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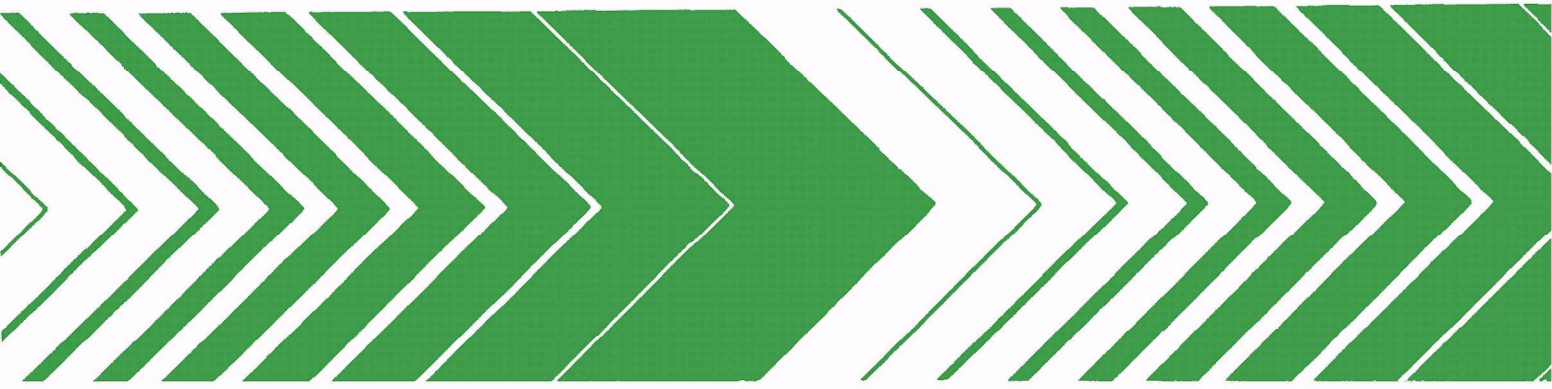
Beta Gauge Operation Manual



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August 1979

BETA GAUGE
OPERATION MANUAL

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ABSTRACT

Commercial beta gauges are presently being utilized to monitor particulates from stacks and for atmospheric monitoring. However, no instrument has been available that is programmed to obtain collections from separate portions of the federal test cycle for mobile sources, with the sensitivity exhibited by EPA's present development unit. Such an instrument is needed in the field as a means to measure mobile source emissions for implementing a possible particulate standard for light duty and diesel equipped vehicles. This project has addressed the urgent need for such an instrument.

Under the terms of the present contract, a previously produced instrument was modified to provide the necessary operations. This instrument was completely rewired to provide reliable field operation. In addition, the control electronics were replaced with a microprocessor-based controller. This controller was provided with all necessary control and computation algorithms for automatic sampling, and for automatically processing the variables to compute the final emission rate in grams per kilometer. The instrument was specifically designed to comply with the sampling sequence described in the Federal Register, Part II, Volume 37, Number 221, November 15, 1972, and it is fully compatible with the Federal Exhaust Emission Testing procedure.

Major modification to the instrument has created significant changes in operating procedures. This manual details the changes made to the instrument and provides complete operating instructions for the unit. From the operator's viewpoint, this manual is complete and self-contained. However, anyone wishing to gain a detailed knowledge of the inner workings of the instrument must use this manual in conjunction with previous operating manual (EPA Report Number EPA-650/2-74-065). Appendix B of this manual lists the sections of the previous manual which are still applicable.

This report was submitted in fulfillment of Contract No. 68-02-2431 by Brower Electronics Laboratories under the sponsorship of the U.S. Environmental Protection Agency. This report covers the period August 17, 1976 to May 24, 1979.

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LIST OF ABBREVIATIONS AND SYMBOLS

ABBREVIATIONS

CTS	-- counts
G/KM	-- grams per kilometer (g/km)
M	-- cubic meters (m^3)
M/C	-- cubic meters per count (m^3/cts)
M/KM	-- cubic meters per kilometer (m^3/km)
SEC	-- seconds
UG	-- micrograms (µg)
UG/M	-- micrograms per cubic meter (µg/m)

SYMBOLS

AC	--air counts (cts)
BC	--beta constant (µg)
B1	--background count #1 (cts)
B2	--background count #2 (cts)
B3	--background count #3 (cts)
C	--concentration (µg/m^3)
FC	--flow constant (m^3/cts)
F1	--flow count #1 (cts)
F2	--flow count #2 (cts)
F3	--flow count #3 (cts)
M	--sample mass (µg)
SC	--sample units (cts)
S1	--sample count #1 (cts)
S2	--sample count #2 (cts)
S3	--sample count #3 (cts)
T1	--sample time 1 - single cycle (sec)
T2	--sample time 2 - unused (sec)
V	--volume collected (m^3)
V1	--volume collected #1 (m^3)
V2	--volume collected #2 (m^3)
V3	--volume collected #3 (m^3)
XQ	--X/QM (m^3/km)
Y	--emission rate (g/km)
Y1	--particulate mass #1 (µg)
Y2	--particulate mass #2 (µg)
Y3	--particulate mass #3 (µg)

SECTION 1

INTRODUCTION

This manual provides a description and operating instructions for the redesigned Beta Gauge. Section 2, BETA GAUGE CHANGES, describes the changes and new controls of the three units. The Computer Unit is described in detail because it differs radically from the former unit, both in controls and operations. Section 3, BETA GAUGE OPERATION, provides complete operating instructions for the Single and Federal Cycles, as well as set-up and calibration procedures. A Troubleshooting Guide completes the manual with instructions for locating problems. Illustrations accompany all sections when needed.

A previous manual, Advanced Prototype Direct Reading Instrument for Particulate Mass Measurement (EPA-650/2-74-065, June 1974), supplied by a previous contractor, provides valuable information about the present Beta Gauge and is referred to as the "previous manual" in this report. Appendix A lists the valid sections of this previous manual.

SECTION 2

BETA GAUGE CHANGES

INTRODUCTION

All units of the Beta Gauge have undergone revision. The following two sections describe changes in the Sample and Flow Units which affect the operation. The previous manual provides additional details not covered here. The Computer Unit is described in detail in the last section. The only valid Computer Unit information in the previous manual is the cassette slide sequencing and the formulas.

Sample Unit Changes

There are two changes in the Sample Unit which need to be mentioned. The first concerns controls available to the operator. The second concerns the cassette slide position.

The front and back-panel controls on the Sample Unit have remained unchanged in labeling and function. The manual drive controls inside the Sample Unit have been relabeled (Figure 1). The ENABLE/DISABLE DRIVE switch directly disables the drive motor. No control signals reach the motor when this switch is in the DISABLE position. The LEFT/RIGHT DRIVE switch moves the cassette slide left or right (facing the front panel) when the drive is enabled and the Computer Unit is not trying to move it in the opposite direction. The center position is "OFF". When not in use, this switch is left in the "OFF" position. These are the only operator controls inside the Sample Unit.

Figure 2 illustrates the cassette slide mechanism and defines the position numbers used throughout the manual. There are four positions. Position 1 is the left-most cassette slide position (facing the front panel). Position 4 is the right-most position.

NOTE: Ignore the cassette slide position numbers in the previous manual -- these are different.

All cassette positions are sensed with mechanical switches. Hystersis is removed by always positioning the cassette with movement to the right. Thus, if the cassette moves from position 4 to position 3, it will actually move left past position 3, then move back and stop at position 3.

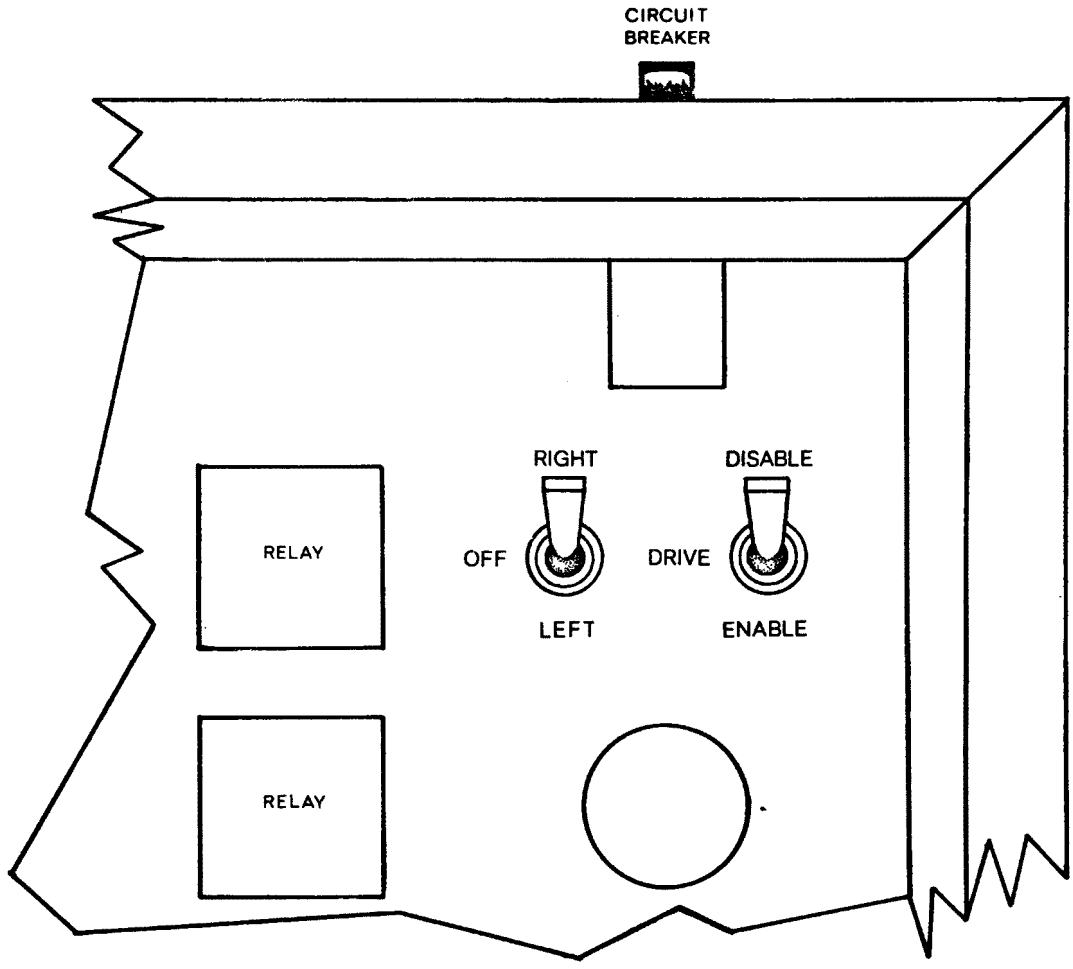

Figure 1. Cassette Drive Switches

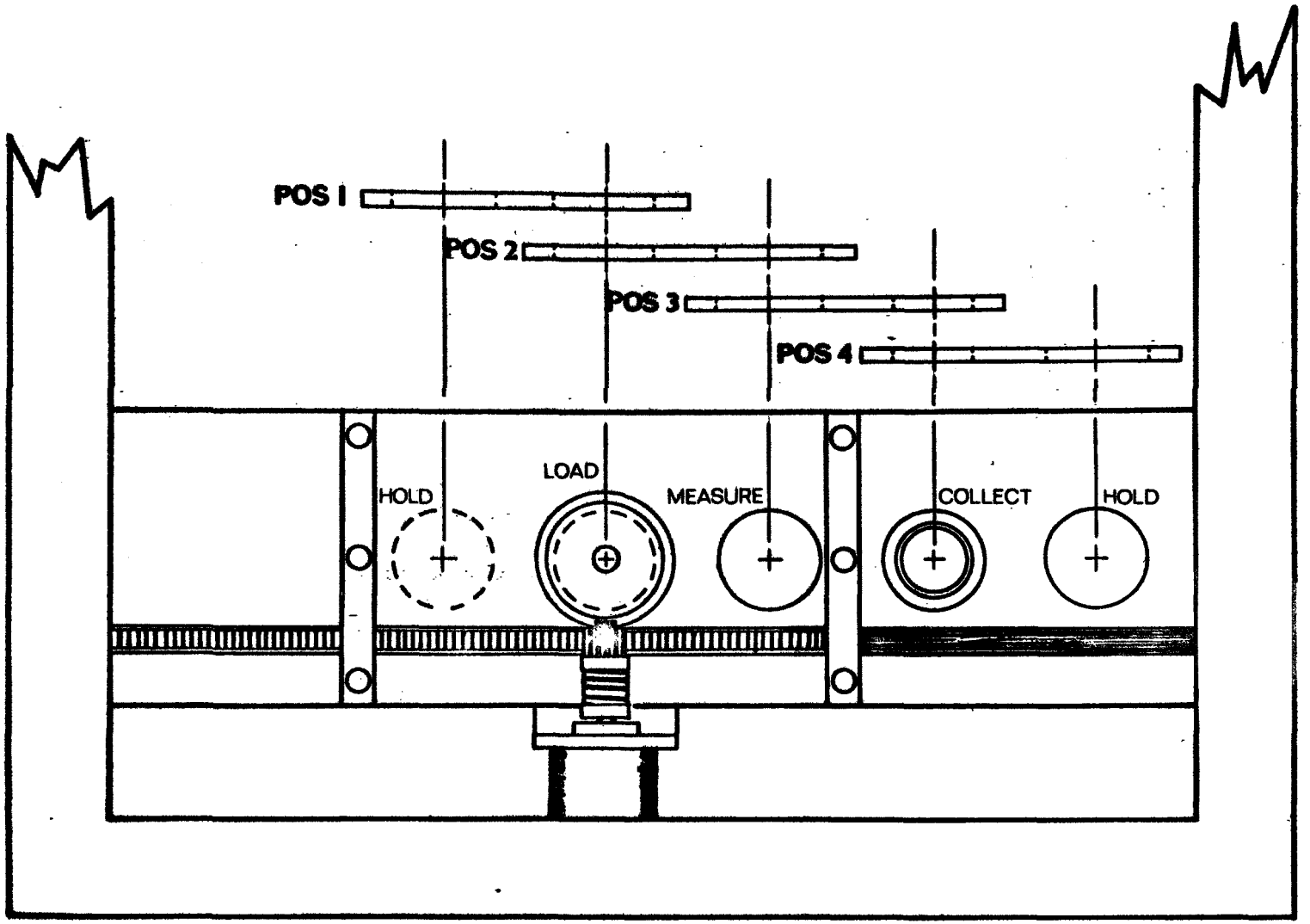

Figure 2. Cassette Slide Positions

Refer to the previous manual for information on external Sample Unit controls.

Flow Unit Changes

The Flow Unit controls have not changed, except the SET FLOW switch function. There are no operator controls inside the Flow Unit.

The SET FLOW switch turns the cassette clamp and pump on when it is "ON". If the SET FLOW switch is turned on after the cassette slide moves to position 3 during the Calibration Cycle, the Computer Unit waits until it is turned off before continuing the cycle. This provides convenient positioning of the test filter cassette for setting the flow.

Refer to the previous manual for information on other Flow Unit controls.

Computer Unit Changes

The following sections define the Computer Unit controls and their function, the subsystems, and interpretation of the output. Instructions on when and how to use the controls are in the section on Beta Gauge Operation.

Front Panel--

The controls on the front panel may be grouped into seven units:

1) Numeric Keypad
2) Control Keypad
3) Status Display
4) Numeric Display
5) Cycle Controls
6) Printer
7) Power Switch

Each unit is described in the following paragraphs. Figure 3 illustrates the front panel controls.

1) Numeric Keypad - The numeric keypad is a group of twelve keys arranged in a 3 x 4 pattern. The keys are labeled 0 through 9, ".", and "-". They are used in the selection and entry of constants. These keys are active only when the PUSH TO CONTINUE switch is illuminated.

2) Control Keypad - The control keypad is a group of eight keys arranged in a 2 x 4 pattern. Six of the keys are defined as follows:

CNTL - The CONTROL key, when followed by a numeric key between 1 and 8, inclusive, selects one of the program constants for review and change. When held down simultaneously with the ABRT key, the CNTL key initiates an abort sequence (see ABRT below).

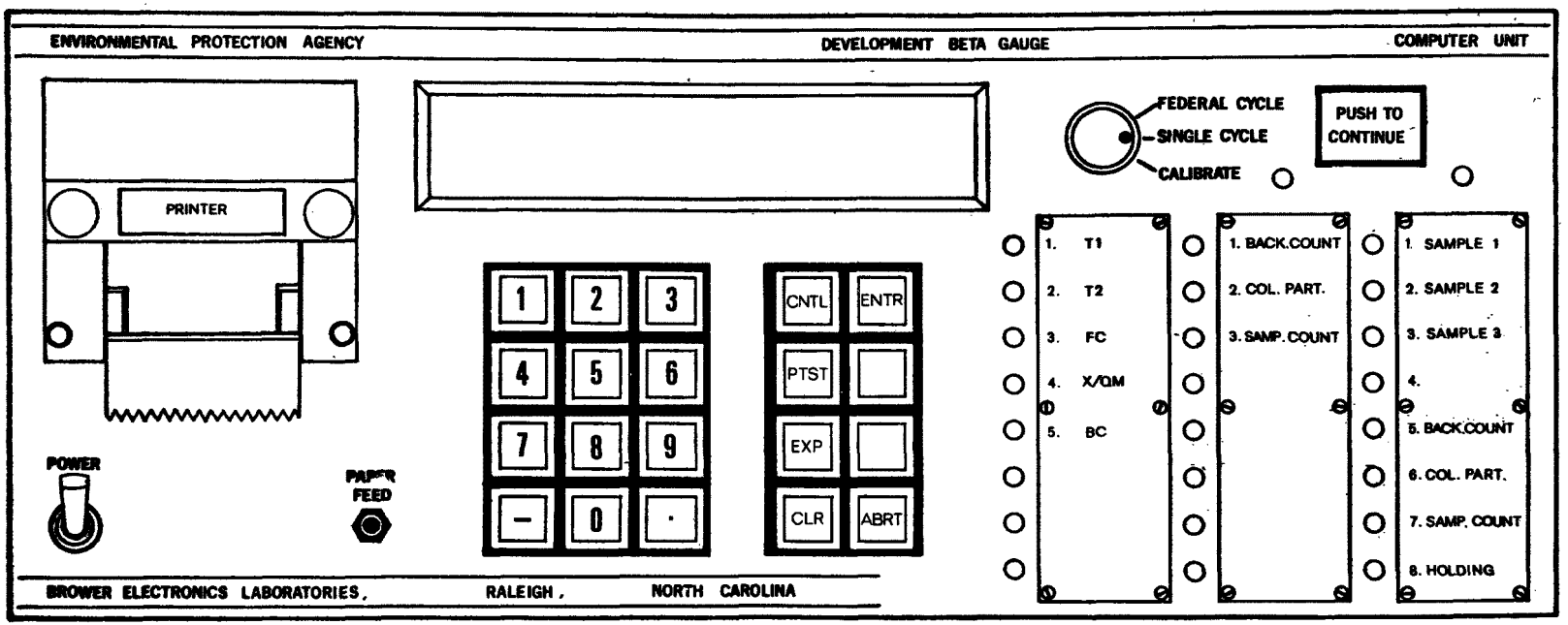

Figure 3. Computer Unit Front Panel

PTST - The PRINT STATUS key prints the system status at that instant. Table 1 shows a sample listing generated when the PTST key is used. The section on System Status explains the constants used.

EXP - The EXPONENT key separates the exponent from the mantissa when entering floating point constants.

CLR - The CLEAR key erases any constant being entered. It is used to recover from an entry mistake when changing constants.

ENTR - The ENTER key stores the displayed number into the constant selected by the CNTL and number keys. This action terminates examination and entry of constants.

ABRT - The ABORT key, when held down simultaneously with the CNTL key for at least one second, initiates an abort sequence. This sequence has the following effects:

1. Termination of any constant examination and entry routine.

2. Termination of all cycles. No results are printed. The cassette slide moves to its initial position, which depends on the MODE switch setting.

When the abort sequence starts, the CNTL key must be released first, followed by the ABRT key. When the abort sequence has finished, the PUSH TO CONTINUE (PTC) switch will light. A constant may now be examined or a cycle started.

With the exception of the ABRT key, the control keypad is recognized only when the PTC switch is illuminated. The CNTL and ABRT keys are recognized at any time if held down simultaneously for at least one second.

3) Status Display - The status display is a group of three labeled columns of eight lamps per column. These indicate the present status of the gauge and define what is presently shown on the numeric display. The left column is active when examining and entering constants. The center column is active during the Single Cycle. The right column is active during the Federal Cycle.

4) Numeric Display - The numeric display contains twelve seven-segment digits with decimal points. The system clock is shown when the gauge is inactive. Constants are shown during the Single or Federal Cycles. The status display defines the contents of the numeric display.

5) Cycle Controls - The MODE switch and PTC switch are the cycle controls. The MODE switch is a rotary switch which chooses the cycle to be exexuted. If the MODE switch is left in an undefined position, the status listing indicates "???" for MODE and the Federal Cycle is executed. The PTC switch initiates all cycles and is used by some cycles to continue the

cycle at a certain point. A lamp inside the PTC switch illuminates the switch when the gauge is waiting for input.

6) Printer - The printer lists the results from each cycle and the system status. The output is alpha-numeric and contains data names and units. The interpretation of these listings may be found in the section on Interpretation of Output. A button marked PAPER FEED advances the printer paper when held down. Loosening the two silver knobs on the printer face enables removal of the mechanism for changing paper. The two black knobs hold the replaceable printer ink pad.

7) Power Switch - The power switch supplies power to the Computer Unit. When "OFF", no control signals are provided to the Sample and Flow Units. Therefore, to avoid any mishap, the Computer Unit should be turned "ON" first and "OFF" last. A Power-On feature resets the Computer Unit when power is first applied.

Back Panel--

The back panel has four details of interest. Each is described below:

RESET - The MASTER RESET switch is located just above the 37-pin connector. Depressing and releasing this switch simulates a power-on clear which, (1) initializes the Computer, (2) erases the system clock, date and runs number, and (3) restores the preset system constants.

POWER - The Computer Unit requires about one ampere at 120 volts a-c, grounded. The line cord is detachable.

FUSE - The Computer Unit uses a 3AG, 2A fuse rated at 125V for overcurrent protection.

SAMPLE UNIT CONNECTOR - The control and data signals from the Sample Unit enter the Computer Unit through this 37-pin connector.

Internal Subsystems--

The right side of the unit houses a four-card, 8080 microprocessor control system. These cards are, from right to left: (1) the CPU card, (2) the V/F and DUAL COUNTER card, (3) the I/O card, and (4) the MEMORY card. Each card is described briefly in the following paragraphs.

The CPU card contains the 8080 CPU, clock and system bus electronics. The operations of the gauge are sequenced by a program executed by the CPU card.

The V/F and DUAL COUNTER card contains two 8-digit BCD counters and one voltage-to-frequency converter. One counter accumulates beta counts from the photomultiplier tube (PMT). The second counter accumulates flow counts

from the V/F converter, whose input voltage comes from the flow meter in the Flow Unit. Both counters may be independently read and reset by the CPU.

The I/O card consists of several buffered input and output ports. Each port provides eight signal lines which sense and control the Beta Gauge mechanisms. Provision is made for additional lines for future refinements. A separate circuit on the I/O card generates a one-second timing signal for the CPU program's internal clocks.

The MEMORY card contains both volatile and non-volatile memory for program storage and use. The program and initial constants are stored in erasable, reprogrammable read-only memories. These retain their contents when power is removed but may be erased and reprogrammed using special equipment. Variables and temporary data are stored in random access memories which lose information when power is removed. Additional capacity is available for enlarging the present program.

The left side of the unit houses the printer and its electronics. The front panel controls and power supplies make up the remainder of the Computer Unit. A fan exhausts air out of the back of the unit to ensure cooling of the printer and control elcetronics.

Interpretation of Output

The output from the Computer Unit is in the form of labeled listings from the printer. The contents of these listings depend on the cycle which generated them. In addition, all listings contain a common section, the system status, which can also be printed on demand with the PRINT STATUS (PTST) switch. Therefore, this section on interpretation of output begins with the system status output, then covers the Single, Federal and Calibration Cycles. All abbreviations used in the output listings are given on page vii.

System Status--

Table 1 is an example of the system status portion of any listing. The following paragraphs describe each line of the listing:

LINES 1-4: HEADER. The heading "EPA BETA GAUGE" is printed at the beginning of all listings.

LINE 5: TIME AND DATE. The system clock is printed first (hours:minutes), followed by the date (month-date-year). These are initialized by the operator after a RESET of Power-On-Clear. The clock is a twenty-four hour format.

LINE 6: RUN NUMBER. A four-digit run number is printed. The run number is initialized to zero after a RESET or Power-On-Clear. The run number is incremented after a Single, Federal or Calibrate Cycle has been completed. The PRINT STATUS (PTST) switch does not affect the run number.

LINE 7: TIME CONSTANT 1 (T1). Time Constant 1 is a four-digit number which determines the collection time (in seconds) during the Single Cycle. T1 is initially zero and must be set by the operator before starting the Single Cycle.

LINE 8: TIME CONSTANT 2 (T2). Time Constant 2 is a four-digit number which is presently unused.

LINE 9: FLOW CONSTANT (FC). The Flow Constant is a seven-digit floating-point constant used exclusively in the Federal Cycle. This number is initially zero and must be set by the operator before running the Single of Federal Cycles.

LINE 10: X/QM CONSTANT (XQ). The X/QM Constant is a seven-digit floating-point constant used exclusively in the Federal Cycle. This number is initially zero and must be set by the operator before running the Federal Cycle.

LINE 11: BETA CONSTANT (BC). The Beta Constant is a seven-digit floating-point constant used to calculate particulate mass from count ratios. This number is initially zero and must be set by the operator before running any cycles.

LINES 12-14: MODE. The present setting of the MODE switch is printed. Question marks (?????) are printed if the setting is not defined.

This completes the common portion of all listings.

TABLE 1. SYSTEM STATUS LISTING

Line	Listing	Description
1	**********	
2	EPA	HEADER
3	BETA GAUGE	
4	**********	
5	12:34 08-05-77	TIME DATE
6	RUN No. 0000	RUN NUMBER
7	T1 0000 SEC	TIME CONSTANT 1
8	T2 0000 SEC	TIME CONSTANT 2
9	FC 0.000000 M/C	FLOW CONSTANT
10	XQ 0.000000 M/KM	X/QM CONSTANT
11	BC 0.000000 UG	BETA CONSTANT
12	----------	
13	?????????????	MODE
14	----------	

Single Cycle--

Table 2 shows a listing from a Single Cycle. The top 14 lines are the system status as described above. The bottom 6 lines are generated by the Single Cycle.

LINE 15: BACKGROUND COUNT (B1). This number of counts is taken on the filter before collecting particulates.

LINE 16: SAMPLE COUNT (1). This number of counts is taken on the fil- after collecting particulates.

LINE 17: FLOW COUNT (F1). This number of counts records the volume increments during collection.

LINE 18: SAMPLE VOLUME (V). The volume of gas sampled is:

$$V = F1 \times FC$$

where	V	= Volume	(m^3)
	F1	= Flow Counts	(cts)
	FC	= Flow Constant	(m^3/cts)

LINE 19: PARTICULATE MASS (M). The mass of the particulated collected is:

$$M = BC \times \ln(B1/S1)$$

where	M	= Mass	(µg)
	BC	= Beta Constant	(µg)
	B1	= Background Count	(cts)
	S1	= Sample Count	(cts)

LINE 20: CONCENTRATION (C). The concentration of particulates in the volume of air collected is:

$$C = M/V$$

where	C	= Concentration	(µg/m^3)
	M	= Mass	(µg)
	V	= Volume	(m^3)

This concludes the listing from a single cycle.

TABLE 2. SINGLE CYCLE LISTING

Line	Listing	Description
1	**********	
2	EPA	
3	BETA GAUGE	HEADER
4	**********	
5	12:34 08-05-77	TIME DATE
6	RUN No. 0001	RUN NUMBER
7	T1 0500 SEC	TIME CONSTANT 1
8	T2 0000 SEC	TIME CONSTANT 2
9	FC 9.82150E-08 M/C	FLOW CONSTANT
10	XQ 1.000000 M/KM	X/QM CONSTANT
11	BC 13711.05 UG	BETA CONSTANT
12	----------	
13	SINGLE CYCLE	MODE
14	----------	
15	B1 5392507 CTS	BACKGROUND COUNT
16	S1 5062870 CTS	SAMPLE COUNT
17	F1 5564534 CTS	FLOW COUNT
18	V .5465066 M	SAMPLE VOLUME
19	M 864.8510 UG	SAMPLE MASS
20	C 1582.508 UG/M	CONCENTRATION
21	----------	

Federal Cycle--

Table 3 shows a sample listing from the Federal Cycle. The top 14 lines are the system status described earlier in this section. The bottom 16 lines are generated by the Federal Cycle.

LINES 15, 18, 21: BACKGROUND COUNTS 1, 2, 3 (B1, B2, B3). These beta counts are taken on each filter before collecting particulates.

LINES 16, 19, 22: SAMPLE COUNTS 1, 2, 3 (S1, S2, S3). These beta counts are taken on each filter after collecting particulates.

LINES 17, 20, 23: FLOW COUNTS 1, 2, 3 (F1, F2, F3). These flow counts record the volume increments for each sample during particulate collection.

LINES 24, 25, 26: PARTICULATE MASSES 1, 2, 3 (Y1, Y2, Y3). These are the calculated particulate masses (in μg) for each sample.

LINES 27, 28, 29: SAMPLE VOLUMES 1, 2, 3 (V1, V2, V3). These are the calculated gas volumes (in m^3) for each sample.

LINE 30: EMISSION RATE (Y). This figure is calculated using

$$Y = XQ \times \frac{(0.43Y1 + 0.57Y2 + Y3) \times 10^{-3}}{V1 + V2 + V3}$$

where Y1, Y2, Y3 = Particulate Masses (μg)
V1, V2, V3 = Sample Volumes (m^3)
XQ = X/QM Constant (m^3/km)
y = Emission Rate (g/km)

This concludes the listing from a Federal Cycle.

Calibration Cycle--

Table 4 shows a sample listing from the Calibration Cycle. The top 14 lines are the system status described earlier in this section. The bottom 3 lines are generated by the Calibration Cycle.

LINE 15: AIR COUNT (AC). The background count on the air between the source and detector.

LINE 16: SAMPLE COUNT (SC). The sample count on the calibrated sample.

LINE 17: SAMPLE MASS (M). The calculated sample mass.

This concludes the listing from the Calibration Cycle.

TABLE 3. FEDERAL CYCLE LISTING

Line	Listing	Description
1	**********	
2	EPA	
3	BETA GAUGE	HEADER
4	**********	
5	12:34 08-05-77	TIME DATE
6	RUN No. 0002	RUN NUMBER
7	T1 0000 SEC	TIME CONSTANT 1
8	T2 0000 SEC	TIME CONSTANT 2
9	FC 9.821250E-08 M/C	FLOW CONSTANT
10	XQ 1.000000 M/KM	X/QM CONSTANT
11	BC 13711.05 UG	BETA CONSTANT
12	----------	
13	FEDERAL CYCLE	MODE
14	----------	
15	B1 6826693. CTS	BACKGROUND COUNT #1
16	S1 4579379. CTS	SAMPLE COUNT #1
17	F1 7105113 CTS	FLOW COUNT #1
18	B2 5059594 CTS	BACKGROUND COUNT #2
19	S2 4734257 CTS	SAMPLE COUNT #2
20	F2 1.208027E+07 CTS	FLOW COUNT #2
21	B3 5419584. CTS	BACKGROUND COUNT#3
22	S3 3002267. CTS	SAMPLE COUNT #3
23	F3 6425761. CTS	FLOW COUNT #3
24	Y1 5474.506 UG	PARTICULATE MASS #1
25	Y2 911.2562 UG	PARTICULATE MASS #2
26	Y3 8098.451 UG	PARTICULATE MASS #3
27	V1 .6978108 M	COLLECTED VOLUME #1
28	V2 1.186434 M	COLLECTED VOLUME #2
29	V3 .6310900 M	COLLECTED VOLUME #3
30	Y 3.770193E-03 G/KM	EMISSION RATE
31	----------	

TABLE 4. CALIBRATE CYCLE LISTING

Line	Listing	Description
1	**********	
2	EPA	
3	BETA GAUGE	HEADER
4	**********	
5	12:34 08-05-77	TIME DATE
6	RUN No. 0003	RUN NUMBER
7	T1 0000 SEC	SAMPLE TIME 1
8	T2 0000 SEC	SAMPLE TIME 2
9	TC 9.821250E-08 M/C	FLOW CONSTANT
10	XQ 1.000000 M/KM	X/QM CONSTANT
11	BC 13711.05 UG	BETA CONSTANT
12	----------	
13	CALIBRATE	MODE
14	----------	
15	AC 9170647. CTS	AIR COUNT
16	SC 5257185. CTS	SAMPLE COUNT
17	M 7628.992 UG	SAMPLE MASS
18	----------	

SECTION 3

BETA GAUGE OPERATION

GENERAL

This section gives general operating information which is valid for all cycles. When power is first turned on, allow 15 minutes of warm-up time before performing any measurements. This time is needed to stabilize the inlet heater and photomultiplier circuits. Initialization may be done during this time.

Constants may be changed anytime the PUSH TO CONTINUE (PTC) switch is illuminated. A new cycle may be started only if (1) the PTC switch is illuminated, (2) the display shows the system clock, and (3) no cycle status lights are on.

Any cycle or entry of constants may be aborted at any time by pushing the CTRL and ABRT buttons simultaneously for at least one second. This action cancels the cycle, prints no results, and leaves the constants unchanged. This also moves the cassette slide to its initial position.

The CASSETTE DRIVE lamp on the Sample Unit is "ON" when the Computer Unit moves the cassette slide during a cycle. If the cassette slide is jammed or disabled, this lamp remains on and the Computer Unit waits at that step until the cassette slide reaches the requested position. The operator may use the DRIVE ENABLE switch to stop the cycle during the cassette moves if difficulties arise. The cycle will be resumed when the drive is enabled.

The system clock is displayed on the front panel when the Computer Unit is idle or a cassette is being moved. This is a pair of two-digit numbers, separated by a space, indicating the hour and minute. At all other times, the front panel display shows a single four-digit number indicating time in seconds. The status columns indicate the occurring event whose time is shown on the display.

Set-up

The Beta Gauge must be set up with cables connected before power can be turned on. The following sections describe the necessary procedure for each unit and the whole system.

Complete these switch position checks before plugging any unit in:

Computer Unit - The front panel power switch must be "OFF". All other switches are momentary (except MODE, which is not important at this point) and are in their correct positions. Install new roll of printer paper if warning color is visible.

Sample Unit - The HEATER switch should be "OFF". The two DRIVE switches (inside the unit) should be "OFF" and "ENABLE". No filters should be in the cassette magazine or slide. The circuit breaker on the back panel should be "OFF".

Flow Unit - The FLOW METER and FLOW CONTROLLER power switches (front panel) should be left "ON". The AUTOMATIC/MANUAL FLOW CONTROL switch should be AUTOMATIC. The INCREASE/DECREASE FLOW CONTROL switch is momentary and should be in its center "OFF" position. The SET FLOW switch should be "OFF". The circuit breaker on the back panel should be "OFF".

Now connect the units as follows:

1) Use the cable with 37-pin connectors to connect the Computer Unit to the Sample Unit.

2) Use the cable with 26-pin connectors to connect the Sample Unit to the Flow Unit.

3) Use the thick-walled hose to connect the Sample Unit gas outlet to the Flow Unit suction inlet.

4) Connect the Sample Unit gas inlet to the gas source to be measured.

5) Plug all units into a grounded, 115vac power receptacle fused for 15 amperes.

This completes the set-up requirements.

Power-Up Sequence

The Computer Unit is always turned "ON" first and turned "OFF" last. Otherwise, the Sampling and Flow Units operate randomly because computer control is not present.

The power-up sequence is (1) Computer Unit, (2) Sampling Unit, and (3) Flow Unit. The flow pump, cassette drive, and cassette clamp will be off and "1" will be displayed on the Computer Unit if power-up is successful.

If this is not the case, press and release the RESET button on the back of the Computer Unit. If this does not produce the above results, turn the power off (Computer Unit last), check all connections (see section on Set-up), then try again. Refer to Troubleshooting Section for additional help.

Initialization

When power is first turned on, allow 15 minutes for the inlet heater and photomultiplier to stabilize. During this time, the Beta Gauge may be initialized as described in the sections below. Initialization must be completed before the first cycle begins.

Time and Date--

The TIME and DATE must be initialized (1) when the power is turned "ON", or (2) after the RESET button is pushed. Do not use the ABRT key until TIME and DATE are initialized.

The TIME is entered when the Computer Unit displays "1". The format is two digits of hours followed by two digits of minutes (12 34). The system clock uses the 24-hour format. The TIME is keyed in most significant digit first. Leading zeroes must be entered. The CLR key erases the display allowing reentry in case of an operator entry error. The ENTR key sets the system clock to the entered time and advances to the DATE.

The DATE is entered when the Computer Unit displays "2". The format is a two-digit month, two-digit day, and two-digit year (08 02 57). The DATE is entered left-to-right, including leading zeroes. Six digits must be entered before continuing. The CLR key erases the display allowing reentry of the date. The ENTR key stores the number on the display as the system date.

At this time, the Computer Unit checks the cassette slide position. Depending on the MODE switch setting, the cassette slide will move to position 1 or 2. When the correct position is reached, the display shows the system clock, the status lights are off, and the PTC switch is illuminated. The Computer Unit is ready to change constants or begin a cycle.

NOTE: The RESET switch must be used to reset the TIME and DATE. ABRT should not be used until the TIME and DATE have been entered.

Constants--

There are five system constants which may be changed by the operator. These are listed in Table 5 along with their initial value and code number. The initial value is always set when power is turned on or after the RESET switch is pushed. The code number is used to select and change the constant from the front panel keyboard.

The constants may be integers or floating-point numbers. T1 and T2 are positive four-digit integers representing time duration in seconds. FC, X/QM and BC are positive, seven-digit floating-point numbers with an exponent

range of 10^{-38} to 10^{+38}.

Follow these steps to view or change a constant:

1) Wait until the PTC Switch is illuminated. The keyboard is ignored when this light is off.

2) Choose the constant and note its code number. These are abbreviated on the left status light column on the front panel.

3) Select the constant for viewing by pressing and releasing the CTRL key, followed by the code number. After the CTRL key is pressed, the display is blank. After the code number is entered, the display shows the present constant value. The status lights indicate which constant is on display.

4) To keep the constant as is, press ENTR. This saves the constant, clears the status lights and displays the system clock.

5) To enter a new constant, key in the number one digit at a time, most significant digit first. The first digit entered clears the display, which now shows the number being entered.

6) To erase a keying error, press CLR. This erases the entered number and blanks the display. Now reenter the new constant.

7) To exit and set the new constant, press ENTR. This stores the displayed number, clears the status lights and displays the system clock.

8) To exit and retain the previously stored constant, simultaneously press and hold the CTRL and ABRT keys for at least one second. Then release the CTRL key first and the ABRT key last. This keeps the old constant, clears the status lights and displays the system clock.

The PTST key will print these and other system constants when pushed. Table 6 gives an example of the listing produced by a PRINT STATUS request.

TABLE 5. SYSTEM CONSTANTS

Code No.	Descriptipn	Abbrv.	Initial Value *
1	SAMPLE TIME 1	T1	0000
2	SAMPLE TIME 2	T2	0000
3	FLOW CONSTANT	FC	0.
4	X/QM	XQ	0.
5	BETA CONSTANT	BC	0.

* These initial values are stored with the program and may be changed by the manufacturer by programming one of the PROM memories.

TABLE 6. SYSTEM STATUS LISTING

Line	Listing	Description
1	**********	
2	EPA	
3	BETA GAUGE	HEADER
4	**********	
5	12:34 08-05-77	TIME DATE
6	RUN No. 0000	RUN NUMBER
7	T1 0000 SEC	TIME CONSTANT 1
8	T2 0000 SEC	TIME CONSTANT 2
9	FC 0.000000 M/C	FLOW CONSTANT
10	XQ 0.000000 M/KM	X/QM CONSTANT
11	BC 0.000000 UG	BETA CONSTANT
12	----------	
13	??????????	MODE
14	----------	

Inlet Heater

If the Inlet Heater in the Sampling Unit is to be used, turn the HEATER switch "ON". Monitor the temperature on the meter and adjust the ten-turn potentiometer to hold the desired temperature. Once the temperature is set, the controls should need no readjustments.

Flow Rate

The flow rate on the Flow Unit must be set before beginning any cycles. To insure proper flow can be maintained, the flow is set using a filter of the same type as to be used during the measurement cycles. The procedure is as follows:

1) Empty the cassette slide and magazine using the manual slide control switch.

2) Set the MODE control to CALIBRATE.

3) Simultaneously press and hold the CTRL and ABRT keys down for at least one second, then release. The cassette slide will move to position 1. The display shows the system clock, the status lights are off, and the PTC switch is illuminated.

4) Load the cassette magazine with one filter cassette.

5) Press the PTC button. The PTC light extinguishes and the cassette slide carries the filter to position 3.

6) Wait until the CASSETTE DRIVE lamp on the Sample Unit extinguishes, then turn the SET FLOW switch on the Flow Unit "ON". The cassette is clamped, the pump starts, and the COLLECTING PARTICULATE lamp on the Sample Unit turns on.

7) Adjust the SET POINT dial on the Flow Unit until the Flow Meter indicates the desired flow.

8) Turn the SET FLOW switch "OFF". The Computer Unit will wait until it is off before continuing the Calibrate Cycle.

9) Simultaneously press and hold the CTRL and ABRT keys down for at least one second, then release. The cassette slide moves to position 1 and ejects the filter cassette. Then the display shows the system clock, the status lights are off, and the PTC switch is illuminated.

This completes the procedure for setting the Flow Rate.

Single Cycle

This section gives the procedure for using the Beta Gauge in the Single Cycle. The Single Cycle requires 7 minutes for the two beta counts, plus the collection time which is variable. Operator intervention is required to start the cycle and to continue it four minutes later. The procedure and results are:

1) Complete the Set-up and Initialization first. No filter cassettes should be in the Sampling Unit. Set constant T1 to the collection time desired.

2) Set the MODE switch to SINGLE CYCLE. The lamp above the Single Cycle status column should be lit.

3) Press the CTRL and ABRT switches simultaneously for at least one second. The cassette slide moves to position 2, then the PUSH TO CONTINUE (PTC) switch illuminates.

4) Load the cassette magazine with filter cassettes. One cassette is required for each Single Cycle.

The Beta Gauge is ready to begin a Single Cycle.

5) To start a cycle, press the PTC switch. The following events should occur:

    a. The PTC switch light turns off. Status lights indicate BACK. COUNT.

    b. The cassette slide moves to position 3. The display shows the system clock.

    c. A 200-second background count is taken on the filter. The display shows count time remaining.

    d. The cassette slide moves to position 4. Status lights indicate COL. PART. The display shows the system clock.

    e. The PTC switch illuminates. The Beta Gauge waits for the operator to continue the cycle.

6) To continue the cycle, press the PTC switch. The following events should occur:

    a. The PTC switch light turns off. Status lights indicate COL. PART.

    b. The filter is clamped, then pumping starts. The filter collects particulate for the time set by constant T1. The display shows collection time remaining.

c. Pumping stops and the filter is released. The cassette slide moves to position 3. Status lights indicate SAMP. COUNT. The display shows the system clock.

d. A 200-second sample count is taken the filter. The display shows count time remaining.

e. The results and data for this cycle are printed. Status lights are "OFF". The display shows the system clock.

f. The cassette slide moves to position 2. The filter is ejected.

g. The system status is printed.

h. The PTC switch illuminates. The Beta Gauge has finished the Single Cycle.

To start a new Single Cycle, go to step 5. To start any other cycle, go to the first step of that cycle's instructions. To interpret the results from the Single Cycle, see that section under Interpretation of Output.

If the events do not follow the sequence above, refer to the Troubleshooting section.

Federal Cycle

This section gives the procedure for using the Beta Gauge in the Federal Cycle. The Federal Cycle requires 52 minutes to execute. Operator intervention is required to start the cycle and to continue it seven minutes later. The procedure and results are:

1) Complete Set-up and Initialization first. No filter cassettes should be in the Sampling Unit.

2) Set the MODE switch to FEDERAL CYCLE. The lamp above the Federal Cycle status column should be on.

3) Press the CNTL and ABRT switches simultaneously, hold for one second, then release. The cassette slide moves to position 1, then the PUSH TO CONTINUE (PTC) switch illuminates.

4) Load the cassette magazine with filter cassettes. Three cassettes are required for each Federal Cycle.

The Beta Gauge is ready to begin a Federal Cycle.

5) To start a cycle, press the PTC switch. The following events should occur:

a. The PTC switch light turns "OFF". Status lights indicate

SAMPLE 2, BACK. COUNT.

b. The cassette slide moves to position 2. The display shows the system clock.

c. A 200-second background count is taken on filter 2. The display shows the count time remaining (seconds).

d. The cassette slide moves to position 3. Status lights indicate SAMPLE 1, BACK. COUNT.

e. A 200-second background count is taken on filter 1. The display shows the count time remaining.

f. The cassette slide moves to position 4. Status lights indicate SAMPLE 1, COL. PART. The display shows the system clock.

g. The PTC switch illuminates. The Beta Gauge waits for the operator to continue the cycle.

6) To continue the cycle, press the PTC switch. The following events should occur:

a. The PTC switch light turns "OFF". Status lights indicate SAMPLE 1, COL. PART.

b. Filter 1 is clamped, then pumping starts. Filter 1 collects particulate for 505 seconds. The display shows collection time remaining.

c. Pumping stops and filter 1 is released. The cassette slide moves to position 3. Status lights indicate SAMPLE 1, SAMP. COUNT. The display shows the system clock.

d. A 200-second sample count is taken on filter 1. Filter 2 is clamped and pumping starts. Both events begin at the same time. The display shows filter 1 count time remaining.

e. Pumping continues on filter 2. Total collection time for filter 2 is 866 seconds. Status lights indicate SAMPLE 2.

f. Pumping stops and filter 2 is released. The 600-second holding clock starts now but does not affect the cycle until event "k". The cassette slide moves to position 2. Filter 1 is ejected. Status lights indicate SAMPLE 2, SAMP. COUNT. The display shows the system clock.

g. A 200-second sample count is taken on filter 2. The display shows count time remaining.

h. The cassette slide moves to position 3. Status lights indi-

cate SAMPLE 3, BACK. COUNT. The display shows the system clock.

i. A 200-second background count is taken on filter 3. The display shows the count time remaining.

j. The cassette slide moves to position 4. Status lights indicate SAMPLE 3, HOLDING. The display shows the system clock.

k. The cycle is held until the remaining holding time elapses. The display shows holding time remaining.

l. Filter 3 is clamped and pumping starts. Filter 3 collects particulate for 505 seconds. Status lights indicate SAMPLE 3, COL. PART. The display shows collection time remaining.

m. Pumping stops and filter 3 is released. The cassette slide moves to position 3. Status lights indicate SAMPLE 3, SAMP. COUNT. The display shows the system clock.

n. A 200-second sample count is taken on filter 3. The display shows count time remaining.

o. The results and data for the cycle are printed. Status lights are "OFF". The display shows the system clock.

p. The cassette slide moves to position 1. Filter 3 is ejected, followed by filter 2.

q. The system status is printed.

r. The PTC switch is illuminated. The Beta Gauge has finished the Federal Cycle.

To start a new Federal Cycle, go to step 5. To start any other cycle, go to the first step of that cycle's instructions. To interpret the results from the Federal Cycle, see that section under Interpretation of Output.

If the events do not follow the sequence above, refer to Troubleshooting section.

Calibration Cycle

This section gives the procedure for using the Beta Gauge in the Calibration Cycle. The Calibration Cycle uses a cassette loaded with a film of known thickness and density (such as mylar). The information obtained by measuring the mass of this film is used to set the Beta Constant.

The results from at least ten runs should be averaged before calculating the Beta Constant.

The procedure and results are:

1) Complete Set-up and Initialization first. No filter cassettes should be in the Sample Unit.

2) Set the MODE switch to CALIBRATE. No status lights are used during this cycle.

3) Simultaneously press and hold the CNTL and ABRT switches down for at least 1 second, then release. The cassette slide moves to position 1, then the PUSH TO CONTINUE (PTC) switch illuminates.

4) Load one calibration cassette into the cassette magazine.

5) Press the PTC switch. The following events occur:

    a. The PTC switch light turns "OFF".

    b. The cassette slide moves to position 3.

    c. A 200-second air count is taken on an empty cassette position. The display shows the count time remaining.

    d. The cassette slide moves to position 2.

    e. A 200-second sample count is taken on the calibration cassette. The display shows the count time remaining.

    f. The two counts and mass are printed. The display shows the the system clock.

    g. The cassette slide moves to position 1. The calibration cassette is ejected.

    h. The system status is printed.

    i. The PTC switch illuminates. The Beta Gauge has finished the Calibration Cycle.

To repeat the Calibration Cycle, go to step 4. To interpret the results from the Calibration Cycle, see the section on Interpretation of Output.

When ten cycles have been run, the Beta Constant may be calculated using the formula on the following page.

$$BC = \frac{\rho \chi \pi(d^2/4)}{\ln (AC/SC)}$$

where ρ = material density ($\mu g/mm^3$)

χ = material thickness (mm)

d = 17mm (aperature diameter)

AC = averaged Air Counts

SC = averaged Sample Counts

BC = Beta Constant (μg)

If the calculated Beta Constant differs greatly from the present Beta Constant, use the keyboard to enter the new Beta Constant (see the section on Constants).

Power-Down Sequence

When the Beta Gauge is turned off, the Computer Unit is turned off last unless all three units are turned off simultaneously with one switch. This avoids random operations of the Sampling and Flow Units.

Before removing power, empty the cassette drive and magazine. Use the SET FLOW switch to exhaust any sample gases from the system, if deemed necessary. Use the PAPER FEED button to advance the last run from the printer.

The power-down sequence is (1) Flow Unit, (2) Sampling Unit, (3) Computer Unit. Use the circuit breakers on the backs of the Flow and Sample Units to turn those units off.

Flow Constant Calibration

The Flow Constant is determined by the Voltage-toFrequency (V/F) conversion circuit and the sample gas composition. The V/F conversion circuit is set by the manufacturer and does not vary. The composition of the sample gas affects the Flow Constant for the Hastings Linear Mass Flowmeter (see Appendix b, Gas Flow System in Section 2.5.3 of the previous manual). A Flow Constant of 9.2571×10^{-9} m^3/cts is recommended by the manufacturer for exhaust gases.

SECTION 4

TROUBLESHOOTING GUIDE

This guide offers suggestions for locating and correcting simple problems. If these suggestions do not eliminate the problem, call the manufacturer for help. This section is not offered as a detailed repair guide.

Firts, repeat the SET-UP procedure. Make sure all connections are tight and each unit is properly powered. Check all fuses for continuity.

When power is turned "ON", observe the Computer Unit. A "-1-" must be on display, the PUSH TO CONTINUE switch illuminated, and all other lights "OFF". If not, press RESET. If that doesn't help, call the manufacturer.

Try the manual controls in the Sample Unit and Flow Unit. Make sure the cassette drive operates freely in both directions. When the manual controls are not in use, the units should be inactive.

Proceed with INITIALIZATION. Use the PRINT STATUS (PTST) to verify correct storage of constants. Run each cycle using the operating instructions and status lights to check for correct sequencing. Check results using the equations in the Interpretation of Output section.

If at any time, the Beta Gauge "runs away", try CNTL/ABRT sequence. If control is not obtained, press RESET.

APPENDIX A. REFERENCE MANUAL

This section lists the portions of the previous manual, Advanced Prototype Direct Reading Instrument for Particulate Measurement (EPA-650/22-74-065, June 1974), which may be referred to for additional information. In general, references to the Sample Unit, Flow Unit, theory of particulate measurement, and the cycles remain unchanged. The Computer Unit, all schematics, and operating procedures have changed.

TABLE 7. VALID REFERENCES

Section	Description	Pages
APPENDIX B	All references below found in APPENDIX B "OPERATION MANUAL"	
1.1	Sensitivity and Range	1-3
1.4	Temperature Requirements	1-5
1.6	Inlet Heater	1-6
2.0	TECHNICAL DISCUSSION	2-1
2.1	System Concept	2-1
2.3	Measurement Precision	2-11
2.4	Detector	2-12
2.5	Mechanical Assembly - all sections except Figure 4	2-13 & 2-22
3.4.1	Automatic Gain Control	3-25
3.5	Selection of a Filter Medium	3-28
3.6	Cassette Preparation	3-22
4.0	PREVENTIVE MAINTENANCE	4-1
5.0	PRECAUTIONS IN HANDLING THE SOURCE	5-1
APPENDIX B	PMT Control: Reference Supplies Schematic	B-6
APPENDIX B	Gear Motor & Heater Supplies Schematic	B-8

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15. SUPPLEMENTARY NOTES

16. ABSTRACT

This manual provides description and operating instructions for a redesigned Beta Gauge for measuring particles from vehicle exhaust. The improvements and a new control system including a control unit which is radically different from the prior unit, are described. Complete Beta Gauge operating instructions for Federal Test Cycles are included as well as set up and calibration procedures. A trouble shooting guide completes the manual with instructions for locating problems. The overall improvements provide (1) all necessary and computation of algorithms for automatic sampling and (2) processing of the variables to compute the final particulate emission rate in grams per kilometer. The instrument also has a single mode operation for sampling from sources with various concentration levels.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
* Air Pollution		13B
* Particles		13F
* Motor Vehicles		20H
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