 REM ***LIMIT TO NO. OF ITERATIONS SET IN LINE 5100***
6700 IF X > 10 THEN PRINT "STAGE ";1;"FAILED TO CONVERGE":
6800 GOTO 5120
6900 REM ***CONVERGENCE CRITERIA SET IN LINE 5110***
7000 IF ABS(1 - CC / CU) > .001 GOTO 5060
7100 D5(I) = D5 * 10000
7200 CC(I) = CU
7300 D6(I) = D5(I) * SQR(CC(I) * RH)
7400 NEXT I
7500 XM = 0: M(S + 1) = FF
7600 FOR I = 1 TO S + 1
7700 XM = XM + M(I)
7800 NEXT I
7900 XM = XM - (S * SC) - FC
8000 FOR I = 1 TO S
8100 CU(I) = 0
8200 FOR J = 1 + 1 TO S + 1
8300 CU(I) = CU(I) + M(J)
8400 IF J < S + 1 THEN CU(I) = CU(I) - SC
8500 IF J = S + 1 THEN CU(I) = CU(I) - FC
8600 NEXT J
8700 CU(I) = CU(I) / XM
8800 NEXT I
8900 PRINT "PRESS ANY KEY TO CONTINUE": GET R$
9000 HOME
9100 IF F1 < > 10 THEN PRINT "STAGE C.CORR. CUMFR DP<P
9200 HY> DP(I,AERO)": GOTO 5297
9300 PRINT "STAGE C.CORR CUMFR DP(CL,A) DP(I,A)"
9400 F$ = "###; ######; ######; #####; #######"
9500 FOR I = 1 TO S
9600 CALL BU,R$,F$,I,CC(I),CU(I) * 100,D5(I),D6(I): PRINT R$
9700 NEXT I

A-82
5330 PRINT
5340 PRINT "PRESS ANY KEY TO CONTINUE": GET R$*
5350 HOME
5360 TC = XM / (QS * TD * .02832): REM MASS PER DN3
5370 RETURN
5380 REM <<<<< SUBROUTINE FIT >>>>
5390 C0 = 2.515517
5400 C1 = 0.302853
5410 C2 = 0.010328
5420 D1 = 1.432788
5430 D2 = 0.189269
5440 D3 = 0.061308
5450 LT = LOG (10)
5460 K = 0
5470 FOR I = 1 TO S
5480 FOR J = 1 TO MR
5490 IF MZ(J) = I THEN I = I + 1
5500 NEXT J
5510 K = K + 1
5520 IF F1 > 0 THEN X(K) = LOG (D5(I)) / LT: GOTO 5600
5530 X(K) = LOG (D6(I)) / LT
5540 FL = 1
5550 CU = CU(I)
5560 IF CU < .5 GOTO 5650
5570 FL = - 1
5580 CU = 1 - CU
5590 IF CU < 0 THEN PRINT "***** !!!! PUNT !!!! *****": PRINT "STAGE WEIGHTS PRODUCE NEGATIVE OR ZERO CUMULATIVE. RECHECK WEIGHTS.": GET R$;2Y = 1: RETURN
5600 T = SQR (- 2 * LOG (CU))
5610 Y(K) = (T + (C0 + C1 * T + C2 * T * T) / (1 + T * (D1 + T * (D2 + T * D3)))) * FL
5620 NEXT I
5630 GOTO 5700
5640 PRINT D$;"OPEN XPOINTS.DAT"
5650 PRINT D$;"READ XPOINTS.DAT"
5660 INPUT NP
5670 INPUT XP(I)
5680 XX(I) = LOG (XP(I)) / LT
5690 NEXT I
5700 PRINT D$;"CLOSE"
5710 S = S - MR
5720 FOR I = 1 TO S / 2
5730 TX = X(I); TY = Y(I)
5740 XI = X(S + 1 - I); YI = Y(S + 1 - I)
5750 XS = X(S + 1 - I) = TX; Y = Y(S + 1 - I) = TY
5760 NEXT I
5770 FOR I = 1 TO S - 1
5780 FOR J = I + 1 TO S
5790 IF X(J) >= X(I) GOTO 5890
5800 TX = X(I); TY = Y(I)
5810 XI = X(J); YI = Y(J)
5820 X(J) = TX; Y(J) = TY

A-83
5890   NEXT J
5900   NEXT I
5910   IF F1 = 1 THEN XX(0) = LOG(X0 / SQR(RH)) / LT: GOTO 5920
5920   XX(0) = LOG(X0) / LT
5920   RETURN
6000   REM '<<<<< SPLINE FIT >>>>>'
6005   YY(0) = -100
6010   QM = 1.071968: 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(I) = 0
6170   S2(S) = 0
6180   REM - SUCCESSIVE 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)) * QM
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
6300   REM '<<< NOW INTERPOLATE >>>'
6310   FOR J = 1 TO NP
6320   PRINT ";."
6330   I = 1
6340   IF XX(J) = X(I) GOTO 6750
6350   IF XX(J) < X(I) GOTO 6630
6360   IF XX(J) = X(S) GOTO 6730
6370   IF XX(J) > X(S) GOTO 6680
6380   I = I + 1
6390   IF XX(J) = X(I) GOTO 6750
6400   IF XX(J) > X(I) GOTO 6580
6410   GOTO 6740
6420   REM 'EXTRAPOLATE BELOW X(I)
6430   S1 = DL(1) - H(1) / (H(1) + H(2)) * 2 * (DL(2) - DL(1))
6435   IF S1 < 0 THEN S1 = DL(1)
6640 \ Y\!(\textit{J}) = \ Y\!(1) + (\textit{XX}\!(\textit{J}) - \ X\!(1)) \times S1
6645 \textbf{IF} \ \ Y\!(\textit{J}) \wedge Y\!(\textit{J} \ - \ 1) \ \textbf{THEN} \ S1 = \ DL\!(1):Y\!(\textit{J}) = \ Y\!(1) + (\textit{XX}\!(\textit{J}) - \ X\!(1)) \times S1
6650 \ \ Y1\!(\textit{J}) = S1
6660 \ \textbf{GOTO} \ 6820
6670 \ \textbf{REM} \ - EXTRAPOLATE ABOVE \ X(S)
6680 \ S1 = \ DL\!(S - 1) + H(S - 1) \times S2(S - 1)
6685 \textbf{IF} \ S1 \wedge 0 \ \textbf{THEN} \ S1 = \ DL\!(S - 1)
6690 \ Y\!(\textit{J}) = \ Y\!(S) + (\textit{XX}\!(\textit{J}) \ - \ X(S)) \times S1
6694 \textbf{IF} \ XX\!(\textit{J}) \wedge XX\!(0) \ \textbf{THEN} \ Y\!(\textit{J}) = 1E6:Y1\!(\textit{J}) = 0: \textbf{GOTO} 6
7100 \ X3 = XX\!(\textit{J}) \ - \ XX\!(0):X1 = \ X(S) \ - \ XX\!(0):X2 = XX\!(\textit{J}) \ - \ X(S)
7105 \ YY\!(\textit{J}) = YY\!(\textit{J}) + (X2 \times X2 / X1 - X2) / X1 + 1 / X1 - 1
7300 \ Y1\!(\textit{J}) = S1 + (2 \times X2 / X1 - 1) / X1 / X1 + 1 / X3 / X3
7400 \ \textbf{GOTO} \ 6820
7600 \ \textbf{REM} \ -INTERPOLATE BETWEEN X(X)
7630 \ I = S
7640 \ I = I + 1
7650 \ H1 = XX\!(\textit{J}) \ - \ X(I)
7660 \ H2 = XX\!(\textit{J}) \ - \ X(I + 1)
7670 \ PR = H1 \times H2
7800 \ Y2\!(\textit{J}) = S2(I) + H1 \times S3(I)
7830 \ D0 = (S2(I) + S2(I + 1) + Y2\!(\textit{J})) / 6
7860 \ YY\!(\textit{J}) = Y(I) + H1 \times DL\!(I) + PR \times D0
7880 \textbf{IF} \ YY\!(\textit{J}) \wedge Y(I) \ \textbf{THEN} \ YY\!(\textit{J}) = Y(I) + H1 \times DL\!(I)
7890 \ Y1\!(\textit{J}) = DL\!(I) + (H1 + H2) \times D0 + PR \times S3(I) / 6
7915 \textbf{IF} \ Y1\!(\textit{J}) \wedge 0 \ \textbf{THEN} \ Y1\!(\textit{J}) = DL\!(I)
7920 \ DG\!(\textit{J}) = \ \textbf{EXP} ( - YY\!(\textit{J}) \times YY\!(\textit{J}) / 2) \times Y1\!(\textit{J}) \times TC \times VT
8300 \ \textbf{NEXT} \ J
8310 \ \textbf{PRINT}
8330 \ S = S + MR
8400 \ \textbf{RETURN}
7000 \ \textbf{REM} \ <<XXX DISPLAY RESULTS XXX>>>
7005 \ XZ$ = "PHYS DIA.":XY$ = "IMP. AERO DIA.":XX$ = "CLASS. AERO DIA."
7006 \ F$ = "---.########;##.########;##.########;##.########;---.########;---.########"
7007 \textbf{IF} \ F1 = 0 \ \textbf{THEN} \ ZZ$ = XY$
7008 \textbf{IF} \ F1 = 1 \ \textbf{THEN} \ ZZ$ = XZ$
7009 \textbf{IF} \ F1 = 10 \ \textbf{THEN} \ ZZ$ = XX$
7010 \ \textbf{HOME}: \ \textbf{PRINT} \ ZZ$ + " CUMFR SLOPE DM/DLOGD"
7020 \ \textbf{FOR} \ I = 1 \ \textbf{TO} \ NP \ \textbf{STEP} \ 2
7030 \ \textbf{CALL} \ BU.R$,F$,F$.,XP(I),YY(I),Y1(I),DG(I): \ \textbf{PRINT} \ R$
7040 \ \textbf{NEXT} \ I
7050 \ \textbf{INPUT} "DO YOU WANT TO SAVE THE RESULTS";Y$
7060 \\textbf{IF} \ Y$ \wedge (Y$,1) \ = \ "N" \ \textbf{THEN} \ \textbf{RETURN}
7070 \ \textbf{IF} \ Y$ \wedge (Y$,1) \ < \ "Y" \ \textbf{THEN} \ 7050
7080 \ \textbf{PRINT} \ D$: "OPEN" + NM$: \ \textbf{PRINT} \ D$: "WRITE" + NM$
7090 \ \textbf{PRINT} \ DT$: \ \textbf{PRINT} \ T$
7110 \ \textbf{PRINT} \ LL$: \ \textbf{PRINT} \ RR$: \ \textbf{PRINT} \ ZZ$
7120 \ \textbf{PRINT} \ TC$
7130 \\textbf{FOR} \ I = 1 \ \textbf{TO} \ NP$
7140 \ \textbf{PRINT} \ XP(I): \ \textbf{PRINT} \ YY(I): \ \textbf{PRINT} \ DG(I)$
7150 \ \textbf{NEXT} \ I

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PRINT S
FOR I = 1 TO S
PRINT D5(I); PRINT D6(I): PRINT CU(I): PRINT Y(I)
NEXT I
PRINT AV: PRINT ND: PRINT IS: PRINT U: PRINT RH
PRINT D$:"CLOSE"
QERRR GOTO 7700: PRINT D$:"VERIFY RUN/NAM": POKE 216, 0
PRINT D$:"OPEN RUN/NAM": PRINT D$:"READ RUN/NAM"
INPUT FI: FOR I = 1 TO FI: INPUT ZZ$(I): NEXT I: FI = F I + 1: PRINT D$:"CLOSE"
ZZ$(FI) = NM$
PRINT D$:"OPEN RUN/NAM": PRINT D$:"WRITE RUN/NAM"
PRINT FI: FOR I = 1 TO FI: PRINT ZZ$(I): NEXT I: PRINT D$:"CLOSE"
RETURN
FI = 2:ZZ$(1) = "99999": POKE 216, 0: GOTO 7185
REM <<<<<<<HARDCOPY<<<<<<
HOME : INPUT "DO YOU WANT HARDCOPY (Y/N) ?"; R$: IF R$ = "N" THEN HOME : GOTO 9040
IF R$ < > "Y" THEN GOTO 9010
HOME : PRINT "TURN PRINTER ON"
PRINT D$:"PR#1": PRINT CHR$ (9) + "80 N" + CHR$ (24)
PRINT "XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX": PRINT
PRINT "XXXXXXXXXXXXXXXXXXXXX INPUT DATA XXXXXXXXXXXXXXXXX": PRINT
PRINT F$(29);: IF F1 = 1 THEN PRINT "PHYSICAL"
IF F1 = 0 THEN PRINT "IMPACT OF AERODYNAMIC"
IF F1 = 10 THEN PRINT "CLASSICAL AERODYNAMIC"
PRINT F$(1);DT$
PRINT F$(2);T$
PRINT F$(3);L$
CALL BU,R$,F$(4),TN: PRINT R$;TR$
PRINT F$(27);I$
PRINT F$(5);RN$;"-FILE NAME":NM$
PRINT F$(6);RR$
PRINT F$(7);IM$; "";IN$
CALL BU,R$,F$(25),RH: PRINT R$
PRINT CALL BU,R$,F$(24),BW * 100: PRINT R$
CALL BU,R$,F$(20),CD,CM: PRINT R$
CALL BU,R$,F$(22),O2,N2: PRINT R$
CALL BU,R$,F$(30),RO$: PRINT R$
PRINT : PRINT
CALL BU,R$,F$(8),VM: PRINT R$
CALL BU,R$,F$(9),DP: PRINT R$
CALL BU,R$,F$(10),DP: PRINT R$
CALL BU,R$,F$(11),PS: PRINT R$
CALL BU,R$,F$(12),PB: PRINT R$
CALL BU,R$,F$(13),TS: PRINT R$
CALL BU,R$,F$(14),TM: PRINT R$
CALL BU,R$,F$(15),TI: PRINT R$
CALL BU,R$,F$(16),TD: PRINT R$
9330  CALL BU,R$,F$(17),AV / 60: PRINT R$
9340  CALL BU,R$,F$(18),PC / 13.569: PRINT R$
9350  CALL BU,R$,F$(19),ND: 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
9420  PRINT : PRINT
9430  X$ = "MASS GAIN OF BLANK SUBSTRATE  ": CALL BU,R$,X$,SC: PRINT R$
9440  PRINT : PRINT
9450  PRINT "XXXXXXXXXX RESULTS XXXXXXXXXX"
9460  F$ = "ACTUAL FLOW RATE ": CALL BU,R$,F$
9470  F$ = "FLOW RATE AT STANDARD CONDITIONS ": CALL BU,R$,F$,GS: PRINT R$
9480  F$ = "PERCENT ISOKINETIC ": CALL BU,R$,F$
9490  F$ = "VISCOSITY ": CALL BU,R$,F$,U: PRINT R$
9500  IF DP = 0 THEN F$ = "CALCULATED SAMPLER DELTA P = ": PRINT R$
9510  PRINT : PRINT
9520  IF F1 = 10 THEN XZ$ = "DP(CLASS AERO)"
9530  IF F1 < > 10 THEN XZ$ = "DP(Physical)"
9540  PRINT "STAGE  CUMN.  DP  DP  CUM.
INLET  SQRT"
9550  PRINT "  CORR. ");XZ$;"(IMP AERO) FREQ. RE
PSI50"
9560  PRINT : PRINT
9570  FOR I = 1 TO S
9580  CALL BU,R$,F$,I,CC(I),D5(I),D6(I),CU(I) * 100,RE(I),SI
9590  NEXT I
9600  IF MR = 0 GOTO 9650
9610  NEXT I
9620  IF MR = 0 GOTO 9650
9630  PRINT "NOTE: THE MASSES ON STAGES ";MZ(I);", AND ";MZ(I)
9640  HAVE BEEN COMBINED FOR THE SPLINE FIT BECAUSE OF CUTS BEING TOO CLOSE TOGETHER"
9650  PRINT : PRINT
9660  IF F1 = 1 THEN PRINT "SPLINE FIT ON PHYSICAL DIAMETER
BASIS": PRINT
9670  IF F1 = 0 THEN PRINT "SPLINE FIT ON IMPACTION AERODYNAMIC DIAMETER BASIS": PRINT
9680  IF F1 = 10 THEN PRINT "SPLINE FIT ON CLASSICAL AERODYNAMIC DIAMETER BASIS": PRINT
9690  IF F1 = 10 THEN PRINT "SPLINE FIT ON CLASSICAL AERODYNAMIC DIAMETER BASIS": PRINT
9700  IF F1 = 10 THEN PRINT "SPLINE FIT ON CLASSICAL AERODYNAMIC DIAMETER BASIS": PRINT
9710  IF F1 = 10 THEN PRINT "SPLINE FIT ON CLASSICAL AERODYNAMIC DIAMETER BASIS": PRINT
9720  IF F1 = 10 THEN PRINT "SPLINE FIT ON CLASSICAL AERODYNAMIC DIAMETER BASIS": PRINT
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9750  IF F1 = 10 THEN PRINT "SPLINE FIT ON CLASSICAL AERODYNAMIC DIAMETER BASIS": PRINT
9760  IF F1 = 10 THEN PRINT "SPLINE FIT ON CLASSICAL AERODYNAMIC DIAMETER BASIS": PRINT
9770  IF F1 = 10 THEN PRINT "SPLINE FIT ON CLASSICAL AERODYNAMIC DIAMETER BASIS": PRINT
9780  IF F1 = 10 THEN PRINT "SPLINE FIT ON CLASSICAL AERODYNAMIC DIAMETER BASIS": PRINT
9790  IF F1 = 10 THEN PRINT "SPLINE FIT ON CLASSICAL AERODYNAMIC DIAMETER BASIS": PRINT
9800  IF F1 = 10 THEN PRINT "SPLINE FIT ON CLASSICAL AERODYNAMIC DIAMETER BASIS": PRINT
9810  IF F1 = 10 THEN PRINT "SPLINE FIT ON CLASSICAL AERODYNAMIC DIAMETER BASIS": PRINT
9820  IF F1 = 10 THEN PRINT "SPLINE FIT ON CLASSICAL AERODYNAMIC DIAMETER BASIS": PRINT
9830  IF F1 = 10 THEN PRINT "SPLINE FIT ON CLASSICAL AERODYNAMIC DIAMETER BASIS": PRINT
9840  IF F1 = 10 THEN PRINT "SPLINE FIT ON CLASSICAL AERODYNAMIC DIAMETER BASIS": PRINT
9850  IF F1 = 10 THEN PRINT "SPLINE FIT ON CLASSICAL AERODYNAMIC DIAMETER BASIS": PRINT
9860  IF F1 = 10 THEN PRINT "SPLINE FIT ON CLASSICAL AERODYNAMIC DIAMETER BASIS": PRINT
9870  IF F1 = 10 THEN PRINT "SPLINE FIT ON CLASSICAL AERODYNAMIC DIAMETER BASIS": PRINT
9880  IF F1 = 10 THEN PRINT "SPLINE FIT ON CLASSICAL AERODYNAMIC DIAMETER BASIS": PRINT
9890  IF F1 = 10 THEN PRINT "SPLINE FIT ON CLASSICAL AERODYNAMIC DIAMETER BASIS": PRINT
9900  IF F1 = 10 THEN PRINT "SPLINE FIT ON CLASSICAL AERODYNAMIC DIAMETER BASIS": PRINT
9910  IF F1 = 10 THEN PRINT "SPLINE FIT ON CLASSICAL AERODYNAMIC DIAMETER BASIS": PRINT
9920  IF F1 = 10 THEN PRINT "SPLINE FIT ON CLASSICAL AERODYNAMIC DIAMETER BASIS": PRINT
9930  IF F1 = 10 THEN PRINT "SPLINE FIT ON CLASSICAL AERODYNAMIC DIAMETER BASIS": PRINT
9940  IF F1 = 10 THEN PRINT "SPLINE FIT ON CLASSICAL AERODYNAMIC DIAMETER BASIS": PRINT
9950  IF F1 = 10 THEN PRINT "SPLINE FIT ON CLASSICAL AERODYNAMIC DIAMETER BASIS": PRINT
9960  IF F1 = 10 THEN PRINT "SPLINE FIT ON CLASSICAL AERODYNAMIC DIAMETER BASIS": PRINT
9970  IF F1 = 10 THEN PRINT "SPLINE FIT ON CLASSICAL AERODYNAMIC DIAMETER BASIS": PRINT
9980  IF F1 = 10 THEN PRINT "SPLINE FIT ON CLASSICAL AERODYNAMIC DIAMETER BASIS": PRINT
9990  IF F1 = 10 THEN PRINT "SPLINE FIT ON CLASSICAL AERODYNAMIC DIAMETER BASIS": PRINT
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NAMIC DIAMETER BASIS": PRINT
9670 PRINT "PARTICLE DIA. CUMFR CUMFR CUM.MASS DM/DLO
60"
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$"###.####; -###.#####; ####.###; ###.####^####; ####

7700 FOR I = 1 TO NP
9706 X1 = YY(I): GOSUB 9900
9710 CALL BU,R$,F$,XP(I),YY(I),X3 * 100,X3 * TC,D6(I): PRINT
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
9841 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 =
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
10060 FRACTION
10070 L2 = L2 + Y(I) * X(I)
10080 L3 = L3 + X(I) * X(I)
10090 L4 = L4 + Y(I) * Y(I)
10100 NEXT I
10110 L5 = (L2 - L1 * L2 / NZ) / (L3 - L2 * L2 / NZ)
10120 L6 = L1 / NZ; L5 * L5 / NZ
10130 L7 = 10 ^ ( - L6 / L5)
10140 L8 = 10 ^ (1 / L5)
10150 L9 = L5 * SQR ((L3 - L2 * L2 / NZ) / (L4 - L1 * L1 / NZ))
10160 L9 = L9 * L9
10170 PRINT "MMD= "; L7; " SIGG= "; L8; " R2= "; L9; PRINT : PRINT
10180 "TO CONTINUE PRESS ANY KEY" : GET R$
10190 PRINT R$: RETURN
30000 DA(0) = F1; DA(1) = VM; DA(2) = DP; DA(3) = OP; DA(4) = PS
30010 DA(5) = PB; DA(6) = TS; DA(7) = TM; DA(8) = TI; DA(9) = TD; DA(10) = AV; DA(31) = WA
30020 DA(11) = FC; DA(12) = ND; DA(13) = X0; DA(14) = TN; DA(15) = RH; DA(16) = S; DA(17) = MR; DA(18) = DC2; DA(19) = NN; DA(20) = DI; DA(21) = CQ; DA(22) = CP; DA(23) = CT; DA(24) = PP; DA(25) = BW; DA(26) = N9
30030 DA(27) = CD; DA(28) = CM; DA(29) = 02; DA(30) = N2
30040 DA = PEEK (107) + 256 * PEEK (108); DL = PEEK (109) + 256 * PEEK (110) - DA; REM START AND LENGTH OF ARRAY STOR AGE
30050 DL = 1000
30060 PRINT : PRINT D$: "BSAVE" + NM$ + ".DATA" + ",A"; DA; ",L"; DL
30070 PRINT D$: "OPEN" + NM$ + ".TEXT"
30090 PRINT D$: "CLOSE" : RETURN
30999 REM RELOAD OLD RUN DATA
31000 PRINT "ENTER FILE NAME OF RUN TO BE RETRIEVED:" : INPUT F1$
31010 DA = PEEK (107) + 256 * PEEK (108)
31020 PRINT D$: "BLOAD" + F1$ + ".DATA,A"; DA
31030 F1 = DA(0); VM = DA(1); DP = DA(2); OP = DA(3); PS = DA(4)
31040 PB = DA(5); TS = DA(6); TM = DA(7); TI = DA(8); TD = DA(9); AV = DA(10)
31050 PC = DA(11); ND = DA(12); X0 = DA(13); TN = DA(14); RH = D
31060 A(15) = DA(16); MR = DA(17); DC2 = DA(18); NN = DA(19); DI = D

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A(25):N9 = DA(26)
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"
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:
   JEXEC BU.STRIP

]
REM WRITTEN BY J.D.MCCAIN, SOUTHERN RESEARCH INSTITUTE - REVISION 8/1/84
1 TEXT : HOME : PRINT "A CATALOG OF RUNS ON FILE WILL BE LISTED NEXT. SELECT THE RUN TO BE PLOTTED AND TYPE IN FILE NAME WHEN REQUESTED. NOTE AMPERSAND "&" LOADER MUST HAVE BEEN RUN PRIOR TO THIS PROGRAM."
2 PRINT " THE RUN WILL THEN BE PLOTTED FIRST AS CUM. % VS. DIA., THEN AS DM/LOGD VS DIA., AND FINALLY AS CUM. CONC. VS DIA. TO PLOT ANOTHER RUN SIMPLY 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

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"
19 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, -.365
151 & LABEL,.068,1.125: & LABEL,.068,.395: & LABEL,.068,1.51
152 & LABEL,.068,2.445
153 & LABEL$ = NM$: & LABEL,.2,3.5
154 FOR I = 1 TO NP
155 FOR CIRCLE,XP(I),YY(I)
156 NEXT I
157 GOSUB 5580
158 FOR I = 1 TO S
159 IF DB$ <> "PHYS DIA." AND DB$ <> "CLASS. AERO DIA." THEN OPENEL,DS(I),Y(I): GOTO 177
160 & CLOSEDEL,DS(I),Y(I)
161 NEXT I
162 FOR I = 1 TO 5000: NEXT I
163 TEXT : HOME : INPUT "HARDCOPY? (REQUIRES GRAPHTTI CARD ) Y/N ":;R$: IF R$ < > "Y" THEN 200
164 PRINT : PRINT : INPUT "S"mall (3X4) OR L)ARGE (6X8) SIZ E FOR PLOT ";;R$: IF R$ < > "S" AND R$ < > "L" GOTO 180
165 IF R$ = "S" THEN P$ = "S2R"
166 IF R$ = "L" THEN P$ = "S2RD"
167 PRINT D$:"PR"$;
168 PRINT CHR$(9) + P$: PRINT CHR$(12): PRINT D$:"PR"$.
169 DB = 0:DL = 1.0E32
200 FOR I = 1 TO 15
210 IF DG(I) = = 0 THEN DG(I) = 1.0E - 15: GOTO 240
220 IF DG(I) > DB THEN DB = DG(I)
230 IF DG(I) < DL THEN DL = DG(I)
240 NEXT I
250 TEXT : HOME : PRINT "MIN DM/DLOGD=";DL
260 PRINT : PRINT "MAX DM/DLOGD=";DB
270 PRINT : PRINT : INPUT "SELECT RANGE FOR DM/DLOGD PLOT - MIN,MAX. MUST BE INTEGRAL POWERS OF TEN ";;YL,YM
271 HGR2
272 & SCALE,.1,100,YL,YM
273 & LOG X: & LOG Y
274 LY$ = "DM/DLOGD, MG/DNM3"
300 & LABELAXES,1,YL
310 LABEL$ = NM$: & LABEL,.2,.6 X YM
320 FOR I = 1 TO 15
325 IF DG(I) = = 0 THEN GOTO 340
330 & OPENCIRCLE,XP(I),DG(I)
340 NEXT I
341 FOR I = 1 TO 5000: NEXT I: TEXT : HOME : INPUT "HARDCOPY Y? (REQUIRES GRAPHTTI CARD) Y/N ";R$: IF R$ < > "Y" THEN 350
342 PRINT : PRINT : INPUT "S"mall (3X4) OR L)ARGE (6X8) SIZ E FOR PLOT ";;R$: IF R$ < > "S" AND R$ < > "L" GOTO 342
A-92
343 IF R$ = "S" THEN P$ = "G2R"
344 IF R$ = "L" THEN P$ = "G2RD"
345 PRINT D$ ; "PR#1"
346 PRINT CHR$(?)+P$; PRINT CHR$(12); PRINT D$ ; "PR#0"
350 REM CUM CONC PLOT
360 D0 = .47047 / SQRT(2); C1 = .34802; C2 = -.0958798; C3 = .7478556
370 TEXT : HOME : PRINT "MIN CONC.="; X1 = YY(I); 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 & CLOSED'CIRCLE, D6(I), CU(I); GOTO 570
560 & CLOSED'CIRCLE, D5(I), CU(I) * TC
570 NEXT I
580 FOR I = 1 TO 5000: NEXT I: TEXT : HOME : INPUT "HARDCOP Y? (REQUIRES GRAPHTI CARD) Y/N"; R$ : IF R$ < > "Y" THEN 70
0
590 PRINT : PRINT : INPUT "SMALL (3X4) OR LARGE (6X8) S12 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 = SQRT(-2 * LOG(CU))
5670 Y(I) = (-T + (C0 + C1 * T + C2 * T * T) / (1 + T * (D1 + 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 NEXT.
T. SELECT THE STATIS FILE TO BE PLOTTED AND TYPE IN FILE NAME
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$:"CLOSE"
85  C0 = 2.515517:C1 = .802853:C2 = .018328
86  D1 = 1.432798:D2 = .189269:D3 = .001308
90  PRINT "MIN CUM = ";YY(I);" MAX CUM = ";YY(20)
92  INPUT "ENTER YMIN, YMAX FOR CUM LOADING PLOT (MUST BE INT
TEGRAL POWERS OF TEN) ";YL,YM
95  HGR2
100  & SCALE,.1,100,YL,YM
101  & LIMIT,.2,7,0,1
110  & LOG X: & LOG Y
120  LX$ = "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" & CENTER ylabel,.02, SQR
(YL X YM)
154  LABEL$ = NM$: & LABEL,.2,.6 X YM
159  FOR I = 1 TO NP
160  & OPENCIRCLE,XP(I),YY(I)
165  & ERR OR BARS,0,CY(I)
170  NEXT I
176  FOR I = 1 TO 5000: NEXT I
179  TEXT : HOME : INPUT "HARDCOPY? (REQUIRES GRAPHITTI CARD
) Y/N ":R$: IF R$ < > "Y" THEN 200
180 PRINT : PRINT : INPUT "$MALL (3X4) OR LARGE (5X8) SI"E FOR PLOT ";R$: 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,.2,.7,0,1
280 & LOG X: & LOG Y
290 LABEL$ = "DM/DLOGD, MG/DNM3"
299 & AXES,.1,YL,1,YM / 2
300 & FRAME
305 & CENTERVLBL,.02, SQRT (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 "$MALL (3X4) OR LARGE (6X8) SI"E FOR PLOT ";R$: 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 = SQRT (-2 * LOG (CU))
5670 Y(I) = (-T + (C0 + C1 * T + C2 * T * T) / (1 + T * (D1 + 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 DELETED ":TN
30 PRINT: INPUT "ENTER RUN ID OF RUN TO BE DELETED ":RN$  
35 PRINT: INPUT "ENTER I>INLET OR O>DUTLE 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 PRINT "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
SETUP

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 10000
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) = "0" 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),G3: PRINT R$
370 CALL BU,R$,F$(11),F1: PRINT R$
380 CALL BU,R$,F$(12),F2: 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 "$ 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

A-99
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
448 IF A$ = "E" AND ST$ = "RECT." THEN INPUT "ENTER DUCT D
449 IF A$ = "D" AND ST$ = "ROUND" THEN INPUT "ENTER DUCT D
450 A = VAL (A$)
451 IF A = 1 AND Q$ = "N" THEN INPUT "RUN NO. = ";N$: GOTO 165
452 IF A = 2 AND Q$ = "N" THEN INPUT "SUBSTRATE SET = "; A2
453 IF A = 3 AND Q$ = "N" THEN INPUT "TYPE/SHELL/PLATE = "; I$; GOTO 165
454 IF A = 1 AND Q$ = "Y" THEN INPUT "TEST CODE = "; M$: GOTO 165
455 IF A = 2 AND Q$ = "Y" THEN INPUT "NO. PORTS = "; B1: GOTO 165
456 IF A = 3 AND Q$ = "Y" THEN INPUT "NO. POINTS/PORT = "; B2: GOTO 165
457 IF A = 4 THEN INPUT "DATE = "; G$: GOTO 165
458 IF A = 5 THEN INPUT "% O2 = "; G1: GOTO 165
459 IF A = 6 THEN INPUT "% CO2 = "; G2: GOTO 165
460 IF A = 7 THEN INPUT "% H2O = "; G5: GOTO 165
461 IF A = 8 THEN INPUT "AMB PRES = "; P1: GOTO 165
462 IF A = 9 THEN INPUT "DEL P STACK = "; P2: GOTO 165
463 GOTO 165
464 G4 = 100 - G1 - G2
465 P3 = P1 + P2 / 13.6
466 M1 = .32 * G1 + .44 * G2 + .28 * G4
467 M2 = (100 - G5) * M1 / 100 + .18 * G5
468 FK = F + 460
469 IF F1 = 1 THEN 1110
470 IF F4 = 1 OR F9 = 1 THEN 1300 REM GOTO PORT 
471 REM ** VEL TRAVERSE
472 I = 0
473 I = I + 1
474 IF I > B1 THEN I = 1
475 HOME : PRINT "VELOCITY TRAVERSE": PRINT
476 CALL BU,R$,F$(14),I: PRINT R$
477 CALL BU,R$,F$(15),C: PRINT R$
478 PRINT : PRINT "POINT # Vp(H2O) T(degF) VEL(ft/s)"
479 SP = 1: IF ST$ = "ROUND" AND I = 1 THEN SP = 0
480 FOR K = SP TO B2
481 CALL BU,R$,F$(15),K,O(I,K),T(I,K),V(I,K): PRINT R$
482 NEXT K
483 CALL BU,R$,F$(17),Y(I): PRINT R$
484 CALL BU,R$,F$(18),X(I): PRINT R$
485 CALL BU,R$,F$(19),O(A(I)): PRINT R$
486 IF SP = 0 THEN PRINT : PRINT "NOTE: POINT '0' IS CENTE
R (FOR CONTOURS)
810 UTAB 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) =
900 HTAB 13: INPUT "T = ";R$: IF R$ < > "" THEN T(I,A) =
910 CJ = 0
915 X(I) = 0
916 Y(I) = 0
918 IF SP = 0 AND A = 0 THEN V(1,0) = 85.48 X C / SQR (P3 X
M2) X SQR (O(1,0) X (T(1,0) + 460))
920 FOR J = 1 TO B2
940 V(I,J) = 85.48 X C / SQR (P3 X M2) X SQR (O(I,J) X (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)) X 85.48 X C) X SQR
<P3 X 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$,F0$,Z3: PRINT R$
1140 PRINT: CALL BU,R$,F$(19),D2: PRINT R$: PRINT
1150 Q2 = Z1 X D2 X 60
1160 Q3 = Q2 X 530 /(460 + Z2) X P3 / 29.92 X (100 - 65) /
100
CALL BU,R$,F$(20),Q2: PRINT R$
CALL BU,R$,F$(21),Q3: PRINT R$
VTAB 20: PRINT "PRESS ITEM NO TO CHANGE,P TO PRINT DATA,A,D FOR DELTA P PROGRAM,V FOR NEW VELOCITY PROGRAM,S FOR DISK SAVE"
VTAB 23: HTAB 13: GET A$
IF A$ = "S" THEN GOSUB 20000: REM SAVE TRAVERSE TO DISK
IF A$ = "3" THEN INPUT "DUCT AREA = ";D2: GOTO 1110
IF A$ = "P" THEN GOSUB 8000: GOTO 1110 REM VEL OUTPUT
IF A$ = "V" THEN F9 = 0: GOTO 150
IF A$ = "D" THEN Q$ = "N":F9 = 1: GOTO 190
IF A$ = "1" THEN INPUT "DUCT VEL = ";Z1: GOTO 1110
IF A$ = "2" THEN INPUT "DUCT TEMP = ";Z2: GOTO 1110
GOTO 1110
REM ** PORT NO.
PRINT : PRINT "SELECT": INPUT "PORT NO., M(<MANUAL), OR A(<ALL) "":O$
IF O$ = "A" THEN 1400
IF O$ = "M" THEN INPUT "MANUAL CALCULATION ON PORT NO.":O$: GOTO 1450
N = VAL (O$)
V = Y(N)
T = X(N)
PRINT : CALL BU,R$,F$(24),V: PRINT R$
CALL BU,R$,F$(25),T: PRINT R$
GOTO 1570
V = 21
T = 22
PRINT : CALL BU,R$,F$(17),V: PRINT R$
CALL BU,R$,F$(18),T: PRINT R$
GOTO 1570
HOME : PRINT "MANUAL VELOCITY": PRINT
CALL BU,R$,F$(26),V: PRINT R$
CALL BU,R$,F$(27),T: PRINT R$
PRINT : PRINT "PRESS 1 OR 2 TO CHANGE,C TO CONTINUE,V TO RESTART": GET A$: PRINT A$
IF A$ = "V" THEN 190
IF A$ = "C" THEN 1580
A = VAL (A$)
VTAB 8: PRINT ": VTAB 8: HTAB 13
IF A = 1 THEN INPUT "GAS VEL = ";V: GOTO 1450
IF A = 2 THEN INPUT "GAS TEMP = ";T: GOTO 1450
GOTO 1450
REM ** IMP FLOW RATE
PRINT : PRINT "C TO CONTINUE": GET Z$: PRINT
HOME : PRINT "IMPACTOR FLOW RATE CALCULATION": PRINT
PRINT "IMPACTOR TYPE 1) ANDERSEN"
PRINT 
2) BRINK"
PRINT 
3) PILAT"
PRINT 
4) SERIES CYCLONE"
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 < 1 THEN PRINT "NO MORE - WILL REST
ART": GOTO 1725
1728 D1 = CNV(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

A-103
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$
1990 IF A$ = "N" THEN 1820
1995 IF A$ < > "Y" THEN 1980
2000 X = (Q1 * (100 - 05) / 100 * P3 / (T + 460)) ^ 2 * FK * M1 / .9254
2010 REM % ORIFICE SELECTION
2050 IF M = 2 THEN 2300
2060 HOME : PRINT "ONE ORIFICE": PRINT
2070 CALL BU,R$,F$(31),1,1,01$: PRINT R$
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 - 05) / 100)
2140 NEXT I
2150 PRINT : PRINT "Psiy < > P Tsec Psiy < > 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 = ";01$: GOTO 2060
2270 IF A$ = "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),1,1,01$: PRINT R$
2320 CALL BU,R$,F$(32),2,1,H1: PRINT R$
2330 CALL BU,R$,F$(31),3,2,02$: PRINT R$
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 "Psiy < > P1 < > P2 Psiy < > 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 + .5
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$)
2540 IF A = 1 THEN HTAB 13: INPUT "ORIFICE #1 ID = ";01$: GOTO 2300
2550 IF A = 2 THEN HTAB 13: INPUT "Kcal #1 = ";H1: GOTO 2300
2560 IF A = 3 THEN INPUT "ORIFICE #2 ID = ";02$: GOTO 2300
2570 IF A = 4 THEN INPUT "Kcal #2 = ";H2
2580 GOTO 2300
2590 REM XX FULL OUTPUT
2600 PRINT : PRINT "INSERT RUN SHEET": PRINT "C TO CONTINUE , S TO SKIP ";: GET Z$: PRINT Z$
2610 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$
2660 PRINT : CALL BU,R$,F$(38),A2,G4,P2,T$: PRINT R$
2670 PRINT : CALL BU,R$,F$(34),G5,P3,O1: PRINT R$
2680 PRINT : PRINT : PRINT : PRINT : PRINT : PRINT
2690 CALL BU,R$,F$(39),O1: PRINT R$: PRINT
2700 IF M = 2 THEN 2840
2710 PRINT " ORI ID: ";01$
2720 PRINT " 
"H1
2730 PRINT " GAS METER ";
2740 R = -.5: PRINT
2750 PRINT " P=$<->P TIME"
2760 PRINT " Hg H20 sec"
2770 PRINT " 
--- --- --- ---
2780 FOR I = 1 TO 24
2790 R = R + .5
2800 CALL BU,R$,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 "
<>H8 #1 : ";H1
2860 PRINT "
  ORI #2 ID: ";O2$
2870 PRINT "
<>H8 #2 : ";H2
2880 R = 0: PRINT
2890 PRINT "
  Psys <>P  <>P"
2900 PRINT "
  Hg  H20  H20"
2910 PRINT "
--- --- ---"
2920 FOR I = 1 TO 24
2930 R = R + .5
2940 CALL BU,RS,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$;"PR#1"
8020 CALL BU,RS,F$(40),M$,G$: PRINT R$: PRINT
8030 CALL BU,RS,F$(41),G1,G4,P1,C,D2: PRINT R$: PRINT
8040 CALL BU,RS,F$(42),G2,G5,P2,F: PRINT R$: PRINT
8050 I = 1
8060 I1 = I + 1;I2 = I + 2;I3 = I + 3
8070 IF B1 < I3 THEN 8160
8080 CALL BU,RS,F$(43),I1,I12,I3: PRINT R$: PRINT
8090 PRINT "PT PV T VEL PV T VEL PV T VEL"
8100 PRINT: PRINT "$ H20 F ft/s H20 F ft/s H20 FT ft/s": PRINT
8110 FOR K = 1 TO 82
8120 CALL BU,RS,F$(44),K,0(I,K),T(I,K),V(I,K),0(I1,K),T(I1,
  K),V(I1,K),0(I2,K),T(I2,K),V(I2,K),0(I3,K),T(I3,K),V(I3,K): PRINT R$
8130 NEXT K
8140 PRINT: PRINT: CALL BU,RS,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
8150 GOTO 8410
8160 IF B1 < I2 THEN 8250
8170 CALL BU,RS,F$(43),I1,I12: PRINT R$: PRINT
8180 PRINT "PT PV T VEL PV T VEL PV T VEL"
8190 PRINT: PRINT "$ H20 F ft/s H20 F ft/s H20 FT ft/s": PRINT
FOR K = 1 TO B2
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$
NEXT K
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$: PRINT : PRINT
GOTO 3410
IF B1 < I1 THEN 3340
CALL BU,R$, F$(43), I, I1: PRINT R$: PRINT
PRINT "PT PV T VEL PV T VEL"
PRINT " # H20 F ft/s H20 F ft/s": PRINT
FOR K = 1 TO B2
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$
NEXT K
PRINT : CALL BU,R$, F$(45), OA(I), X(I), Y(I), OA(I1), X(I1), Y(I1): PRINT R$: PRINT : PRINT
GOTO 3410
CALL BU,R$, F$(43), I: PRINT R$: PRINT
PRINT "PT PV T VEL"
PRINT " # H20 F ft/s": PRINT
FOR K = 1 TO B2
CALL BU,R$, F$(44), K, O(I,K), T(I,K), V(I,K): PRINT R$
NEXT K
PRINT : CALL BU,R$, F$(45), OA(I), X(I), Y(I): PRINT R$: PRINT : PRINT
I = I + 4
IF I <= B1 THEN 8060
CALL BU,R$, F$(46), Z1, Q2: PRINT R$
CALL BU,R$, F$(47), Z2, Q3: PRINT R$
CALL BU,R$, F0$, Z3: PRINT R$
PRINT : PRINT D$: "PR#0"
RETURN
REM ** FORMATS **
C = .83; P1 = .30: DIM CN(12); ST$ = "RECT."
F$(0) = "IMPACTOR OP & VELOCITY PROGRAM"
F$(1) = "1) RUN NUMBER (xxxxxI-n) #######"
F$(2) = "2) SUBSTRATE SET "####"
F$(3) = "3) IMP TYPE/ SHELL NO/PLATE NO #######"
F$(4) = "4) TEST CODE (xxxxxI) "####"
F$(5) = "5) NUMBER OF PORTS "####"
F$(6) = "6) NUMBER OF POINTS PER PORT "####"
F$(7) = "7) DATE "####"
F$(8) = "8) % O2 "####"
F$(9) = "9) % CO2 "####"
F$(10) = "10) % H2O "####"
F$(11) = "11) AMBIENT PRESSURE "#### in. Hg"
F$(12) = "12) DELTA P STACK "#### in. H20"
F$(13) = "13) AMBIENT TEMP "#### deg F"
F$(14) = "14) PORT NO "####"
F$(15) = "15) PITOT CONSTANT "####"
F$(16) = "16) "####
F$(17) = "17) AVG DUCT VELOCITY = "#### ft/sec"
19999 REM TRAVERSE SAVE
20000 PRINT :D$ = CHR$(4) ; F1$ = "VEL DATA." + M$
20100 PRINT D$ ; "OPEN" + F1$
20110 PRINT D$ ; "WRITE" + F1$
20120 PRINT ST$ ; PRINT B1 ; PRINT B2 ; PRINT DL ; PRINT DB ; PRINT INT (Z1 X 100 + .5) / 100 ; PRINT INT (V(1,0) X 100 + .5) / 100
20130 FOR I = 1 TO B1
20140 FOR J = 1 TO B2
20150 PRINT INT (V(I,J) X 100 + .5) / 100
20160 NEXT J
20170 NEXT I
20180 PRINT D$ ; "CLOSE" ; RETURN
63999 BU = PEEK (121) + 256 X PEEK (122) + 286 ; CALL BU ; BU = PEEK (6) + 256 X PEEK (7) ; CALL BU + 3 ; RETURN ; REM

==> DO NOT EDIT 63999.

65535 REM
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==> TO REMOVE 'APPENDAGE', ENTER:
JEXEC BU.STRIP

]
1 REM *** DEF/ORI PROGRAM V1.1 ***
2 REM ***CREATES/UPDATES/LISTS INFORMATION IN &.ORI FILE ***
3 REM *** VERSION 1.1 2/2/83 ***
4 REM
5 REM
6 GOSUB 63999
7 D$ = CHR$(4)
8 F1$ = "YES":F2$ = "YES"
9 DIM JN(15), JS(15), JD(15), JL(15), MZ(15)
10 DIM F$(13), A$(30)
11 NMS$ = "--------": SH$ = "CIRC.": SH$ = 0: EF = 0
12 REM ** MAIN PROGRAM **
13 GOSUB 1000
14 GOSUB 2000
15 IF R$ = "Q" THEN GOTO 130
16 GOSUB 2500
17 IF R$ = "Q" THEN GOTO 135
18 IF R$ = "P" GOTO 120
19 IF F1$ = "YES" THEN GOSUB 4000
20 IF F2$ = "YES" THEN GOSUB 5000
21 PRINT "RUN MAIN MENU"
22 REM PRINT D$:"RUN MAIN MENU"
23 REM GOTO 110
24 REM END
25 REM ** FORMAT DEFINITION **
26 REM HOME
27 P = 1
28 F$(0) = "DEF ORI V1.0"
29 F$(1) = "1) HARD COPY OPTION: &"
30 F$(2) = "2) DISK FILE UPDATE: &"
31 F$(3) = "3) ORIFICE SET NAME: &"
32 F$(4) = "4) DESCRIPTION:"
33 F$(7) = "5) NUMBER IN SET: ##"
34 F$(8) = "ORIFICE DIA.(IN) QCAL JET"
35 F$(11) = "ORI. DIA. QCAL PCAL TCAL DPCAL"
36 F$(12) = "NO. (IN) (CMF) (IN HG) (DEG F) (H2O)"
37 F$(13) = "##; #####; ######; #######; ######; ######; ######; ######"
38 REM ONERR GOTO 1170
39 REM HOME
40 PRINT "ERROR: TO CONTINUE PRESS ANY KEY; ERROR CODE = ";
41 PEEK (222): INPUT R$: GOTO 120
42 V TAB 22: PRINT "P)AGE, Q)UIT, OR NUMBER OF ITEM TO ER/CHANGE: ";
43 INPUT R$
44 IF R$ = "Q" THEN RETURN
45 IF R$ = "P" THEN P = P + 1: IF P > 2 THEN P = 1: RETURN
46 IF R$ = "P" THEN RETURN
47 A = VAL(R$): IF A < 1 OR A > 9 THEN GOTO 1400
48 RETURN
REM ** MAIN MENU
2000 P = 1
2010 HOME : PRINT F$(0) + "-PAGE 1 OF 2" 
2020 VTAB 3: CALL BU,R$,F$(1),F1$: PRINT R$
2030 CALL BU,R$,F$(2),F2$: PRINT R$
2040 CALL BU,R$,F$(3),F3$: PRINT R$
2050 CALL BU,R$,F$(4),F4$: PRINT R$
2060 CALL BU,R$,F$(5),F5$: PRINT R$
2070 CALL BU,R$,F$(6),F6$: PRINT R$
2080 CALL BU,R$,F$(7),F7$: PRINT R$
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
2135 A = 0 : IF F1$ = "YES" THEN F1$ = "NO" : RETURN
2140 IF F2$ = "YES" THEN F2$ = "NO" : RETURN
2145 F2$ = "YES" : RETURN
2150 A = 0 : HOME : PRINT F$(0) + " PAGE 1 OF 2"
2155 VTAB 3: INPUT "KEY IN ORIFICE SET LETTER DESIGN: ";Y$
2160 IF Y$ = NI$ THEN RETURN
2165 NI$ = Y$:NF = 1;NM$ = Y$ + "/ORI" : ONERR GOTO 2440
2170 PRINT Y$ : PRINT D$ ; "OPEN ORI/NAM"
2175 PRINT D$ ; "READ ORI/NAM"
2180 OK = 0
2185 INPUT TI: IF TI = 0 THEN PRINT D$ ; "CLOSE ORI/NAM" : PRINT "TI=0" : FOR I = 1 TO 2000: NEXT I: RETURN
2190 DIM N$(TI)
2195 FOR I = 1 TO TI
2200 PRINT D$ ; "CLOSE ORI/NAM"
2205 IF OK = 0 THEN PRINT "OK=0 TI=0" : FOR I = 1 TO 2000: NEXT I: RETURN
2210 REM RETURN
2215 PRINT D$ ; "OPEN" + NM$
2220 PRINT D$ ; "READ" + NM$
2225 INPUT NS
2230 IF NS = 0 GOTO 2450
2235 FOR I = 1 TO NS
2240 INPUT JN(I),JS(I),JD(I),JL(I),JA(I)
2245 NEXT I
2250 GOTO 2450
2255 NF = 0 : PRINT "FILE ERROR "; PEEK (222):EF = 1: STOP
2260 PRINT D$ ; "CLOSE" + NM$: ONERR GOTO 1170 : RETURN
2265 IF A = 0 THEN RETURN
2270 A = 0 : HOME : PRINT F$(0)
2275 VTAB 3: INPUT "ENTER REMARKS/DESCRIPTION: ";RM$: RETURN
2280 A = 0 : HOME : PRINT F$(0)
2285 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 QUIT OR P)AGE"
3100 VTAB 22: HTAB 29: INPUT R$: IF R$ = "Q" OR R$ = "P" THEN RETURN
3108 J = 0
3110 I = VAL (R$): IF I < 1 OR I > NS GOTO 3090
3112 VTAB 21: PRINT "TO CHANGE ENTRY AT CURSOR PRESS 'C' - TO MOVE TO NEXT ENTRY PRESS ANY OTHER KEY"
3115 VTAB 9: HTAB I + 4: HTAB HH - 1: GET R$: IF R$ < > "C" GOTO 3
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$; HH = 5: GOTO 3000
3300 J = J + 1: ON J GOTO 3310, 3320, 3330, 3340, 3350
3310 HH = HH + 7: GOTO 3115
3320 HH = HH + 8: GOTO 3115
3330 HH = HH + 7: GOTO 3115
3340 HH = HH + 5: GOTO 3115
3350 HH = 5: GOTO 3090
3499 STOP
4000 REM *** HARDCOPY OPTION
4010 PRINT "PRINTED COPY OPTION NOW BEING EXECUTED-TURN PRINTER ON AND PRESS ANY KEY": GET R$
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$: PRINT R$

A-112
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$;"PR#0": RETURN
5000 REM XX DISK UPDATE
5081 PRINT ": PRINT D$;"OPEN" + NM$: PRINT D$;"CLOSE" + 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
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"
5600 RETURN
5900 PRINT "DISK ERROR: "; PEEK (222)
5910 PRINT "CHECK DRIVE, ETC. IF NEEDED PRESS 'CONTROL C' AND 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
65536 †BUILDUSING (2,0) †APPENDED.

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== TO REMOVE 'APPENDAGE', ENTER:  
JEXEC BU,STRIP
STATIS

1 REM ISOCORR V 1.0 - AVERAGES DATA AFTER MAKING CORRECTIO
2 REM FOR ISOKINETIC SAMPLING ERROR - USES BELAYEV & LEVIN ALGLR
3 REM COMPUTES AVERAGES AND CONFIDENCE INTERVALS FOR DM
4 REDO AND CM. LOADING. CM. LOADING OBTAINED BY INTEGRATIO
5 N OF AVG DMDLOGD AFTER OUTLIER REMOVAL.
6 REM ORG 2/25/83 JDM - V1.3 4/2/83 - V1.4 2/22/84 - V
7 REM 2.0 8/17/84
8 D$ = CHR$ (4):KF = 180000000:BA = 2:BB = .617
9 HOME
10 DIM X(21),Y(21,20),XP(20),YY(20),DG(20),CP(20)
11 GOSUB 63999
12 GOSUB 1800
13 HOME : PRINT F0$: PRINT ; PRINT
14 PRINT "DO YOU WANT THE DATA CORRECTED FOR" ;IC$: IF IC$ < "Y" AND IC$ <
15 "N" THEN 40
16 HOME : PRINT "IMPACTOR DATA STATISTICS PROGRAM"
17 GOSUB 2000
18 IF OK = 0 GOTO 140
19 GOSUB 3000
20 GOTO 110
21 GOSUB 4000
22 GOSUB 5000
23 GOSUB 6000
24 GOSUB 7000
25 REM PRINT D$;"RUN MAIN-MENU"
26 REM ** INITIALIZE**
27 NF = 20
28 C1 = .34802:C2 = -.0958798:C3 = .7478556:D0 = .47047 / SOR (2)
29 N = 0:IO$ = "INLET":I$ = ".IT"
30 F0$ = " STAT. VER 2.0"
31 F1$ = "####.####
32 F2$ = "####.####; ####.####; ####.####; ####.####; ####.####"
33 F3$ = "#####.####"
34 PRINT D$;"OPEN RUN/NAM" + ",D2"
35 PRINT D$;"READ RUN/NAM"
36 INPUT NR
37 DIM RN$(NR)
38 FOR I = 1 TO NR
39 INPUT RN$(I)
40 NEXT I
41 PRINT D$;"CLOSE RUN/NAM"
42 PRINT FM$(2) = "1) TEST TYPE &; 2) TEST NUMBER ####"
43 PRINT FM$(3) = "3) RUN ## ; &".
44 RETURN
45 REM MENU INSTRUCTIONS
46 VTAB 23: PRINT "C)AT. OF RUNS, Q)UIT, OR NUMBER OF ITE
M TO ENTER/CHANGE: ";
1425 IF R$ = "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,FI$(I): PRINT R$
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 "
19: INPUT "TN= ";TN: GOTO 2020
2170 VTAB 24: HTAB 19: PRINT "
19: INPUT "RUN = ";RN$
2175 NM$ = "T" + STR$(TN) + "R" + RN$ + I$:OK = 0
2176 FOR I = 1 TO NR
2177 IF NM$ = RN$(I) THEN OK = 1
2178 NEXT I
2179 IF OK = 1 THEN RETURN
2180 VTAB 24: INVERSE: PRINT " RUN NOT IN CATALOG - TRY AGAIN"
AIN ": NORMAL : FOR I = 1 TO 2000: NEXT I: GOTO 2020
3000 REM READ RUN FILES
3010 CK = 0
3020 PRINT D$:"OPEN" + NM$ + ",D2": PRINT D$:"READ" + NM$
3030 INPUT DT$: INPUT T$: INPUT LS$: INPUT RR$: 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
INPUT AV; INPUT ND; INPUT IS; INPUT U; INPUT RH
PRINT D$;"CLOSE": IF IC$ = "N" THEN 3050
IF AV < = 0 OR ND < = 0 OR IS < = 0 THEN PRINT "NO VELOCITY OR NOZZLE DIAMETER FOR RUN": PRINT "SPECIFIED - CASE NOT DO ISOKINETIC ERROR": PRINT "CORRECTION - RUN REJECTED": RETURN
IF NI = 1 THEN 22$: DB$: FOR I = 1 TO NP:X(I) = XP(I)
NEXT I
FOR I = 1 TO NP: IF XP(I) < > X(I) THEN CK = 1: NEXT I
IF DB$ < > 22$ THEN CK = 1
IF CK = 1 THEN VTAB 24: INVERSE: PRINT "LAST RUN WAS INCOMPATIBLE IN DIAMETERS": NORMAL: FOR I = 1 TO 2000: NEXT I: RETURN
X1 = YY(1): IF X1 > 0 THEN FL = 1
IF X1 < 0 THEN X1 = -X1: FL = -1
X2 = 1 / (1 + D0 X X1)
X3 = 1 - ((C3 X X2 + C2) X X2 + C1) X X2 X EXP (-X1 X X1 / 2)
Y(0,NI) = TC X (1 + FL X X3) / 2:Y(NP + 1,NI) = TC
IF IC$ = "Y" THEN R = 100 / IS:AV = AV X .508: ND = ND X 2.54
FOR I = 1 TO NP
IF IC$ = "N" THEN Y(I,NI) = DG(I): GOTO 3150
RT = RH X XP(I) X XP(I) / (KF X U)
B = (BA + BB / R) X RT X AV / ND
B = DG(I) / (1 + (R - 1) X B / (B + 1))
NEXT I
HOME: PRINT: PRINT "COMPUTING STATISTICS"
DIM TC(10), CI(NP + 1)
TC(2) = 6.314
TC(3) = 2.920
TC(4) = 3.353
TC(5) = 2.132
TC(6) = 2.015
TC(7) = 1.943
TC(8) = 1.895
TC(9) = 1.86
DIM M(NP + 1), S(NP + 1), C(NP + 1)
INPUT "REMOVE OUTLIERS ? (Y/N)"; OL$: IF OL$ < > "Y" AND OL$ < > "N" THEN 4125
FOR I = 0 TO NP + 1
PRINT "C": SX = 0
SS = 0
FOR J = 1 TO N
Z = Y(I,J)
SX = SX + Z
SS = SS + Z X Z
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 CI(I) = 3E33; GOTO 4380
4235  IF N = 2 THEN CI(I) = TC(2) * S(I) / SQR (2); GOTO 438
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
4285  Z = Y(J, J)
4290  IF ABS (Z - M(I)) > ZZ GOTO 4340
4300  SX = SX + Z
4310  SS = SS + Z * Z
4320  NN = NN + 1
4330  NEXT J
4335  M(I) = SX / NN
4340  IF NN < 1 THEN S(I) = 0; CI(I) = 3E33
4345  S(I) = SQR (ABS ((SS - SX * SX / NN) / (NN - 1)))
4350  IF NN > 2 AND NN < 10 THEN CI(I) = S(I) * TC(NN) / SQR (NN)
4355  IF NN > 10 THEN CI(I) = 1.645 * S(I) / SQR (NN)
4360  NEXT I
4365  REM INTEGRATE FOR AVERAGE CUM. USING MODIFIED SIMPSON'S RULE - MOD. GIVES VALUES AT EVERY X RATHER THAN ONLY FOR ALTERNATE X'S
4370  YY(I) = M(I); DG(I) = CI(I) * CI(0)
4375  FOR I = 2 TO NP
4380  YY(I) = YY(I - 1) + 0.2 * (((I - INT (I / 2) * 2) = 0)  
4385  * (2 * M(I) + M(I - 1)) + (I - INT (I / 2) * 2) = 1) * (2  
4390  * M(I - 1) + M(I)) / 3: DG(I) = DG(I - 1) + (CI(I) * CI(I - 1)) * CI(I - 1) * CI(I - 1) * .01
4395  NEXT I
4400  PRINT
4405  RETURN
5000  REM *** DISPLAY RESULTS ***
5010  HOME
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$,X(I),M(I),S(I),CI(I); PRINT R$
5075  REM FIX SO THAT NA IS PRINTED IF CI=3E33
5080  IF I > NP AND I / 10 = INT (I / 10) THEN PRINT "<  
5090  PRESS SPACE BAR FOR MORE>"; GET R$
5100  NEXT I

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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"
6055 FB$ = " MICRON MG/DNM3 INT MG/D"
6060 FM$ = "####.###; #.###^##; #.###^##; #.###^##; #.###^##; #.###^##; #.###^##; NA #.###^##; NA ;#.# wrongful"
6070 IF ICP$ = "Y" THEN PRINT "******** RESULTS OF STATISTICS WITH ISOKINETIC CORRECTIONS XXXXXXX": GOTO 6075
6072 PRINT "******** RESULTS OF STATISTICS **********"
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 CP(I) = 0
6145 IF CI(I) > 1E32 THEN CALL BU,R$,$FP$,$X(I),$M(I),$S(I),$Y(I),$CP(I): PRINT R$: GOTO 6160
6150 CALL BU,R$,$FM$,$X(I),$M(I),$S(I),$CI(I),$YY(I),$SQR($D6(I)),CP(I): PRINT R$
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$(12)
6210 PRINT D$: "PR#0"
6220 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
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 BUILD USING (2.0) APPENDED.

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==> TO REMOVE 'APPENDAGE', ENTER:
JEXEC BU.STRIPL
UNIT CONVERSION TABLE

<table>
<thead>
<tr>
<th>English to Metric</th>
<th>Metric to English</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 in = 25.40 mm = 2.540 cm</td>
<td>1 cm = 0.3937 in.</td>
</tr>
<tr>
<td>1 ft = 0.3048 m</td>
<td>1 m = 3.281 ft</td>
</tr>
<tr>
<td>1 ft^3 = 0.02832 m^3 = 28.32 liters</td>
<td>1 m^3 = 35.31 ft^3</td>
</tr>
<tr>
<td>1 lb = 453.6 gm</td>
<td>1 gm = 0.002205 lb</td>
</tr>
<tr>
<td>1 grain = 0.06480 gm</td>
<td>1 gm = 15.43 grains</td>
</tr>
<tr>
<td>1 lb/ft^3 = 1.602 x 10^4 gm/m^3</td>
<td>1 gm/m^3 = 6.243 x 10^{-5} lb/ft^3</td>
</tr>
<tr>
<td>1 gr/ft^3 = 2.288 gm/m^3</td>
<td>1 gm/m^3 = 0.4370 gr/ft^3</td>
</tr>
</tbody>
</table>

Nozzle Sizes

<table>
<thead>
<tr>
<th>Others</th>
<th>Fractional Inches</th>
<th>Decimal Inches</th>
<th>Decimal mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 m^3 = 10^3 liters = 10^6 cm^3</td>
<td>1/8 = 0.125</td>
<td>= 3.18</td>
<td></td>
</tr>
<tr>
<td>1 cm^3 = 1 cc = 10^-3 liters</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 µm = 10^-6 m = 10^4 Å</td>
<td>3/16 = 0.1875</td>
<td>= 4.76</td>
<td></td>
</tr>
<tr>
<td>1 lb = 7,000 grains</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 in. Hg = 13.6 in. H_2O</td>
<td>1/4 = 0.250</td>
<td>= 6.35</td>
<td></td>
</tr>
<tr>
<td>R = 0.08205 liter-atm/mole-K</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 gm/gm-mole = 1 lb/lb-mole = 1 amu</td>
<td>5/16 = 0.3125</td>
<td>= 7.94</td>
<td></td>
</tr>
<tr>
<td>°R = °F + 460</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>°K = °C + 273.2</td>
<td>3/8 = 0.375</td>
<td>= 9.53</td>
<td></td>
</tr>
<tr>
<td>°C = (5/9) (°F - 32)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>°F = (9/5) °C + 32</td>
<td>1/2 = 0.500</td>
<td>= 12.70</td>
<td></td>
</tr>
<tr>
<td>1 ft/sec = 0.6818 miles/hr</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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_d, for a isolated Type S Pitot Tube may be assigned a baseline value of 0.83 if the geometry of the Pitot meets the dimensional criteria 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.

\[ V_A = \left( \frac{P_N}{P_A} \right) \left( \frac{T_A}{T_N} \right) V_N \]

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